New York State Museum Bulletin

Published by The University of the State of New York

No. 302 ALBANY, N. Y. September 1935

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE OSWEGATCHIE QUADRANGLE

BY NELSON C. DALE PH.D.
Temporary Geologist, New York State Museum

CONTENTS

ALBANY
THE UNIVERSITY OF THE STATE OF NEW YORK
1935

M310r-Je34-2000

THE UNIVERSITY OF THE STATE OF NEW YORK

New York State Museum Bulletin

Published by The University of the State of New York

No. 302 ALBANY, N. Y. September 1935

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE OSWEGATCHIE QUADRANGLE

BY NELSON C. DALE PH.D.

Temporary Geologist, New York State Museum

CONTENTS

ALBANY

THE UNIVERSITY OF THE STATE OF NEW YORK

1935

ILLUSTRATIONS

All figures are from photographs and drawings by the author.

GEOLOGY OF THE OSWEGATCHIE QUADRANGLE

By Nelson C. Dale

Temporary Geologist, New York State Museum

INTRODUCTION

The Oswegatchie sheet is situated along the east-west diameter of the Adirondack Precambrian area, and its mapping provides another element in the series of quadrangles necessary to the completion of a geological cross section of that region. The Port Henry, Elizabethtown and Mount Marcy sheets on the eastern end have already been mapped, as well as the Long Lake sheet in the middle and the Lake Bonaparte quadrangle on the west. There remains now only the Santanoni, Tupper Lake and Cranberry Lake sheets to complete the series.

Only meager knowledge of the geology of the area is to be found in existing literature. There is a passing reference to the occurrence of iron ore by E. Emmons in the survey of 1836–42; from the context the locality mentioned appears to be in the vicinity of the present Benson Mines. In his reconnaissance surveys of the western Adirondacks C. H. Smyth jr, ('99) traversed some of the region and recorded certain features of the geology of the northern part of the quadrangle. To be noted also is the description of the iron ore deposits at Benson Mines, Jayville and to the south of Fine village by Newland ('08) and of the quarry materials along the Carthage and Adirondack railroad by the same writer ('16).

Substantial help in the work of geological mapping has been obtained from the investigations by Smyth and Buddington ('26) of the adjacent Lake Bonaparte quadrangle. Their report has been freely used in the survey along the western border where the two areas join, for some of the major formations delimited on their map extend onto the Oswegatchie sheet.

The survey has occupied parts of the field seasons 1926–29 inclusive, a period of three and one-half months altogether. Acknowledgment is here made for valuable assistance in the field to the following students of geology in Hamilton College: G. W. Slaughter, C. Virkler, Allan Ostrander, C. F. Ferry and G. F. Shepherd.

LOCATION AND GENERAL FEATURES

The Oswegatchie quadrangle covers about 219 square miles of the northwestern Adirondacks. On the map its limits are defined by the parallels 44° and 44° 15′ north latitude and the meridians 75° and 75° 15′ west longitude. Nearly two-thirds of the area, the middle and northern parts, fall within Pitcairn, Fine and Clifton townships, St Lawrence county. The southern district is divided between the towns of Diana and Croghan, Lewis county, and the town of Webb, Herkimer county.

In its general features the area shares much that is common to the larger Adirondack region of which it is a part. It is mainly covered by forest growth of one kind or another, although most of the merchantable timber was lumbered 25 years or more ago. Large tracts subsequently were burned over so that they now support only small trees and scrub. There is still a small stand of virgin forest in the inaccessible southeastern corner of the sheet. south and east of Alder Bed flow.

The cleared lands represent less than 5 per cent of the surface, confined mostly to the northern quadrant, which is also the only district that is easily accessible from the outside. The Carthage and Adirondack railroad, a branch of the New York Central Lines, crosses the sheet in a general east and west direction at about one-third of the distance from the northern to the southern border and marks the approximate limit between the areas of cultivation and the forested region. To the south of that line there are no improved roads worthy of the name; a few trails provide the only means of access to the camps maintained there for hunting, fishing and lumbering. One of the through Adirondack highways (Edwards-Tupper Lake-Saranac Lake) enters the area on the northern border at Fine and runs southeast through Oswegatchie, Star Lake village and Benson Mines, where it crosses onto the Cranberry Lake sheet.

