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The University of the State of New York
New York State Museum

I. CLARKE, DIRECTOR

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GEOLOGY OF THE SCHROON LAKE QUADRANGLE

By

WILLIAM J. MILLER

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ALBANY

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EXCHANGE

EX LIBRIS

*The University of the State of New York
Science Department, November 12, 1918*

*Dr John H. Finley
President of the University*

SIR:

I transmit to you herewith and recommend for publication as a Bulletin of the State Museum, a manuscript entitled *Geology of the Schroon Lake Quadrangle* which has been prepared, at my request, by Prof. William J. Miller.

This report is accompanied by necessary maps.

Very respectfully yours

JOHN M. CLARKE

Director

Approved for publication this 13th day of November, 1918

A handwritten signature in dark ink, appearing to read "John H. Finley", written in a cursive style with a horizontal line underneath.

President of the University

N52

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The University of the State of New York New York State Museum

JOHN M. CLARKE, DIRECTOR

GEOLOGY OF THE SCHROON LAKE QUADRANGLE

By WILLIAM J. MILLER

GENERAL GEOGRAPHIC FEATURES

The Schroon Lake quadrangle¹ represents an area of approximately 215 square miles in the central-eastern portion of the Adirondack mountain region. The territory is all in Essex county except the southern margin, which lies in Warren county. All the quadrangle is rugged, moderately mountainous, and mostly a wilderness, in these respects being quite typical of the 10,000 square miles of the Adirondack region.

The southern half of the quadrangle is less rugged than the northern and contains several farms, roads and villages. Schroon Lake, the largest village, is a well-known summer resort situated near the northern end of the lake of the same name. The other principal villages are Minerva, Olmstedville, South Schroon and Adirondack.

No railroad enters the quadrangle, the nearest being the Adirondack branch of the Delaware and Hudson with stations at Riverside and North Creek in the northern portion of the quadrangle next to the south.

The northern half of the quadrangle is notably more mountainous and less settled, there being but one traveled highway (the Newcomb and Port Henry road) across it. All the permanent settlements of the northern portion of the quadrangle, including the little village of Blue Ridge, are located on this road.

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

Both the highest and most rugged mountains are in the northeastern one-fourth of the quadrangle. Hoffman mountain is the highest with an altitude of 3715 feet, but it does not stand out as a conspicuous peak because it is simply the loftiest of a considerable group of mountain summits in this vicinity. In this northeastern quarter, no other mountain rises to 3500 feet, but several lie between 3000 and 3500 feet, like Wolf Pond mountain (3473), Ragged mountain (3290), Sand Pond mountain (3040), Texas ridge (3212), and several unnamed points on Blue ridge.

In the northwestern quarter of the quadrangle the country is notably less mountainous, the highest summits being Bailey hill (3115), the western peak of Sand Pond mountain (2970), and Hewitt Pond hill (2480+).

In the southern half of the quadrangle no peak rises to 3000 feet, and only three rise to 2500 feet or more, these being Ore Bed mountain (2856), a peak 1 mile northeast of Ore Bed mountain (2584), and Hayes mountain (2822). A number of others have altitudes between 2200 and 2500 feet, among them being Cobble hill, Oliver hill, Beech hill, Pine hill, Green hill, Moxham mountain, and a group of points around Barnes pond.

There is a marked tendency for the mountains and valleys to show a north-northeast by south-southwest trend. Among the more or less well-defined ridges are the following: from Bailey hill, through Hayes and Ore Bed mountains, to Moxham mountain (12 miles); from north of Ragged mountain, through Sand Pond mountain, Washburn ridge, and Bigsby hill, to south of Oliver hill (14 miles); Texas ridge (3 miles); Blue ridge (7 miles); Beech hill to south of Pat pond (6 miles); and from Dirgylot hill, through Severance hill, Hedgehog hill, and Merrills hill, to Ledge hill (10 miles). For the most part these ridges are separated by narrow, nearly straight valleys. The most notable exception is the fairly well-defined east-west valley which the road follows across the northern part of the quadrangle.

Schroon river, by means of a network of tributaries, drains all the area of the quadrangle except most of the northeastern portion, which is drained by Boreas river. Both the Schroon and the Boreas pass into the Hudson river.

Altogether, there are about 30 lakes and ponds, the largest being Schroon lake with 7 miles of its length within the quadrangle. Next largest are Cheney pond nearly 2 miles long, and Hewitt pond about 1 mile long.

General view of the mountains looking north and northeast from Warren's hotel, 1 mile southeast of Bailey pond, Texas ridge on the right and Hoffman notch on the left

W. J. Miller, photo, 1916

GENERAL GEOLOGIC FEATURES AND PUBLICATIONS

Most of the more common and well-known rock formations of the Adirondack region, as well as certain unusual ones, are abundantly represented in the Schroon Lake quadrangle. In the regular order of their geologic ages the principal rocks are as follows:

Pleistocene

Glacial and Postglacial deposits

Paleozoic (Cambrian)

Little Falls (?) dolomite

Potsdam sandstone

Precambrian

Diabase dikes

Aplite and pegmatite dikes

Gabbro stocks and dikes

Keene gneiss, and assimilation product of the anorthosite and syenite-granite series

Syenite-granite series

Anorthosite series

Grenville series of metamorphosed strata

The Precambrian formations constitute the foundation rocks of the entire quadrangle. Oldest of all are the Grenville strata, probably of Archeozoic age, which are thoroughly crystalline. Grenville strata are well developed in the southern half of the quadrangle, but their distribution is very "patchy" because they were invaded and cut to pieces by great masses of intrusive rocks.

Next to the oldest known is the anorthosite series which occupies most of the northeastern half of the area. The great bulk of this rock is very coarse grained and highly feldspathic (Marcy anorthosite), but it has a more or less well-defined border development (Whiteface anorthosite).

The syenite-granite series, so common throughout the Adirondack region, is next in order of age, being clearly intrusive into both the Grenville and the anorthosite. This series, more particularly its granite facies, is wholly confined to the southwestern half of the quadrangle where it is the most prominent rock formation.

Several considerable areas of Keene gneiss lie in general between the anorthosite and syenite or granite areas. This rock is regarded by the writer as an assimilation product which resulted from the incorporation and digestion of anorthosite by the molten syenite-granite.

Gabbro stocks and dikes of the usual Adirondack sort are prominently developed in the southwestern half of the quadrangle, each of two of the stocks occupying several square miles.

Pegmatite and diabase dikes of the usual kinds, both later than the gabbro, are well represented. A few small dikes of aplite were also observed cutting the gabbro.

Two small areas of Paleozoic strata are known in and near Schroon Lake village. One of these is Potsdam sandstone and the other is Little Falls (?) dolomite.

Fifteen faults and zones of excessive jointing have been located and these have notably influenced the topographic development.

Pleistocene deposits are very widespread, being especially thick in the more prominent valleys where the underlying rocks are in many places effectually concealed by them.

The following list includes the principal publications which contain statements regarding the Schroon Lake quadrangle itself and the adjoining districts, as well as certain other papers which aid in understanding the geologic features of the quadrangle:

- 1842 **Emmons, E.** Geology of the Second District. Pt 2 of The Geology of New York
- 1879 **Hall, C. E.** Laurentian Magnetic Iron Ore Deposits of Northern New York. N. Y. State Mus. Rep't 32, 1879, p. 133-40
- 1895 **Kemp, J. F.** Preliminary Report on the Geology of Essex County. 15th Annual Rep't N. Y. State Geol., p. 590-604
- 1897 **Kemp, J. F. & Newland, D. H.** Preliminary Report on the Geology of Washington, Warren, and Parts of Essex and Hamilton Counties. 17th Annual Rep't N. Y. State Geol., p. 547-48
- 1897 **Kemp, J. F.** Physiography of the Eastern Adirondack Region in the Cambrian and Ordovician Periods. Geol. Soc. Amer. Bul. 8, p. 408-12
- 1902 **Finlay, G. I.** Preliminary Report of Field Work in the Town of Minerva, Essex County. 20th Annual Rep't N. Y. State Geol., p. 196-102.
- 1905 **Cushing, H. P.** Geology of the Northern Adirondack Region. N. Y. State Mus. Bul. 95
- 1905 **Ogilvie, I. H.** Geology of the Paradox Lake Quadrangle. N. Y. State Mus. Bul. 96
- 1906 **Kemp, J. F.** The Physiography of the Adirondacks. The Popular Science Monthly, March 1906
- 1910 **Kemp, J. F. & Ruedemann, R.** Geology of the Elizabethtown and Port Henry Quadrangles. N. Y. State Mus. Bul. 138
- 1912 **Miller, W. J.** Early Paleozoic Physiography of the Southern Adirondacks. N. Y. State Mus. Bul. 164, p. 80-94
- 1913 **Miller, W. J.** The Geological History of New York State. N. Y. State Mus. Bul. 168
- 1914 **Miller, W. J.** Magmatic Differentiation and Assimilation in the Adirondack Region. Geol. Soc. Amer. Bul. 25, p. 243-61

A view southeast from a point one-half mile northeast of Bailey pond, Bailey pond near the middle, Hayes mountain on the right, and Ore Bed mountain in the distance.

J. W. Forrest, photo, Troy, N. Y.

- 1914 **Miller, W. J.** Geology of the North Creek Quadrangle. N. Y. State Mus. Bul. 170
- 1916 **Miller, W. J.** Origin of Foliation in the Precambrian Rocks of Northern New York. Jour. Geol., 24:578-619
- 1917 **Miller, W. J.** The Adirondack Mountains. N. Y. State Mus. Bul. 193
- 1918 **Miller, W. J.** Adirondack Anorthosite. Geol. Soc. Amer. Bul. vol. 29, no. 4

PRECAMBRIAN ROCKS

Grenville Series

General character. The Grenville series of strata, including possibly some contemporaneous igneous rocks, are considered to belong among the oldest known, or Archeozoic, rocks of the earth. These strata represent original shales, sandstones and limestones which have become thoroughly crystallized into various schists and gneisses, quartzites and crystalline limestone or marble. The stratification is usually rather distinctly preserved though not with its original sharpness. A more or less well-developed foliation is always parallel to the stratification.

Grenville rocks are not very prominent in the Schroon Lake quadrangle, the combined definitely known areas totaling not over 12 square miles. It is quite certain, however, that Grenville strata of great thickness once spread over not only the whole area of the quadrangle and the 10,000 square miles of the Adirondack region, but also over much of eastern Canada. They were, no doubt, mostly deposited under marine waters much like the typical sediments of later ages. Within the quadrangle no positive proof for great thickness has been obtained, but in other districts a thickness of at least several miles has been demonstrated. Regarding the lands from which the Grenville sediments were derived, and the floor upon which they were deposited, we know nothing at present. That organisms lived in the waters while Grenville deposition took place those many millions of years ago seems evident from the dissemination of graphite (crystallized carbon) through much of the limestone as well as through certain of the schists and gneisses.

A glance at the accompanying geologic map will show the very "patchy" distribution of the Grenville rocks, this being due to the fact that the original body of thick strata, which was the universal country rock of the quadrangle, has been badly broken up, lifted or tilted in masses great and small, more or less engulfed and, in some cases, injected or even partially assimilated by the great intrusive bodies of the region. The entire absence of Grenville strata from the anorthosite area is doubtless due to a laccolithic structure of the anorthosite whereby the Grenville was notably lifted or domed over the rising magma, and completely removed

W. J. Miller, photo, 1917
 A view of the mountains looking northwest across Schroon lake and the village from Isola Bella. Blue ridge with Mount Hoffman, its highest point, in the distance. The Schroon Valley fault passes along the base of the nearer ridge.

by subsequent erosion. The later syenite-granite magma, however, had a much greater tendency to more or less intimately break up, penetrate, and even engulf the Grenville strata. All except possibly the few largest areas of the quadrangle may well be regarded as true inclusions in the syenite-granite series.

Since nearly all the various types of Grenville rocks below mentioned in the descriptions of the Grenville areas have been described in the writer's report on the *Geology of the North Creek Quadrangle*,¹ it seems needless to repeat the details here.

Description of Grenville areas. The rocks of the various Grenville areas are described somewhat in detail, in order to have on record the more important data which may possibly aid in working out at least the broader stratigraphic relations of the Adirondack Grenville series. The structural features of the Grenville are discussed in the chapter on Structural Geology. Dips and strikes are shown on the accompanying geologic map.

Minerva area. This is the largest area of the quadrangle (see map) and, although there are many excellent exposures, nevertheless they are not numerous enough to make it possible to gain anything like an accurate idea of the stratigraphy and structure of the area. The best exposures are north, northwest and west of Minerva. South and southeast of that village there are very few outcrops so that the southern boundary of the area is mostly rather uncertain. Practically all the Grenville rocks of the area show a northwest strike (see map).

The little hill just west of Minerva consists of well-bedded quartzitic, biotitic and hornblendic gneisses, all very typical of the usual Grenville series. Just back of the hotel a small mass of twisted crystalline limestone lies in contact with the granite there mapped.

On the steep hillside one-half of a mile farther west the rock is mostly hornblende gneiss, some with garnets, and with some bands of biotite gneiss and quartzite interbedded.

Northwest of Minerva, in and near the garnet mine, crystalline limestone associated with much red garnet and green pyroxene is closely involved with granite, this being separately mapped as mixed rocks. Just south of the mine there is a vertical ledge, nearly 100 feet high, of well-bedded granitic-looking gneiss, impure quartzite, and some limestone.

¹ N. Y. State Mus. Bul. 170.

On the hillside north of the road, from Calahan pond southeast for 1 mile, there are many fine exposures of crystalline limestone with some closely involved pyroxene and hornblende gneisses toward the north. Toward the south this limestone contains yellow quartz and graphite.

That portion of the area near the map edge from Calahan pond northward shows a number of fine exposures of crystalline limestone mostly containing graphite associated with some pyroxene and hornblende gneisses, and exhibiting local foldings or contortions. Just north of the small gabbro stock at the map edge the Grenville consists of hornblende, hornblende-garnet and pyroxene gneisses, and some quartzite.

A very fine outcrop of Grenville was observed a few rods west of the quadrangle boundary on the southern side of the small gabbro stock 1 mile southwest of Sherman pond, the ledge being clearly visible from the road. In a section fully 100 feet thick pyroxene gneiss and biotite gneiss and quartzite are beautifully stratified in thin beds. In the lower half of the section a dike of granite several feet thick has been intruded, both the dike and its foliation being perfectly parallel to the stratification of the Grenville.

Most of the ridge 1 mile east of Calahan pond appears to be quartzite with hornblende and pyroxene gneisses and some limestone at its eastern base, and hornblende gneiss at its western base, but the outcrops are not very good. On and near the road 1 mile a little north of east of Minerva there are several ledges of rather coarse graphitic limestone associated with some thin-bedded, gray, rusty graphitic gneiss and quartzite.

Exposures showing contorted limestone with pyroxene and hornblende gneisses occur three-fifths of a mile west of the mouth of Kelso brook.

The hill 1 mile west of Irishtown consists of hornblende and biotite gneisses on the south side of the small gabbro stock, and quartzite underlain by some limestone on the north side.

On the slope northwest of the hill just mentioned, several exposures of well-bedded hornblende-garnet gneiss, and one of limestone, were observed. From Falls brook northward the Grenville nearly all appears to be typical hornblende-garnet gneiss in good exposures. Limestone shows in a small exposure on the trail one-half of a mile northwest of Irishtown.

W. J. Miller, photo, 1917

The northern end of Blue ridge as seen from a point at the base of Saywood hill. The valley in the foreground, which is the bed of the extinct glacial lake Blue Ridge, lies at an altitude of 1200 feet and the mountain rises 2300 feet above it.

Olmstedville-Irishtown area. This area of Grenville is almost certainly connected, under the Pleistocene of Minerva stream valley, with the Minerva area.

In Olmstedville, by the stream one-fifth of a mile east of the mill, there is a big ledge of typical limestone. At the bridge just east of Olmstedville, limestone underlying hornblende gneiss forms a ledge 100 feet long. By and near the road one-third of a mile east of the bridge just mentioned, there are several outcrops, including hornblende gneiss, rusty mica quartzitic gneiss and limestone.

Two small outcrops of limestone occur by the road about a mile east of Olmstedville.

In a field $1\frac{1}{3}$ miles northeast of Olmstedville, there is a large exposure of typical graphitic limestone with some small masses of rusty gneiss twisted into it. Nearby is an outcrop of hornblende gneiss.

Near the road one-half and three-fourths of a mile, respectively, southwest of the village, there are several small exposures of graphitic limestone with some small masses of closely involved pyroxene gneiss. The one nearest the village is weathered to a friable mass and is used for repairing roads.

Near the road corners one-half of a mile northwest of Olmstedville there are several outcrops of limestone, some containing graphite and green pyroxene and associated with hornblende gneiss. From this locality northward for a mile, by and near the road, there are other good exposures of similar rocks.

From one-half to 1 mile east-southeast of Irishtown there are interesting exposures of Grenville. Coming against the syenite on the south side (see map) there are several good exposures of limestone arranged along a strike $N\ 70^{\circ}\ W$. Just within the syenite there is a long, narrow inclusion of quartzite. Where the limestone belt comes to the road, hornblende gneiss outcrops. Just north of the tongue of syenite there are large exposures of quartzite with a little associated limestone arranged along a $N\ 70^{\circ}\ W$ strike.

One mile north-northwest of Olmstedville, and extending from the road eastward for 200 yards, there are good outcrops of rusty biotite gneiss, hornblende gneiss and quartzite.

Along the road from one-half to 1 mile north of Irishtown, there are several exposures of hornblende gneiss (some garnetiferous) and a little associated limestone.

The tongue of Grenville which forms part of the mountain spur 1 mile north-northeast of Irishtown consists of hornblende and

hornblende-garnet gneisses with a little interbedded quartzite and biotite gneiss.

Catamount hill area. Catamount hill itself is a practically solid mass of well-bedded biotite-graphite schist or gneiss with some belts of quartzitic rock toward the summit.

At the old graphite mine by the road west of Catamount hill, the rock which was mined is a rusty looking biotite-graphite schist in very thin layers. Most of this rock, forming a belt 30 to 40 feet wide, contains tiny flakes of graphite, but one zone in it only a few feet wide is very rich in large flakes of graphite. In contact with this graphite-rich rock there is a narrow band of limestone containing green pyroxene and graphite.

Near the road one-fifth of a mile north of the mine there occurs a ledge of quartzitic to granitic looking gneiss with one two-foot wide band containing lenslike garnets up to an inch long.

Adirondack village area. This small area shows only a few outcrops. A small exposure of limestone just east of the village contains some graphite and green pyroxene. By the road one-half of a mile south of the village, there occurs a ledge of bedded hornblende-biotite gneiss. At the southern end of the area there are several good exposures of variable rocks, mostly hornblende gneiss, biotite gneiss and pyroxene-garnet gneiss. These are mostly well bedded but shot through with some coarse granite. No outcrops occur along, or just east of, the map boundary here, but, judging by Doctor Ogilvie's Paradox lake map, this Adirondack village area of Grenville probably extends across the boundary.

Areas on the shores of Schroon Lake. At the southern end of Isola Bella there is a mass of limestone 20 feet long, really an inclusion in the granite. This limestone contains pyroxene, quartz and some graphite.

At Grove Point there are two exposures by the lake shore, one being limestone with bunches and strips of green pyroxene gneiss kneaded into the mass, and the other pyroxenic and hornblendic gneisses with a little associated limestone.

A few rods south of the Grove Point Grenville, syenite contains a long, narrow inclusion of Grenville limestone.

On the lake shore one-half of a mile east of South Schroon, limestone with patches of green pyroxene gneiss twisted into it shows in a good exposure.

Areas northwest of Schroon Lake village. The small lens-shaped area shown on the map 1 mile northwest of the village con-

sists of interbedded quartzite (some garnetiferous), quartz-pyroxene gneiss, and quartz-feldspar gneiss with several thin layers of limestone containing green pyroxene.

The area just east of North pond shows a number of good exposures of well-bedded hornblende-garnet gneiss and hornblende gneiss with one two-foot thick layer of limestone in the hornblende gneiss. Near the western corner of the area there are many large reddish brown garnets up to 4 or 5 inches in diameter, but without hornblende rims as is often the case with such large garnets in the Grenville hornblende-garnet gneiss elsewhere in the Adirondacks.

Other areas of Grenville. In the small area on the west face of Wilson mountain, pyroxenic, hornblendic and quartzitic gneisses are well exposed, some of these being locally contorted. Along the eastern side of this area the Grenville rocks are more or less intimately charged with granite.

At the western end of the area just southwest of Oliver pond there is a big exposure of hornblende-garnet gneiss interstratified with thin-bedded, fine grained, pinkish gray, quartz-biotite schist. A few rods farther east there occurs a ledge of limestone containing green pyroxene, quartz and a little graphite. Toward the eastern end of the area the rock is hornblende-garnet gneiss.

A small lenslike inclusion of hornblende-garnet gneiss with garnets up to an inch across occurs in the granite one-half of a mile west of Oliver pond.

One mile northeast of Loch Muller,¹ in the small area mapped, there is a single large outcrop of hornblende gneiss, somewhat garnetiferous.

On the southern slope of Hayes mountain, three-fourths of a mile from its summit, a small lenslike body of typical hornblende-garnet gneiss with garnets up to an inch across occurs as an inclusion in granite. A similar small inclusion occurs in the syenite 2 miles north-northwest of Irishtown, and still another in granite $1\frac{1}{4}$ miles west-southwest of the summit of Hayes mountain.

¹This is the place printed on the map accompanying this bulletin, but since the map was printed the post office has been moved 2 miles to the northwest to Warren's hotel.

Some interesting exposures occur in the small area $1\frac{1}{2}$ miles northwest of the summit of Hayes mountain. In the old stone quarry the rock is greenish limestone containing serpentized green pyroxene and some graphite. This is associated with some hornblendic and quartzitic gneisses. Similar rocks outcrop on the west bank of the stream, but there the pyroxene is less serpentized. Undoubtedly this mass of Grenville is a fairly large inclusion in the granite which outcrops close by on all sides.

In the Hewitt Pond brook area there are several good outcrops of Grenville hornblende gneiss and hornblende-garnet gneiss.

A conspicuous lenslike mappable inclusion of hornblendic and quartzitic well-bedded gneisses occurs in the granite $1\frac{1}{4}$ miles east-southeast of Boreas river.

Still other masses of Grenville occur within the quadrangle, but these are so closely associated with other rocks that they are mapped and described as "mixed rocks."

Anorthosite Series

General considerations. Recently the writer has published a rather elaborate paper¹ on the whole problem of the age, relations, and origin of the Adirondack anorthosite. The interested reader is referred to that paper for much more material than is presented in this bulletin. Some years ago, Professor Cushing, in his report² on the *Geology of the Long Lake Quadrangle*, presented evidence to show that the anorthosite is a great intrusive body distinctly younger than the great syenite-granite series of the Adirondacks. The writer heartily agrees with this view, and in his own field studies, particularly in the Lake Placid and Schroon Lake quadrangles, he has found much more evidence in support of Cushing's view. Recently, however, Dr N. L. Bowen³ has offered quite a different explanation of the origin and relations of the anorthosite. His hypothesis and the writer's objections to it are briefly stated below, but a fuller criticism is presented in the paper above cited.

