New York State Museum Bulletin

Published by The University of the State of New York

No. 308 ALBANY, N. Y. May 1937

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE THIRTEENTH LAKE QUADRANGLE, NEW YORK

BY MEDORA HOOPER KRIEGER

CONTENTS

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1937

(M322r-Je-36-2000)

THE UNIVERSITY OF THE STATE OF NEW YORK

New York State Museum Bulletin

Published by The University of the State of New York

No. 308 ALBANY, N. Y. May 1937

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE THIRTEENTH LAKE QUADRANGLE, NEW YORK

BY MEDORA HOOPER KRIEGER

CONTENTS

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1937

(M322r-Je-36-2000)

LIST OF ILLUSTRATIONS

GEOLOGY OF THE THIRTEENTH LAKE QUADRANGLE, NEW YORK

By Medora Hooper Kreiger

INTRODUCTION

LOCATION

The Thirteenth Lake quadrangle is in the southeastern part of the Adirondack mountains, south and slightly west of the high peaks that make up the more rugged portion of the Precambrian region. The area includes approximately 215 square miles and lies between parallels 43° 30′ and 43° 45′ north latitude and meridians 74° 00′ and 74° 15′ west longitude.

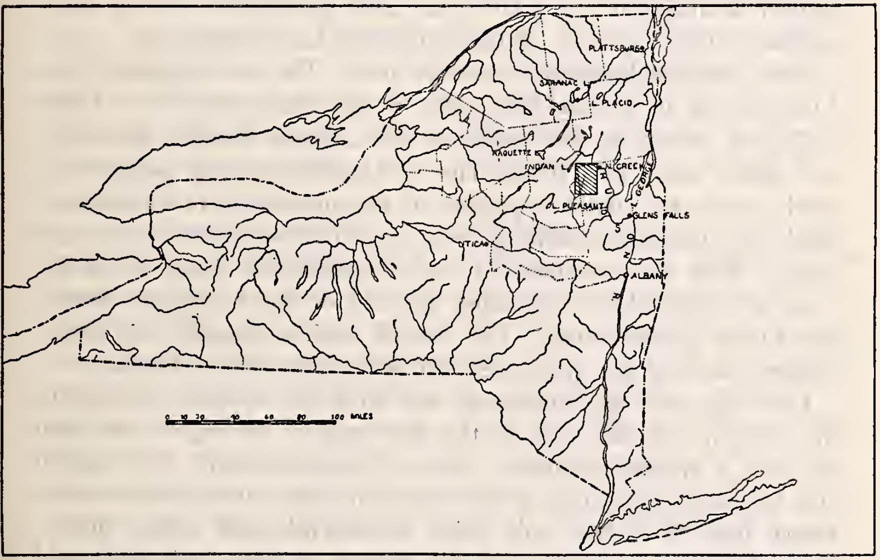


Figure 1 Sketch map of New York State showing the location of the Thirteenth Lake quadrangle

Approximately two-thirds of the district falls within the northwestern corner of Warren county. A portion on the western and northern border of the quadrangle, containing about 52 square miles, extends into Hamilton county. A small section, about one-half square mile, in the northeast corner of the quadrangle lies in Essex county (figure 1).

CULTURE

The only settlements within the area are the small villages of Bakers Mills, in the middle eastern part of the quadrangle; North River, in the northeast; and Garnet, in the southeast. The population of each village does not exceed more than a few hundred persons. The mining camp of the North River Garnet Company at Thirteenth lake for a time previous to 1928 had a population of about 250 persons. Since then, however, the mine has ceased operations and the camp is now occupied mainly during the summer. The remaining population is distributed principally in the middle eastern, northeastern and northwestern portions of the quadrangle where a few small areas are devoted to agriculture.

North Creek, the terminus of a branch of the Delaware and Hudson Railroad, is the nearest village of consequence. It is located in the northern part of the North Creek quadrangle, one mile from the eastern boundary of the Thirteenth Lake quadrangle. There is no railroad within the limits of the Thirteenth Lake quadrangle.

Two principal highways cross the area. The state highway from North Creek to Indian Lake, one of the main roads from Glens Falls and Albany to the north and west, passes through the northeast corner along the Hudson river. Another highway passes diagonally across the southern portion of the quadrangle in a northeast-southwest direction, following the course of East Branch Sacandaga river. With the exception of the last-mentioned road, all of the roads are confined to the farming districts, or lead to summer resorts and to the garnet mines. The central, middle western and southwestern parts of the quadrangle are accessible only by trails.

Until 25 years ago lumbering was an active industry throughout the district, and like most of the Adirondacks the region has been cut over a number of times. A heavy second growth of evergreen and hardwood trees now exists except in those areas where severe forest fires have left only thick underbrush and fallen timber. These features, combined with the scarcity of trails and roads, add to the difficulty of travel through the region.

The garnet mine on Gore mountain is the only mine now operating in this section. This mine, a small amount of farming and a few sawmills are the only active industries within the area at the present time. The tanneries at Oregon, extensive lumbering and the operation of other garnet mines in former years employed many workmen. With the decline of these industries, however, the population has decreased, and many of the small farms are now abandoned.

Some parts of the quadrangle, especially Thirteenth lake, Kings flow (now lake Humphrey) and Mill Creek pond (now Garnet lake) are ideally situated for summer resorts. Small hotels and camp sites, with guides and boats, are available on many of the small lakes and ponds. Various picturesque parts of the central Adirondacks are within easy reach of the area.

ACKNOWLEDGMENTS

The present work has been carried on through the cooperation of the New York State Museum. Dr Charles C. Adams, Director of the Museum, and Dr David H. Newland, State Geologist, have shown the utmost courtesy in assisting the progress of the work.

Appreciation is extended to Frank C. Hooper for valuable information and advice and the benefit of his wide knowledge of the region, particularly with reference to the garnet deposits. Thanks are also due Professor Roy J. Colony and Professor William M. Agar, of Columbia University, for aid in the interpretation of petrologic and structural features. Extended discussions with Dr Robert Balk aided greatly in the attempt to unravel many of the complex features of the region. Dr Philip Krieger, of Columbia University, gave assistance and critical review in preparation of the manuscript.

Appreciation is extended to Dr William J. Miller for his many contributions to the geology of the region. In the plotting of the areal distribution and structural features of the quadrangle considerable data have been taken from Miller's published ('29) and unpublished maps of the quadrangle. These include measurements of dip and strike of foliation and bedding, glacial striations, the location of several small diabase dikes and boundary lines between formations wherever this data supplemented the writer's own observations. Miller's unpublished report on the geology of the quadrangle has been available and some of his data have been incorporated in the present report.

PREVIOUS GEOLOGIC WORK

Compared to other sections of the Adirondack mountains, the geologic features within the limits of the Thirteenth Lake quadrangle have received but little attention. In the latter part of the 19th century James F. Kemp began a study of that part of the Adirondack mountains which includes the Thirteenth Lake region. Most of the field work in this area, however, was done by D. H. Newland and B. F. Hill. The results of these studies were published as preliminary reports on the geology of the different counties.

The first of these by Kemp and Newland ('99), containing a short description of the garnet mine northwest of North River, is the earliest published account calling attention to the boulders of Potsdam sandstone occurring just south and east of the mine.[1] The second report by Kemp, Newland and Hill, ('00) which contains the first geologic map of the town of Johnsburgh (northwest part of Warren county), was essentially a reconnaissance survey in which many of the general geologic features of the region were recognized. They discovered anorthosite along the west shore of Thirteenth lake and along the road from Bakers Mills to Wells. Owing to the inaccessibility of the extreme western part of the quadrangle, however, the full extent of the anorthosite was not known. Most of the area was mapped as gneiss. Some of the gneiss was recognized as having had a sedimentary origin. Other varieties were believed to represent metamorphosed augite-syenite. Limestones and quartzites were mapped along the North Creek-Bakers Mills road, around Bakers Mills and to the south. The above-mentioned small area of Potsdam sandstone, west of North River, was also mapped.

An article on Chimney mountain in the northwest part of the quadrangle by Miller ('15) gives a description of that interesting feature and a possible explanation of the structure, as well as several photographs and diagrams.

Later Miller ('29) published a short paper on the geology of the Thirteenth Lake quadrangle. He gives a summary of the geology and a geologic map of the region, together with various hypotheses regarding the origin of anorthosite. This article is discussed in the present paper, since the conclusions presented here differ somewhat from those presented by Miller.

Articles by various authors have been published on the garnet deposits, which constitute the only economic deposits of the region. Most of these articles, however, deal mainly with the operation of the garnet industry and only slight reference is made to the geology of the deposits. The articles appear as reports on Mineral Resources and on the Mining and Quarry Industry, published by the New York State Museum. Miller ('12) made a detailed study of the geology of these deposits, in which theories of the origin of the garnet were presented. A more recent paper by Myers and Anderson ('25) contains a comprehensive historical account of the discovery and early operation of the garnet deposits.

[1] At the time this report was written this section was included in Essex county. Due to a change in the county line it is now in Hamilton county.

Serendibite, a boro-silicate which has been previously reported only from Ceylon, its type locality, occurs rather abundantly in one place in the southeastern part of the quadrangle. An account of its occurrence and a description of the mineral is given by Larsen and Schaller ('32).

SCOPE OF THE PRESENT WORK

The present work has developed through the writer's interest in a small portion of the quadrangle in the vicinity of the Barton (Moore) garnet mine on Gore mountain. Detailed mapping of this

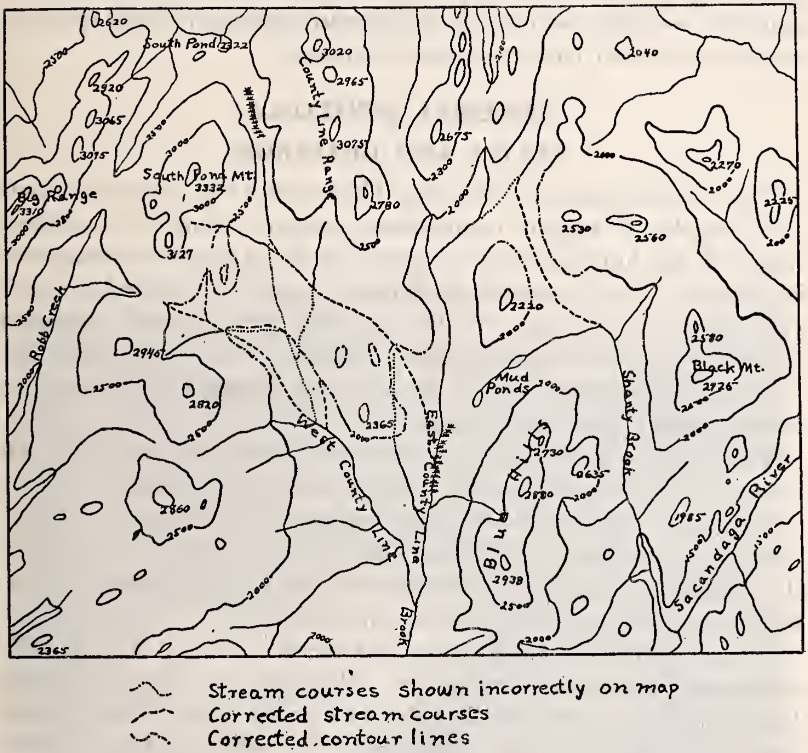


Figure 2 Sketch map of Thirteenth Lake area to show corrections in contours and stream courses as these are drawn on the United States Geological Survey topographic sheet

area during the summer of 1929 revealed certain features which seemed to warrant revision of at least the northern half of the quadrangle as previously mapped by Miller ('29). Consequently, in cooperation with the New York State Museum, two months were spent in the field the following summer and one and one-half months were occupied in field work in the southern half of the quadrangle during the summer of 1931. The field work has been supplemented by petrographic studies of a suite of representative specimens.

The topographic map of the Thirteenth Lake quadrangle by the United States Geological Survey was used as a base map, and was of great assistance during the progress of the work. Certain densely wooded, inaccessible parts of the quadrangle, however, were found to be inaccurately drawn. The chief inaccuracies consist in the faulty mapping of the courses of some of the principal streams in the southwestern part of the area, for example, the east and west branches of County Line brook, and Shanty brook. The principal peaks are correctly located. A sketch map (figure 2) shows approximately the correct courses of these streams.

GENERAL GEOLOGY

RELIEF AND DRAINAGE

The district included within the Thirteenth Lake quadrangle consists largely of rugged mountainous country along the southern fringe of the Adirondack area, typical of the Adirondack mountains in general. The Newcomb quadrangle, an area of somewhat lower relief, lies to the north. To the east and south of the Thirteenth Lake area the elevations gradually decrease. On the western side of the quadrangle, however, in the adjoining Indian Lake quadrangle, several higher peaks are found.

The maximum difference in elevation within the area is about 2600 feet. The lowest points, located along the Hudson river, are slightly more than 1000 feet above sea level. The highest elevation, 3595 feet above sea level, is the summit of Gore mountain, also in the northeast. A number of peaks ranging from 2500 feet to 3500 feet in altitude are located within the district.

There are more than 40 lakes and ponds, most of them entirely within the limits of the quadrangle. The largest of these, Thirteenth lake, is two miles long and one-third of a mile wide. Siamese pond and Mill Creek pond are next in size. The latter has been dammed to make a body of water about twice its former area and is now called Garnet lake. Kings flow, in the northwestern part of the area, has also been dammed to form artificial Lake Humphrey.

The mountains are drained by many small streams. Across the northeast corner of the quadrangle the upper Hudson river, the largest stream, extends for several miles. This stream receives directly the drainage of the eastern and northeastern part of the region. In the northwestern border of the quadrangle the drainage flows first into Indian river and thence into the Hudson river.

Figure 3 View of Garnet lake (Mill Creek pond) from near the summit of Mount Blue, showing Crane mountain (North Creek quadrangle) at the left. Note the rounded mountain tops and the densely wooded character of the country so typical of the quadrangle

Figure 4 Peaked Mountain pond, from the top of Peaked mountain, one of many glacial lakes which occur in the quadrangle. The ledges at the right are bare because the mountain was swept by a forest fire some years ago. The steep slope is at right angles to the dip of the foliation. H. Ludwig, photographer

About two-thirds of the area drains into east branch Sacandaga river, the second largest stream in the region. This stream heads only two and one-half miles from the Hudson river in the northeast portion of the quadrangle. After a very circuitous course Sacandaga river enters the Hudson about 30 miles farther south. A few streams in the southwestern part of the area flow directly into the main Sacandaga river.

PHYSIOGRAPHY

The topography of the area is typical of the Adirondacks, the mountains presenting rounded erosional surfaces that are somewhat emphasized by the heavy growth of timber. The forest growth tends to obscure the more rugged character of the mountains. The ruggedness of the scenery is more noticeable in those areas where the timber has been burned off by forest fires (figures 3 and 4). The upper surfaces of the hills are usually gentle and rounded and probably represent an old erosion level that has been uplifted and subsequently dissected.

Although the drainage of the smaller streams and valleys has been somewhat modified by Pleistocene glaciation, the larger drainage features undoubtedly existed long before that time. The fact that the lowest points within the quadrangle are developed on the softer Grenville sediments, or along fault lines, whereas the higher mountain peaks consist of the more resistent igneous rocks, such as anorthosite and syenite, is believed to be good evidence that the larger valleys were formed before the glacial period.

Although indications of a general northeast-southwest topographic trend appear, this characteristic is less conspicuously developed than in most parts of the eastern and southeastern Adirondacks. A study of the topographic map of the quadrangle brings out a number of interesting features the most striking of which are: (1) the straight course of Thirteenth Lake valley over a distance of nearly nine miles, and (2) the course of East Branch Sacandaga river from above Oregon for the remainder of its course within the quadrangle. These two features are believed to be due to faulting and are discussed in greater detail in the chapter on Structural Geology (page 84). Many other streams and valleys are developed irregularly in a northeast or northwest direction, following the general trend of the mountain ranges.

A study of the topographic map gives only a slight indication of the effects of foliation and bedding on the topography. From them has resulted a pronounced development of asymmetrical land forms that is readily observed in passing through the area.

GEOLOGIC HISTORY AND AREAL GEOLOGY

The Thirteenth Lake quadrangle contains most of the rock types that occur in other sections of the Adirondacks. The oldest rocks are the Grenville sediments. These rocks were widely deposited in the Grenville seas which once occupied the Adirondack region. Later they were cut or engulfed by igneous intrusions and carried away by erosion, so that in most of the eastern Adirondacks they have a very patchy areal distribution. The Grenville sediments were folded and metamorphosed before and during the intrusion of the igneous rocks. The long-continued complex processes operative on these ancient sediments have converted them into a series of crystalline limestones, quartzites, gneisses and amphibolites, as well as into various types of mixed rocks whose origin and history are problematic. Among these should probably be included the garnet deposits which are widespread in the district (page 100). The Grenville rocks occur on the northern and eastern borders and as a small mass in the center of the quadrangle (page 15).

The igneous rocks range from gabbro and anorthosite to syenite and granite. Field and petrographic evidence suggests a close age-relationship between all of the deep-seated igneous rocks of the area. Anorthosite, consisting of both Marcy and border phase types, occurs in two large and in several small masses, covering nearly two-fifths of the surface. It extends to the southwest into the adjoining Stony Creek, Lake Pleasant and Indian Lake quadrangles. The great extent of this second largest occurrence of anorthosite in the Adirondacks was unknown until its areal distribution was determined by Miller ('29) and the present writer, although anorthosite was known to occur within the quadrangle (Kemp, Newland and Hill, '00). Gabbro masses are present but not abundant (page 27).

The syenite-granite series covers nearly half of the quadrangle. It consists of typical medium-grained gray and pink syenite, medium-grained pink granite and occasionally medium-grained granite with a porphyritic structure (page 57).

Diabase dikes, the youngest of all the Precambrian rocks, are fairly abundant and are a distinctly later intrusion. Throughout the Adirondack area these dikes have usually been referred to the Keewanawan, although some of them may be of post-Ordovician age (page 65).

During early Paleozoic (Cambrian) time the sea again encroached upon the Adirondack region. Evidence of its presence in the Thirteenth Lake quadrangle is found in the form of remnants of Cambrian (Potsdam) sandstone at one locality (page 68).

Little is known of the subsequent history of the region, except that it undoubtedly existed as a land surface over vast time periods and was subjected to long and very extensive erosion. Pleistocene glaciation was widespread and minor topographic features were modified by its influence (page 96).

Several changes in the areal geology of the quadrangle as mapped by Miller ('29) will be noted by comparison with the accompanying geologic map. One of the principal changes is the areal extent of the anorthosite. This was mapped by Miller as a continuous mass consisting almost entirely of Marcy anorthosite. He has recognized no Whiteface anorthosite or Keene gneiss in the quadrangle, although several small areas of "anorthosite-gabbro" were mapped.

After detailed work in the center of the quadrangle it was found that the anorthosite, drawn by Miller as a continuous mass, is separated by syenite and granite into a smaller mass northeast of the Twin Pond-Cross Brook area and a larger mass southwest of this line. Several changes in the outline of the two masses were made, especially in the western part of the quadrangle: (1) on Puffer mountain, which was found to consist mainly of granite, and (2) west of Robb creek, where a large area of additional anorthosite was noted. The writer differs from Miller in the classification of the anorthosite in these two areas and recognizes a large amount of border phase anorthosite. The border phase varieties include gabbroic and Whiteface anorthosite and Keene gneiss. Minor changes will also be noted in the mapping of additional garnet deposits, diabase dikes, gabbro masses and the extent of the Grenville, as well as changes in structural features. Interpretations of special features differing from those held by Miller ('29 and unpublished manuscript) are presented below.

PRECAMBRIAN ROCKS

GRENVILLE SERIES

General statement. The Grenville sediments and the complex mixtures of Grenville and igneous rocks have been well described and their history discussed in New York State Museum reports on the geology of the Adirondacks, including the quadrangles surrounding the Thirteenth Lake area (Miller, '19a; '14; '23; '16; '17; and Balk '32). As the Grenville sediments of this quadrangle are in nearly every respect typical of the Adirondack Grenville, a general description and history of the rocks will be given as briefly as possible in this report. More emphasis will be placed on petrologic features, especially on the effects of igneous activity on the Grenville.

Estimates of the total thickness of the Grenville sediments or of local thicknesses have frequently been given. In the present report no attempt has been made to measure the probable thickness of these sediments for the following reasons: (1) The Grenville has been cut to pieces and pushed aside by the igneous rocks and extensively carried away by erosion, so that only a very small part of the original sediments is present. (2) The actual amount of sediment in any outcrop or series of outcrops is much less than the body of the outcrop on account of the intrusion of small and large sills, mainly of syenite and granite; the injection of quartz, feldspar and other minerals of igneous origin and the formation of assimilative or syntectic products which undoubtedly have increased the volume of the original rock. (3) The structure seen in the field may not represent the original structure, also the beds may be isoclinally folded and repeat the actual thickness. A discussion of the structural features is included in the chapter on Structural Geology (page 69).

Most of the Grenville rocks are less resistant to erosion than are the igneous intrusions. For this reason they have been almost entirely removed from the higher elevations and are found mainly in lower areas into which they have been folded, down-faulted or engulfed by the invading magmas and were, therefore, somewhat protected from erosion. Where the rocks are more quartzitic, however, they may be as resistant to erosion as the igneous bodies. Within this quadrangle little of the Grenville or mixed rocks occur at an elevation above 2000 feet, except in the case of very small xenoliths. Most of it occurs at much lower elevations. Two exceptions to this are: (1) the Mount Blue area of mixed rocks occurring at an elevation of 2925 feet. This is a quartzitic rock with a large amount of admixed granite; and (2) the Chimney Mountain area, which rises to an elevation of 2600 feet. At this locality the rock is also quartzitic and on the mountain west of Chimney mountain it is protected by a cap of granite and gabbro.

The Grenville rocks have been mapped as Grenville sediments and Grenville-syenite-granite mixed rocks. This does not mean that the Grenville sediments are free from igneous material. Small or large sills and dikes of syenite and granite occur and the Grenville rocks frequently show the effect of minute igneous injection or soaking and of assimilation. The mixed rock areas contain many lenses of quartzite, limestone and associated metamorphosed sedimentary rocks, but the percentage of igneous material is much larger. It has been impossible to map these igneous and sedimentary lenses in the field in the amount of time available. Because of the heavy cover of glacial moraine and the small size of many of the lenses, it would undoubtedly be difficult to map many of them accurately even with very detailed work.

The origin and history of many of the rocks in both the Grenville and mixed rock areas are uncertain. Intense metamorphism and recrystallization have changed the original rocks into crystalline limestones or marbles, quartzites, gneisses, schists and amphibolites. As the original sediments consisted of all gradations from pure limestone and sandstone through impure varieties to shaly types, metamorphism has consequently resulted in a great variety of rocks. This has been further complicated by at least two, and probably three, distinct periods of intrusion during which igneous material was injected into the sediments and absorption of the sediments took place to a considerable extent. A petrologic study of the Grenville rocks has revealed that few, if any, of the sedimentary rocks are entirely unaffected by igneous activity. The sills and dikes of syenite-granite belonging to the anorthosite-syenite (Algoman) period of intrusion can easily be recognized in the field. It is more difficult, however, to attribute entirely to this period the effects of igneous activity that are seen only under the microscope. It seems probable that the sediments were first intruded by a basic igneous rock, which has undergone essentially the same amount of metamorphism as the invaded material. This basic rock can seldom be recognized in the field, unless it is represented by some of the outcropping pyroxene and hornblendic bodies. Balk ('32, p. 15) believes that many of the mixed gneisses in the Grenville areas are the result of widespread injection by an early (Laurentian) granite, although few, if any, rocks of Laurentian age can be recognized as such in the field. This granite has been recognized in the western Adirondacks by Smyth ('12, p. 144), Cushing ('25, p. 38–39) and others. Miller, however, would attribute all igneous injection effects to the syenite-granite of Algoman age. No granite of undoubted Laurentian age was found in the Thirteenth Lake quadrangle, although the writer believes that Balk's interpretation of the mixed gneisses is probably true in this quadrangle as well (page 22).

Grenville sediments occur in four different parts of the quadrangle: the northwest corner, northeast corner, eastern and southeastern border, and center. There are, in addition, small lenses and xenoliths throughout the igneous rocks of the area.

Northwestern area. The valley of Center brook is apparently underlain by limestone, but few outcrops are exposed in the thick drift filling. Those that occur are mainly crystalline limestone with a small amount of associated hornblende gneiss. A few small lenses of granite were noted.

Many excellent exposures of Grenville quartzite and gneiss occur in the area extending for two and one-half miles west and northwest from the summit of Chimney mountain. Pyroxene, mica and hornblende-garnet gneiss, prevailingly rusty in appearance, are abundant. No limestone was found in the area. The rocks are well exposed in the walls of the rift which occupies the top of the western peak of the mountain (see figures 25 and 26). This rift is described in the chapter on Structural Geology (page 90). The rocks are strongly banded in layers from six inches to several feet thick. Most of the bands show no contortion or folding over considerable distances. As many small isoclinal folds, however, are visible, it is not certain whether the straight bands represent limbs of larger isoclinal folds or a secondary structure in which original bedding has been obliterated, probably the former. The rocks dip 20° to 60° west and rest upon the granite which forms the eastern peak of the mountain. Numerous quartz dikes and dikes of granite pegmatite cut the sediments.

Rocks of similar character continue to the west and northwest of this area. On the side of the mountain due north of Kings flow the sediments dip to the northeast under a narrow belt of granite. The granite in turn dips under the gabbro which forms the mountain top.

East and northeast of John pond a long, narrow inclusion of Grenville rocks occurs in syenite and granite. The south end of this inclusion is composed of quartzite associated with mica and pyroxene gneiss. At the north end the inclusion consists of granitic material mixed with bands and augen of pyroxene and garnet.

Miller ('29) has mapped two areas of gabbro-granite mixed rock, one occurring west of Center brook and the larger one extending for several miles along the western part of the northern border of the quadrangle. Miller describes the rocks of the larger mass as consisting mainly of pinkish gray, well-foliated granite containing many small garnets and bands of gneiss. The garnets and gneiss are considered by him to have been derived from remnants of gabbro. A small body of gabbro has been mapped one-eighth of a mile north of Center pond, and Balk ('32) has mapped several larger masses of gabbro just north of here in the Newcomb quadrangle. In spite of the occurrence of some gabbro, however, the writer believes that the garnets and bands of gneiss owe their origin to the presence of Grenville sediments which have been assimilated by the granite.

The smaller area west of Center brook contains a large amount of amphibolite, pyroxene gneiss and hornblende gneiss with a smaller percentage of granite.

Northeastern area. Many small lenses of rocks, so intimately mixed and consisting of such diverse types that they can be mapped only as masses of mixed rocks are distributed throughout this area. Grenville rocks predominate along the river, especially on the northeast side, west and south of Carter pond. Hornblende garnet gneiss with garnet crystals up to one inch in diameter is associated with a more quartzitic rock, and with coarse-grained limestone. The limestone contains graphite and occasionally a minor amount of quartz and ferromagnesian minerals. It occurs as bands with maximum thicknesses of six feet between layers of quartzite and gneiss. Biotite gneiss is frequently associated with the hornblende gneiss. Many outcrops of limestone also occur northwest and southeast of Carter pond.

Syenite-granite is more abundant along the immediate northern and eastern border of the quadrangle. A large amount of Grenville, however, has been caught up in the syenite-granite. The Grenville consists of small lenses of quartzite, limestone and gneiss, as well as small masses of mixed or partially assimilated rocks.

Two masses of rock, one west of Clear and Long ponds and another east of Carter pond, were originally mapped by Miller ('29) as gabbro. A large part of the rocks in these localities he believes to be metagabbro and gabbro which has been intensely cut and injected by granite. The writer considers the first of these two areas as Grenville amphibolite and gneiss which is a continuation of the amphibolite mapped by Balk ('32) in the Newcomb quadrangle. The rocks in the vicinity of Carter pond also appear to be Grenville gneisses which have been injected and partially assimilated by the later syenite-granite intrusions. No rocks which could be classed as true gabbros of Algoman age were found in this area. Some of the dark gneisses may represent an earlier basic intrusive, mentioned on page 17.

The hill due south of North River village consists largely of Grenville limestone and associated gneiss with a very minor amount of syenite-granite. Additional outcrops of limestone were mapped west of North River. Syenite-granite with small amounts of various gneisses and mixed rocks probably underlie most of the remainder of this area, but the rocks are largely covered by glacial material and few outcrops are exposed.

Eastern and southeastern area. The rocks covering about six square miles along the middle eastern border of the quadrangle consist of Grenville and syntectics with minor amounts of small scattered sills and lenses of syenite-granite. This is the westward extension of the large mass of Grenville represented on Miller's ('14) geologic map of the North Creek quadrangle. Much of the northern part of this area is drift covered, and only occasional outcrops of limestone with associated pyroxene and hornblende gneiss and quartzite can be seen. The best exposures of Grenville are found in the steep southwestern face of the ridge two to two and one-half miles south of Bakers Mills. Limestone is well developed toward the base of this ridge. Hornblende gneiss, quartzite and rusty mica, pyroxene and garnet gneisses and schists occur above the limestone.

The valley of Mill creek contains only a few outcrops. These consist mainly of Grenville limestone with some quartzite. In this locality, just west of the road between the words "Mill" and "Creek," on the map, is located the deposit of the rare mineral serendibite, recently described by Larsen and Schaller ('32).