Agriculture is mainly carried on in the district about Fine and East Pitcairn, where the presence of the Grenville sediments is marked by a less rugged surface and deeper soils than is characteristic of the hard gneisses and igneous rocks. Dairying and small farming are the chief branches of agriculture.

Mining has been an important activity in earlier years. The period of depression immediately following the World War brought about the suspension of operations which have not subsequently been renewed. Iron ore has been the principal product, with large shipments made by Benson Mines in the form of high-grade magnetite concentrates. The enterprise once supported a community of several hundred inhabitants, and smaller operations were once carried on at Jayville and on the ridge south of Fine.

Star Lake is a well-known summer resort, as well as headquarters for those engaging in hunting and fishing, for which this district is reputed as one of the best in the Adirondacks. The elevation of about 1500 feet and the surrounding pine and fir forest make it a favorite locality, also, for health seekers.

The Oswegatchie river is important for power; the electric generating stations at Brown's falls and Flat rock have a combined capacity of 28,000 horse power. The stations belong to the Northern Utilities Company. Undeveloped power exists west of Fine and also on the Middle branch, west of the Tunnel. On the latter stream the fall from the Tunnel to Bryant's bridge, a distance of three and one-half miles, is nearly 300 feet, as given by the topographic map. The streams draining the western Adirondacks have a more equable flow than is normal to the region in general, because of the gradual slope of the surface and the many swampy tracts on their headwaters.

TOPOGRAPHY

The topography of the Oswegatchie area is not as rugged as that of the interior of the Adirondacks, even as that of the Cranberry sheet which bounds it on the east. The average relief between valley and hilltop is not more than 400 or 500 feet. The maximum difference in elevation is shown between Snyder lake, in the northwest, 772 feet above tide, and the unnamed knobs north of Emerald lake, which rise to 2000 feet or a little more.

The lowest, as well as the most smoothly contoured lands are in the northwestern corner on the outcrop of the Grenville limestone. The few square miles included in that belt have an average elevation of 800 feet above sea level. A gradual rise takes place in the surface from north to south and from west to east, with a gain of a little more than 1000 feet for the general elevation.

Devoid of marked topographic relief, the surface of much of the area is, nevertheless, very broken and even rugged in a minor way. A distinctive mark of the topography in the eastern, southern and southeastern parts is the lack of any decided trend to the hills and valleys, a condition undoubtedly related to the absence of diversity in the rock formations and their major structures. There are a few conical hills in the area, also irregular ridgelike masses, typified by Vrooman ridge, with steep eastern and southern slopes, the latter undoubtedly caused by glacial plucking in the production of what are known as lee slopes. In the northwestern part of the area there appears a more definite arrangement of the topography, arising from the great diversity in the rock formations with the consequent accentuation of erosional effects. It is in this area that the Grenville formations, the single representatives of Precambrian sedimentation, are found in association with the hard igneous rocks which prevail elsewhere.

Pleistocene glacial deposits include the serpentinous ridgelike eskers of subglacial stream origin and oval or conical kames of glaciofluviatile origin. The eskers are best exemplified by the ridges east of Lower Oswegatchie, near Twin lakes, Star lake, Streeter lake and Rock and Sand lakes. Those near Lower Oswegatchie are double in development and those on Star lake are multiple, as can be readily seen from a study of the topographic map. Kames are more conspicuous in the vicinity of Lower Oswegatchie and the region south of Star lake.

Depressions of inverted conical shape, so-called kettle holes, are found bordering the southeastern part of Star lake, in the Readway pond district, to the northeast of Tamarack creek and in Twin lakes. As these depressions are now water filled they may be more properly treated under lakes and ponds.

Nowhere over the area are terraces so well preserved and conspicuous as those to the south of Star lake, although others are seen north of that lake and north of Little river. Some in the East Pitcairn area are worthy of note. In the region about Star lake terraces at 1420, 1440 and 1500 feet mark the ancient water levels, whereas in the East Pitcairn region there are also 800 and 820-foot levels. The terraces are made up largely of stratified sand deposited by the flood waters that stood over the region during the Pleistocene period.

Drainage. The drainage of the whole quadrangle is tributary to the Oswegatchie river, which consists of the main or North branch, the Middle and the West branches, and which joins the Black river before it enters the St Lawrence at Ogdensburg.