The anorthosite occupies a largely unbroken area of about 1200 square miles of the central-eastern Adirondack region. It is prominently developed with nearly all its facies in the Schroon Lake

¹ Geol. Soc. Amer. Bul. 29 No. 4, 1918, p. 399-462.

² N Y. State Mus. Bul 115, p. 479-82. 1907.

³ Jour. Geol., 25:209-43. 1917.

quadrangle where, as a result of its careful study, important light has been thrown upon the age, relations, structure, and origin of the great anorthosite body. Most of the northeastern half of the quadrangle, or an area of over 80 square miles, is occupied by anorthosite to the exclusion of all other formations except Pleistocene deposits and a few small basic dikes.

Marcy type of the anorthosite. By far the most abundant general facies of the rock may be called Marcy anorthosite because of its great exposures on Mount Marcy in the quadrangle next to the north. The most typical portions of the Marcy anorthosite are coarse grained, light to dark bluish gray, and consist largely of basic plagioclase feldspar, mainly labradorite. The dark bluish gray labradorite crystals usually vary in length from a fraction of an inch to several inches, crystals about an inch long being very common. Among other places, labradorites from 5 inches to 1 foot long were observed on the western of the three Peaked hills, and on the ridge 1 mile north-northwest of Blue Ridge village. Only occasionally do these labradorites exhibit the play of colors so characteristic of this species of feldspar. Twinning striations are often evident to the naked eye on the cleavage faces.

Accessory minerals visible to the naked eye are large individuals of pyroxene and hornblende, and small individuals of biotite, ilmenite, pyrite, garnet, and more rarely chalcopyrite or pyrrhotite. These accessory minerals ordinarily constitute 5 to 10 per cent of the typical coarse anorthosite, but there are local developments of the rock which are made up almost entirely of plagioclase, and still others, rather abundantly developed as zones, bands and irregular masses, which contain from 10 to 25 or more per cent dark minerals, these last named types being really anorthosite-gabbros. Such gabbroid facies are more fully described below.

An important facies of the anorthosite is one in which the dark labradorites, from a few millimeters to an inch or more across, stand out conspicuously in a distinctly granulated groundmass of feldspar. The granulated material varies from light gray to pale greenish gray. It is very evident that the large labradorites are roughly rounded uncrushed cores of what were considerably larger individuals before the rock was subjected to the process of granulation. All degrees of granulation are exhibited to extreme cases where the rock has been so thoroughly granulated that few, if any, labradorite cores remain.

Much of the typical Marcy anorthosite is devoid of foliation, though in some local zones of almost perfectly pure plagioclase rock there is a notable tendency for the feldspars to show a crude parallelism (plate 6). The more gabbroid facies of the rock, however, often exhibit a fair to well-defined foliation accentuated by the crudely parallel arrangement of the dark minerals.

In thin section, with a low power of the microscope, the larger labradorites are usually seen to be filled more or less with myriads of very dark dustlike particles, probably ilmenite. The minerals contained in several thin sections of the Marcy anorthosite are shown in table 1 below.

Chilled border facies of the anorthosite (Whiteface anorthosite). Around the borders of the great body of Adirondack anorthosite, and in some places a number of miles within it, there is quite generally a notable development of white or very light-gray labradorite and an increase in the femic minerals causing such rocks to be anorthosite-gabbro or even gabbro. Such rocks, well developed in the Schroon Lake quadrangle, are almost invariably finer grained and lighter colored than the typical Marcy anorthosite, though in some localities a few large, scattering labradorite individuals occur. A foliated structure is generally evident.

Although they are more or less variable in general appearance and composition, the writer has proposed that these border phases of the anorthosite be classed as Whiteface anorthosite, a name given by Professor Kemp to the type which occurs abundantly on Mount Whiteface near Lake Placid. At the summit of Mount Whiteface the rock is medium grained and consists of white plagioclase (chiefly labradorite) with 10 to 15 per cent of dark minerals scattered through the mass parallel to a crude foliated structure. Such rock, which is quite typical of the Schroon Lake quadrangle Whiteface anorthosite, stands out in marked contrast against the typical Marcy anorthosite which is not so gabbroid, very coarse grained, light to dark bluish gray, and generally not so well foliated. More exceptionally the Whiteface anorthosite is nearly pure white, being quite free from femic minerals. Much of the rock, however, is locally richer in dark minerals, which may constitute 15 to 30 per cent of the whole. The minerals other than the feldspar are practically the same as in the Marcy anorthosite. Table 1 gives a good idea of the mineral content of the Whiteface anorthosite of the quadrangle.

Marcy anorthosite in the bed of The Branch brook one-third of a mile west of Blue Ridge village
W. J. Miller, photo, 1917

Table 1 Thin sections of anorthosite

	Slide no.	Field no.	Labradorite	Andesine	Pyrox. (Mono.)	Diallage	Quartz	Hornblende	Hypersthene	Biotite	Garnet	Magnetite	Pyrite	Limonite	Apatite	Zircon	Titanite	Hemalite	Calcite (Sec.)	Chl. rite
Marcy An.	20	11 k 1	99	...	1/2	...	...	...	...	...	...	1/2	...	...	little	...	...	...	...	...
	23	14 d 3	77	...	12	2	1 1/2	...	...	...	5	2	1/2	...	...	...	...	...	...	...
	24	15 i 6	70	...	...	...	1	1	27	...	...	1	little	...	...	...	...	...	...	...
Whiteface anorthosite	10	4 f 8	99	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
	11	5 d 11	75	10	...	12	...	1 1/2	...	...	...	1 1/2	...	...	little	little	little	...	...	...
	12	6 l 2	92	...	...	4	...	2	...	1	1/2	...	little	...	...	...	little	...	...	...
	13	7 e 12	68	...	...	5	10	5	...	1/2	10	1	little	...	...	...	little	...	...	...
	14	7 e 9	85	...	2 1/2	...	...	12	...	...	...	...	...	...	...	...	little	...	...	...
	15	7 h 1	81	...	5	...	2	3	...	...	5	1 1/2	...	...	little	little	...	...	2	...
	16	7 g 1	68	...	10	2 1/2	8	8	...	...	...	3	...	...	...	...	...	...	...	...
	17	8 m 6	88	...	...	...	...	1/2	1/2	...	9	1 1/2	...	...	little	...	little	...	...	...
	18	9 e 9	78	...	4	...	10	4	...	...	1 1/2	1 1/2	...	...	...	little	little	...	...	...
	19	10 l 1	98	...	...	...	...	...	...	...	1	1	...	...	...	little	little	...	...	...
	21	13 g 2	94	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
	22	14 c 4	38	...	35	...	15	little	...	...	10	1	...	...	...	...	...	...	...	...
	37	8 f 25	67	10	14	...	...	8	...	...	...	...	...	...	...	little	1/2	...	...	...

No. 20, three-fourths of a mile southeast of summit of Hoffman mountain; no. 23, by the road 1 mile northeast of Boreas river; no. 24, by the stream 1 mile east-southeast of summit of Ragged mountain; no. 10, 1 mile southeast of summit of Oliver hill; no. 11, 1 1/2 miles a little west of north of Irishtown; no. 12, lake shore just north of Grove Point; nos. 13 and 14, one-half of a mile west-northwest of Bigsby hill; no. 15, by road at Loch Muller; no. 16, one-third of a mile west of Loch Muller; no. 17, one-half of a mile south-southeast of summit of Severance hill; no. 18, top of Hayes mountain; no. 19, by the brook southwest of Smith hill; no. 21, near western summit of Sand Pond mountain; no. 22, near cross-roads at Boreas river; no. 37, southern brow of Cobble hill.

No. 17 of table 1 exhibits very fine reaction rims as follows: (1) magnetite with rims of garnet; (2) pyrite with rims of garnet; and (3) magnetite with successive rims of hypersthene and garnet.

Both the Marcy and Whiteface types of anorthosite are quite certainly differentiation phases of the same cooling magma, the latter representing a chilled border or marginal portion. The one type grades into the other, and nowhere has one been found definitely to intrude the other.

Special descriptions of Whiteface anorthosite occurrences. In the Boreas river area the Whiteface anorthosite is mostly rather uniformly moderately gabbroid and foliated with scattering bluish labradorites, but some local variations from this composition and structure were observed. Near the cross-roads at Boreas river (no. 22 of table 1) a ledge is unusually rich in pyroxene and quartz.

In the eastern portion of the Sand Pond mountain area the rock is nearly white and free from femic minerals, nonfoliated, and with only a few scattering blue labradorites (no. 21 of table 1). The rock of the western portion of the area strongly suggests Marcy anorthosite and grades into it. It is light gray and non-foliated with 10 to 20 per cent dark minerals and garnets and many blue labradorites.

The Severance-Smith hill area, the largest shown on the map, comprises mostly rather uniform, very typical, Whiteface anorthosite (nos. 17 and 19 of table 1). At the extreme southern end it contains an admixture of Grenville.

In the large area southwest of Bailey hill the Whiteface anorthosite is mostly very typical. By the old road on the west side there are some rather gabbroid, garnetiferous, foliated zones, and in the eastern portion there are locally developed masses with many garnets and some scattering blue labradorites.

A large ledge of Whiteface anorthosite at Loch Muller is exceedingly variable as regards both content of femic minerals and foliation. It contains some bluish labradorites and scattering garnets (no. 15, table 1). One-third of a mile farther west in the same area the rock is distinctly gabbroid and foliated and carries 8 or 10 per cent of quartz (no. 16, table 1). In the western part of the area the rock is very typical Whiteface anorthosite.

The long, narrow area south of Hewitt road shows Whiteface anorthosite varying from light-colored, moderately gneissoid to dark-colored, gabbroid, very gneissoid facies.

The rocks of the area west of Bigsby hill exhibit many local variations from typical anorthosite to very gabbroid, gneissoid anorthosite. In some ledges quartz is visible to the naked eye. Nos. 13 and 14 of table 1 are from this area.

A big ledge of gabbroid, very gneissoid Whiteface anorthosite (no. 11 of table 1) in the small area $1\frac{1}{2}$ miles a little west of north of Irishtown is intimately associated with Grenville hornblende-garnet gneiss, the latter commonly occurring as distinct strips or lenslike inclusions in the anorthosite.

The remaining small areas of Whiteface anorthosite require no special description here.

Variable composition and structure of the anorthosite and its significance. *General statements.* Contrary to Bowen's statement that "anorthosites are made up almost exclusively of the single mineral plagioclase," the writer's experience in the field has made

Near view of part of a boulder of Marcy anorthosite in a field three-fourths of a mile northwest of Pat pond. Foliation, due to crude parallelism of large crystals of labradorite, is very distinct in the lower part but not in the upper.

W. J. Miller, photo, 1917

it clear that the Adirondack anorthosite is by no means an almost perfectly homogeneous mass of plagioclase. The main bulk of the Marcy anorthosite contains at least 5 to 10 per cent of minerals other than plagioclase. Portions with about 10 per cent are common, and in many places there are 10 to 20 per cent, or even more, of dark minerals. It is also true that some portions of the great mass contain less than 5 per cent of femic constituents. Conservatively estimated, the average Marcy anorthosite carries fully 10 per cent of minerals other than plagioclase.

In the writer's work in both the Lake Placid and Schroon Lake quadrangles, many observations have been made of anorthosite-gabbro and more typical anorthosite exhibiting perfect gradations from one into the other. Such gabbroid facies exist locally throughout the body of Marcy anorthosite, in many places as rather distinct zones or belts a few feet or rods wide, and in other places on much larger scales. Many other gabbroid portions are much more irregular in shape, and not so distinctly separated from the purer Marcy anorthosite.

The anorthosite-gabbro very commonly, and the typical Marcy anorthosite less commonly, locally exhibit more or less well-developed foliation with exceedingly variable strikes. Marked variations in degree of foliation often occur in single ledges. It is also important to note that granulation, so prevalent throughout the anorthosite body, shows many extreme variations, often in single outcrops.

Another variation of the anorthosite from a pure plagioclase rock consists in the dustlike (schillerization) inclusions of a dark mineral, probably ilmenite, in the labradorite. These are so numerous as to cause most of the labradorites to have a dark bluish gray color. Thus even the plagioclase crystals are not pure lime-soda feldspar.

Finally in this connection, attention should be called to the presence of a very appreciable amount of potash in the typical Marcy anorthosite, as shown in an analysis made for Professor Kemp. Whether this potash exists in regular potash-feldspar form, or is part of the labradorite proper, it is additional proof that the anorthosite is not a practically pure mass of lime-soda feldspar.

Some examples of variations of Marcy anorthosite. Near the top of the hill 1 mile a little to the west of north of Blue Ridge village, the following variations across the strike from south are finely exhibited: first, there is typical Marcy anorthosite; then, a band 2 feet wide of gneissoid, moderately coarse-grained, gabbroid

anorthosite with a few labradorite phenocrysts; then, a belt 40 feet wide of less coarse-grained anorthosite with a few labradorite phenocrysts and scarcely any femic minerals; next, a belt 35 feet wide of very coarse-grained, gabbroid anorthosite with pyroxene and labradorite crystals from 6 inches to 1 foot each in length. None of these belts or zones is very sharply separated, though in some cases the change from one into the other takes place within a few inches.

At the rapids of Boreas river, just before the stream enters the Brace dam reservoir, a big ledge of typical Marcy anorthosite with very few femic minerals contains a very irregular shaped mass of highly femic and garnetiferous anorthosite some 30 feet long with a maximum width of 10 feet. Except for the 20 to 30 per cent of dark minerals, this femic anorthosite is much like the inclosing anorthosite. Boundaries against the typical anorthosite are not sharp, but the complete transition takes place within 5 or 6 inches. The femic rock is nonfoliated, but the typical Marcy anorthosite on one side of it has most of its labradorites (1 to 2 inches long) arranged parallel to the contact with the femic rock. This parallelism is most evident close to the contact and not at all noticeable 6 or 8 feet out.

By the road three-fourths of a mile east of where it crosses Boreas river, a 50-foot exposure of typical Marcy anorthosite, with less than 5 per cent femic constituents and with many labradorites an inch long, exhibits very distinct foliation due to parallelism of the labradorites. This rock grades into typical nonfoliated anorthosite of the adjacent exposure.

By the same road above mentioned, but one-third of a mile farther east, a 50-foot ledge of anorthosite with 10 or 15 per cent femic minerals contains several distinctly foliated zones not sharply separated from the rest of the rock.

In a ledge of typical Marcy anorthosite on the middle-southern slope of Saywood hill, a distinctly foliated zone occurs in contact with nonfoliated anorthosite on either side.

From Saywood hill to Clear Pond mountain there are large scale variations represented chiefly by typical, nongabbroid, mostly nonfoliated, Marcy anorthosite with some labradorites up to 3 inches long on Saywood hill; very coarse, rather gabbroid, nonfoliated anorthosite containing labradorites up to 6 or 7 inches long and 10 to 20 per cent femic minerals on Clear Pond mountain; and many fine exposures of more typical Marcy anorthosite with usually 10 to 15 per cent femic minerals and little foliation.

In the whole area from Blue Ridge mountain eastward to the map limit, there are many excellent exposures of remarkably uniform, very typical Marcy anorthosite, there being few gabbroid or foliated variations in this large area.

Where the road crosses the Branch brook a ledge of typical Marcy anorthosite contains an irregular gabbroid mass about 2 feet wide without sharp boundaries against the inclosing rock.

Variations similar to those just described were observed in many other places, but enough have been described to illustrate the nature of the variability of the anorthosite.

Significance of the composition and variations of the Marcy anorthosite. According to Bowen, "anorthosites are made up almost exclusively of the single mineral plagioclase" and therefore "the conception of the mutual solution on minerals in the magma and the lowering of temperatures consequent thereon is no longer applicable." But, in view of the facts above presented which show that the anorthosite averages fully 10 per cent femic minerals visible to the naked eye; that the labradorites carry myriads of tiny inclusions of a dark mineral; and that the anorthosite contains a notable percentage of potash, is the mutual solution theory necessarily precluded? Have we any proof that a rock with such a quantity and variety of constituents other than plagioclase could not have been, largely at least, molten as such? Is it safe to argue from experiments on small amounts of rather pure melts under ordinary laboratory conditions that a rock like the Adirondack anorthosite could not have existed as a true magma? Bowen says that "a rock containing 10 per cent diopside (and 90 per cent plagioclase) could have had a maximum of 35 per cent liquid" in an artificial melt, and that in a natural melt "the probability is that the amount of liquid would be relatively somewhat larger on account of the presence of orthoclase in the liquid." But the Adirondack anorthosite would have formed a melt of notably more complicated composition than an artificial melt with 10 per cent diopside, and this *under deep-seated geologic conditions*. Is it safe to say, therefore, that such a melt may not have been a true magma with a high percentage of liquid? Furthermore, allowance should be made for various agencies well within the earth, particularly dissolved vapors the escape of which pressure tends to prevent, and which tend to increase fluidity.

Since the foliation of the anorthosite is essentially a magmatic flow-structure, it shows that, at the very least, large portions of the

body of anorthosite once possessed fluidity enough to permit distinct magmatic currents or movements. The significance of the foliation is thus an important consideration. Even the typical Marcy anorthosite, almost entirely free from femic minerals, not rarely exhibits a magmatic flow-structure foliation (plate 6), the labradorite crystals having been strung out into crude parallelism in a yet molten portion of the rock. Not only was this interstitial liquid in sufficient quantity to permit the development of distinct magmatic flowage, but it was essentially *molten plagioclase*. It could have been nothing else. Hence we here have evidence directly opposed to Bowen's statement that the anorthosite was never at a temperature sufficiently high to melt plagioclase. It is not argued, however, that the anorthosite as such necessarily was intruded in the form of a true magma to its present position, having been differentiated at a much lower level. Rather, it is probable that a gabbroid magma was the original intrusive which, either during the process of intrusion or after the magma came nearly to rest, or both, differentiated to give rise to the anorthosite which was then, in considerable part at least, really molten. This matter is more fully discussed below.

Though the writer believes the anorthosite as such to have been molten to a very considerable degree at least, it is by no means necessary to assume that it was ever completely molten with a high degree of fluidity, or even only a moderate degree of viscosity. None of the field facts, however, necessarily preclude the hypothesis that the whole mass of the anorthosite may once have been completely molten, but without a high degree of fluidity.

Before leaving this consideration of the significance of the variability of the anorthosite, emphasis should be placed upon the fact that, in many places, its mass shows unmistakable evidence of having differentiation phases of anorthosite-gabbro or even gabbro, while there is no positive evidence for its differentiation into syenite or granite as should be the case according to Bowen's hypothesis.

Relation of Whiteface and Marcy types of anorthosite. In the Schroon Lake quadrangle as elsewhere, it is clear that the Whiteface anorthosite is a gabbroid border facies of the Marcy anorthosite with perfect gradations from one into the other, and with no evidence that syenite or granite was ever developed as a rock intermediate between the border phase and the true anorthosite as required by Bowen's hypothesis. Though it has been notably cut into, and partly assimilated by the syenite-granite body, a glance at

the geologic map shows beyond question that this Whiteface anorthosite was formerly a continuous border phase of the Marcy anorthosite which latter occupies the whole northeastern one-third of the quadrangle. Three large bodies of the Whiteface anorthosite still lie against the Marcy anorthosite in their original positions. There is strong evidence that this border phase was formerly at least 7 or 8 miles wide because, within that distance out from the Marcy anorthosite, many smaller widely scattered masses of the Whiteface rock occur as inclusions in the syenite-granite series all the way across the quadrangle. In other words, only remnants of the original border rock now occur. Further, since this border rock is notably finer grained than the Marcy anorthosite, it is very reasonable to interpret it as a chilled gabbroid border phase comparable in position and origin to Cushing's Long Lake border phase of the anorthosite, though of lighter color and usually not so gabbroid. The Schroon Lake quadrangle Whiteface anorthosite commonly carries 10 to 20 per cent dark minerals, but it is very variable, some phases containing only 5 per cent or even less, and some more than 20 per cent.

There is strong evidence that the chilled gabbroid border phase developed not only as an *outer* limit but also as an *upper* limit which formerly existed as a cover resting directly upon the whole great mass of anorthosite. Thus, as already pointed out in the writer's Lake Placid report, the Whiteface anorthosite of that area does not exist merely as a definite fringe around the outer margin of the Marcy anorthosite. Whiteface anorthosite there occurs fully 14 or 15 miles within the present border of the anorthosite area, and inclusions in the syenite-granite series outside the general anorthosite area show that the Whiteface anorthosite formerly extended at least a few miles farther out than the present boundary. One area of Marcy anorthosite, 12 miles long within the Lake Placid quadrangle and extending an unknown distance into the Ausable quadrangle, is flanked on either side by Whiteface anorthosite. It is hard to resist the suggestion that the Whiteface rock formerly covered this whole mass of Marcy anorthosite. There is thus a distinct difficulty in the way of considering this Whiteface anorthosite as merely an outer border facies. If we do regard it as merely an outer facies, we are forced to conclude that it is exceedingly thick, that is to say fully 10 or 15 miles, the width of the area containing Whiteface anorthosite representing practically the thickness of the border facies. This is scarcely conceivable.

The Schroon Lake quadrangle yields similar evidence since, as

above pointed out, the border facies (Whiteface type) there formerly extended fully 7 or 8 miles out beyond the present margin of the Marcy anorthosite as indicated by numerous inclusions in the syenite-granite series. In this connection, a very interesting inclusion of fragments of very typical Marcy anorthosite in the granite of Wilson mountain, over 6 miles out from the present border of that type of anorthosite, may be reasonably interpreted as Marcy anorthosite caught up in the granite magma at a lower level (below the Whiteface anorthosite cover) and carried upward to the present position (see figure 1). In any case it is certain that Marcy anorthosite existed that far out.

Within the Schroon Lake quadrangle no Whiteface anorthosite was found within the large area of Marcy anorthosite, it apparently all having been removed by erosion. Unless definite areas of the basic chilled border facies are found far within the great anorthosite area, positive proof that such a border once existed as a cover over the whole will be wanting. But such a cover, if once universally present, would show few, if any, remains far within the anorthosite area because of the widespread and deep erosion to which the region has been subjected.

In short, the evidence from the outer portions of the great Adirondack anorthosite body strongly supports the view that a chilled gabbroid border facies should be regarded as having formerly existed as a cover resting upon the whole mass of Marcy anorthosite. The evidence from the interior is negative, but nothing in the field is opposed to the conception of a former universal cover. But this does not preclude Cushing's conception of an outer chilled border of the anorthosite, provided we regard the anorthosite as a great laccolithic intrusive body (see figure 2) over all of which a border facies developed as an upper limit, and at the margins of which a border facies developed at the same time as an outer limit. The writer therefore agrees with Cushing that the area of anorthosite shown on the state geologic map shows practically "the original size of the mass at the depth represented by the present erosion surface," and that the anorthosite can not extend out to, or even close to, the margins of the whole Adirondack region.