More numerous outcrops of Grenville occur on the low hills along the edge of the map east of Mill creek. Just southeast of *k* in Mill cree*k* biotite schist and hornblende-garnet gneiss occur. The gneiss and schist have been intruded by a sill-like mass of strongly foliated granite which dips to the southeast and is conformable with the Grenville. The gneiss and schist are overlain by limestone and the latter is cut by numerous quartz veins which are from three to four inches in width. The quartz veins are parallel to the foliation of the limestone. North of here, to the point where Mill creek leaves the map, there are many outcrops of granite, limestone, quartzite and gneiss. A steep cliff of quartzite about 50 feet high is the most northerly outcrop of Grenville strata in this section. This quartzite is apparently the continuation of a large body of quartzite mapped by Miller ('14) in the North Creek quadrangle.

The southeastern part of the quadrangle consists largely of granite and mixed gneiss with minor amounts of Grenville strata, covering an area of about 12 square miles. Excellent exposures are found in the large barren ledges on the top and southern slope of Mount Blue. Many of these rocks are highly contorted. They consist almost entirely of medium-grained, light gray garnetiferous, quartz-feldspar-biotite gneiss; gray garnetiferous granite; medium to fine-grained pink granite gneiss; some quartzite and dark gneiss and scattered, broken masses of quartz. Alternating bands of these different types of rock, cut by many small pegmatite dikes are scattered over the mountain. The southeastern slope of the ridge northeast of Mount Blue contains similar rock types, although a larger percentage of quartzite and quartzitic gneiss is present.

Along the southern border of the quadrangle the rocks consist mainly of granite containing small scattered lenses of Grenville strata. Crystalline limestone outcrops in several places in the vicinity of Mill Creek pond (Garnet lake), most of which is associated with hornblende-garnet gneiss and granite. Serpentinous marble outcrops just east of the lake.

The area east of Mill Creek pond is largely granite with included lenses of quartzite and gneiss. The higher elevations consist chiefly of granite with but small lenses of Grenville strata. In the lower elevations, just east of the lake and southeast of the word "Garnet," Grenville strata predominate; granite is present only as small lenses or sill-like masses. East of the lake the Grenville consists mainly of quartzite and quartzitic gneiss. East and northeast of the northern end of the lake layers and bands of fine-grained hornblende-feldspar-garnet rock appear in the granite. These lenses become more abundant to the north where they grade into hornblende-garnet gneiss.

Central area. Grenville and mixed gneiss associated with syenite and granite cover nearly three square miles just west of the center of the quadrangle. Outcrops are not numerous and most of the valley of East Branch Sacandaga river is drift covered. Limestone outcrops along Siamese brook just above its junction with East Branch Sacandaga river. Quartzite outcrops below the limestone in East Branch. Limestone also occurs near the top of elevation 2352 feet, one mile northwest of Diamond mountain. The rocks on the west slope of this mountain, east of B. M. 1661, are of interest. They consist mainly of mixed, quartzitic, biotitic and garnetiferous gneisses in which syenitic and granitic minerals are abundant. Much of the rock is light greenish gray or whitish in color, with fine to medium-grained texture and foliated and massive structures. Graphite is a common component, even in the rocks which closely resemble typical syenite. The rocks are undoubtedly of syntectic origin.

The rest of the outcrops consist principally of syenite or granite with smaller amounts of Grenville strata and mixed gneiss.

Other occurrences. A number of small inclusions or xenoliths of Grenville strata and mixed gneiss occur in the igneous rocks and have been indicated on the geologic map. Many others undoubtedly occur, but were not seen in the heavily drift-covered regions. Small masses of gneissic or schistose rocks, frequently similar to the hornblende-garnet gneiss types, were encountered. Some of these are undoubtedly of sedimentary or syntectic origin. Others may represent foliated gabbro, an early basic rock, or in some cases parts of a diabase dike.

Amphibolites. Most of the rocks classified as amphibolites or as hornblende, pyroxene or biotite gneiss and schist are of doubtful origin. Throughout the Adirondacks, as well as in the Precambrian of Canada, the origin of such types is obscure. They have been discussed by Adams ('09), Adams and Barlow ('10, p. 157–72), Martin ('16, p. 50–53), Smyth and Buddington ('26, p. 88–91) and others. These investigators have shown that amphibolite may originate in three entirely distinct ways, resulting in rocks which may be essentially identical in appearance and composition. They may be products of (1) metamorphism and recrystallization by regional forces of impure calcareous sediments, (2) alteration of basic igneous rocks such as diabase dikes and gabbros, or (3) alteration of limestone through the contact action of intruding bodies of granite.

In the Thirteenth Lake quadrangle amphibolites were found associated with Grenville limestone and quartzite, with gabbro masses and as small inclusions or lenses in the anorthosite and syenite-granite. Frequently their occurrence may suggest any one of the three origins mentioned above. In some cases they may even resemble the younger basic dikes, but where field relations are obscure, their origin is always doubtful. Balk ('32, p. 14) doubts the igneous derivation of most of the amphibolites in the Grenville, but recognizes gabbro-amphibolites which surround some of the gabbro bodies, as well as accumulations of ferromagnesian minerals which he considers segregations from the syenite magma. The amphibolites and similar rocks are discussed in connection with the origin of the garnet-rich deposits (page 116).

Evidence of igneous activity. A petrologic study of the Grenville sediments and mixed gneisses has shown that these sediments have, in practically all cases, been affected by igneous activity.

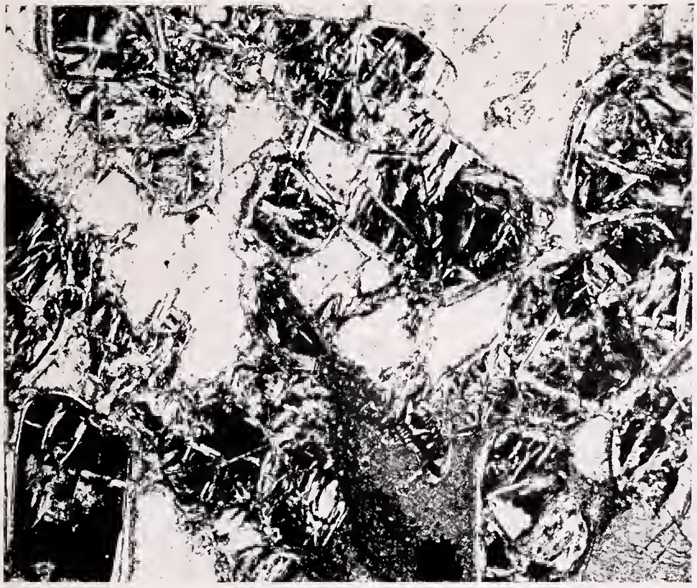


Figure 5 Photomicrograph of crystalline limestone containing serpentinized olivine crystals. From an outcrop one-third mile northeast of *k* in Mill Cree *k*. Crossed nicols. x35.

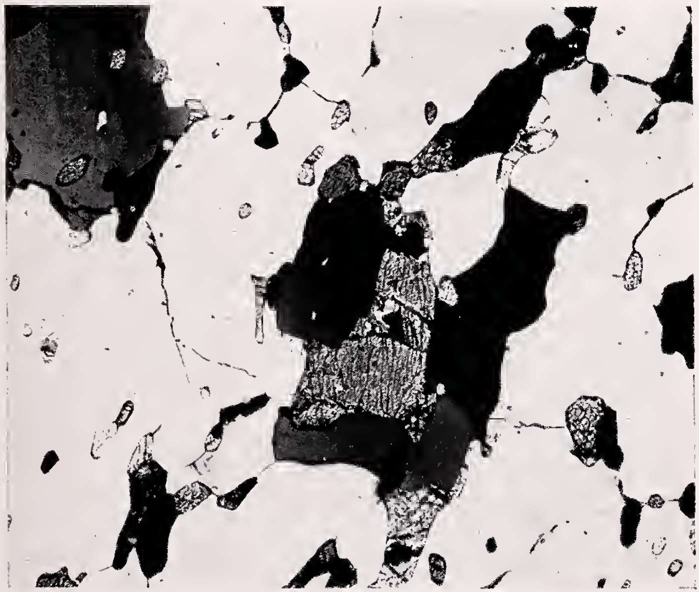


Figure 6 Photomicrograph of quartzite with small crystals of pyroxene showing a general parallel orientation. Crossed nicols. x 35.

Almost no specimens from the Thirteenth Lake quadrangle were observed which showed simple regional metamorphism without the addition of igneous material. A few examples will be discussed.

1 A specimen taken from near the top of the northwest end of the ridge two miles south of Bakers Mills. This is in the region of Grenville strata where syenite-granite lenses are relatively scarce. A thin section (V-25) shows an abundance of biotite, altered plagioclase feldspar, hypersthene and clinohypersthene and titanite. Clearly later, and of igneous origin, are fresh alkali feldspars that are mainly perthitic, and quartz, apatite and tourmaline. In many cases the feldspar and quartz clearly replace the older basic plagioclase. Some of the quartz undoubtedly belongs to the earlier sedimentary stage, but the major portion of it is believed to be of igneous origin. Another thin section (V-31) cut from a sample taken just northwest of the previous specimen is composed mainly of augite and a small amount of hypersthene. Antiperthite, made up of plagioclase feldspar and potash feldspar, replaces cloudy areas which may represent either clastic grains derived from an old sediment, or the feldspars of an earlier basic rock. Pyrite is abundant and quartz and graphite are present in minor amounts.

2 A specimen from just southeast of *k* in Mill Cree*k* on the map. The rock is a biotite schist associated with hornblende gneiss and granite. The thin section (V-22) shows numerous biotite flakes, pyroxene, perthite, magnetite, graphite and remnants of old basic feldspar. The feldspar is now badly sericitized. The minerals in this section are interpreted as follows: The biotite and graphite represent recrystallized products of original sedimentary material; the badly altered remnants of basic feldspar, and possibly the pyroxene, represent an early basic intrusive which has assimilated and metamorphosed the sediment; the perthite is definitely younger than the other minerals, and, in some cases, replaces the older feldspars.

3 About one-half of a mile north of (2) and occurring above an outcrop of granite is an impure, greenish colored limestone, or ophicalcite. In thin section (V-23) this rock is seen to contain many crystal forms of what originally were olivine. The olivine is now entirely altered to serpentine (figure 5). West of this point, on the Garnet road, unaltered olivine occurs in crystalline limestone. The olivine may be a product of igneous activity, owing its origin to the introduction of igneous material which caused the recrystallization of impurities in the limestone.

4 The north end of the lens of Grenville east of John pond. The rock consists of granite with bands and augen of pyroxene. In thin

section (V-5) the specimen shows disseminated pyroxene with an abundance of microcline, green diopside, garnet, perthite, quartz and a small amount of titanite and epidote. The garnet is of unusual brown color in thin section. The microline, perthite, quartz and some of the ferromagnesian minerals are definitely of a later age. The bands and augen of pyroxene, represented in the thin section by the disseminated pyroxene and some of the other minerals, may represent remnants of an early basic intrusive or recrystallized sedimentary material.

5 Lens in syenite at the south end of Kings flow, west side. A quartzite, containing bands of greenish colored augite, one-quarter to one-half inch wide. Augite is also disseminated through the quartzite. A study of a thin section (V-1) shows that the augite crystals cut across the interlocking quartz crystals irrespective of crystal boundaries. These augite crystals, therefore, appear to be the result of igneous attack on the quartzite (figure 6). If they were products of recrystallization derived from impurities in the original sediment they would be more likely to occupy interstitial positions between the quartz grains. It is believed that the quartzite was injected by a basic rock (now represented by the pyroxene bands and disseminated pyroxene) and later caught up as a xenolith in the syenite.

6 Grenville rocks also occur on the hillside east of Diamond brook along the Bakers Mills-Siamese trail and continue for some distance north of the trail. They consist of quartzite and gneiss. A thin section (V-32) of a specimen from near the top of the divide, three-quarters of a mile west of the main road, contains a large amount of quartz and plagioclase feldspar. Hypersthene is distributed through the rock in the same manner as the augite is distributed in section V-1 (5). Magnetite is also present in this rock. The quartz may be of sedimentary origin. The other minerals, however, probably represent the effect of igneous injection.

7 A specimen from the southeast end of Garnet lake (Mill Creek pond) is an excellent example of the complexity of the Grenville mixed rocks. It is nearly black, fine-grained, strongly foliated or schistose. The foliated structure is well shown in thin section (V-19). The rock contains altered biotite, epidote, diopside, tremolite, magnetite, titanite and apatite, with a very fine groundmass of serpentine and chlorite. It was apparently a foliated schist that was thoroughly soaked by later basic igneous material. Another section (V-20) of a sample from just north of the above specimen is an altered Grenville (?) rock consisting of biotite, pyroxene, mus-

covite and epidote, and is clearly injected or swamped by later quartz.

8 Quartzite along the north shore of the Hudson river west of Carter Pond brook contains many biotite flakes. The biotite in a thin section (V-2) cuts across the quartz crystals in the same manner as the pyroxene in the quartzite previously mentioned in 5. The rock also contains basic plagioclase feldspar.

9 On the west slope of elevation 2352 northwest of Diamond mountain the rock is greenish gray in color with a fine-grained texture and foliated structure. The section (V-18) shows quartz, perthite, oligoclase, biotite and graphic intergrowths of quartz and feldspar, with a small amount of graphite and apatite. It has the appearance of a closely interlocking and recrystallized mass. The biotite has the same general arrangement as that found in the quartzites previously mentioned. Most of the feldspars are fresh, although the oligoclase, and occasionally some of the perthite, show a slight alteration to sericite. Because of the presence of graphite, some of the rock, at least, is believed to have been derived from original sediments. Much of it, however, is clearly of igneous origin, and the rock in its present state is probably a mixed, or syntectic, type.

10 On the top of the hill south of *B* in Thirteenth *B*rook on the map the rock is banded and contains coarse quartz and feldspar pegmatites. The pegmatites cut the rock parallel to the structure. A thin section (V-13) suggests that possibly the rock was originally an old sill that was first metamorphosed to a hornblende schist, with the development of some quartz and feldspar. This was later injected with granitic material. It would be possible, however, for this earlier rock to have been a part of the Grenville sediments, or a Grenville rock that was affected by igneous activity and later swamped with additional granitic material. The thin section contains green hornblende, pyroxene, plagioclase, magnetite and carbonate. The hornblende is a bright green variety, and, in some cases, it surrounds pyroxene from which it may have been derived. About 30 per cent of the slide is fine, cloudy, sericitic material that was probably derived from the older basic feldspar. This has been replaced by a fresh feldspar approximating andesine in composition. A small amount of quartz is present. Magnetite is very abundant.

GABBRO

General statement. Eight areas of gabbro are represented on the accompanying geologic map, six of which occur in the northern half of the quadrangle. In addition to these, several small outcrops, which may represent gabbro, are known. These do not resemble typical gabbro and because of their doubtful origin are mapped as amphibolite. They consist mainly of fine-grained, strongly foliated, basic rock. Undoubtedly some of these represent the gabbro "in statu nascendi" of Balk ('31, p. 351), which are segregations of ferromagnesian minerals from the syenite magma. Others have been tentatively classed as dikes or as amphibolitic masses of Grenville age caught up by later intrusives. Many are simply basic or gabbroic phases of the anorthosite.

These gabbro bodies are similar to most of the gabbro which occurs throughout the eastern Adirondacks and should undoubtedly be correlated with them as belonging to the Algoman period of anorthosite-syenite-granite intrusions. The question of age relationships is discussed below (page 32). The gabbro is usually a massive, medium-grained rock with a dark greenish-gray or black color. A good ophitic texture is often well developed. Foliation is locally present and is apparently a primary or magmatic flow structure. The central portions of the larger bodies of gabbro are usually more massive in appearance than the border zones, which commonly exhibit a stronger foliation and finer texture. This difference in structure is believed to be due to the obliteration of the primary arrangement by recrystallization.

The typical massive gabbro is made up of labradorite and augite with varying amounts of hypersthene, clinohypersthene, diallage, biotite, hornblende, olivine and garnet. Accessory minerals are pyrite, magnetite, ilmenite, apatite and spinel. The feldspars may occur as large lath-shaped crystals up to one inch or more in longest diameter. Frequently, however, they are without definite shape, and show interlocking crystal boundaries due to crushing and recrystallization. An interesting and persistent feature of the massive gabbro is the occurrence of rounded areas of radiating ferromagnesian minerals up to one-fourth of an inch in diameter. These rosettes are usually surrounded by a narrow rim of garnet. They stand out strikingly on the more weathered portions of the rock and give it a speckled appearance characteristic of all the gabbros of this quadrangle.

As the Gore Mountain gabbro was studied in greater detail than any of the other areas, the petrographic features are described from rocks taken from this locality. The contact relations between syenite-granite and gabbro are particularly well shown at Humphrey mountain. Other gabbro masses are discussed only where they serve to illustrate particular features and throw some light upon the

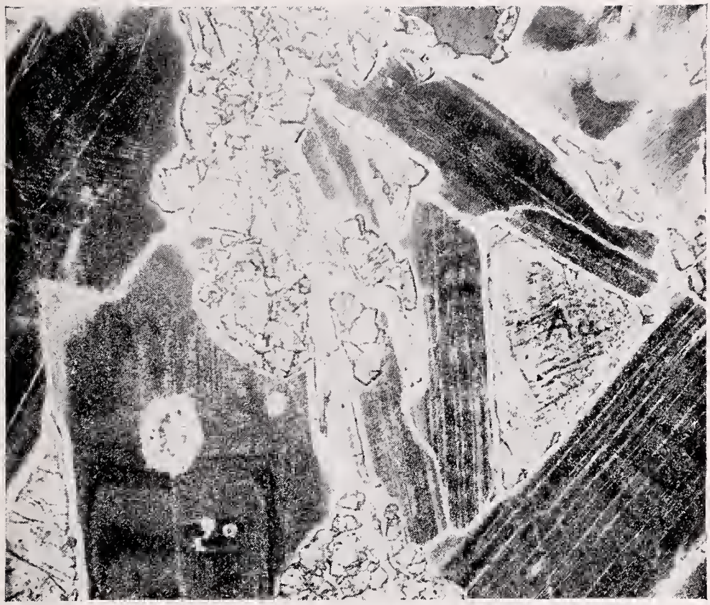


Figure 7 Photomicrograph of gabbro showing feldspar laths full of inclusions with inclusion-free borders, triangular crystals of augite (Au) and irregular shaped masses of garnet and ferromagnesian minerals. Plain light. x 23

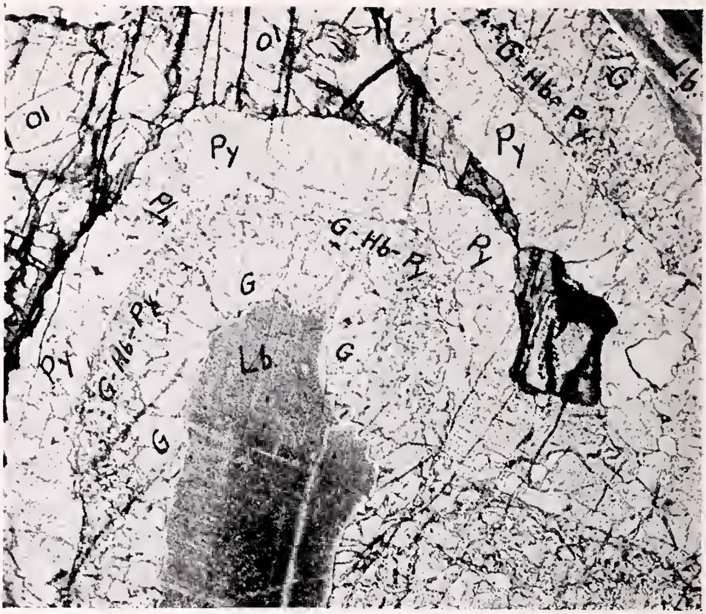


Figure 8 Photomicrograph of gabbro showing labradorite (Lb) crystals full of inclusions. Olivine (Ol) crystal in the upper left corner is surrounded by (1) radiating rim of augite, hypersthene and clino-hypersthene (Py); (2) a narrow rim of plagioclase with some biotite (Pl); (3) garnet with some associated hornblende and pyroxene (G-Hb-Py) and (4) garnet (G). Outside of this is the feldspar with inclusions. Plain light. x23

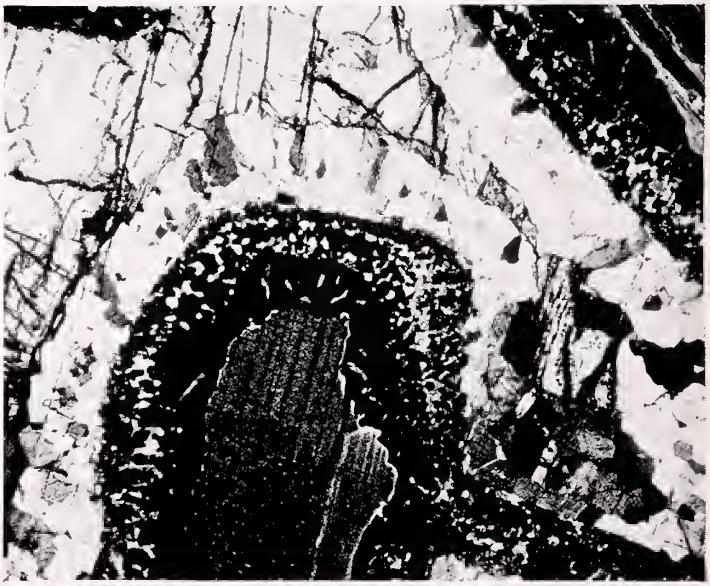


Figure 9 Same thin section as figure 8. Crossed nicols

problems of the age and origin of the gabbro. As stated in the preceding chapter (page 19), several areas of rock which were previously mapped as gabbro by Miller ('29) have been found to resemble amphibolite and have been included with the Grenville sediments in this report.

The Gore mountain gabbro is by far the most interesting because of its association with several different rock types. It is bounded on the north and east by a large body of gabbroic and Whiteface-type anorthosite; on the south by the rich hornblende-garnet deposit described below (page 109) and on the west by Marcy-type and gabbroic anorthosite. It is nowhere in contact with syenite, although syenite occurs within 100 to 300 feet of the gabbro on the south side of the garnet deposit. Immediately north of the gabbro, between it and the anorthosite, is a narrow zone of garnet gneiss similar to the deposit of garnet gneiss east of Thirteenth lake (page 104). A large part of the rock is medium-grained, massive, hypersthene-olivine gabbro or norite. The speckled appearance of this rock on a weathered surface is one of the most characteristic features.

Petrographic features. Microscopic study of the gabbro from Gore mountain shows it to be similar in many respects to the gabbro of the eastern Adirondacks. The plagioclase feldspar is usually filled with inclusions ranging from tiny, black, dustlike particles which are probably ilmenite to larger ones that are more readily recognized and consist of green spinel and many of the ferromagnesian minerals of the gabbro. The inclusions are frequently so small and numerous, that, in a hand specimen, the feldspars are dark greenish or black in color. In a thin section the inclusions impart a dark gray or black color to the feldspar. The inclusions are usually arranged parallel to the twinning planes of the feldspar and are concentrated in the centers of the crystals. This gives the labradorite a clear, transparent margin, a feature usually characteristic of the feldspars in the gabbro. The area filled with inclusions varies considerably. Where the inclusions are very minute and closely spaced they may occupy a greater portion of the crystal and leave only a narrow margin of transparent material. Rarely, the entire crystal is filled with inclusions. In other cases, only the very center of the labradorite crystal may contain irregular patches of inclusions.

The principal ferromagnesian minerals are hypersthene or clinohypersthene, hornblende, augite, olivine and biotite. Myrmekite-like intergrowths of laboradorite and augite and of labradorite, augite and garnet are often present. Where labradorite crystals show well-developed euhedral forms, augite usually occupies an interstitial position in the form of triangular masses (figure 7). This association and structure would seem to indicate a primary origin without subsequent recrystallization. Most of the ferromagnesian minerals, as well as garnet and labradorite, also occur as recrystallization products in the form of reaction rims surrounding earlier formed or primary minerals. The reaction rims consist either of complex mixtures or of successive rims of these minerals surrounded, in practically all cases, by garnet. The feldspars frequently show the effect of crushing and recrystallization around their outer border. Frequently garnet appears to occur as a rim around labradorite crystals (Balk, '32, p. 17–18). (Figures 8 and 9 also show a rim of garnet around labradorite.) A close inspection of the garnet rim in the above examples, however, has shown that the "rim" around the plagioclase is made up of rims belonging to several ferromagnesian minerals which surround the feldspar. Garnet has not been observed adjacent to a labradorite crystal unless a ferromagnesian mineral is also present.

Age relations of the gabbro. Small isolated masses of gabbro, associated with Grenville sediments and with anorthosite and syenite-granite, are widespread throughout the Adirondacks. Undoubtedly there have been several periods of intrusions of basic or gabbroic rocks in the Adirondack region. The question of the age of the gabbros and age relationships to other rocks is, therefore, rather complex. All the gabbros, however, are considered younger than the Grenville series. Some of the Grenville amphibolites may represent an early basic intrusive into the Grenville sediments. These amphibolites frequently resemble the more foliated or schistose borders of the younger gabbros. Some of the gabbros of the western Adirondacks are believed to be pre-Laurentian in age (Martin, '16, p. 12). These gabbros occur as sill-like masses, as well as with rounded outline. Most gabbro exposures of the eastern Adirondacks, with the exception of some of the amphibolites mentioned above, have rounded outlines, and their period of intrusion is generally believed to be Algoman. It is these gabbros that will be discussed below.

Most writers have considered the Algoman gabbros of the eastern Adirondacks as younger than the syenite-granite series (Cushing, '05; Kemp, '10; Miller, '14). They were believed to cut across the preexisting structure of the syenite-granite, anorthosite and Grenville rocks.

As a result of further study of the gabbros in the Luzerne and Lyon Mountain quadrangles, however, Miller ('23, p. 15; '26, p. 11) came to the conclusion that they occurred as inclusions in, and not intrusive into, the syenite-granite and were, therefore, older than the syenite-granite. Later work by Miller ('29) in the Thirteenth Lake quadrangle supported this conclusion.

A subsequent petrographic study to determine the age of the gabbros was made by Gillson, Callaghan and Millar ('28). In spite of Miller's evidence, they came to the conclusion that the gabbros were younger than the syenite-granite. They believe that the recrystallization of the gabbros, with the development of reaction rims and the clear transparent borders around the edges of the feldspar crystals, is due to the addition of material as an end-stage residuum of the gabbro upon the earlier crystallized minerals. The more massive structure of the gabbros as compared to the more foliated structure of the syenite-granite was also considered as additional evidence for the younger age of the gabbros.

In reply to this paper, Alling ('29) states that, as a result of the study of the literature, he does not believe there is as much confusion as to the age of the gabbros as the above paper would imply. He states (1) that syenite and anorthosite have gabbroid borders and that calcareous Grenville sediments can become amphibolitic on metamorphism, but that these rocks can be distinguished from the younger gabbros; (2) that, with the exception of Miller, most geologists have recognized gabbros of post syenite-granite age, as well as older gabbros (amphibolites) which cut the Grenville but which are older than the syenite-granite and are possibly pre-Laurentian in age.

More recently Balk ('31) published the results of a comprehensive study of the Adirondack anorthosite and related intrusives. This paper is discussed more fully in the chapter on anorthosite, but certain features concerning the gabbros will be brought out here. Balk found evidence in the field which he considers proof that the anorthosite, syenite-granite and gabbro are all differentiated products of one parent magma, as previously suggested by Bowen ('17). According to Balk, the gabbros were, for the most part, among the earliest masses to crystallize, and in this respect they are older than the anorthosite. Gabbro masses, however, continued to form until the whole mass had solidified, so that in places the gabbros may be younger than the anorthosite, and nearly as young as, but never younger, than the syenite-granite, the latter representing the final constituents to solidify. This explanation for the origin of these rocks possibly reconciles the widely divergent ages assigned to the gabbros by different workers. Balk has recognized all stages of gabbro masses in the field, from the small masses which were just beginning to form when the syenite magma solidified to those which were formed early and grew to a large size.

Quoting from Balk ('31, p. 353-57): "The gabbros have the same disturbing effect on the foliation of the wall-rocks as wooden balls floating in (or on) water. . ." When the gabbro lenses become of sufficient size "beyond something like 50 feet—an average of field observation,—the central portions of such lenses seem to have recrystallized in such a way that the foliation was locally blurred and the rock became massive and coarser-grained than the foliated fringe.

"If such gabbro lenses grew still larger, they took on a spherical or torpedo-like shape, with round or oval ground-plan. . . The problem of crystal settling presents itself at this stage in the evolution of the gabbros. . . The field observations show that almost all spherical gabbros are underlain by strongly foliated, even-schistose and mylonite-like anorthosite. And since the wall-rocks on the flanks and near the top of the gabbros (wherever they could be examined) are not nearly as strongly foliated, it is believed that the larger gabbros have, indeed, moved downward with reference to the surrounding magma."

Balk states further that "if the problem of crystal settling is advocated for labradorite masses whose specific gravity differs but little from that of the associated mother liquor, it must certainly be considered for the dark silicates which are heavier." Also, "small isolated crystal grains will be kept suspended in the parental magma by the considerable surface friction, the viscosity of the melt and the movement of the magma: three forces acting against gravity. However, with increasing diameter of the cluster of ferromagnesian minerals, the relation between surface friction and weight will be shifting towards a condition where the weight is greater than the combined effect of surface friction and magma motion, and from this stage on the gabbro mass will begin to settle downward."