In the absence of any notable and general structural control on the part of the underlying rocks the drainage pattern may be said to be dendritic. This statement applies to the sheet as a whole, although some evidence of structural control is seen in the Tunnel, a conspicuous gorge cut by the Middle branch in pink granite gneiss with vertical sides, 20 to 40 feet high, in the direction N. 80° E. Intersecting joint planes control the direction of the stream from the Tunnel to Bryant bridge. The Gulf stream, tributary to the Oswegatchie, also shows the control which the prevailing strike and dip exert upon the direction of flow.

Whether the main Oswegatchie and the Middle branch are flowing in their preglacial channels or not is difficult to determine; but in general it is safe to conclude that the ice scour, as manifested in the steep lee slopes of some of the hills and the drift deposits, has so modified the drainage that the streams today are flowing downhill, that is following the slope to the west or northwest (von Engeln '30). Suggestive evidence of former stream flow is found in the cliff overlooking the Gulf. A semicylindrical pothole at the base of a cliff, 100 feet above Tamarack creek, in granite gneiss, may be referable to the action of an ancient waterfall on a stream coming from the east.

The lakes in this area are small, shallow and inconspicuous although none the less beautiful; they are caused variously by differential stream erosion, glacial scour, glacial damming, kettle hole action, and by solution. Such lakes as Elijah, Long, Jenny and Greenwood may very well have been formed in part through glacial scour; Smith pond in the northwest part of the area and Snyder lake fill depressions in the Grenville limestone, arising, perhaps, to some extent through solution by underground waters. Portaferry lake may be due to this same action as we find some Grenville in the immediate environment of the lake. The constriction in the northern part of Cage lake is brought about by glacial deposits known as kames, and at the outlet we find a dam of glacial boulders.

By far the most interesting body of water is Star lake, well known as a summering resort (Star Lake village) and the largest lake on the sheet, being about five and one-half miles in circumference and a mile across in its widest part. It is hardly as symmetrical as a star, a form suggested by its somewhat radiating arms. Morainal material makes up all of the shoreline except for a ledge of granite gneiss near the outlet. An esker nearly bisects the lake. The several promontories projecting into the lake consist entirely of morainal matter. Only when the lake is very full does it overflow and then the water finds its way down into kettles of the Readway ponds, which themselves are without an outlet. It has been suggested by residents of the neighborhood that there may be a subterranean passage for the waters flowing into Twin lakes which are 89 feet lower than Star lake. As there is no visible surface inlet for either Star lake or Twin lake such a connection between the two lakes might explain the large flow of water from the southern one of Twin lakes into the northern one. Undoubtedly all three lakes are spring fed.

Twin lakes themselves are water-filled kettle holes, the water undoubtedly coming from springs. It is possible also that some of the supply may come from Star lake as has been suggested.

Rock and Sand lakes in the southeastern part of the sheet are of interest in that they are shallow, water-filled depressions formed in morainal deposits, as is shown by the bouldery and sandy nature of their shores as well as by the fact that they are separated by a very well defined esker which extends for 1000 feet in a northeasterly direction.

GENERAL GEOLOGY

THE ROCKS

The rock formations of the Oswegatchie sheet belong to two widely separated ages, Precambrian and Pleistocene. There are no representatives of the Paleozoic division, although outcrops of Potsdam sandstone occur within the western margin of the Adirondacks and are even present on the Lake Bonaparte sheet next west. In past geologic times the whole region may have been mantled by the sandstone, as well as possibly by beds higher up in the series, the last remnant of this cover having been removed as late, perhaps, as the glacial invasion. The evidences regarding the former existence of the Paleozoic beds will be discussed under the geologic history of the region.

The Precambrian formations constitute the present bedrock geology throughout the area. They are made up of a heterogeneous assemblage of petrologic types, igneous and sedimentary, besides some of very complex nature, the so-called "mixed" rocks. The igneous members belong to the class of deep-seated intrusives, which cooled far below the existing surface. They include granite, of more than one kind and probably more than one age, syenite, diorite, gabbro and pegmatitic and aplitic offshoots. They are known to be later than the sedimentary formations but their exact position in the Precambrian succession is in doubt. There is but one Precambrian sedimentary series in the Adirondacks, the Grenville, regarded as the oldest of all the formations, with which the igneous rocks have intrusive relations wherever the two are in

Figure 1 Grenville exposures; East Pitcairn.