According to Bowen, the femic constituents of a great gabbroid magma, as wide as the Adirondack region, first separated (or sank) by gravity, while the plagioclase crystals (then in the form of basic bytownite) remained practically suspended. At a later stage, when the liquid became light enough, plagioclase crystals (then in

the form of labradorite) accumulated by sinking, thus giving rise to the mass of the anorthosite, leaving the overlying liquid of such composition as to yield syenite or granite. In his first paper, Bowen does not consider the development of a chilled border of the Adirondack anorthosite. In his second paper, by way of reply to Cushing, he modifies his idea of the stratiform arrangement of the igneous complex by considering the development of a "gabbroid chilled upper portion of a laccolithic mass extending far beyond the limits of the present exposure." Directly under the chilled border, according to Bowen, the great body of syenite-granite developed; still lower down the typical anorthosite formed; and at the bottom, pyroxenite and gabbro.

Since the evidence above presented shows that the great body of Adirondack anorthosite has a chilled gabbroid border which can not possibly extend far out beyond the present exposure of the anorthosite, and evidence below presented is distinctly against existence of syenite or granite formed as a differentiate between the border facies and the typical anorthosite, it is clear that Bowen's hypothesis of the origin of the anorthosite by the settling of plagioclase crystals is untenable. There simply is nothing from which they could have settled. The writer believes, therefore, that it is out of the question to interpret the Adirondack igneous complex as even in a general way a "sheetlike mass with syenite above and anorthosite below" as required by Bowen's hypothesis.

Relation of the syenite-granite to the Whiteface anorthosite. According to Bowen, the syenite-granite and anorthosite are not distinctly separate intrusives, but both formed as differentiates from a single great body of intruded gabbroid magma. Cushing and the writer both believe the syenite-granite series to be distinctly later, and the writer has found abundant evidence in support of this view in both the Lake Placid and Schroon Lake quadrangles. see page 10

For the Long Lake quadrangle Cushing says¹: "The field evidence seems clear that the anorthosite had solidified, with a chilled border, and had then been attacked from the side by a mass of molten syenite, which in places cut deeply into it." With this statement the writer agrees, but he would further say that both granite and syenite of the syenite-granite series have, in certain other districts like the Lake Placid and Schroon Lake quadrangles, not only cut deeply into, but also they have either largely cut out

¹ Jour. Geol., 25:507. 1917.

or more or less assimilated, the border facies of the anorthosite. Detailed field evidence in support of this view is presented below.

Cushing maintains that the chilled border is fatal to Bowen's conception that molten overlying syenite may have been faulted down against solid anorthosite so that it could have laterally attacked the anorthosite, thus accounting for the intrusive features including the syenite dikes. Much detailed field work by the writer shows that the chilled border (Whiteface anorthosite) grades directly into the typical anorthosite, and that there is no reason to think that the syenite-granite series developed between the chilled border and the typical Marcy anorthosite. Even if we assume, what has not been found in the field, that some such syenite or granite exists as a rock intermediate between the chilled border and the typical anorthosite, it is most unreasonable to suppose that the chilled border would, in some places, grade first into the syenite or granite and then into the Marcy anorthosite. Either one of these might be the case, but not both.

Bowen suggests that the syenite-granite may have developed between the chilled border and the Marcy anorthosite, and then have been reintruded through the chilled border. But how can we possibly imagine such a vast bulk of syenite-granite to have been so largely reintruded that not any of it has been discovered in its supposedly original position? Also how can we imagine the reintrusion of such a tremendous volume of syenite-granite through the chilled border facies, leaving this latter as a definite fringe about, and grading into, the Marcy anorthosite for so many miles?

Dikes of syenite and granite in anorthosite. Some years ago, in his report on the *Geology of the Long Lake Quadrangle*,¹ Cushing showed that several narrow well-defined dikes of syenite there cut the typical Marcy anorthosite, one of these dikes being several miles within the border of the great anorthosite body. He also states that one of the small outlying masses of anorthosite is "definitely cut by syenite which sends dikes into it."

As a result of the surveys of both the Lake Placid and Schroon Lake quadrangles by the writer, various excellent examples of dikes and broad tongues of syenite and granite cutting anorthosite have come to light. A number of fine examples of such dikes are described in the report on the *Geology of the Lake Placid Quadrangle*.

¹ N. Y. State Mus. Bul. 115, p. 480-84. 1907.

In the Schroon Lake quadrangle a number of clearly defined dikes of granitic syenite and granite were observed in the anorthosite. One of these is well shown by the road $1\frac{1}{2}$ miles west of Boreas river where a dike of granite 5 feet wide cuts rather femic Whiteface anorthosite without very sharp contacts. Another is a dike of typical pinkish gray granite 25 feet wide 1 mile west of the western summit of Sand Pond mountain. It sharply cuts Whiteface anorthosite which lies near, and closely resembles Marcy anorthosite. Both dikes just mentioned are quite certainly off-shoots from large bodies of typical granite which, in a general way, cut into the marginal portion of the great body of anorthosite. A wide dike of gray granite cuts Marcy anorthosite just north of the summit of Texas ridge (see map). The granite is very gneissoid with highly flattened quartz and feldspar crystals. The small mass of Whiteface anorthosite on the side of Beech hill (see map) is cut by a number of narrow dikes of granitic syenite and granite which are doubtless off-shoots from the large surrounding body of syenite-granite. Contacts between these dikes and the anorthosite are usually not very sharp.

Also in the Schroon Lake quadrangle many dikes or narrow intrusive bodies of syenite and granite were observed in the areas of anorthosite and syenite-granite mixed rocks, and to some extent in the areas of Keene gneiss. Some of these are referred to below. The evidence, therefore, from the dikes, that the syenite-granite series is distinctly younger than the anorthosite series, is very strong.

Broad intrusive tongues of syenite and granite in anorthosite. Broad tongues of syenite and granite extending, in a number of places for miles, into the great body of anorthosite furnish perhaps even more impressive evidence than the dikes that the syenite-granite series is really younger than the anorthosite.

Cushing's Long Lake geologic map shows an intrusive tongue of syenite from 1 to 3 miles wide cutting into the anorthosite for a distance of 2 miles.

The writer's Lake Placid geologic map shows a fine example of a tongue of syenite-granite with a maximum width of $1\frac{1}{2}$ miles cutting Whiteface anorthosite across a portion of Wilmington mountain. A great body of syenite-granite from 1 to 6 miles wide extends into the anorthosite for 13 miles across the Lake Placid quadrangle, and thence for an unknown distance into the Mount Marcy quadrangle on the south.

In the Schroon Lake quadrangle, a tongue of granite from 2 to 4 miles wide in the vicinity of Cheney pond extends into the anorthosite for fully 4 miles, reaching all the way through the border facies and into the Marcy anorthosite (see map). The large intrusive mass of later gabbro lies within this salient and cuts out much of the originally present granite. Two of the small dikes of granite above mentioned are off-shoots of this salient of granite in the anorthosite.

Inclusions of anorthosite in the syenite-granite. Inclusions of anorthosite in the syenite-granite series furnish very strong evidence that the syenite-granite body is an intrusive distinctly separate from, and later than, the anorthosite. Such evidence is scarcely, if at all, mentioned by Bowen, probably because few examples of such inclusions were known to him. Many excellent examples have come under the writer's observation.

It seems evident from a glance at the accompanying Schroon Lake geologic map that the anorthosite once extended out as a continuous broad belt at least 7 or 8 miles beyond the present margin of the Marcy anorthosite because, within that distance from the Marcy anorthosite, there are many inclusions of anorthosite (mostly of sufficient size to be mapped) in the syenite-granite series all the way across the quadrangle. In other words, only mere remnants of the former anorthosite are now visible. With the exception of one locality, these are all inclusions of Whiteface anorthosite. The exceptional locality is of particular interest. It is on top of Wilson mountain, and represented on the geologic map as a small area of mixed rocks. One patch of the granite 12 feet across contains large dark bluish gray labradorites an inch or more across and several small pieces of typical Marcy anorthosite as distinct inclusions, mostly arranged roughly parallel to the foliation of the granite (see figure 1). Immediately around the larger fragments the granite exhibits fine magmatic flow-structure. A similar exposure occurs close by. A reasonable interpretation is that the granite magma moving upward enveloped two small masses of Marcy anorthosite and tore them into small fragments which became somewhat scattered and arranged parallel to distinct magmatic currents which moved up nearly vertically as shown by the high angle of dip of the magmatic flow-structure foliation.

A fine example is in the bed of the brook 1 mile southeast of the summit of Oliver hill where a mass of Whiteface anorthosite 20 feet across is inclosed in the granite (see map). This outcrop con-

sists of alternating bands of partly white and partly rather gabbroid Whiteface anorthosite.

An interesting ledge outcrops in the small mapped area $1\frac{1}{2}$ miles a little west of north of Irishtown. The rock is extremely gneissoid, moderately gabbroid, Whiteface anorthosite containing many lens-shaped labradorities or "augen" up to $1\frac{1}{2}$ inches long, and in some portions red garnets. This anorthosite also has in it many

Fig. 1. Sketch of part of an exposure on top of Wilson mountain showing small inclusions of Marcy anorthosite in gneissoid granite. Note the magmatic flow-structure foliation about the larger fragments.

inclusions of Grenville hornblende-garnet gneiss in the form of lenses, strips and layers from less than 1 foot long to 1 or 2 rods long, these being arranged parallel to the foliation of the ledge. It is thus certain that this anorthosite must have been in a truly magmatic state when it caught up the fragments of Grenville. The immediate relation of this ledge to the nearby syenite is obscured by drift, but no doubt it is an inclusion.

Along the western side of the Beech hill anorthosite, which is an inclusion in the syenite-granite, there are, in the granite, some small, irregular inclusions of Whiteface anorthosite with indefinite boundaries, and with distinctly curving flow-structure in the granite around them.

In the narrow belt one-fourth of a mile long, already described as extending across the southern brow of Cobble hill, many small inclusions of the Whiteface rock occur in the granite.

A number of inclusions of the Whiteface rock, each from 1 to 20 feet across, are finely shown in the granitic syenite on top of the hill 1 mile east-southeast of Cobble hill.

All the inclusions of anorthosite above mentioned bear exactly the same relations to the inclosing syenite-granite as do the inclusions of Grenville, and it seems clear that the upward moving syenite-granite magma enveloped masses of both these rock series in exactly the same manner. Thus we have just as strong evidence that the syenite-granite is distinctly younger than the anorthosite as that it is distinctly younger than the Grenville.

Absence of Grenville and syenite-granite from the anorthosite area. It is a striking fact that both Grenville and syenite-granite are almost, if not quite, absent from a large part of the anorthosite area of the Adirondacks. In the northeastern half of the anorthosite area there are considerable developments of both Grenville and syenite-granite. In the southwestern half of the Adirondack anorthosite area, including the Schroon Lake quadrangle, the absence of Grenville and syenite or granite is, however, an impressive fact, though it must be remembered that many square miles of this have not been carefully studied. The detailed Long Lake, Schroon Lake and Paradox Lake maps, and the southern half of the Elizabethtown map, show no Grenville or syenite-granite well within the anorthosite there mapped. So far as known to the writer this is also true of the southern half of the Mount Marcy quadrangle.

Bowen, in his paper on "The Problem of the Anorthosites," dwells upon this absence of Grenville and syenite-granite from so much of the anorthosite, and he offers an explanation briefly stated as follows:¹ "If one pictures the syenite and the anorthosite as conventional batholiths, some difficulty is experienced in accounting for the foregoing facts [see above paragraph]. It is necessary to imagine an early intrusion of a huge plug of anorthosite followed by an intrusion of syenite which took the form of a hollow cylinder circumscribing it and invading it only peripherally. . . . On the other hand, if one pictures the Adirondack complex as essentially a sheetlike mass with syenite overlying anorthosite . . . one would expect to find areas of Grenville roof covering the syenite in places and to find it relatively little disturbed. In the interior and eastern region of maximum uplift one would expect to find the deep-seated anorthosite laid bare and to find it free from areas of the roof." Also, he says, because of the deep erosion in the region of maximum uplift one would expect to find the layer of syenite removed.

¹ Jour. Geol., 25:223-24. 1917.

Some of the more important objections to the view just expressed are: (1) the anorthosite represents a separate and distinctly older intrusion than the syenite-granite, and so the sheetlike arrangement advocated by Bowen is out of the question; (2) the Adirondack anorthosite area is by no means practically free from masses of syenite-granite, this being particularly true of the whole northeastern half of the area where there are many large and small bodies of syenite and granite in the form of real intrusives in the anorthosite; and (3) it is not at all necessary to assume that both syenite-granite and anorthosite were batholithic intrusions.

An explanation offered by the writer to account for the absence of Grenville and syenite-granite from so much of the anorthosite area may be briefly stated as follows. The anorthosite is considered to be a laccolith not much greater across than the present area of outcrop. Its intrusion was soon followed by a very irregular intrusion of the great body of generally rather highly fluid syenite-granite magma. That the syenite-granite magma was mostly rather highly fluid is proved by its great power to cross-cut, intimately penetrate, break up and tilt the Grenville strata. Only exceptionally did local portions of this magma invade the Grenville strata in true laccolithic fashion. Both the anorthosite and the syenite-granite are believed to have intruded a very thick mass of essentially undisturbed Grenville strata, largely or altogether free from orthogneiss. The southwestern half of the anorthosite body, which is so free from masses of Grenville and syenite-granite, is believed to represent the greatest bulk of the anorthosite where the laccolithic magma was thickest and reached its highest level. The northeastern half of the anorthosite as now exposed is regarded as the portion where the anorthosite magma spread out as a relatively much thinner layer whose surface was at a notably lower level than that of the thicker portion to the southwest (see figure 2). Because of the greater uplift of the southwestern portion, the Grenville cover has there been almost, if not completely, removed by erosion. But many areas of the Grenville roof remain over the thinner northeastern part of the anorthosite where the uplift was much less. Thus we have a simple explanation of the absence of the Grenville from so much of the anorthosite area. After the solidification of the great body of anorthosite, the syenite-granite magma was batholithically intruded in a rather highly fluid state, and it tended to avoid penetration of the anorthosite which was much more massive, homogeneous and

resistant than the great mass of surrounding practically undisturbed Grenville strata. This satisfactorily explains not only why syenite-granite masses are scarcer within the anorthosite area than in the Adirondack region in general, but also why syenite-granite is almost, or entirely, absent from the southwestern half of the anorthosite area. May not there have been a wide magmatic feeding channel extending northwest by southeast under the main body of the southwestern half of the anorthosite? On this view, the thickest portion of the laccolith developed directly over the wide feeding channel which extended far down, with the result that this portion of the anorthosite intrusive body was very resistant to intrusion by the syenite-granite magma. The northeastern portion of the anorthosite, because notably thinner, was penetrated by considerable masses of the syenite-granite magma, as, for example, in the Lake Placid and Ausable quadrangles. Here again we have a simple explanation of the field facts.

Strongly supporting the above conception is the evidence from the distribution of the stocks of later gabbro. All the recent workers in Adirondack geology recognize this gabbro as distinctly younger than the syenite-granite series. It usually occurs in the form of stocks or pipelike bodies rarely more than a few miles across. Such stocks are common and widespread throughout the Adirondack region, except the anorthosite area. Like the syenite-granite, this gabbro is singularly absent from the southwestern half of the anorthosite area. In the Schroon Lake and Elizabethtown quadrangles a number of such gabbro stocks each from 2 to 4 miles long lie right along the border of the anorthosite but none well within it. In the northeastern half of the anorthosite area gabbro stocks occur in moderate size and number. It is, then, very clear that this later gabbro shows the same sort of distribution with reference to the anorthosite as does the syenite-granite, and it is believed that the same explanation (see above) applies to both. Evidently the gabbro intrusions, too, were unable to penetrate the thick, very resistant southwestern half of the anorthosite laccolith.

Origin of the anorthosite by differentiation in a laccolith of gabbroid magma. *Laccolithic structure of the anorthosite.* After considering a number of the better known anorthosite bodies of the world, Daly¹ concludes that all of them, including the Adirondack mass, are to be regarded as laccoliths.

² Igneous Rocks and Their Origin, p. 328-35. 1914.

The writer believes the Adirondack anorthosite (not necessarily the anorthosite as such) was intruded essentially laccolithically, and the syenite-granite was intruded essentially batholithically. But it is not at all necessary to assume, as does Bowen, that both great bodies are batholithic if they are regarded as distinctly separate intrusions.

Fig. 2 Highly generalized northwest-southwest structure section through the Adirondack anorthosite body, showing the relation of the anorthosite to the Grenville and syenite-granite series

Positive proof for the laccolithic structure of the Adirondack anorthosite can not be won from a study of its relation to the intruded Grenville strata. In the first place, only a very few (usually small) areas of Grenville are known to lie against the borders of the anorthosite because the Grenville has been so extensively cut out by the syenite-granite, and these few contacts are almost all concealed under Pleistocene deposits. In the second place, such Grenville strata were more or less disturbed a second time by the later syenite-granite intrusion.

Many of the most important field facts best harmonize with the conception of a laccolithic structure of the Adirondack anorthosite. Among these facts which have already been discussed, are the following: The chilled border facies which developed as an upper as well as an outer margin resting directly upon and against the Marcy anorthosite; failure to find masses of Grenville farther down in the body of the anorthosite than just below the level of the inner margin of the chilled border, thus indicating the power of the

anorthosite to have lifted rather than to have extensively cross-cut or engulfed Grenville strata; and failure of both syenite-granite and later gabbro to penetrate the southwestern half of the great anorthosite body, and moderate penetration of the northeastern half by the rocks just named, thus very strongly suggesting a laccolith very thick toward the southwest and relatively thin toward the northeast.

Probable origin of the anorthosite by settling of femic minerals. The writer's conception is that the anorthosite resulted from the settling of femic constituents in an originally gabbroid intruded or intruding magma. This is fundamentally the view expressed by Daly¹ who says: "The anorthosites of the world are best regarded as . . . gravitative differentiates of gabbroid magma" usually in laccoliths. Regarding differentiation in general by sinking of crystals, F. W. Clarke² says: "Gravitative adjustment is presumably most effective in slowly cooling magmas, especially when partial crystallization has occurred. The minerals first formed must have time to sink. The rate of cooling, therefore, is a distinct factor in the differentiation of igneous rocks." There is every reason to think that the great igneous body of Adirondack anorthosite cooled very slowly.

Very briefly stated, the writer considers the main steps in the development of the anorthosite to have been as follows: first, intrusion of a laccolithic body of gabbroid magma only somewhat greater across than the exposed area of the anorthosite; second, relatively rapid cooling of the marginal portion to give rise to the chilled gabbroid border phase; and, third, settling of many of the slowly crystallizing femic minerals in the still molten interior portion of the laccolith, leaving a great body of magma to crystallize gradually into anorthosite. Thus at the bottom, and probably nowhere visible in the field, lies a mass of pyroxenite or peridotite; next above it the thick body of Marcy anorthosite; and at the top and on the outer margins the chilled gabbroid border facies known as Whiteface anorthosite.

The border facies thus merely represents the very outer and upper portions of the original gabbroid magma which solidified too rapidly to permit much settling or separation of femic minerals from it. This marginal phase came into direct contact with the

¹ *Igneous Rocks and Their Origin*, p. 229-43. 1914.

² *U. S. Geol. Survey Bul.* 491, p. 297. 1911.

country rock (Grenville) and, at first, when it was in its most highly fluid state, attacked the country rock with sufficient force to engulf portions of it, send some dikes into it, and even intimately penetrate it. Such phenomena have been observed in the Lake Placid and the Schroon Lake quadrangles. For most part, however, the gabbroid magma was too stiff to cross-cut, penetrate, break up and tilt masses of the Grenville in a manner at all comparable to the later syenite-granite magma.

Soon after the intrusion of the laccolith, many of the femic minerals which began to form in the magma just below and within the chilled border phase began to precipitate, thus permitting the accumulation of plagioclase in the upper levels of the magmatic chamber. Though this idea of settling of femic minerals is much like that advocated by Bowen, the writer's hypothesis differs in two important respects. First, the anorthosite did not form by settling of plagioclase crystals, and, second, there was no development of syenite-granite residual magma over the anorthosite. It is not necessary to believe that there was any great amount of settling of femic constituents unless we assume a very femic original gabbroid magma, because femic minerals up to fully 10 per cent never precipitated at all, these being now present in the typical Marcy anorthosite. Further, the femic constituents did not settle through anything like such a thick mass of magma as required by Bowen's hypothesis, and only heavy femic minerals sank, and not femic minerals followed by plagioclase in a magma which must have become increasingly viscous.

It is evident, then, that the gabbroid magma in the Adirondack region must, to the very last of the process, have contained at least a very considerable percentage of liquid of sufficient fluidity to have allowed the crystals to sink through, and this residual magma is represented by the present anorthosite, which was once to a very considerable degree molten as such. Could the magma have possessed sufficient fluidity long enough to have permitted repeated wholesale sinking of crystals through a very great thickness of magma as required by Bowen's hypothesis?

Origin of variations in the anorthosite. As already shown, the anorthosite contains many zones or belts and irregular-shaped portions, some distinctly more gabbroid, and others distinctly more highly feldspathic than the average Marcy anorthosite. Many of these show relatively wide gradation zones into the typical rock,

while others are more sharply separated. There are also many degrees of foliation and granulation, and differences in coarseness of grain.

The conception of the origin of such variations which best harmonizes with the field facts may be briefly stated as follows. During the crystallization of the anorthosite magma, formed by the process outlined above, there was local differentiation in the upper portion of the magma reservoir whereby many portions relatively richer in femic constituents separated from the much larger portions relatively poor in femic constituents. The more femic portions, which contained more liquid, and hence were freer to flow, were, in many cases, more or less shifted by movements during a late stage of magma consolidation to form the crude bands or zones often well foliated and rather sharply separated from the purer anorthosite. Those belts or zones of more gabbroid anorthosite which gradually pass into purer anorthosite probably represent differentiates essentially *in situ*. That there must have been notable movements during a late stage of magma consolidation is abundantly proved by the magmatic flow-structure foliation, more especially in the gabbroid zones, but also not rarely in the typical Marcy anorthosite. It is also believed that these late magmatic movements caused much, or all, of the notable granulation of the anorthosite. But this granulation is by no means true only of the anorthosite. The syenite-granite series and the later gabbro usually exhibit high degrees of granulation and more or less well-developed foliation due to the same cause.

Syenite-granite Series

General statements. The syenite-granite series is very prominently developed in the Schroon Lake quadrangle where it occupies most of the southeastern half of the area. Definitely known areas, essentially free from intimate associations with other rocks, total fully 75 square miles. To these must be added a few square miles more which are mapped with the mixed rocks or are concealed in the areas mapped as Pleistocene. The syenite-granite series is, therefore, about as extensively developed as the anorthosite series of the quadrangle. No syenite or granite whatever was found in the great area of Marcy anorthosite, and an explanation of this fact is offered above in the discussion of the anorthosite. The

series shows many variations from quartz syenite through, granitic syenite to granite. Since it is part of, and in almost every way similar to, the well-known syenite-granite series of the Adirondack region, it seems unnecessary to enter into detailed descriptions here. The interested reader will find more or less elaborate descriptions and discussions of the age and relations of the syenite-granite series in the various special papers and New York State Museum bulletins pertaining to the Adirondack region.