Field evidence observed in a study of the Thirteenth Lake quadrangle supports the conclusions of Miller ('23, '26) and Balk ('31) that the gabbros are at least relatively older than the syenite-granite. Pegmatite dikes and veinlets of syenite-granite were found distinctly cutting the gabbro in the center of the mass extending from the hill, elevation 2080 feet, to the hill, elevation 2260 feet, south of Center brook (figure 10). The gabbro outcrops on the south side of the valley at the edge of the clearing, a few hundred feet south of a small house. This area contains typical gabbro cut by pegmatite and granite dikes which are undoubtedly related to the syenite-granite, although they could not be traced directly back to the syenite-granite mass.

Field evidence also appears to support Balk's interpretation of the origin of the gabbros and their structural and age relationships with the anorthosite as well as the syenite-granite. The writer believes, however, that, as in the case of the other problems relating to Adirondack geology, more detailed studies will be necessary before adequate interpretations can be presented. Wherever the contact between a gabbro mass and syenite-granite is exposed, the gabbro occurs as an inclusion in the syenite. The foliation of the syenite dips under the gabbro on all sides. Two excellent examples of this were found:

1 The mass of gabbro occupying the top of elevation 2525 feet, one mile northwest of Chimney mountain. On the southwest side of this mass Grenville rocks and granite dip under the gabbro to the northeast. At the northwest end of the mass, the foliation of the granite strikes S. 8° W. and also dips under the gabbro. On the northeast side, about one-fourth mile from the gabbro the foliation of the granite strikes N. 82° W. and dips south.

2 The syenite-granite surrounding the gabbro on Humphrey mountain also shows foliation dipping under the gabbro on the south, southeast and northeast sides. The gabbro here extends into the adjoining Indian Lake quadrangle. During a study of this quadrangle by the writer in the summer of 1932 the granite was found to dip to the east under the gabbro on the western side and to the northeast on the southwest side of the gabbro. This is the largest body of gabbro in the Thirteenth Lake quadrangle; including the part which extends into the Indian Lake quadrangle, it is about one and one-half miles in diameter and nearly round in outline.

It would hardly be possible to find better exposures of the contact relationship between granite and gabbro than are to be found on the western slope of Humphrey mountain in the Indian Lake quadrangle. Nearly every foot of rock is exposed in the steep slopes and cliffs through a vertical distance of over 400 feet. Near the base of the mountain the granite contains layers of hornblende-garnet gneiss or amphibolite from one-fourth inch to several feet in thickness. These layers are usually strongly foliated, medium to fine-grained and dip in the same direction as the granite. Although the majority of them are but a few inches thick, they become more numerous near the higher portion of the mountain, and between elevations 2300 feet and 2400 feet only a few small bands of syenite-granite are present. The angle of dip increases before the rock grades into more normal massive gabbro.

The same general relation between syenite-granite and gabbro can be seen on almost any side of Humphrey mountain. On the east side of the mountain, the zone of medium to fine-grained hornblende-garnetiferous gneiss is rather wide and contains but little syenite. Just below the massive gabbro making up the top of the mountain, the hornblende-garnetiferous gneiss is coarser, more hornblendic and frequently contains large garnet crystals. This type of rock grades or passes into the garnet deposit located on the northeast side of the mountain (page 115).

The Gore Mountain gabbro is surrounded by anorthosite and garnet-rich deposits. This mass, including the anorthosite and garnet deposits, is oval in shape and when considered as a whole it appears as an inclusion in the surrounding syenite. The foliation of the syenite dips under the mass on all sides.

Features observed at the contact between the gabbro and anorthosite on Gore mountain indicate a very close relationship between these two rocks. The anorthosite in this area is mainly a gabbroic variety, containing more than 10 per cent of ferromagnesian minerals. Neither rock appears to cut or be intrusive into the other. At its eastern end the gabbro contains a large number of labradorite crystals and is more coarse-grained than normally. The labradorite occurs mainly as long narrow lath-shaped crystals and except for the presence of occasional black rosettes of ferromagnesian minerals, characteristic of the normal gabbro, it might be considered a dark gabbroic phase of the anorthosite. It is abruptly terminated at this end by a steep clifflike scarp, approximately 100 feet high. The rock east of this scarp, and about 100 feet from its base, is anorthosite in which the labradorite crystals are arranged in much the same manner as in the gabbro. On the western side the gabbro becomes much finer grained and appears to grade into the anorthosite. No sharp, well-defined contacts between these two rocks were discovered.

Additional evidence of the close relationship between anorthosite and gabbro in this area is found in the occurrence of the same kinds of reaction rims common to both rocks. A typical example from the anorthosite contains olivine surrounded by a rim of radiating hypersthene and clinohypersthene. This is surrounded by a light brown to green hornblende, also arranged in a radial manner. All of these minerals are inclosed within a solid shell of garnet. The gabbro contains reaction rims similar to this, as well as variations. In some

Figure 10 Outcrop of gabbro in the northwest part of the quadrangle, showing small pegmatite dikes and veinlets

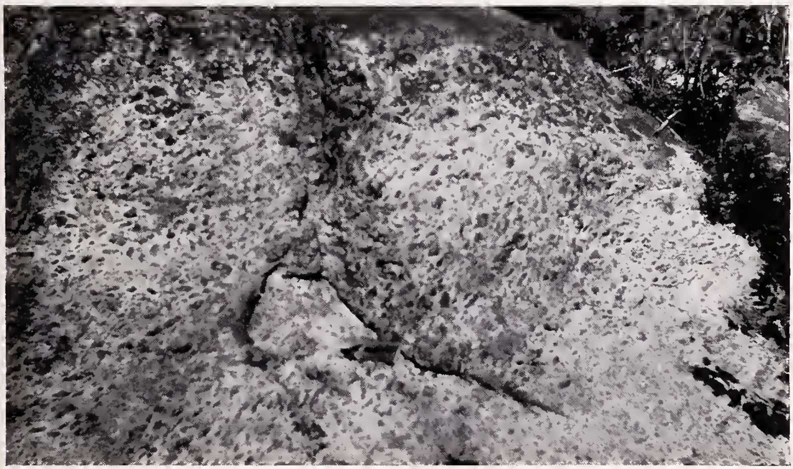


Figure 11 Ledge of Marcy anorthosite on northwest shore of Thirteenth lake, showing many large labradorite crystals

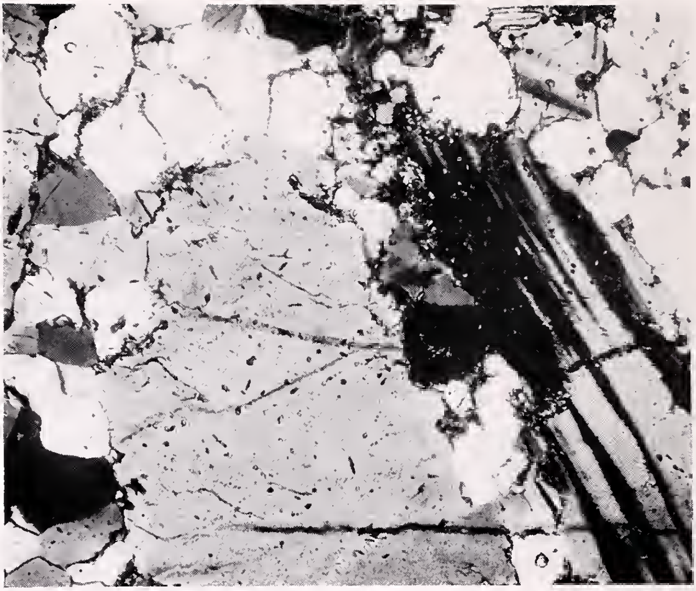


Figure 12 Photomicrograph of anorthosite showing large crystal of labradorite surrounded by finer, crushed labradorite crystals. To the right of the center is a large crystal showing twinning lamellae. The large crystals are full of minute inclusions, while the small ones contain no inclusions. Crossed nicols. x23

Figure 13 Marcy anorthosite on the top of Durant mountain. The light-colored, irregular stringers working out from the large mass of light-colored material in the lower central part is syenitic materal supposed to be the trapped "mother liquor" of Balk. The boundaries have been traced with ink. In the field they are faint and by no means sharp

cases, olivine is surrounded by hypersthene, clinohypersthene and augite, followed by a narrow rim of plagioclase feldspar and biotite. Garnet also forms the outer borders of these rosettes. These rims frequently contain hornblende and any one of the ferromagnesian minerals may occur in the center. The groups of ferromagnesian minerals are usually larger and more irregular in shape in the anorthosite than in the gabbro.

The inclusions in the feldspars of the anorthosite and gabbro, also, suggest a close relationship. The same minerals occur as inclusions in both rocks and they have a similar arrangement in the feldspar crystals. They are somewhat more numerous, however, in the feldspars of the gabbro than in those of the anorthosite. The anorthosite of Gore mountain contains a greater quantity of these inclusions than does the anorthosite in other parts of the quadrangle.

ANORTHOSITE

Distribution and types. One of the most important results of the detailed mapping of the Thirteenth Lake quadrangle is the delimitation of a considerable amount of hitherto little known anorthosite, whose total area, including its extent into the adjoining quadrangles to the southwest, is about 90 square miles. It is, therefore, the largest mass of anorthosite outside of the main formation of 1200 square miles in the eastern Adirondacks.

The anorthosite in the Thirteenth Lake quadrangle occurs in two large and several small masses. The largest occupies an area of approximately 70 square miles. It extends from the west central part of the quadrangle over 12 miles to the south into the Stony Creek quadrangle, which has not yet been mapped. It extends southwest, also, into the Lake Pleasant quadrangle, where about one square mile of anorthosite was mapped by Miller ('16). Its greatest extension, however, outside of the Thirteenth Lake quadrangle, is to the west, into the Indian Lake quadrangle, where preliminary field mapping by this writer has revealed at least eight square miles of this rock type, in one place reaching as far west as Kunjamuk creek. Within the Thirteenth Lake quadrangle the larger body is eight to ten miles wide in the south, four to five miles wide across the center and less than one mile wide across the north end. An area of about five square miles along the middle western border of this anorthosite consists of an interesting mixture of syenite, granite and anorthosite (page 53).

The smaller mass of anorthosite lies northeast of the large one and underlies nearly ten square miles. It is about eight miles long and between three-quarters of a mile to two miles wide. It extends along the northwest side of Thirteenth lake and for some distance south of the lake. It is separated from the larger mass by an area of syenite and granite one to two miles wide.

Additional small areas of anorthosite are located in the northeast quarter of the quadrangle. The largest of these is approximately two miles long by three-quarters of a mile wide.

Several varietal facies of anorthosite are recognized in the Adirondacks. The same general types occur in the Thirteenth Lake quadrangle. The most common facies of the Adirondack anorthosite is the Marcy type, so named by Miller ('18) some years ago because of the excellent exposures on Mount Marcy in the eastern Adirondacks.

Typical Marcy anorthosite is a coarse-grained bluish gray rock which contains more than 90 per cent of plagioclase feldspar, usually considered to be labradorite (figure 11). According to Barth ('30), however, it contains only 45 to 55 per cent of the anorthite molecule and should, therefore, be classed as andesine-labradorite. The term "labradorite," however, has been retained by Balk ('31 and '32) and will be used in this report. The plagioclase crystals usually vary from one-quarter of an inch to several inches in length. Crystals an inch long are common. They usually lack the iridescence so characteristic of much labradorite. Fine twinning striations on cleavage faces are apparent in many hand specimens and the outer margins of these crystals frequently show crushing and granulation, which may be observed by the unaided eye. In a large part of the Marcy anorthosite the amount of crushed feldspars is greater than that of the uncrushed cores. In this case the darker bluish feldspars, up to an inch or more in length, stand out conspicuously in the finer, distinctly granulated mass which is nearly always lighter in color than the uncrushed cores. It varies in color from light gray or brown to light greenish gray. All degrees of granulation can be seen, up to those extreme cases in which the feldspars have been so thoroughly granulated that few, if any, uncrushed plagioclase cores remain. In some cases the rock is nearly devoid of foliation. Many areas of nearly pure plagioclase rock, however, exhibit a tendency toward parallel arrangement of the feldspars, which in some instances is obvious.

Garnet and magnetite (or ilmenite) are the common accessory minerals usually visible to the unaided eye. Augite, hornblende, biotite and hypersthene are frequently present, and apatite, pyrite and zircon form occasional minor accessories. Alkali feldspars and quartz often occur as interstitial material around the borders of the large labradorite crystals.

Inclusions are common in the large, uncrushed crystals of labradorite. They are similar to those found in the feldspar crystals of the gabbro, although not nearly so abundant. None has been observed in the crushed and granulated feldspars (figure 12). According to Barth ('30), the dustlike particles are probably pyroxene. In some cases larger inclusions can be identified as magnetite or ilmenite, spinel and the various ferromagnesian minerals that are common to the anorthosite.

The border phase anorthosite may be divided into three types: Whiteface anorthosite, gabbroic anorthosite (frequently called anorthosite-gabbro) and Keene gneiss. The Whiteface anorthosite was named by Kemp ('98*a,* p. 58) because of its extensive development on Whiteface mountain. It occurs mainly as a border zone associated with the main mass of anorthosite of the eastern Adirondacks. It is typically a foliated rock consisting of white or nearly white labradorite with 5 to 15 per cent of ferromagnesian minerals. These are mainly garnet, hornblende and augite, together with small amounts of magnetite, biotite, apatite and zircon. It frequently contains a few scattered crystals of darker, blue-gray labradorite. According to Balk ('31), Whiteface anorthosite is always foliated. Miller, Kemp and others class as Whiteface, rocks which are sometimes lacking in foliation, but have the characteristic white plagioclase.

The gabbroic border phase variety of anorthosite is a medium-grained, moderately foliated rock containing from 10 to 40 per cent of hornblende, augite, hypersthene, biotite and garnet. The feldspars are andesine-labradorite, antiperthite and oligoclase. Small amounts of orthoclase and quartz may also be present, and there are frequently many large labradorite crystals arranged parallel to the foliation of the rock.

The Keene gneiss was so named because of its occurrence in Keene Valley (Miller, '18). These are the "sye-blue rocks" of Alling ('32). The Keene gneiss is a medium-grained, strongly foliated, notably granulated rock containing uncrushed remnants of labradorite similar to those seen in other varieties of anorthosite. The groundmass consists of labradorite, oligoclase, orthoclase, microperthite, quartz, pyroxene, hornblende and several accessory minerals. The general mineral composition suggests a syenite or granite, containing labradorite crystals. The labradorite content of the rock varies from only a few crystals up to 50 or 75 per cent. According to Kemp, Cushing and Miller, the Keene gneiss is a fusion or assimilation product of anorthosite by syenite in which some labradorite crystals have been picked up. Bowen ('17) and Balk ('31), however, explain these rocks as a differentiation *in situ* from a parent magma (page 46).

Variations in the anorthosite and gradations between the different types of anorthosite are common features of these rocks. All gradations are found between coarse-grained anorthosite, whose feldspar is only slightly granulated around the edges, to rocks so thoroughly crushed that few, if any, uncrushed cores remain. Almost monomineralic varieties containing little but plagioclase grade into rocks that carry up to 40 per cent of other minerals. The structure may be massive or foliated. The latter structure is usually emphasized by the parallel arrangement of labradorite crystals or by streaks of ferromagnesian minerals.

Miller ('29) classed the anorthosite of the Thirteenth Lake quadrangle as the Marcy and "gabbroic" varieties. He also stated that little, if any, Whiteface anorthosite or Keene gneiss is present in the area. He mapped the anorthosite as a continuous mass extending from Thirteenth lake to beyond the southwestern limits of the quadrangle and interpreted it as consisting mainly of Marcy anorthosite with local areas of "gabbroid" anorthosite. He considered the smaller bodies in the northeastern part of the map as "anorthosite-gabbro," probably related to the main anorthosite mass and originally connected to it. Certain areas of rock, tentatively classed as Keene gneiss by Miller, were later found to contain neither microperthite, orthoclase nor quartz and were, therefore, regarded by him as a crushed and granulated facies of true anorthosite, containing a few cores of uncrushed plagioclase.

On the map accompanying this report a large part of the anorthosite of the southwestern area has been shown as Marcy anorthosite. Only in the following areas, however, is the rock the coarse-grained variety that contains nearly equal amounts of granulated groundmass and uncrushed cores, or a greater percentage of the latter: (1) Buckhorn mountain and Buckhorn ponds and for some distance to the south and east; (2) a large part of the area between Stewart creek and Kibby brook; (3) many small patches in the central part of the anorthosite mass, especially on the Blue hills and Black mountain. Only a few small areas of coarse-grained Marcy anorthosite occur in the northern half of the quadrangle. They are as follows: (1) the rocks along the northern half of the west shore of Thirteenth lake; (2) the top of Durant mountain (figure 13); (3) at the outlet of Hour pond.

A considerable portion of the center of the southern area and small parts of the northern area are Marcy anorthosite in which only scattered cores of blue-gray labradorite crystals remain, the rest of the feldspars having been completely crushed and granulated.

Most of the border portions of both masses as well as the northern part of the southern mass, on Puffer mountain, and a large part of the northern body is one of the border phase varieties. Most of it is a foliated gabbroic anorthosite in which ferromagnesian minerals vary from 10 to occasionally over 50 per cent. Garnet forms abundant crystals up to one inch in diameter in many of the border phase rocks as well as in the Marcy anorthosite.

Certain areas of rock were definitely classed as Keene gneiss, although the microscope reveals that some specimens do not always contain microcline, orthoclase and quartz in any appreciable quantity. A large amount of the feldspar, however, is oligoclase, the plagioclase which occurs in the basic syenite, and in smaller amounts in the more acid quartz-syenite and granite. A small quantity of crushed labradorite is often scattered throughout the more alkaline feldspars. Many specimens of Keene gneiss, however, are composed of typical syenite with large bluish gray labradorite crystals.

A specimen of Keene gneiss (Sy-7) taken from northeast of Bakers Mills has the appearance of strongly foliated syenite with many dark crystals of labradorite arranged parallel to the foliation. A thin section (A-39) of this rock at first suggests anorthosite. A study of the feldspars, however, reveals that most of them have the composition of oligoclase. The larger, dark crystals are labradorite, whose many small inclusions probably account for their color. A few small, irregular crystals of labradorite occur scattered throughout the rock, and may represent crushed particles of original labradorite. The larger, dark crystals of labradorite commonly have borders of antiperthite (albite and labradorite), which also occurs as separate individuals throughout the thin section. In another thin section (A-40) from the same hand specimen orthoclase, perthite and quartz are very abundant. The ferromagnesian minerals are hypersthene, augite, hornblende and garnet arranged in streaks or bands throughout the rock. These minerals are common to both the syenite and anorthosite. Accessory minerals associated with the ferromagnesian minerals are magnetite, zircon and apatite. A list of the Keene gneiss areas is given on page 56.

Because of the divergent opinions as to what constitutes Whiteface anorthosite, due in part to the different origins assigned to it (page 46), it is possible that certain rocks which the writer has classed as Whiteface would not be recognized as such by Miller. Many of the specimens are light-colored, foliated rocks whose ferromagnesian content is somewhat greater than 10 per cent. The feldspars of the groundmass seldom exhibit the chalky white aspect so characteristic of those in the rock found on Whiteface mountain. They are, however, extremely light in color and contain some white feldspars. Furthermore, Miller's description of the Whiteface anorthosite, which he says is "light gray in color with white or nearly white feldspars," fits many of these rocks.

Small outcrops of rock, classed as Whiteface anorthosite and found in several places are of especial interest. Specimens from the mountain west of the southern end of Thirteenth lake are medium-grained, light gray to white in color with a massive structure. Except for occasional small, bluish gray labradorite crystals with crushed borders which merge into the surrounding groundmass, these rocks would never be considered as basic as anorthosite. The feldspars are very pale pink or gray and only a few scattered flakes of ferromagnesian minerals are present. A thin section shows that one specimen is composed almost entirely of crushed and recrystallized labradorite. In some localities, rocks of this type also contain considerable orthoclase and sodic plagioclase.

The small areas of anorthosite in the northeastern part of the quadrangle are similar in many respects to the larger areas and there is no valid reason for doubting the anorthositic affinities of these rocks. Many specimens duplicate those found in the larger areas. The largest of these small bodies lies north of Gore mountain and is nearly two miles long by three-fourths of a mile wide. Around the northern and eastern side of this body there is a band of light-colored garnet gneiss (page 103) dipping under the anorthosite. On the west and southeast the anorthosite is in contact with syenite. Marcy anorthosite, gabbro and the garnet deposit of the Barton (Moore) mine border this body of anorthosite on its southern side. The rock in this area shows considerable variation in mineral composition, structure and texture. None of it resembles coarse-grained Marcy anorthosite. Portions in the northern part of the area are typical light-colored, somewhat foliated Whiteface anorthosite containing varying amounts of garnet. In some places, especially along the road across the western part of the area, the rock is crushed and granulated, with well-developed foliation. Cores of bluish gray plagioclase crystals up to six or eight inches in length are sometimes found. They are usually arranged parallel to the foliation. Ferromagnesian minerals frequently constitute 15 to 20 per cent of the rock. On the summit of the highest elevation the percentage of ferromagnesian minerals is much greater and the rock is dark-colored, almost gabbroic in appearance.

In some areas, notably the eastern part of this mass, the ferromagnesian minerals and garnet occur as intimate mixtures in large rounded masses up to three inches in diameter. These give the rock a blotchy appearance, and except for their size, suggest the rosettes of the gabbro.

A large part of the rock should probably be classed as Whiteface anorthosite; rocks of unquestionable Whiteface character occur in the northern part of the region.

Garnet, very abundant in most of the rock, occurs both as fine grains and as larger crystals whose dimensions exceed an inch. Occasionally the rock has the appearance and composition of Marcy anorthosite in which few uncrushed labradorite crystals remain.

A small amount of border-phase gabbroic anorthosite whose boundaries were not accurately mapped, occurs on the top and southern slope of the western peak of Height of Land mountain. It is similar to much of the border phase anorthosite of the larger masses.

Two small areas of coarse-grained anorthosite occur on Gore mountain. The larger body is at the west end of the Barton (Moore) garnet mine, in contact with gabbro and border phase anorthosite on its northeast side. Syenite surrounds it on all other sides, except where it is in contact with the garnet-rich rock. Except for its very dark color and the larger percentage of ferromagnesian minerals, it is similar to the typical coarse-grained Marcy anorthosite. It is a massive, very coarse-textured rock containing 80 to 90 per cent of nearly black labradorite crystals which are usually about an inch in their longest dimension and which frequently show microscopic crushing and granulation along their borders. The rock contains interstitial masses of ferromagnesian minerals with well-developed rims of garnet.

The limits of the small anorthosite mass on the east side of Gore mountain were not accurately mapped, but the rock was found to consist chiefly of coarse-grained Marcy anorthosite.

Although the rock surrounding the North River Garnet Company's mine contains a few labradorite crystals, it appears to be a garnet gneiss of low-grade garnet content. For the greater part it is similar to the garnet-rich rock of the mine into which it grades by an increase in the garnet content. The boundaries against the syenite are by no means sharply defined. Most of the rock is foliated or banded similar to the garnet-rich rock. Close inspection discloses occasional labradorite cores from one-eighth of an inch to three-fourths of an inch in length, but labradorite cores are entirely lacking in many of the exposures. Some were observed on the western and southeastern sides of the mine area and a few scattered cores of labradorite occur in the area east and southeast of the mine.

Miller ('29), who has mapped this rock as anorthosite-gabbro, states that the rather basic composition and variable character of this "anorthosite" are probably the result of more or less irregular and complete assimilation of an older dark rock by the anorthosite—the assimilation which produced the garnet rock.

The writer believes that this border zone should be classed as a low-grade garnet rock. There are many small exposures of this type of rock throughout the quadrangle and most of these have been considered a garnet gneiss similar to the light-colored garnet rock, but of lower grade. Labradorite cores are rare. This problem is discussed more fully in the chapter on garnet deposits (page 116) and the possibility of a close relationship between anorthosite and garnet gneiss is suggested.

Small masses of rock in the area east and southeast of the mine, extending nearly over to the Gore Mountain road, are of similar character. Occasional labradorite crystals may be found, but in most cases the rock resembles a low-grade garnet gneiss.

Origin of the anorthosite. Although the problem of the origin of anorthosite has been discussed by numerous writers, it is still far from being completely solved. Alling ('32) gives the most recent discussion of the various theories which have been presented with respect to the origin of the Adirondack anorthosite. He states that in addition to the complexity of the problem itself, the following features have tended to confuse the workers: "(1) no one geologist has seen all that there is to see, due to the extent of the area, (2) the Adirondack geologists do not agree regarding the facts, (3) the same field facts are not interpreted alike by any two geologists, and (4) there are a number of preconceived views regarding the rock units and their interrelations that undoubtedly influence their thinking." Alling also gives a table contrasting the four main theories which have been presented. Many minor theories modifying each one to some extent have been proposed.

The geological studies of early workers in the Adirondack mountains led to the following theory concerning the origin and history of the igneous rocks. These were thought to have resulted from separate periods of igneous activity closely following one another in time and probably coming from a parent magma which had differentiated at depth. Anorthosite was considered to be the oldest, followed by the syenite-granite series and then by gabbro. As already stated, later study led some of the geologists to believe that some of the gabbro was older than the syenite-granite.

The anorthosite was first believed to have the form of a batholith. Later it was thought to be a laccolith. The border which surrounded the anorthosite, sometimes approaching the composition of a gabbro and sometimes having the appearance of Whiteface anorthosite, has been interpreted as a chilled border of the anorthosite magma. Certain areas of rocks, called Keene gneiss, have been considered to be the result of assimilation or actual fusing of the still hot anorthosite by syenite or granite. Dikes of syenite and granite cutting anorthosite; dikes of anorthosite in older rocks; inclusions of older rocks in anorthosite and contact effects of anorthosite on these rocks have been cited as evidence, on the one hand, of the intrusive character of the anorthosite, and, on the other, of its greater age. Many discussions of these views have appeared in the publications on Adirondack geology and it is not necessary to go into details of the theory. Cushing ('07), in his report on the geology of the Long Lake quadrangle, first presented evidence to show that the anorthosite was distinctly older than the syenite-granite series.

Bowen ('17) advanced the theory that all the igneous rocks of the Adirondacks represent the products of a single parent magma that had differentiated in place. Basing his work on a physico-chemical study, Bowen concluded that the anorthosite was "never liquid as such, but that its material when liquid was part of a solution of a gabbroid nature" ('17, p. 211). He stressed the simple mineral composition of the anorthosite and pointed out that most rocks are made up of several minerals and that their magmas are considered as mutual solutions of the various substances present. This allowed the magma to remain "liquid at temperatures far below the temperatures of fusion of the individual minerals that enter into the magma" ('17, p. 209). Field evidence does not uphold the alternative theory that these nearly monomineralic rocks were exceptional as to temperatures before crystallization.

The Adirondack anorthosite is interpreted by Bowen as part of a stratiform laccolith or lens-shaped mass, resulting from the fractional crystallization of a gabbroic magma. This resulted in the formation of a layer of pyroxene and gabbro at the bottom, due to sinking of femic minerals; overlain by a layer of anorthosite formed by the sinking of labradorite crystals. Syenite and granite formed the upper layer and crystallized from what remained of the magma after minerals forming the anorthosite and gabbro had settled out.

At the time Bowen presented his theory, relatively little had been published on structural relations of the igneous rocks in question. Various field facts which were known to the Adirondack geologists, mainly Cushing, Kemp and Miller, contradicted Bowen's theory. The chief objections have been discussed by Cushing ('17), Miller ('18, '29) and Alling ('32). The objections given below are taken principally from Miller's paper ('29 p. 396-97).

(1) The sharply defined inclusions of Grenville rocks which occur in various border portions of the anorthosite. These appear to have been enveloped in an active magma.

(2) Clearly defined inclusions of anorthosite occurring in the syenite-granite series. Could fragments of the anorthosite, if formed by the settling of plagioclase crystals, have been forced upward by some process into the syenite-granite magma? Is it not far more plausible to regard such inclusions as indicating the envelopment of previously solidified anorthosite in an active syenite-granite magma?

(3) Tongues and dikes of syenite and granite occur as offshoots of the great syenite-granite series. These are known definitely to cut the anorthosite in many places. Must we assume that masses of overlying molten syenite or granite were forced downward into the anorthosite?

(4) In some places there is clear evidence that anorthosite has cut to pieces and intimately injected the Grenville strata. Could such injection gneisses have developed except by forcible and intimate intrusion of highly molten anorthosite into the Grenville?

(5) Certain areas of mixed rocks consist of anorthosite literally cut to pieces by syenite. These often show fairly sharp contacts. Such a relationship is anything but stratiform as conceived by Bowen. Gabbro, also, occurs as individual masses and not as a basal layer. Syenite-granite, according to Bowen's theory, would be expected to occur within the "chilled" border of anorthosite. However, it is found to occur mainly outside of this border.

(6) The anorthosite is by no means an almost perfectly homogeneous mass of plagioclase. From 2 to 10 per cent of other minerals are common, and local facies carry 10 to 20 per cent, or more, of dark minerals. Is the mutual solution theory, therefore, necessarily excluded?

(7) Foliation of the anorthosite is by no means rare, and it is believed that it was produced essentially by forced differential flowage in a congealing magma.

Both Cushing and Miller believed that some of the features mentioned above might be harmonized with Bowen's hypothesis, but that these field facts on the whole render the hypothesis untenable. They were convinced, however, that the syenite-granite series is a distinctly later intrusive, in which crystal settling was not operative.

Miller ('29, p. 394) has advanced the following theory for the origin of the anorthosite:

First, laccolithic intrusion of a gabbroid magma; second, relatively rapid cooling of the upper and outer portions to give rise to a chilled, gabbroid, border phase; and third, settling of many of the slowly forming femic minerals in the still molten interior of the laccolith, leaving a great body of magma to crystallize into anorthosite.

