New York State Museum Bulletin

Entered as second-class matter November 27, 1915, at the Post Office at Albany, New York, under the act of August 24, 1912

Published monthly by The University of the State of New York

No. 192 ALBANY, N. Y. DECEMBER 1, 1916

The University of the State of New York

New York State Museum

JOHN M. CLARKE, DIRECTOR

GEOLOGY OF THE BLUE MOUNTAIN, NEW YORK, QUADRANGLE

BY WILLIAM J. MILLER

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1917

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The University of the State of New York

Department of Science, July 10, 1916

Dr John H. Finley
President of the University

SIR:

I am transmitting to you herewith a manuscript entitled "The Geology of the Blue Mountain Quadrangle" with the necessary maps and illustrations. This is a report of special investigations carried on for this Department by Dr William J. Miller and I recommend that it be published as a bulletin of the State Museum.

Very respectfully

JOHN M. CLARKE

Director

UNIVERSITY OF THE STATE OF NEW YORK

OFFICE OF THE PRESIDENT

Approved for publication this
11th day of July 1916

President of the University

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GEOLOGY OF THE BLUE MOUNTAIN, NEW YORK, QUADRANGLE

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GENERAL GEOGRAPHY AND GEOLOGY

The territory covered by the Blue Mountain quadrangle[1] lies in the heart of the Adirondack mountain region and all in northern Hamilton county excepting less than 2 square miles of its northeastern corner which extends into Essex county. It comprises an area of nearly 215 square miles. The geographic center of the 10,000 square miles of Precambrian rock in northern New York lies within, or close to, the northern portion of the quadrangle. The region is very typical of the great Adirondack wilderness, being rough, well watered, densely wooded, sparsely settled, and with few traveled roads or trails. The difficulties of making a systematic geological survey of such a region, especially those portions where forest fires have wrought havoc, are not easily exaggerated. It is a pleasure to record that several of the writer's former students of geology — Messrs J. P. Hull, H. Insley, and L. W. Bissell — at different times accompanied him into some of the roughest country and rendered valuable assistance.

The only villages in the area are Indian Lake, Blue Mountain Lake, and Long Lake, no one of which has more than a few hundred residents. Most of the comparatively little farming of the region is confined to the vicinities of these villages and along Cedar river. Lumbering is still an important industry, though much of the first-growth timber has been cut. During the summer

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

seasons hundreds of people go to the hotels or occupy cottages on Long lake and Blue Mountain lake.

No railroad enters the quadrangle, the nearest one being the Raquette Lake Railroad branch of the New York Central (Adirondack division) with terminus at Raquette Lake village about 8 miles from the western edge of the quadrangle. The traveled roads are clearly shown on the accompanying map. It is of interest to note that fully one-third of the area of the quadrangle (or about 75 square miles), including the northern-central and eastern-central portions, is wholly without a used or well-defined road, or even trail.

The maximum range of altitudes within the map limits is from a little less than 1560 feet, where Cedar river leaves the map on the east, to 3759 feet at the summit of Blue mountain. Ranking next in altitude are the two summits of Dun Brook mountain, 3580 and 3565 feet respectively, and Fishing Brook mountain, 3550 feet. The largest, high, rugged mountain group occupies some 35 or 40 square miles bounded by Mount Sabattis on the west and Fishing Brook and Dun Brook mountains on the east. At least 15 points within this group reach altitudes of 3000 feet or more. In the southeast, Blue Ridge and the prominent ridge just south of it show altitudes of over 3000 feet, the maximum figures being respectively 3481 and 3350 feet. Along the central-southern border, two points attain altitudes of about 3150 feet, these really being only on spurs of the Panther mountain mass of the northern part of the Indian Lake quadrangle. As compared with the eastern and southeastern Adirondacks, there is no very prevalent trend of mountain masses, though there are some suggestions of the usual northeast–southwest strike.

An important division of drainage — that between the Raquette and the Hudson rivers — passes across the quadrangle. Beginning at the middle of the northern boundary of the quadrangle, this watershed passes over Burnt mountain, Fishing Brook mountain, the northern summit of Dun Brook mountain, Buck mountain, Blue mountain, less than a mile south of Blue Mountain and Eagle lakes, and along the crest of Blue Ridge to the western border of the area. This watershed marks essentially the crest of the central portion of what has been called the main axis of elevation of the Adirondack region. Two valleys (below described), with greatest altitudes of only about 1800 feet, cut completely across this axis within the quadrangle and constitute two of the three or four lowest valleys

Plate 1

Photo by E. E. Kellogg, Blue Mountain Lake, N. Y.

Blue mountain (altitude 3759 feet) as seen from the southwest across the southeastern arm of Blue Mountain lake

Plate 2

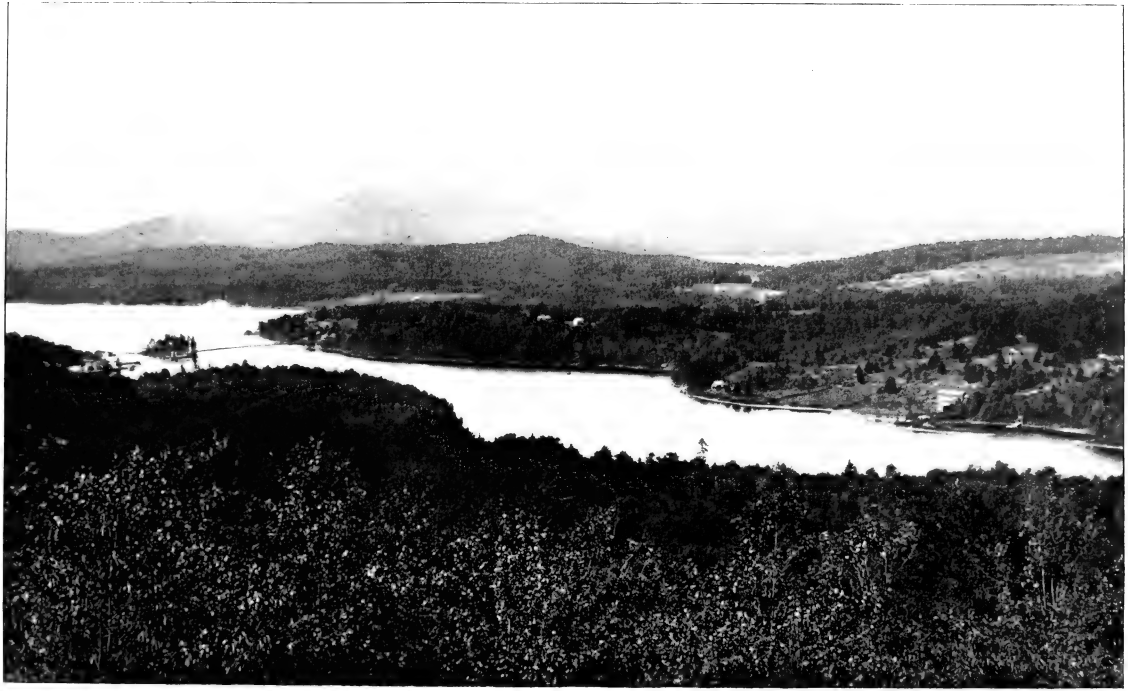

Photo by Dewitt Allen, Potsdam, N. Y.

View southwestward across Long lake from a point about a mile northeast of Long Lake village. Owl's Head mountain lies just to the left and Clear pond just to the right of the middle background.

Plate 3

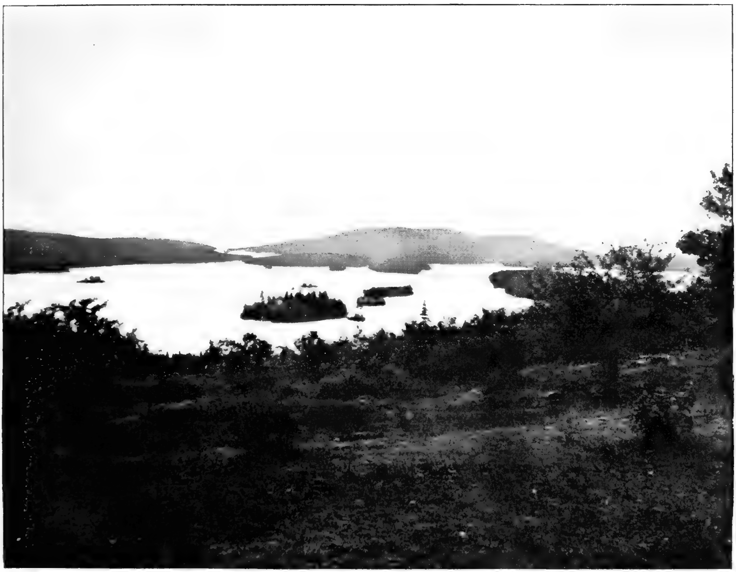

Photo by G. B. Wells, Blue Mountain Lake, N. Y.

View southwestward across Blue Mountain lake from Merwin's Hotel. Eagle and Utowana lakes are just visible in the distance.

of this sort in the Adirondacks. One of these extends across the quadrangle from the vicinity of Pine lake westward to Blue Mountain and Utowana lakes, and the other across the northern side of the quadrangle.

Raquette river, a tributary of the St Lawrence, is the largest north-flowing stream out of the Adirondack region. Blue Mountain lake drains westward through Raquette lake into Raquette river and into Long lake which latter is merely an enlargement of the river itself. Two prominent northeast-flowing tributaries of the upper Hudson river (Cedar river and Indian river) cross the southeastern portion of the quadrangle, Cedar river having some 15 or 16 miles of its course, and Indian river only 2 or 3 miles of its course, within the map limits. Rock river, the largest feeder of Cedar river within the area, has its source in the hills south of Blue Mountain lake and flows eastward nearly across the quadrangle, Rock lake being only an enlargement of the river. The Chain lakes, which are partly within the map limits, drain southward into Rock river about a mile above its mouth. In all, more than fifty ponds and lakes, or parts of lakes, lie within the quadrangle.

Excepting the glacial and postglacial deposits, all the rock formations of the quadrangle are of Precambrian age. Given in the regular geologic order they are as follows:

Glacial and postglacial deposits: Till, moraines, erratics, kames, lake deposits, etc.

Diabase: Two or three small dikes; nonmetamorphosed.

Pegmatite: Frequently found cutting nearly all types of the older rocks, including the gabbro; nonmetamorphosed.

Gabbro: Occasionally occurring as dikes or small stocks; more or less gneissoid; intrusive into the older rocks.

Syenite and granite: These are the most widespread rocks of the region with many facies from a basic or gabbroic phase of the syenite to typical granite and granite porphyry; distinctly gneissoid; intrusive into the Grenville and anorthosite.

Anorthosite: Two small masses only which are separated from the great area lying mostly in Essex county; more or less gneissoid; intrusive into the Grenville.

Grenville series: Prominently developed only in the southern half of the quadrangle; thoroughly crystalline stratified rocks, including various gneisses, limestones, and quartzite.

Some normal faults are present but they are far less prominent than in the eastern and southeastern Adirondack region.

Published statements dealing directly with the geologic features of the quadrangle are very scant, consisting of only a few paragraphs altogether. The following list includes the principal papers containing references to the quadrangle itself or the Adirondack region in general:

1839–41. **Emmons, E.** Geological Reports on the Second District of New York. 1839, p. 224–30; 1841, p. 113–33. These are the earliest published statements on the geology of Hamilton county.

1842. **Emmons, E.** Geology of New York, pt 2, on the Geology of the Second District, p. 414–17.

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 Geologist, p. 551–53.

1898. **Kemp, J. F., Newland, D. H., & Hill, B. F.** Preliminary Report on the Geology of Hamilton, Warren, and Washington Counties. 18th Annual Rep't N. Y. State Geologist, p. 156–57.

1905. **Cushing, H. P.** Geology of the Northern Adirondack Region. N. Y. State Mus. Bul. 95. A valuable treatise on Adirondack geology in general.

1907. **Cushing, H. P.** Geology of the Long Lake Quadrangle. N. Y. State Mus. Bul. 115. A detailed account of the geology of the region immediately north of the Blue Mountain quadrangle.

1912. **Miller, W. J.** Early Paleozoic Physiography of the Southern Adirondacks. N. Y. State Mus. Bul. 164, p. 80–94. Presents evidence to show that the central Adirondack area was not submerged during the Paleozoic era.

1913. **Miller, W. J.** The Geological History of New York State. N. Y. State Mus. Bul. 168. A book on the geology of the State with many references to the Adirondack region, particularly in chapter 3.

1914. **Miller, W. J.** Magmatic Differentiation and Assimilation in the Adirondack Region. Geol. Soc. Amer. Bul., 25:243–64. Discusses the origin and age relations of the various facies of Adirondack syenite and granite.

1916. **Miller, W. J.** Origin of Foliation in the Precambrian Rocks of Northern New York. Jour. Geology, 24:587–620.

PRECAMBRIAN ROCKS

Grenville Series

General character. The Grenville rocks of the Adirondack region, so far as our present knowledge is concerned, are to be classed with the oldest known formation in the crust of the earth. They are very largely, at least, stratified rocks, the original sediments such as limestones, sandstones and shales having been thoroughly metamorphosed into crystalline limestones, quartzites, and various schists and gneisses. Since the foliation and stratification planes are always coincident, it seems quite certain that the Grenville strata have never been subjected to very severe lateral compression, at least not sufficiently great ever to have obliterated the bedding surfaces. As judged by the character, great thickness and areal extent not only throughout the Adirondack region but also through much of eastern Canada, we may safely conclude that the Grenville beds were deposited under marine waters much as were the sediments of later geologic periods. Concerning the character and location of the lands from which the sediments were derived and the sea floor upon which they were deposited, we are at present ignorant. It is certain that the Grenville rocks are many millions of years old.

Areal distribution. Approximately 26 square miles of Grenville rocks are separately represented on the accompanying geologic map of the Blue Mountain quadrangle. There must also be added some 10 or 12 square miles more represented in the mixed gneiss areas and also inclusions mapped and unmapped in the igneous rocks. Thus about one-sixth of the area of the quadrangle is occupied by Grenville strata. On the Newcomb sheet the writer has seen large areas of Grenville; Cushing has mapped considerable areas on the Long Lake sheet; and the writer has seen many Grenville outcrops on the Tupper Lake sheet along the road from Long Lake to Long Lake West. Our knowledge is therefore sufficient to make it positive that the Grenville is prominently represented in the midst of the Adirondack region. Accordingly, certain older views implying very slight development of the Grenville there must be abandoned.

Within the quadrangle no attempt has been made to map the different facies of the Grenville separately because the heavy drift accumulations and consequent scarcity of exposures in certain portions of the Grenville valleys render any satisfactory areal subdivisions impossible. To a very considerable extent the crystalline limestone with its closely associated hornblende and pyroxene gneisses might be separately mapped, but it has seemed best to allow the known extent of the limestone areas to be brought out by indicating the actually observed outcrops of that rock upon the geologic map.

An important Grenville area, nearly 4 miles wide from north to south across the valley at Indian Lake village, extends without an interruption up the Cedar river valley for 11 miles with a width usually from one-quarter to 1 mile. The most abundant rock of this area appears to be coarse, crystalline, graphitic limestone with closely associated hornblende and pyroxene gneisses. Exceptions are 1 to 1½ miles north and northwest of Indian Lake village where the rock is largely a white feldspar-quartz gneiss.

Another prominent Grenville belt extends from Pine lake without a break through the valley of Rock river to Thirty-four marsh and thence into the basin of Blue Mountain lake. Its widest places are in the vicinity of Rock lake (nearly 2 miles) and in the Blue Mountain lake basin (nearly 1½ miles). The basin of Blue Mountain lake is largely occupied by Grenville limestone, many ledges being visible both above and below the water level. Within this belt the only other limestone exposures were observed on Rock river about a mile below the outlet of Rock lake. In the vicinity of Thirty-four marsh, gray Grenville gneisses only were seen. Quartzite and gray gneisses are prominent in the ridge just north of Pine lake, while on Cedar river, between one-half and 1 mile above the mouth of Rock river, white feldspar-quartz gneiss together with quartzite, hornblende gneiss and gray banded gneisses are prominently developed. Northwest of Rock lake heavy drift rather effectually conceals the Grenville.

As shown on the geologic map, the two belts of Grenville just described — one along Cedar river and the other along Rock river — are certainly connected through the valley south of Rock lake, but only a few exposures of hornblende and hornblende-garnet gneisses and white gneisses could be found on account of the heavy drift in this valley.

The small area extending northeastward from Unknown pond contains several exposures of Grenville limestone and it apparently consists mostly of this rock and associated hornblende gneiss.

The prominent depression crossing the line from the Blue Mountain to the Newcomb sheet and containing the Chain lakes (except the first and second), Mud, Deer, and Jackson ponds, is certainly almost entirely occupied by Grenville limestone and its associated hornblende gneiss.

Where the road to Newcomb crosses the Essex county line, a small area of Grenville shows various quartzitic and pyroxenic gneisses in comparatively thin layers. This is really only the westward extension of the large Grenville area in the vicinity of Newcomb.

In the extreme northeastern corner of the map an area of less than a square mile shows few outcrops, these being chiefly of hornblende gneiss.

The inclusions large enough to be separately mapped north of Sprague pond, 2 miles south-southwest of Sprague pond, west of Grassy pond, west of Minnow pond, and west of Buck mountain consist of hornblende gneiss. The small mass on the side of Stephens pond consists of white feldspar and pyroxene gneiss with some limestone. The small area on the road 1 mile west of Fishing brook crossing in contact with, and more or less shot through by, pink granite consists of hornblende gneiss and nearly white feldspar-quartz gneiss containing some pyrite and pink garnets.

Three small areas of Grenville within the mixed gneisses are respectively on the eastern shore of Long lake one-third of a mile south of the northern map limit; on the western shore of the lake directly opposite the last named area; and on the western shore of Long lake a little south of west of Long Lake village. The first two areas named show large exposures of white sillimanite gneiss and gray gneisses containing red garnets and pyrite, while the second named area shows large outcrops of a greenish gray almost syenitic looking gneiss with specks of pyrite.