That the syenite-granite is younger than the anorthosite of the quadrangle is proved by dikes and a broad tongue of granite intrusive into the anorthosite, and by inclusions of anorthosite in both the syenite and granite. Actual examples are cited above in the discussion of the anorthosite. In fact, the occurrence of numerous small to large inclusions and isolated areas of anorthosite in the syenite-granite series as far out as 7 or 8 miles from the solid body of anorthosite, strongly supports the view that the whole anorthosite border was badly intruded and cut to pieces by the syenite-granite magma, the present inclusions and isolated masses being merely remnants of the former more extensive body of anorthosite.

That the syenite-granite is distinctly younger than the Grenville is abundantly proved by many small to large inclusions of the Grenville, and by tongues and dikes of the syenite or granite in the Grenville. Some of the inclusions large enough to be separately mapped are, 1 mile northwest of Schroon Lake village; western side of Thurman pond; one-half of a mile east of South Schroon; western face of Wilson mountain; both south and west of Oliver pond; $1\frac{1}{2}$ miles east of Sherman pond; $1\frac{1}{4}$ miles west-southwest, and $1\frac{1}{2}$ miles north-northwest of the summit of Hayes mountain; and $1\frac{1}{2}$ miles east-southeast of Boreas river. Most of these are lens-shaped inclusions parallel to the foliation of the inclosing rocks. The larger masses of Grenville represented on the geologic map are probably also best to be regarded as inclusions. In the granite of the Lester dam mixed rock area there are numerous drawn out or lenslike inclusions of hornblende gneiss. The mixed rocks in the areas south of Calahan pond, southwest of Minerva, west and southwest of Charley hill, north of Loch Muller, and west of Schroon Lake village are Grenville gneisses all cut to pieces by dikes or tongues of syenite or granite. Tongues or broad

dikes of granite and syenite extending right out into Grenville are well represented on the map north and northwest of Minerva, and south-southwest of Irishtown.

Description of syenite and granitic syenite. Practically all the syenite of the quadrangle is more or less quartzose. As has been the writer's custom for some years, when the rock contains not over 20 per cent quartz it is classed as normal quartz syenite, when the quartz content lies between 20 and 25 per cent it is called granitic syenite, and when there is more than 25 per cent quartz the rock is called granite. The syenite of the quadrangle is much less extensively developed than usual in the Adirondack region, and much of this is really granitic syenite, no attempt having been made to separate the normal and granitic phases on the geologic map because of the general unsatisfactoriness of exposures.

The two facies of the syenite are typically medium grained, though somewhat variable to finer and coarser grained. Distinctly porphyritic facies were not observed. Granulation is very common, in some cases being highly developed especially as regards the feldspar, and less commonly the quartz.

A dark greenish gray is the prevailing color of the fresh syenite as usual in the Adirondacks, though the more granitic facies are often pinkish gray. Reddish syenite, directly associated with green syenite, is well exposed in and near the quarries one-half of a mile east of South Schroon. All, except some of the pinkish facies relatively free from femic minerals, weather to light brown, the weathered portion seldom extending more than a few inches below the surface.

Seldom does the syenite fail to exhibit a foliated structure. It is, in most cases, moderately developed, but in some cases it is faint and in others very pronounced.

It should be noted that marked differences in granularity, granulation, foliation and color not uncommonly occur locally, in some cases in single outcrops, or even in hand specimens.

Very typical, fresh, moderately gneissoid, greenish gray, normal quartz syenite is finely exposed in the larger of the two quarries by the road one-half of a mile east of South Schroon. No. 6 of table 2 shows the mineral content of a thin section of this rock.

Table 2 Thin sections of syenite, granitic syenite, and granite

	Slide no.	Field no.	Microperthite	Orthoclase	Oligoclase	Microcline	Andesine	Quartz	Hornblende	Pyrox. (Mono.)	Diallage	Hypersthene	Chlorite	Hematite	Magnetite	Pyrite	Biotite	Garnet	Apatite	Zircon	Sericite	Calcite
Syenite and granitic syenite	5	415	45	8	10	..	..	22	5	..	..	..	..	..	2	..	..	..	..	..	..	..
	6	415	45	8	10	..	..	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	7	6g	635	20	30	..	..	8	..	..	3	2	..	..	..	..	..	..	little	little	..	..
	26	9f	240	13	10	..	..	20	..	7	5	2	..	..	1	..	little	..	..	..	..	..
	28	10g	1080	5	5	..	..	13	..	..	1	..	..	..	..	..	..	3	..	..	..	..
Granite	49	8m	564	..	6	..	4	15	2	3	..	..	..	..	2	..	..	2	..	..	..	..
	1	1k	820	..	1	40	..	34	3	..	..	..	..	..	..	..	1	..	..	..	..	..
	2	2c	450	..	3	..	..	40	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	3	2m	224	..	2	24	..	42	6	..	..	..	..	..	..	..	..	..	..	..	..	..
	4	3h	146	5	2	2	..	24	2	..	..	..	..	..	..	1	..	..	..	..	..	..
	8	8f	341	..	8	..	..	35	15	..	..	..	..	..	..	..	..	..	..	..	..	..
	9	13f	632	15	..	..	..	30	..	..	..	..	..	..	..	..	1	..	..	..	..	..
	25	9d	335	1	..	..	..	40	..	..	..	..	..	..	..	..	..	7	..	..	..	..
	31	10g	257	..	1	..	..	35	5	..	..	..	..	..	..	..	..	1	..	..	..	..
	32	9b	133	..	6	..	4	35	12	4	..	..	..	..	1	..	..	3	..	..	..	..
	34	8f	13b	65	..	..	5	28	..	..	1	..	..	..	..	..	..	..	..	..	..	..
	35	8f	25b	54	..	2	..	35	2	..	4	..	..	..	2	..	..	..	..	..	..	..

No. 5, by road one-third of a mile east of South Schroon; no. 6, quarry one-half of a mile east-northeast of South Schroon; no. 7, cross-roads one-half of a mile northeast of Muller pond; no. 26, one-half of a mile north-northwest of Bailey pond; no. 28, from granitic syenite area 1¾ miles northeast of Bailey pond; no. 49, southeastern base of Severance hill; no. 1, top of hill 1½ miles southwest of Taylors on Schroon; no. 2, quarry one-half of a mile a little west of north of Moxham pond; no. 3, lake shore one-third of a mile northwest of Adirondack village; no. 4, 1 mile east-northeast of Pat pond; no. 8, one-half of a mile northeast of summit of Cobble hill; no. 9, from tongue of granite cutting anorthosite 1 mile south of Sand pond; no. 25, old road crossing Minerva stream 1 mile north of mouth of Hewitt pond brook; no. 31, east of brook at north end of granite area 2 miles northeast of Bailey pond; no. 32, little hill just west of Hewitt pond; nos. 34 and 35, southern brow of Cobble hill.

From table 2 it is seen that microperthite always occurs as the most prominent constituent of the syenite, while oligoclase and quartz are always present in smaller amounts. Orthoclase is more variable and sometimes absent. No. 7 is a fine example of a distinctly basic or dioritic facies of the syenite. Nos. 26 and 49 show reaction rims of garnet around magnetite. No. 31 is highly granulated along some zones parallel to the foliation in the thin section.

Description of granite and granite porphyry. The granite and granite porphyry are regarded as differentiation facies of the great Adirondack syenite-granite series. There are many places where

the syenite grades through granitic syenite into granite, but not a single locality was observed where syenite definitely cuts granite or vice versa. The writer has been unable to demonstrate the existence of any considerable mass of granite either distinctly older or younger than the normal syenite, though small pegmatite and aplite dikes are not uncommon.

As regards granularity, granulation and foliation the statements above made with reference to the syenite apply almost equally well here. Excessively gneissoid granite with highly flattened quartz and feldspar were observed, among other places, one-fourth of a mile northeast of the summit of Cobble hill, on the southern brow of Bigsby hill, at the summit of Oliver hill, and in the small area of granite just east of the brook near the trail 2 miles northeast of Bailey pond.

Most of the granite is pinkish gray, to pink, or even reddish where fresh, but locally it is greenish gray or gray. It usually weathers to pinkish gray or light brown.

Like the syenite, the granite exhibits many local variations. A hand specimen from a ledge by the lake shore one-fifth of a mile north of the Adirondack village steamer landing is distinctly foliated and granulated, with one pink band especially rich in feldspar adjacent to a band very rich in quartz plus some garnets, these two bands having on either side granite consisting of quartz, feldspar, and hornblende with some biotite. These bands are not sharply separated. In the quarry one-half of a mile north of Moxham pond, the granite shows notable variations in coarseness of grain often within a foot or two.

Table 2 shows the minerals contained in some thin sections of the granite. From this table it is seen that the two most conspicuous never failing constituents are microperthite and quartz. In a few slides microcline occurs, and in only two does it equal or exceed the microperthite. Orthoclase usually fails and it is never prominent.

Granite with scattering garnets was observed in several places as, for example, the whole mass of Pine hill, three-fourths of a mile west-southwest of Taylors on Schroon, on top of Ledge hill, and by the road three-fourths of a mile north-northeast of Pat pond.

In a number of localities numerous lenslike inclusions of hornblende gneiss (metagabbro or Grenville), too small to be mapped, occur in the granite as, for example, one-half of a mile west of Oliver pond, at the summit of Cobble hill, and on Ledge hill just

north of the small gabbro stock. An inclusion of particular interest is shown in figure 8.

The granite porphyry is quite certainly a differentiation phase of the granite, and it is only moderately developed within the quadrangle. One small area is represented on the map in the very southeastern corner, and another on the southern brow of Ledge hill, while the largest area (about 1 square mile) takes in the vicinity of Pat pond. The granite porphyry differs from the granite only in being coarser grained and usually more or less porphyritic.

Grenville or Hornblende Gneiss (Metagabbro?) and Syenite-granite Mixed Rocks

A number of small areas of mixed rocks of this sort are represented on the geologic map. The Grenville or hornblende gneiss (metagabbro?) and granite are so intimately associated that any attempt to separate them on the map would be unsatisfactory. The old rocks are usually cut to pieces by, or form inclusions in, the syenite-granite.

In the small area just south of Calahan pond, typical granite contains small to large well-defined inclusions of Grenville. In the two garnet mines, the larger of which is located near the edge of the map and the other just to the west, the rocks are highly granular red garnet in considerable masses closely associated with coarse pyroxenic crystalline limestone. Contacts are sharp against the granite in the smaller mine, but not in the larger one. A few rods to the north and by the old road, there is a small, sharply defined inclusion of limestone in the granite parallel to the foliation of the latter.

In the area covering about one-half of a square mile southwest of Minerva there are many outcrops of both granite and Grenville, the two often being closely associated in single outcrops. Evidently the Grenville has here been badly cut to pieces by the granite.

The mixed rocks of the small area 2 miles north of Minerva are described along with the associated iron ores in the last chapter of this bulletin.

At and near Lester dam there are extensive outcrops of pinkish, very gneissoid granite containing much hornblende gneiss in the form of flattened or lenslike inclusions more or less fused into the mass.

The small area three-fourths of a mile north of Loch Muller shows good exposures of hornblende and hornblende-garnet gneisses shot through by some dikes of granite. Some of the garnets up to 1 or 2 inches in diameter have distinct rims of hornblende.

In the small area three-fourths of a mile northwest of Loch Muller, hornblende gneiss (metagabbro?) is shot through by granite and considerable magnetite is associated with the rocks.

Of the small areas west and southwest of Charley hill, the two farthest out are chiefly granite with considerable intermixed older dark gneisses, while the one nearer Charley hill is chiefly well-bedded hornblende gneiss shot through by irregular dikes of granitic syenite.

The small area 1 mile south-southwest of South Schroon is mostly hornblende gneiss intricately cut into, and apparently more or less assimilated by, granite.

The area of about one-fourth of a square mile 1 mile west of Schroon Lake village shows many good exposures of hornblende and hornblende-garnet gneisses, some very intimately associated with granite in the form of small streaks and bands, and some less intimately associated in bodies of considerable size.

An exposure by the road $1\frac{1}{2}$ miles a little north of west of Schroon Lake village consists of very gneissoid to almost banded intimately mixed dark gneiss and granite.

The small area 1 mile northeast of South Schroon contains very gneissoid syenite or granitic syenite more or less intimately associated with Grenville hornblende and pyroxene gneisses.

Hornblende gneiss and syenite are associated in the area on the west side of Thurman pond.

Keene Gneiss

General statements. One of the most interesting rock types of the region is locally developed as belts or irregular bodies along or near portions of the borders between the anorthosite and the syenite-granite series. Both the Marcy and Whiteface types of anorthosite show such border rocks. There is very strong evidence, based upon field work and a study of thin sections, that this is really a transition rock between anorthosite and syenite or granite formed by actual digestion or assimilation of anorthosite by the invading syenite-granite magma along portions of its borders. The writer has proposed that this rock be called "Keene gneiss," because a fine exposure of the typical fresh rock occurs by the

road just north of the village of Keene in the Lake Placid quadrangle.

Fifteen areas of mostly Keene gneiss are represented on the writer's Lake Placid geologic map and the rocks are described in the accompanying report. Cushing has described rocks which probably belong in the same category, from two localities on the western side of the great anorthosite area. Cushing suggests that these rocks, particularly in the Long Lake quadrangle, are magmatic assimilation products. Kemp has described certain peculiar types of gabbro, called the Woolen Mill and Split Rock Falls types, as occurring in the Elizabethtown quadrangle. Kemp says nothing regarding the origin of these types, but, in the writer's judgment, they are to be classed as Keene gneiss. These seem to be the only rocks of the sort in the Adirondack region regarding which even brief published statements by other workers have been made. The whole problem of the Keene gneiss is rather fully discussed in the writer's recent paper¹ on "Adirondack Anorthosite."

Megascopic characters. The typical Keene gneiss presents a different appearance from any other Adirondack rock. In the Lake Placid and Schroon Lake quadrangles, the typical rock is medium grained, gneissoid, notably granulated, and looks much like some facies of the syenite-granite series except for scattering phenocrysts of bluish gray labradorites up to an inch long. These phenocrysts, which are rounded and usually elongated parallel to the foliation of the rock, doubtless represent cores of crystals which survived the process of granulation. Locally the phenocrysts are absent or only sparingly present, and such facies of the Keene gneiss are often difficult to distinguish in the field from certain phases of the syenite-granite series. Under the microscope, however, the distinction may generally be made. A gneissoid structure is nearly always present but it varies notably, in some cases being practically absent. The fresh rock is usually greenish gray, and it weathers brown.

Microscopic characters. The mineral contents of thin sections of selected samples of various phases of the rock from the Schroon Lake quadrangle are shown in table 3. It is quite clear from this table that the Keene gneiss is mostly distinctly intermediate in composition between the syenite-granite and the anorthosite.

¹ Geol. Soc. Amer. Bul. v. 29, no. 4. 1918.

Table 3 Thin sections of Keene gneiss

Slide no.	Field no.	Orthoclase	Olig.-And.	Olig.-Lab.	Quartz	Pyrox. (Mono.)	Hornblende	Chlorite	Garnet	Magnetite	Pyrite	Apatite	Zircon	Zoisite	Titanite	Biotite
27	9 f 2	21	66	...	...	7	2	...	2	1	...	...	...	...	...	...
29	10 g 12	...	...	92	7	...	2	...	...	...	...	little	...	1	little	...
30	10 f 2	45	25	...	15	5	4	...	4	...	...	...	...	...	...	...
33	12 f 4	...	...	75	7	4	2	...	8	2	...	little	...	2	...	...
36	8 f 13 a	30	...	56	10	...	3	...	little	1	...	...	...	...	...	...
36a	8 f 13 a	15	...	36	10	30	5	...	3	1	...	...	...	...	...	...
38	8 f 25 a	10	75	...	15	4	3	...	2	1	...	...	...	...	...	...
46	8 c 5	29	38	...	...	...	35	...	...	6	...	...	...	...	...	...
48	8 d 7	12	...	35	1	25	20	...	little	6	...	...	...	...	...	...

No. 27, one-half of a mile north-northwest of Bailey pond; no. 29, just north of the granite by the trail 2 miles northeast of Bailey pond; no. 30, 1 mile northeast of Bailey pond; no. 33, eastern slope of Bailey hill; nos. 36, 36a and 38, southern brow of Cobble hill; no. 46, just south of the brook 1 mile east of Hewitt pond; no. 48, one-fourth of a mile south of the mouth of Hewitt pond brook.

Descriptions of occurrences in the Schroon Lake quadrangle. Most of the Keene gneiss of the quadrangle occurs in the two largest areas separately mapped as such, but in the areas mapped as anorthosite and syenite-granite mixed rocks, there are many excellent local developments, and certain of these will be considered first.

An outcrop on the southern brow of Cobble hill, 1 mile due south of Bailey pond, is very significant because of the light it throws upon the local origin of the Keene gneiss. The accompanying sketch (figure 3) shows the relationships. This Keene gneiss is distinctly granitic or syenitic in appearance except for the many labradorite crystals, mostly an inch long, which stand out as phenocrysts more or less parallel to the crude foliation of the otherwise medium grained rock. Nos. 36, 36a and 38 represent thin sections of this Keene gneiss which, though variable, is distinctly intermediate between the granite and the anorthosite in the same ledge. Within this Keene gneiss there are inclusions of Whiteface anorthosite (no. 37 of table 1) which contain some large labradorites and also scattering femic minerals up to 2 inches long, more or less lenslike and parallel to a distinct foliation. Contacts between the inclusions and the Keene gneiss are not very

sharp. Immediately above this Keene gneiss, but not in very sharp contact with it, is a very gneissoid granite (nos. 34 and 35 of table 2) which contains many garnets. This gneissoid granite grades upward into typical, medium grained, only moderately foliated granite without garnets. A similar typical granite lies against the Keene gneiss at the bottom, but the contact there is quite sharp. The writer's interpretation is that the upward moving granite magma more or less assimilated some Marcy or Whiteface

Fig. 3 Sketch of part of the great ledge at the southern brow of Cobble hill showing Keene gneiss in its relation to both granite and Whiteface anorthosite. Contacts between the Keene gneiss and both Whiteface anorthosite and garnetiferous granite are not sharp, but the contact between the Keene gneiss and the lower granite is rather sharp.

anorthosite at a considerable depth, and that this molten mass (Keene gneiss magma) rose still higher and caught up and only partly fused the borders of fragments of Whiteface anorthosite. The origin of the garnetiferous granite is not so certain, though it may represent a mass of granite with a small quantity of anorthosite very thoroughly digested.

An interesting assemblage of rocks is well exposed on the steep hillside one-half of a mile north-northwest of Bailey pond. Commonest of all is good Whiteface anorthosite, but some tongues or dikes of granite cut through it, and still other rock is quite certainly an assimilation product of the two, that is to say, Keene gneiss. Most of the rock taken to be Keene gneiss is of syenitic aspect both with and without quartz, but some contains phenocrysts of labradorite. No. 27 of table 3 represents a thin section of this Keene gneiss, but the labradorite does not show in the thin section.

Still other local developments in the large area of "anorthosite and syenite-granite mixed rocks" are described below.

A number of small (not mappable) inclusions of Whiteface anorthosite occur in the granite along the western side of the Beech hill Whiteface anorthosite area. The borders of these inclusions have been fused and assimilated by the granite which shows curved flow-structures around the inclusions.

Interesting exposures occur in the small area of Whiteface anorthosite and syenite-mixed rocks near the southeastern base of Severance hill. The rock is mostly quartz syenite (no. 49 of table 2) which contains numerous inclusions of Whiteface anorthosite. These inclusions are very irregular and usually only a few feet long without sharp boundaries against the syenite. Evidently syenite magma rising through Whiteface anorthosite caught up numerous small fragments of it, the borders having been assimilated to form Keene gneiss on small scales.

On large scales the geologic map shows two areas of Keene gneiss, one occupying about 6 square miles, and the other nearly 3 square miles, in the central portion of the quadrangle. Before the intrusion of the large gabbro stock, the two areas were probably connected with a total length of 7 miles, extending from Rogers pond to and beyond Bailey hill. These bodies of Keene gneiss lie mostly against typical Marcy anorthosite, but also, to some extent, against Whiteface anorthosite, the border facies of the anorthosite here having been very largely assimilated by the syenite-granite magma. Throughout the larger area especially, there are a good many small masses of Whiteface anorthosite, a few of sufficient size to be mapped. There are also some outcrops of fairly good granite and granitic syenite, thus showing that all the original Whiteface anorthosite was not assimilated. The main body of the rock is, however, quite typical Keene gneiss, there being

particularly fine exposures on the eastern slope of Bailey hill, and along the middle of the crest of Washburn ridge.

Certain localities of special interest in the larger area will now be described. One of these is along the brook 2 miles northeast of Bailey pond. By the trail there is a large outcrop of peculiar, variable rock. There are some small patches of Whiteface anorthosite embedded, but most of the rock has a granitoid texture and contains scattering bluish gray labradorites up to an inch long (see no. 29 of table 3). This latter rock looks much like the Cobble hill rock above described except for fewer labradorites, and it is considered to be Keene gneiss with a history similar to that on Cobble hill. Just across the brook to the east there is a big ledge of very highly foliated medium-grained granite gneiss with both the quartz and feldspar highly flattened out parallel to the foliation.

An interesting lot of rocks occur on Washburn ridge 1 mile north-northeast of Bailey pond. A little to the north of this locality (see map) a considerable body of typical Whiteface anorthosite is exposed. A few rods to the south of the anorthosite there are exposures of mostly distinctly gneissoid rocks, syenitic in appearance but containing tiny garnets and some large bluish labradorites, these latter not always being arranged parallel to the foliation. No. 30 of table 3 represents a thin section of this rock, but none of the labradorite happened to appear in the section. This rock is quite certainly Keene gneiss. Some portions of these same ledges strongly suggest rather gabbroid garnetiferous facies of Whiteface anorthosite. A few rods still farther south, typical granitic syenite is exposed as shown on the geologic map. A careful study of these ledges on Washburn ridge strongly supports the view that Whiteface anorthosite has there been acted upon by granitic or syenitic magma, some of the anorthosite having remained unaffected, some having been partially assimilated, and still others completely assimilated, while unaffected granitic syenite outcrops at the south. The actual extent of the granitic syenite here is unknown because no exposures of any kind occur for fully a mile to the south. On the crest of the southern portion of Washburn ridge, and continuing for one-half of a mile north from the area of Whiteface anorthosite (see map), a somewhat variable, medium to fine-grained, basic, syenitic-looking rock full of tiny garnets shows in good exposures. Though large labradorites are absent, this rock is thought to have

resulted from pretty thorough assimilation of Whiteface anorthosite by syenite or granite magma. Still farther north on Washburn ridge very typical Keene gneiss is well exposed.

Many fine ledges of very typical Keene gneiss occur on the eastern face of Bailey hill, no. 33 of table 3 representing a thin section of this rock.

In the smaller of the two largest areas of Keene gneiss, exposures are generally rather scarce except on the ridge north of Rogers pond where the rock toward the south contains relatively few large labradorites and suggests a gradation into granite, while toward the north the large labradorites are common and the rock appears to grade into the Marcy anorthosite.

An area about $1\frac{1}{2}$ miles long of mostly Keene gneiss occupies approximately one-half of a square mile west, south and south-east of the mouth of Hewitt pond brook (see map). A number of good exposures show the rock to be somewhat variable, but it is unusually rich in hornblende and never contains phenocrysts of labradorite. In the field the rock looks much like a gabbroid facies of Whiteface anorthosite, but thin sections (nos. 46 and 48 of table 3) and the field relations cause it to be rather confidently classed as Keene gneiss.