Balk ('31) made a detailed study of Adirondack anorthosite, emphasizing the physical and structural aspects of the problem rather than the petrographic and physico-chemical aspects.

Separation of labradorite crystals and of ferromagnesian minerals and their accumulation in a still liquid residual magma, similar to Bowen's theory, is postulated. Instead of the process taking place under conditions of rest, however, the magma is pictured as in motion during the entire process. The magma is believed to have been intruded in the form of a great sill or lens dipping to the north and northeast. The forward motion of the magma was sufficient in most cases to overcome the downward settling process. The liquid material moved faster than the already solid particles, which lagged behind on account of friction among themselves and with the older Grenville rocks which formed the walls of the magma chamber.

Balk ('30, p. 296–97) states that:

The exposed structural features point to the following process of emplacement and differentiation: A "parent magma" in which appreciable quantities of solid labradorite and also ferromagnesian minerals were already suspended has been intruded into the Grenville formation from the north and northeast . . . obliquely upward to the south and southwest. The farther the magma advanced, the narrower grew the channels along which it moved, the greater became the effect of friction between the magma and the relatively stationary walls, as well as between the magma and its suspended crystals. The increasing friction must have retarded the motion of the suspended crystals; it has gradually crowded them together and reduced the mobility of these gathering crystal masses. The liquid portion of the parent magma ("syenite"), however, has continued to move on, probably as far as 10 or 20 miles into the Grenville strata, always conformable to the gliding planes of the (partly liquefied) sediments.

a *The anorthosite.* Because of the widening and coalescence of the originally narrow channels, due to the intrusion of additional magma, the arrested crystals have gradually united and formed a central body of labradorite. It has apparently grown under great pressure and little by little as new crystal residues were left behind by the passing parent magma. The crystals were predominantly labradorite (anorthosite), but there were also smaller quantities of ferromagnesian minerals (gabbro), and still smaller portions of mother-liquor, trapped here and there between the potentially solid blocks of crystals (local syenitic schlieren in anorthosite and gabbro). What is now a large body of anorthosite, covering some 1,200 square miles on the surface, seems to have been originally a much smaller cluster of labradorite which has gradually attained its present size owing to the constant addition of arrested crystals. The oldest part of the anorthosite lies in the southwest, and the youngest portions are in the northeast.

The advance of parent magma must have continued over an extremely long period of time. Passing through the space where the crystals were gathering, it seems to have pushed them about, stirred them up and disturbed them time and again, so that for a long time the clusters of crystals could not come to rest, although they have frozen into smaller blocks here and there.

This unique stage in the history of the anorthosite has left unmistakable traces: anorthosite is known as a thoroughly protoclastic rock in which practically every crystal of labradorite has its crushed border. In addition, many exposures display what might be termed a "block structure," in which the rock consists of a multitude of round or angular blocks, each one differing in color, proportion of labradorite phenocrysts, and mineral composition. There are almost always shear zones along the surfaces of these blocks of different composition, and it is a common thing to see blocks of anorthosite surrounded and included by anorthosite of slightly different color. These are features unknown from any other igneous rock, as far as the writer knows.

Apparently, mother-liquor and crystals separate owing to frictional forces. These forces are the stronger, the narrower the available channels and the larger the proportion of suspended crystals in the parent magma. The principle of "filter pressure" and "squeezing out," often advocated by Bowen, seems best to explain the observed phenomena, even though the mechanical problems implied by these terms lack, as yet, accurate experimental investigation.

When Bowen presented his theory the structural features of the Adirondacks had not been worked out in detail. Many of the objections against Bowen's theory that the igneous rocks of the Adirondacks are the differentiates in place of one parent magma are untenable when interpreted in the light of Balk's studies. A discussion of these objections in relation to Balk's theory is presented here.

1 One of the main objections was the stratiform arrangement of the rocks as presented by Bowen. It is no longer necessary to assume that the syenite-granite was forced downward into the underlying anorthosite. It is possible for the anorthosite to have been cut by syenite and granite, just as dikes of granite and pegmatite cut the syenite-granite itself. Labradorite crystals which make up the anorthosite proper accumulated as small clusters, most of them finally coalescing into one large mass, but it is to be expected that many small groups remained separate from the main mass and now appear as inclusions in the syenite-granite. Small masses may also have broken away from the main mass, and been carried along by the syenite-granite. The accumulations of gabbro have not settled to any great extent in relation to the original magma and have accumulated as small rounded or elliptical bodies and not as a basal layer.

2 The Whiteface and gabbroic facies of the anorthosite are interpreted by Balk as a foliated and crushed border of the anorthosite and not a chilled border as previously held. Therefore, the syenite-granite is expected to occur mainly outside of this border rather than inside it. Keene gneiss, instead of being a fusion of anorthosite and syenite, represents syenite with a few stray labradorite crystals that had not joined a larger cluster of crystals.

3 It is expected that foliation would be developed as the whole mass was in motion during the entire process of solidification, so that ferromagnesian minerals would frequently be arranged in streaks or bands and labradorite crystals often given a parallel arrangement. The block structure of much of the anorthosite is the result of long-continued movement within the magma during solidification. This structure is believed to be a very strong argument in favor of Balk's interpretation.

4 A perfectly homogeneous mass of plagioclase would not be expected under such an interpretation. It is also entirely possible to have "anorthosite dikes" if the rocks still contained sufficient interstitial liquid. Bowen states that 50 per cent liquid would give a rock with 85 per cent plagioclase and 15 per cent diopside, and that as soon as the bisilicates amount to 20 or 25 per cent there is no lack of evidence of the power of the mixture to penetrate openings in the surrounding rock. It is also possible for nearly pure labradorite dikes to occur if the interstitial liquid had continued to move on leaving the already solid labradorite crystals behind.

5 One important question, which has already been raised and which needs considerably more study, is the occurrence of inclusions

in anorthosite. Inclusions of Grenville in anorthosite are not an objection to Balk's theory, as labradorite crystals would tend to be retarded by and gathered about any solid masses in the original magma. Grenville inclusions would be expected to be caught up frequently in the forward-moving magma. An important problem, however, is the fact that many of these inclusions appear to have been attacked by a magma rich in basic plagioclase. In connection with this the composition of the original magma seems to be of vital importance. Bowen ('17) believed that the original magma was gabbroic in composition. Balk ('31, p. 400–1) is of the opinion that it was more acid, probably a diorite. His reasons for this conclusion are that syenite-granite is very widespread and that the known gabbro masses are not sufficient to account for all the basic minerals that must have been present in the original magma, if it was of gabbroic composition. He points out that one difficulty in determining the composition is the difficulty of distinguishing the syenite-granite of the anorthosite series from the granite of a preanorthosite stage which is widespread in the western part of the Adirondacks and may occur to some extent in the eastern Adirondacks. Alling ('32) points out that many Grenville rocks seem to show evidence of having been soaked by a magma rich in plagioclase and suggests that an original gabbroid magma would readily account for this. It is possible, however, that much of the basic plagioclase in the Grenville rocks may be due to soaking by an earlier basic intrusive, which a study of many thin sections of Grenville rocks indicates must have occurred. It is also possible that more detailed study of the feldspars in question would show that many of these have the composition of oligoclase rather than a more basic feldspar. Oligoclase is a common mineral in the syenite, especially the more basic types. Balk ('32, p. 21; see also Barth, '30, p. 134) found that the plagioclase minerals of the anorthosite-syenite series in most cases consist of either oligoclase or andesine-labradorite. Many of the previous reports list plagioclase feldspars as ranging from oligoclase to labradorite with no indication of the distinct break between the composition of the two plagioclases.

The writer is of the opinion that evidence found in the Thirteenth Lake quadrangle supports Balk's theory in regard to the relation and origin of syenite and anorthosite, although the problem is by no means solved. Numerous dikes of syenite do occur throughout the anorthosite. But the existence of these does not seem to impair in any way the validity of the hypothesis that the anorthosite is a differentiate of the same magma as the syenite. The syenite and granite are themselves cut by dikes of granite and pegmatite. The following example of this occurs near the southeastern end of Mill Creek pond. An outcrop of syenite is cut by a small medium-grained granite dike and the whole mass is cut diagonally by a pegmatite dike nearly six inches in width. According to the writer's interpretation, the anorthosite, which consisted of already solid clusters of labradorite, was surrounded by still molten syenite and was, therefore, in a more favorable condition for being cut by dikes than was the syenite-granite.

Following Balk's suggestion, it is believed, however, that many of these "dikes" may be interpreted as the residual magma which solidified during the process of being squeezed out from the already solid anorthosite. The striking lack of sharp boundaries would, of course, be expected if this is what had occurred. Careful inspection shows that many of these "dikes" do not have typical dikelike form, but often occur as more or less irregular masses apparently working out from a central body. An excellent example of this occurs in the Marcy anorthosite on the top of Durant mountain (figure 13). In a similar manner the alkali feldspars and quartz which occur as interstitial grains around larger labradorite crystals represent residual material of the syenite magma which solidified in the process of being squeezed out. It is also possible that many of the so-called dikes of syenite and granite are sill-like masses such as are described below.

The sill-like relation of syenite-granite and anorthosite is an interesting feature that is well developed in the Thirteenth Lake quadrangle. This can be best seen on the southeastern slope of the Big range from the valley of Robb creek to the top of the mountain, where syenite-granite and Whiteface or gabbroic anorthosite occur. Most of the rocks are strongly foliated with the foliation dipping consistently to the northwest at angles between 15° and 35°. The southeast slope of the range is extremely steep, and many excellent exposures occur from top to bottom. A series of steps, consisting of nearly vertical ledges a few feet to 20 or 30 feet high, with intervening flatter areas occur. Layers of syenite, granite and anorthosite alternate and frequently in a single ledge the gradation from syenite or granite to anorthosite is exposed. This feature has been discussed with Doctor Balk, who said he knew of no other place in the Adirondacks where this relation is so excellently exposed.

Most of the syenite and granite is fine-grained and intensely foliated. Frequently the syenite contains labradorite crystals. A typical specimen is a light orange-yellow color on weathered surface and dark gray when fresh. It is fine-grained and very strongly foliated.

The anorthosite is mainly of the Whiteface variety. A specimen from 2820 feet on the southeast slope of the range is medium-grained and very light in color. It contains white, light grayish and slightly pinkish labradorite feldspars, which have been crushed and granulated, as well as a few bluish gray, uncrushed labradorite crystals. Foliation is strongly emphasized by the grouping of dark minerals in streaks. The ferromagnesian minerals, however, do not amount to more than 15 per cent of the rock. Another specimen is slightly coarser in texture. A few garnet crystals as large as one-half inch in diameter occur. Very small flakes of ferromagnesian minerals are scattered throughout the rock, but are not abundant. The structure is massive.

Nearly all of the top 300 feet of the southeast slope of the mountain is Whiteface anorthosite. Below this is a layer of syenite and granite with some hornblende-garnet gneiss. The greatest variety of rocks occurs in the bottom 600 or 700 feet of the slope. Syenite occurs at the base of the mountain west of Robb creek. About 100 feet above this is Whiteface anorthosite with narrow layers of syenite and granite within it, then syenite with labradorite crystals, followed by syenite and granite showing well developed foliation and quartz plates. Above this is more Whiteface anorthosite. This is repeated on a small and large scale over the entire slope. The different layers appear to be continuous along the strike for some distance.

At the northeast end of the range on the northwest side of the valley between South Pond mountain and Big range, an outcrop of syenite occurs. Above it, and exposed in the same ledge is Whiteface anorthosite, and about ten feet above the base of the latter (but not in the same exposed ledge) is syenite. The rocks all dip 30° to the northwest.

Because of the inaccessibility of the region this interesting area of anorthosite and syenite-granite has not been studied in as much detail as the features found there seem to warrant. It is not known whether most of the individual layers are continuous along the strike for any distance, or not. Results of field work on the extension of Big range to the west into the Indian Lake quadrangle during the summer of 1932 indicate that the layers may occur as wedge-shaped masses which taper out at one end. One large-scale example of a wedge-shaped mass of granite between anorthosite was mapped. One mile southwest of the Indian Lake quadrangle-Thirteenth Lake quadrangle boundary line this granite is nearly one mile wide. On the boundary line it is about one-half mile wide, and one mile northeast of this line it tapers out to nothing. The foliation of both rocks is conformable to the contacts and dips to the northwest.

The same sill-like structure occurs on top of County Line[1] mountain. The top of the highest peak of the range is Whiteface anorthosite. Ten feet below the top to the south is granitic syenite. One hundred feet below Whiteface anorthosite again occurs with syenite below it. All the rocks dip about N. 15° E.

In the area north and northeast of Siamese ponds the syenite also occurs as sill-like masses or lenses in anorthosite, but not nearly so extensively, or so well developed as on the Big range. The same relationship was found on Siamese mountain and on the hill (2040 feet) south of the junction of Siamese brook and East Branch Sacandaga river.

All of South Pond mountain is a complex mixture of syenite and anorthosite. The foliation of the rocks appears to be conformable, but not nearly as regular as on the Big range. Horseshoe mountain has a similar alternation of syenite and border phase (or Whiteface) anorthosite, with occasionally cross-cutting dikes of syenite and coarse pegmatite in the anorthosite.

Wherever the border between anorthosite and syenite or granite was observed, evidence of a foliated border zone was found. Sharp contacts were absent. In the southern area of the anorthosite the Marcy type is located toward the center of the mass. As the borders are approached the rock becomes more of a gabbroic anorthosite, usually with a foliated structure. In thin section the rock is seen to contain a larger percentage of antiperthite than the normal anorthosite, as well as oligoclase, orthoclase and a little quartz. The contact about one-half of a mile north of Fish ponds is typical of many contacts and is worthy of mention. The rock at the top of the hill east of the contact is normal, slightly porphyritic granite. As the valley is approached the rock becomes more syenitic in appearance and contains labradorite crystals. Just west of the valley the rock is foliated gabbroic anorthosite, and this rock continues for at least one-half a mile to the west before Marcy anorthosite is encountered.

The contact between anorthosite and granite at the western end of Eleventh mountain is similar to that just described. The anorthosite north of the Siamese trail is a foliated gabbroic anorthosite. In the valley just west of the contact the rock is more strongly foliated and contains a larger percentage of ferromagnesian minerals. It then becomes more nearly syenitic, and east of the valley it is a strongly foliated granite.

The rock associated with anorthosite at the northeast end of Thirteenth lake is of special interest. A considerable amount of labradorite crystals from two to three inches long occurs in a groundmass of typical foliated syenite. The labradorite crystals are oriented parallel to the foliation of the groundmass. The foliation dips 30° to the northeast, away from the anorthosite. This transition zone between typical syenite and gabbroic or Whiteface anorthosite is from one-quarter to one-half a mile wide. Typical Marcy anorthosite occurs to the southwest of this "Keene gneiss" area. A study of thin sections of both types of transition rock discloses that a large amount of orthoclase and sodic plagioclase is present.

The writer believes that the presence of labradorite crystals in syenite, especially at some distance from associated bodies of anorthosite, is good evidence of the close relation between syenite and anorthosite, as suggested by Alling ('32, p. 237). There are many places where labradorite crystals occur in the syenite of the Thirteenth Lake quadrangle. Many of these are located along the border between syenite or granite and anorthosite. These are the areas of so-called Keene gneiss. Labradorite crystals in syenite are, however, frequently found at considerable distances from any known anorthosite. Some of these localities are as follows:

In rocks bordering anorthosite

1 Northeast end of Thirteenth lake
2 Along the trail about one mile southeast of Thirteenth lake
3 South slope of Slide mountain, one-eighth of a mile east of Peaked Mountain brook. The syenite contains many labradorite crystals arranged parallel to the foliation of the syenite, and the whole mass is cut by a small granite dike.
4 East side of the contact between granite and anorthosite, one-half of a mile north of Fish ponds
5 The area for three-fourths of a mile east of Robb creek
6 On the south peak of South Pond mountain
7 The divide south of South Pond mountain
8 Three-eighths of a mile southeast of the top of Big range
9 One-fourth of a mile south of Sound pond
10 One-half of a mile southeast of Moose mountain

In syenite at some distance from anorthosite

1 One-fourth of a mile west of the north end of Botheration pond (two and one-half miles from anorthosite on the west and one and one-half miles from anorthosite on the east)
2 One mile northeast of Bakers Mills (three and one-half miles from the nearest anorthosite)
3 One-fourth of a mile north of east end of Puffer pond (one-half of a mile from anorthosite)

4 South slope of Slide mountain (one-fourth of a mile from anorthosite)
5 Top of west peak of Height of Land mountain (one and one-half miles from anorthosite). Some of the rock here appears to be border phase anorthosite
6 One-half of a mile west of Twin Pond brook and one and one-fourth miles northwest of East Branch (one-half of a mile from anorthosite)
7 One and one-half miles west of Peaked Mountain pond (one miles from anorthosite)
8 In many places in the syenite of Gore mountain and on the ridge northeast of Gore mountain (one-half to one mile from anorthosite)
9 One-half of a mile south of Mill Creek pond (three miles from anorthosite)

In conclusion it should be said that the theory presented by Balk has been found more satisfactory than those previously given, in the interpretation of the field facts found in the Thirteenth Lake quadrangle. There are, of course, many features to which the writer would give different interpretations. The association of anorthosite and syenite-granite on the Big range and at other localites suggests a very close relationship between these rocks and supports Balk's conclusion that they have a lens-shaped or sill-like structure. The writer agrees, however, with Alling ('32) that the major problems regarding Adirondack geology are far from solved and that a much more detailed study of the Adirondacks, along the lines suggested by Balk, as well as microscopic studies, will be necessary to unravel the many complex problems.

SYENITE-GRANITE SERIES

General statement. Throughout the eastern Adirondacks the syenite-granite series is abundantly developed; it consists of a variety of rocks ranging from basic syenite to normal granite. Petrographic terms such as akerite (Cushing, '99), laurvikite (Kemp and Alling, '25, p. 52), and nordmarkite or quartz nordmarkite (Kemp and Alling, '25, p. 42) have been applied to these rocks, but these terms are not considered sufficiently comprehensive for the whole group.

In the western Adirondacks some of the granite is considered Laurentian in age. Cushing ('15) has also advocated the presence of two distinct granites (Laurentian and Algoman) for the eastern

Adirondacks. This problem has frequently been discussed by Miller, who concludes that the granites of the eastern Adirondacks are of the same age (Algoman). He admits, however, the possibility that some of the granite may be older, but does not believe that it would ever be feasible to map them as separate units. Balk ('32, p. 15) has found that in the Newcomb quadrangle rocks which can be definitely mapped as Laurentian granite are extremely rare. He cites a few exposures where the age relation of the two granites could be determined. In the Thirteenth Lake quadrangle no older granites have been definitely recognized. Small masses of rocks, usually associated with the Grenville sediments, may represent an older granite. These rocks are usually rusty colored, due to the oxidation of pyrite. Balk concludes, however, that "Even if the few exposures of Laurentian granite were concealed, the existence of an older magma could be inferred from the occurrence of injected, highly feldspathic rocks within the Grenville formation, without any noticeable relation to the local distribution of syenite." As already stated on page 22 of this bulletin, most of the Grenville rocks show the effect of attack by igneous material, and it is probable that much of the acid igneous material has come from an older granite, rather than from the younger Algoman granite or syenite. The writer, however, agrees with Miller and Balk that the older, Laurentian granite is extremely rare and difficult to recognize in this part of the Adirondacks, and that the larger masses of granite free from Grenville strata are of Algoman age.

The age relations of the syenite-granite series to the Grenville sediments, anorthosite and gabbro have already been discussed in the preceding chapters. The syenite-granite is younger than the sedimentary rocks, as shown by the fact that dikes and pegmatites of granite and syenite have cut the older rocks, in places surrounding them as inclusions, and it has also partially assimilated them. It is also relatively younger than the gabbro and anorthosite, since these rocks occur as large inclusions in the syenite-granite with syenite foliation flowing around them. Dikes of syenite-granite are also found cutting the more basic rocks. In this report the acid rocks are interpreted as a differentiate in place of the same magma which produced the more basic types.

The rocks of this series consist of syenite and medium-grained, prophyritic and coarse-grained granite. All gradations, however, between the various types are found in the field and in thin sections. Sharp boundaries between them do not occur. Certain areas have been mapped as syenite, while others are shown as consisting of granite. Many small lenses or layers of granite, however, may occur in the syenite areas and vice versa.

Syenite. The rocks belonging to the syenite group show all gradations from basic syenites to quartz or granitic syenites. The quartz syenite is probably the most abundant throughout the eastern Adirondacks. It is normally a medium-grained, moderately foliated rock, which is usually greenish gray in color on a fresh surface and light brown when weathered. The color may be locally light gray or pinkish gray. The foliation is brought out by more or less straight, parallel streaks or narrow bands of dark ferromagnesian minerals. Most of the rocks show a considerable degree of foliation, although in some it is practically absent, while other rocks show very intense foliation. Hornblende, pyroxene and occasionally biotite are nearly always present either separately or collectively. The feldspars consist of perthite, microperthite, orthoclase and a small amount of oligoclase. Quartz is present in varying amounts up to 25 per cent. It occurs as rounded grains or as large platelike masses. Occasionally phenocrysts of perthite up to an inch in length are present, although they are not abundant, being only locally developed. As previously stated in the chapter on anorthosite, bluish gray labradorite crystals, ranging from one-fourth of an inch to three or more inches in length, and arranged parallel to the foliation of the syenite, are frequently found. These may be especially abundant near the anorthosite areas, but they also occur at a distance of several miles from the anorthosite. The relation of syenite to anorthosite has already been discussed.

Garnet is not a common mineral in the syenite of the Thirteenth Lake quadrangle. This in itself is an unusual feature, as in all the remaining igneous rocks of the area, and in many of the Grenville sediments, garnet is one of the conspicuous rock components. Wherever garnet does occur in the syenite, it is usually confined to the contact with some other rock or near the garnet deposits. Where large crystals of garnet occur, they are usually well developed, with the foliation of the syenite passing around them. An excellent example of this is found in the syenite, just south of the Barton garnet deposit. Garnet, mainly as small crystals and irregular masses, is common in the granite and more acid phases of the syenite.

In thin section the syenite shows all gradations from a basic variety to a more acid, granitic type. The most common variety is an acid syenite, containing perthite, microcline-perthite, myrmekite-like intergrowths of quartz and orthoclase, plagioclase feldspars of oligoclase composition and a varying amount of quartz. Hornblende and pyroxene, either hypersthene or augite, are present in varying amounts, but they are usually not abundant. A small amount of biotite may be present. Pyroxene, hornblende and biotite frequently occur in the same thin section. Magnetite, ilmenite, zircon, titanite, apatite and a little garnet are minor accessory minerals which, at times, are more abundant than the ferromagnesian minerals. The ferromagnesian minerals are frequently somewhat altered, often to a brownish-looking mass. A small amount of sericite, serpentine, leucoxene and occasionally chlorite is present. An interesting characteristic of all the dark minerals in both the syenite and granite is the irregular, more or less "chewed" appearance of the crystals. Where the rock is at all foliated they are elongated parallel to the foliation, but they do not have definite crystal outlines.

From a study of thin sections it is observed that as the rock becomes more acid, an increase in microcline, perthite and quartz, with a corresponding decrease in plagioclase, is noticeable. In the more basic types, the quartz, microcline and perthite may entirely disappear, and plagioclase feldspars (oligoclase) become more abundant. Varying amounts of orthoclase are usually present. A common characteristic of the plagioclase feldspar in the more basic type of syenite, as well as in some of the border phase anorthosite, is its lack of twinning or such faint twinning that it can be seen only with the high power.

A specimen of basic syenite from the north slope of Eleventh mountain is quite similar to the normal, foliated quartz syenite, but contains an abundance of small garnets. A thin section (S-13) of the rock contains hornblende, hypersthene, augite, garnet, apatite, magnetite and zircon. These are the same minerals common to the quartz syenite and granite. Most of the feldspar is oligoclase with a little orthoclase, perthite and quartz.

Syenite is extensively developed in the northern half of the Thirteenth Lake quadrangle covering more than one-fourth of this area. A large part of the rock is quartz syenite. Usually quartz can be recognized only in thin section, but occasionally it is abundant and easily recognized in hand specimen. This is especially true of the rocks on Slide mountain and to the northwest. Miller ('29) mapped much of this area as granite. The writer believes, however, that the quartz content, except locally, is not high enough to class the rock as granite. Small masses of basic syenite also occur in many localities. Among these are the outcrops on the north slope of Eleventh mountain and along the road northeast of Bakers Mills. Several smaller areas of syenite, covering not over one-fourth of a square mile, occur. In addition there are numerous small sills of syenite or granite both in the Grenville rocks and in the areas of anorthosite.

Granite. Many of the statements made in regard to foliation, texture and general appearance of the syenite apply also to the medium-grained granite. The color of the granite is frequently pink of varying shades, due to the color of the feldspar. Large masses of it, however, are light brown in color due to weathering; fresh exposures are rare. Some of the rock is greenish gray like most of the syenite. Locally it is white.

Often the only distinguishing characteristic between granite and syenite is the quartz content. All gradations, from rocks containing only a small percentage of quartz to those carrying 30 or 40 per cent, are found. A large portion of the rock of Slide mountain and to the north is a granitic-syenite, on the border line between syenite and granite. The gradation into normal quartz syenite is so gradual that boundary lines could not be mapped.

In addition to quartz and feldspar, hornblende, biotite, pyroxene and garnet can frequently be recognized in the hand specimen. These rocks exhibit all degrees of foliation, ranging from massive types which are essentially nonfoliated to strongly foliated and intensely granulated rocks. Where the rock is at all strongly foliated the quartz is drawn out in the form of thin flat plates often as much as six inches long and varying in width from minute dimensions up to about one-fourth of an inch. This is one of the most striking features of much of the granite of the Thirteenth Lake quadrangle; it is especially well developed on the summit and southern slope of Puffer mountain and the mountain to the south of it. In fact, most of this western area of granite is of this type, as well as the granite of the Cross Brook area in the central part of the quadrangle, and parts of the southeastern area of granite. These quartz plates sometimes have a wavy appearance corresponding to the undulations on the foliation of the granite. The ferromagnesian minerals are often concentrated along the edges of the quartz.

The granite frequently grades into quartz syenite, this feature being especially noticeable along the borders between syenite and granite areas. Pegmatities, both parallel to and intersecting the foliation are occasionally found in both the syenite and granite.

Granite is well developed in the Thirteenth Lake quadrangle, covering about 11 square miles in all. It occurs mainly in the northwestern part of the quadrangle, and in many places throughout the larger eastern area of porphyritic granite and as small sill-like masses in the other rocks of the quadrangle.

In thin section the granite closely resembles the more acid phases of the syenite. Quartz is more abundant, however, occurring as small crystals and as long stringers or plates that may show optical continuity over considerable areas, although they are frequently made up of interlocking quartz crystals. These stringers of quartz sometimes extend entirely across a single slide. Microcline and perthite are very abundant. Twinned plagioclase feldspars are not so numerous as in the syenite. A varying amount of ferromagnesian minerals occurs. At times they may amount to only a few per cent, but usually they are more abundant. They consist mainly of hypersthene, augite, hornblende and occasionally biotite. Garnet, apatite, magnetite, ilmenite and zircon, with occasional titanite crystals are present as accessory minerals, although, at times, these minerals may be more abundant than the ferromagnesian minerals. The ferromagnesian minerals show a parallel arrangement and often occur as bands with intimate mixtures of pyroxene, garnet, magnetite, ilmenite, apatite and any other dark minerals which may be present.

Alteration in the granite is not pronounced. Sericite has been developed from some of the more basic feldspars, and biotite sometimes shows alteration to chlorite and serpentine. Small quantities of leucoxene, and hematite or limonite are present.

Medium-grained porphyritic granite is also developed throughout the Adirondacks, and most of the eastern (Eleventh mountain) area of granite in the Thirteenth Lake guadrangle is of this type.