Figure 2 Weathering in glacial boulder of Grenville limestone; Pitcairn.

contact. The series includes crystalline limestone, quartzite and a variety of gneisses, all showing evidences of intense metamorphism and regional compression.

The Pleistocene deposits of sands and gravels lie in a discontinuous mantle over the Precambrian formations. They are all products of the glacial invasion, some consisting of unsorted morainal accumulations and some showing a more or less stratified appearance indicative of water action in their deposition.

In as much as the Grenville sedimentary series is the oldest of the formations in the quadrangle its description will be considered first, although in areal importance it is quite subordinate to the igneous rocks. The series belongs to the most ancient (Archeozoic) period of the Precambrian. Its name is taken from the town of Grenville, north of the St Lawrence river.

GRENVILLE LIMESTONE

The principal exposure of this material, as indicated on the areal map, lies in the northwestern quadrant. A band of the limestone one and one-half miles wide crosses the corner of the sheet in continuation of a belt which has its main outcrop on the Lake Bonaparte sheet. The band is somewhat more than three miles long. Minor and poorly defined areas occur at Flat rock, Greenwood creek, Fine and Portaferry lake, all with the exception of the last-named in the valley of the North branch of the Oswegatchie. These scattered areas, taken in connection with the topography, particularly about Fine and Flat rock, point to the probable occurrence of much larger bodies under the valley where the outcrops are now concealed by alluvial deposits or by the ponded waters of the river.

The northwestern, or East Pitcairn, body has the character of a coarse-grained marble, light to bluish gray in color, and much weathered on the surface. Its outcrop is rather conspicuous in the vicinity of Snyder lake, less so to the north, and as seen from the road above Manchester school presents an imposing sight. A characteristic exposure is shown in figure 1.

The coarse crystalline rock disintegrates commonly to a loose gravelly condition to form talus at the base of the hills. Occasionally organic weathering aids in this disintegration. Miniature dendritic drainage grooves are carved on the sloping flanks of outcrops by the corrosive effect of running water with its carbonic acid (figure 2). Grooves and flutings may be as much as three inches deep and five inches wide. This effect together with that produced by solution along divisional planes causes a miniature karst topography. In the stream bed to the east of the road and south of the corners at East Pitcairn the marble for long distances is channelled and fluted with grooves to the depth of as much as three feet.

The Grenville limestone varies considerably both in size of grain and purity. In some occurrences, as at Fine, the grain is almost indistinguishable. Again at Manchester school the crystals measure from six to eight inches in diameter. Grains measuring three and four inches are common. Some strata show cataclastic and protoclastic textures resembling those of the syenite. In these occurrences the limestone has been under the influence of contact metamorphism from adjacent syenites and pegmatites.

In purity the limestone shows considerable variation. In contact metamorphic relations the limestone acquires various silicates such as pyroxene, scapolite, feldspar, and phlogopite, also pyrite, magnetite and hematite. At Flat rock the limestone in a small hill is very coarsely crystalline and contains only small amounts of secondary minerals. In fact the remains of a lime kiln at that point confirms the latter statement as to freedom from inclusions. The foreign material consists of thin bands and stringers of silicates with folded and disrupted structures arising from mass flowage of the limestone under compression. Some of these inclusions appear, however, to be disrupted apophyses from the near-by syenite. The method of occurrence of the limestone at Flat rock is shown in figure 3.

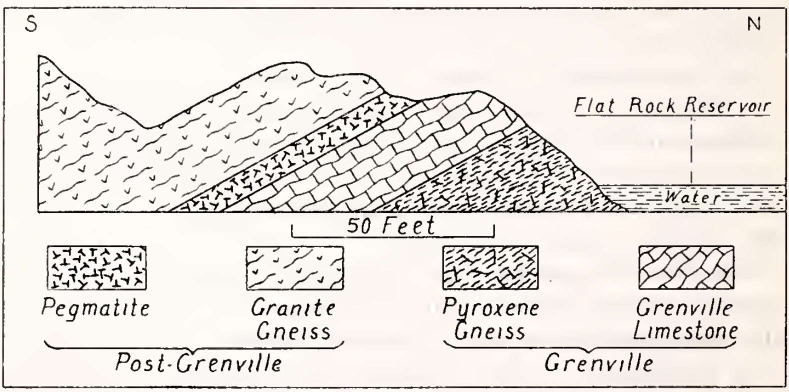


Figure 3 Precambrian rock relations near Oswegatchie.