Conclusion as to the origin of the Keene gneiss. Enough examples have been described to prove that the Keene gneiss of the Schroon Lake quadrangle has developed on small and large scales by assimilation of anorthosite by granite and syenite magmas. If we adopt Bowen's hypothesis, this Keene gneiss must be regarded as having developed by differentiation *in situ* between an overlying sheet of syenite-granite and underlying anorthosite. If one admits, as the writer does not, that syenite usually may have developed by differentiation *in situ* close upon the Marcy anorthosite, how can one imagine, in places like in the Schroon Lake quadrangle, a similar development of granite close upon the anorthosite? It might be argued that the granite magma formed at a higher level and was then forced downward. But, if so, it must have been forced downward through still lower syenitic material. Not only is the field evidence against this view, as already pointed out, but even if we grant it, we are still forced to conclude, by the obvious field facts, that the granite magma produced the transition rock (Keene gneiss) by assimilation of more or less anortho-

site, and that the Keene gneiss was not formed as a differentiate *in situ* between an overlying sheet of syenite-granite magma and underlying anorthosite.

Significance of distribution of Keene gneiss. The Keene gneiss can not be a direct differentiate of either the syenite-granite series or the anorthosite because it never occurs except on the border, or close to the contact, between the syenite or granite and the anorthosite. If we make the very simple and plausible assumption that the anorthosite was still very hot when the syenite-granite magma was intruded, or, in other words, if this latter magma was forced up comparatively soon after the development of the anorthosite, the usual strong objection to magmatic assimilation, namely, that a magma does not possess a sufficiently high temperature to raise relatively cold country rock to the point of fusion, is distinctly obviated. But the Keene gneiss is not universally present. In many cases where no Keene gneiss occurs along the borders between anorthosite and syenite or granite, it may be reasonably assumed that either the anorthosite or the syenite-granite, or both, in those places may not have been hot enough to permit assimilation.

The presence of Keene gneiss in one place and its absence from the same border nearby, may, in some cases, have been the result of unequal upward intrusion of Keene gneiss magma which originated at lower levels.

The small isolated masses of Keene gneiss some distance out from the main body of the anorthosite doubtless represent inclusions of anorthosite which were partly or completely assimilated by the enveloping syenite or granite magma.

The failure to find any considerable assimilation of Grenville either along its borders with, or where involved with, the syenite-granite series may be explained on the basis of a temperature of the Grenville too low to have permitted any more than comparatively slight assimilation by the invading syenite-granite magma. It should be borne in mind, however, as pointed out in a recent paper¹ by the writer, that local assimilation of the Grenville is known to have taken place in certain parts of the Adirondack region.

Anorthosite and Syenite-granite Mixed Rocks

A very irregular-shaped area of about $5\frac{1}{2}$ square miles, including Hayes mountain, is represented on the map as anorthosite and

¹ Geol. Soc. Amer. Bul., 25:254-60. 1914.

syenite-granite mixed rocks. Enough outcrops were observed to render it certain that practically all this area was originally Whiteface anorthosite which was intruded, and more or less cut to pieces, by the syenite-granite magma. Many individual outcrops are either anorthosite or syenite or granite clearly recognizable as such, but here and there local assimilation has taken place resulting in the development of some Keene gneiss. In a few cases the rocks are admittedly of doubtful origin. Some portions of the area show few if any exposures as, for example, north and northeast of Bailey pond, and in the valley between Hayes mountain and Cobble hill. In view of the facts just stated, it has seemed impossible to represent satisfactorily the various rock types on the geologic map. A few occurrences of particular interest will be described.

Perhaps the most interesting occurrence in the area just mentioned is at the summit of Cobble hill and in the belt containing Keene gneiss which extends east-west for fully one-fourth of a mile across the southern brow of the hill (see page 46). Surrounded by typical granite, there are inclusions of Whiteface anorthosite, most of them not more than a few feet long, arranged roughly parallel to the foliation of the granite. Some of the inclusions are rather sharply separated from the granite, many of them had their borders assimilated, while still other anorthosite caught up in the granite magma was completely assimilated to form Keene gneiss.

The interesting lot of rocks on the steep hillside one-half of a mile north-northwest of Bailey pond has been described above under the caption "Keene gneiss."

A big ledge in the brook at the old road crossing 1 mile west-northwest of the summit of Hayes mountain shows typical Whiteface anorthosite closely involved with granite with apparently slight development of Keene gneiss.

The margins of the small body of Whiteface anorthosite separately mapped on top of Hayes mountain appear to have been assimilated and close to its borders the anorthosite carries quartz (no. 18 of table 1).

The small area of anorthosite and granite mixed rocks on top of Wilson mountain shows numerous little inclusions of Marcy anorthosite in the granite, these having been described in the above discussion of the anorthosite. The relations are shown in figure 1.

In the small area near the southeastern base of Severance hill, syenite contains numerous inclusions of Whiteface anorthosite. These inclusions are usually only a few feet long and very irregular with their borders more or less assimilated by the syenite.

Gabbro and Metagabbro(?)

Distribution. These gabbro and metagabbro (?) bodies are, in most respects, very similar to those of the North Creek quadrangle next to the south which have been rather fully described by the writer in his report on the *Geology of the North Creek Quadrangle*¹ and also in the *Journal of Geology*, volume 21, pages 160-80. On the accompanying Schroon Lake geologic map, twenty-five gabbro masses are represented, all but four of these lying wholly within the quadrangle. They are well scattered over the southeastern two-thirds of the quadrangle, but not one has been found within the area of Marcy anorthosite. A possible explanation of their absence from the anorthosite area is given above in the discussion of the anorthosite. As usual in the writer's experience in the Adirondacks, these gabbro masses appear to have rounded to elliptical ground plans and very steep walls. The variation in length of the areas of outcrop is from one-fifth of a mile or less to 3 miles. In a few of the areas but one or two outcrops could be located.

A striking feature of the distribution is the fact that the three largest bodies of the quadrangle lie along the border of the Marcy anorthosite. Kemp's Elizabethtown map shows a similar distribution of the largest gabbro masses there. Also on Ogilvie's Paradox Lake map the largest mass of gabbro occurs along the anorthosite border. This remarkable distribution of the gabbro bodies with reference to the anorthosite may be merely a coincidence, or it may have a real significance. If the latter, the writer can think of no very plausible explanation.

Age. Most or all of the gabbro is younger than the Grenville, anorthosite and syenite-granite series (1) because of the intrusive contacts against rocks of those series, (2) because dikes of gabbro extend into rocks of those series, and (3) because inclusions rep-

¹N. Y. State Mus. Bul. 170.

representing fragments of all three series occur in the gabbro. Some of the metagabbro (?) is quite certainly older than the syenite-granite.¹

Pegmatite dikes and certain small aplite dikes have been observed as sharply defined intrusions in the gabbro. The diabase dikes are later intrusions than the gabbro as proved by their distinctly finer grain, and the fact that one actually cuts the gabbro in the northern part of the North Creek quadrangle. It is therefore evident that at least three very distinct minor intrusions succeeded the gabbro intrusions of the quadrangle.

Megascopic features. The typical nonfoliated gabbro is readily distinguished from all the other rocks of the quadrangle. Such rock makes up the main or interior masses of nearly all the stocks, especially the larger ones. It is medium to moderately coarse grained, dark gray to almost black where fresh, and it weathers to a deep brown. The plagioclase feldspar varies in color from a light gray to a dark bluish gray. A diabasic texture is usually more or less well developed, this being particularly striking in the coarser grained facies. Minerals recognizable with the naked eye or hand lens include plagioclase, pyroxene, hornblende, ilmenite (or magnetite) and nearly always biotite and red garnet.

Variations from the typical nonfoliated gabbro just described are common, one of the most abundant being highly foliated border facies (usually amphibolite) which do not show a diabasic texture. Taken by themselves, some of the amphibolitic border facies are very difficult to distinguish from certain Grenville hornblende gneisses, or even from certain very gneissoid gabbroid facies of the Whiteface anorthosite. Nearly always, however, the mode of occurrence or the gradation into more typical gabbro renders certain the recognition of the gneissoid border facies of the gabbro (figure 4). Even the more typical inner portions of the gabbro stocks show many notable variations in structure, texture and mineralogical composition as pointed out below in the special descriptions.

Microscopic features. In the following table the mineral contents of the gabbro is represented by thin sections of samples from several of the areas.

¹ Recent work by the writer in the Lyon Mountain quadrangle has shown that most of the gabbro and metagabbro are there older than the syenite-granite series which leads to the suspicion that some of the Schroon Lake quadrangle gabbro may also be older but definite evidence is lacking.

Table 4 Thin sections of gabbro and diabase

	Slide no.	Field no.	Orthoclase	Labradorite	Olig. to lab.	Hypersthene	Diallage	Hornblende	Biotite	Olivine	Magnetite	Pyrite	Apatite	Zircon	Calcite (Sec.)	Garnet
Gabbro	30	2 c 2	8	...	47	20	...	15	3	...	1	little	little	little	1	5
	40	9 h 1	15	...	45	8	...	25	...	...	...	...	...	...	...	4
	41	9 h 4	...	40	...	24	5	...	5	8	3	...	...	...	...	15
	42	12 c 4	...	45	...	26	...	...	6	4	1	little	...	...	...	18
Diabase	43	15 j 3	...	48	...	30	...	6	...	...	6	...	...	...	...	10
	44	16 j 6	...	...	40	25	10	3	...	...	4	...	little	...	...	18

No. 39, 1 mile southeast of Minerva; no. 40, 1¼ miles east of Bailey pond and near the mapped inclusion of granite; no. 41, middle of Texas ridge gabbro area; no. 42, 1½ miles northeast of Lester dam; no. 43, top of Saywood hill; no. 44, one-third of a mile north of summit of Saywood hill.

In the above table, nos. 41 and 42 are more typical of the gabbro of the quadrangle, while nos. 39 and 40 are rather more special or acidic facies. The more normal rock is therefore an olivine-bearing hypersthene gabbro or norite. The garnet, which is no doubt of secondary origin, mostly forms granulated borders about granulated hypersthene. In slide no. 41 the biotite mostly forms reaction rims about magnetite, and granulated garnet forms rims around granulated hypersthene in nos. 41 and 42. Nearly colorless diallage in no. 41 exhibits wonderful parting and schillerization inclusions. The labradorite of nos. 41 and 42 are filled with tiny dustlike dark inclusions.

Special descriptions. The Texas ridge mass is the finest large scale example of a gabbro stock in the quadrangle. It covers an area of approximately 3½ square miles. An almost continuous outcrop occurs along the whole crest of the ridge. Near the southern end of the ridge a considerable mass of well-foliated pinkish gray granite forms an inclusion in the gabbro (see map). Immediately south of this inclusion the gabbro is notably variable, being mostly moderately foliated, but some big ledges are medium grained and very massive. None of this rock exhibits a diabasic texture. No. 42 of the table shows the mineral contents of a thin section of the more common rock, and this is seen to be a distinctly acidic or dioritic facies even carrying considerable orthoclase. The near-

ness of this facies to the inclusion of granite from which it is not very sharply separated, taken in the light of various observations made by the writer on the North Creek quadrangle gabbro, strongly supports the view that this acidic facies of the gabbro was produced by assimilation of some granite during the intrusion of the gabbro magma. In this same vicinity some outcrops of rather coarse-grained, nonfoliated gabbro show 5 to 10 per cent red garnets ranging in diameter from a millimeter or two to one-third of an inch. These variations all occur within a stone's throw. Just north of the granite inclusion, the gabbro is medium to fine grained, very gneissoid, and relatively richer in feldspar. Gabbro similar to this latter also appears on the ridge crest about three-fourths of a mile northeast of the granite inclusion; otherwise the many exposures along the whole ridge crest are very typical, medium grained, nonfoliated gabbro with diabasic texture. No. 41 of table 4 shows the mineral content of a thin section of this typical gabbro. Similar gabbro outcrops in considerable force near the extreme southwestern end of the area, and also on the ridge along the eastern side of the area.

The Cheney pond stock is the second largest. It covers nearly 3 square miles. There are many good exposures. Most of this gabbro is very typical in every way, being medium to moderately coarse grained, nonfoliated, and possesses a diabasic texture. No. 42 of table 4 shows the minerals contained in a thin section. Good exposures of the amphibolitic border facies occur along the southern border between the pond and the old road, on the little island in the pond, and where the river enters the pond. In a field a few rods south of where the river enters the pond, a sharply defined 8-inch inclusion of typical Whiteface anorthosite occurs in the gneissoid gabbro. A body of granite large enough to be mapped occurs as an inclusion in the gabbro $1\frac{1}{4}$ miles northeast of the Lester dam. Whether or not the gabbro near this inclusion is more acidic than usual was not determined.

The large stock partly shown within the map limits northwest of Cheney pond is mostly very typical gabbro with considerable amphibolite developed as a border facies. In a field a few rods north of the house (where the trail leads off) there are some very interesting ledges showing amphibolitic gabbro and Whiteface anorthosite rather intimately associated.

A number of good exposures show the gabbro of the stock about a mile southeast of Minerva to be mostly medium grained and massive with only poor development of diabasic texture. Locally

a gneissoid structure is clearly evident. Much of this rock well exhibits the peculiar mottled appearance so often seen in those Adirondack gabbros which are relatively free from diabasic texture and foliation, this mottling being due to the irregular distribution of black minerals through the more or less granulated mass of feldspar. No. 39 of table 4 gives the mineral content of a thin section. This is a distinctly acidic facies and, like the local acidic facies of the Texas ridge gabbro above described, may have resulted from assimilation of granitic material by the gabbro.

The small gabbro stock on the hill one-half of a mile west of Irishtown contains a 10-foot inclusion of thin-bedded Grenville quartzite.

Fig. 4 A small exposure showing three facies of gabbro at the eastern margin of the Oliver hill stock. The gabbro is cut by aplite and pegmatite dikes.

Some interesting features were observed in connection with the Oliver hill gabbro stock. Just south of the summit of the hill the gabbro sends three dikes into the granite. None of these dikes is more than a few rods wide, and one is amphibolitic. At the extreme eastern end of the stock a small outcrop shows three facies of gabbro — one nonfoliated, another highly foliated, and a third

amphibolitic — cut by several white, fine-grained, aplite dikes and a pegmatite dike. The relations are brought out in figure 4.

The stock southeast of North pond shows large developments of very gneissoid to amphibolitic facies of gabbro, especially in its eastern portion. A ledge of rather typical, medium-grained gabbro just east of the brook one-fourth of a mile north of its junction with Rogers brook, contains many lenses and strips of nearly white Whiteface anorthosite as inclusions with parallel arrangement. A number of small faults intersect the ledge. The relations are brought out in figure 5. On the small hill in the western part of the area, typical nonfoliated gabbro is involved with

Fig. 5 A sketch of part of an outcrop near the brook at the southern margin of the gabbro stock southeast of North pond. The normal gabbro (cross-lines) contains many parallel strips of Whiteface anorthosite (black), and the whole is intersected by several minor faults.

well-foliated gabbro, these two facies forming zones or belts not very sharply separated from each other. This foliation is very clearly a flow-structure due to magmatic currents, with the wavy

flow-lines clearly preserved. Further, these well-foliated zones bear a distinct resemblance to the gneissoid or amphibolitic border facies of the gabbro already described, and thus we have here evidence strongly supporting the view that the foliation of the amphibolitic border facies of the gabbro is really essentially the result of magmatic flowage.

The northern part of the small stock near the southern end of Ledge hill is typical gabbro cut by one small pegmatite dike and several small aplite dikes.

Two small masses, one on Cobble hill and the other three-fourths of a mile northwest of Loch Muller are hornblende gneiss (meta-gabbro?) quite certainly older than the granite.

Aplite and Pegmatite Dikes

Aplite. Aplite dikes were observed in only a few localities but probably others occur within the quadrangle. These are represented only in a general way on the geologic map. They probably do not all belong to the same period of intrusion.

The best display of aplite dikes is on Wilson mountain. These are all medium to fine grained and none are foliated, neither do they show any notable difference in coarseness of grain between center and sides. On the western summit of the mountain a number of small aplite dikes, none over a foot wide, cut clearly gneissoid, coarse-grained, pinkish granite. These do not have very sharp boundaries against the granite. This fact, together with their uniform medium-grained texture, suggests that these aplite dikes were intruded under fairly deep-seated conditions not long after the intrusion of the granite, or at least before the granite cooled very much, so that the aplite magma was able to blend with the walls of the granite country rock.

On the eastern summit of Wilson mountain, numerous aplite dikes very similar to those just described, and with a maximum width of 4 feet, cut gneissoid medium-grained granite also without very sharp contacts.

The small mass of anorthosite and granite mixed rocks on Wilson mountain (see map) is cut by a number of medium-grained aplite dikes, the widest being 5 inches, and all showing rather sharp contacts against the granite.

Another locality is near the southern end of Ledge hill where several aplite dikes very sharply cut the small gabbro stock. The

largest is 5 inches wide, visible for 10 or 12 feet, and has a branch bearing off abruptly at right angles. Another is 2 inches wide and traceable for 20 feet in the gabbro. None of these dikes could be traced into the surrounding granite. In certain respects these aplite dikes are quite different from those on Wilson mountain. Most of the dike material is fine grained, particularly so at the margins, but this grades into a medium-grained, narrow, middle portion which is very persistent. The dike rock is somewhat weathered and of light-brown color, this latter probably due to stains from iron-bearing minerals in the gabbro. Because these dikes sharply cut the gabbro, which is distinctly later than the granite, and because of their chilled margins, it is believed that they were intruded considerably later than the aplite dikes on Wilson mountain above described. A thin section shows the following mineral percentages: microperthite, 65; oligoclase, 1; quartz, 20; diallage, 12; magnetite, 2; and very little zircon. The thin section shows a granitoid texture and no granulation.

At the eastern end of the Oliver hill gabbro stock a few branching, fine-grained, white, aplite dikes a few inches wide cut the gabbro, the relations being shown in figure 4. Although these dikes are white and do not have distinctly coarse portions, it is probable that they were intruded at about the same time as those on Ledge hill.

Pegmatite. A number of pegmatite dikes were observed in the granite on top of Ledge hill for one-half of a mile northward from the gabbro stock. None of these is more than 2 feet wide, and they all cut sharply across the foliation of the granite very irregularly. Near the eastern margin of the gabbro stock a very small pegmatite dike cuts across the foliation of the granite, and nearby another cuts the gabbro.

On the western summit of Wilson mountain near the aplite dikes, a number of very small pegmatite dikes sharply cut the granite. Near the eastern margin of the Grenville area on the western face of Wilson mountain, several small pegmatite dikes cut a mixture of Grenville and granite.

At the eastern end of the Oliver hill gabbro stock the same ledge which contains the aplite dikes (see figure 4) is also cut by a small pegmatite dike which is without very sharp contacts against the gabbro. Whether this is older or younger than the aplite was not determined.

Pegmatite dikes are scarcer in the Schroon Lake quadrangle than is usual in the Adirondack region. Not one was observed in

the large body of anorthosite. In certain other quadrangles, like the Blue Mountain, the writer has found at least two sets of pegmatite dikes notably different in age, one occurring in the form of narrow masses essentially parallel to the foliation of, and not very sharply separated from, the inclosing syenite or granite, and the other, generally coarser grained, cutting across the foliation of, and in sharp contact with, syenite or granite. The second set is quite certainly the younger, and probably all the observed pegmatites in the granites of the Schroon Lake quadrangle belong with the younger set.¹

Diabase Dikes

Diabase dikes were observed in nine localities within the quadrangle, but doubtless others exist. They are represented on the geologic map. Most of these are like the usual diabase dikes of the Adirondacks, more particularly like those of the North Creek quadrangle described by the writer. Unlike the gabbro, aplite, and pegmatite, several of the diabase dikes cut the anorthosite. The diabase probably represents the latest Precambrian intrusion in the Adirondack region as shown by the fine-grained texture and usually very distinct chilled borders, and also by the fact that a diabase dike actually cuts one of the late pegmatite dikes in the adjoining North Creek quadrangle. A diabasic texture is not always evident to the naked eye, but in thin section it is generally recognizable. None are porphyritic, but several show very distinct magmatic flow-structure foliation. All have sharp contacts against the country rocks.

About one-fifth of a mile north of the old graphite mine at the western base of Catamount hill, a small typical diabase dike with strike N 40° E cuts Grenville gneisses.

A diabase dike 2 feet wide with strike S 20° W is well exposed in the syenite of the quarry one-half of a mile east-northeast of South Schroon.

In a ledge of gneissoid granite by the road 1 mile west of Schroon Lake village, there are several small dikes varying in width from 2 to 8 inches. One is faulted 6 or 8 inches at two places.

A very typical diabase dike with a maximum width of 40 feet and strike N 20° E is clearly traceable for fully one-half of a mile in the Whiteface anorthosite about 1½ miles north-northwest of

¹ Certain Adirondack pegmatites are discussed by the writer in a recent paper (*Jour. Geol.*, vol. 27, no. 1, 1919) where it is shown that some pegmatites developed as satellites of the cooling magmas of the late gabbros.

Schroon Lake village. At one place many small off-shoots from the dike were observed to cut sharply the Whiteface anorthosite.

A dike 6 inches wide with strike N 20° E cuts Whiteface anorthosite at the summit of Severance hill.

A dike of very typical diabase with maximum width of 40 feet cuts pinkish granite for one-quarter of a mile across the top of the little hill 1¼ miles due west of Grove Point.

Three dikes of particular interest cut typical Marcy anorthosite at the summit of Saywood hill. They vary in width from 6 inches to 1½ feet and strike N 20° W. These dikes all show rather distinct magmatic flow-structure foliation. Diabasic texture is absent, and the fresh rock is dark gray with numerous black ferro-magnesian minerals each from 1 to 3 millimeters long. A close inspection reveals many tiny red garnets. In thin section (no. 43 of table 4) this rock is seen to be a hypersthene diabase.

Near the top of the hill one-third of a mile due north of the summit of Saywood hill there are two diabase dikes, one 15 feet wide and the other 2 feet wide, traceable for a number of yards in sharp contact with the Marcy anorthosite. The narrower dike is probably a branch of the wider one. These dikes have a good diabasic texture, and they are finer grained toward their margins. Myriads of tiny red garnets are visible under the hand lens. They show no foliation. A thin section (no. 44 of table 4) shows these dikes to differ from those on Saywood hill by carrying 10 per cent diallage, and oligoclase to labradorite instead of labradorite alone.

On the ridge one-half of a mile north-northwest of Blue Ridge village a dike 2 feet wide sharply cuts the Marcy anorthosite with strike N 40° W. This dike looks almost exactly like those on Saywood hill above described.

PALEOZOIC ROCK OUTLIERS

Two outliers of early Paleozoic strata occur within the Schroon Lake quadrangle. One of these, in and near the village of Schroon Lake, has long been known, but the other, 1½ miles southwest of the village, was located by the writer in 1916. During 1917 the writer discovered another outlier in the valley of Schroon river 7 miles north of Schroon Lake village. The outliers at and near the village are of particular geological significance, having been formerly connected with the main body of early Paleozoic strata of both the Champlain and Mohawk valleys, but now being isolated masses from 13 to 16 miles from the Champlain valley strata.