In typical facies it is similar in every respect to the medium-grained granite, with the exception of phenocrysts which are embedded in the finer groundmass. It is gray to pinkish gray in color, and moderately to highly foliated, frequently containing well-developed quartz plates. The phenocrysts consist of alkali feldspar, usually perthite, up to an inch in length, more or less flattened parallel to the foliation. These phenocrysts are embedded in a fine to medium-grained groundmass consisting of feldspar (microcline-perthite, perthite and orthoclase), quartz and ferromagnesian minerals (hypersthene, hornblende, biotite) and accessory minerals. The phenocrysts usually have the form of augen with the dark mineral streaks bending around them. They vary considerably in number

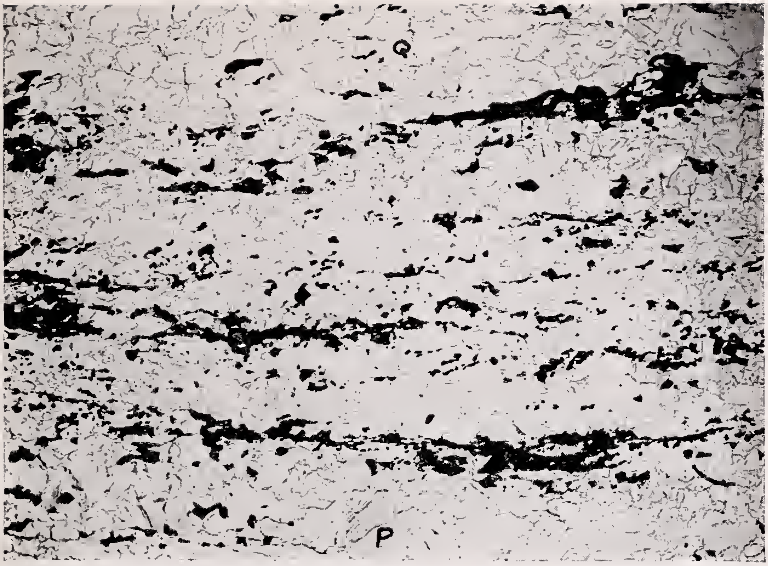


Figure 14 Photomicrograph of strongly foliated, fine-grained grano-syenite from the Big range. The ferromagnesian minerals forming the black streaks have very irregular outlines. The groundmass is quartz and feldspar. Note the large crystal of perthite (P) in the lower center of the picture and the long stringer of quartz (Q) in the upper part. Plain light. x 23

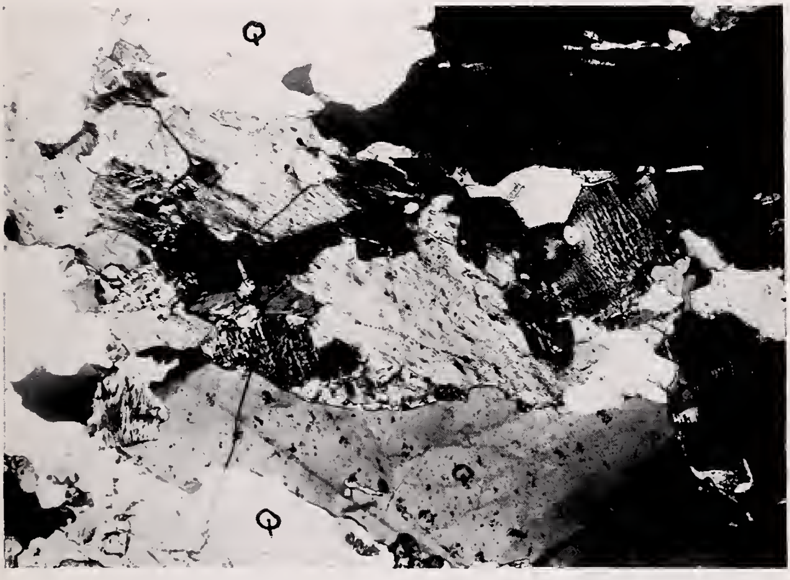


Figure 15 Photomicrograph of coarser grained granite, showing long quartz (Q) crystals and smaller crystals of perthite. Crossed nicols. x23

Figure 16 Photomicrograph of a basic dike, composed mainly of plagioclase and pyroxene. Note the lack of diabasic structure. Crossed nicols. x35

Figure 17 Basic dike ten inches wide cutting the garnet deposit on the west slope of Ruby mountain

from specimens in which they are numerous, to other localities where only a few, scattered crystals occur in otherwise typical medium-grained granite. At times the quartz content diminishes to such an extent that the rock is a porphyritic syenite. All the above types are well developed in the Eleventh Mountain granite area. Granulation is usually a notable feature of the rock, this being particularly true of many of the feldspar phenocrysts whose highly granulated texture is visible in a hand specimen.

There are many excellent exposures of this rock in the numerous ledges which occur on Eleventh mountain. It is usually highly foliated and moderately porphyritic. Small garnets are distributed locally throughout the rock. The granite to the south of Eleventh mountain is, on the whole, much less porphyritic and frequently more syenitic in composition.

Miller has suggested in his report on the Luzerne quadrangle ('23) that the porphyritic granite owes its origin to the injection and assimilation of dark Grenville gneisses by the granite, rather than having formed as a simple magmatic differentiate from the syenite-granite series. Many of the thin sections of the granite of the Thirteenth Lake quadrangle suggest that they may have had a similar origin.

Coarse-grained granite is rather abundantly developed throughout the Adirondacks, but almost none of the granite of the Thirteenth Lake quadrangle is of this type. In its typical development the rock is strikingly different in appearance from the syenite and the medium-grained granite, although it shows every possible gradation into medium-grained granite. A very small amount of this type of granite was found on the eastern slope of Eleventh mountain.

BASIC DIKES

Basic dikes have been mapped throughout the eastern Adirondacks. They are frequently referred to as diabase dikes of late Precambrian age (Keweenawan). Some of them are believed to be camptonite dikes related to the post-Ordovician dikes of the Champlain valley (Kemp, '21). The number of dikes found in the different quadrangles varies considerably. Miller ('26) has mapped 120 in the Lyon Mountain quadrangle. In most areas they are less numerous. Twenty-four have been mapped in the Thirteenth Lake quadrangle. Many others may exist, which were not seen in the course of the field work. In several places dark rocks somewhat similar to the dike rocks were found, but where field associations were obscure one could not be certain of the exact character of the rock.

The basic dikes of this area are dark, usually black, in color with a very fine to medium-fine texture. They frequently exhibit chilled borders, especially on the edges of the larger dikes, which may have a medium texture in the center. They range in width from a few inches to 50 or more feet, but the majority are less than one foot in width. These dikes have been intruded along joint planes in the older rocks. Most of the dikes of this type in the eastern Adirondacks have a northeast-southwest strike, following the principal jointing of the region. In this area, however, the greater number of these dikes have a northwest-southeast strike; only occasional ones strike north-south or northeast-southwest. With four exceptions all of the dikes observed occur in anorthosite, confined to a comparatively small area in the middle southern part of the quadrangle.

Only a few of the dikes of the Thirteenth Lake quadrangle have a true diabasic structure. The small ones are relatively finer grained than the larger ones, which at times resemble a fine-grained gabbro in hand specimen. Many of the dikes, especially the larger ones, are garnetiferous. Thin sections show basic plagioclase feldspar (50–60 per cent), with hypersthene, augite, green hornblende, varying amounts of magnetite and garnet and a small quantity of biotite. Some of the smaller, finer grained dikes are composed almost entirely of plagioclase and hypersthene (figure 16).

A few of the dikes which have been mapped in the quadrangle deserve special mention. A large one of unknown width occurs in East Branch Sacandaga river, three-fourths of a miles northwest of Cod pond. This dike follows a crush-zone in anorthosite which undoubtedly represents a fault. The anorthosite in the bed of the stream and in the walls of the gorge is broken up by many closely spaced joints, often showing slickensides on their surfaces. The dike itself is notably crushed. Several branch dikes from eight to 15 feet wide can be seen on the northwest wall of the gorge.

The largest dike in the quadrangle is of especial interest because of the control which it exerts on the topography. It extends up the side of the small mountain situated one and one-third miles northeast of the summit of Corner mountain in the southern part of the quadrangle. As seen from the main road just south of Stewart creek, a wide flat depressed gorge runs up the side of the mountain. High cliffs, almost vertical, form the east wall and lower cliffs the west wall. The gorge is 50 to 100 feet wide and the anorthosite walls of the gorge are from 50 to more than 100 feet high.

At the summit of Harrington mountain the anorthosite is cut by several small, roughly parallel, dikes with a north-south strike. The largest is only a foot wide.

The dike one-half of a mile south-southwest of Lizard pond sharply cuts the mixed gneisses. It is ten inches wide, fine-grained and garnetiferous.

Two dikes occur close together on the east slope of the Blue hills (peak, 2938 feet). Both are about 25 feet wide.

A dike on the northwest face of Moose mountain is two feet wide. It has various small branches cutting both anorthosite and the granite sills which occur in the anorthosite.

A small dike with diabasic structure extends along the contact between the garnet deposit and the small mass of anorthosite one and one-half miles northeast of the summit of Gore mountain and three-fourths of a mile south of Roaring brook.

At the north end of the Ruby Mountain garnet deposit the garnet gneiss is cut by a dike about ten inches wide which strikes N. 83° E., nearly parallel to the strike of the foliation of the garnet gneiss at this place. The dike is composed of garnet, pyroxene, magnetite and a very little basic plagioclase. It is medium to fine-grained in texture. The contact with the surrounding rock is sharp and about one-fourth of an inch of fine-grained, dense, black material borders the dike on each side. Such a large amount of garnet (30 to 40 per cent) occurs in this dike, that it is probable that the dike absorbed garnet from the surrounding garnet-rich rock (figure 17).

The dike on Shanty brook about one-half of a mile north of East Branch Sacandaga river is of interest. For some distance above the dike the rocks in the bed of the stream are strongly jointed in a north-south direction. The stream falls over a ledge of anorthosite about eight feet high, with the same strike, and flows for some distance in a narrow gorge. The west wall of the gorge is Marcy anorthosite. The east wall and the bottom of the gorge is a basic dike. The rock, however, closely resembles a fine-grained gabbro. There is a faint suggestion of diabasic structure in a hand specimen. A thin section shows many feldspars to be antiperthitic. It contains a large amount of garnet as imperfectly developed rims; large crystals of augite, some of which are triangular and some lath-shaped; brown biotite; olivine and magnetite. The centers of a few of the larger feldspars contain irregular patches of dark inclusions. In other words, the rock closely resembles a fine-grained gabbro with a dikelike form.

No very definite conclusions can be reached concerning the exact age of the basic dikes of this quadrangle. They are younger than the Grenville sediments, and also than any of the other igneous rocks of the region, as they are frequently found sharply cutting all of these rocks. The dike in East Branch Sacandaga river occurs in a fault zone; but as the dike rock itself is notably crushed it may have been intruded along a joint plane in the anorthosite which was later the location of faulting. This fault is of Ordovician or post-Ordovician age (page 84). Although the diabasic structure is usually lacking in these rocks, they are undoubtedly of the same age as the diabase dikes in the surrounding quadrangles.

OUTLIER OF CAMBRIAN SANDSTONE

Proof of the fact that Cambro-Ordovician seas spread over at least part of the Adirondacks is found in the occurrence of small remnants or outliers of Cambrian (Potsdam) sandstone and Ordovician (Theresa, Little Falls and Hoyt) limestone in 11 widely separated localities in the southeastern Adirondacks.

Many angular boulders of Cambrian (Potsdam) sandstone, strewn over a hillside in the northeastern part of the Thirteenth Lake quadrangle, one and one-third miles west of North River, undoubtedly locate the former position of a considerable extent of Cambrian sandstone. This sandstone was discovered and mapped many years ago by Kemp and Newland ('99). A careful search by these men, as well as by Miller and the present writer, has not revealed any actual outcrops of sandstone in this area. Hundreds of angular fragments and slabs of white sandstone, occasionally exhibiting cross bedding, are strewn over the hillside in this area and blocks up to 12 feet wide and four feet thick may be found among them. These blocks are so angular that it is quite certain they were not carried any distance by the glacier. They may, therefore, be considered as representing bedrock.

This outlier is situated farthest within the Adirondacks of any so far mapped. The nearest known similar occurrences are in the Schroon Lake quadrangle to the northeast and the Lake Pleasant quadrangle to the southwest. No Cambro-Ordovician rocks were found by Balk ('32, p. 12) in the Newcomb quadrangle to the north.

A full account of the Paleozoic outliers of the southeastern Adirondacks is given in a paper by Miller ('13). According to him, most of these occur on the downthrow side of prominent faults; because of this down-faulting they have been favorably situated against erosion. This is true of the sandstone occurrence of the Thirteenth Lake quadrangle which lies near the base of the high fault scarp of the Thirteenth Lake fault (page 88) (see also Kemp, '97).

STRUCTURAL GEOLOGY

The most detailed structural survey of the Adirondacks has been done by Balk, who has applied the structural methods of Professor H. Cloos to the Precambrian rocks of the Newcomb quadrangle ('32) followed by a study of the problems of the anorthosite and related igneous rocks of the eastern Adirondacks ('30, '31). Balk has recorded many interesting observations concerning these problems and undoubtedly many of his interpretations will be confirmed. Much more detailed work along these lines, as well as microscopic study of the structures, will eventually lead to a much better understanding of the complex Adirondack geology. In the western Adirondacks considerable attention has been paid to the structural problems, and important contributions have been made by Smyth and Buddington ('26) and Martin ('16).

While a detailed study of the structural features of the Thirteenth Lake quadrangle has not been made, certain observations tend to confirm some of Balk's interpretations of the structure of the igneous rocks of the eastern Adirondacks; and also some of the conclusions reached by Buddington and Martin in the western Adirondacks concerning both the sedimentary and igneous rocks.

STRUCTURE OF THE GRENVILLE SERIES

The interpretation of the structure of the Grenville sediments and the amount of deformation which they have undergone is still a moot question among Adirondack geologists. The main problems according to Smyth and Buddington ('26, p. 49) are "(1) Have any or all of these rocks undergone intense lateral compression? (2) has the foliation of the igneous rocks arisen for the most part subsequent to the complete consolidation of the rock or during the process of consolidation? In other words, is the foliation a cataclastic or a protoclastic structure?" Both of these problems have a bearing on the structure of the Grenville. With the exception of Miller ('16*a*), geologists who have studied the Adirondacks generally believe that at least the Grenville rocks have undergone intense deformation. Conditions are somewhat different in the western and eastern Adirondacks. In the former, broad belts of Grenville are present, whereas in the latter they have been broken apart to a greater extent and now have a very patchy areal distribution. Martin ('16) has proved the existence of isoclinal folding in the Canton quadrangle; Cushing believed in the isoclinal folding of the Grenville and has explained the parallelism of foliation and bedding of these strata as due to the fact that "the foliation must have preceded the folding and that the rocks were already recrystallized and foliated at the time when they were folded," and that, therefore, with the foliation and bedding parallel it is conceivable that the rocks were folded without the destruction of this parallelism, (Cushing and Newland, '25, p. 52–53). Smyth and Buddington ('26, p. 53) conclude that many forces have acted upon an early foliation in the Grenville, so that the structure is now very complex; and that recrystallization, following intense lateral compression, has obliterated much of the original bedding, early foliation and later granulation and cataclastic texture.

Miller ('16*a*, '23 etc.) has repeatedly maintained in his publications on the geology of the eastern Adirondacks that the Grenville strata have never been highly folded or severely compressed. He cites many examples of broad belts of strata that are practically horizontal or only very moderately folded, and other masses which have been merely tilted or domed at various angles. He explains these structural features as due to the slow irregular upwelling of great bodies of more or less plastic magmas, probably under moderate compression. This also resulted in the breaking apart of the Grenville into small masses. He interprets the local areas of strata that exhibit contortions as due to the proximity to igneous contacts of these small masses (mainly the more plastic, incompetent limestones). He interprets the practically universal parallelism of foliation and stratification as due to crystallization of essentially horizontal strata under load of much overlying material (static metamorphism aided by the heat of the large bodies of rising magmas). Miller also points to the lack of granulation in the Grenville strata and the lack of cataclastic structure in the younger igneous rocks as an argument for the lack of intense lateral compression.

Evidence of isoclinal folding is much less pronounced in the eastern Adirondacks than in the western Adirondacks. Balk ('32, p. 33) agrees with Miller that folds of appreciable size are rare in the Grenville marble, but he does not agree with Miller's interpretation that the Grenville never was intensely folded. He interprets the present structure as due to excessive recrystallization which has blotted out most of the previously existing isoclinal folds.

The structure of the Grenville rocks in the Thirteenth Lake quadrangle is similar to all the rest of the Grenville rocks in the eastern Adirondacks. In many areas the Grenville sediments and the igneous rocks (mainly syenite and granite) are intimately mixed, while in others the sediments occur as small inclusions in the igneous rocks, or sills of syenite-granite have been intruded into the strata. The foliation of igneous and sedimentary rocks is always conformable. In some places, such as the northwestern and eastern areas, the Grenville is relatively free from syenite-granite in the form of sills. It has already been mentioned, however, (page 22) that most of these rocks contain a large amount of igneous material when examined microscopically and they have been intensely recrystallized.

Conclusive proof was found in the Thirteenth Lake quadrangle that the Grenville sediments of this area have been isoclinally folded. On account of the intense recrystallization which they have undergone and their patchy areal distribution, it has been impossible to trace any one bed for any distance, or to find any large-scale folds. Small isoclinal folds and contortions, however, indicate the presence of these features on a larger scale.

It seems probable that the Laurentian granite was also intensely folded. In some areas, especially the rocks on Chimney mountain described below, the sediments seem to have been injected in a lit-par-lit manner by granite and quartz pegmatites. The quartz pegmatites also show isoclinal folds. It is possible that this material was intruded after the folding and followed the already existing folds; but, on the other hand, these veinlets and pegmatites have been intensely recrystallized, much more so than other pegmatites which cut across the structure and are definitely of later (Algoman) age. It is frequently difficult to distinguish between the quartz veins and layers of quartzite, as the two may merge into one another.

Little evidence of intense folding of the Grenville rocks on Chimney mountain can be seen at a glance (see figure 25). The dips are not steep, 15° to 60°, and changes in direction of dip and strike are gradual. In the walls of the "rift" the sediments are well exposed. Straight bands consisting of quartzitic layers which alternate with gneisses and schists extend for some distance. A careful examination of the rocks in the rift and over the whole mountain side has shown, however, that the rocks are anything but gently folded. Almost every outcrop reveals folds or contortions from minute dimensions up to several feet across. In the northwest wall of the rift a six-inch quartzitic layer shows an isoclinal fold about five feet wide. Other small folds occur in the walls of the rift. Rounded masses of pyroxene, up to a foot in diameter, gneisses and broken masses of quartz veins suggest that the surrounding rock was at one time in a plastic condition and intensely recrystallized.

The Grenville-syenite-granite mixed rocks on Mount Blue, especially the southeast slope, show the effect of intense lateral compression in the form of contorted and crumpled structures. There are large areas of these crumpled rocks with steep dips and rapidly changing dips and strikes. Broken and drawn-out masses of quartz are scattered throughout. The sills of syenite-granite and the pegmatites of Algoman age, however, do not show any contortion.

Evidence that the limestones have been subjected to sufficient pressure to cause them to become plastic enough to flow is plentiful, dating back to the description of limestone "dikes" by Emmons ('42, p. 45–51). Where the limestone has been intensely recrystallized the associated gneisses, schists and amphibolites frequently show isoclinal folds and contortions on a small scale, or they may occur as broken and rounded masses where a once continuous layer of more resistent rock has been broken apart and rolled around while the limestone was in a semiliquid condition. Miller ('14) has attributed the contortions in amphibolitic layers to the incompetence of the surrounding limestone. Martin ('16, p. 94) and Smyth and Buddington ('26, p. 78), on the other hand, have suggested that the limestones, which have yielded more readily to pressure, have protected the more competent layers to some extent from the severe compressive forces, so that these rocks have not been as intensely folded, crushed or recrystallized as have similar rocks which were not associated with limestone. The writer agrees with this interpretation.

The best example of contortion of amphibolitic layers and of the plastic state of the limestone was found in an outcrop one-fourth of a mile east of the road forks one and one-half miles north of Garnet; this is well shown in the accompanying illustration (figure 18.)

The dips and strikes of foliation and bedding of the Grenville strata shown in the structure map of the quadrangle present little evidence of isoclinal folding. Miller ('29) has described the quaquaversal dips of the Grenville around the syenite and anorthosite of the quadrangle and has pointed to the continuation of these dips into the surrounding quadrangles (to the north in the southern part of the Newcomb quandrangle, to the east in the North Creek quadrangle and to the southwest in the Lake Pleasant quadrangle). He attributes this large-scale laccolithic structure to the lack of more than gentle folding and uplifting of the Grenville strata. The writer interprets the structure as due to the obliteration of much of the original bedding by recrystallization and to the gentle uplifting of the isoclinally folded sediments by the igneous magma.

Figure 18 Outcrop one-fourth mile east of the road forks one and one-half miles north of Garnet. Grenville crystalline limestone has been rendered plastic by heat and pressure, causing the obliteration of original bedding. The dark, hornblende gneiss has been squeezed, contorted and broken by the same process

STRUCTURE OF THE IGNEOUS ROCKS

Foliation or flow layers in the Precambrian rocks of the Adirondacks have been described from all of the quadrangles which have been studied. Flow lines or linear parallelism has been studied in detail only by Martin ('16) and Balk ('31, '32). Both of these features are the result of primary magmatic flowage. It is generally believed that the foliation of the igneous rocks of the Adirondacks is due to flowage resulting from magmatic movements while the magma was in the process of solidifying (Miller '16*a*, Alling '24, Smyth and Buddington '26, Balk, '31, '32 and others). On the other hand Cushing ('10, p. 101) says that while some of the structure may be due to flowage, this feature has been largely disguised by subsequent compressive stresses. Smyth and Buddington ('26) have also proved the existence of cataclastic, as well as protoclastic, structures in some of the syenite-granite of the Lake Bonaparte quadrangle, indicating, therefore, that the compressive stresses in some localities continued after the magma had solidified.

Structure of the gabbro. Miller ('26, p. 11) considers the foliation of the gabbro to be due to two distinct causes; (1) a primary magmatic flow structure which occurs in many of the gabbros, especially the larger ones, and (2) a secondary structure, occurring in portions of the borders of the gabbros, which is due to pressure upon the gabbro bodies where they were caught up in the syenite-granite magma. In the latter case the rock is a finer grained, more or less foliated amphibolite or metagabbro. The gabbros, according to Miller are older than the syenite-granite and occur as inclusions, usually with their long axes parallel to the foliation of the inclosing rock.

Balk ('31) likewise considers the gabbros relatively older than the syenite-granite, although they differentiated from the same magma and were formed while the syenite-granite was in the process of solidifying. Balk, also, interprets their foliation as a primary flow structure. In the centers of the larger masses recrystallization has obliterated some of the structure and produced a coarser rock. Gillson ('28) also believed that recrystallization within the gabbros has occurred, although he considers the gabbros younger than the syenite-granite. The borders of the larger masses are usually more strongly foliated and finer grained. These represent a primary flow structure according to Balk, who has found that the rock underlying the larger gabbros is usually more strongly foliated than in other places and he believes this condition to be due to the sinking of the gabbros in the still molten, but solidifying magma.

The gabbros have already been discussed in some detail (page 27) and it has been pointed out that, in general, the features observed by Balk ('31) are true of the Thirteenth Lake gabbros. The centers of the larger gabbros are usually somewhat recrystallized and coarser than the borders, which are more foliated and frequently amphibolitic. Wherever observed the syenite-granite dips under the gabbros on all sides.

The gabbros in the western Adirondacks occur as sills and as small bosses. In general, they are believed to be the oldest igneous rocks. Intrusions of granite, possibly of Laurentian age, followed the gabbros. If the gabbros of the western Adirondacks are pre-Laurentian in age, they are older than the eastern Adirondack gabbros. There are, however, many small masses of amphibolite in the Grenville of the eastern Adirondacks which have sill-like or dikelike structures and, therefore, may be of igneous origin and of the same age as the older gabbro-amphibolites of the western Adirondacks. This problem is not yet solved, however.

Structure of the anorthosite. In his article on the anorthosite of the Thirteenth Lake quadrangle Miller ('29) describes the laccolithic structure which covers almost all of this quadrangle as well as parts of the adjoining quadrangles, citing this as proof that the Thirteenth Lake anorthosite was intruded as a laccolith. The structure is at least 20 miles long from north to south and 15 miles wide. Syenite-granite surrounds the anorthosite. Grenville strata in turn almost completely surround the syenite-granite. Both these rocks, in general, dip away from the anorthosite, and this structure is continued into the surrounding quadrangles (Newcomb, Schroon Lake, North Creek, Lake Pleasant). The Grenville sediments do not lie against the anorthosite, but are separated from it by syenite-granite. Miller ('29) believes that the syenite-granite structure (quaquaversal magmatic flow structure dips away from the anorthosite) was determined or controlled by the preexisting large-scale quaquaversal structure of the Grenville strata, and that the syenite-granite came in along the contact between anorthosite and Grenville sediments.

As stated in the chapter on anorthosite, the results of detailed structural study of the great mass of Adirondack anorthosite by Balk ('31) has led him to interpret the structure of the igneous rocks as the result of intrusion of, and differentiation within, a sill-like body. According to him, this magma, which had the composition of a diorite, was intruded from the north and northeast obliquely upward. In this large sill the central part, which consisted mostly of anorthosite, is believed to have a lenslike form. Balk says in part ('31, p. 399–400):

1 The foliated border of the anorthosite, and the foliation in the entire northeastern portion of the anorthosite massif dip gently to the northeast, or in such directions as are components of this direction . . . The southwestern border of the massif, although dipping to the southwest and south for the most part, is steeper and narrower, which results in an asymmetric structure of the whole massif to be explained in the next paragraph.

2 In the sills of the syenite and in the Grenville sediments which lie to the south and southwest of the anorthosite, the foliation dips to the northeast, under the anorthosite . . . The zone of vertical foliation which extends between these northeastward dipping rocks and the southern border of the anorthosite is interpreted as the narrow zone in which the advancing front of the magma lens has rolled up the wall rock in front of it . . . Flow structures found in exposures of a smaller size indicate that this interpretation is mechanically possible and even probable . . .

3 In the southwest, near Tupper Lake, both the border of the anorthosite and sills of syenite in front of it dip to the northeast and east, under the southernmost exposures of anorthosite . . .

The structure map of the Thirteenth Lake quadrangle shows the general quaquaversal dips of the Grenville and syenite-granite away from the Thirteenth Lake anorthosite, as has been described by Miller ('29). The writer, however, would like to point to certain features which suggest that Balk's ('31) interpretation of the sill-like or lenslike shape of the anorthosite can be applied to these two anorthosite masses as well as to the main body of Adirondack anorthosite. More detailed dip and strike measurements will, of course, have to be made before the structure can be correctly interpreted. The structure map shows that, for the most part, syenite dips away from the smaller, northeastern anorthosite mass on all sides. At one locality, however, on the eastern side and close to the anorthosite-syenite contact (one to one and one-fourth miles south of the south end of Thirteenth lake) syenite dips to the southwest under the anorthosite. Southeast of this point no observations close to the contact were made. The northern part of the larger anorthosite body has a more definite lenslike shape. On the east side syenite dips toward the west under anorthosite and away from the anorthosite along its western border. Quaquaversal dips in syenite-granite and Grenville, in general, surround the southern part of the large anorthosite body. The sill-like or lenslike relationship of anorthosite and syenite-granite west of Robb creek (page 53) is well shown in the field and is a very strong argument in favor of Balk's theory.

In connection with Miller's ('29) description of the Thirteenth Lake anorthosite Balk ('31, p. 333) suggests that (1) this anorthosite may also have a lens-shaped form, rather than a laccolithic shape, and (2) may dip gently toward the north. It has just been mentioned that observations in the Thirteenth Lake quadrangle suggest a sill-like arrangement of syenite and anorthosite rather than a laccolithic shape. In regard to Balk's second suggestion, however, the two lenses of anorthosite dip in general toward the west, rather than toward the north. The foliation in the syenite-granite in the southeastern part of the Indian Lake quadrangle and in the Lake Pleasant quadrangle (west and southwest of the southern anorthosite area) dips west and southwest.

In connection with Balk's suggestion that the anorthosite-syenite was intruded from the north and northeast obliquely upward, it should be observed that considerable faulting has occurred around the border of the Adirondacks. In addition to this the Adirondacks have been a positive area almost continuously since Precambrian times and have therefore been uplifted repeatedly in one way or another. Just what effect these two features have had on the direction of dip and strike of the foliation which can be observed is not now known. The structural relations between the different rocks, however, was probably not affected, as large areas were undoubtedly uplifted as a unit.

The anorthosite exhibits all degrees of foliation from rocks which are entirely massive to those in which the structure is well brought out by parallel layers of rocks, containing larger or smaller percentages of labradorite crystals and ferromagnesian minerals. The border phase varieties, which contain a higher percentage of dark minerals, are usually more strongly foliated than the Marcy type. The foliation is generally recognized as a primary magmatic flow structure developed under conditions of moderate pressure.

Flow lines or linear parallelism of minerals are also well developed in the anorthosite and are frequently more prominent than the foliation. They are brought out by the parallelism of labradorite crystals and ferromagnesian minerals in the plane of the foliation.

Considerable crushing and granulation has taken place in the anorthosite due to movement within the partially solidified mass and has resulted in finer grained areas of crushed feldspars which surround nuclei or uncrushed cores of once much larger labradorite crystals. The block structure of the anorthosite is a large-scale example of this same protoclastic structure. These rounded and angular blocks of anorthosite are surrounded by anorthosite of slightly different character. Shearing or crushed areas have frequently been developed around the blocks by movement of the blocks against each other. Slight parallelism of minerals around the surface of earlier segregations of anorthosite has frequently been developed in the surrounding anorthosite. Kemp and others have recognized blocks of anorthosite in anorthosite of slightly different character and have attributed it to slightly different ages in the anorthosite. Balk ('31) explains the block structure as due to friction and flowage in the magma, which already contained a large number of labradorite crystals and of solid clusters of labradorite crystals. Good examples of the block structure have been found in the anorthosite of the Thirteenth Lake quadrangle, especially on the east shore of the largest Buckhorn pond and at the outlet of Hour pond.

For a detailed discussion of Balk's interpretation of the structure of the anorthosite the reader should refer to Balk's ('31, p. 314–27) paper. In brief, he believes that the magma, probably of dioritic composition, was intruded in the form of a sill-like or lenslike body. Due to differentiation during the course of intrusion, the magma already had a large number of labradorite crystals, as well as ferromagnesian minerals, suspended in it. The friction between the floating solid mineral grains or larger solid masses and the liquid portion of the magma developed a foliation or magmatic flowage structure. Where the magma chamber was small, or where Grenville inclusions or labradorite crystals and solid blocks of these crystals were numerous, the friction was more intense.