Description of Grenville types. For purposes of comparison with other areas with the idea of possibly working out certain of the broader structural and stratigraphic relations of the Grenville series in the Adirondack region, the more important types of Grenville of the quadrangle are here described somewhat in detail.

Crystalline limestone. The southern half of the quadrangle, in common with the Newcomb, the southern half of the Schroon Lake, the North Creek, and the Thirteenth Lake quadrangles, shows rather extensive development of Grenville limestone, decidedly more so in fact than the southeastern, southern, and southwestern border portions of the Adirondacks. Throughout all the area just mentioned much of the limestone is very similar, being thoroughly crystalline, very calcitic, usually graphitic, mostly closely associated with hornblende, hornblende-garnet or pyroxene gneisses, and of great thickness — several thousand feet at least.

Sometimes the limestone ledges scarcely show stratification, but usually the original bedding surfaces are marked by layers in which the dark minerals are more abundant (see plate 4). Because of its plasticity under pressure, the limestone is generally much folded or twisted so that dips and strikes are very variable.

As already stated, the actually observed limestone outcrops are indicated upon the accompanying geologic map.

Perhaps the most abundant variety of limestone is medium to moderately coarse grained, nearly white, with irregular quartz grains in varying amount up to 20 per cent, scattering flakes of graphite (often with perfect hexagonal outlines) up to 4 or 5 mm across, and sometimes tiny specks of pyrrhotite. Many big exposures of such rock occur along Cedar river within 2 miles of where it enters the quadrangle; in the vicinity of Indian Lake village, and in and around Blue Mountain lake.

Another variety is much like the above except for numerous grains or small crystals of pale to dark green pyroxene (coccolite) scattered through the rock. The pyroxene is often more or less serpentinized.

Still other variations are due to absence of quartz or graphite from either of these varieties.

Irregular shaped masses of pyroxene or hornblende gneiss have sometimes been forced into the relatively plastic limestone under pressure (see plate 4).

Hornblende-garnet gneisses. Rocks of this kind are frequently found in contact (or interbedded) with the limestone. The most common facies is a fine to medium-grained, dark-gray gneiss consisting of about equal parts of hornblende and feldspar and in which are embedded scattering red garnets (almandite) up to three-quarters of an inch across. Among the readily accessible exposures are: one-half of a mile east of Indian Lake village; 1½ miles southeast of Forest House; and on the island one-quarter of a mile northwest of Blue Mountain Lake village (no. 21, table 1).

A less common facies is somewhat similar to the above but has some biotite and the scattering, rounded, red garnets (almandite) up to 5 or 6 inches in diameter which are completely inclosed within envelops of black hornblende crystals. This type of garnet gneiss is exactly like that recently described by the writer as occurring at the garnet mine on Gore mountain near North Creek.[1] Good outcrops may be seen 2½ miles south-southeast of Forest House in a small mine prospect. Better exposures occur in the old garnet

[1] Econ. Geol. Magazine, 7:5, 1912, p. 493–501. Also N. Y. State Mus. Bul. 164, 1913, p. 95–103.

Plate 4

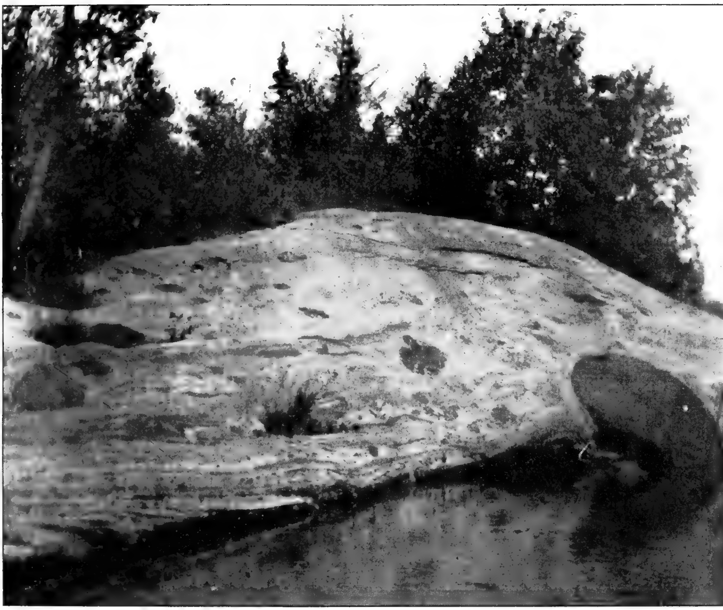

Photo by W. J. Miller, 1914

A ledge of Grenville limestone on Cedar river, one-half mile northeast of the main road bridge across the river. Stratification of the limestone is well shown as well as the rounded masses (dark colored) of Grenville pyroxene gneiss which have been kneaded into the relatively plastic limestone under pressure.

Plate 5

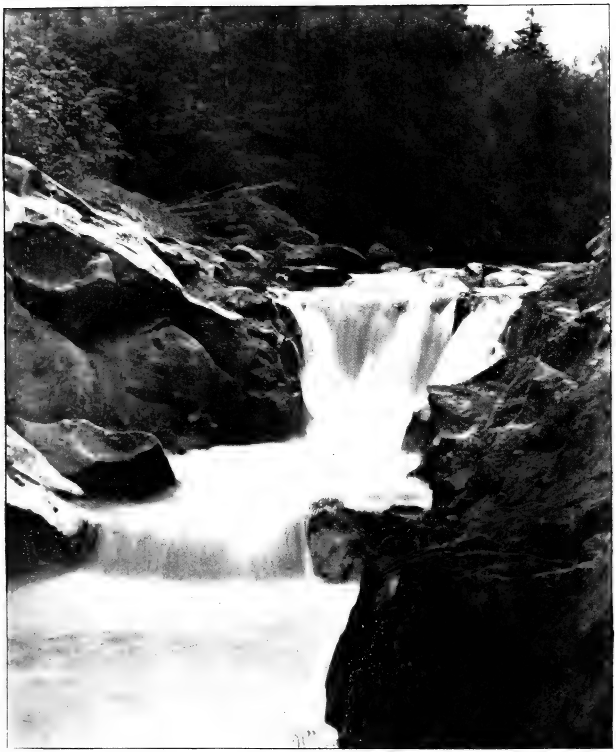

Photo by W. J. Miller, 1914

Falls at the head of the gorge on Cedar river due east of Waterbarrell mountain. The rock is Grenville limestone.

mine one-half of a mile east of Bullhead pond on the adjoining Newcomb sheet.

Hornblende-feldspar gneiss. These gneisses are also very commonly found in contact (or interbedded) with the limestone. They are to be distinguished from the hornblende-feldspar-garnet gneisses above described chiefly by the absence of garnet. One facies is medium grained and nearly black with only 10 to 20 per cent of feldspar. Sometimes this gneiss, within an inch of a limestone contact, is full of tiny red garnets, the lime for their development apparently having been furnished by the adjacent limestone during the process of metamorphism.

Another variety is fine to medium grained and contains perhaps 30 to 40 per cent of feldspar together with a few per cent of biotite

These hornblende-feldspar gneisses are nearly always found where there are extensive exposures of limestone.

Pyroxene gneisses. So far as could be determined, these gneisses also mostly appear to be closely associated with the limestone either clearly interbedded with them or distributed in irregular shaped masses in them, having been broken up and forced into the relatively plastic limestone under pressure (see plate 4).

A common variety of the pyroxene gneisses is fine to medium grained and greenish gray, consisting largely of bright green pyroxene (coccolite), quartz and feldspar with numerous tiny red garnets and some titanite through the mass. Sometimes a crude banded appearance is due to a concentration of the pyroxene in layers parallel to the foliation. Excellent exposures occur 1 mile south-southwest of Indian Lake village in the mixed gneiss area (nos. 6 and 11, table 1).

A rock very similar to this, but with numerous graphite flakes instead of garnet, outcrops along the river just east of Waterbarrel mountain.

Another variety consisting mostly of green pyroxene (coccolite) with some quartz and a little feldspar is very frequently closely involved with the limestone. Excellent outcrops occur along the road near the county line 9 miles east of Long Lake village, and near the eastern end of the largest island in Blue Mountain lake (no. 22, table 1).

Quartzites. As compared with the mapped areas of the southern and southeastern Adirondacks, quartzites are not so prominently developed in the Grenville of the Blue Mountain quadrangle. Also they vary greatly in composition, scarcely any two localities showing

Table 1 — Thin-sections of Grenville rocks

Slide no.	Field no.	Orthoclase	Microperthite	Microcline	Plagioclase	Quartz	Monoclinic pyroxene	Hornblende	Biotite	Tremolite	Garnet	Magnetite	Calcite	Pyrite	Apatite	Zircon	Zoisite	Titanite	Muscovite	Graphite	Hematite
6...	2l 2(a)	....	15	3	Al. 10	43	15	......	......	......	10	......	1½	½	......	......	......	2	......	......	......
7...	2d 3	10	50	15	....	20	......	......	......	......	4	......	......	little	......	......	......	1	......	......	......
11...	2l 1	....	20	20	....	35	20	......	......	......	2	......	2½	......	......	......	......	½	......	......	......
19...	5k 2	40	....	....	Ol.-An. 35	23	little	......	1	......	½	1	......	......	......	little	......	......	little	......	......
20...	7m 5	....	52	5	Al.-Ol. 15	22	......	......	1	......	5	......	......	......	little	......	......	......	......	......	......
21...	8d 11	....	....	....	Lab. 37	......	10	50	½	......	......	2	......	......	little	little	......	......	......	......	......
22...	8c 7	....	....	....	Ol. 2	15	72	......	......	......	......	......	10	......	......	little	......	1	......	......	......
23...	8d 10	....	26	....	Ol.-An. 1	40	......	......	16	......	16	little	......	½	......	little	......	......	......	......	......
26...	8c 19(b)	17	20	....	Ol.-An. 2	20	40	......	......	......	......	½	......	......	......	......	......	little	......	little	2
43...	15d 10	....	48	5	Ol. 10	35	......	½	......	......	......	little	......	1	......	little	little	little	......	......	......
51...	16m 2(b)	....	....	....	....	40	5	......	......	54	......	......	......	......	......	......	......	......	......	1	......
53...	16j 1	....	29	29	....	40	......	......	......	......	1	little	......	½	......	little	......	......	......	......	......

No. 6, 1¼ miles south-southeast of Indian Lake village (from a mixed gneiss area); no. 7, on Cedar river 1½ miles northeast of Waterbarrel mountain; no. 11, 1 mile south-southwest of Indian Lake village (from a mixed gneiss area); no. 19, top of mountain 1 mile southwest of Unknown pond; no. 20, on Cedar river one-half of a mile southwest of Pine lake; no. 21, on island one-half of a mile northwest of Blue Mountain Lake village; no. 22, eastern end of largest island in Blue Mountain lake; no. 23, small island just southeast of next to the largest island in Blue Mountain lake; no. 26, small island one-fifth of a mile southeast of largest island in Blue Mountain lake; no. 43, 1 mile southwest of Long Lake village; no. 51, main road one-third of a mile east of Essex County line; no. 53, on the road 6 miles west of Long Lake village.

Plate 6

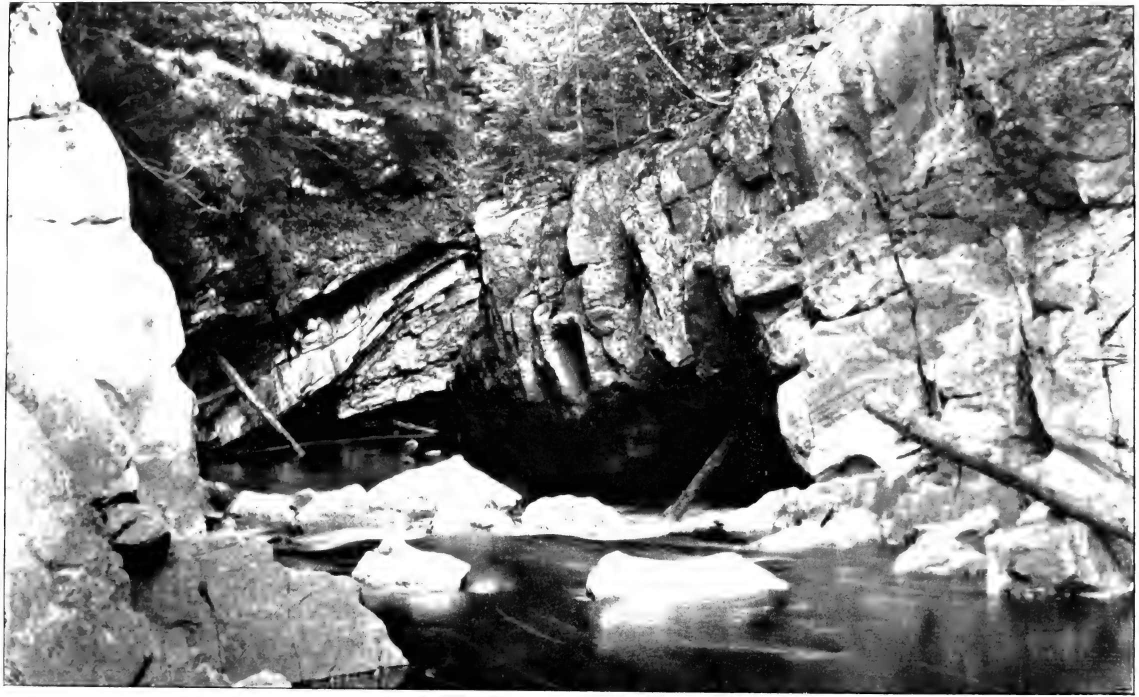

Photo by W. J. Miller, 1914

View in the gorge of Cedar river due east of Waterbarrell mountain. The white rock is Grenville limestone and the overlying gray rock is Grenville hornblende gneiss. A small thrust fault shows in the distance.

the same kind of rock. Most of the quartzites are fine to medium grained and thin bedded. In general there are two important varieties — one with feldspar and the other without.

The feldspathic quartzites carry from 10 to 25 per cent of feldspar together with 5 to 15 per cent of either biotite, muscovite or green pyroxene, or slight amounts of tiny red garnets or graphite flakes.

The nonfeldspathic varieties contain 90 or more per cent of quartz together with either biotite or muscovite.

Among the better quartzite exposures are the following: on several islands in the northern part of Blue Mountain lake; in the ridge just north of Pine lake; and along the road at the county line 9 miles east of Long Lake village.

Feldspar-quartz-biotite-garnet gneisses. These gneisses are not very abundant and vary greatly. Perhaps the most common variety is a fine to medium-grained, crudely banded, light-gray rock made up mostly of feldspar and quartz in addition to 10 or 15 per cent of biotite and varying amounts of pale pink garnets.

Good exposures may be seen respectively three-quarters of a mile and 1½ miles east of Blue Mountain Lake village on the road; on the small island just southeast of next to the largest island in Blue Mountain lake (no. 23, table 1); and on the ridge just north of Pine lake.

Feldspar-quartz gneisses. These light-gray to white gneisses are represented in considerable amount.

The most common variety is medium grained and made up very largely of feldspar and quartz with scattering red or pink garnets and almost no dark minerals. In exceptional cases grains of pyrrhotite or pyrite, or flakes of graphite, occur. Rocks of this sort are extensively exposed from 1 to 1½ miles northwest and north of Indian Lake village. Other good outcrops occur on Cedar river one-half to three-quarters of a mile southwest of Pine lake (no. 20, table 1); on Cedar river 1½ miles northeast of Waterbarrel mountain; and on the road respectively 6 miles (no. 53, table 1) and 9 miles (at the map edge) east of Long Lake village.

Apparently these gneisses are the same as certain white gneisses recently described by the writer as occurring within the Lake Pleasant [1] and the North Creek [2] quadrangles. That these are not eruptive rocks is quite certainly proved by their interstratification with definitely known Grenville strata and by their content of

[1] N. Y. State Mus. Bul. 182, p. 11. 1915.
[2] N. Y. State Mus. Bul. 170, p. 13. 1914.

graphite at some localities, for example, on Cedar river from one-half to three-quarters of a mile southwest of Pine lake. This matter is of considerable importance because these rocks so closely resemble certain white gneisses recently described from the Saratoga quadrangle by Cushing and by him rather thought to be ancient granites belonging with the so-called "Laurentian granite."[1]

Another variety of the feldspar-quartz gneisses is light gray, medium grained, very homogeneous and rather syenitic looking. This rock contains specks of pyrite and weathers brown. When first encountered it was thought to be a special facies of the syenite, but later the same sort of rock was found interbedded with true Grenville gneiss. Good outcrops may be seen in the small Grenville area 1 mile southwest of Long Lake village (no. 43, table 1); in the small Grenville area 2 miles northeast of Long Lake village; and on Cedar river respectively 1½ (no. 7, table 1) and 3½ miles northeast of Waterbarrel mountain.

Sillimanite gneisses. These are also light gray to white gneisses but are rare, having been found at only two places. A big ledge, 100 feet across within the small Grenville area 2 miles northeast of Long Lake village, consists of fine to medium-grained, banded, feldspar-quartz gneiss with some layers very rich in glistening needles of sillimanite.

The top of the mountain ridge (mixed gneiss) just southwest of Unknown pond shows sillimanite and garnet gneisses all shot through by granite. The sillimanite gneiss is a mass of fine-grained feldspar through which are scattered delicate, glistening needles of sillimanite in great abundance.

Tremolite gneiss. At the map edge on the Long Lake-Newcomb road, tremolite gneiss is interstratified with thin-bedded quartz-feldspar gneiss and dark pyroxene gneiss. The composition of this rock is shown by no. 51, table 1.