Potsdam Sandstone Southwest of Schroon Lake Village

This area of Potsdam sandstone lies $1\frac{1}{2}$ to 2 miles southwest of Schroon Lake village, or about 1 mile west to southwest of Grove Point. It was discovered by the writer in 1916. Just southwest of the forks of the road three-fourths of a mile west of Grove Point, there are four exposures, three of them in the road and the other just across the fence to the south of the road. The largest outcrop is several rods long. Paced at right angles across the strike of these exposures the distance is 45 yards. Since the dip is west 5° , a thickness of about 12 feet of the sandstone occurs here with neither top nor bottom visible. The strata strike $N\ 30^\circ\ E$. In the brook just north of these exposures there are many angular fragments of the sandstone, but still farther north neither fragments nor outcrops occur, so that the northern limit of the area must be about as indicated on the accompanying geologic map. For fully one-half of a mile to the south-southwest, within the area mapped, a number of small exposures of the sandstone were observed, and also hundreds of angular fragments up to several feet across. Hundreds of angular fragments of the sandstone also occur on both the north and south sides of Thurman pond, but a careful search failed to reveal an outcrop. Probably these are simply fragments in the glacial drift.

In all the outcrops the rock is in every way typical Potsdam sandstone, being gray, well stratified, often cross-bedded, and not very coarse grained. The layers are generally from a few inches to a foot thick. No fossils were found. That these beds are very close to the bottom of the Potsdam formation is evident from the fact that granitic syenite, the immediately underlying rock, outcrops close by on the east (see map). A fault passes along the foot of the hills just west and this probably marks the western boundary of the sandstone, though no exposures of any kind occur close to the fault on its east side.

Little Falls (?) Dolomite in and near Schroon Lake Village

Description of occurrences. In a paper dealing with the iron ores of northern New York published by C. E. Hall¹ in 1879, mention is made of this outlier.

In his *Preliminary Report on the Geology of Essex County*,² Professor Kemp briefly describes the outlier and discusses its significance.

¹ N. Y. State Mus. Rep't 32, p. 130-40. 1879.

² N. Y. State Geol., 15th Annual Rep't, 1895, p. 596-98.

Since no detailed study of this outlier has yet been published, the observations made by the writer during the summers of 1916 and 1917 are here somewhat fully recorded.

The dolomitic limestone is well exposed for a distance of fully 100 feet along the shore of the lake just north of the steamer landing in the village. Plate 7 shows the general appearance of the outcrop. The strike of the beds is N 50° E and the dip N 23°. A detailed measured section follows:

	Feet	Inches
6 Dolomitic limestone without chert.....	3	0
5 Dolomitic limestone with much dark chert in the form of irregular bunches up to 6 inches or even a foot long.....	3	8
4 Dolomitic limestone without chert or calcite.....	2	0
3 Dolomitic limestone much like 2 below, except that chert is less conspicuous and not in layers.	3	8
2 Dolomitic limestone with much chert mostly in thin layers, but some in irregular bunches. Also numerous veinlets and bunches of calcite, some of which is dark to black with bituminous mat- ter. On the weathered surface there are signs of stratification surfaces separating the rock into thin layers	5	6
1 Dolomitic limestone with considerable chert (below the water)	2	
Total.....	19	10

The dolomitic limestone of this section is dark gray weathering to light gray, crystalline, fine grained and compact in texture. It contains numerous rounded quartz-sand grains not visible to the naked eye, but bits of the rock treated with hot hydrochloric acid leave considerable residues of the fine quartz-sand grains. Weathered surfaces of the rock are generally rough and deeply pitted due to more rapid removal of the irregular calcite bunches.

The greatest thickness of limestone exposed in any one section is in the bed of Rogers brook between its mouth and the main road. These beds strike N 50° E and dip N 23°, and the stream descends about 25 feet as a cascade over the ledge. The approximate thickness of this section, based upon careful pacing (160 feet) across the strike, is 85 feet. There are several intervals in the section, a thickness of 5 or 6 feet being concealed in one place.

The ledge of Little Falls (?) dolomite by the Lake shore a few rods north of the steamer landing in Schroon Lake village
W. J. Miller, photo, 1916

Most of the beds are from 6 inches to 2 feet thick with stratification surfaces between them very evident. Such beds are in nearly every way like those above described as occurring just north of the steamer landing. Chert is often present. Kemp, in the paper above referred to, states that "thin sections of the chert merely exhibit a brown, nearly isotropic base with numerous rhombohedra of calcite or dolomite scattered through it." Some relatively thin layers are, however, very sandy. Considering the strike, dip and location of this section and the one just north of the steamer landing, it is quite clear that the latter underlies the former with an intervening thickness not definitely known, but probably about 10 feet. Adding this 10 feet to the combined thickness of the two known sections, the thickness of the dolomitic limestone underlying this part of the village is at least 115 feet, with neither top nor bottom visible.

Another excellent outcrop occurs in the quarry in the northeastern portion of the village. This exposure is about 150 feet long (1917) parallel to the strike which is N 50° E. At the north end the dip is W 34°, and at the south end W 30°. A thickness of 28 feet was measured across the southern end of the quarry, and 30 feet across the northern end. The rocks are very distinctly bedded in layers a few inches to 2 feet thick, usually 1 to 2 feet. Plate 8 gives a good idea of the appearance of the rock in the quarry. Except for a few thin, black shale and sandy shale partings, the rock is all dark gray, fine grained, crystalline, dolomitic limestone very similar to that of the other localities above described. Scattering veinlets and bunches of calcite, often dark with organic matter, are common, but no chert was observed. The rock weathers to a light gray. Judging by the strike, dip and location, this quarry section probably lies in part at the horizon of the upper beds of the Rogers brook section, but mostly above it. On this basis, and barring the possibility of an intervening fault, a thickness of something like 20 feet should be added to the thickness above determined for the southern part of the village. This would make the total thickness of dolomitic limestone under the village approximately 135 feet, with neither top nor bottom exposed.

On the lake shore one-third of a mile southwest of the mouth of Rogers brook, there are two small exposures of dolomitic limestone in beds from 6 inches to 1 foot thick, with a total thickness of 10 feet. These beds, with strike N 60° E and dip W 7°, are about on a line with, and look much like, the beds at the steamer

landing. On the weathered surfaces the rock is very rough and deeply pitted due to dissolving out of calcite bunches.

A very careful search southwest, west and north of the village failed to bring to light any other exposure of either dolomitic limestone or Potsdam sandstone than those above described, the glacial drift masking the underlying rocks to the foot of the hills (see map). Neither does the drift in this area anywhere carry angular fragments of either sandstone or dolomite which would strongly suggest the existence of concealed ledges. In fact, even rounded fragments are very rare. An angular fragment of typical Trenton limestone with fossils just west of the southern end of Thurman pond suggests such limestone in place, either now or just before the Ice age, not farther south than the vicinity of Schroon Lake village.

Age of the dolomite. A diligent search through the dolomitic limestone of all the exposures failed to reveal any remains of organisms. Kemp, in his report of 1895, likewise states that he was unable to find fossils. This absence of fossils, combined with the isolation of the limestone at Schroon Lake, renders it practically impossible to correlate very definitely or determine the age of this limestone. C. E. Hall, in the paper above mentioned, makes the following very brief statement: "At Schroon Lake village the Chazy limestone occurs with fossils. The outcrops are not extensive, being covered by a sand clay deposit." With Hall, however, consideration of the Schroon Lake outlier was an incidental matter and more than likely, on the basis of general resemblance, the Schroon Lake limestone was classed with the fossiliferous Chazy limestone of the Champlain valley, the fossils having been assumed to be present.

Kemp¹ notes the close resemblance of the Schroon Lake limestone "to the cherty magnesian limestones that are undoubtedly Calciferous (in age) and nonfossiliferous on Lake Champlain," and with some hesitation he correlates them. The writer believes Kemp essentially correct in this view. But the old Calciferous formation, many hundreds of feet thick in the Champlain valley, was then considered to be wholly Ordovician in age, with cherty beds in the lower portion.

As a result of more recent work, important changes of view regarding the old Calciferous formation have taken place, these changes being concisely stated by Cushing² as follows: "The name

¹ 15th Annual Rep't N. Y. State Geol., 1895, p. 597.

² N. Y. State Mus. Bul. 169, p. 42. 1914.

A near view of Little Falls (?) dolomite in the quarry in the northern part of Schroon Lake village. Glacial drift rests upon the rock.

W. J. Miller, photo, 1916

'Calciferosus' was originally applied to the considerable thickness of dolomitic rocks which overlies the Potsdam sandstone in the Champlain and Mohawk valleys. Later on Clarke and Schuchert replaced this by the name Beekmantown, and to the rather unfossiliferous phase of the formation in the Mohawk valley gave the local name of Little Falls dolomite. . . . Recent work of Ulrich, Ruedemann and Cushing showed that the Little Falls dolomite of the Mohawk valley was the equivalent" of the lower portion of the Champlain Beekmantown, and that it was really separated from the overlying Beekmantown by unconformity and graded through transition beds (Theresa) into the underlying Potsdam sandstone.

The Schroon Lake and Little Falls dolomitic limestones are almost exactly alike in nearly every way, both being very largely dark-gray, fine-grained, crystalline, usually rather thick bedded, dolomitic, sandy limestones with considerable chert as irregular masses and irregular bunches of crystalline calcite at certain horizons, and almost, or entirely, devoid of fossils. Cavities containing very clear quartz crystals, so characteristic of certain horizons of the Little Falls dolomite of the Mohawk valley, were not observed at Schroon Lake, but it is quite possible either that the proper horizons are not there exposed or that such cavities may never have formed there. It is also of interest to note that Potsdam sandstone, the rock with which the Little Falls dolomite is almost invariably affiliated, outcrops to the southwest of the Schroon Lake dolomite.

All points considered, then, it is very probable that the Schroon Lake dolomitic limestone should be regarded as Little Falls (Upper Cambrian) dolomite.

Newly Found Outlier in the Paradox Lake Quadrangle

During the summer of 1917 the writer discovered an outlier of Paleozoic rock in the Schroon river valley of the Paradox Lake quadrangle $2\frac{1}{2}$ miles due north of Schroon Falls, or 7 miles north of Schroon Lake village. It lies west of the river and only one-fourth of a mile east of the boundary of the Schroon Lake quadrangle. In an area of about 2 acres there are exposures of dolomite in fairly thick beds resting upon sandstone, a total thickness of not over 25 feet being visible. These strata lie in practically horizontal position. Whether this is true Little Falls dolomite resting upon Potsdam sandstone, or the rocks represent transition

(Theresa) beds between the two, the writer does not know. In any case, it is quite certain that the rocks of this outlier are to be classed with the Potsdam-Little Falls series in general.

Significance of the Outliers

The significance of the outliers of Paleozoic rocks at and near Schroon Lake should be considered in the light of all the outliers of Paleozoic strata in the southeastern portion of the Adirondack region. Altogether they afford positive evidence that early Paleozoic sea waters spread over all or nearly all of that region. All the definitely known outliers which occur well within the area of Precambrian rocks of the southeastern Adirondacks are as follows:

1 A small exposure of Potsdam sandstone near the southwestern corner of the Elizabethtown quadrangle.

2, 3, 4 Three small areas of Potsdam sandstone along the eastern side of the Paradox Lake quadrangle.

5 Little Falls (?) dolomite at Schroon Lake village.

6 Potsdam sandstone $1\frac{1}{2}$ miles southwest of Schroon Lake village.

7 A small area of sandstone and dolomite belonging to the Potsdam-Little Falls series $2\frac{1}{2}$ miles due north of Schroon Falls in the Paradox Lake quadrangle.

8 A small mass of Potsdam sandstone $1\frac{1}{2}$ miles west of North River village in the Thirteenth Lake quadrangle.

9 A small body of sandstone and dolomite belonging to the Potsdam-Little Falls series 1 mile west of High Street village in the northern part of the Luzerne quadrangle.

10 A large outlier, several miles long, in the Sacandaga river valley at Wells in the Lake Pleasant quadrangle where are well-exposed Potsdam sandstone, Theresa transition beds, Little Falls dolomite, Black River (Lowville) limestone, Glens Falls limestone and Canajoharie (Trenton) shale.

11 A considerable outlier showing Theresa beds, Little Falls dolomite, and Black River limestone between 1 and 3 miles north of Hope in the Sacandaga valley of the Lake Pleasant quadrangle.

Of these, nos. 6, 7, 9 and 11 have been discovered by the writer during the last 6 or 7 years. Besides the above, a number of outliers occur close to the main body of Paleozoic strata.

Wherever detailed geologic maps have been made in the southeastern Adirondacks, the region is shown to be literally cut to

pieces by numerous normal faults, the most prominent of which usually strike from north-south to northeast-southwest, with known displacements ranging from a few hundred to 2000 feet or more. It is important to note that the outliers above listed, except possibly nos. 2, 3 and 4, lie on the downthrow sides of such faults. Thus a prominent fault bounds the Schroon Lake valley on the west. It appears, therefore, that the valleys containing these outliers have been largely produced by faulting, and that the Paleozoic strata formerly lay at much higher levels, that is, the general level of the surface of Precambrian rocks of the region.

Were the early Paleozoic sediments deposited in embayments or estuaries of the sea extending well into the area of Precambrian rocks, or were they deposited as a general mantle over the Precambrian rocks of the whole southeastern Adirondack region? As a result of detailed studies it has been established that the southern half or two-thirds of the Adirondack area was, by the beginning of Potsdam time of the late Cambrian period, worn down to the condition of a peneplain upon whose surface only a few minor knobs or prominences existed. This being the case, notable embayments or estuaries could scarcely have existed. Still further evidence against the embayment idea comes out of the character of the sediments. Thus the rocks of the outliers, including those of Schroon Lake and Wells, are distinctly marine formations of exactly the same character as those of the same age in the general Paleozoic rock area of the Champlain and Mohawk valleys. Estuarine deposits would show certain distinct local variations and hence the very uniformity of the marine sediments in the outliers precludes the possibility of their deposition in estuaries. Thus we conclude that when the early Paleozoic, or more precisely late Cambrian, sea encroached upon the southeastern Adirondack area a general mantle of sediments was deposited over the whole region including much at least of the area of the Schroon Lake quadrangle, and that, subsequent to the emergence of the region, normal faulting took place whereby portions of the Paleozoic strata were, in many places, carried so far down that remnants have to this day been protected against complete removal by erosion. Thus we explain the existence of the outliers of early Paleozoic marine strata in the Schroon valley.

Early and Middle Cambrian strata are unknown in northern New York, and there is no evidence that early and middle Cambrian seas ever spread over any portion of that area. But with the late

Cambrian the case is different. The first deposit to form in the late Cambrian sea was the Potsdam sandstone which is well represented in the St Lawrence, Champlain and Mohawk valleys, these regions all having been submerged under the Potsdam sea. In the southeastern Adirondacks the Potsdam sea certainly extended in as far as Wells (southern Hamilton county), North River (north-western Warren county), and Schroon Lake (southern Essex county), because small outlying masses of Potsdam sandstone occur in those localities, having been formerly connected with the larger areas around the Adirondacks as above explained. The Potsdam sea surrounded and more or less lapped over on the borders of the Adirondack region, particularly the southeastern portion. There is no evidence that the interior of the Adirondack region was submerged, but rather it almost certainly formed a large island in the Potsdam sea.

Marine conditions continued with the deposition of alternating layers of sandstone and dolomite upon the Potsdam. This is called the Theresa formation. After still greater submergence, the important formation known as the Little Falls dolomite was deposited layer upon layer to a thickness of usually several hundred feet in the comparatively clear waters of the latest Cambrian sea. The Little Falls sea swept all around the Adirondacks. Occurrences of the formation in the outliers at Wells (Hamilton county) and at Schroon Lake prove that the Little Falls sea extended well over the eastern Adirondack area, including much at least of the Schroon Lake quadrangle. Map figure 6 graphically shows the approximate relations of land and water during late Cambrian time.

The Cambrian period closed with all of northern New York above sea level, but early in the Ordovician period a submergence set in, reaching a maximum about the middle of the period. Even at the time of maximum submergence in the Middle Ordovician, the best evidence points to the existence of a considerable island comprising the interior of the Adirondack region (see map figure 6).¹ Mid-Ordovician strata at Wells indicates the presence of the sea of that age over southern Hamilton county. Though mid-Ordovician strata are not exposed at or near Schroon Lake, such rocks may be there concealed; or they may formerly have been present. In any case, their strong development in the Champlain valley only 15 or 20 miles to the east renders it highly probable

¹The early Paleozoic physiography of the southern Adirondacks is discussed by the writer in a paper in N. Y. State Mus. Bul. 164, p. 80-94, 1913.

that the mid-Ordovician sea spread far enough westward to cover at least the eastern part of the Schroon Lake quadrangle.

We have no positive evidence that any part of the Schroon Lake quadrangle has ever been submerged under sea water since mid-Ordovician time.

Fig. 6 Map of northern New York showing the general relations of land and water during parts of the Cambrian and Ordovician periods. The whole shaded portion represents land during the late Cambrian time, and the cross-lined portion represents land during the middle of the Ordovician.

STRUCTURAL GEOLOGY

Structure of the Grenville Series

Tilting and folding. Evidence has recently been presented by the writer¹ to show that the Grenville strata of the Adirondacks

¹ Jour. Geol., 24:588-96. 1916

have never been highly folded or severely compressed. Many broad belts of the strata are known to be practically horizontal or only very moderately folded, while many masses are merely tilted or domed at various angles. Very locally the strata exhibit contortions. The many scattering bodies of Grenville strata throughout the Adirondacks do not show any very persistent strike as would be the case had they been subjected to notable orogenic pressure.

The structural relations of the Adirondack Grenville strata are reasonably explained as having been the result of the slow, irregular upwelling of the great bodies of more or less plastic magmas, probably under very moderate compression, whereby the strata, previously deformed little or none at all, were either broken up, tilted, lifted or domed, or engulfed in the magmas. According to this view, many large blocks or belts of Grenville strata, or several such rather locally separated by intrusive masses, with strike of intrusive masses parallel to the strike of the Grenville, show monoclinical dips; many masses of Grenville were shifted around in the irregularly rising magmas to show various strikes and dips according to the direction of magmatic currents; some bodies of Grenville were merely domed over bodies of laccolithically rising magma and hence exhibit more or less quaquaversal strikes and dips; some masses of strata were considerably bent or even folded into synclines by being caught between bodies of magma upwelling at about the same rate; some masses, especially the more plastic limestones, were locally contorted near the igneous contacts; and many masses of strata were caught up or enveloped by the rising magmas.

The Grenville series within the Schroon Lake quadrangle is not extensively developed, and the exposures are mostly too scattering to throw much light upon its structure, but most of the types of occurrence above mentioned seem to be present, except probably the laccolithic. Strikes and dips are platted on the accompanying geologic map, though where several similar observations were made within one-fourth of a mile of each other but one is usually recorded.

In the Minerva area the Grenville strata seem to show a synclinal structure with a west-northwest strike of the axis through the village, but the outcrops are too scant to make this certain. If synclinal, it is not a very sharp fold because the dips generally vary from 30 to 50 degrees. A structure of this sort may be readily explained as due to greater upwelling of the granite magma on both the north and south sides of the mass of Grenville causing

the strata to be notably bent upward along those sides. It should be noted, in accordance with this view, that the strikes of the Grenville strata and the adjacent igneous rocks are essentially parallel.

In the northern portion of the Olmstedville area five good observations show the Grenville to have persistent dips of from 20 to 70 degrees northward, which is precisely the opposite of the Grenville of the northern portion of the nearby Minerva area, this latter being on the same strike. Such a sharp change would scarcely be expected as a result of ordinary orogenic folding, and it is more likely the result of the magmatic intrusion. The granite magma north of Olmstedville apparently broke through and flowed

Fig. 7 An early north-south section through Olmstedville illustrating the geologic structure and the probable mode of origin of the valley in the vicinity of the village and the escarpment on the north. Several stages of erosion are shown from the late Mesozoic or early Cenozoic peneplain level (dotted upper line) to the present surface (heavy lower line). Length of section, 4 miles. Vertical scale, $2\frac{1}{2}$ times the horizontal.

intrusively upon the Grenville strata, thus accounting for the northward dip of both granite and Grenville with the latter dipping under the former. Because of the much greater resistance of the granite to weathering and erosion, it stands out as a local scarp (see map), while the much weaker Grenville has been notably worn down to form the valley around Olmstedville. Figure 7 illustrates the principles here involved.

The very irregular dips and strikes in the small area of Grenville just east of North pond are no doubt due to deformation of this block of strata by one or more of the various intrusive masses which rose adjacent to, or possibly engulfed it. A similar condition is true of the Grenville south of Adirondack village.

The other mapped areas of Grenville are relatively small, and they are merely inclusions in the syenite-granite series. They

are usually lenslike or elliptical in ground plan and essentially parallel to the foliation of the inclosing rocks.

Figure 8 shows an interesting case of a sharply bent small mass of Grenville gneiss in granite on Ledge hill.

Foliation of the Intrusive Rocks

The anorthosite and syenite-granite series. The great intrusives of the quadrangle, including both the anorthosite and the syenite-granite series, exhibit more or less foliation, though large

Fig. 8 Sketch showing ground plan of part of an exposure near the eastern border of the gabbro stock on Ledge hill. The gneissoid granite, with its sharply curving foliation, wraps about a portion of a sharply bent small inclusion of hornblende gneiss.

portions of the Marcy anorthosite commonly show practically none. In the syenite-granite series at least a faint foliation seldom fails to appear, and it varies from this to very highly foliated. The degree of foliation often varies notably within very short distances. Both strike and dip of the foliation also often vary notably, though the general trend or strike is from east-west to northwest-southeast. Regarding the foliation in the adjoining Paradox Lake quadrangle, Doctor Ogilvie says: "The general direction of strike is similar. A direction of N 40° E is the prevailing one, with low southeast dips." According to this, the general strike of foliation of the Schroon Lake quadrangle is almost at right angles to that of the Paradox Lake quadrangle. In many ledges the general strike

can be made out but not the dip, this being particularly true of the locally gneissoid portions of the Marcy anorthosite. The gneissoid structure is usually accentuated by the roughly parallel arrangement of dark minerals, though locally the granite, comparatively free from dark minerals, is strikingly gneissoid due to excessive flattening of feldspar and quartz.

Granulation of minerals, especially feldspar, is common in many localities and often highly developed, the more highly foliated rocks generally being most granulated.

On the accompanying geologic map there are recorded representative strikes and dips of foliation selected from many field observations.

The writer considers the foliated igneous rocks to be so-called "primary gneisses" whose gneissoid structure was developed as a sort of magmatic flow-structure under moderate compression rather than by severe lateral (orogenic) pressure brought to bear upon the region after the cooling of the magmas. Briefly stated, the writer's explanation follows.¹ During the processes of intrusion, which were long continued, the great magmatic masses were under only enough lateral pressure to control the general strike of the uprising magmas with consequent tendency toward parallel arrangement of intrusives and invaded Grenville strata; the foliation is essentially a flow-structure produced by magmatic currents under moderate pressure during the intrusions; the sharp variations of strike on large and small scales, and rapid variations in degree of foliation, are essentially the result of varying magmatic currents under differential pressure, principally during a late stage of magma consolidation; the almost universal but varied granulation of these rocks was produced mostly by movements in the partially solidified magma, and possibly to some extent by moderate pressure after complete solidification; and the mineral flattening or elongation was caused by crystallization under differential pressure in the cooling magma.