Foliation in the syenite-granite. The syenite-granite exhibits a foliation which varies from very faint to highly foliated. It is usually well developed and is accentuated by roughly parallel layers of dark minerals. Where the granite is relatively free from ferromagnesian minerals the foliation may be brought out by long flattened plates of quartz. The foliation is usually straight, although at times undulations in the quartz plates and ferromagnesian layers occur. The structure is generally believed to be due to magmatic flowage, as in the case of the gabbro and anorthosite just discussed. This interpretation is confirmed by the fact that the structure bends around any inclusions which occur in it. This feature is strikingly shown where labradorite crystals occur in the syenite. An excellent example occurs between one-fourth and one-half of a mile north of the north end of Thirteenth lake near the contact between anorthosite and syenite. The syenite contains many labradorite crystals all oriented parallel to the foliation.

Evidence of the fact that the foliation was formed before the complete solidification of the magma is found in the fact that pegmatites, which frequently can be traced back to the syenite-granite from which they came, cut across the syenite foliation and are themselves nonfoliated. Balk ('31) and Miller ('16*a*) both attribute the structure entirely to magmatic flowage with accompanying crushing before the magma had completely solidified.

Alling ('24), however, suggests that some of the structure may be inherited, since the intrusive rock has injected older rocks (Grenville) along its structure to such an extent that little, if any, recognizable Grenville remains. While no rocks have been found in the Thirteenth Lake quadrangle in which it is certain that this has occurred, it is entirely probable that more detailed observations might reveal local areas of inherited structures. On the other hand, it has already been suggested that much of the igneous material which has intimately attacked the Grenville rocks may be of Laurentian age and the inherited structure is, therefore, associated with the Laurentian granite. In this case the Algoman syenite-granite has been intruded in the form of sills and not as minute injections, and hence its foliation is not an inherited structure. The writer is in favor of this interpretation.

Buddington ('19) has found good evidence of both protoclastic and cataclastic structure, as well as a primary foliation, in the syenite-granite of the Lake Bonaparte and Lowville quadrangles. Local areas of syenite-granite in the Thirteenth Lake quadrangle suggest that these features are present. The phenocrysts of feldspar in some of the porphyritic granite, especially in the Eleventh Mountain area, have the appearance of augen surrounded by a finer, crushed and granulated groundmass of feldspar. Many of the rocks have been crushed and granulated and now occur as very fine-grained rocks in which only the quartz shows little effect of crushing. This feature is due partly to the fact that the quartz was one of the last minerals to crystallize and may have come in after the severe lateral pressure had subsided. Buddington ('19) has shown that in the Lake Bonaparte and Lowville quadrangles there are successive zones of syenite-granite in which the pressure has been increasingly severe. In the first of these, only the feldspars have been crushed; in the second, the feldspars have been pulverized and the quartz somewhat crushed; and in the third, even the quartz has been granulated. Although no zones which show the evidence of increasing deformation have been found in the Thirteenth Lake quadrangle, the quartz exhibits varying degrees of crushing, similar to that found by Buddington. A large amount of the quartz, however, occurs as large plates which are free from crushing. The texture of some of the syenite-granite associated with anorthosite on the southeast slope

Figure 19 Peaked mountain from Peaked mountain pond, showing the asymmetrical outline of the mountain with the gentler, dip slope to the northwest. Photograph by Ray Galusha, North Creek, N. Y.

Figure 20 View from the top of Big range (elevation 3310 feet) showing from left to right Puffer, Peneplane, Horseshoe, Hayden, County Line and South Pond mountains. In the foreground is the ridge running northeast from the Big range. Note the gentle slope in the foreground. This follows the foliation of the anorthosite, syenite and granite which dips to the northwest

of Big range is very fine grained and may be due to rather intense granulation. Balk ('31) would undoubtedly attribute it to intense friction between the sills of syenite and lenses of anorthosite.

EFFECT OF FOLIATION ON TOPOGRAPHY

The long gentle slopes conforming to the dip of the foliation are very striking topographic features. The slopes in the opposite direction to the foliation are steep and abrupt, giving a decided asymmetrical form to the hills which frequently suggests faulting. This feature, which is found to be due in most cases to the foliation of the underlying rocks, is particularly well developed in the syenite. Areas worthy of mention occur as follows: (1) Peaked mountain. Syenite dips to the northwest (figure 19). (2) Slide mountain. Syenite-granite dips to the northwest. This is a long narrow ridge, which, when seen from the northeast or southwest at right angles to the dip, has the form of a sharp peak with the gentler slope to the northwest. (3) The two small peaks on the west slope of Bullhead range about one and one-fourth miles southeast of John pond. The syenite here also dips to the northwest. (4) The ridge about two miles south of Bakers Mills. Grenville rocks dip to the northeast. (5) Big range. Syenite-granite and anorthosite all dip to the northwest (figure 20).

Balk ('32, p. 72, 76) attributes these asymmetrical forms to the occurrence of Grenville lenses in the igneous rocks. These lenses dip in the same direction as the foliation of the igneous rocks, are eroded more rapidly than the igneous rocks, and, therefore, have the same effect on topography as interbedded layers of soft sediments in a tilted sedimentary series. Masses of rock which may represent Grenville inclusions were found in a few places at or near the base of these scarps. Others are probably covered by glacial material and talus.

Garnet gneiss occurs on the south slope of Peaked mountain and dips to the northwest under the mountain. On the Big range there is an alternation of syenite, granite and anorthosite on the steep southeast slope of the mountain and these have produced a step-like ascent of the slope. At an elevation of about 3000 feet there is a break in the topography and to the west, at the base of the main peak (elevation 3310 feet), there is a considerable band of hornblende-garnet gneiss which occurs as a lens in syenite. It is possible that this lens of gneiss, which may have been more easily eroded than the igneous rocks, is the cause of the break in the ascent of the mountain.

Between the two peaks three-fourths to one mile northeast of Gore mountain there is a depressed area (not well shown on the map) which, when seen from the road northeast of Bakers Mills, has the appearance of a sunken block or graben, with a flat bottom and nearly vertical side walls. Foliation on the east side dips gently toward the east. Observations were not made on the west side. It hardly seems possible that faulting has occurred here. It is more probable that a lens of weaker (Grenville) rocks was included in the syenite and that, as the foliation of the syenite is nearly horizontal and the lens was parallel to the foliation of the surrounding rock, erosion has produced this grabenlike area.

FAULTS

Considerable faulting has taken place in the Adirondacks. Definite recognition of most of the faults, however, is extremely difficult as exposures along these faults are not numerous and the rocks on both sides of the fault may be the same. Considerable difference of opinion as to the extent of faulting and the advisability of indicating them on the map occurs. Brigham ('98) described the trellised drainage of the Adirondacks, and Kemp ('21, p. 57) believed that most of these drainage peculiarities are due to fault lines and that a large number are present, although the existence of only a few can be definitely proved. Miller, especially in his reports on the North Creek, Lake Pleasant and Schroon Lake quadrangles ('14, '16, '19*a*) has mapped numerous faults. Among the positive criteria for the recognition of faults according to him are "(1) long, narrow, almost straight valleys which trend at high angles across the strike of the older rock structures . . .; (2) steep to vertical scarps, often miles long, in hard, homogeneous rocks; (3) actual presence of crushed, sheared, slickensided or brecciated rock zones; and (4) Paleozoic strata lying at the base of steep hills of Precambrian rocks." (Miller, '19*a*, p. 77–78).

According to Balk, however, there is very little evidence of faulting in the Newcomb quadrangle ('32, p. 63–64, 70–79). Closely spaced joints, foliation and lenses of weaker (Grenville) rocks in the more resistant (igneous) rocks can, he believes, explain most of the topographic trends. Unless brecciated zones are found and can be traced he does not consider the evidence sufficient to prove the existence of faults.

In the Thirteenth Lake quadrangle Miller ('29) has mapped five major faults. Only two of these have been mapped in this report, as definite proof of the existence of the others was not found.

Figure 21 Thirteenth lake as seen from the North River Garnet Company's quarry to the east. Note the steep slope on the northwest side of the lake (fault scarp) and the gentler slope in the foreground. The lake lies in the Thirteenth Lake fault valley. Photograph by Ray Galusha, North Creek, N. Y.

Figure 22 Jointed anorthosite in the bed of Roaring brook, three-fourths of a mile east-northeast of the Barton garnet mine. Photograph by W. J. Miller

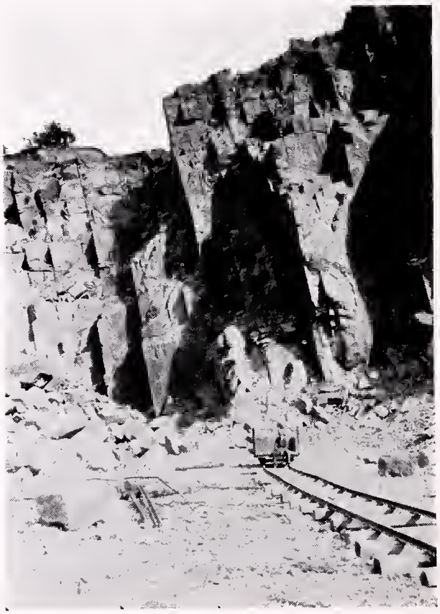


Figure 23 Strongly jointed garnet gneiss in the North River Garnet Company's mine. Photograph by W. J. Miller

According to Miller, the longest fault extends for about 14½ miles in a northeast direction across the southeastern part of the quadrangle. He has mapped the extension of this fault to the northeast across the North Creek quadrangle ('14) and for some distance into the Schroon Lake quadrangle ('19*a*). To the southwest he has extended it across the Stony Creek quadrangle and for 15½ miles into the Lake Pleasant quadrangle ('16). This fault, 45 miles in length, is, according to Miller, the longest fault within the Adirondacks, with its greatest displacement, at least 2000 feet, in the Lake Pleasant quadrangle near Wells. At this locality, Cambro-Ordovician sediments occur on the east, or downthrow, side of the fault. This fault has been mapped in the Thirteenth Lake quadrangle, along East Branch Sacandaga river. The writer found no definite evidence outside of certain possible topographic features, to prove the existence of the fault as mapped by Miller along its northeastern extension. In other words, no proof of faulting was found on the southeast side of Eleventh mountain or along the contact between the syenite and Grenville rocks northeast of Bakers Mills. Only seven miles of the fault are shown on the accompanying map. At several places along East Branch Sacandaga river distinct crush-zones and decomposed rocks occur. The rocks in the bed and walls of the river, one-third to one-half of a mile south of the mouth of Stewart creek are badly crushed and most of the plagioclase feldspar of the anorthosite is almost completely altered. Much of the rock has a greenish, greasy appearance due to this alteration. At this locality a diabase dike in the bed of the stream and several branch dikes in the walls of the small gorge are also badly crushed. The main dike was undoubtedly intruded along a joint in the anorthosite, and later faulting was responsible for the crushing. About one-fourth of a mile northeast of the mouth of County Line brook the rock has the same greasy appearance and contains many joints only a few inches apart. The joints strike S. 15° W. and S. 85° W. Considerable crushing also occurs along the road at the river level on the east side, just south of Oregon. Some of the anorthosite and small lenses of garnetiferous amphibolite and gneiss are completely crushed and brecciated, now forming a gouge. Slickensides and round balls of brecciated rock also occur. Much of the rock has a greasy appearance. Along the road the joints and crush-zone strike S. 45° W. and S. 80° W. This probably represents cross-faulting. Crushing and greasy looking rocks were also noted at other places along the river.

Miller ('29) considers the Eleventh Mountain mass a fault block covering several square miles and bounded by four faults. No definite evidence for any of this was found, except that the mountain stands out rather prominently in the surrounding country.

The second largest fault in the Thirteenth Lake quadrangle extends for about seven miles in a northeast direction through the Thirteenth Lake valley. The topographic evidence for this fault is very strong (figure 21). In addition to this, a fault crush-zone was located at the Hooper garnet mine during quarrying operations there many years ago. The pit in which this zone was exposed is now filled with water, but, according to F. C. Hooper, it contained a large amount of fault breccia and gouge and was about two feet wide. It cut off the garnet deposit on its eastern end and was parallel to the strike of the Thirteenth Lake valley. One-fourth to one-half of a mile south of the garnet deposit is the outlier of Potsdam sandstone previously described (page 68). It is located on the east or downthrow side of the fault and at the base of the steep slope of the mountain.

Miller ('29) has also mapped a fault parallel to the Thirteenth Lake fault and lying two and one-half miles southeast of it. The region between these two faults has the appearance of a graben. No other evidence, in addition to that offered by the topographic expression, sufficient to warrant the mapping of this fault, was found. Along the road to the Barton (Moore) mine two and one-fourth miles south of *N* in *N*orth River on the map the rock is strongly jointed. Two systems of joints are developed, one striking N. 45° E. and the other N. 45° W. No slickensides or crushing were noted. The best evidence for any structural disturbance along this line is found at the small pond one and one-fourth miles northeast of Botheration pond, where a sharp change in the dip and strike of the foliation of a layer of garnet gneiss can not be easily explained by folding. West of the pond the structure dips 25° toward the northeast, whereas east of the pond it dips toward the southeast (page 103). The rocks could not be studied in detail, as the critical points are located under the pond and surrounding swampy area. Miller mapped the fault as extending about one-fourth of a mile west of this pond, but if the existence of a fault can be proved, the line undoubtedly passes through the vicinity of the pond.

Greasy looking altered anorthosite also occurs in East Branch Sacandaga river at the mouth of Second Pond brook (one mile southwest of the top of Durant mountain). No other evidence of faulting, however, was found, except the straight course of the valley for a distance of about four and one-half miles. For two miles of this distance the valley is in Grenville rocks.

It is entirely possible that other faults occur in the Thirteenth Lake quadrangle, but sufficient evidence of their existence was not discovered to show them on the map. In some places the topographic expression suggests a fault, but other factors than faulting can explain the features observed. Some of these are described below under joints. Others have been described above under effects of foliation on topography.

JOINTS

Most of the rocks of the area are strongly jointed (figures 22 and 23). Many of the streams have straight courses for considerable distances, mainly in a northeast or northwest direction. Jointing is a reasonable explanation of these courses, and is believed to be responsible for the development of drainage in these directions in the eastern Adirondacks. Of the 45 measurements of joints made in the quadrangle, 22 had a northeast-southwest strike, 13 a northwest-southeast strike and nine a strike ranging from N. 12° E. to N. 12° W. Balk ('31, p. 413–25) has made a detailed study of the joints in the eastern Adirondacks and has found that the regional tension joints are the most important in controlling topographic features. These joints persistently follow a northeast-southwest direction. Local cross-joints which are also tension joints and cut across the flow lines approximately at right angles are next in importance. As the flow lines change their direction frequently, however, the local cross-joints do not play so important a part in controlling topographic trends as do the regional tension joints.

Balk ('32, p. 58–59) states that slickensides on joint surfaces have hardly ever been observed, but that the planes may be coated with a greasy looking veneer of serpentine and chlorite. On many of the joint faces of the Thirteenth Lake quadrangle the writer has observed similar greasy looking surfaces which frequently appear to have been formed by movement along the joint plane. In most cases, however, there is no evidence of any displacement. Numerous joint planes are well developed in the rock of the North River Garnet Company's quarry. Most of these joints have either a N. 53° W. or N. 35° E. strike. The northwest joints in this place appear to be the more strongly developed than the northeast joints. Slickensided surfaces have been developed on most of them and occasionally there may be a narrow crush-zone, but there is no apparent evidence of any displacement. Some of the joints have been filled with calcite. Similar slickensides were noted on the joints in some of the small quarries of the Humphrey Mountain garnet deposit. The strike of some of these joints is nearly north-south, in line with the north-south valley of Kings flow.

THE RIFT AND CAVES ON CHIMNEY MOUNTAIN

One of the most interesting topographic features is Chimney rock with its rift and "caves" on the western peak of Chimney mountain in the northwestern part of the quadrangle. The rift is more than 600 feet long, 150 to 200 feet deep and 200 to 250 feet wide across the top. It strikes N. 20° E. On the east side the wall is precipitous, the highest point being Chimney rock, which rises about 35 feet above the general level of the top of the east wall of the rift. The total distance of the nearly vertical cliff from the top of the "Chimney" to the talus accumulations at the base is about 80 feet (figure 24). The greatest angle of slope of the west wall is about 50°. The bottom of the rift slopes downward to the north. The bottom of the rift and the eastern base of Chimney rock are filled with angular blocks of rock, up to 20 feet or more across, which have accumulated there since the development of the rift. The rift is developed entirely within Grenville strata (gneisses, quartzite and mixed rocks, page 18), which rest by igneous contact upon the granite of the main mass of Chimney mountain. The foliation of the Grenville rocks dips about 50° toward the west and strike N. 20° E. On the east side of the rift the rocks strike N. 40° W. and dip not more than 20° to the northeast. The rocks on the opposite sides of the rift, however, are identical in character. As seen from figures 25 and 26, there are the same number of white quartzitic layers with similar spacings in the opposite walls of the rift. Many prominent joints occur in the Grenville strata. The most important ones are developed parallel to the strike of the rocks (approximately at right angles to the dip) and also parallel to the main rift. Others cut across the strike. Several of these can be seen in the walls of the rift, the one in the center of the east wall being a continuation of the one in the west wall which occurs just to the right of the center of the picture.

Miller ('15) has described the rift in some detail and has given an interpretation of the structure. A summary of his explanation of the development ot the rift follows: The base of the Grenville sediments which rest directly on the granite of the mountain mass probably consists of weaker rocks (limestone) than either the overlying gneisses now exposed or the underlying granite. The posi-

Figure 24 Chimney rock on the east wall of the rift on Chimney mountain

Figure 25 Grenville sediments forming the "chimney" (east wall) on Chimney mountain as seen from the west wall of the rift. Compare with Figure 26 and note the similarity of the rocks on the two sides of the rift

Figure 26 The west wall of the rift on Chimney mountain

tion of these weaker rocks was favorable for undermining due to removal by erosion or solution, or both, by waters moving down from the still higher portions of the mountain to the east. The undermining proceeded far enough so that a great block of gneiss, already practically separated by a prominent joint plane from the ledge of the mountain side, was pulled over by force of gravity. Undoubtedly wedgework of ice in the joint aided the separation. This block, 600 to 700 feet long and 100 to 250 feet high, swung through an angle of 60°–70° with greatest subsidence toward the north, thus accounting for the marked difference of strike and dip of the strata on opposite sides of the rift. The rift is certainly Postglacial in age, as indicated by the utter absence of any evidence of glaciation within it. On the other hand, it has been in existence for more than 100 years (and probably much longer), as proved by the size of the trees which have grown up in it and by the large accumulations of talus material.

Although this explanation of the development of the rift is entirely plausible, there are other features not described by Miller. Additional observations during the course of the field work suggested a modification of Miller's explanation or a different theory entirely, and the necessity of a more detailed study of the whole mountain. This study was conducted by Priscilla Foote and the writer.

The observations and conclusions resulting from this study are as follows:

1 It can hardly be doubted that the rocks on the opposite sides of the rift are identical and must have once been a part of a continuous mass, as suggested by Miller (figures 25 and 26).

2 Miller's theory was worked out on the assumption that the Grenville rocks on Chimney mountain had been gently tilted into their present position by the intrusion of granite which underlies the sediments and forms the eastern peak of the mountain. Although the Grenville strata have a fairly persistent dip and strike, it has since been proved that they were isoclinally folded and intensely crumpled and recrystallized. The difference in dip and strike of the two sides of the rift can, therefore, be explained by folding.

3 The large block forming the east wall of the rift, when seen from the top of the "Chimney," appears to have been badly smashed and broken, as it would have been if the rift developed in the manner suggested by Miller. On the other hand, the western slope of the mountain is also broken apart and badly jointed and fractured. Large joints, some of which are 60 feet in depth and 30 feet wide

across the top, extend for 200 to 600 feet along the strike. They are frequently filled with snow and ice the year round and are also partially filled with large and small blocks of rock which have fallen into them.

4 The best explanation of the opening of these joints is slumping of all the Grenville rocks down the mountain side. An example of this occurs at the main ice cave, which is located about 230 feet from the top of the west wall of the rift down the slope of the mountain, and 100 feet lower than the top. A large joint (A) strikes N. 20° E., parallel to the strike of the rocks and to the strike of the main rift. It can be traced for at least 500 feet and is well developed for a distance of 200 feet. Where well developed it is from three to 30 feet wide and ten to 60 feet deep. Loose blocks of rock which have slid down from above fill in the cracks in places. At the northeast end of joint (A) joint (B) branches off and strikes S. 21° E. It dips 84° N. E., is one to ten feet wide and over 60 feet deep. The deepest part is continuously filled with snow. Seventy-five feet southwest of the intersection of joints (A) and (B) joint (C) branches off from joint (A) and strikes N. 60° E. Joint (C) intersects joint (B) 50 feet from the intersection of joints (A) and (C) and 50 feet from the intersection of joints (A) and (B). It is, therefore, a block of rock whose surface is nearly an isosceles triangle, covering approximately 1250 square feet, with its apex pointing up the slope. The block is completely separated from the surrounding rocks and must have slid down from the rock above it, while the rocks on the lower (west) side of joint (A) have in turn slid down hill.

These crevices are similar to those developed in certain localities in the Shawangunk mountains. The "ice caves" located about two miles east of Ellenville, N. Y. (Ellenville quadrangle) were visited by the writer some time ago. Doctor Holzwasser ('26, p. 68) has described the origin of the "crevices" east of Lake Minnewaska in the Newburgh quadrangle as follows:

> The smaller features in the topography of the Shawangunk mountains are influenced by joints developed in two prominent systems, one along the strike, north 20° east, and the other transverse to the strike, north 60° west. These intersecting joint planes have outlined large rectangular blocks, which have separated by settling due to weathering and to the undermining of the Hudson River rocks beneath. This has resulted in the formation of fairly deep vertical clefts, several of which may be connected and be continuous for 500 feet or more.

5 There are many large blocks of rock which have rolled part way down the mountain. One of these blocks, near the southern end of the rift and 200 feet down the slope of the mountain, came to rest with its banding in a vertical position. The block is bounded on its northwest side by a face (bed?) which is 40 to 45 feet in height and dips 88° southeast (slightly overturned). The block is about 100 feet in length along its strike (N. 40° E.) and 20 to 25 feet thick.

6 During the fall of 1931 and the summer of 1932 two "caves" were discovered within the rift, one near the north end and the other near the south end, by Charles Carroll, proprietor of the Chimney Mountain House at Lake Humphrey (Kings flow). One of these has not been explored, but a weighted rope is said to have been lowered into the opening for more than 100 feet without reaching the bottom. The one at the south end has been more thoroughly explored. An opening about five feet square, similar to many other openings in the rift and on the western slope of the mountain, extends vertically to a depth of about ten feet. From this a horizontal passage, just large enough for a man to crawl through, extends for about 15 feet toward the north. The passage, sometimes widening out a little, then descends in a zigzag manner and at an incline for a distance of nearly 20 feet. At this point the opening is very small and there is a drop of eight to ten feet into a large "room." This room extends from the opening for about 45 feet to the southeast. It is ten to 20 feet wide and ten to 15 feet high. Many large icicles hang from the ceiling. Down to this point the irregular passages and larger openings have been formed by the filling up of the bottom of the rift by an accumulation of talus derived from the walls. From this room a passageway extends downward for at least 40 feet. It dips 38° to 45° northwest and strikes N. 24° E. and has, therefore, opened up along the dip of the strata. It is up to 30 feet long across the strike at the top, and the hanging wall is from one to five feet above the foot wall. The passage gradually pinches out at the bottom. Undoubtedly the opening was formed by the downward movement of the underlying rock, or by the wedge-work of ice which has shoved up the overhanging layers of rock. A large number of rocks have fallen into the opening, partially filling it up.

The rocks forming the caves are like those in the walls of the rift. They are, on the whole, rather weathered and predominantly rusty in appearance. Sand, consisting of quartz and pyroxene and resulting from the separation of mineral grains, has collected on the floors of the caves. If the opening at the north end of the rift extends to a sufficient depth, in a vertical direction, instead of following down a dip slope, exploration of it may determine the character of the weaker rocks which underlie the gneisses and supply more information concerning the formation of the caves and rift.

7 No limestone has been found associated with the gneisses and quartzite of Chimney mountain although a search has been made in the valley between the east (granite) peak of the mountain and the east wall of the rift. This valley, like the rift to the west of it, is partially filled with large angular boulders so that much of the bedrock is covered. No signs of solution of the rocks were noted in the caves.

8 Regardless of what explanation for the development of the rift is found to be the most satisfactory, slumping of the rocks is certainly partly responsible for the opening up of the large joint planes. Solution of underlying limestone or an underlying layer of soft, schistose rock may have aided the slumping.

The various theories explaining the rift are: (*a*) Miller's explanation, (*b*) a breached anticline, (*c*) an anticline in the position of the rift to account for the difference in dip and strike, and the opening up of a joint by the sliding down hill of the rocks on the western side of the joint. Some slumping must also have occurred in the eastern block (Chimney block). It is also possible that several closely spaced joints between the east and west walls are responsible for the rift. From the observations already made the writer prefers this last explanation. It is often extremely difficult to determine whether the variation in strike and dip of a given block of rock is due to folding, or whether this variation is caused by the fact that the block is not in place.

GLACIAL GEOLOGY

Widespread glaciation in the Adirondacks during Pleistocene time has produced minor topographic changes. Glacial and Postglacial features similar to those occurring in the surrounding country are found in the Thirteenth Lake quadrangle. Although no detailed studies have been made by the writer in this area, certain observations were recorded during the course of the field work which are presented here. Evidence of the former presence of ice over the entire quadrangle is found in the occurrence of glacial boulders and drift even on the tops of the highest mountains, glacial striae, the absence of Preglacial soil or much decomposed rock and the presence of numerous lakes throughout the region.

DIRECTION OF ICE MOVEMENT

Glacial striae were noted at four localities as shown on the accompanying map. They are as follows: (1) north-south, on anorthosite one and one-third miles southeast of the summit of Siamese mountain; (2) north-south, on Grenville gneiss two miles north-northwest of Garnet; (3) south 20° east, on syenite along the road two miles north-northwest of the Barton (Moore) mine; and (4) south 10 ° east on garnet gneiss at the northwest edge of the North River Garnet Company's mine. About halfway between this mine and Thirteenth lake there is a number of large boulders of garnet gneiss which have undoubtedly come from the Ruby Mountain garnet deposit. These also show a direction of ice movement similar to that indicated in (4), or slightly east of south. The direction of movement across the quadrangle was, therefore, nearly due south, or the same as it was across the adjoining North Creek quadrangle (Miller, '14).

GLACIAL EROSION AND TOPOGRAPHIC CHANGES

Glacial erosion in the quadrangle has modified major topographic features very slightly. Practically all of the Preglacial soil and most of the decomposed rock was removed, exposing nearly fresh ledges of rock. At the western end of the Barton (Moore) mine, however, the garnet rock is very badly weathered to a depth of ten feet or more. The top of the whole deposit as removed consisted of rather soft, decomposed material, and it was in this rock that the early hand-picking operations were carried on. It is believed that the position of the deposit, in an east-west valley between two high peaks, is responsible for its protection. Large and small boulders of fresh rock were also picked up by the ice, probably by a plucking process, and were worn down, rounded or faceted during transportation.

Although the main depressions and drainage lines existed long before Pleistocene times, minor changes in the topography of the valleys were made by the dumping of morainal matter during the melting of the ice, some of this material being reworked and redeposited by the waters coming from the glaciers. It is difficult in this region of relatively small streams to detect these changes, but a few which are suggested by a study of the map are as follows: (1) The valley of Garnet lake (Mill Creek pond) may have drained to the southwest into Madison creek and thence to East Stony creek and Sacandaga river. The divide to the south of the lake is low and the valley (the present outlet) east of Garnet is very narrow and undoubtedly of Postglacial origin. (2) The valleys of Fish ponds and Stewart creek may also have drained to the south into East Stony creek, although this is by no means certain. (3) The valley of East Branch Sacandaga river opposite Moose mountain is very narrow and the river flows through a series of small gorges for part of the distance. It is possible that the river may have passed through Stewart creek and then south. On the other hand, it seems more probable that the gorges owe their development to the rapid erosion of the rocks in the fault zone at this locality.

GLACIAL DEPOSITS

Glacial boulders and ground moraine occur even on the tops of the highest mountains. The morainal deposits are much more thinly distributed on the higher elevations than in the valleys. This may be due to thinner original deposits or to erosion from the higher and steeper slopes after deposition, or more likely to a combination of both of these factors. The thinness of the deposits on the higher slopes leaves numerous outcrops exposed, although where the slope of the mountain follows the general slope of the foliation of the underlying rock, fewer outcrops are visible. Other evidence of the lack of abundant drift and soil is found in the rapid run-off of water after rains and in the landslides which may occur after very heavy rains, leaving long streaks of barren ledges down a mountain. Several of these were formed a few years ago on the southeast slope of the Blue hills. One of them is ten to 12 feet wide and extends for a vertical distance of nearly 400 feet down the slope.

The ground moraine consists mainly of unsorted coarse and fine material, locally somewhat stratified. Boulder clay is not abundant, but was observed in a few places, especially in a road cut on the west side of the road to the Barton (Moore) mine, about one mile south of the Hudson river, where a small amount is exposed. The moraine does not exceed 100 feet in thickness and is usually considerably less than this. One well, three-fourths of a mile east of *K* in *K*ibby creek on the map, is 40 feet deep in unconsolidated material. Ten to 20 feet of moraine are frequently exposed in road cuts.

Ground moraine is especially abundant in two areas of several square miles each; one of these is west and northwest of North River, and the other is in the vicinity of Bakers Mills. Most of the bedrock in these places is concealed from view because of this glacial cover.

Deposits of stratified sand and small pebbles are abundant. Some of these are believed to be lake deposits, but as much of the material is coarse and poorly sorted and contains considerable cross-bedding, many of the sands were undoubtedly deposited as deltas by streams flowing into lakes, or as outwash plains along the front of the glacier.