The structural relations of the Grenville limestone have to be studied almost entirely from the bandings, although these should not be mistaken, necessarily, for stratification planes which have been almost or quite erased through the processes of earth movements. The bandings are brought about by the parallel arrangement of the impurities or it may be the layers differ from each other by variation in grain size, those of finer grain alternating with coarser.

South of East Pitcairn Corners, the limestone shows divisional planes with a strike N. 20°–24° E. and a nearly vertical dip, but does not maintain the same structure throughout. High westerly dips generally prevail. Strikes of N. 50° E. and N. 10° E. are found in the central part of the body and toward the northwest. In the absence of sufficient data from which to decipher fully the structure of this body before erosion set in, it may only be said that the available information suggests a westerly inclined isoclinal fold for this area. This structure seems to be borne out in miniature by the forms assumed by inclusions which originally were a part of the pyroxene gneiss-quartzite series.

In McDonald's sugar bush, south of Snyder lake, several structural features of a minor sort occur that appear to have a bearing on larger problems. The limestone is not only intruded by syenite but also by pegmatites and quartz veins. In the pegmatite occur inclusions of calcite which appear to be recrystallized limestone fragments. We also find that the syenite body on the north side of the orchard is most irregular, although not visibly continuous throughout its length. It is a series of surficially disconnected bodies branching and bifurcating along the solution joints. It may be that the sill through deformation during intrusion became disconnected and later took on the appearance of an inclusion or series of inclusions. In this same mass are two sill-like bodies of porphyritic syenite, one on the southeast side and the other on the northwest, both with westerly dips.

An interesting occurrence of blue calcite is found in limestone to the west of Snyder lake in zones following the strike over a width of four or five feet, both in connection with pegmatites and in areas free from pegmatites. This blue color disappears upon heating, indicating its organic origin. Fetid limestone or marble also occurs in certain parts.

One of the largest areas of Grenville limestone is just north of the village of Fine where exposed in sections are some 300 feet of beds which differ among themselves in composition, texture and purity. In some beds the grain is very compact, but in others the particles may reach several inches in diameter. The more impure limestone carries such minerals as wollastonite, coccolite, tremolite, phlogopite, and pyrite.

Other occurrences of Grenville limestone, such as those between Flat Rock and Brown's Falls power plants, at the three corners where the South Edwards road branches off from the Harrisville road, and near Portaferry lake, are all very small as far as we can tell at present and very much involved with syenite and its contact effects. For these reasons it would be more appropriate to include their descriptions under the subject of contact metamorphism.

As we pass eastward from the limestone in the East Pitcairn district for about a quarter of a mile we find the following sequence:

Grenville limestone
Quartz-mesh silicate rocks
Pyroxene gneiss
White weathered quartzite with quartz veins
Rusty quartzite
White and gray banded quartzite

This series is generalized on the areal map and lies as a gently curving and northerly tapering body between the limestone on the west and the syenites on the east. Generally speaking, the area may be said to consist of quartzites on the east and the pyroxene gneisses on the west, both formations showing numerous intrusions of syenite and its aplitic variants. This body at the southwestern part of the area measures about five-eighths of a mile in width with northeasterly strikes and westerly dips, but at the convex part of the curve widens to over a mile with more northerly strikes until at the northern part of the area the formation is not more than a quarter of a mile wide. Both within this body and along the contact are large and small bodies of the syenite which have worked their way through and along the divisional planes of the quartzites and pyroxene gneisses. One especially large body or sill is just west of Portaferry lake and east of East Pitcairn. The Fine-Harrisville road cuts through it.