It would seem, therefore, that the general absence of foliation from so much of the Marcy anorthosite is best explained as the result of the much more uniform (laccolithic) intrusion of this single great body which is much less involved with Grenville masses, or, in other words, to much less forced differential flowage.

Figure 8 shows a case of sharp variations in strike within a few feet in the granite of Ledge hill.

¹The writer has presented a rather full discussion of this subject in *Jour. Geol.*, 24:600-16. 1916.

It is quite possible that much or all of the pressure within the intruding magmas was simply "shouldering pressure exerted (by the magmas) on the adjacent rocks under bathylithic, or deep-seated, conditions" as suggested by Cushing.

The gabbro and diabase. As already stated, the interior portions of most of the gabbro stocks are nonfoliated and they possess a diabasic texture, while the outer portions are usually highly foliated rocks, often true amphibolites. More or less granulation is common as seen in the thin sections. In many places the degree of foliation varies considerably within single stocks, a very fine example already having been described as occurring on the little hill just south of North pond (see page 58). The foliation shows a strong tendency to box the compass around the borders of the stocks, and, therefore, often strikes across the structures of the older adjacent rocks. If due essentially to regional compression after the solidification of the gabbro, should not the foliation everywhere strike at least approximately at right angles to the direction of application of the pressure? Also, how are the notable variations in foliation and granulation to be explained on the basis of regional pressure?

It is believed that the foliation and granulation of the gabbro stocks are largely, if not wholly, primary features due to movements in the magma before final consolidation. Considerable pressures must have obtained within the stock chambers while the magmas were being intruded under deep-seated conditions. Such pressure against the country rock, combined with the development of differential flowage particularly in the magmatic borders, would readily account for the peripheral foliated zones which were, no doubt, produced during a late stage of magma consolidation. But the conditions of magmatic pressure and flowage must have varied considerably, and thus the local variations in degree of foliation and granulation are accounted for.

Certain of the diabase dikes which cut the Marcy anorthosite in the vicinity of Blue Ridge village are also more or less foliated, their borders particularly so. As in the gabbro stocks, so here, the foliation is considered to have been due to differential magmatic flowage under moderate pressure during a late stage of magma consolidation. In these dikes, however, the foliation was developed parallel to the strike of the dikes because cross-sections of these magma chambers were long and narrow rather than rounded or elliptical as in the gabbro stocks.

Faults and Zones of Excessive Jointing

General features. The Schroon Lake quadrangle lies in the midst of the faulted eastern Adirondack region. Fifteen earth fractures are represented on the accompanying geologic map. More than likely there are others, but only those which show at least fairly satisfactory evidence for their existence are mapped. In most cases these earth fractures are rather well-defined faults, while in others they appear to be zones or belts of excessive jointing in which more or less crushing and minor faulting have taken place. These faults or broken-rock zones are relatively straight for considerable distances, ranging from a mile or two to 10 or 12 miles within the quadrangle. Where observations were made, the fault crush-zones are commonly from 25 to 100 feet wide. In accordance with most of the more conspicuous faults of the eastern Adirondacks, those of the Schroon Lake quadrangle mostly strike north-northeast. The topographic influence of the fault zones is usually very striking as a glance at the geologic map will reveal. It is very important to note that the fault zones of weakness, mostly clearly marked by long, narrow valleys, nearly all trend almost or quite at right angles to the strike of the foliation of all the rocks and to the general trend of the belts of relatively weak Grenville which are essentially parallel to the foliation (see map).

The faults are all of the normal type with fault surfaces vertical or very steep. Within the area of Precambrian rocks of the eastern Adirondacks it is often difficult to demonstrate the existence of faults and, when a given fault has been proved to exist, it is usually difficult or impossible to trace it across country with any great degree of accuracy because of scarcity of exposures due to accumulation of glacial and postglacial deposits in the fault valleys. Because of the character and structure of the rock masses (mostly igneous) and the lack of any very clearly defined stratigraphic relations, it is practically impossible to determine the actual amounts of displacements, though in some instances minimum figures can be given. Within the quadrangle such minimum figures are not definitely known to be more than some hundreds of feet, but actual displacements may have been many times as great.

Among the more positive criteria for the recognition of the faults and zones of excessive jointing in the quadrangle are the following: (1) long, narrow, almost straight valleys which trend at high angles across the strike of the older rock structures such as the foliation and the belts of Grenville strata; (2) steep to vertical

scarps, often miles long, in hard, homogeneous rock; (3) actual presence of crushed, sheared, slickensided or brecciated rock zones; and (4) Paleozoic strata lying at the base of steep hills of Precambrian rocks.

Age of the faulting. That some Adirondack faulting took place in Precambrian time has been pretty well established, but, so far as definitely known, such fractures are of minor importance. There is no positive evidence for such faulting in the Schroon Lake quadrangle. It seems quite likely as Cushing has suggested,¹ that considerable faulting took place during, or toward the close of, the Paleozoic era.

Any fault scarps, ridges or valleys which may have been produced by the close of the Paleozoic must have been nearly or quite obliterated by the long subsequent time of erosion. If so, how do we account for the present Adirondack ridges and valleys which follow the fault lines or zones? Accompanying the uplift of the late Mesozoic or early Cenozoic peneplain of the Atlantic coast region, or following it, there was either new faulting, or renewed movement along old faults, or old fault zones, including zones of excessive jointing with little displacement, were not affected by new movements. How much is new faulting, and how much renewed faulting along old lines or zones of fracture is not known, but it is quite certain that considerable faulting in the eastern Adirondacks must date from the uplift of the peneplain just mentioned as shown by fault scarps in homogeneous rocks and by the existence of tilted fault blocks which have been little modified by erosion. Some relatively long, deep, narrow, valleys of the Schroon Lake quadrangle, like that which follows the Minerva stream fault or the Hoffman notch fault (see below), are due essentially to erosion along the fault or broken-rock zones of weakness irrespective of when they originated, while others which are broader, like the Schroon Lake valley and the lowland between Green hill and Oliver hill, are due either to comparatively recent sinking of fault blocks, or removal of weaker rocks by erosion whereby old fault scarps are renewed, or both. Distinctly tilted fault blocks, like some in the North Creek quadrangle just to the south, are not certainly present in the Schroon Lake quadrangle.

Schroon valley fault. As represented on the geologic map, this is one of the two longest and most conspicuous faults of the quadrangle. Its scarp marks the western boundary of the Schroon

¹ N. Y. State Mus. Bul. 95, p. 405.

Plate 9

W. J. Miller, photo, 1917

The zone of excessive jointing accompanied by some faulting in the road metal quarry by the main road one-half mile east-northeast of South Schroon

valley for 12 miles across the quadrangle and beyond (northward) for fully 8 miles more. As regards both length and topographic influence, this fracture takes rank as one of the most prominent faults in the eastern Adirondacks. It probably does not extend south of the quadrangle limit. The topographic evidence for the fault is very strong (plate 3). The Potsdam sandstone east of Grove Point and the sandstone and dolomite in the valley 7 miles north of Schroon Lake village also both lie against the base of the scarp and hence furnish strong evidence for faulting with downthrow side on the east. Several ledges in the bed of Horseshoe pond brook are badly broken parallel to the course of the stream and these furnish still more positive evidence for the existence of the fault. Nowhere else along the immediate base of the scarp were outcrops of any kind observed, so that further evidence such as slickensides and crushed or brecciated zones, is lacking. From Thurman pond southward the trace of this fault is much less certain. Some idea of the minimum displacement along this fault may be gained not only from the height of the scarp but also from the positions of the outliers of Paleozoic strata. Thus the sandstone and dolomite 7 miles north of Schroon Lake village lie at an altitude of 900 feet, while the summit of the mountain just west is nearly 2300 feet, thus indicating a minimum downthrow of about 1300 feet on the east side of the fault. The position of the Potsdam sandstone west of Grove Point indicates a minimum displacement of at least 400 feet, and probably 600 feet.

Schroon lake faults. The topographic evidence for a fault, or at least a zone of excessive jointing, along the western side of Schroon lake is strong, as shown on the map. A very conspicuous zone of excessive jointing accompanied by moderate faulting (see plate 9) occurs in the road metal quarry one-half of a mile east-northeast of South Schroon. The strike of this jointed zone is parallel to the strike of the fracture as mapped but at a high angle to the strike of the foliation of the rocks. Probably the jointing exhibited in the quarry lies a little to the west of a real fault, because the topography strongly points to a downthrow of fully 200 feet on the east side.

From Adirondack village southward close to the lake shore there is a fault which is but the northern extension of a rather prominent fault several miles long which has been mapped and described in the writer's report on the North Creek quadrangle.

Along the eastern lake shore at the base of Quackenbush hill, and extending several miles into the Paradox Lake quadrangle, a

long, nearly straight line, with hills rising steeply hundreds of feet above it and at right angles to the old rock structures, makes the existence of a line or zone of fracturing there almost certain. This being the case, the outliers of Paleozoic strata in and near Schroon Lake village really lie in a "graben" or fault trough.

Fuller brook fault. This zone of fracture separates Pine hill and Ledge hill rather sharply and continues northward at least to Horseshoe pond. The topographic evidence is quite clear and, in the bed of the little brook about a mile south of Marsh pond, the rock is considerably broken as a result of earth movements. The topography suggests a moderate downthrow on the east, but instead of being a true fault this may be simply a zone of excessive jointing with little displacement.

Alder brook and Trout brook faults. That Alder brook and Trout brook follow fault zones for several miles as shown on the map is quite certain. Not only are these valleys narrow and remarkably straight, but they have been cut into granite at right angles to its structure. Such could scarcely be the case unless the positions of the valleys were determined by zones of weakness due to faulting. Further, the earth block between these two streams is very distinctly depressed below the country immediately on either side. The evidence, then, renders quite certain the existence of a fault block from $1\frac{1}{2}$ to nearly 3 miles wide and several miles long which has sunk between two faults, one along Alder brook and the other along Trout brook. The topographic influence of this sunken fault block is particularly striking in its southern half where the Pine-Green hill mass on the east and the Oliver-Snyder hill mass on the west each rise hundreds of feet very abruptly. Direct evidence for the faulting from ledges along the fracture lines or zones is wholly wanting, not a single outcrop occurring on either of the brooks. The Alder brook fault continues for several miles south into the North Creek quadrangle (see North Creek geologic map).

Minerva stream fault. As regards both length and topographic influence, this fault takes rank as one of the most prominent known lines of fracture in the eastern Adirondacks. On the accompanying map it shows a length of $12\frac{1}{2}$ miles. It continues southward for $6\frac{1}{2}$ miles across the northwestern part of the North Creek quadrangle and thence for at least 3 miles into the Thirteenth Lake quadrangle. Its total length is, therefore, at least 22 miles. Its topographic influence is very striking since a deep, usually narrow, nearly straight valley has been cut out along this zone of weakness along its whole course of over 12 miles in the Schroon

W. J. Miller, photo, 1917

The steep mountain 1 mile southwest of Moxham pond as seen from a point one-half mile east of the base. The face of the mountain is 800 feet high and it lies on the upthrow side of the Minerva stream fault which passes along its base. This is a fine example of an exfoliation dome, many great slabs of the granitic syenite having peeled off due to changes of temperature.

Lake quadrangle (plate 10). Southward, also, the topographic influence is pronounced. It seems quite clear that the downthrow side is on the east, this being most evident in the North Creek quadrangle where, just east of the Gore mountain mass, the displacement is at least 1500 feet. Within the Schroon Lake quadrangle the topography does not indicate so much displacement, though it is mostly at least some hundreds of feet except at the north where it is much less. In the Minerva stream valley no outcrops occur along the fault, but in the bed of the brook just west of Washburn ridge there are several exposures of rock badly broken by the faulting in zones parallel to the course of the stream. It is very important to note that the strike of this fault is almost exactly at right angles to the strike of the foliation of all the rocks, and also at right angles to the strike of the prominent belt of Grenville strata around Minerva and Olmstedville. It is difficult to conceive how such a long, narrow valley could have developed for 12 miles across these structures except along a fault zone of weakness in the rocks. The lowlands in the vicinity of Minerva and Olmstedville, and also in the vicinity of North Creek, are due to more rapid erosion of the comparatively weak Grenville strata in those localities.

Hoffman notch fault. Evidence for either a fault or zone of crushed or excessively jointed rock in the Hoffman notch valley is twofold. In the first place, the long, straight, deep, narrow valley, with north-northeast strike parallel to most of the prominent faults of the eastern Adirondacks and at right angles to the rock structures of the immediate region, almost certainly must have been carved out along a fault zone of weakness. This valley is $5\frac{1}{2}$ miles long with a maximum depth of 1200 to 1500 feet. In the second place, actual crushed to even brecciated rock zones in the bottom of the valley and parallel to it were observed at a number of places, the principal ones being as follows: several ledges in the brook between one-half and $1\frac{1}{2}$ miles north of the pond in Hoffman notch and several ledges in the brook between $1\frac{1}{2}$ and 2 miles south of the same pond. The brook northeast of Hoffman notch pond follows a short branch fault for about one-half of a mile with much evidence of crushed rock. That the Hoffman notch fault continues northward across the east-west Blue Ridge-Boreas river road is proved by the existence of a ledge in the Branch brook just north of the road where closely spaced jointing with strike $N\ 20^{\circ}\ E$ is well shown.

Faults between Hayes mountain and Hewitt pond. West of Hayes mountain, Minerva stream flows through a narrow north-south valley which for $2\frac{1}{2}$ miles has been carved out along a distinct fault zone of weakness. In the bed of the stream three-fourths of a mile north of the place marked "Camp" on the map, the granite is considerably broken due to the faulting. Along the stream one-third and three-fourths of a mile, respectively, south of "Camp," there are ledges distinctly broken or excessively jointed parallel to the stream channel. In one case a crushed-rock zone 10 to 15 feet wide is finely exhibited. The topography suggests moderate downthrow on the west.

A ledge in the bed of the stream one-half of a mile southeast of the mouth of Hewitt pond shows a distinct crush-zone with almost north-south strike, but with little or no topographic influence.

Hewitt pond brook also follows a fault zone of weakness with nearly east-west strike, this being the only definite fault in the quadrangle with such a strike. A few rods above the mouth of the brook in a small gorge the rock is considerably broken parallel to the channel.

Wolf pond brook fault. A narrow nearly straight valley $5\frac{1}{2}$ miles long extends from Lester dam to north of Wolf pond. It has probably been developed along a zone of excessive jointing rather than along a distinct fault. In the bed of Wolf pond brook, one-third of a mile from its mouth, a big ledge is considerably broken by closely spaced joints parallel to the channel.

Boreas river fault. Boreas river, for $1\frac{1}{2}$ miles after it enters the map area, quite certainly follows a channel which has been cut out along a fault zone or a zone of excessive jointing. One ledge along the stream shows the broken rock. This fault zone is really only the southern end of what is evidently a very prominent earth fracture extending far into the Mount Marcy quadrangle. The Ausable lakes are there located in this fault zone. The topographic influence in the Mount Marcy quadrangle is very striking.

Niagara brook fault. The long, deep, straight, narrow valley occupied in part by Niagara brook has quite certainly been determined by a fault or joint-zone of weakness. Counting its northern extension beyond the map area where its topographic influence is even more pronounced, this fault or joint-zone is 6 miles long. No broken-rock zone was observed within the Schroon Lake quadrangle, the bed of the brook there all being in glacial drift.

Other faults. A big ledge at the road corners southeast of Oliver pond is all cracked into small blocks. Also, ledges by the

road one-third of a mile west of Oliver pond show many closely spaced joints with nearly north-south strike. These zones of broken rock are apparently minor, and since they have no topographic influence they are not mapped.

The steep southern face of Moxham mountain strongly suggests a fault scarp, but it might have resulted by removal of Grenville strata, such rock now forming a considerable belt not far to the south.

In the bed of Boreas river 1 mile below Lester dam, the granite is much broken and badly weathered in a fault zone of weakness with nearly north-south strike, but there appears to be no topographic influence.

In still other places the topography suggests the presence of fault zones, but in no case has the evidence seemed strong enough to warrant mapping.

PLEISTOCENE GEOLOGY

General Statements

It is well known that, during the great Ice Age of the Quaternary period, all of New York State except portions of the extreme southern side was buried under a sheet of ice. That this great sheet of ice was thick enough to bury even the highest mountains of northern New York is proved by the presence of glacial pebbles and boulders at or close to many of their summits. This is true in the Schroon Lake quadrangle. In some cases striae and glaciated ledges have been observed several thousand feet above sea level, the highest which happened to be noted in the Schroon Lake quadrangle being at 2200 feet. Adirondack glacial lakes at altitudes of several thousand feet above sea level also bear strong testimony to great depth of ice. The general direction of movement of the ice across the Adirondacks was toward the south and southwest, with comparatively few local exceptions. Such a persistent direction of movement also strongly argues for complete burial of the region under ice. The ice spread southward as a part of the great Labradorean ice sheet of eastern Canada. When the ice, early in its southward movement, struck the Adirondack highland district, one portion flowed southward through the Champlain valley and sent a branch lobe westward into the Mohawk valley. At the same time another portion flowed around the western side of the mountains and sent a lobe eastward into the Mohawk valley. The two lobes, one from the east and the other from the west, met in the

Mohawk valley leaving the main portion of the Adirondacks free from ice. But, as the ice increased in volume, more and more of the Adirondack region was covered till finally even the highest points were buried. In a paper published by the writer some years ago, the movement of the great ice sheet across northern New York is discussed.¹ During the ice retreat the higher east-central Adirondack region was the first to be freed from the ice, and the ice-freed portion gradually increased in size.

Direction of Ice Movement

The direction of ice movement across the Schroon Lake quadrangle is clearly recorded by both glacial scratches (striae) and the distribution of glacial boulders. Distinct glacial striae were observed in twenty localities, their bearings and locations being plotted on the accompanying geologic map. They are as follows:

1 S 10° W. On Grenville gneiss 1¼ miles west-southwest of Schroon Lake village.

2 S 10° E. On granite by the road 1½ miles west-northwest of Schroon Lake village.

3 S 10° E. On diabase 1⅓ miles due west of Grove Point.

4 N-S. On granite three-fourths of a mile northeast of Charley hill.

5 N-S. On granitic syenite near the summit of Beech hill.

6 S 10° E. On granite by the road 1 mile west of Charley hill.

7 N-S. On granitic syenite by the road 1 mile northwest of Taylors on Schroon.

8, 9 S 10° E. Two records one-fifth of a mile apart on granite by the road three-fourths of a mile north-northeast of Pat pond.

10 S 10° E. On Grenville gneiss three-fourths of a mile due west of Minerva.

11 S 10° E. On granite by the road just south of Oliver pond.

12 N-S. On granite by the road one-third of a mile west-southwest of Oliver pond.

13 S 30° W. On granite by the road one-half of a mile west-southwest of Oliver pond.

14 S 10° E. On syenite by the road one-half of a mile northeast of Muller pond.

15 S 10° E. On Whiteface anorthosite by the road 1¾ miles west-northwest of Boreas river.

¹Amer. Jour. Sci., 27:289-98. 1909.

16 S 15° E. On Marcy anorthosite near the creek three-fourths of a mile northeast of Boreas river.

17, 18, 19, 20 S 10° E. Four records on Marcy anorthosite by the road between 1 and 1¾ miles east-northeast of Boreas river.

It will be seen from this list that the extreme range in direction of the glacial striae is from S 15° E to S 30° W. Further, all but two sets of the striae run from N-S to S 15° E. It is evident, therefore, that the general direction of movement of the ice over the quadrangle, except possibly its northeastern one-fourth where no striae were observed, was a little to the east of south. This harmonizes closely with the sixty sets of glacial striae observed by the writer¹ in the North Creek quadrangle next to the south, the average direction of which is almost exactly N-S.

Regarding the Paradox Lake quadrangle which lies just east, Doctor Ogilvie says:² "The more southerly and easterly parts of the quadrangle were in the region of the southwesterly moving ice current." Professor Kemp³ has reached a similar conclusion regarding the southeastern portion of the Elizabethtown quadrangle, and further observations there by the writer reinforce this view. In the Blue Mountain quadrangle, the second to the west of the Schroon Lake quadrangle, the writer⁴ has recently shown that the general direction of ice movement was southwestward. Professor Cushing⁵ reached the same conclusion regarding the Long Lake quadrangle. As shown by the writer,⁶ the general ice current was southwestward across the Lake Pleasant quadrangle in the south-central Adirondacks.

From the above facts it is evident that the southward to even slightly southeastward movement of the ice across the Schroon Lake and North Creek quadrangles was rather strikingly exceptional, having been surrounded by the great sheet of generally southwestward moving ice. The writer has no explanation for this puzzling fact. Local topographic control of the ice current in the Schroon Lake area can not have been the cause of the deflection because most of the prominent ridges and valleys have a north-northeasterly strike and the others vary from east-west to north-west, so that the ice moved across these sets of valleys at angles of from 20 to 90 degrees. The location and strike of striae in valleys,

¹ N. Y. State Mus. Bul. 170, p. 66. 1914.

² N. Y. State Mus. Bul. 96, p. 470. 1905.

³ N. Y. State Mus. Bul. 138, p. 95. 1910.

⁴ N. Y. State Mus. Bul. 192, p. 48. 1916.

⁵ N. Y. State Mus. Bul. 115, p. 495. 1907.

⁶ N. Y. State Mus. Bul. 182, p. 63-64. 1916.

like those north of Pat pond and east of Boreas river or at the summit of Beech hill, clearly prove the failure of the topography to determine the direction of the ice movement.

Ice Erosion

There is no evidence that the ice was a vigorous agent of erosion within the quadrangle. It may possibly have scoured out and somewhat deepened the basin of Schroon lake, but definite proof is lacking. Certainly none of the more prominent valleys were produced by ice erosion, for, as above shown, the main body of the ice flowed across the trend of the valleys rather than parallel to them as would have been necessary for ice erosion to have been very effective for their development or even notable modification.

It is quite certain, however, that the ice did remove from its original position practically all the preglacial soils and most of the rotten rock. Further, the vast number of glacial pebbles and boulders of comparatively fresh rocks clearly show that much relatively fresh rock must have been removed probably by the process of plucking or pushing off joint blocks which during transportation became more or less rounded. Altogether, however, the total amount of material eroded by the ice made no marked difference in the preglacial topography. The dumping of glacial material in the valleys during and after the ice retreat has probably altered the topography more than erosion by the ice.

Glacial Deposits

Morainic deposits. Typical morainic deposits, mostly glacial till or ground morainic material, are common throughout the quadrangle though usually they are more or less associated with stratified or fluvio-glacial materials. Boulder clay is seldom seen. Morainic deposits are particularly well developed over the lower lands or valleys, while well up on the hills and mountains they are usually absent or thin. It is evident that, during the retreat of the great ice sheet, the burden of morainic material was largely dumped in the valleys either by direct deposition from the ice or by water in connection with the ice, or both.