A number of large boulders up to 12 feet in diameter occur in the valley south of Peaked mountain. They have been moved a short distance only, probably from the south slope of the mountain, but they are somewhat rounded and faceted nevertheless. A large boulder of coarse-grained anorthosite eight feet in height occurs on the top of Harrington mountain. Many other large boulders are scattered throughout the quadrangle. They consist of any of the rocks of the region, with limestone by far the rarest, on account of its softness.

LAKES

A large number of lakes and ponds were developed during the retreat of the ice from the Adirondacks. They occur at almost every elevation, the highest in the Thirteenth Lake quadrangle being nearly 2600 feet above sea level. No large glacial lakes, comparable in dimension to those which existed in other parts of the Adirondacks, were formed, however, in the Thirteenth Lake quadrangle. This is undoubtedly owing to the fact that the topography is more rugged than in some of the surrounding quadrangles (North Creek, Schroon Lake and Lake Pleasant quadrangles). Many of the lakes were in existence for only a short time subsequent to the retreat of the ice, but remnants of some have lasted to the present day. The lakes disappeared or shrank in size from the filling or partial filling by sands carried into them by streams and by draining incident to melting of the ice barriers and erosion of the morainal dams. Stratified sands, terraces, deltas, large sand flats and swampy areas frequently indicate the former existence of a lake or pond.

Miller ('14) has described glacial Lake North Creek and the occurrence of thick stratified sands in the vicinity of North Creek village. This lake extended an arm up the Hudson river, at least as far as the northern boundary of the Thirteenth Lake quadrangle. A large part of the lake deposits between North River and North Creek have been eroded. Some sand flats and terraces remain, however, on the north side of the river opposite the village of North River and on both sides of the river between one and one-half miles southeast of the village. The small hill on the south side of the river, three-fourths of a mile northwest of *N* in *N*orth Creek on the map, is composed almost entirely of stratified sand, a thickness of approximately 25 feet being exposed in a sand pit. This hill is in the North Creek quadrangle, one-fourth of a mile east of the Thirteenth Lake quadrangle.

Most of the existing lakes were formed by morainal dams and were once larger than now. Garnet lake (Mill Creek pond) has been artifically enlarged to cover the swampy area shown on the map. The pond was probably originally much larger than this, however, as there are rather extensive sand deposits associated with it, those at the southeast end of the pond (as mapped) rising 20 to 30 feet above the present lake level. The valleys of Fish ponds and Cod pond-Stewart creek probably contained two lakes or possibly one large one. No evidence for a once much larger Thirteenth lake was found, but a morainal dam occurs at the present outlet. Kings flow, a swamp recently dammed to form artificial Lake Humphrey, was undoubtedly the site of a former lake. It may have been considerably larger than the present artificial lake, as there are some accumulations of sand ten to 20 feet above the water level. They are not sufficiently well exposed for one to be certain that they are well stratified and represent lake deposits rather than a moraine. On the lower side of the dam, however, about 20 feet of varved clays are exposed in a cut. These are the only varved clays which have been observed in the quadrangle. Siamese ponds are separated by a ridge of morainal material. Along East Branch Sacandaga river, near Oregon, there is also evidence of a former glacial lake in the form of sand flats and terraces. The river has washed much of this away, leaving well-developed meander scarps just above Oregon. Many of the ponds were dammed by lumbermen, partially restoring their former condition.

ECONOMIC GEOLOGY

BUILDING STONES

The supply of building stone is inexhaustible, but there is no market demand, except locally for the maintenance of roads. Near Thirteenth lake is a huge pile of crushed rock, representing the tailings from the North River Garnet Company's mine, accumulated over a period of 20 years. Because of the distance from the railroad and the cost of transportation, this material is used only locally for roads.

GARNET DEPOSITS

Garnet is abundantly developed throughout the Adirondacks and deposits of garnet-rich rock have been mined at various localities. The rocks of the northern part of the Thirteenth Lake quadrangle and surrounding areas are unusually rich in garnet and most of the garnet mines of the Adirondacks are located within this relatively small district. Garnet-rich deposits of special interest are shown at 11 localities on the accompanying geologic map. Garnet has been mined at five of these localities and two of them (North River Garnet Company's mine and Barton (Moore) mine) have been large producers of garnets for use as abrasive material. Since 1928 the Barton mine has been the only one of importance in operation in the Adirondacks. In addition to these, there are many masses or inclusions of garnet-rich rock similar to the garnet deposits, but usually of lower garnet content and of very small extent. These are believed to be closely related to the garnet deposits and may throw some light on the problem of origin and history of these interesting rocks.

The garnets of these localities are light red in color and until recently have generally been classified as the almandite variety. According to Myers ('26), they contain both FeO and MgO and are between almandite and pyrope in composition. The mineralogical composition was calculated by Myers from the analysis given below. This shows a higher per cent of pyrope than almandite.

SiO_2	40.24	Andradite	13.8
Al_2O_3	20.06	Grossularite	1.2
Fe_2O_3	4.65	Pyrope	43.7
FeO	18.58	Almandite	40.8
CaO	5.34	Spessartite	.5
Mgo	11.18		
MnO	.25		
	100.30	(Myers '26, p. 15, 17)	

Myers, however, points out that there may be considerable variation in the garnets of different deposits and possibly within any one deposit and that many samples would have to be tested before definite conclusions as to the composition of the garnets could be reached.

Although many of the garnets have gem-stone color and translucency, their highly fractured character renders them, on the whole, unfit for use as jewelry. For a description of the characteristics of the garnet, its milling and mining see Myers and Anderson ('25).

The problem of the origin of the garnets is a very puzzling one and as yet is far from solved. Miller ('12) has described many of the deposits and discussed their origin. Since then, however, he has modified some of his ideas of genesis. The various problems concerning these deposits are presented on page 116 of this bulletin and tentative explanations of some of the features are made, but the writer does not believe that sufficiently detailed observations of the structure and petrography have been made to warrant definite conclusions.

The deposits in the Thirteenth Lake area are of two distinct types which differ from each other both according to the size of the individual crystals or "pockets" of garnet, as well as in the composition and general appearance of the rock in which the garnets occur. In one case the garnets occur as small crystals in a light to dark gray, gneissoid rock. This rock is usually referred to as a garnet gneiss. In the other type, the garnet is found in much larger crystals in a dark hornblendic rock which is not as strongly foliated or banded as the first type. The garnets of this type are usually surrounded by hornblende rims. Small masses or lenses of the latter type of rock occur in the areas of Grenville rock and both types occur as inclusions in the igneous rocks. Most of these are not of mappable size. The dark hornblendic type of rock is more abundant than the garnet gneiss.

Garnet gneiss. What is locally known as the Hooper vein is a light to dark gray, gneissoid rock composed of plagioclase feldspar, ferromagnesian minerals and garnet crystals which range up to four inches in diameter. The mass of rock, with the exception of the garnet crystals, is medium textured and resembles a typical banded gneiss. The garnet gneiss apparently occurs as a layer or band ten to 100 feet thick which outcrops intermittently for about 12 miles. The strike and dip are continuous for considerable distances and conformable to the foliation of the igneous rocks with which it is in contact. Its occurrence and the general appearance of the rock suggest that the intermittent outcrops may have originally been continuous.

Northwest of Peaked mountain this rock can be traced continuously for one mile. Over this distance it has a strike of N. 3° to 7° E. and dips 10° to 15° to the west. It is at least 40 feet thick throughout most of this area. The foot and hanging walls are syenite with the same dip and strike as the deposit. This area has never been mined. The garnet percentage is rather low (5 to 6 per cent), but it is very uniformly distributed throughout the gneiss.

Two-fifths of a mile south of the southern end of this mass of garnet gneiss more of the same type of rock occurs. It is not more than 30 feet thick at this locality. Like the deposit to the north, it is underlain and overlain by syenite having the same conformable structure. The deposit can be traced continuously for about one-half a mile up the south side of Peaked mountain to the east. In going from west to east along the deposit, the strike swings around from northwest, through east-west, to northeast. The dip is from 25° to 35° toward the north. Much of the rock here is lower grade than it is toward the north. On the southwest slope of Peaked mountain layers of syenite occur in the garnet gneiss in such a way as to suggest that the garnets were present before the intrusion of the syenite.

The garnet horizon could not be traced from the south side of Peaked mountain to the east. The strike of the syenite over this area is continuous with the strike of the garnet deposit (northeast; it dips to the northwest). About one mile northeast of the summit of Peaked mountain the strike swings around to the northwest and the dip changes to northeast. Here a few large garnet crystals occur in the syenite. The strike at this place points toward the garnet deposit on Ruby mountain.

The same type of garnet rock occurs on the southwest slope of Ruby mountain and at the North River Garnet Company's mine one mile east of Thirteenth lake. Both of these deposits are described in more detail below. In the former deposit the rock dips about 35° to the north. This deposit consists of lenslike masses of garnet gneiss with intervening lenses of syenite. The rock in the latter deposit strikes N. 53° E. and dips to the northwest.

West of the small pond about one mile northeast of Botheration pond garnet gneiss again is found. It can be traced almost continuously to the northeast for about one and one-half miles. West of the pond it dips to the northeast. East of the pond the strike changes to east and northeast and the rock dips to the south, under Whiteface-type and gabbroic anorthosite, and rests on syenite and low-grade garnet gneiss. This band of garnet gneiss is about 20 to 30 feet wide and similar to the other masses.

Three other small bodies of garnet gneiss which appear to be closely related to those just described and probably are a continuation of them occur. One is in Roaring brook, a second about three-eighths of a mile north of Roaring brook and a third about one and one-fourth miles south of Roaring brook. All of these dip to the west, the first two under the east end of the Whiteface and gabbroic anorthosite. West of the third mass is a small body of coarse-grained anorthosite. A diabase dike separates the two formations along the strike. Syenite dips under all the deposits.

Along the north side of the gabbro mass north of Gore mountain there is garnet gneiss containing garnet crystals up to four inches in diameter. It is similar to the rock of the areas just described, although it does not appear to be connected with the other deposits. At its eastern and western extensions it is closely involved with or grades into anorthosite and gabbro, and only a small quantity of typical garnet gneiss is present.

Small amounts of the same type of rock occur south of the Barton garnet deposit, between the mine rock and the syenite, and at the east end of the deposit. This is discussed in more detail in connection with the origin of the Barton garnet deposit.

Two small lenses of garnet gneiss occur in the syenite southwest of the Hudson river as well as other minor lenses too small to map.

Of the areas just described, only one has been mined. At the North River Garnet Company's mine extensive operations were carried on for about 20 years. A small pit was opened up in the deposit on Roaring brook and operated by hand-picking methods for a short time.

North River Garnet Company's Mine. This mine is located one mile east of the northern end of Thirteenth lake as shown on the accompanying geologic map. It was operated nearly continuously for a period of more than 20 years, until 1928. The deposit occupies the top of the mountain (elevation 2230 feet). The pit has been opened up to a maximum diameter of more than 300 feet and a depth of 140 feet below the top of the mountain. The garnet-rich zone extends for a depth of at least 50 feet below the main quarry level, on the northeast side of the quarry. The greater depth here is due to the dip of the deposit to the northwest. The rock becomes lower in garnet content toward the base. Some garnet gneiss is found to the east of the peak. The garnet occurs in crystals up to three inches in diameter and averaging one-half to one inch in diameter. They frequently show good crystal faces and dodecahedral crystals are not uncommon. Garnet constitutes 4 to 8 per cent of the rock and the crystals or "pockets" are scattered throughout a medium-grained, dark to light banded gneiss. Hornblende does not occur as rims around the garnets as in the case of the hornblende type of deposit. The groundmass consists of plagioclase feldspar and hornblende, with some hypersthene and clinohypersthene, augite, biotite and a small amount of pyrite and apatite. Early tables giving the mineralogical composition of the groundmass usually show 20 to 50 per cent orthoclase with some plagioclase of oligoclase-andesine composition (Miller, '12, p. 501). Miller's unpublished report on the Thirteenth Lake quadrangle estimates the plagioclase content of the garnet rock as 60 to 65 per cent of oligoclase-andesine (largely andesine)

Figure 27 Garnet gneiss at the top of the quarry of the North River Garnet Company's mine. Note the well-developed flow lines which are brought out by streaks of ferromagnesian minerals and rounded crystals of garnet.

Figure 28 Barton garnet quarry on the north side of Gore mountain, looking east. Gabbro outcrops on the north (left). The light-colored boulders and the ledge on the right near the back of the picture are syenite. Photograph by Cornwall, North Creek, N. Y.

feldspar. The thin sections that have been studied in connection with this report contain very little orthoclase and the plagioclase is about andesine in composition. The garnet is always found as crystals and never occurs in fine granular masses and rims such as are common in many of the igneous rocks of the region. In thin section the hornblende frequently shows marginal alteration to granular magnetite and hypersthene(?). There is considerable variation in the foliation and banding of the rock shown in the quarry. The structure may be brought out by bands of dark ferromagnesian minerals up to one or two inches in width or by wider bands of light and dark rock. The foliation is not pronounced in thin section. In addition to the foliation and banding, flow lines in the plane of foliation are extremely well developed. These flow lines stand out prominently on all the weathered surfaces around the edges of the quarry and are emphasized by streaks of garnet crystals and dark minerals (figure 27). They dip 12° N. 50° W.

Throughout the quarry there are many variations of the above described rocks. Small lenses or bands may be lighter in color due to the very small percentage of ferromagnesian minerals, while in others the dark minerals, especially hornblende, are very abundant. Biotite, frequently altered to chlorite, is occasionally the most abundant of the ferromagnesian minerals, and the texture of the rock is inclined to be variable, as certain areas are much finer grained than others. The garnet content and size of the garnet crystals also varies.

Much of the gneiss which occurs in a small, older pit north of the main opening contains magnetite in such quantities as to make separation of the garnet difficult. The rock in this locality is quite variable in appearance and garnet content. Narrow bands of biotite schist up to several inches wide occur, as well as larger bands of dark material (very hornblendic) containing many small garnets. All the bands or zones are parallel to the foliation and merge into the surrounding rock. On the east side of this pit a lens of light greenish gray, rather massive rock occurs, about a foot in thickness, which contains only a few tiny garnets and a few scattered flakes of ferromagnesian minerals. Most of the groundmass comprising the lens is composed of plagioclase feldspar, among which a few small bluish gray labradorite cores occur. The rock is very similar in appearance to some of the Whiteface-type anorthosite which occurs north of Gore mountain, and locally in the border phase anorthosite of the two larger anorthosite areas. It grades into a more foliated rock with a larger percentage of dark minerals.

The rock surrounding the garnet-rich formation of the mine and merging into the syenite which surrounds it has already been described (page 45). Owing to this occurrence of low-grade garnet gneiss which contains a few labradorite crystals, Miller suggests the following origin of the garnets (unpublished manuscript on Thirteenth Lake quadrangle). A large lenslike inclusion (or several small ones) of either an early, basic metagabbro or Grenville, hornblende gneiss, probably the former, was caught up, cut to pieces and assimilated by the anorthosite magma, producing a basic plagioclase hornblende gneiss with many small garnets. The garnets were undoubtedly produced by the reaction between plagioclase of the anorthosite and hornblende of the older rock. This lens was then assimilated by the syenite magma producing the garnet-rich dioritic gneiss which occurs now. The writer's interpretation of the origin of the garnet deposits is given at the close of this chapter.

Ruby Mountain deposit. A large deposit of garnet occurs on the southwest slope of Ruby mountain. Although garnets have not been mined in this area, the deposit has been surveyed and test pits opened up by the North River Garnet Company. The supply of garnet is estimated as large enough to last 30 or 40 years. It is, therefore, larger than the North River Garnet Company's mine east of Thirteenth lake and compares as to quantity of garnet with the Barton (Moore) mine.

The garnet rock consists of a series of lenses with some associated syenite. The syenite surrounds the deposit, as well as the individual lenses, which have not been mapped separately. The actual area of high-grade garnet gneiss is, therefore, much smaller than the extent of the deposit as shown on the map. A considerable amount of it contains insufficient garnet to warrant mining. These areas of low-grade rock occur mainly around the edge of the deposit and along the edges of the smaller lenses.

The garnet gneiss is very similar to that found in the mine previously described, although it is, on the whole, more variable in appearance and composition, containing numerous small streaks and lenses of hornblende. Miller has assigned the same origin to the garnet of this formation as he did to the garnets of the North River Garnet Company's mine. He describes a glacial boulder, eight feet in diameter, which occurs in a field one-third of a mile north of the north end of Thirteenth lake. It consists of Marcy-type anorthosite with a five-foot inclusion of hornblende-garnet-feldspar gneiss. The anorthosite also contains many streaks of hornblendic material. Miller suggests "that the boulder represents approximately the condition of the material of the garnet-rich lenses on Ruby mountain before it was affected by the intrusion of the syenite which gave it its present characteristics."

Hornblende-garnet deposits. This type of deposit is much more abundant than the garnet-gneiss type, although most of the deposits are too low grade to warrant mining on an extensive scale. With the exception of the Barton deposit on Gore mountain, those which have been worked are of small size and mainly low grade or erratic in garnet content. The dark rock in which the garnets occur is composed of plagioclase feldspar and hornblende, with small amounts of hypersthene, biotite, augite, pyrite and magnetite. The hornblende comprises 40 to 60 per cent of the rock in most cases. The garnets are usually of larger size than those in the garnet gneiss, the largest which have been found coming from the Barton mine. Rims of hornblende, in some cases rather perfectly developed and in others only partially so, usually surround the garnets. Frequently the rock is distinctly foliated owing to the orientation of the hornblende. In the Barton deposit, however, foliation is practically absent. Banding, such as occurs in the garnet gneiss, is not common, although there may be a variation in garnet or hornblende content in the form of layers or lenses. Some of the deposits lack any observable foliation.

Barton mine. The Barton garnet deposit (Moore or Rogers mine) is by far the most interesting deposit of garnet in the Adirondacks, because of the large size of the garnets, their striking setting and the association of the deposit with the surrounding rocks. This deposit furnished the first Adirondack garnet to be used for abrasive purposes. Mining operations have been carried on irregularly since 1882 and continuously since 1924 (Myers and Anderson, '25). The mine is located about two-thirds of a mile north of the summit of Gore mountain.

The garnet-rich rock occurs as a narrow, lenslike mass about three-fourths of a mile long with a nearly east-west strike (figure 28). It varies from 50 to 300 feet in width. It is in contact on the south side with syenite, on the west end with Marcy anorthosite, on the north with gabbro and on the east with gabbroic and Whiteface-type anorthosite. The foliation of the syenite dips about 15° to the north. The contact between syenite and mineable garnet is nearly vertical, sloping but slightly to the north. Layers of light-colored garnet gneiss up to one foot in thickness occur in the syenite. These frequently extend for 50 feet from the hornblende garnet rock and have the same dip as the syenite.

Large garnet crystals with good crystal faces occur in the syenite. In one case, two crystals, each about four inches in diameter, were noted occurring close together. One of these was inclosed in a hornblende rim, whereas the other was entirely surrounded by syenite. An irregular mass of hornblende, similar to the hornblende which forms the rim, occurs in the syenite a short distance from the garnet crystal which lacks the hornblende rim. In other cases garnet crystals and irregular masses of hornblende occur near each other in the syenite. Frequently hornblende incloses or partially incloses the garnet crystals. This association of garnet and hornblende in the syenite suggests that the large garnet crystals with the enveloping hornblende rims existed previous to the intrusion of the syenite, or that the formation of the crystals was independent of the syenite magma directly associated with this garnet deposit. The syenite appears to have separated the hornblende rims from the inclosed garnet crystals while in motion.

On the west end of the deposit a coarse-grained anorthosite, appearing to be closely connected with syenite, contains a considerable amount of fine, massive garnet. This zone is somewhat similar to the normal contact zones between syenite and anorthosite of the quadrangle.

The structural relations of the gabbro and garnet on the north side is of interest. Where the lenslike mass of garnet rock is narrower on the surface than normal the gabbro acts as a cap over the garnet deposit and in some cases may extend almost entirely across it to the syenite on the south side. Under this gabbro cap, the garnet rock continues as much as 100 to 150 feet to the north. In some places thick, nearly horizontal layers of gabbro extend for some distance into the garnet rock below the gabbro cap. The significance of this structural relation is not clearly understood. It suggests, as do the layers of light-colored garnet rock in the syenite on the south side, that the original rock, from which the present hornblende garnet deposit was formed, may have had a bedded structure.

The deposit occurs as a lens, which dips 7° to 9° toward the west. At the east end of the deposit, which is the upper end of the small valley in which the lens occurs, it is underlain by low-grade garnet gneiss which dips to the west at about this angle. The present quarry workings are near the west end of the deposit and the quarry is being extended to the east on a nearly horizontal level. In

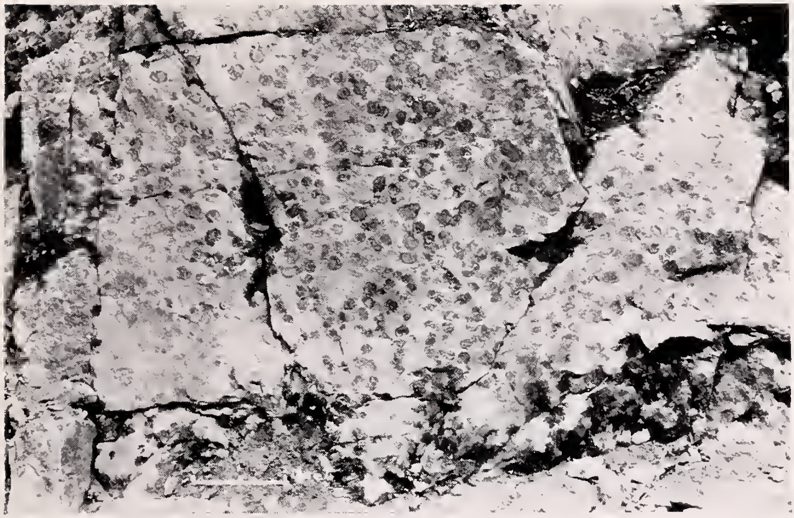


Figure 29 Ledge of garnet rock on the north side of the Barton quarry. Note the absence of gneissoid structure, the abundance of garnet crystals, and the narrow (darker) hornblende rims surrounding the garnet crystals. Photograph by Cornwall, North Creek, N. Y.

Figure 30 Large garnet crystals surrounded by well-developed hornblende rims (dark) in a boulder of garnet rock in the Barton quarry. Note the well-developed fracture planes, especially in the crystal in the lower right-hand corner. Photograph by Cornwall, North Creek, N. Y.

Figure 31 Crystal of solid garnet nearly ten inches in diameter taken from the Barton garnet deposits. Note the well-developed crystal (dodecahedral) boundaries. Scale shown by six-inch ruler

the opinion of F. C. Hooper, manager of the Barton Mines Corporation, the floor of this quarry should intersect the base of the deposit when operations have been extended only a short distance to the east. If this is found to be the case, it will be a check on the depth and dip of the deposit and on the supply of garnet available. It was the opinion of many of the previous managers of the mine that the deposit extended indefinitely in depth and the garnet supply was, therefore, unlimited. Other quarries that have been worked in the deposit east of the large quarry are only superficial openings.

The garnet-rich rock with its large red garnets, black hornblende rims and grayish matrix presents a striking appearance in the walls of the quarries (figure 29). The groundmass of the rock is made up of about 40 per cent hornblende, 40 to 50 per cent plagioclase feldspar (andesine?), hypersthene and clinohypersthene, with smaller amounts of biotite, apatite and pyrite as the remaining minerals. It therefore has the composition of a hornblende-rich hypersthene gabbro or diorite. The individual minerals of the groundmass average about one-eighth of an inch in diameter. Throughout this rock, which has a massive structure, are scattered many large reddish garnets which make up about 10 to 12 per cent of the deposit. The crystals average four to five inches in diameter. Crystals a foot in diameter are frequently found and garnets three feet in diameter and yielding about one and one-half tons of garnet have been taken out. A rim or shell of black hornblende completely incloses each garnet crystal. The hornblende of the rim is usually coarser than the groundmass, the individual crystals averaging about one-fourth of an inch in diameter. In most cases the width of the hornblende rim increases with the size of the garnets, some of the rims being three inches thick. Biotite crystals and irregular masses of plagioclase sometimes occur between the garnet crystal and its hornblende rim. Biotite and other minerals also occur as inclusions in the garnet. The garnets are always highly fractured with the development of many fracture planes which have the appearance of cleavage planes (figure 30). The surfaces of these planes are frequently coated with chlorite, pyrite or other minerals. It has usually been stated that the garnets of this mine do not show crystal outlines (Miller, '12, p. 495, and others). Nevertheless, crystal faces are often well developed on the garnet in this deposit. While perfect crystals are not numerous, they do occur. An example of one of these is the garnet crystal, nearly ten inches in diameter with its well-developed dodecahedral faces, shown in the accompanying photograph (figure 31).

A section across the deposit is of interest. The greatest part of the deposit, 50 to 150 feet in width, is similar to that just described. On the south the rock grades into the typical foliated quartz syenite of Gore mountain. On the north it grades into normal gabbro. The contact zones between the syenite and the garnet formation have already been described (page 109). These three zones, approaching the garnet rock in the order given, are: (1) layers of garnet gneiss in the syenite, (2) syenite with numerous small garnets showing good dodecahedral crystals and (3) syenite with irregular masses of hornblende and larger garnet crystals some of which are inclosed in hornblende rims. The succeeding zones are: (4) garnet gneiss which resembles the gneiss of the North River Garnet Company's mine and (5) normal garnet-rich rock; between the syenite and garnet deposit in places there is a narrow, nearly vertical mass of biotite schist which may represent a metamorphosed dike; (6) a few feet of dark rock containing numerous small garnets (one-fourth to one inch in diameter) with poorly developed hornblende rims; (7) gabbro containing a large percentage of hornblende; and (8) normal hypersthene-olivine gabbro. All the zones grade into one another.

Miller ('12) originally considered the garnet-bearing rock to be an inclusion of Grenville in the Gore Mountain syenite. He has modified this view, and in his unpublished report on the Thirteenth Lake quadrangle he suggests an origin similar to his theory of the origin of the garnet of the North River Garnet Company and on Ruby mountain (page 108). In this case he believes the old basic rock to have definitely been the foliated, southern border portion of the gabbro. Digestion by anorthosite and then syenite produced the zone of garnet gneiss on the south side of the deposit. Contact effects of the syenite on the southern part of the gabbro produced the present hornblende-garnet formation.

Hooper mine. A small deposit of a hornblende-garnet-rich rock, at the base of the mountain one mile northeast of the summit of Ruby mountain, was operated by the North River Garnet Company from 1894 to 1904, where the first mill for concentrating garnet was built. The garnets occur in a lens of hornblende gneiss, somewhat similar to the hornblende garnet deposit at the Barton mine. The lens is surrounded by typical foliated quartz syenite. It is parallel to the foliation of the syenite immediately surrounding the lens and dips about 39° to the north-northeast. To the northwest the dip changes to northwest. Most of the syenite in this area dips northwest. The southeast end of the deposit is cut off by the Thirteenth Lake fault (page 88). Contacts between the gneiss and syenite are not sharp and are occasionally cut by granite pegmatites.

The rock is quite similar to the Barton deposit, with the following exceptions: (1) the garnets are not as large and the crystals usually lack crystal outlines and are frequently slightly elongated in the direction of the foliation; (2) hornblende rims, while usually present, are not nearly as well developed; (3) most of the rock contains a higher percentage of hornblende; and (4) the rock is more strongly foliated. The hornblende and garnet content varies considerably. Small areas are much richer in hornblende and may contain very few garnets, or none at all. Locally the garnet is scattered through the groundmass as fine masses instead of crystals. There is also variation in foliation from rocks which are nearly massive to those in which foliation is prominent. Some biotite-hornblende-garnet schist is present.

Kemp and Newland ('99, p. 548–49) suggested that the deposit was an altered impure limestone caught up in syenite. Miller has considered the lens to be "an old dark rock (probably metagabbro)."

Humphrey Mountain deposit. A small amount of garnet was mined many years ago on the northeast face of Humphrey mountain along the contact between the gabbro of the mountain top and the surrounding syenite. Some garnet was also mined for use as watch jewels during the World War when the foreign supply was cut off. The deposit is somewhat similar to both the Barton deposit and the Hooper deposit. The same gradation from garnet-rich rock to gabbro also occurs, as at the Barton mine. The actual area of high-grade garnet rock is rather limited and occurs on the northeast side of the mountain at about 2500 feet elevation, just below normal gabbro. Hornblende gneiss, similar to the hornblende gneiss at the west end of the Hooper mine, is rather extensive and grades into the richer variety. It occurs between the garnet rock and the syenite which surrounds the base of the mountain. Near the syenite it is finer grained than just under the gabbro. Except for the small mass of garnet rock below the gabbro on the northeast side of the mountain, the hornblende gneiss usually extends up to, and more or less completely surrounds the gabbro (page 35). There are local areas of garnet-rich rock below the gabbro at various places. Miller has suggested that the contact metamorphic action of the syenite on the gabbro produced the garnets of this deposit.

Garnet deposits of adjoining quadrangles. Garnet deposits, where quarrying operations have been carried on at one time or another, are located in the quadrangles adjacent to the Thirteenth Lake quadrangle. The most important include the American Glue Company mine, situated in the Newcomb quadrangle, and the Oven Mountain, Rexford and Sanders Brothers (Warren County Garnet Company, Inc.) mines located in the North Creek quadrangle. Many small prospect holes and pits have been opened up in the garnet-bearing rocks. In most cases the garnet occurs in the hornblende type of deposit. Many of them are closely associated with Grenville rocks. For a description of the deposits see Miller ('12, '14, '19*a*), Myers and Anderson ('25) and Balk ('32).