Feldspar-graphite gneiss. On the largest of the three small islands just southeast of the largest (Long) island in Blue Mountain lake, there are good exposures of gray to brown, medium-grained, thin-bedded, feldspar-graphite gneiss, the graphite being disseminated through the rock as numerous tiny flakes (no. 26, table 1).

Anorthosite-gabbro

Two small areas of anorthosite-gabbro are shown on the geologic map respectively 1¼ miles northeast and 1½ miles north of the

[1] N. Y. State Mus. Bul. 169, p. 21–26. 1914.

Long Lake bridge. In spite of considerable variations in the character of these rocks, they are distinctly different from any other rocks observed within the quadrangle. In every essential respect they appear to be like the anorthosite-gabbro border facies and small outlying masses of the great anorthosite body within the Long Lake quadrangle as described by Cushing.[1] Also they are precisely like the border facies of the anorthosite area along the Hudson river (Newcomb sheet) as seen by the writer during the summer of 1914. Therefore it is with some confidence that the two small masses of anorthosite-gabbro within the Blue Mountain quadrangle are regarded as of the same age as the great anorthosite body, being simply outlying masses or off-shoots of the large body similar to those within the Long Lake quadrangle described by Cushing. Identity of age has of course not been established since the two small areas are separated from the main anorthosite body by an interval of nearly 10 miles. According to Cushing the anorthosit (and associated anorthosite-gabbro) is distinctly older than the syenite.

In the area on the eastern shore of the lake the best and most typical exposures are in the immediate vicinity of the southern end of the diabase dike (see map) on the point which there extends into the lake.[2] This whole point is practically a solid exposure. Within 30 or 40 feet of the dike the anorthosite-gabbro best shows its variable character. It is mostly light gray to nearly white, medium to very coarse grained and largely devoid of gneissic structure. One patch of the rock is almost pure labradorite feldspar with fresh, bluish gray, rounded cores up to 1 or 2 inches across clearly showing the twining bands and embedded in a finer grained granular matrix of white plagioclase. These cores clearly represent the portions of the original large labradorite crystals which were uncrushed during the process of metamorphism. Most of the rock, however, is medium to only moderately coarse grained with fewer and smaller uncrushed labradorite cores, some andesine, a considerable percentage of dark minerals (chiefly hornblende, pyrite and magnetite), and some red garnets. Very locally the dark minerals may reach 30 to 40 per cent, when the rock is dark gray and distinctly gneissoid. The gneissoid structure becomes fainter with diminution of dark minerals, much of the rock not showing it at all. Some of the rock close to the contact with the diabase dike

[1] N. Y. State Mus. Bul. 115, p. 473-76. 1907.

[2] This anorthosite-gabbro, at the water's edge, contains a small inclusion of typical Grenville limestone.

is very light gray and more compact looking, the feldspar having a dull instead of the usual shiny luster. In thin section (no. 66, table 2) the feldspar and hornblende appear to be badly decomposed. Possibly this facies is an effect of the heat of intrusion of the diabase dike. About 50 feet east of the dike the anorthosite-gabbro has the same mineral composition (no. 64, table 2) but is considerably weathered to brownish gray, shows very few, small, uncrushed feldspar cores, and is moderately gneissoid. From 75 to 90 feet east of the dike the rock is weathered to a deep brown, is clearly gneissoid and looks so much like a basic phase of the syenite that, seen alone, it would scarcely be regarded as belonging with anorthosite (no. 65, table 2). All the facies just described grade perfectly from one into the other, but farther eastward, that is beyond 100 feet from the dike, there are no exposures at the base of the mountain so that the relation of the anorthosite to the syenite of the mountain could not be determined. Along the lake shore for one-quarter of a mile northward from the rocky point just described there are ledges of gray anorthosite-gabbro. Then, after a short interval, there is a ledge of what is taken to be a basic (gabbroic) phase of the syenite (no. 55, table 4). A few rods directly south of the rocky point there is a ledge of either gabbroic anorthosite or a basis phase of syenite, probably the latter (no. 56, table 4). Still farther south along the lake shore, there are outcrops of basic facies of the syenite. Thus, although the evidence is not conclusive, the anorthosite-gabbro appears to grade into a basic phase of the syenite of the region. Similar gradations have been quite definitely proved within the Long Lake quadrangle by Cushing who suggests that "the observed relations seem to point to the conclusion that the change is due to actual digestion, by the molten syenite, of material from the adjacent (anorthosite) gabbro."[1]

In the small anorthosite-gabbro area west of the lake, big outcrops cover fully one-half of an acre. The rock is much like the main bulk of the anorthosite-gabbro just described as occurring on the eastern shore of the lake. Toward the interior the mass is entirely devoid of foliation, is light gray, shows occasional uncrushed, bluish-gray labradorite crystal cores up to one-half or three-quarters of an inch across, and contains a considerable percentage of dark-colored minerals and some garnet. Otherwise much of the rock is darker gray and moderately gneissoid to almost black

[1] N. Y. State Mus. Bul. 115, p. 479. 1907.

and highly gneissoid. Within this anorthosite-gabbro there are several inclusions of light gray Grenville gneiss up to 2 or 3 feet wide, some bands of amphibolite and a few masses (one 25 feet across) of granitic syenite, all of these being arranged approximately parallel to the foliation of the inclosing rock where that structure is present. Whether the granitic syenite occurs as inclusions or as dikelike intrusions could not be positively determined, though they are most likely the latter.

Table 2 — Thin-sections of anorthosite — gabbro

Slide Number	Field no.	Plagioclase	Hornblende	Diallage	Enstatite	Augite	Magnetite	Quartz	Garnet	Apatite	Zoisite	Zircon	Pyrite	Biotite	Chlorite
61.......	17e 5(c)	an.-Lab. 63	35	...	...	.....	1	...	...	little	little	little	.....	.....	...
62.......	17e 5(d)	an.-Lab. 88	1	9	...	.....	1	...	...	little	little	.....	.....	little	...
63.......	17e 5(e)	an.-Lab. 70	11	15	...	.....	3	...	...	½	.....	½	.....	.....	...
64.......	17e 5(f)	an.-Lab. 77	15	...	...	1	2	...	4	.....	little	little	little	.....	...
65.......	17e 5(g)	an.-Lab. 80	16	...	...	little	1	...	...	½	½	.....	.....	2	...
66.......	17e 5(h)	an.-Lab. 80	...	...	...	.....	1	...	...	.....	.....	little	.....	.....	19
58.......	17e 9	ol.-Lab. 66	6	...	2	2	1½	12	10	.....	little	little	.....	.....	...

Nos. 61 to 66 inclusive are from the area on the eastern shore of Long lake; no. 58 is from the area west of Long lake and is more acidic than the usual rock there.

A number of small pegmatite dikes cut through the whole mass of rock. There are no exposures of any kind immediately surrounding the anorthosite-gabbro area so that nothing could be learned regarding its relation to the other rocks of the vicinity.

Syenite and Its Facies

The syenite and its basic and acidic facies are the most widespread of all the rocks. As here considered they vary greatly, ranging from what may be termed a normal quartz syenite to a basic (dioritic to gabbroic) facies on one hand to granitic syenite and granite on the other. Since these facies grade back and forth into one another, sharp boundary lines between them do not exist and their separation on the geologic map depends to a considerable extent upon personal judgment based upon some years of experience with the rock types and checked up by the study of numerous thin sections.

As is now well known, the syenite is younger than the Grenville series and distinctly intruded into it, there often being dikelike tongues of syenite cutting the Grenville and clearly defined inclusions of Grenville in the syenite. According to the work of Cushing on the Long Lake quadrangle, the syenite is also younger than, and intrusive into, the anorthosite.[1] For most part at least, the granites of the Blue Mountain quadrangle are only differentiation phases of the great syenite body and of practically the same age as the syenite, though the possible presence of some unproved granite either distinctly older or younger than the syenite must be admitted. This matter is more fully discussed in connection with the granite. Both the gabbro stocks or dikes and the diabase dikes are certainly younger than the syenite.

Normal quartz syenite. More than one-third of the area of the quadrangle is occupied by the normal syenite, it being widely distributed in exceedingly irregular bodies.

As usual throughout the Adirondacks, the normal or most typical syenite is dark greenish gray when fresh and weathers to a light brown, though apparently fresh pinkish or reddish syenites do occur rather locally. The depth of weathering usually varies from a fraction of an inch to several inches or, more locally, to a foot or more. In general the amount of weathered rock here seems to be greater than in the border regions of the Adirondacks, doubtless due to the fact that the central region was neither so long nor so vigorously glaciated. Immediate surfaces of syenite ledges are sometimes light gray to almost white, probably due to the leaching out of iron compounds by water rich in decomposing organic matter. A case in point is the big, bare ledge which looks like a snow bank in midsummer well up on the side of Blue mountain and clearly visible from the south for some miles. A hand specimen from this ledge shows a thin, white surface layer under which is a brown zone an inch thick and which in turn merges downward into the greenish gray fresh rock.

As regards granularity, the normal syenite is mostly medium grained; that is, the crystals range in length from 1 to 5 mm. Sometimes, however, it is finer grained while again it becomes moderately coarse to even slightly porphyritic. More or less granulation of the rock is a very common feature, the feldspars showing the greatest effect of the crushing of the mineral grains.

All the rock is foliated, most of it moderately so. At times the foliation is very faint, while at other times it is excessively developed, especially along shear zones where the rock may have an almost schistose appearance.

[1] N. Y. State Mus. Bul. 115, p. 479–82. 1907.

The normal syenite always contains quartz, the average amount being 12 to 20 per cent in the slides examined, and when it is greater than 20 per cent the rock is no longer regarded as normal, but rather granitic syenite to granite. Microperthite almost invariably makes up from one-third to two-thirds of the rock. Orthoclase is much less constantly present in variable amounts. Plagioclase (albite to andesine) never fails in amounts up to 35 per cent. When the rock is relatively rich in plagioclase it is a monzonite, though here, for convenience, classed with the normal syenite. Common hornblende with yellowish green to dark green pleochroism usually occurs in variable quantities up to 25 per cent, while green monoclinic pyroxene (usually diallage) frequently makes up 2 to 20 per cent of the rock. Enstatite was observed in only one slide. Both hornblende and pyroxene sometimes occur in the same rock. Magnetite (ilmenite), apatite and zircon in small quantities rarely fail. Biotite, garnet, zoisite and titanite are more sporadically present in small amounts.

The following table will serve to show the mineralogical variations of thin sections from carefully selected specimens of the normal syenite.

Table 3 — Thin-sections of normal quartz syenite

Slide Number	Field no.	Orthoclase	Microperthite	Microcline	Plagioclase	Hornblende	Biotite	Augite	Enstatite	Diallage	Magnetite	Quartz	Garnet	Apatite	Zircon	Zoisite	Hematite	Titanite
3	1c 9	8	45		Ol.-An. 20	10					1½	15		little	½			
4	1l 4		67		Ol. 10	5				2	1	15			little			
9	2d 4		35	20	Ab.-Ol. 10					20	1	14			little			
13	3e 4	25	30	10	Ol. 7	8	1				little	18		little	little	little		
14	3a 4	13	52		Ab.-Ol. 12	7					½	15			½			
31	9e 8	63			Ol.-An. 10	1		5			little	20			little	little		½
34	10b 1		72		Ol.-Ar. 4	3	2				½	15	2	little	little		½	
41	15d 3(a)		50		Ol. 20				10		1½	18		little	little	little		
49	16e 7		52		Ol. 18	9					2	18		½	½			
38	14m 6		27	8	Ol. 15	25	3				3	18		½	½			
45	16e 16		48		Ol. 35	½				3	1	12		little	little	little		
46	16e 9		42		Ol. 35	3	½			3	1	15			little	little		little

Nos. 38, 45 and 46, though practically monzonites, are for convenience classed with the syenite. No. 3, on Cedar river northeast of Waterbarrel mountain; no. 4, main road near map edge west of Indian lake; no. 9, Cedar river 1½ miles northeast of Waterbarrel mountain; no. 13, Cedar river 2 miles south of Stephens pond; no. 14, summit of Blue ridge at map edge; no. 31, close to Blue mountain trail at altitude 2400 feet; no. 34, 1½ miles west of west end of Minnow pond; no. 41, road 1½ miles southwest of Long Lake village; no. 49, eastern shore of Long lake one-quarter of a mile northeast of the bridge; no. 38, map edge 1⅔ miles south of the road to Newcomb; no. 45, one-quarter of a mile southeast of Long Lake bridge; no. 46, one-half of a mile northeast of Long Lake bridge.

Basic (dioritic to gabbroic) facies of the syenite. The rocks included under this caption really have the composition of diorite or gabbro though they have been quite certainly produced either by pure differentiation of the syenite magma or by the assimilation of country rock through which the syenite magma was intruded. They are quite different in aspect from the typical later gabbros which are separately represented on the geologic map in that they show neither the diabasic texture nor the peculiar mottled appearance of these later gabbros. In fact the color, texture and structural features are essentially the same as those of the normal quartz syenite already described.

Mineralogically, the basic facies of the syenite differ from the normal syenite chiefly by absence of microperthite, reduced amount or absence of orthoclase and quartz, and predominance of plagioclase (oligoclase to andesine).

The following tabular summary illustrates the mineralogical composition of typical thin sections from several areas of the so-called basic syenite.

Table 4 — Thin-sections of basic (dioritic to gabbroic) phases of the syenite

Slide no.	Field no.	Orthoclase	Plagioclase	Hornblende	Hypersthene	Diallage	Biotite	Garnet	Magnetite	Quartz	Pyrite	Zircon	Apatite	Zoisite
2....	1h 6	23	Ol.-An. 35	....	....	....	15	10	1	15	....	½	½	......
36....	12b 1	....	Ol.-An. 33	25	12	8	....	8	1	12	....	little	½	little
44....	15b 3	8	Ol.-An. 26	35	20	5	....	....	4	....	1½	little	little	......
55....	17f 9	....	Ol.-An. 70	1	25	....	....	....	3	....	½	little	little	little
56....	17e 4	....	Ol.-An. 42	35	....	....	....	15	1½	6	....	little	little	little

No. 2, 2½ miles south-southeast of Sprague pond; no. 36, Buttermilk falls on Raquette river; no. 44, eastern base of Owl's Head mountain; no. 55, eastern shore of Long lake 1½ miles northeast of the Long Lake bridge; no. 56, eastern shore of Long lake 1⅛ miles northeast of the Long Lake bridge.

The rock in the small area near the middle southern border of the quadrangle (no. 2, table 4) is pale greenish gray, medium grained, clearly gneissoid, with occasional crystals of biotite and red garnet set in a granular mass of feldspar. This rock appears to grade into the surrounding normal syenite.

In the area including Buttermilk falls there are many outcrops, the best being at the falls where, in a great ledge, the rock (no. 36, table 4) is mostly rather homogeneous, greenish gray when fresh, though somewhat darker than the normal syenite on account of a larger percentage of dark minerals, moderately gneissoid, and with some small garnets. At times there are streaks of dark, basic gneiss (presumably Grenville) more or less fused in, giving the rock something of a wavy or contorted aspect and suggesting the possibility that the basic syenite here has been produced by assimilation of such dark gneiss by the syenite magma. Ledges on the low mountain ridge to the east and southeast of the falls are very similar.

The rock of the Owl's Head mountain area (no. 44, table 4) is dark, greenish gray when fresh and weathers to a deep brown. It is very homogeneous, medium grained, clearly gneissoid, and usually rather rich in dark minerals though without garnets. The darker portions have a decided gabbroic look though not like the later gabbros of the quadrangle. Occasionally a small phenocryst of plagioclase stands out in the medium-grained, granulated matrix.

The area northeast of Long Lake village borders the anorthosite-gabbro and seems to form a transition between that rock and the normal syenite, though such a transition is not positively demonstrable as above discussed in connection with the anorthosite-gabbro. Exposures occur only close to the lake either side of the anorthosite-gabbro, the rock (nos. 55 and 56, table 4) being fine to moderately coarse grained, greenish gray weathering to brown, clearly gneissoid and fairly rich in dark minerals. Sometimes there is a suggestion of a porphyritic texture. A few bands of amphibolite parallel to the foliation occur in the rock along the lake shore south of the anorthosite-gabbro.

The Triplet Hill mass is probably only a westward extension, under the lake, of the area last described, the rock being very similar though at the summit of the hill some of the rock is rather distinctly porphyritic.

A very small body of basic syenite shown on the map northeast of Long Lake village is only a wide band parallel to the foliation of the syenite and not sharply separated from it. The rock is of decided igneous aspect, rather hornblendic and with occasional garnets up to more than an inch across. Apparently this rock has been produced by the assimilation of some Grenville hornblende-garnet gneiss by the syenite magma. The rock bears a very close resemblance to a definitely proved assimilation product of this sort at the garnet mine on Gore mountain near North Creek in Warren county.

Granitic syenite. The granitic syenite is really only an acidic phase of the syenite in which the quartz content lies approximately

Plate 7

Photo by W. J. Miller, 1914

Buttermilk falls on Raquette river, two miles southwest of Grove (Deerland). The rock is a typical basic facies of the syenite. A broken rock zone due to faulting shows just to the left of the middle of the falls.

between 20 and 25 per cent. So far as could be determined in the field, this granitic syenite is intermediate between the normal syenite and the granite, always grading into one or the other or both. Nothing like definite evidence was obtained to show that any one of these rock types cuts another. Though any attempt separately to delimit the granitic syenite on the geologic map must be rather arbitrary, it is believed that, as a result of careful attention to the matter in the field and the study of thin sections, the areal relation of the granitic syenite to the normal syenite and the granite are fairly well brought out.

This granitic syenite occupies nearly one-third of the area of the quadrangle and, like the normal syenite, is widely distributed in very irregular shaped bodies.

Much of the rock shows the usual color of the normal syenite, but pinkish to reddish granitic syenite is not uncommon, thus suggesting the typical granite into which it grades.

Texturally and structurally the granitic syenite shows essentially the same sorts of variations as the normal syenite.