GRENVILLE QUARTZITE

Much of the quartzite in the eastern part of the Grenville area is feldspathic and resembles an aplite. As a matter of fact, there has been such a drenching and soaking of the rock from juices of the syenite body that in places it is extremely difficult to differentiate between what is true quartzite and what is not. Some of the quartzites found on and above the western shore of Portaferry lake and along Greenwood creek are not by any means pure types. One of the types near the northwest shore of Portaferry lake is a minutely banded dark and brownish gray silicious rock containing very fine pegmatitic matter. One band may be said to be micro-gneissic with silicious and ferromagnesian minerals aligned in exceedingly thin laminae. The rock, according to microscopic examination, contains over 75 per cent quartz, with plagioclase and hornblende as substantial ingredients, besides zircon, apatite, magnetite and pyrite as accessories. Its sutured contacts in places, as well as protoclastic texture, indicate the effects of deformation accompanied by recrystallization.

The relation of the quartzite to the granite gneiss and syenite gneiss is shown in figure 4, based on the outcrop about three-fourths of a mile north of Red school. It is possible that such an occurrence as this may be explained by isoclinal folding although the quartzite could not be followed for more than one-half mile both north and south of this locality along the strike. Here the quartzite occurs in beds one foot thick which weather to a rusty brown color and have a sandy or friable texture. Its thin-bedded structure and its quartzose nature are indicative of a sedimentary origin.

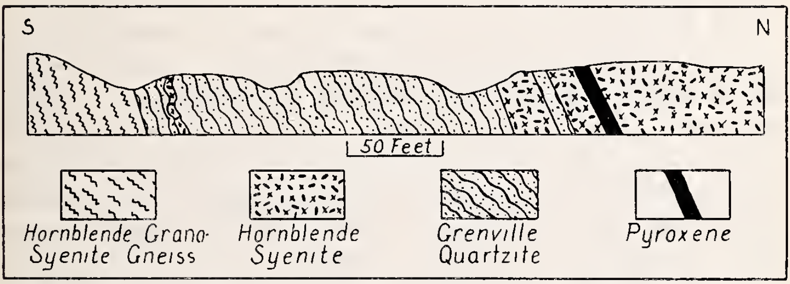


Figure 4 Grenville quartzite and intrusive rocks north of Red School.

About one-half mile south of Portaferry lake and north of Greenwood creek is an outstanding occurrence of banded and injected quartzites not unlike that of Portaferry lake. The series strikes N. 25° W. and dips 55° SW. giving rise to sharp westerly slopes in this area. The rock is pinkish gray in color and distinctly banded. The bands and laminae are often accentuated by products of pegmatization. Some bands are extremely fine grained, homogeneous pink in color and crystalline in texture, suggesting an aplite; others are slightly coarser in grain and grayish brown in color, with inclusions of orthoclase, pyroxene and quartz. Under the microscope this type of rock, due to the predominance of perthite over quartz and the presence of such minerals as albite, diopside, zircon and magnetite, seems more akin to the igneous than to the sedimentary rocks. Nevertheless, in outcrop it shows a banded, stratified appearance, is extremely fine grained and hard, characteristics which point to relationship with the Grenville series.

PRYOXENE GNEISSES ETC.

Closely associated with the quartzites are the pyroxene gneisses, which contain dominant quartz, pyroxene and feldspar together with such accessories as pyrite and magnetite. By weathering of the pyrite to limonite the rocks take on a rusty color, characteristic of their outcrop in most places. Close to the western margin of the sheet, north and south of the Harrisville-Fine road, the gneisses are finely crystalline and banded, with calcite and dolomite as more or less persistent ingredients. In this area some zones are more silicious than others. The calcareous zones are metamorphosed parts of the Grenville limestone in proximity to the nearby syenite bodies. A rusty weathered surface, laminated structure, and high westerly dip characterize this body.

Both the quartzites and pyroxene gneisses are intruded by sills and veins of the syenites and their differentiates, so that it would be difficult even for this reason to estimate the thickness of the series. The width across the strike of these formations at the widest place measures a mile and with 50° to 60° for the average dip the thickness would be 4000 feet or a little more. If these rocks in an earlier stage of their history have been isoclinally folded, as seems to be the case, this estimate could hardly answer. Barring intrusions and inclined isoclinal folding in the north where, according to the map, the series measures approximately three-eighths of a mile in width, we arrive at the estimate of 1715 feet for the thickness of the quartzite-pyroxene gneiss formation at this point.