Conclusions. The writer is of the opinion that the problem of the origin of the garnet deposits is as yet far from solved, and that sufficiently detailed study of these deposits has not yet been made. An exhaustive structural and petrographic study of the deposits, as well as of all the garnet-bearing rocks, should reveal important and conclusive information concerning the origin of the garnet. Much of the field evidence is confusing and suggests more than one interpretation. Some of the observations which have been made are given here, as well as interpretations which these facts seem to suggest.

Miller ('12, p. 498) has recognized the following modes of occurrence of garnets in this section of the Adirondacks:

1 As crystals or grains in various Grenville rocks, for example, the garnet-pyroxene gneiss; the hornblende-garnet gneiss; biotite-garnet gneisses, etc.

2 As distinct crystals frequently occurring in all types of intrusive rocks—syenite, granite, granite porphyry, and gabbro—except the diabase. [Garnet has been noted in some of the dikes of the Thirteenth Lake quadrangle.]

3 As large, more or less rounded masses with distinct hornblende rims in the long lenslike inclusions of Grenville hornblende gneiss in syenite or granite. [Miller now doubts the sedimentary origin of some of these lenses, especially in the case of the Barton mine.]

4 As more or less distinct crystals (dodecahedral), without hornblende rims, in a certain special basic syenite-like or acidic diorite-like rock. [This type is now known to be more basic in composition (dioritic or gabbroic).]

It is believed that a discussion in considerable detail of the modes of occurrence of the garnet will be of value in understanding the problem of the garnets.

1 Garnet is extremely abundant in most of the rocks of the quadrangle. It is well developed in many of the Grenville and mixed rock areas, especially in some of the rocks whose origin and history is still in doubt. In this class are the hornblende-garnet gneisses

and hornblende gneisses, or amphibolites, garnet-pyroxene gneiss and biotite-garnet gneiss, which occur interbedded with limestones and quartzite, and which may be closely related to the garnet-rich deposits. An interesting exposure occurs at the road forks one and one-half miles north of Garnet. Hornblende-garnet gneiss, containing seams or veinlets of pyroxene bearing graphite, occurs on the west side of the road. On the east side of the road there is an outcrop of graphitic crystalline limestone. It is possible that the pyroxene seams represent an early intrusive which picked up the graphite from the near-by limestone. If this is the case, then the hornblende-garnet gneiss existed prior to the intrusion of the anorthosite-syenite series. It should be observed, however, that this gneiss differs somewhat from the garnet-rich, hornblende rocks. It is more gneissoid, and the hornblende rims and garnet crystals are smaller and less perfectly developed. The impression one gains in the field is that these rocks have not been metamorphosed as completely as some of the hornblende deposits which are richer in garnet. In some of the hornblende or amphibolitic rocks associated with Grenville strata the garnet is more or less intergrown with hornblende, or occasionally pyroxene. In this case the large masses or pockets are not composed entirely of garnet, but of a mixture of garnet and hornblende. The lack of foliation, the large size and the crystal outlines of the garnets in the Barton deposit suggest more intense recrystallization than has occurred in some of the other hornblende-garnet rocks, provided these deposits had a similar origin to start with. This may be due to the fact that these areas were small and were more or less protected by the surrounding limestone or other Grenville rocks.

2 It is interesting to note that the syenite of this area is practically free from garnet except where it is in contact with the garnet deposits, or with the other igneous rocks. Large crystals up to two and three inches in diameter are found at certain localities in the syenite, but in most cases there are indications of another rock being involved. It has already been suggested that at the Barton mine and Peaked Mountain deposit syenite appears to be younger than the garnets.

3 Garnet is more abundant in the granite than in the syenite. Small crystals and fine granular masses occur. The fine garnets are often concentrated along the edges of the large quartz plates where the latter are well developed. A large part of the granite, however, contains no garnet.

4 One diabase dike which contained 30 to 40 per cent of fine granular, or massive garnet was observed (page 67). Lenses of massive garnet which constitute 50 per cent or more of the rock occur in various places throughout the Adirondacks and are usually associated with Grenville strata. The massive type of garnet is not suitable for abrasive purposes.

5 Garnet is always present in the gabbros of this area. In the more massive recrystallized centers of the gabbro, the garnet occurs mainly as fine granular masses forming rims around the ferromagnesian minerals. The borders of some of the gabbro masses contain large garnet crystals with hornblende rims in a hornblende gneiss or amphibolitic rock, similar to the hornblende gneisses of the Grenville areas. Similar to these rocks and also associated with gabbro are the garnet-rich rocks of the Barton mine and Humphrey Mountain deposit. The deposit of the Hooper mine is similar, but it is not associated with either gabbro or Grenville. It is possible that these amphibolitic borders of the gabbro may represent some of the early "Grenville" rocks which have been involved with the gabbro. Associated with the Humphrey Mountain deposit and the Hooper mine rock are finer grained, foliated or gneissoid rocks consisting of hornblende, fine garnet, pyroxene and plagioclase feldspar. In the Humphrey Mountain deposit, this rock is found between syenite and gabbro, more or less completely surrounding the gabbro. It is considered a foliated or amphibolitic border of the gabbro (page 35). Similar rocks occur along the border zones of other gabbro masses, in the Grenville areas and as small masses within the syenite and anorthosite. In the latter cases it frequently resembles rocks which Balk ('31) calls gabbro *in statu nascendi.*

Balk ('32, p. 84) considers the garnetiferous amphibolite of the American Glue Company's Mine "a lenticular segregation of the syenite rather than an assimilated inclusion of Grenville marble." He discards as unsatisfactory the possibilities that inclusions of Grenville may have been transformed into amphibolites or that the rock may represent a metamorphosed basic dike. He points out, also, ('32, p. 56) that massive gabbros are associated with amphibolitic borders and with basic hornblende-bearing phases of the syenite. He suggests that the gabbros accumulated as ferromagnesian minerals from the syenite. These consisted of hornblende and biotite with some augite. The centers of the gabbros were then recrystallized to a greater extent than the borders which remained amphibolitic and sometimes garnetiferous. While the writer recognizes this as a possible explanation of the origin of the garnet deposits, it should be pointed out that in the case of the Barton deposit especially, the rock shows evidence of intense recrystallization. It seems likely that the problem of the origin of the garnets is not so simple as Balk considers it to be. It is possible, however, that the hornblende garnet deposits which occur in the igneous rocks accumulated in some such manner as the gabbro masses and that a similar recrystallization after accumulation took place, but that as the original compositions were different, the results were not the same. Although the writer is inclined to believe that the garnets in the different garnet-bearing rocks are closely related, it has already been mentioned (page 22) that amphibolites may originate in at least three distinct ways resulting in rocks which may be identical in appearance and composition.

6 Garnet is abundantly developed in the anorthosite. Almost half of the specimens of Marcy-type anorthosite examined contained garnet, mainly as rims around ferromagnesian minerals. In the border phase anorthosite garnet is still more abundant. The anorthosite of the northern part of the quadrangle contains more garnet than that of the southern half. It is present as rims and as small crystals up to an inch or more in diameter. Most of the Whiteface-type anorthosite contains these garnet crystals which frequently become so abundant that hand specimens very closely resemble light-colored garnet gneiss in appearance. Frequently, also, as mentioned above (page 45), the garnet gneiss may resemble Whiteface-type or gabbroic anorthosite in hand specimen, and may even contain occasional labradorite crystals (North River Garnet Company's deposit). Balk ('31, p. 336) observes that flow lines in border phase anorthosite may be brought out by long straight streaks of individual garnet crystals spaced as much as two inches apart. These flow lines are similar to those occurring in garnet gneiss of the North River Garnet Company's deposit (page 107). It is evidence that the garnet crystals of the anorthosite were present in the magma before consolidation, and it is possible that some of the light-colored garnet-rich deposits may have accumulated in some such manner as this. The garnet crystals, however, need not have been a simple product of differentiation or crystallization from the intruding magma. They may have existed in the Grenville rocks as a result of metamorphism previous to the intrusion of the anorthosite-syenite series and may have been picked up by the igneous magma as it was being intruded. On the other hand, the garnets may have formed through a process of metamorphism of Grenville rocks by the anorthosite-syenite magma, after which they were picked up and carried along and accumulated in the form of garnet-rich deposits by this same magma. Small lenses and irregular

masses of hornblende are scattered throughout the garnet gneiss and may represent some of the groundmass of the original garnet-amphibolite which was picked up by the anorthosite-syenite magma. The hornblende garnet types, such as the Barton deposit, under such a theory, represent large masses of garnet amphibolite which were intensely recrystallized, but not separated into separate garnet crystals and lenses or small irregular masses of hornblende.

7 While small garnet deposits are numerous in the Grenville rocks, it is the opinion of F. C. Hooper, manager of the Barton Mines Corporation, that high-grade garnet-rich rocks of sufficient size to warrant extensive development are never found associated with Grenville rocks, but may occur in the igneous rocks. This is true in the case of the Barton, North River Garnet Company and Ruby Mountain deposits, which are the three largest and richest deposits of garnet known. It seems probable, therefore, that the igneous rocks have been at least partially responsible for the development of the large deposits of garnet.

If Bowen and Balk are correct in their assumption that the anorthosite was never truly molten as such, then the origin of the garnets by the assimilation of an older rock like metagabbro by the anorthosite magma, followed by the assimilation of this mixed rock by syenite, is hardly tenable; first, because of the condition of the anorthosite and second, because anorthosite, syenite and gabbro were intruded simultaneously as one magma, so that the only age question involved is in regard to the relative time of cooling and solidifying.

BIBLIOGRAPHY

Adams, F. D.
1909 On the Origin of the Amphibolites of the Laurentian Area of Canada. Jour. Geol., 17:1–18

——— & Barlow, A. E.
1910 Geology of the Haliburton and Bancroft Areas, Province of Ontario, Can. Geol. Survey, Memoir 6, 419p.

Alling, H. L.
1924 The Origin of the Foliation and the Naming of Syntectic Rocks. Amer. Jour. Sci., 5th ser., 8:12–32

——— & Kemp, J. F.
1925 Geology of the Ausable Quadrangle. N. Y. State Mus. Bul., 261, 126p.
1929 The Ages of the Adirondack Gabbros. Amer. Jour. Sci., 5th ser., 18:472–76
1932 The Adirondack Anorthosite and Its Problems. Jour. Geol., 40:193–237

Balk, Robert
1930 Structural Survey of the Adirondack Anorthosite. Jour. Geol., 38:289–302
1931 Structural Geology of the Adirondack Anorthosite. Sonderdruck aus Mineralogische und Petrographische Mitteilunger, Bd. 41, H. 3–6:308–434
1932 Geology of the Newcomb Quadrangle. N. Y. State Mus. Bul., 290. 106p.

Barth, T. F. W.
1930 Mineralogy of the Adirondack Feldspars. Amer. Mineralogist, 15:129–43

Bowen, N. L.
1917 The Problem of the Anorthosites. Jour. Geol., 25:209–43
1917a Adirondack Intrusives. Jour. Geol., 25:509–12

Brigham, A. P.
1898 Note on Trellised Drainage in the Adirondacks. Amer. Geologist, 21:219–22

Buddington, A. F.
1919 Foliation of the Gneissoid Syenite-Granite Complex of Lewis County, New York. N. Y. State Mus. Bul., 207–8:101–10

——— & Smyth, C. H. jr
1926 Geology of the Lake Bonaparte Quadrangle. N. Y. State Mus. Bul., 269. 106p.

Cushing, H. P.
1899 Augite-Syenite Gneiss near Loon Lake, N. Y. Geol. Soc. Amer. Bul., 10:177–92
1905 Geology of the Northern Adirondack Region. N. Y. State Mus. Bul., 95:271–453
1907 Geology of the Long Lake Quadrangle. N. Y. State Mus. Bul., 115:451–531

———, Fairchild, H. L., Ruedemann, R. & Smyth, C. H. jr
1910 Geology of the Thousand Islands Region. N. Y. State Mus. Bul., 145. 194p.
1915 Age of the Igneous Rocks of the Adirondack Region. Amer. Jour. Sci., 4th ser. 39:288–94
1917 Structure of the Anorthosite Body in the Adirondacks. Jour. Geol., 25:501–9
1917a Adirondack Intrusives. Jour. Geol., 25:512–14

——— & Newland, D. H.
1925 Geology of the Gouverneur Quadrangle. N. Y. State Mus. Bul., 259. 122p.

Emmons, E.
1842 Geology of New York, part II, Albany, 437p.

Gillson, J. L., Callahan, W. H. & Millar, W. B.
1928 Adirondack Studies: The Age of Certain of the Adirondack Gabbros, and the Origin of the Reaction Rims and Peculiar Border Phases Found in Them. Jour. Geol., 36:149–63

Holzwasser, F.
1926 Geology of Newburgh and Vicinity. N. Y. State Mus. Bul., 270. 95p.

Kemp, J. F.
1897 Physiography of the Eastern Adirondacks in the Cambrian and Ordovician Periods. Geol. Soc. Amer. Bul., 8:408–12
1898 Preliminary Report on the Geology of Essex County. N. Y. State Mus. Ann. Rep't, 49, v.2:575–614
1898a Geology of the Lake Placid Region. N. Y. State Mus. Bul., 21

——— & Newland, D. H.
1899 Preliminary Report on the Geology of Washington, Warren and Parts of Essex and Hamilton Counties. N. Y. State Mus. Ann. Rep't, 51:499–53. Essex Co., Minerva Township, 547–50

———, Newland, D. H. & Hill, B. F.
1900 Preliminary Report on the Geology of Hamilton, Warren and Washington Counties. N. Y. State Mus. Ann. Rep't, 52:137–62; Warren Co., Johnsburgh Township, 157–61

——— & Ruedemann, R.

1910 Geology of the Elizabethtown and Port Henry Quadrangles. N. Y. State Mus. Bul., 138. 173p.

1921 Geology of the Mount Marcy Quadrangle, Essex County. N. Y. State Mus. Bul., 229–30. 86p.

——— & Alling, H. A.

1925 Geology of the Ausable Quadrangle. N. Y. State Mus. Bul., 261. 126p.

Larsen, E. S. & Schaller, W. T.

1932 Serendebite from Warren County, N. Y. and Its Paragenesis. Amer. Mineralogist, 17: 457–65

Martin, J. C.

1916 The Precambrian Rocks of the Canton Quadrangle. N. Y. State Mus. Bul., 185. 112p.

Miller, W. J.

1912 The Garnet Deposits of Warren County, New York, Econ. Geol., 7: 493–501. N. Y. State Mus. Bul., 164: 95–102 (1913)

1913 Early Paleozoic Physiography of the Southern Adirondacks. N. Y. State Mus. Bul., 164: 80–94

1914 Geology of the North Creek Quadrangle, Warren County. N. Y. State Mus. Bul., 170. 90p.

1915 The Great Rift on Chimney Mountain, Adirondack Mountains. N. Y. State Mus. Bul., 177: 143–46

1916 Geology of the Lake Pleasant Quadrangle, Hamilton Co. N. Y. State Mus. Bul., 182. 75p.

1916*a* Origin of Foliation in the Precambrian Rocks of Northern New York. Jour. Geol., 24: 587–619

1917 Geology of the Blue Mountain, New York, Quadrangle. N. Y. State Mus. Bul., 192. 68p.

1917*a* The Adirondack Mountains. N. Y. State Mus. Bul., 193. 97p.

1918 Adirondack Anorthosite. Geol. Soc. Amer. Bul., 29: 399–462

1919 Geology of the Lake Placid Quadrangle. N. Y. State Mus. Bul., 211–12. 104p.

1919*a* Geology of the Schroon Lake Quadrangle. N. Y. State Mus. Bul., 213–14. 102p.

1923 Geology of the Luzerne Quadrangle. N. Y. State Mus. Bul., 245–46. 66p.

1924 The Geological History of New York State. N. Y. State Mus. Bul., 255. 148p.

1926 Geology of the Lyon Mountain Quadrangle. N. Y. State Mus. Bul., 271. 101p.

1929 Significance of Newly Found Adirondack Anorthosite. Amer. Jour. Sci., 5th ser., 18: 383–400

Myers, W. M. & Anderson, C. O.

1925 Garnet; Its Mining, Milling and Utilization. U. S. Bur. Mines Bul., 256

Myers, W. M.

1926 The Mineralogy of some Commercial Garnets. Amer. Jour. Sci., 5th ser., 12: 115–18

Newland, D. H.

1906 The Mining and Quarry Industry of New York State. N. Y. State Mus. Bul., 102: 70–73, and notes in later bulletins

1921 The Mineral Resources of the State of New York. N. Y. State Mus. Bul., 223–24. 315p.

Smyth, C. H. jr

1912 On the Genesis of the Pyrite Deposits of St. Lawrence County. N. Y. State Mus. Bul., 158: 143–82

——— & Buddington, A. F.

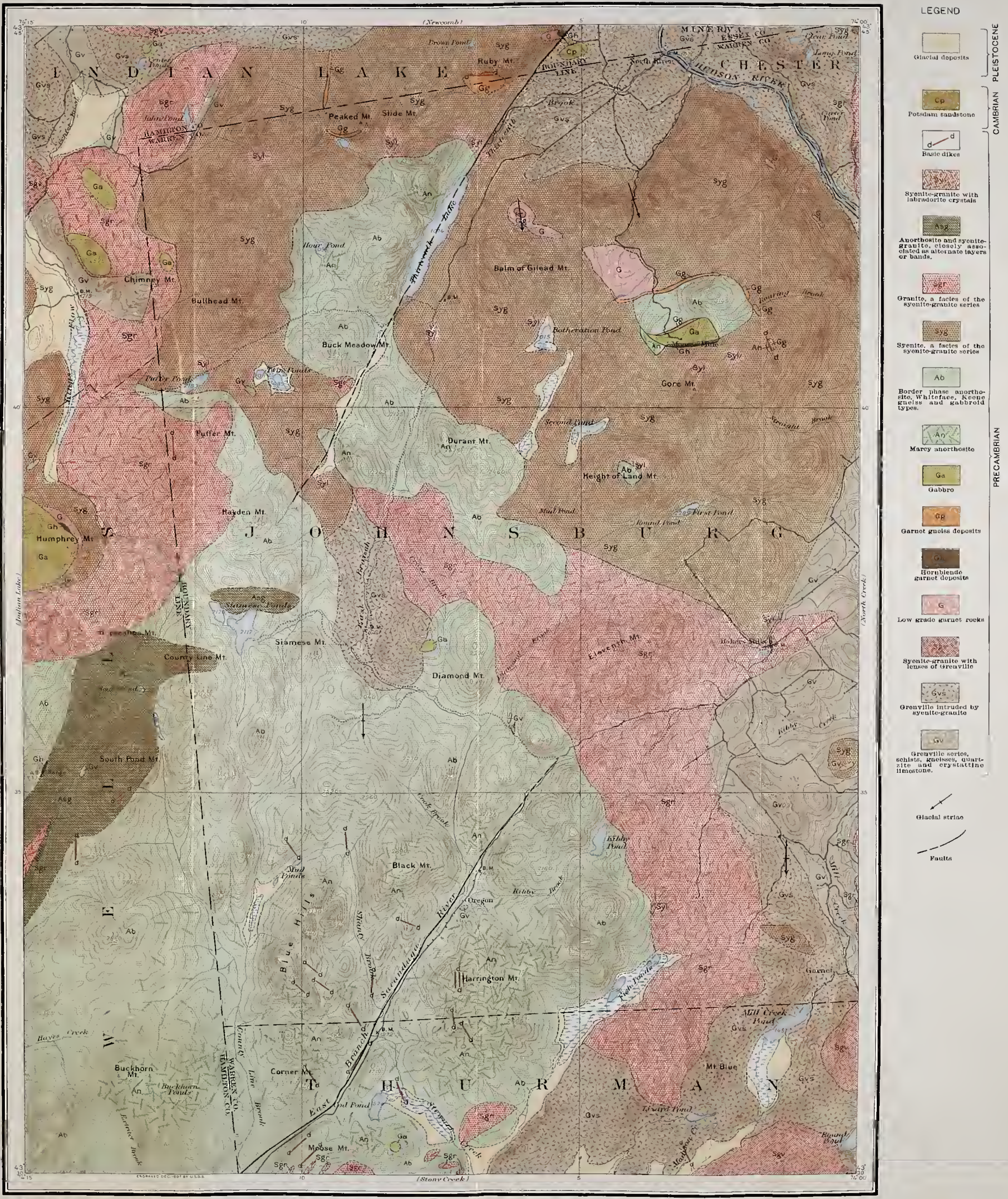
1926 Geology of the Lake Bonaparte Quadrangle. N. Y. State Mus. Bul., 269. 106p.

INDEX

Map 1 Geology and Topography of Thirteenth Lake Quadrangle

Map 2 Structure map, showing foliation, strike and dip angle

Map 3 Structure map, showing general strike and dip of foliation



GEOLOGY OF THIRTEENTH LAKE QUADRANGLE

Topography by U. S. Geological Survey
and State of New York, 1896

Geology by M. H. Krieger
1930-1931

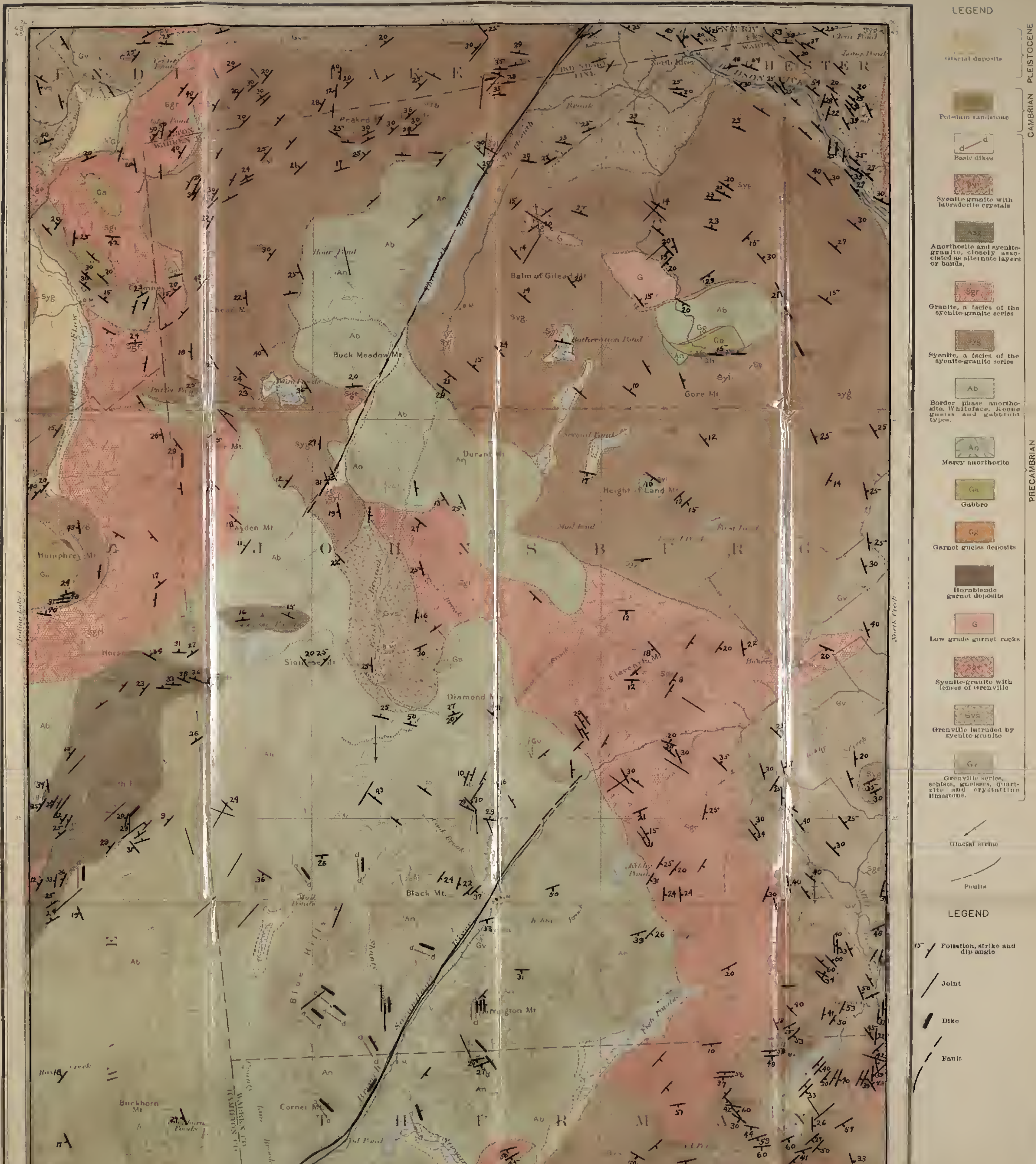
Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level

NEW YORK STATE MUSEUM
CHARLES C. ADAMS, DIRECTOR

UNIVERSITY OF THE STATE OF NEW YORK

BULLETIN 308
THIRTEENTH LAKE QUADRANGLE



Topography by U. S. Geological Survey and State of New York, 1896

MAP 2. STRUCTURE MAP SHOWING FOLIATION, STRIKE AND DIP ANGLE

GEOLOGY OF THIRTEENTH LAKE QUADRANGLE

Geology by M. H. Krieger 1930-1931

Scale 1:62500

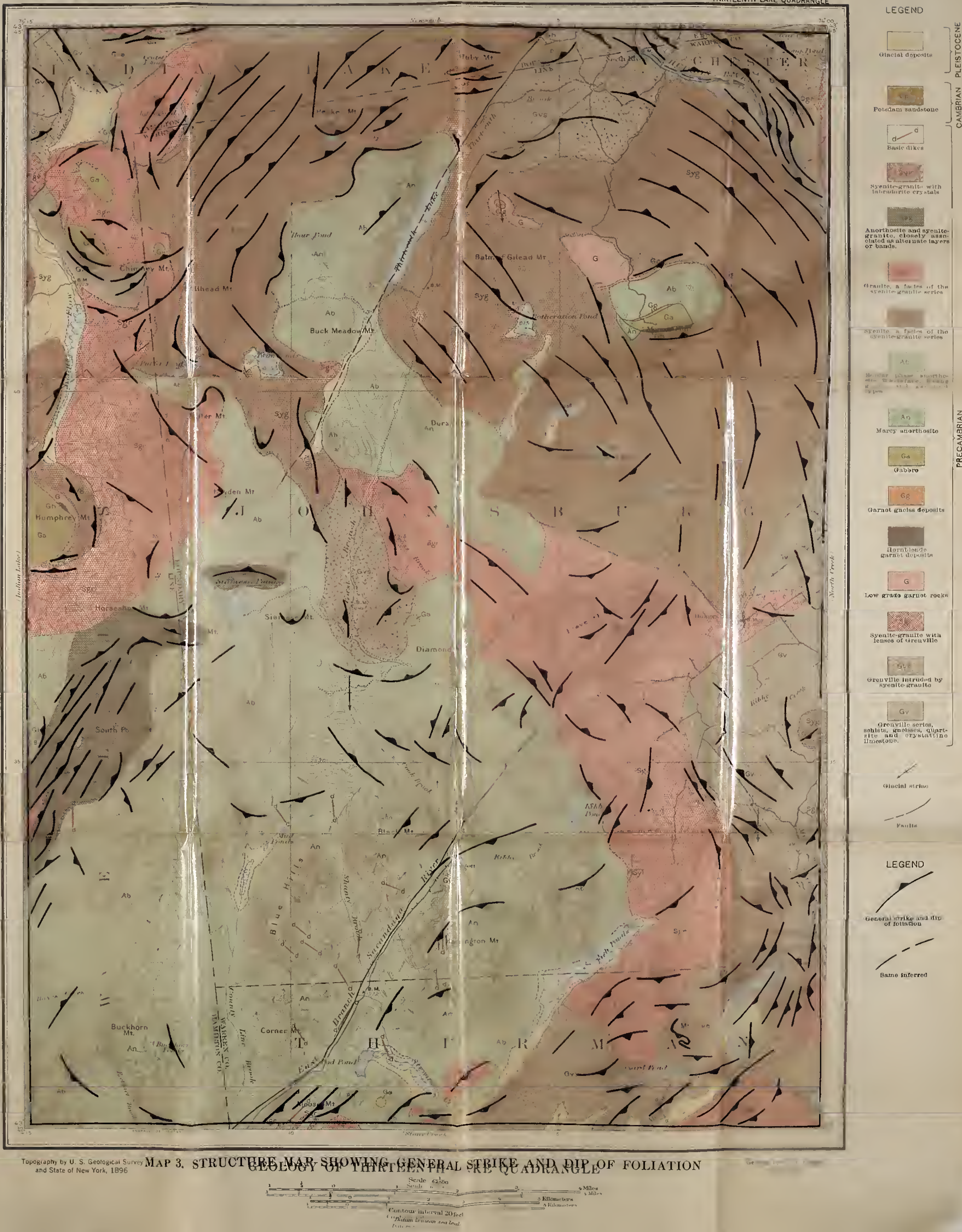
Contour interval 20 feet

NEW YORK STATE MUSEUM
CHARLES C. ADAMS, DIRECTOR

UNIVERSITY OF THE STATE OF NEW YORK

BULLETIN 308
THIRTEENTH LAKE QUADRANGLE

BULLETIN 308
THIRTEENTH LAKE QUADRANGLE



Topography by U. S. Geological Survey and State of New York, 1896

MAP 3. STRUCTURE MAP SHOWING GENERAL STRIKE AND DIP OF FOLIATION

GEOLOGY OF THIRTEENTH LAKE QUADRANGLE