Mineralogically the granitic syenite differs from the normal syenite chiefly in the larger content of quartz, somewhat smaller content of plagioclase, and absence of pyroxene.

In table 5 the compositions of a number of thin sections of granitic syenite are shown.

Granite

About 15 square miles of the quadrangle are separately mapped as granite, but, since this rock is abundantly represented in most of the mixed gneiss areas, the actual extent must be increased to something like 25 square miles. No field evidence was found to show that any of the granite is distinctly older or younger than the syenite or granitic syenite, though in many places perfect gradations from one to another were observed.

The granite facies vary in color from light gray or greenish gray to pinkish gray or light red. In some cases the reddish color is a mere surface weathering effect as, for instance, on the eastern face of Waterbarrel mountain where, within 1 or 2 feet, a superficial pink color passes downward into a light brown, and finally into a greenish gray color where the rock is very fresh. In other cases the reddish color permeates the rock to depths of 10 or 20 feet as is well exhibited in the quarry on the road 2½ miles east of Long Lake village. In still other places the pinkish or reddish color seems to be the inherent color of the rock or, if due to

Table 5 — Thin sections of granitic syenite and granite

	Slide no.	Field no.	Orthoclase	Microcline	Microperthite	Plagioclase	Quartz	Hornblende	Biotite	Magnetite	Hematite	Pyrite	Zircon	Apatite	Zoisite	Titanite
Granitic Syenite	18	5m 3	15	......	40	Ol. 10	22	8	3	1	......	little	little	little	......	......
	29	9e 5	......	......	54	Ol. 10	24	8	......	1	little	......	little	......	little	......
	30	9f 4	......	......	65	Ol. 8	22	4	......	1	......	......	little	......	......	......
	33	10d 8	......	10	54	Ol. 8	25	1	......	1	1	......	little	......	......	little
	35	12d 3	......	......	56	Ol. 12	25	4	2	1	......	......	little	......	......	......
	39	14d 7	......	......	50	Ol. 13	25	11	......	$\frac{1}{2}$	......	......	little	little	......	......
	40	14e 1	......	......	47	Ol. 10	24	15	3	$1\frac{1}{2}$	......	......	little	little	......	......
	57	17c 3	......	3	56	Ol. 5	24	10	1	$\frac{1}{2}$	......	little	little	little	......	......
Granite	5	1c 2	......	18	25	Ol. 2	50	4	......	$\frac{1}{2}$	......	......	little	little	......	......
	16	4g 9	25	......	30	Ol.-An. 5	30	9	$\frac{1}{2}$	little	......	......	little	little	......	......
	37	12g 5	......	......	48	Ol. 12	28	9	......	$1\frac{1}{2}$	1	......	little	little	......	......
	42	15d 3(b)	......	8	40	Ol. 10	35	6	......	1	......	......	little	......	......	......
	48	16k 1	5	5	32	Ol. 20	26	9	......	2	......	......	little	......	......	1
	50	16h (a)	......	25	27	Ol. 10	28	5	4	......	$\frac{1}{2}$	......	little	little	......	......
	54	17b 1	......	......	50	Ol. 10	30	6	3	$\frac{1}{2}$	......	......	little	little	......	......

No. 18, 2½ miles north-northeast of Indian Lake village; no. 29, 1 mile north-northeast of Blue Mountain Lake village; no. 30, summit of Blue mountain; no. 33, one-half of a mile south of Mud pond; no. 35, 2 miles southeast of Grove (Deerland); no. 39, 1 mile northeast of Grove (Deerland); no. 40, summit of Mt Sabattis; no. 57, on road 1½ miles due west of Triplet hill (from mixed gneiss area); no. 5, eastern face of Waterbarrel mountain; no. 16, summit of mountain one-half of a mile north of Sprague pond; no. 37, one-half of a mile northwest of Salmon pond; no. 42, road 1½ miles southwest of Long Lake village (from local band in syenite); no. 48, stone quarry on road 2 miles west of eastern map limit; no. 50, road close to gabbro stock 3½ miles east of Long Lake village; no. 54, northeastern shore of Clear pond.

weathering, the color change has affected the apparently fresh rock to depths beyond the zone of observation.

As regards texture and degree of foliated structure, the facies of granite show practically the same kinds of variations as the normal syenite already described.

Mineralogically, the granite differs from the facies of the syenite chiefly in the higher quartz content and more common occurrence of microcline. Table 5 includes examples of the more common variations of granite from different parts of the quadrangle.

Various types of light to dark-gray Grenville gneisses occasionally occur as distinct inclusions in the granite, but limestone inclusions were never noted. Where such inclusions are of sufficient abundance to make up a considerable percentage of the mass, the rock has been classed with the mixed gneisses (see below). The inclusions are nearly always flattened and drawn out parallel to the foliation of the granite almost exactly as in the case of the syenite and granitic syenite. Also, as in the mixed gneisses below described, many of the inclusions are sharply separated from the inclosing rock, while others grade into the granite as a result of partial fusion.

Long, narrow, amphibolite (presumably Grenville) inclusions, apparently like those so characteristic of the so-called " Laurentian granite " of the Thousand Islands region, also occur in some parts of the granite, but are not abundant. Perhaps the best observed locality for such inclusions is on the north shore of Clear pond where numerous streaks or narrow layers of amphibolite are drawn out parallel to the foliation of the pink granite and sometimes in sharp contact with it. Such amphibolite inclusions are, however, by no means characteristic of the granite since they are about as commonly present in the facies of the syenite. Thus the normal syenite and its basic variation on either shore of Long lake northeast of Long Lake village afford excellent exhibitions of amphibolite inclusions of the kind just described. The nature and frequency of the inclusions therefore afford no criterion by which any possible age differences between the syenite and granite could be determined.

The absence of distinct limestone inclusions from the granite harmonizes with the Thousand Islands region as described by Cushing and Smyth [1] and the Haliburton-Bancroft area of eastern Canada as described by Adams and Barlow.[2] According to Adams, the lenses

[1] N. Y. State Mus. Bul. 145, p. 37. 1910.

[2] Canada: Department of Mines, Geol. Survey, Memoir 6, p. 62–114.

of limestone caught up by the granite or syenite magma were converted into amphibolite.

Still another feature of interest is the occasional occurrence of rapid transitions from syenitic to granitic material and vice versa, giving rise to a kind of banded structure parallel to the foliation but with the bands not at all sharply separated from each other. A case in point is the freshly blasted ledge on the road 1½ miles southwest of Long Lake village where a band of light-gray hornblende granite (no. 42, table 5) 2½ feet wide passes by insensible gradations on either side into a greenish gray pyroxene syenite (no. 41, table 3). Such phenomena appear to be rather common in the Adirondack region, many observations having been made in the various quadrangles studied by the writer, and also in the Long Lake and Elizabethtown-Port Henry quadrangles by Cushing and Kemp respectively. For most part these banded structures are believed to be a result of magmatic differentiation, but in some cases it is probable that lenslike inclusions of Grenville rocks have been more or less assimilated by the inclosing syenite or granite.

Granite Porphyry

Many times the pink or gray granites have suggestions of porphyritic texture, though there is but one small area of typical granite porphyry which could be mapped as such. This is in marked contrast with the relative prominence of such porphyry within the Broadalbin, North Creek and Lake Pleasant quadrangles mapped by the writer in the southeastern Adirondack region.

The small area of granite porphyry occupies about one-quarter of a square mile in the vicinity of the Indian lake dam. Some of the rock has been used in the construction of the dam. There are many good exposures, the best being at the dam and in the quarries just east. Where fresh the rock is greenish gray, and where weathered it is pinkish. The rock is always coarse grained and rather gneissoid with the porphyritic texture usually well developed though at times only poorly so. The feldspar phenocrysts are always highly granulated. Locally biotitic shear zones occur. At times some small Grenville gneiss inclusions may be seen.

A thin section of the typical rock from near the dam shows the following mineral percentages: orthoclase 10; microline 25; microperthite 15; oligoclase to andesine 4; quartz 40; hornblende 2; biotite 1; garnet 2; apatite ½; and a little zircon and magnetite.

Plate 8

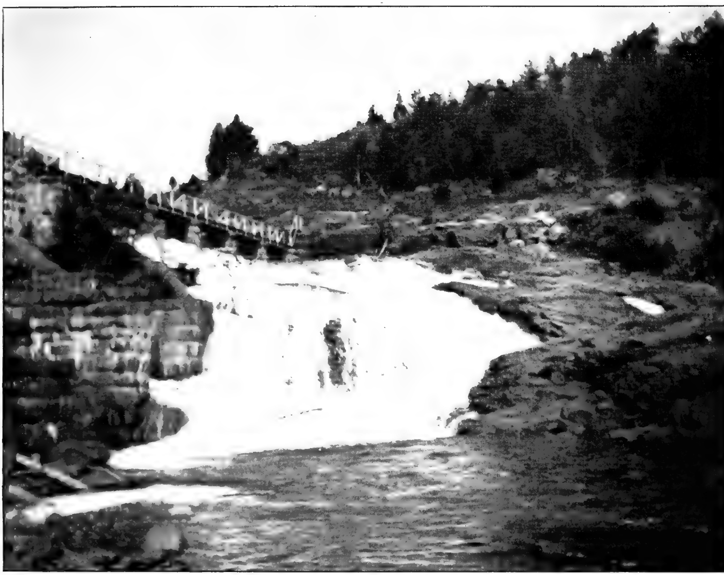

Photo by W. J. Miller, 1914

The State dam at the end of Indian lake. All of the rock is granite porphyry. A vertical fault surface is visible at the end of the footbridge.

Mixed Gneisses

General statements. Under this caption are included chiefly Grenville rocks which are cut to pieces by, and more or less closely involved with, various facies of the syenite-granite body. Sometimes the Grenville, and sometimes the igneous, rocks prevail. Of the igneous rocks in most of the areas, granite appears to predominate. In general it may be said that these mixed gneisses include: long, narrow masses of Grenville and syenite or granite distinctly recognizable as such but showing rapid alterations at right angles to the strike of the foliation; bodies of syenite or granite containing numerous sharply defined lenslike inclusions of Grenville; Grenville rocks intimately shot through by igneous rocks after the fashion of so-called "lit-par-lit" injection; bodies of syenite or granite containing a multitude of small, lenslike Grenville inclusions whose borders commonly grade into the inclosing rock so that the Grenville is often difficult to recognize as such; rocks which are intermediate in character between the Grenville and igneous rocks and which have clearly been produced by magmatic assimilation; and still other rocks of variable types and puzzling character whose origins are admittedly rather uncertain. The small scale of the map, together with the usual lack of sufficient outcrops has, for most part, rendered inadvisable any attempt to map separately very small masses of Grenville or igneous rocks recognizable as such within these mixed gneiss areas. It is not uncommon to find small exposures with a so-called "mixed gneiss" aspect within the great syenite-granite intrusive body, but here too it would be unsatisfactory to attempt any consistent separate delimitation of such rocks.

Area south to southwest of Indian Lake village. This area of about 2½ square miles shows many features characteristic of a typical mixed gneiss area.

Along the river and in the fields east of Indian lake dam, there are numerous outcrops of granite and Grenville rocks (even including limestone) which are clearly recognizable as such, while certain other outcrops consist of more or less intimately associated granite and Grenville rocks where the distinctive characters are not so evident.

Very instructive exposures occur along the road 1 mile a little west of south of Indian Lake village. Going southward the first outcrop beyond the pink granite is well-banded pyroxene (coccolite), Grenville gneiss, most of which contains considerable feldspar and quartz together with some calcite and tiny brown garnets and a little titanite (no. 11, table 1). There are occasional nests, up to 8 inches in diameter, of pure bright-green pyroxene (coccolite). Some of the layers of Grenville are pyroxene quartzite. The next ledge on the road, a few yards to the south, contains Grenville gneisses exactly like those just described, but which are all shot through by pinkish granite with more or less assimilation of the Grenville by the granite. Sometimes Grenville streaks are fairly distinct, and sometimes they clearly fade into the granite which latter rock then contains a sprinkling of small crystals of green pyroxene and has a composition really much more like granitic syenite to normal quartz syenite, though quite different in outward appearance. A thin section of this changed rock shows the following mineral percentages: orthoclase 18; microcline 24; microperthite 25; oligoclase to andesine 5; quartz 21; pyroxene (coccolite) 6; and less than 1 per cent each of magnetite, titanite, zircon and muscovite. It is certain that the pyroxene of this granitic syenite has somehow been derived from the Grenville gneiss, the evidence rather clearly pointing to actual absorption or assimilation of some of the Grenville by the granite.

Area between Indian Lake village and Rock lake. In this area of some 3 square miles, the most interesting exposures are on the mountain lying southwest of Unknown pond. For about a mile the top of the fire-swept mountain is an almost continuous, barren rock-ledge in which a certain type of the mixed gneisses is beautifully exhibited. Pink, medium-grained, biotite granite is all shot through Grenville white gneiss and Grenville light-gray, feldspar-quartz-garnet gneiss, these gneisses usually occurring in wavy, disconnected, thin layers throughout the granite. It is evident that there has been no considerable assimilation, though usually the gneiss boundaries are not sharply defined against the granite. Farther down, on the south face of this mountain, fairly large masses of dark, rusty-looking, Grenville gneisses occur in the granite.

Along the road directly west of the mountain just described, there are closely associated gray granite and gray Grenville gneisses.

The mountain directly south of Unknown pond consists mostly of pink granite with numerous streaks or bands (sometimes 10 to 20 feet wide) of Grenville hornblende gneiss.

Area south of Blue Mountain lake. This area of about 9 square miles, extending from Blue Mountain lake southward to the base of

Blue ridge, is in most respects very typical of central and southern Adirondack mixed gneisses. Throughout the area various types of Grenville strata have been more or less cut to pieces by pink granite or granitic syenite, the dips generally being very steep and the igneous masses having nearly always penetrated the Grenville parallel to the foliation. More rapid wearing away of the weaker Grenville belts accounts for the arrangement of low ridges approximately parallel to the foliation. Many exposures show either pure Grenville or pure granite, while in many others the granite and Grenville are more or less intimately associated, in some cases local assimilation having taken place. Excellent outcrops in the open field between Blue Mountain Lake village and Crystal lake afford a practical demonstration of the very intimate relations of granitic and Grenville gneisses with some intermediate rocks due to magmatic assimilation. The granites are pinkish to grayish and rather variable though always gneissoid. In certain outcrops gray, biotite or dark garnet or pyroxene, Grenville gneisses may be seen to grade into the igneous rock with no visible contacts. In a few cases the contacts are fairly sharp. Most of the exposures, however, consist of rocks of distinctly intermediate character which are clearly the products of local assimilation.

Area south to southwest of Grove (Deerland). This body of mixed gneisses, covering about 2 square miles, mostly comprises outcrops of gray to pinkish granitic to syenitic gneisses filled with streaks or inclusions of dark to light-gray gneisses (presumably Grenville), the rocks being crudely banded, very gneissoid, and often considerably contorted.

Exceptional exposures occur as big ledges in the bed of the stream which is the outlet of South pond. The rock, instead of being distinctly gneissoid to banded, is streaked or wavy as though small amounts of dark Grenville had been partially fused and assimilated by syenite magma, the syenitic character being preserved in spite of the inclusions. The whole presents what might be termed a "marble-cake" appearance.

Area across the northern portion of the quadrangle. This area of about 12 square miles extends completely across the northern portion of the quadrangle and is apparently the southern border of the so-called "Long Lake gneiss" as mapped by Cushing in the region immediately to the north. For most part the rocks of this area are rather typical mixed gneisses, that is, they are largely granite or syenite more or less intimately associated with Grenville, these latter being chiefly dark hornblende gneisses and light-gray quartz-feldspar gneisses arranged as bands, belts, or lenslike inclusions in the igneous rocks and parallel to the foliation. In some cases these belts or inclusions of Grenville merge into the inclosing igneous rocks because of melting of their borders at the time of the magmatic invasion. Though the outcrops are rather poor in many portions of the area, it seems fairly certain that the granitic and syenitic rocks predominate.

A solid ledge for 200 yards in the gorge of Fishing brook just east of the county line shows a preponderance of pink granite which contains distinct belts of both dark and light Grenville gneisses parallel to the foliation.

Where the secondary roads diverge two-thirds of a mile west of the Long lake bridge, there are fine ledges of rather variable rock consisting in part of syenitic and gray granitic gneisses with distinct amphibolite and gray Grenville gneiss bands parallel to the foliation. Much of the rock, however, is streaked to almost thin-banded due to injection of the gneisses by thin layers of magma (see plate 9). At one place a very small mass of Grenville limestone was noted.

On the shores of Long lake within one-half of a mile of the northern map edge, there are fine exhibitions of typical mixed gneisses. Thus on the eastern shore one-eighth of a mile southwest of the small mapped Grenville mass, there is a big ledge of syenitic to almost gabbroic looking gneiss with streaks, blotches and bands of dark, biotite-garnet and gray, biotite-quartz gneisses arranged parallel to the foliation. The southern portion of this ledge is pink granite which merges (as a result of fusion) into a biotite-quartzite.

The end of the sharp point projecting into the lake less than one-quarter of a mile southwest of the locality last described is a solid ledge of mixed gneisses which looks as though Grenville strata had been thoroughly cut up, and more or less fused, by the syenite magma so that both Grenville and syenite often do not show their typical features.

In certain other ledges on the lake shores there is good evidence for some fusion of Grenville strata, and frequently bands of amphibolite up to 20 or 30 feet wide occur parallel to the foliation of the syenitic or granitic gneisses.

Other areas. In the bed of Rock river nearly 1 mile below the outlet of Rock lake, large exposures show green pyroxene, white

Plate 9

Photo by W. J. Miller, 1914

A ledge of mixed gneisses, two-thirds of a mile west of the Long Lake bridge. The rock is streaked to thin-banded due to injection of the gray Grenville gneiss by thin layers (light colored) of granitic material but without notable assimilation.