The most extensive development of morainic and fluvio-glacial deposits is in the area of over 6 square miles mapped as Pleistocene in the central portion of the quadrangle. Within this area the hard rocks are everywhere concealed under glacial deposits

W. J. Miller, photo, 1916

A great glacial boulder of Marcy anorthosite near the southeastern base of Cobble hill three-fourths of a mile southwest of Warren's Hotel. It is approximately 33 feet long, 27 feet wide, and 25 feet high. It was carried at least a few miles from its parent ledge by the ice during the Ice Age. Due to weathering and freezing of water along a joint crack, the boulder has been split open since it was left by the ice.

except at the four places indicated on the map. A little west of the middle of this area, there is an area of nearly a square mile, mostly an old clearing, where a boulder moraine is conspicuously shown.

In the area of Pleistocene east and southeast of Olmstedville morainic and fluvio-glacial deposits are also well exhibited, with boulders especially prominent in the northern half. In and near Olmstedville, in the area of Grenville, there are also fine developments of morainic and fluvio-glacial materials with boulders common.

Very conspicuous boulder morainic deposits occur for a mile on either side of the Trout Brook valley from 1 to 1½ miles southeast of Muller pond.

The Pleistocene of the area between South Schroon and Grove Point is largely morainic material.

Among many smaller scale morainic deposits are those in the valley east of Catamount hill, and three-fourths of a mile southwest of Irishtown.

Glacial boulders (erratics). Glacial boulders or erratics are very abundant and widespread over the quadrangle, though they are much less common on the tops of mountains and hills than over the lowlands. Some of the more prominent groupings of boulders in so-called "boulder moraines" are mentioned above. In addition to those there should be noted the accumulation of hundreds of large and small angular masses of Potsdam sandstone just southwest of Thurman pond and all over the area of Potsdam sandstone north of the pond.

An 8-inch angular fragment of typical Trenton limestone was noted a few rods west of the south end of Thurman pond. This suggests either a hidden ledge of such rock in this portion of the Schroon valley, or a mass scraped off and broken up by the ice, though the fragment might possibly have been carried by the ice for many miles.

While numerous boulders represent various types of the region, most of the largest ones are of Marcy anorthosite. The writer was particularly impressed by many boulders, usually only moderately rounded, ranging from 10 to 20 feet in diameter in the woods on the southern portion of Texas ridge.

A very large and interesting glacial boulder of Marcy anorthosite lies in an old field near the southeastern base of Cobble hill three-fourths of a mile southwest of Warren's hotel. Roughly meas-

ured, it is 33 feet long, 27 feet wide and 25 feet high. Since its deposition by the ice it has been split open along a joint surface. Plate 11 shows the appearance of this boulder. It was transported at least several miles, since the nearest outcrops of Marcy anorthosite are that far to the north.

Two remarkable boulders of Marcy anorthosite are shown in plate 12. They are close to the road two-thirds of a mile south of Wolf pond. Both are notably rounded, suggesting transportation for a number of miles at least. One of them, at least 14 feet in diameter, rests in a remarkably balanced position upon the other large one which is partially buried in the glacial drift. It scarcely seems possible that the upper boulder can retain such a position, and yet it remains there in spite of an attempt some years ago to pry it off.

Kames and eskers. Kames and eskers definitely recognizable as such are not common in the quadrangle. In the areas of heavy glacial and fluvio-glacial deposits, some of the little hills strongly suggest their origin as kames, but, since their structure is rarely ever revealed, this is not certain.

But one clearly defined esker was observed, and this is a very fine one. It lies just northwest of Schroon Lake village with a sinuous course and a general north-south strike for more than two-thirds of a mile. Its northern end comes against the base of the steep hill. The contour map only roughly suggests its position. It consists of sand and well-rounded small to large pebbles. In height it varies from 20 to 75 feet. Toward the north where it is highest and covered with trees, it is a very steep-sided narrow ridge. Plate 13 shows part of it toward the south in an open field where it is neither so high nor so sharply defined. This esker was probably formed by a debris-laden stream from the hillside upon or under the ice of the great waning ice sheet which still lay in the valley.

Lakes and Their Deposits

Extinct lakes. *Glacial Lake Pottersville.* This former large lake was first recognized by the writer and described in his report on the North Creek quadrangle.¹ It is named from the village of Pottersville which lies on the old lake bottom. Its waters spread through the Schroon valley from near Chestertown, over the site of Schroon lake, and to north of North Hudson. Branches of the

¹ N. Y. State Mus. Bul. 170, p. 70-72. 1914.

W. J. Miller, photo, 1917

A rounded glacial boulder of Marcy anorthosite fully 14 feet in diameter resting in a remarkably balanced position upon another boulder of the same kind of rock by the Blue Ridge-Boreas River road two-thirds of a mile south of Wolf pond

Fig. 9 Map showing the general extent of glacial Lake Pottersville.

lake spread out over the sites of the present Paradox, Brant and Loon lakes. Figure 9 shows the general extent of the waters of this great lake.

Glacial Lake Pottersville came into existence after the retreat of the ice because of a dam, probably morainic, across the Schroon valley east of Chestertown.

The former existence of this large body of water is demonstrated by the presence of numerous almost perfectly preserved very typical delta sand flats or plains at nearly accordant levels. Such deposits must have formed in standing water. In the vicinity of Pottersville the highest water-laid lake deposits are a little below the 900-foot contour; near Schroon Lake village they are at about 920 feet, and at North Hudson about 960 feet. In the Schroon valley of the Paradox Lake quadrangle there is an almost continuous succession of finely developed sand flats or terraces. The northward increase in altitude of these high level lake deposits is due to postglacial differential uplift of the land with a northward increase at the rate of several feet a mile. This harmonizes with similar findings regarding postglacial changes of level in the Champlain valley.

A fine section exhibiting the structure of the delta material occurs along the state road just west of Schroon Lake village. The delta terrace is well displayed for 2 miles northward from the village, several kettle-holes occurring on it, these having probably resulted from the melting of stranded icebergs which had been surrounded by, or possibly buried under, the delta sands. The steep eastern front of this terrace, so clearly shown on the contour map for 2 miles northward from the village, is the result of erosion by the meandering Schroon river.

Glacial Lake Pottersville was destroyed as such by cutting down its outlet east of Chestertown. Schroon lake is but a remnant of the former great lake.

Glacial Lake Minerva. This former lake is so named because it lay in the valley of Minerva stream in the town of Minerva. Moxham pond is a tiny remnant of this body of water which was fully 6 miles long. The area of the lake was almost exactly the same as that of the area of Pleistocene represented on the geologic map. A morainic dam at Olmstedville was quite certainly the cause of the ponding of this water. At the village, Minerva stream has cut a deep channel through this morainic deposit, and thus the lake has been drained. The water level stood at what is now the

A view of part of the southern end of the esker just northwest of Schroon Lake village. Looking north from the top of the esker

W. J. Miller, photo, 1917

1180-foot contour level toward the south end, and the 1200-foot contour toward the north end. Fine displays of delta sand flats occur in the vicinity of Irishtown, and along the lower road between Irishtown and Olmstedville. Along the old road near the northern end of the lake bed there is a long delta terrace of mostly fine to coarse gravel, such coarse material being due to the fact that Minerva stream there emptied into the lake and dumped its load of coarse debris. The old lake deposits have been considerably cut away throughout the valley by the meanderings of Minerva stream.

Glacial Lake Blue Ridge. The bottom of the valley of the Branch west of Blue Ridge village is remarkably flat and free from boulders. It is certainly the bed of a former lake. The 1200-foot contour closely follows the old shore line of this body of water which was fully 3 miles long and one-fourth to two-thirds of a mile wide. Its water was held up by a barrier of either ice or morainic material (probably the latter) in the vicinity of Blue Ridge village. In the vicinity of the village the limits of the lake are not very clear, but otherwise the area of the lake was approximately that of the area of Pleistocene shown on the geologic map.

Other extinct lakes. All the flat areas of swamp lands indicated on the map are beds of former ponds and small lakes, the more conspicuous ones being along Ryan, Alder, Trout and Wolf pond brooks, and from 1 to 2 miles southeast of Lester dam. In these cases the pond or lake basins have been completely filled with sediments and vegetable accumulations. Among the cases where the lake-filling process has been only partially completed are the basins of Bailey, Muller, Rogers, Marsh, Thurman, Hoffman notch, and Wolf ponds. The swamp areas around these ponds represent the amount of pond filling which has taken place since the Ice Age.

Existing lakes. Of the thirty or more lakes and ponds of the quadrangle, all except a few with artificial dams have their waters held up by dams of glacial drift. Largest of all is Schroon lake, 7 miles of whose 9 miles in length lie within the quadrangle. As already pointed out, it is but a remnant of former glacial Lake Pottersville. It may be regarded as merely a local enlargement of Schroon river whose waters are held back by Pleistocene deposits in the vicinity of Pottersville. It is possible that the Schroon lake basin was somewhat deepened by ice erosion during the great Ice Age, but data regarding this point are not in the possession of the writer.

Cheney pond was a small natural pond in the northern part of the basin now occupied by the large body of water of the same name, the building of Lester dam having raised the water to the present level.

Brace dam no longer holds back the water of Boreas river as shown on the map.

Hewitt pond occupies a rather delicately balanced position as regards its outlet. A trench, perhaps not more than 10 feet deep, cut through the narrow barrier of loose glacial drift along its southwestern side would allow the pond to drain westward into the Boreas and Hudson rivers, instead of eastward as now into the Schroon river.

The other ponds of this region require no special description.

Postglacial Changes of Level

It is a well-known fact that, during the closing stages of the Ice Age and just afterward, northern New York, including the area of the Schroon Lake quadrangle, was submerged hundreds of feet below the present altitude, and that tide water extended through the Champlain valley. This is proved by the presence of marine beaches with fossils several hundred feet above sea level in the Champlain valley. The most recent earth movement in northern New York has been that which has brought the marine deposits to their present position above sea level. This earth movement has been differential with greatest uplift toward the north, the rate of increase northward having been several feet a mile. The differential uplift appears to be clearly recorded within the Schroon Lake and adjoining Paradox Lake and North Creek quadrangles where, as already shown, the delta terraces and sand plains of former glacial Lake Pottersville gradually increase in altitude northward at the rate of several feet a mile. The deposits in glacial Lake Minerva also seem to show a similar uplift, but the evidence there is not so decisive.

Looking south through the narrows of Schroon lake from the village

SUMMARY OF GEOLOGICAL HISTORY¹

Prepaleozoic History

The Grenville series comprise the oldest known rocks of the quadrangle. They are metamorphosed sediments usually with their stratification more or less well preserved. They are thought to be of Archeozoic age; that is, they belong among the oldest known rocks of the earth. Since Grenville strata are widespread in northern New York and much of eastern Ontario, it is probable that they were deposited under sea water, and, since they are at least some miles thick, the time required for their deposition must have been no less than a few millions of years. In the Adirondacks the Grenville strata were probably subjected to static metamorphism whereby the original shales, sandstones and limestones were completely crystallized into various gneisses and schists, quartzite and crystalline limestone (marble). The Grenville strata show a very irregular or "patchy" distribution because they have been badly cut to pieces by great bodies of intrusive rocks. Because of the breaking up of the strata into masses great and small by the intrusives, they are in many places highly tilted or moderately bent, and in some places locally contorted, but there is no evidence that they were ever notably folded by orogenic pressure. In fact the combination of well-preserved stratification of the thoroughly crystallized sediments and foliation due to flattening of minerals always parallel to the stratification would scarcely be expected if severe lateral compression of the strata had ever taken place.

The oldest known intrusive is the anorthosite which worked its way up into the crust of the earth as a relatively stiff gabbroid magma, probably laccolithically. From the gabbroid magma the anorthosite differentiated. The rising magma for most part lifted or domed the Grenville strata over it, but also to some extent its borders engulfed fragments of the strata.

Distinctly later, though apparently not very much (geologically) later, came the intrusion of a tremendous body of magma now represented by the syenite-granite series. This vast magma for most part slowly and very irregularly worked its way upward, and

¹ The interested reader who may not be very familiar with the science of geology might care to consult a recent work by the writer entitled *The Adirondack Mountains*, which is a somewhat untechnical guide to the geology and physiographic history of the Adirondack region. This is published as New York State Museum Bulletin 193.

in places actually domed the Grenville over itself. Mostly, however, this magma either broke up or tilted masses of Grenville great and small, or broke through it as great off-shoots from the magma, or even more intimately intruded or injected it. The more or less well-developed foliation of both the anorthosite and syenite-granite is regarded as essentially a magmatic flow-structure produced under the pressure conditions of the intrusions.

At some time after the deposition of the Grenville strata, the whole Adirondack region was elevated well above sea level. Whether this uplift took place prior to the great igneous activity; or during the intrusion of the anorthosite or syenite-granite, or both, is not definitely known, but it is reasonable to think that the same great force which caused the upwelling of one or both these magmas also produced the general uplift of the region.

Just when the metamorphism of the Grenville strata took place is not known, but there is strong evidence that it took place either before or during the great igneous activity and not afterward.

Following the intrusion of the syenite-granite series, there was a time of minor igneous activity when the gabbro magma was forced upward into the earth's crust mostly in the form of stocks sharply cutting the older rocks. Intrusions of pegmatite and aplite dikes also took place, some after the gabbro, and some probably before it.

The general elevation of the region above referred to inaugurated a time of profound erosion which lasted at least some millions of years, even well into the Cambrian period of the Paleozoic era. This is proved by the fact that all the rocks above mentioned are now at the surface and exhibit textures and structures which could have been produced only under deep-seated geologic conditions, that is many thousands of feet below the surface of the earth.

After the removal, by erosion, of a great thickness of rock material, the last Prepaleozoic igneous activity of the region took place when the molten diabase was forced into narrow fissures in the earth and cooled in the form of dikes. This diabase is known to cut all the other rocks. That it must have cooled rather near the earth's surface is evidenced by the usually fine-grained to even glassy texture.

Paleozoic History

As a result of the vast erosion above mentioned, the whole Adirondack area was worn down to near sea level and it presented at most only a very moderate relief. Then, in late Cambrian time,

a gradual submergence took place which allowed the sea to encroach well upon the old land surface. As shown by the outliers at and near Schroon Lake and elsewhere in the eastern and southern Adirondacks, the first sediment to deposit on the floor of the encroaching sea was the Potsdam sandstone, followed in turn by the Theresa sandstone and dolomite and the Little Falls dolomite, all of late Cambrian age. That the eastern and southern sides of the Schroon Lake quadrangle were submerged under the late Cambrian sea is proved by the existence of the outliers of rocks of that age in the Schroon valley and near North River close to the southwestern corner of the quadrangle. There is no evidence that the late Cambrian sea covered the northwestern portion of the quadrangle (see figure 6).

Within the quadrangle, positive data regarding the Ordovician history are wholly lacking. It is however known that all of northern New York was moderately above sea level toward the close of the Cambrian, and that submergence again occurred during the Ordovician so that, toward the middle of that period, all but probably a large low island in the east-central Adirondack region was under sea water (see figure 6). It is highly probable that, during part of the period at least, the Ordovician sea spread over part of the Schroon Lake quadrangle.

There is no reason to believe that marine waters ever spread over any more than the fringe of the Adirondack area at any time since the Ordovician. In other words, the Adirondack district has been a land area subjected to erosion ever since Ordovician time.

Mesozoic and Cenozoic History

As a result of the long time of erosion from the Ordovician period to late in the Mesozoic era or early in the Cenozoic era, most of northern New York was reduced to the condition of a fairly good peneplain with some masses of relatively hard rocks, especially in the east-central Adirondacks, rising to moderate heights above the general level.

Then the great peneplain (commonly called the "Cretaceous peneplain") was upraised and a new period of active erosion was inaugurated which has continued to the present day. There is some reason to think that this erosion proceeded far enough to permit the larger rivers, like the Schroon, to reach an almost graded condition, after which there was moderate renewed uplift.

Much of the faulting of the eastern and southern Adirondacks dates from the time of this peneplain uplift or even later, though it is likely that some took place much earlier.

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 the lower Hudson and St Lawrence.

During the Ice Age of the Quaternary period, the area of the quadrangle, in common with nearly all of New York State, was buried under the great ice sheet which has left many records, such as striae on the ledges, glacial boulders, moraines and glacial deposits in general. The preglacial topography was not profoundly affected by ice erosion and deposition. The many extinct and existing lakes of the quadrangle were formed either by 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 for this latitude, when arms of the sea extended through the Champlain and St Lawrence valleys. The area of the Schroon Lake quadrangle was then, of course, lower than now.

The most recent movement of the land has been a differential uplift with greater elevation toward the north. At the latitude of the Schroon Lake quadrangle, this postglacial uplift has amounted to several hundred feet with greater uplift toward the north, the rate of increase in elevation northward having been several feet a mile. The differential character of this uplift is well shown by the delta deposits of the extinct glacial Lake Pottersville.

MINES AND QUARRIES

Graphite

A graphite mine is located at the western base of Catamount hill about 10 or 15 rods northeast of the confluence of Trout and Alder brooks. The mine has not been in operation for several years, but the buildings still stand, and a considerable quantity of the graphite-bearing rock is piled up.

The mine workings are located on a belt of Grenville biotite-graphite schist some 30 or 40 feet wide. Most of the rock of this belt is in very thin layers and contains tiny flakes of graphite, but one zone in it, a few feet wide, is extra rich in large thin flakes

of graphite, many of which range from 1 to 5 millimeters across. This extra rich layer was the one principally worked. A band of crystalline limestone a few feet thick, containing graphite and green pyroxene, lies in contact with the graphite schist. The strike of the rock is N 50° W and the dip S 60°. Some small workings are at the surface, but the main operation was running a shaft said to be 75 feet deep and now filled with water.

Graphite flakes commonly occur scattered through the crystalline limestone of the Grenville areas around Minerva and Olmstedville, but not in such form or quantity as to be commercial at present.

Garnet

On the hill one-third of a mile southwest of Calahan pond, there are two places close together where red garnet was mined to some extent a good many years ago. In the smaller mine opening, which lies just west of the map boundary, the garnet, in irregular to rounded highly fractured masses up to several inches in diameter, is associated with Grenville coarse crystalline limestone and considerable green pyroxene in crude crystals up to an inch in length. This Grenville is twisted into gneissoid granite, the relationship being very clear. Some much smaller inclusions of pyroxene and garnet rock are sharply defined in the granite. The larger opening, whose location is indicated on the map, is 50 feet long and 30 feet wide. It shows similar rocks except that no granite actually appears in the mine opening. Granite does, however, outcrop only a few rods away. It is probable that these garnets developed during the process of metamorphism along and close to the contact between the Grenville strata and the granite.

Garnets occur in various other rocks of the quadrangle, being especially abundant in certain of the Grenville hornblende-garnet gneisses, and in certain facies of the anorthosite and syenite-granite series, but in all these the garnets are generally too small and scattering to be of commercial value.

Iron Ore

Minerva mine. This small mine is situated $2\frac{1}{4}$ miles due north of Minerva village or three-fifths of a mile southeast of Sherman pond and at an altitude of 1900 feet (see map). The Burden Iron Company conducted the last mining operations in 1881 and sent the ore to Troy.

In a description of this mine Newland¹ says: "The deposit has a northwesterly strike in conformity to the general trend of the country rocks. It has a flat dip of not more than 10° northeast, but as the surface rises sharply in that direction, the overburden soon becomes too heavy for open-cut work. There are a number of pits and trenches along the outcrop, extending altogether for a distance of 100 rods. A breast of ore 12 or 15 feet thick is exposed in the middle section. The thickness diminishes toward the ends, but it was not possible to estimate the size with accuracy owing to the partial filling in of the pits. Some drilling is said to have been done a number of years ago to test the ore body in depth; the records, however, have not been available for use in this report."

"The ore is a fairly coarse, granular magnetite. Samples taken from different parts of the body indicate an iron content above 50 per cent on the average, so that it would be classed as of rich grade. The principal impurity is pyrite which seems to be concentrated in narrow bands and is not generally admixed with the magnetite. A quantity of the more sulfurous ore has been left on the surface near the openings."

As far as could be determined in the old pits, now considerably filled with water, the ore appears to be a crude, lenslike mass directly associated with an intimate mixture of granite and older dark gneisses. The granite is gray to pinkish gray with well-developed foliation, being locally almost schistose. The older rocks are chiefly hornblende and hornblende-biotite gneisses with some garnet and pyrite, and dark green pyroxene gneiss. In this connection it may be noted that similar ore has been described by the writer as occurring in like association with closely involved syenite or granite and dark gneisses in both the Port Leyden and Remsen quadrangles, and by Cushing in the Little Falls quadrangle, all of these along the southwestern border of the Adirondacks. It would seem that when the syenite or granite magma worked its way through or alongside the dark gneisses, the conditions were somehow favorable for the segregation of the magnetite.

Prospect near Loch Muller. In and about a small prospect opening three-fourths of a mile northwest of Loch Muller, magnetic iron ore also occurs in direct association with intimately mixed

¹ N. Y. State Mus. Bul. 119, p. 89-90. 1908.

granite and hornblende gneiss. Hornblende gneiss is all shot through by pink granite, and the magnetite occurs as small, irregular masses through the mixture.

Road Materials

So-called "trap rock" is typically represented by the diabase dikes of the quadrangle. Such rock ranks among the very finest of all natural road-building material because of its hardness, fineness of grain, homogeneity, freedom from mica, and good binding power, this last being due to richness in iron-bearing minerals. None of the diabase dikes of the quadrangle has ever been worked though two of them, northwest and southwest of Schroon Lake village (see map), are large and well located for quarrying purposes.

The gabbro stocks, especially those free from mica, would furnish a large amount of hard, homogeneous road material with good binding power. None of these stocks has been quarried, though some of them are very favorably situated with reference to prominent highways.

Rocks of the syenite-granite series, particularly those portions free from mica, also yield a good quality of road material where an artificial binder such as tar is used. There is practically no limit to the available quantity of such rocks, though only two quarries for road material have been opened in them. One of these (with a smaller one close by) is in syenite by the state road one-half of a mile east-northeast of South Schroon, and the other is in granite near the state road one-half of a mile north of Moxham pond.

The quarry in the Little Falls (?) dolomite in Schroon Lake village has been operated for road material.

In several places small quarries or pits are located in disintegrated, coarse, crystalline Grenville limestone. This material, which is gravelly and readily dug out, is used for local road repairing. Among such small quarries are those near the road one-half of a mile southwest of Olmstedville, and 1 mile northwest of Olmstedville.

Building Stone

Building stones of fine quality occur in practically inexhaustible amounts within the quadrangle. The members of both the anorthosite and syenite-granite series would rank as very strong, durable, often beautiful building stones. In a few places very small

quantities have been quarried for local purposes, but none has been quarried for shipment.

An interesting old quarry in Grenville crystalline limestone is situated $1\frac{1}{2}$ miles northwest of the summit of Hayes mountain and one-fourth of a mile west of Minerva stream (see map). The rock is a greenish, more or less mottled, medium-grained, crystalline limestone of the sort usually known as "verde antique." It contains serpentinized pyroxene and some graphite. Many years ago the quarry was operated by Daniel Lynch and some of the stone was shipped.

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