Plate 10

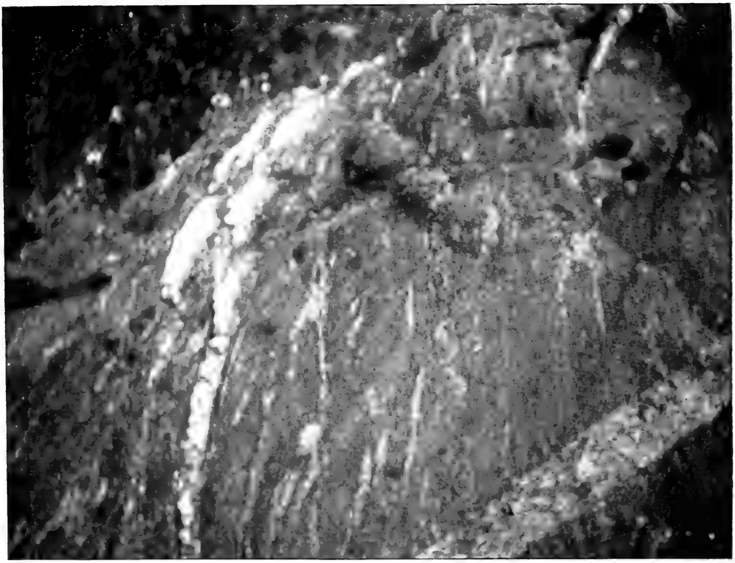

Photo by W. J. Miller, 1914

A ledge of Grenville and granite mixed gneisses, two-thirds of a mile west of the Long Lake bridge and similar to that shown in plate 9, but with two veins of pure white quartz parallel to the foliation on the left and a dike of pegmatite at the lower right. The pegmatite sharply cuts both the gneiss and one of the quartz veins, the latter not being shown in the picture. The camera was pointed downward to get the picture.

granitic-looking and hornblende gneisses cut by masses of granitic syenite and pink granite.

The small body of mixed gneisses exposed along the river south-southwest of Sprague pond shows not only normal syenite and Grenville hornblende gneiss, but also a basic, igneous-looking gneiss apparently an assimilation product.

The other small areas mapped as mixed gneisses require no special description. It is of course to be remembered that small exposures showing the so-called "mixed gneiss" aspect are occasionally met with in many parts of the quadrangle.

Gabbro Stocks and Dikes

Thirteen gabbro stocks or dikes have been discovered and separately represented on the accompanying geologic map. They are rather widely distributed over the quadrangle, though eight of them are confined to its southern one-fourth. That these gabbro masses are younger than any facies of the great intrusives already described is clearly proved by their sharp contacts against those intrusives. In many respects these gabbros are similar to those of the North Creek quadrangle recently described somewhat in detail by the writer,[1] but they do not present so many variations. Most of them at least have rounded to elliptical ground plans and practically vertical contacts with the country rock, so that they are of the nature of stocks, but in some cases where the exposures are not very satisfactory, they may exist as dikelike forms. As a rule, the long axes of the exposed gabbro bodies are almost, or quite, parallel to the foliation of the country rock. No branching of any gabbro mass was noted. The observed variations in size of the areas is from a single small exposure a few rods across to others from one-half to three-fourths of a mile long.

A feature of particular interest is the almost invariable association of pegmatite dikes or veins with the gabbros, the former cutting the latter. The same thing has been noted in connection with the gabbro stocks of the North Creek and Lake Pleasant quadrangles, but its significance is scarcely known.

Megascopically, the gabbros are seen to be medium to moderately coarse grained and dark gray when fresh with roughly equal amounts of feldspar and dark minerals, the latter including hornblende or pyroxene or both, biotite, ilmenite and usually tiny reddish garnets scattered through the rock. On weathering, the gabbros

[1] N. Y. State Mus. Bul. 170, p. 26–38. 1914.

assume a deep-brown color. The larger and more typical stocks commonly have a nonmetamorphosed interior facies which has a more or less well-developed diabasic texture, and a border facies (often amphibolite) which is so thoroughly gneissoid that the diabasic texture has disappeared. The typical nonmetamorphosed gabbros, with diabasic texture and large percentage of black minerals, is readily distinguished from all other rocks of the region. Some of the border facies, however, are either amphibolites which look much like certain dark gneiss inclusions commonly seen in the granite and syenite, or dark gneisses which might be easily confused with certain basic facies of the syenite.

Under the microscope the mineralogical composition of the gabbros is shown by the following examples taken from various stocks or dikes.

Table 6 — Thin sections of typical gabbros

Slide no.	Field no.	Plagioclase	Hornblende	Hypersthene	Diallage	Biotite	Magnetite	Pyrite	Garnet	Apatite
8........	20 1	Ol.-Lab. 20	35	40	......	1	1	......	3	......
15........	4g 1	An.-Lab. 28	20	15	10	2	little	little	25	......
17........	4m 15	Lab. 31	15	15	17	2	2	......	15	......
25........	8c 19 a)	An.-Lab. 55	20	15	4	5	little	......	1	......
27........	8c 8	An.-Lab. 55	25	15	1	1	3	......	......	little
52........	161 8	Lab.-An. 55	......	20	......	5	8	......	12	......

No. 8, 1 mile north of Waterbarrel mountain; no. 15, one-third of a mile west-southwest of Sprague pond; no. 17, 1½ miles north-northeast of Indian Lake village; no. 25, small island one-quarter of a mile southeast of the largest island in Blue Mountain lake; no. 27, largest island in Blue Mountain lake; no. 52, eastern side of stock 4 miles east of Long Lake village.

The largest gabbro stock, 4 miles east of Long Lake village, is very typical (no. 52, table 6) and has numerous outcrops with the amphibolite border facies well exhibited along the road.

On the largest island in Blue Mountain lake the gabbro (no. 27, table 6) is not so typical, its interior being somewhat gneissoid, medium grained and with only slightly developed diabasic texture, while its border facies is finer grained, more granulated, and amphibolitelike. Very similar rock (no. 25, table 6) outcrops on the small island just to the southeast and it is probable that these two masses are parts of the same gabbro stock now mostly covered by water. If they are connected, the submerged portion may be nonmetamorphosed and with better diabasic texture.

The large stock north of Waterbarrel mountain shows some big ledges of medium to coarse-grained rock with perfect diabasic texture, and feldspar laths up to three-quarters of an inch long (no. 8, table 6). Some amphibolite occurs, especially on the north side of the stock, but much of the gabbro is very gneissoid, this being true in places (particularly toward the east) of even the coarsest grained rock, the feldspars having been highly granulated, the diabasic texture destroyed and occasional garnets developed. This very coarse-grained, gneissoid gabbro so greatly resembles a large mass somewhat doubtfully called gabbro along the West Branch of the Sacandaga river in the Lake Pleasant quadrangle[1] that this latter rock is now quite confidently regarded as a metamorphosed coarse gabbro. Apparently it is a facies of gabbro not often met with.

The other gabbro masses of the quadrangle are quite typical in every way and require no special description.

Pegmatite

Pegmatite dikes or veins were occasionally met with in many parts of the quadrangle. One type occurs as narrow masses of moderately coarse grain with long axes essentially parallel to the foliation of, and not very sharply separated from, the inclosing syenite or granite. Dikes of this sort were, no doubt, injected practically contemporaneously with the great intrusives, possibly as a late phase of the intrusions.

Another type of pegmatite, clearly later in origin, is generally very coarse grained, cuts through rocks of all ages except the diabase, shows very sharp boundaries and usually cuts across the foliation of the country rock. Dikes of this sort are wholly devoid of metamorphism. They range in width from 1 or 2 inches to 100 feet and in length up to 200 yards or more. A few of the most conspicuous observed examples are as follows: coarse-grained dike 10 or 15 feet wide cutting Grenville hornblende gneiss on Cedar river 3½ miles west of Indian Lake village; a 15 foot wide dike some 40 or 50 feet long cutting Grenville limestone just southeast of the small gabbro stock 1 mile north-northeast of Indian Lake village; small but very sharply defined dikes cutting the basic syenite at the summit of Owl's Head mountain; a dike fully 100 feet wide and 200 yards long at the western border of the gabbro on the largest island in Blue Mountain lake; small dikes cutting syenite near the western end of Long Lake bridge; small dikes cutting mixed

[1] N. Y. State Mus. Bul 182, p. 29. 1916.

gneisses two-thirds of a mile west of Long Lake bridge; a number of small dikes cutting the anorthosite-gabbro west of Long lake; and several small dikes cutting the large gabbro stock 1½ miles north-northeast of Indian Lake village.

Veins of pure white quartz a few inches wide sometimes occur in the syenite, granite or mixed gneisses and apparently always parallel to the foliation. On top of Owl's Head mountain and also two-thirds of a mile west of Long Lake bridge, sharply defined pegmatite dikes a few inches wide were observed to cut such quartz veins (see plate 10). Within the North Creek quadrangle the writer has found diabase cutting pegmatite of the kind here described. So far as the evidence goes, therefore, this type of pegmatite is intermediate in age between the gabbro and the diabase.

Graphite in pegmatite. A feature of particular interest in connection with the pegmatites is the content of graphite in two small dikes cutting Grenville limestone respectively one-half and three-fifths of a mile northwest and north of the bridge across Cedar river. In addition to some large flakes of graphite, these dikes contain numerous balls or globular masses of graphite from 1 to 5 mm in diameter. They look exactly like tarnished lead shot. They occur either as inclusions in feldspar or along contacts between feldspar and quartz. When broken open these graphite balls are seen to possess a perfectly developed radiated structure.

Diabase Dikes

Only two small diabase dikes were located within the quadrangle. It is quite possible, if not probable, that others exist but were not encountered in the rough and heavily glaciated region, though no boulders were anywhere found which would lead to the suspicion of the presence of other dikes. So far as the positive evidence goes for this and the adjoining Long Lake quadrangle, diabase dikes are notably smaller and rarer in the central than in the eastern and southeastern Adirondacks. The finer grained, to sometimes even glassy, texture of the diabase proves it to be the youngest of the Adirondack intrusives.

The larger dike cuts the anorthosite gabbro on the shore of Long lake a little over a mile northeast of the bridge. The best exposures are on the point already described as showing the most typical anorthosite-gabbro. Here the dike is considerably branched but shows a maximum width of 57 feet including two or three bands or inclusions of the country rock. Sharp contacts against the anorthosite-gabbro are visible across the whole rock ledge, the country rock (in places) at the contacts plainly showing the effects of the heat of intrusion. Toward the interior of the mass the diabase exhibits an excellent diabase texture, white feldspar laths up to one-quarter of an inch long standing out in a finer grained, dark, bluish gray ground mass. A thin section from the interior of the dike shows the following mineral percentages: labradorite 44; augite (pale reddish brown) 18; biotite 8; chlorite 18; magnetite (or ilmenite) 11; and pyrite 1. Due to more rapid chilling, the dike borders are very fine grained to even glassy. About 100 yards northeast at the lake edge, this dike again outcrops. It here also shows branches, the greatest visible width being 27 feet. The dike strikes south 40° west.

The other dike also lies on the shore of Long lake and less than one-half of a mile northeast of the bridge. Its main body is exposed for 35 feet with strike south 40° west and a width up to 6 feet, though one wall only is shown. A very small tongue branches off this portion. It is fairly evident that this dike formerly extended at least 200 feet farther northward but has been eroded away along the shore leaving the vertical wall of the country rock distinct. What appears to be a separate dike here 6 inches to 1 foot wide and 30 to 40 feet long is quite certainly only a branch of the larger one now eroded away toward the north. This branch dike is distinctly brecciated due to faulting. In thin section the rock from the 6 foot wide dike shows practically the same mineral composition as the larger one farther northward already described.

The perfect alignment of the strikes of these two dikes suggests the possibility that they are really portions of a single intrusive which is largely concealed under the lake, but of course they may be entirely separate. Also the fact that these dikes lie in or close to, and parallel to, the zone of fracture (fault) which has determined the position of the Long lake depression, would suggest that the diabase was intruded along this fault zone but, if so, there was renewed faulting in the same zone because one of the dikes is brecciated.

ROCK STRUCTURES

Foliation

Except the diabase and certain pegmatites, all the Precambrian rocks of the quadrangle show more or less foliation. As a rule, the gabbro masses are devoid of foliation except around the borders where they are usually amphibolitic. The members of the syenite-granite series are mostly distinctly gneissoid, though at times they are only very faintly so. A striking feature is the frequent rapid change within a few rods from rocks which are very clearly gneissoid to others in which foliation is scarcely visible. The Grenville strata, as usual in the Adirondacks, always show perfect parallelism of stratification and foliation, these rocks invariably being thoroughly crystalline.

Of the many strike and dip observations made in the field, the better ones, so distributed as to show the principal variations, have been selected and plotted on the accompanying geologic map. In a general way nearly east-west strikes greatly prevail, with southerly dips most common in the north and northerly dips most common in the south. To be more exact, the northwestern half of the quadrangle, or all lying north of a line passing from the northern base of Blue ridge to the eastern base of Fishing Brook mountain, shows very few exceptions to a nearly east-west strike and southerly dip, the amount of the dip generally being from 60 to 80 degrees; while the southern half of the quadrangle, or all south of the line above indicated, exhibits more variations but with an average nearly east-west strike and prevailing northerly dip generally from 25 to 50 degrees.

A noteworthy feature is the occasional local occurrence of strikes making high angles with the general trend of the foliation of the quadrangle. An example of this in syenite is in the mountain mass lying just east of Tirrell pond (see map). Such a sharp change in strike is more in harmony with the idea that the foliation of the syenite and granite was produced as a kind of flow structure during the process of intrusion rather than by a great force of compression because, if due wholly or even largely to compression, the foliated structure must everywhere have developed essentially at right angles to the direction of the compressive force.

Exceptional strikes are of most common occurrence in the Grenville limestones and in the mixed gneisses, these being readily explained by the fact that such rock masses were most subject to being twisted and disturbed at the time of the great igneous intrusions.

A most interesting arrangement of strikes and dips occurs along the southern side of the quadrangle within a strip 2 or 3 miles wide. Thus, within the eastern portion of this strip the strikes are mostly northwest-southeast, with dips to the northeast; toward the middle the strikes are nearly east-west, with northerly dips; and within the western portion of the strip the strikes are northeast-southwest, with dips to the northwest. The dips seem to radiate from a center not far south of the middle of the southern boundary of the map or apparently from the great Panther-Snowy mountain mass of the Indian Lake sheet. A series of flattened elliptical curves drawn from the center just mentioned would approximately parallel the strikes as shown on the southern side of the Blue Mountain quadrangle. It would be interesting to know how the strikes and dips run across the northern few miles of the Indian Lake quadrangle. The significance of this symmetric arrangement of strikes and dips is not precisely known, though the presence of the belt of Grenville some distance out (along Cedar river) with strike practically parallel to the curving strike of the igneous rock may imply something. This belt of Grenville on the east is known to continue from the vicinity of Indian Lake village across the southeastern corner of the Newcomb sheet and for at least several miles southward on the Thirteenth Lake sheet. On the west this same Grenville belt quite certainly continues southward for some miles through the Cedar river valley in the northwestern part of the Indian Lake sheet. Thus the great Panther-Snowy mountain mass of igneous rock is known to be completely bounded on the west, north and northeast by this belt of Grenville strata whose strikes and dips show it to lap upon the flanks of the great igneous mass. The writer is inclined to believe that we have here a large scale radial development of strikes and dips produced in the syenite as a kind of flow structure when the magma was being intruded, and if we consider the Grenville to have been more or less raised or domed over the surface of the invading magma, this readily accounts for the existing circumferential belt of Grenville whose dips show it to lap upon the flanks of the syenite, the general cover of Grenville having been removed from the dome by erosion. In other words, we here appear to be dealing with something of the nature of a laccolithic intrusion.

Folds

The general change from southerly dips in the northern portion of the quadrangle to northerly dips in the southern portion may possibly indicate a great synclinal fold in the foliation with axis passing from the northern base of Blue Ridge through Dun Brook mountain. This may, however, be interpreted simply as due to differences in flowage of the great masses of intruding magma.

Very local twisted or contorted structures within the Grenville limestones and associated pyroxene and hornblende gneisses, and also within portions of the mixed gneisses, are frequently met, but practically nothing like distinct folds could be determined within the Grenville formation, or rather such fragments of the formation as now remain. There is no evidence that the Grenville strata were ever thrown into folds as a result of any great compressive or mountain-making force brought to bear upon the region, the present strikes and dips probably, for most part at least, having been due to tilting and upturning of the strata as a result of the great igneous intrusions.

Faults

General considerations. In marked contrast with the eastern and southeastern Adirondack regions, recognizable faults are few in number and their topographic influence relatively minor. Of the five faults represented on the accompanying geologic map, four strike northeast-southwest or parallel to the predominating fracture lines of the Adirondacks. All five of the faults might more properly be called zones of fracture or crushed zones which are nearly straight for considerable distances. In no case was the whole displacement found to follow a sharply defined fault-surface, but rather there are broken-rock zones from 25 or 30 to 100 or more feet wide in which fault breccias, slickensided surfaces, and local fault surfaces are frequently seen.

Referring to apparently similar phenomena on the Long Lake sheet, Professor Cushing says: "Lines of excessive faulting are not infrequent in the eruptives. In such places from two to four joint sets are well marked, and the joints are closely spaced, their distance apart being measured in inches rather than feet, chopping up the rock into a multitude of small blocks, and forming prominent lines of weakness in it. Often multiple faulting has taken place along these strips on one of the joint sets, grinding and slickensiding the rock surfaces."[1] The longest shattered-rock zone of this kind mentioned by Cushing on the Long Lake sheet is in the Raquette falls gorge which is nearly a mile long. Within the Blue Mountain quadrangle, the writer has in several instances observed crushed-rock zones frequently occurring along nearly straight lines for from 2 to 8 miles, and with distinct topographic influence. Such alignments of crushed-rock zones are regarded by the writer as due primarily to faulting, probably multiple faulting. Further-

[1] N. Y. State Mus. Bul. 115, p. 488. 1907.

more, within the quadrangle, finely developed crushed zones have been observed in the Grenville as well as in the eruptives.

Long Lake fault. This fault, with a length of 8½ miles and strike north 30° east, is the longest one within the quadrangle. It has a decided topographic influence, the long, straight, narrow valley now occupied by Long lake having been determined by the crushed-rock zone of weakness. The topography suggests its continuation for at least a few miles into the Raquette Lake quadrangle, and it almost certainly continues the length of Long lake and thence probably along the channel of Calkins brook across a part of the Long Lake sheet. The evidence for the continuation of the fault beyond the limits of the Blue Mountain quadrangle is, however, largely topographic, since but few field observations were made by the writer there.

Passing diagonally across the ledge at Buttermilk falls (plate 7) there is a very distinct crushed-rock zone of considerably decomposed rock 2 or 3 feet wide and traceable for 50 yards with strike north 30° east. Just on the east side of the falls there are two smaller broken-rock zones parallel to the first. Other places where broken-rock zones, with strike north 30° east, may be seen are on the west shore of the lake three-fourths of a mile north of Grove (Deerland); on the shore of the lake just south of the Adirondack Hotel in Long Lake village; on the lake shore nearly one-half of a mile northeast of the eastern end of the bridge across the lake (at the brecciated diabase dike); and on the eastern shore of the lake directly east of Triplet hill where a long ledge shows a broken-rock zone 20 feet wide.

There is no satisfactory evidence for a determination of the upthrow side or amount of displacement of this fault. At present one side of the fault is not notably raised above the other, thus suggesting that any displacement along the fracture zone antedated the development of many of the fault scarps and blocks of the eastern and southeastern Adirondacks. The movements may have taken place even as early as Precambrian time as suggested by Cushing for similar phenomena on the Long Lake sheet.

Cedar river-Squaw brook fault. This fault, with north 30° east strike, extends for over 6 miles across the southeastern corner of the quadrangle, being coincident with the course of Cedar river north of Indian Lake village and continuing southward along Squaw brook of the Indian Lake sheet for fully 6 or 8 miles. Due north of the village, Cedar river follows a remarkably straight course, mostly in a narrow rock channel, for at least 2 miles, this being due to the fact that the position of the channel there has been determined along the crushed zone of weakness. Along this gorgelike channel wide crushed-rock zones are beautifully developed at many places, one fine example being in the Grenville white gneiss about 1⅔ miles due north of the village. The continuation of the fault across the valley west of Indian Lake village is not actually demonstrable, the outcrops being scarce with heavy drift covering the apparently critical localities. Its extension along the Squaw brook valley of the Indian Lake sheet is, however, certain as shown by the topography and the presence of crushed-rock zones.

Somewhat higher altitudes immediately on the eastern side of this line of fracture within the adjoining Indian Lake and Newcomb quadrangles, suggest that the upthrow side is on the east, though the difference is not enough to make this at all certain. The prominent scarp northwest of Indian Lake village is due to difference in rock character rather than faulting, the Grenville limestone on the east side having been much more readily worn down than the relatively hard gneisses on the west side. If any movements took place along this line of fracture since the existence of the Cretaceous peneplain, they must have been relatively slight. The principal movements are certainly much older and they may possibly date back to Precambrian time.

Indian Lake fault. This long prominent fault, with northeast-southwest strike, has but 2 miles of its course across the southeastern corner of the quadrangle. The granite porphyry near the western end of the Indian Lake dam is full of shear zones and much of the rock is broken up into a multitude of small blocks. Just at the end of the dam there is a distinct slickensided fault scarp 100 feet long and 15 feet high with some fault breccias. This scarp dips 80° west. There is also a distinct crushed zone parallel to this in the eastern of the two quarries just across the river. No other exposures of the zone of fracture were seen within the quadrangle, but it continues with very prominent topographic influence into both the adjoining Newcomb and Indian Lake sheets. The remarkably straight channels of the Indian and Hudson rivers on the Newcomb sheet are almost certainly developed along a fault which is but a continuation of the Indian Lake fault.

On the Indian Lake sheet this fault has a most decided topographic influence, the long, straight, Indian Lake depression having been determined along the zone of weakness with the Snowy mountain mass rising very steeply for more than 2000 feet above the lake. The fault divides with one portion following the Miami river valley and the other the long, narrow southern extension of Indian lake, the Mossy Vly brook valley, and thence along the western side of Piseco lake on the Piseco Lake sheet, the southern portion of this line of fracture having already been described by the writer in his report on the Lake Pleasant quadrangle.

From these statements it will be seen that there is a prominent line of fracture, with decided topographic influence, extending from Piseco lake northeastward to near Lake Harris on the Newcomb sheet, or a distance of some 45 or 50 miles. This Indian Lake fault, therefore, ranks as the longest continuous line of fracture yet located in the Adirondack region. This fault is also the only one touching the Blue Mountain quadrangle which gives quite certain evidence regarding the relation of upthrow and downthrow sides. The upthrow side is clearly on the west with the amount of displacement ranging up to 1000 feet or more, as, for example, on the Indian Lake sheet. On the Blue Mountain and Newcomb sheets the amount of displacement is much less. In the vicinity of Indian Lake village the fault has no conspicuous topographic influence because the soft Grenville limestone has there readily been worn down on both sides of the line of fracture.

The generally much greater altitudes on the west side, even in homogeneous igneous rock, shows that important movements have taken place along this fault since the development of the Cretaceous peneplain. Hence this fault is in most respects very similar to many of the prominent ones of the eastern and southeastern Adirondacks.

Other faults. The fault along Cedar river east of Pine lake strikes north 40° east and shows excellent crushed zones but it can not be traced far. On Cedar river, one-half of a mile above the mouth of Rock river, a beautifully developed crushed-rock zone 50 to 75 feet wide is exhibited in the bed and in one wall of the river channel and it can be traced several hundred yards. Absence of any notable topographic influence, except the local determination of the river channel here, suggests that the principal movements along this fault must have antedated the Cretaceous peneplain.

Another line of fracture extends for 2 or 3 miles from the Cedar river valley into the eastern end of the deep valley just south of Blue ridge in the southeastern part of the quadrangle. Crushed-rock zones are well developed with strike north 70° east along the river and also at several places along the brook in the valley just mentioned. Nothing is known regarding the upthrow side or amount of displacement. It is possible that this fault may extend farther westward through the valley south of Blue ridge.

It is quite possible that other minor zones of fracture occur within the quadrangle but, if so, they are either effectually concealed under heavy drift or escaped detection in the rough, densely wooded country.

Irregular Surface of the Syenite-Granite Intrusive Body

Since the Blue Mountain quadrangle lies in the rugged mountainous district west of that portion of the Adirondacks which is profoundly affected by comparatively recent faulting and contains considerable areas of Grenville strata through which the great intrusions of syenite-granite have taken place, an excellent opportunity is afforded to study the character of the surfaces of the great bathylithic masses.

A glance at the southern half of the accompanying geologic map will reveal the fact that mountains of syenite or granite frequently rise conspicuously above the masses of Grenville. Differences in altitude, often quite abrupt, between syenite or granite and Grenville commonly range from a few hundred to 2000 or more feet. Such marked differences in altitude must be accounted for in either of two ways: (1) by faulting, whereby the Grenville has been relatively dropped down with respect to the igneous masses; or (2) by irregularities on the surfaces of the igneous masses produced during the process of intrusion. That faulting can not be invoked as an explanation in many cases at least is perfectly clear by the fact that direct evidence for faulting is absent from many places where outcrops are good at critical localities, and also by the fact that certain mountain masses of syenite or granite are so nearly surrounded by Grenville strata as to preclude the explanation by faulting. A few concrete examples will serve to prove that the bathylithic surfaces have very notable original irregularities.

Just east and northeast of Rock lake a mountain of granite rises fully 600 feet above the Grenville which latter reaches continuously almost two-thirds of the way around the mountain. Even if we grant the possibility of a fault on one side (though there is not the slightest field evidence for it), we are still forced to conclude that the magma rose at least a few hundred feet above the Grenville now nearly surrounding the mountain and across its strike. A very similar example is furnished by the mountain south of Rock lake.

The great igneous mass making up Blue mountain rises 2000 feet above the Grenville immediately to its southwest and south. Also the presence of glacial boulders of Grenville limestone and the nature of the topography very strongly suggest that Grenville now is, or formerly was, present in the Tirrell pond valley. No rock exposures occur around the shores of the pond or along its outlet for some distance southward. At any rate, it is clear that much of the great difference in altitude between Blue mountain and the adjacent Grenville must have been caused by the intrusion of the magma through the Grenville.

Perhaps the finest example of marked irregularity of a bathylithic surface is that of the great Panther-Snowy mountain mass occupying the southern portion of the Blue Mountain quadrangle and the northern portion of the Indian Lake quadrangle and already described in detail under " foliation." This large body of syenite, as above explained, apparently rose under and raised up (domelike) the Grenville strata which have all been removed by erosion except the peripheral belt now remaining on the west, north, and northeast. As a result of this intrusion and subsequent removal of Grenville, the higher portions of the syenite mass now rise fully 2000 feet above the Grenville.

A striking illustration of another type of irregularity of bathylithic surface is furnished by the basin (partly on the Blue Mountain and partly on the Newcomb sheet) which contains the Chain lakes (except the first and second lakes), Deer pond, Mud pond, and Jackson pond. The bottom of this basin, which has a length of 4 miles and maximum width of 1½ miles, is wholly occupied by Grenville limestone and its associated hornblende gneiss at an altitude of 1600 to 1700 feet. This valley is completely surrounded by a body of syenite and granite which everywhere rises (usually abruptly) from about 150 to over 800 feet above the valley floor except in the vicinity of the outlet in the southwest. The distinct basinlike character of the depression is clearly brought out on the topographic maps. It is certain that, very largely at least, the differences in altitude between the Grenville and surrounding igneous rocks is due to original irregularities of the surface of the igneous mass produced at the time of the intrusion.

One further point needs emphasis, namely, that the figures above given as representing the amounts of irregularity of bathylithic surfaces are in all cases minima, because no account has been taken of the fact of the depth of the existing Grenville below the surface. In many places this depth must amount to some hundreds of feet at least.

GLACIAL AND POSTGLACIAL GEOLOGY

Ice Movement, Depth, and Erosion

Eighteen sets of glacial striae have been observed and plotted upon the accompanying geologic map. Their bearings and distribution are as follows:

1 S 25° W. On the road three-fourths of a mile south of Indian Lake village.

2, 3 S 20° W. On roads respectively 2⅓ miles south-southeast, and 1¼ miles a little east of south, of Indian Lake village.

4, 5 S 30° W. On the road respectively 3 miles, and 2½ miles, southeast of Forest House.

6 S 45° W. On the road 2 miles east-southeast of Forest House.

7, 8 S 40° W. Near the road at Forest House, and on the road 1½ miles east-southeast of Forest House.

9 S 30° W. On the road 1¼ miles north of Blue Mountain Lake village. Several sets of striae in this vicinity.

10 S 40° W. On the road 1⅓ miles southwest of Deerland (Grove).

11 S 45° W. On the road 1⅓ miles southeast of Deerland (Grove).

12 S 20° W. On the road one-fourth of a mile northeast of Deerland (Grove).

13 S 50° W. Near the Mount Sabattis trail one-half of a mile south of Long Lake village and at an altitude of about 2000 feet.

14 S 40° W. On the branch road to the Sagamore Hotel just southwest of Long Lake village.

15 S 40° W. Close to the lake shore 1½ miles north-northeast of Long Lake village.

16 S 50° W. On the road 1½ miles west-northwest of Long Lake village.

17 S 50° W. On the road nearly 4 miles east of Long Lake village.

18 S 40° W. Near the mountain top (at altitude 2550 feet) 2½ miles west of where the road to Newcomb crosses the county line.

According to this list, it is seen that the extreme range in directions of the glacial striae is from south 20° west to south 50° west.

with an average direction of about south 30° to 40° west. All but three of these sets of striae were found along roads, a reason for this being that unweathered, glaciated rock surfaces are there frequently stripped of drift artificially, thus exposing the glacial marks. This is quite the rule in the Adirondack region.

No striae were noted in the southwestern portion of the quadrangle, nor on the great mountain mass between Mount Sabattis and Dun Brook mountain. The eighteen observed striae are, however, so distributed over the quadrangle as to furnish positive evidence that the general ice current was southwestward across this portion of the Adirondacks. This accords essentially with the observations made by Cushing on the Long Lake quadrangle immediately to the north, and by the writer on the Lake Pleasant quadrangle to the south.

Certain striae, as, for example, those of the Long Lake basin, closely follow the trend of, and may have been influenced by, the topography, though it is quite possible that such parallelism may be largely a coincidence. Other striae are so situated as to demonstrate independence of direction of ice flow and trend of the topography. Examples of such are in the depression between the mountains southeast of Forest House; on the south side (several hundred feet below the top) of the northwestern spur of Blue mountain; and well up on the mountain (altitude 2550 feet) in the northeastern part of the quadrangle.

That the great ice sheet was thick enough to overtop the highest mountains of the region is practically demonstrated by the persistence of the southwesterly ice current in spite of the topography. Actual striae 2550 feet above sea level near the top of the mountain in the northeast and distinctly glaciated ledges (without striae) above 3000 feet on the side of Dun Brook mountain conclusively prove ice currents at such altitudes. Well-worn pebbles and small boulders of Potsdam sandstone derived from the St Lawrence valley were occasionally observed on mountain tops at altitudes of from 2500 to 3500 feet. Again, the great surfaces of comparatively hard and fresh rock on such mountains as Owl's Head, Mount Sabattis, Blue mountain, etc., were quite certainly stripped of rotten rock by the ice and have since been only slightly modified by Postglacial weathering.

The great ice sheet, in its passage across the region, was a sufficiently active agent of erosion to remove most of the Preglacial soils and rotten rock from their original positions. For this reason, it is quite the rule to find ledges of relatively fresh rock, such ledges frequently being in sharp contact with overlying loose glacial debris. Deeply weathered to even rotten rock is, however, not of very rare occurrence, and the writer believes that such decomposed rock is appreciably more common in this central Adirondack region than, for example, in the southeastern portion. This is quite in harmony with the generally accepted belief that the central Adirondacks were neither so long ice occupied nor subjected to such vigorous ice currents as were the border portions of the mountains.

Rock basins due to ice erosion are not known within the map limits though certain valleys, like those of Long Lake and Blue Mountain lake, may have been deepened by ice erosion, the available data not being sufficient to make any certain decision.

Glacial Deposits

Erratics. Erratics (glacial boulders) are numerous and widely scattered over the quadrangle. As usual they are mostly of very local origin so that, in the absence of sufficient outcrops from certain areas, some idea of the underlying rock formations may be gained by noting the relative numbers of glacial boulders.

Among the erratics which have been derived from ledges wholly without the area under consideration are those of anorthosite and of Potsdam sandstone. Anorthosite boulders, with maximum diameters of 8 or 10 feet, are not very common, they having been most frequently noted in the northern portion of the quadrangle. In view of the fact that the extensive anorthosite body is exposed in great force on the quadrangles immediately to the north and northeast, with the nearest exposures only 5 to 7 miles distant, it is somewhat surprising that fragments of this formation are not more common over the Blue Mountain quadrangle. The combination of shorter time of ice occupancy and less vigorous ice currents over the central Adirondacks than around its borders probably accounts for the relative scarcity of anorthosite boulders within the Blue Mountain quadrangle.

Pebbles and small boulders of Potsdam sandstone occasionally noted, even on mountain tops at altitudes of from 2500 to 3000 feet, are of special interest because of the long distance they have been transported, the nearest known outcrops being some 50 to 55 miles away in the St Lawrence and northern Champlain valleys. These erratics are always well worn and hard.

Kames and eskers. Kames, generally in groups, were sometimes observed, but the dense vegetation and lack of proper exposures have often prevented the definite recognition of this type of glacial deposit. A group of low kamelike hills spreads across the valley at the eastern end of Blue Mountain lake and forms the dam which holds up the water of the lake. Most of the area between South pond and Mud pond appears to be of kame or kame-morainic origin. Along the road between Long Lake village and Deerland (Grove) there are many good exposures of kame deposits, this being a fine example of an extensively developed kame-moraine along the eastern side of the valley. Along the northern border of the quadrangle for several miles eastward from Long lake kames or kame-moraines are well developed.

A very typical esker about a mile long, 20 to 30 feet high, with winding course and just wide enough for the main road at its top, lies in Thirty-four marsh from 1 to 2 miles east-southeast of Blue Mountain Lake village. It consists of stratified sands and gravels. This esker looks much like an artificial embankment built through a portion of the swamp, very little grading having been necessary to convert it into a highway. About one-half of a mile southeast of the outlet of South pond, the main road follows another, though smaller and less typical, esker. These long, low ridges of stratified glacial materials were no doubt deposited in streams either at the bottom of the ice or in channels within the ice during the waning of the great ice sheet.

Moraines. Ground morainic material (till) is very widespread, particularly over the lower lands. As usual in the Adirondacks, it is very sandy or gravelly with numerous small to large embedded boulders. Typical boulder clay was nowhere noted. Ground morainic material is abundantly present in the vicinity of Indian Lake village, and in the Cedar river valley from the village westward for several miles. Good exposures may also be seen along the new state road for 8 or 9 miles eastward from Long Lake village, and along the road between 1 and 3 miles north of Blue Mountain Lake village. Perhaps the most extensive morainic deposits occupy much of the area from 1 to 5 miles east of Long Lake village and thence northward to the border of the quadrangle. Nothing like a distinct boulder moraine across the quadrangle or any portion of it was recognized.

Lakes and Their Deposits

Extinct lakes. In a general way it is important to note that extinct glacial lakes of considerable size are less common in this central Adirondack region than they are farther out toward the borders. In part this may be due to the fact that the central Adirondack region, which was first freed from the ice sheet, was too small to permit of much gathering of water against either the ice margin or morainic deposits across valleys. Also the relatively less thick morainic deposits were probably not so effective in forming dams across the valleys as they were when the ice had retreated much farther toward the borders of the region.

A series of small glacial lakes of short duration, and of successively lower levels, once occupied the bottom of the Cedar river valley between 3 and 8 miles west of Indian Lake village. Thus, between 7 and 8 miles west of the village the surface of a small lake stood at an altitude corresponding approximately to the 1880 foot contour. The delta sands, chiefly brought in by the large stream from the west, are well shown at several places along the road. Between 5½ and 7 miles west of the village another lake stood at a level now corresponding to 1820 to 1840 feet with flat-topped delta sands well exhibited along the road. At a still lower level, from 3 to 4½ miles west of Indian Lake village, there existed another glacial lake with delta sands now lying at about 1760 feet. These lakes were drained in succession either by retreat of the ice front or cutting down morainic deposits either of which must have formed dams across the valley.

Most of the swamp areas, particularly those of considerable size which are nearly flat, were formerly occupied by shallow lakes held up by drift dams, the lakes having been destroyed by filling with vegetable matter and sediment and cutting down of outlets. Excellent examples are the swamp areas along Sixmile brook and Fishing brook, just east of the south end of Tirrell pond; O'Neil flow; Thirty-four marsh; and just northeast of Indian Lake village.

Existing lakes. Existing lakes of the quadrangle illustrate all stages from those which are only remnants of formerly much larger bodies of water to those which are now nearly as large as they ever were. Some examples of the former are Unknown pond, the first of the Chain lakes, and the Grassy ponds; while examples of the latter are Long lake and Blue Mountain lake.

As already stated, there is no positive evidence that any lake occupies a true rock basin scoured out by the action of the great ice sheet. The maximum depth of Blue Mountain lake is said to be about 90 feet. If so, it appears that this basin has, very locally at least, been ice eroded to a depth below any possible Preglacial outlet. The comparatively soft Grenville rocks of this basin would have been very susceptible to ice erosion. The basin of the third of the Chain lakes, mostly in soft Grenville limestone, is said to have a depth of 40 or 50 feet and it may thus also have been locally somewhat deepened by ice erosion.

The present water levels of the existing lakes all appear to be held up by glacial drift dams, usually across the outlets. Notable exceptions to dams across the outlets are Blue Mountain lake with drift dam across the eastern end, and Long lake with drift dam blocking a Preglacial channel on the east side of the present lake either 1½ miles south of the outlet of the lake or about 2 miles northeast of Long Lake village. The first named locality is much the more likely as will be pointed out below. South pond, judging by the rock ledges across the outlet, appears to be held up by the heavy morainic deposits just southwest of the pond.

None of the existing lakes appear ever to have been more than 10 or 15 feet higher than their present levels. Along the shores of Long Lake there are occasional sand flats or delta deposits representing a former lake level 8 or 10 feet higher than the present. Perhaps the best of these sand flats is one-quarter of a mile long on the south side of the cove 1½ miles southwest of Long Lake village. There is no evidence that Blue Mountain lake was ever more than a few feet higher than now.

Drainage Changes Due to Glaciation

As would be expected, because the watershed between the Hudson and St Lawrence basins passes across the quadrangle, there are certain rather delicately balanced drainage conditions.

Blue Mountain-Eagle lake basins. Before the ice age the basins now occupied by Blue Mountain and Eagle lakes quite certainly drained eastward into the Hudson river by way of Rock river instead of westward as at present through Raquette lake and thence northward into the St Lawrence (see figure 1). Evidence in support of this view is twofold, namely, the rock barrier at the eastern end of Utowana lake and the drift dam at the eastern end of Blue Mountain lake. Rock ledges are practically continuous across the narrow channel at the eastern end of Utowana lake, while the channel connecting Eagle and Blue Mountain lakes is entirely in drift deposits. Thus the movement of water must here have been eastward in Preglacial time. Thirty-four marsh on Rock river comes to within one-half of a mile of Blue Mountain lake and it is about 20 feet lower than the lake surface, the intervening space being occupied by loose sands and gravels. It would be a simple matter, by shoveling out a trench nowhere over 20 feet deep, to cause Blue Mountain and Eagle lakes to drain eastward. Years ago such an attempt was actually made but stopped by law. The

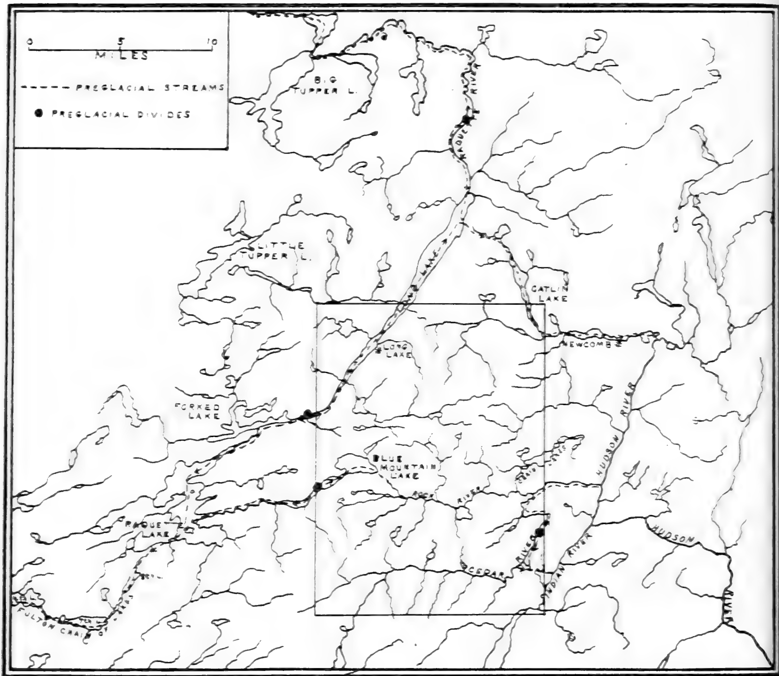

Fig. 1. Sketch map of a portion of the central Adirondack region showing the relations of the principal Preglacial stream courses to those of the present. Preglacial streams show only where essentially different from those of today. The rectangular area shows the position of the Blue Mountain quadrangle.

Preglacial drainage eastward through the lake basins was more in harmony with the course of the upper waters of Rock river which has its sources in and around Wilson pond about 3 miles southwest of Blue Mountain lake village.

Utowana-Raquette lake basins. That the Preglacial drainage through the Utowana lake basin passed westward into the basin now occupied by Raquette lake is certain, there being only a drift dam at the western end of Utowana lake. From the Raquette lake basin the Preglacial drainage was either northeastward by way of Raquette river as now, or southwestward by way of the valley now occupied by the Fulton Chain lakes. Although this problem has not been carefully studied in the field, the presumption favors the southwesterly course. Thus, the interval of a mile between Brown's Tract inlet and Eighth lake is wholly occupied by drift deposits, while the valley occupied by the upper lakes of the Fulton Chain has its bottom covered with drift which, because of irregular thickness, at times acts as dams to pond the waters of the upper lakes. A maximum thickness of less than 100 feet of drift just north of Eighth lake is all that is necessary to account for the blockade of the southwesterly Preglacial channel with resultant ponding of the waters to form Raquette lake. Further evidence for this view lies in the fact that between Forked lake and Long lake, Raquette river descends more than 100 feet in about 3 miles mostly by a series of cascades over rock ledges which extend across the narrow channel. Apparently a Preglacial col was situated not far below the outlet of Forked lake, the drift accumulation southwest of Raquette lake being sufficient to pond the waters of the Raquette and Forked lake basins to overflow this col (see figure 1).

Long lake basin. Granting the source of a Preglacial stream on a col (near the outlet of Forked lake) a few miles above the upper end of Long lake, did this stream follow the present course of Raquette river into the St Lawrence? That the depression now occupied by Long lake was a Preglacial stream channel is certain, and also there is strong evidence that the drainage from this channel passed eastward into the Hudson river rather than northward by way of Raquette river. Regarding Raquette falls, on the river a few miles below the outlet of Long lake, Cushing says: "There is a fall of 70 to 80 feet in a gorge three-quarters of a mile long, in which the water is rapid throughout, but with two principal falls. There is an impassable rock barrier here, with no opportunity for a buried channel, so that there could have been no Preglacial drainage line; rather, there was here a col between small streams flowing both ways from the obstruction."[1] Thus, in Preglacial time, two streams drained into the depression now occupied by Long lake, one north-flowing from the col near the outlet of Forked lake (Raquette lake quadrangle), and the other south-flowing from the col at

[1] N. Y. State Mus. Bul. 95, p. 444. 1905.

Raquette falls (Long lake quadrangle). These streams met to flow eastward into the Hudson river, as Cushing has suggested, either through the Sixmile-Fishing brook valley in the northeastern part of the Blue Mountain quadrangle, or through the Catlin lake-Round pond valley in the southeastern part of the Long lake quadrangle. In the writer's opinion, the best evidence favors the Catlin lake-Round pond channel (see figure 1). The surface of Catlin lake is over 30 feet below that of Long lake and the two lakes are now separated by a divide of loose glacial debris only about 20 feet high. Years ago an attempt was made to cut a trench through this divide in order to drain Long lake through Catlin lake and thence into the Hudson river.

Sixmile-Fishing brook valley. The Sixmile-Fishing brook valley is heavily drift-filled, especially on the west where, in the vicinity of Polliwog pond, the drift at the bottom of the valley is nearly 100 feet above the level of Long lake. From its sources on Fishing Brook mountain, Fishing brook pursues a northwesterly course for several miles after which it swings sharply eastward to even southeastward to near its mouth, thus showing a striking tendency to double back on its course. Sixmile brook also shows a sharp eastward swing. The more normal Preglacial courses of these streams would appear to have been westward into the Long lake valley. Evidently the eastward deflection of these streams was caused by glacial drift accumulations, especially in the vicinity of Polliwog pond, and the narrow gorge of Fishing brook cut in solid rock near the map edge is of Postglacial origin.

Cedar river. Near Indian Lake village a very low divide of loose glacial debris separates Cedar river and Indian river which are here only about 2 miles apart, the latter river being about 70 feet lower than the former. North of the village one-half of a mile, the crest of the divide is less than 20 feet above the level of Cedar river which is only two-thirds of a mile distant. West of Indian Lake village Cedar river pursues a meandering course with low gradient, while from 2 to 3 miles north of the village the river is very swift and usually confined to a deep, narrow, gorgelike channel in solid rock with no possibility of a buried channel on either side. Thus the evidence is clear that there was a Preglacial col between 2 and 3 miles north of Indian Lake village, and that the Preglacial Cedar river, which emptied into Indian river east or southeast of the village, was deflected over the col by the accumulation of drift north of the village.

ORIGIN OF RELIEF FEATURES

Influence of Rock Character

In common with the Precambrian rock area of northern New York in general, differences of rock character have been very influential in the production of the existing relief features of the quadrangle. Most important is the relatively weak Grenville formation which almost invariably occupies valleys or lowlands. As a result of the long Preglacial time of weathering and erosion, the Grenville strata were much more readily worn down than the very hard and resistant syenites and granites. Fine illustrations of this principle are the two prominent belts of Grenville represented on the southern half of the accompanying geologic map. One of these belts extends for 11 miles from the vicinity of Indian Lake village westward through the Cedar river valley, and the other from the vicinity of Pine lake westward nearly across the quadrangle to Blue Mountain lake, these two belts being connected through the valley south of Rock lake. There are smaller areas of Grenville from Unknown pond northeastward, and in the vicinity of the third of the Chain lakes. These Grenville areas include most of the lowest land of the southern half of the quadrangle, the prevailing rocks of the lowlands being Grenville limestone with more or less closely associated hornblende and pyroxene gneisses.

About 1½ miles northwest of Indian Lake village the Grenville is much more resistant than usual, being a white feldspar-quartz gneiss which stands out 300 to 500 feet above the valley bottom. It is a very unusual example of this kind. The deep valley immediately south of Blue ridge has probably been developed by removal of a belt of Grenville. If so, the removal of the Grenville has been almost, if not quite, complete since no outcrop of such rock was anywhere found. The small fault at the eastern end of the valley may have been a factor in determining the location of the valley, but its influence was probably not sufficient to account for so large a valley. A similar explanation probably applies to the long, narrow depression between Blue mountain and the sharp ridge immediately to the south of it, and also to the deep depression now in part occupied by Tirrell pond.

The mixed gneisses, because of their considerable content of relatively weak Grenville, also tend to occupy the lower lands. Within such areas, the bolder relief features are due to the local presence of the more homogeneous and resistant igneous masses, the weaker

Grenville strata generally having been removed or at least much worn down parallel to the foliation. Two large areas — one across the northern side of the quadrangle, and the other south of Blue Mountain and Eagle lakes — afford fine illustrations of such phenomena. In those mixed gneiss masses where the Grenville is unusually resistant and intimately involved with the granite or syenite, the rocks may stand out in rather bold relief as, for instance, south and southwest of Unknown pond, and west of the south end of Long lake.

It is important to note that the main axis of elevation of the Adirondack region which extends across the Blue Mountain quadrangle is cut through by two of the few lowest passes with maximum altitudes of about 1800 feet. One of these is the Grenville valley across the quadrangle from Pine lake westward to Blue Mountain lake, and the other is the broad lowland belt of mixed gneisses across the northern side of the quadrangle.

The highest mountain masses always consist of facies of the great syenite-granite intrusive body with rarely more than slight amounts of admixed Grenville. Such rocks are exceedingly resistant to weathering and erosion, and it would require a very long time (a few million years perhaps) to cut down these mountains to the general level of the valleys now occupied by the Grenville strata.

The gabbro appears to be about as resistant as the syenite or granite, but its small masses do not permit any notable topographic influence. Where completely surrounded by weak Grenville, the gabbro usually stands out distinctly as small knobs like those either side of Sprague pond. The rather prominent gabbro knob between 3 and 4 miles east of Long Lake village shows outcrops of inclosing rock on one side only, and it is possible that more or less Grenville or mixed gneiss has been removed from around it.

Influence of Rock Structures

Where relatively weak Grenville strata dip downward against large masses of homogeneous syenite or granite, high and very steep slopes, simulating fault scarps, are usually developed as a result of weathering and erosion. Cases in point are the steep escarpment on the western face of the mountain from 1 to 2 miles south of Rock lake, and the steep eastern front of Waterbarrel mountain, each rising fully 700 feet. There is some reason to believe, as already suggested, that a mass of Grenville has been removed from the depression now in part occupied by Tirrell pond. If so, the very steep mountainside just east of the pond (see plate 11) may be accounted for in a similar manner.

Where weak Grenville beds overlie the granite or syenite, and both show moderate dips in the same direction, the effect has been to produce longer and more gentle slopes due to removal of the Grenville. In a general way, the whole southern side of the Cedar river valley from Indian Lake village westward illustrates this principle.

If granite or syenite and overlying Grenville both show steep dips in the same direction, removal of the Grenville may leave a steep slope, as seems to be the case on the mountainside just northwest of Blue Mountain lake.

The Blue Mountain region, unlike the eastern and southeastern Adirondacks, shows no prevalent tendency of mountain ridges to trend northeast-southwest because of faulting. Faulting has, however, been a prime factor in the production of a few important topographic features of the quadrangle, the known faults having been described above. We need only to repeat here that the straight, narrow depression the full length of Long lake; the straight, deep channel of Cedar river north of Indian Lake village; and the great depression which contains Indian lake all have been developed along fault zones of weakness. Very little of the topographic effect of the last named fault, however, shows within the Blue Mountain quadrangle.

Influence of Exfoliation

Exfoliation has produced some interesting, though comparatively minor, topographic effects. The steep eastern face of Waterbarrel mountain is almost impossible of ascent because its upper 400 feet is completely covered with smooth, mostly barren exfoliation slabs from 50 to 100 feet across and several feet thick. As a result of the sliding of such great rock slabs down the scarp, and their breaking up into large angular blocks, an extensive talus deposit has been built up toward the base of the mountain. Because of gradual removal of weak Grenville strata which dip under the granite of this mountain, the face of the mountain has, for a long time, been retreating westward by splitting off of exfoliation slabs.

Other fine exhibitions of exfoliation on large scales are on the steep mountainsides northeast of Tirrell pond, east of Salmon pond, and west of Salmon pond. In many other places more or less exfoliation was observed, but the ones above mentioned are the most interesting.

Influence of Glaciation

The glaciation of the quadrangle having already been described, it is now necessary to refer briefly to only a few effects of the ice sheet which have modified the relief.

Ice erosion appears to have modified the relief to a very minor extent only. The soil and rotten rock were largely scraped off down to the fresh rock particularly on the higher lands. Mountain masses may have been somewhat rounded off. As already pointed out, the basins of Long lake, Blue Mountain lake, and the third of the Chain lakes may have been locally slightly deepened by ice erosion.

The principal topographic effect of glaciation has been the almost universal tendency to accumulate the scraped off soil and rotten rock in the valleys. Accordingly the relief is lower now than at the time immediately preceding the ice age. Most of the valleys contain large accumulations of glacial debris, stratified and unstratified, with thickness up to several hundred feet. Most of the streams have only here and there cut through these deposits to the underlying rock.

The Cretaceous Peneplain

It is well known that toward the close of the Cretaceous period, a more or less well-developed peneplain existed over the northern Appalachian district, central and southern New York, the western side of the Adirondacks, and southern New England. As a result of the uplift and dissection of this great peneplain, the chief relief features of the northern Atlantic coast have been produced. Any very satisfactory evidence for a well-developed Cretaceous peneplain over the central and eastern Adirondacks has so far not been obtained, and the topography of the Blue Mountain quadrangle does not throw much light upon the problem. The most probable explanation is that the great masses of very resistant igneous rocks in the Adirondack region favored the existence of rather numerous and prominent monadnocks which rose above only a crudely developed peneplain surface. Hence it is difficult, if not impossible, to locate remnants of the peneplain surface with any certainty.

Within the Blue Mountain quadrangle, many mountain summits lie at altitudes of from 3000 to 3500 feet, with many others only a little higher or lower. This is well shown in the large mountain

Plate 11

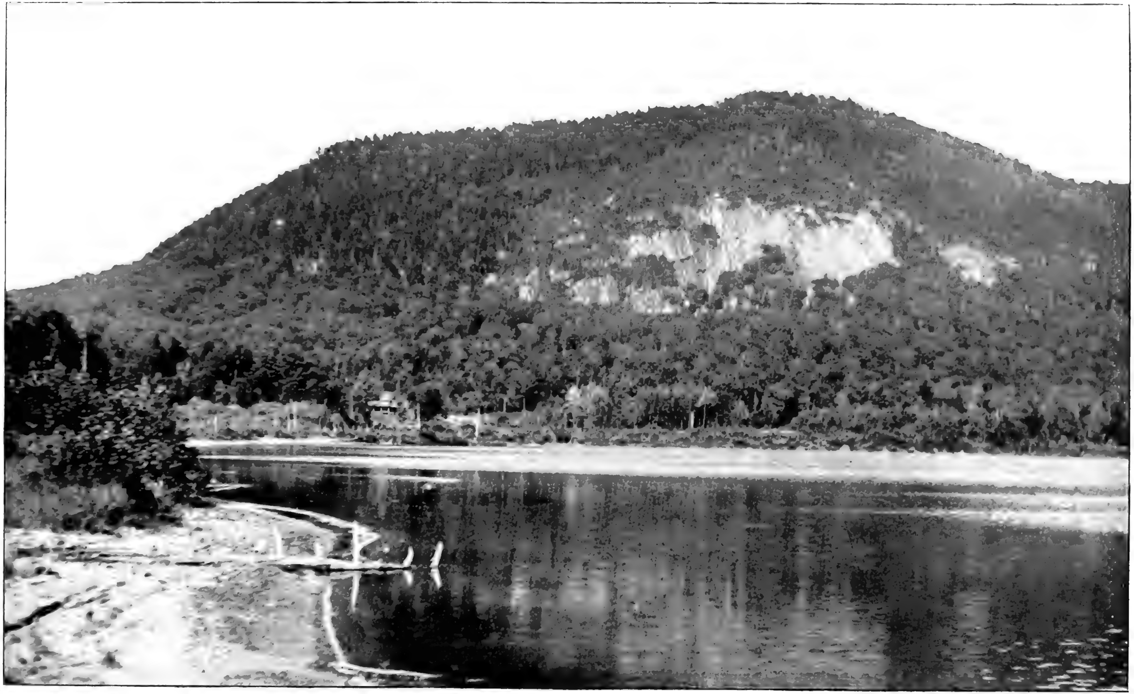

Photo by E. E. Kellogg, Blue Mountain Lake, N. Y.

View westward across Tirrell pond. The barren portion of the mountainside shows the effect of the splitting off of large slabs of rock due to exfoliation.

group lying between Chain lakes and Long lake. Adjoining quadrangles show the common occurrence of similar altitudes. It would seem, therefore, that, if at all recognizable, remnants of the old peneplain surface now lie somewhere between 3000 and 3500 feet, altitudes higher than this representing what were the more prominent monadnocks. The concordance of altitudes is not very satisfactory, and so it must be admitted that the proof is by no means conclusive. At any rate, it is quite certain that the principal valleys and depressions of the quadrangle have been carved out of what was an upraised and at least crudely developed Cretaceous peneplain.

OUTLINE OF GEOLOGIC HISTORY

Those interested in the natural history of the Adirondack region, but not familiar with geologic lore, might do well first to consult the writer's New York State Museum Bulletin 168 entitled "The Geological History of New York State." This work has been prepared primarily for laymen. The only treatise on Adirondack geology in general is Cushing's excellent Museum Bulletin 95.[1] In the very brief summary immediately following, the attempt is to present only the most salient events now known to be recorded within the Blue Mountain quadrangle with some reference to the relation of these events to the geologic history of the Adirondacks in general.

Precambrian History

The oldest known geologic records in the Blue Mountain quadrangle are contained in the rocks of the Grenville series which, in the light of present knowledge, are to be grouped with the oldest known rocks of the earth's crust. Since these rocks are distinctly stratified, very thick (many thousands of feet), and of wide areal extent not only throughout the Adirondacks but also in eastern Canada, we may be sure that the earliest known condition of the area of the quadrangle was the presence of a sea in which the Grenville strata were being deposited layer upon layer. As yet nothing is known either regarding the floor of this very ancient sea or of the land masses from which the sediments were derived. During part of Grenville time the sea water was very clear as shown by the comparative purity of the great masses of limestone. That the Grenville ocean persisted for some millions of years is proved

[1] Since the above was written the author has prepared a small treatise for laymen entitled "The Adirondack Mountains." This contains an account of the geography and geology of the region in simple language. It is now being published by the New York State Museum.

by the great thickness of the sediments. A most conservative estimate by geologists gives the age of the Grenville strata as no less than 25 or 30 million years, though of course we have no means of accurately determining geologic time in terms of years.

After the deposition of the Grenville strata came vast intrusions of igneous rocks, including first the eruption of a great body of anorthosite mostly in Essex county and including the two small masses in the Blue Mountain quadrangle, and then the still greater bodies of syenite and granite, examples of which are so well shown in the quadrangle. Also the whole Adirondack region was raised well above sea level probably at or near the time of the eruption of the syenite-granite series. The tilting and metamorphism of the Grenville strata were most likely largely concomitant with the great igneous intrusions.

The great Precambrian land mass underwent profound erosion for some millions of years at least, extending through later Precambrian time and even into the early Paleozoic, as shown by the facts that the oldest rocks deposited upon the Precambrian are of late Cambrian age, and that the Precambrian rocks immediately below the Cambrian exhibit textures and structures which could have developed no less than some thousands of feet below the earth's surface.

Following the great intrusions and during the time of erosion above referred to came the minor intrusions of gabbro and diabase. The gabbro is definitely known to be much older than the diabase, the fine-grained texture of the former proving it to have cooled comparatively near the surface of the earth either in late Precambrian or very early Paleozoic time.

Paleozoic History

By late Cambrian time the profound erosion above mentioned had worn down the whole Adirondack region to the condition of a more or less well-developed peneplain. This we know because late Cambrian strata (particularly the Potsdam sandstone), which are the oldest to have been deposited upon the Precambrian, everywhere rest upon a peneplain surface of the Precambrian.

There is no evidence that Paleozoic strata were ever deposited over the area of the quadrangle, though late Cambrian or Ordovician strata now almost completely surround the whole Adirondack region. These Paleozoic rocks formerly mantled all but the central Adirondacks. A number of erosion remnants of the Paleozoic rock cover still exist in the southeastern Adirondack region, the nearest to the Blue Mountain quadrangle being a small area of Potsdam sandstone near the village of North River about 16 miles a little south of east of Indian Lake village.

The best available evidence shows that the ancient peneplain became sufficiently submerged during late Cambrian time to allow the sea to cover all but a considerable part of the central Adirondack region, and that the maximum submergence occurred during mid-Ordovician (Trenton) time when only a comparatively small portion of the central Adirondack area (including the Blue Mountain quadrangle) remained as a small low island. During this Trenton time the sea may have extended over some of the southeastern portion of the Blue Mountain quadrangle, though of course any positive evidence is entirely lacking.[1]

At some time (or times) during the middle or late Paleozoic era the whole Adirondack region, then largely mantled with Paleozoic sediments, was raised well above sea level. Some of the upward movement may have taken place at the time of the Taconic revolution (close of the Ordovician), though it is generally considered that the major uplift occurred at the time of the Appalachian revolution (toward the close of the Paleozoic). In northern New York this upward movement was not accompanied by folding, but there was a general tilting of the strata downward toward the south or southwest.

Mesozoic History

The erosion cycle inaugurated by the Paleozoic elevation of northern New York continued for a vast length of time or till the close of the Cretaceous period when the Paleozoic strata were largely removed from the Adirondack area and another eroded surface approaching the condition of a peneplain was produced. Apparently this peneplain was least perfectly developed in the central and east-central Adirondacks where various hard rock masses (monadnocks) stood out more or less prominently above the general peneplain surface. This peneplain was upraised about the close of the Cretaceous period so that remnants of it in northern New York now lie at altitudes of from 2000 to 3000 feet or possibly more. Within the quadrangle no very accurate idea of this peneplain or

[1] Certain oscillations of level between land and sea, which are clearly recorded in the rocks around the Adirondacks, may also have affected the central Adirondack area, but the utter absence of all Paleozoic strata from the central area renders any determination of this kind difficult if not impossible.

its remnants can be gained because it was only imperfectly developed there.

It is quite certain that much of the faulting, including the Indian lake fault, which has so largely influenced the major topographic features of the southeastern half of the Adirondacks took place after the development of the Cretaceous peneplain and probably at the time of its uplift. Other zones of fracture, however, like the Long Lake fault, whose displacements show little if any in the existing topography, are probably much older, and they may in part at least be of even Precambrian age.

Cenozoic History

The existing relief features of the Blue Mountain quadrangle have been produced chiefly by the dissection of the upraised Cretaceous peneplain. As a result of the uplift the streams were greatly revived as erosive agents and they proceeded to carve out channels and valleys principally along the comparatively weak Grenville belts and the fault zones of weakness.

Late in the Cenozoic era the area of the quadrangle, in common with most of the State, was deeply buried under the great ice sheet of the glacial epoch. Many local details of topography, especially in the valleys, are due to accumulation of glacial deposits.

ECONOMIC PRODUCTS

As compared with many portions of New York State, the Blue Mountain quadrangle is notably deficient in geologic deposits of value under present-day commercial conditions. The lack of cheap transportation facilities prevents the working of certain deposits which might otherwise have some value. Building stones, so-called "road metal," sands and gravels for local use are the only materials now taken out. No ore deposit of any kind which may ever be successfully mined was observed by the writer. All the stone quarries and prospect holes of the quadrangle are indicated on the accompanying geologic map.

Building Stones

Fresh rock from any of the facies of the large masses of syenite or granite would yield building stones of great strength, resistance to weather and adaptability to high polish, but no large quarry exists in the region. Some typical greenish gray, quartzose syenite has been taken out for local use from the quarry one-half of a mile northeast of Long Lake village. From two or three small quarries close together 1 mile northeast of Grove (Deerland) some pink granite has been taken out. Near the dam across the end of Indian lake two considerable openings have been made in the granite porphyry to furnish stone for the masonry of the dam.

Road Metal

The building of state roads between Grove (Deerland), Long Lake, and Newcomb has caused the recent opening of several large road metal quarries within the quadrangle. One of these is in typical, greenish gray, quartzose syenite on the road 1½ miles southwest of Long Lake village. This rock makes a good grade of road metal.

Another quarry in pink granite, and a third in greenish gray granite are situated along the road about 2½ and 7 miles, respectively, east of Long Lake village. On account of their content of mica, these granites are not quite so satisfactory for road work as the normal and basic facies of syenite or gabbro. The large body of gabbro, crossed by the road between 4 and 5 miles east of Long Lake village, was not used for state road work but it would have been excellent for the purpose on account of its richness in iron-bearing minerals.

In some cases the coarse, crystalline Grenville limestone, where sufficiently weathered to crumble easily, is used to repair roads. Such limestone is taken from the pit indicated on the map one-third of a mile northwest of where the road crosses Cedar river.

Sand and Gravel

Sand and gravel of good quality are present in abundance, especially in the valleys where the sorting power of Glacial and Postglacial streams has been most effective. Such materials are taken from many localities for road and concrete work and for making mortar.

Garnet Deposits

The development of the garnet industry in northwestern Warren county has led to considerable exploration for similar workable deposits for some miles around Indian Lake village. At two places, indicated on the map, respectively 1½ miles southeast and 2¼ miles south-southeast of Forest House, several small prospect holes have been opened in the hornblende gneiss which is so commonly associated with Grenville limestone. At the first-named locality the garnets are of the red almandite variety up to 5 inches in diameter and without hornblende rims, while at the second-named locality similar garnets up to 6 or 7 inches in diameter are enveloped in black hornblende, these latter, therefore, presenting an appearance very similar to those long known from the mine on Gore mountain in Warren county near North Creek. It is this Grenville, hornblende gneiss which is most likely to yield large garnets, but lack of transportation facilities and the general condition of the garnet market have thus far prevented any real mining within the quadrangle. A number of years ago some garnet was shipped from an excellent deposit, similar to those above described, about 2½ miles northeast of Indian Lake village (one-half of a mile east of Bullhead pond) on the adjoining Newcomb sheet. Garnets are crushed and used for abrasive purposes.

Feldspar

For some years those engaged in pottery and chinaware industries have been seeking suitable deposits of feldspar. While feldspar is the most common mineral within the quadrangle, it is not commercially valuable unless occurring as the white potash (orthoclase) variety in large masses, usually in pegmatite dikes or veins. There are many pegmatite dikes ranging from a few inches to a hundred feet wide within the quadrangle, but none promising to be of commercial value could be located. Some of the largest observed deposits are located as follows: 1 mile a little east of north of Indian Lake village where there is a dike or vein about 15 feet wide and 40 or 50 feet long; just southeast of the small gabbro stock on the largest island in Blue Mountain lake and in contact with the gabbro on the west, this dike being fully 100 feet wide and 200 yards long; and a dike 10 or 15 feet wide cutting Grenville hornblende gneiss on Cedar river 3½ miles west of Indian Lake village.

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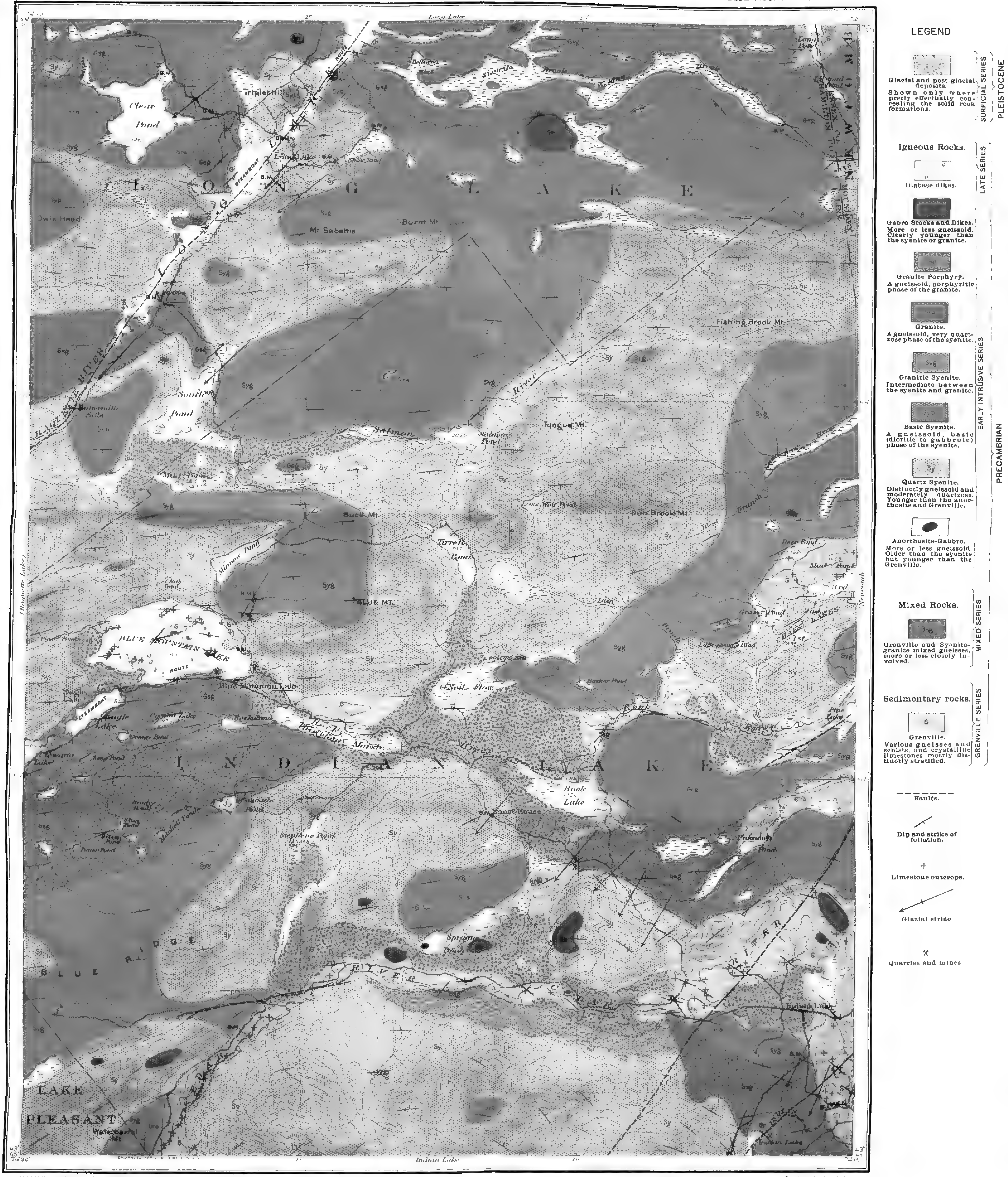
UNIVERSITY OF THE STATE OF NEW YORK
STATE MUSEUM

BULLETIN 192
BLUE MOUNTAIN QUADRANGLE



H.M. Wilson, Geographer in charge
Triangulation by W.J. Peters and W. C[illegible]
Topography by A.M. Walker, [illegible] S. Smith and A.H. Bumstead
Surveyed in 1899-1900.

SURVEYED IN COOPERATION WITH THE STATE OF NEW YORK.

APPROXIMATE MEAN DECLINATION

Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level

Geology by W. J. Miller.
1913-1914.