Close inspection both in the field and in the laboratory shows that many of the pyroxene gneisses contain a large proportion of igneous material although it is believed they were originally sedimentary and probably limestone in some cases, as shown by Adams and Barlow ('10) and Buddington ('29). Subsequent soaking of the series by magma derived from post-Grenville intrusions has altered them to such an extent that, with the development of new minerals, the banding, flexures and general association with other Grenville formations of undoubted sedimentary origin are all that is visibly left of their sedimentary lineage.

The main body of pyroxene gneisses, for which the term "modified Grenville" may be used, is found along the valley of the Oswegatchie with two southern extensions, one toward Sucker pond, and the other toward Star lake. No attempt has been made to show the differentiations of this series other than what the map indicates owing to the thick glacial cover and forested condition.

North of Fine is a large exposure of coarse, banded, pink and green pyroxene gneiss, some bands of which are highly pegmatitic, some have quartz injections, and others have a large content of pyroxene and feldspar. Strong complex folding characterizes this area, as shown by the varying strikes which range from N. 55° W. to N. 30° E. Reference will be made later to the same type of banding and folding as found in the region northwest of Benson Mines.

A very good exposure of the pyroxene gneiss occurs along the state road just east of Fine in and near the road cuttings. Of somewhat rusty appearance, the body is intruded by pink granite gneiss and syenitic pegmatites and has the structure of an anticlinal fold, exhibiting great crushing effects near the contact with the pegmatite. In this series the bands measure a foot or less in width; the general strike is about N. 30° W. and the dip, 35° W. Inclusions of fine and coarse-grained limestone are found in the gneiss.

In composition these rocks resemble igneous types, and, viewed as a whole, represent a very wide range and great difference in mineralogy. The normal banded pyroxene gneiss as observed at Fine consists of orthoclase, diopside, and quartz in descending order of abundance with accessory zircon, apatite and magnetite. Under the microscope there appears to be considerable variation in composition within any one band and much more across the bands. In some bands orthoclase is the dominating feldspar; in others it shares importance with albite. All color tints are found from dark green arising from dominant diopside, through moderate green, in which feldspar is conspicuous, to much lighter colors, in which the pyroxenes are more thoroughly disseminated or only slightly represented. Injections of pegmatites are also to be seen. In other bands biotite, phlogopite and hornblende, with feldspars and quartz, make up the composition. The appearance of a representative sample of the gneiss under the microscope is shown in figure 5.

Two characteristic types of this series—one north of Fine and the other south—showed the following percentage content by microscopic analysis:

Slide	*Orthoclase*	*Microcline*	*Diopside*	*Quartz*	*Zircon*
$33B_1$	36.5	26.0	26.0	9.05	2.0
$79A_7$	60.7	....	16.0	23.2	...

It would be possible to present a selected list of microscopic analyses from the pyroxene gneisses which show even greater differences than the above. Much magnetite, garnet, hornblende and apatite were seen in some of the slides besides these components.

Certain banded and exceedingly fine-grained rocks occurring to the south of the state road at Fine and between the river and the road to Harrisville should be considered in this place although they do not all belong to the pyroxene gneiss group. The only undoubted Grenville appears to be the marble which is found as moderate westerly dipping strata between highly pegmatized banded gneisses and pink granite gneiss, the latter, apparently, taking the form of sills. The rocks lying on either side of the gneiss are characterized by extreme fineness of grain and have, at the first glance, the appearance of either pink feldspathic quartzites or pink aplites in parallel bands. They are distinctly banded, finely gneissic, of pinkish gray color and of slightly waxy luster. Under the microscope protoclastic augen structures dominate with phenocrysts of microcline, perthite and quartz, all showing wavy extinction and set in a ground mass of finely granulated feldspar and quartz grains. The evidence of recrystallization seems to be very strong as these finely divided grains have more or less sutured contacts. In the lighter colored types muscovite and sericite are found along the foliation planes where they assist in producing the augen structure as well as cut across the primary foliation planes. Magnetite is fairly abundant, and zircon is also found along these foliation planes.

In other bands the groundmass appears to consist largely of phenocrysts of quartz, microperthite and microcline about which are wrapped, as in augen structure, a groundmass of very finely divided quartz, feldspar and green hornblende with some zircon and chlorite, this latter mineral undoubtedly an alteration product of the hornblende. In both of these types the sutured relationship, as well as the general structure, bears evidence of the effects of dynamic metamorphism.

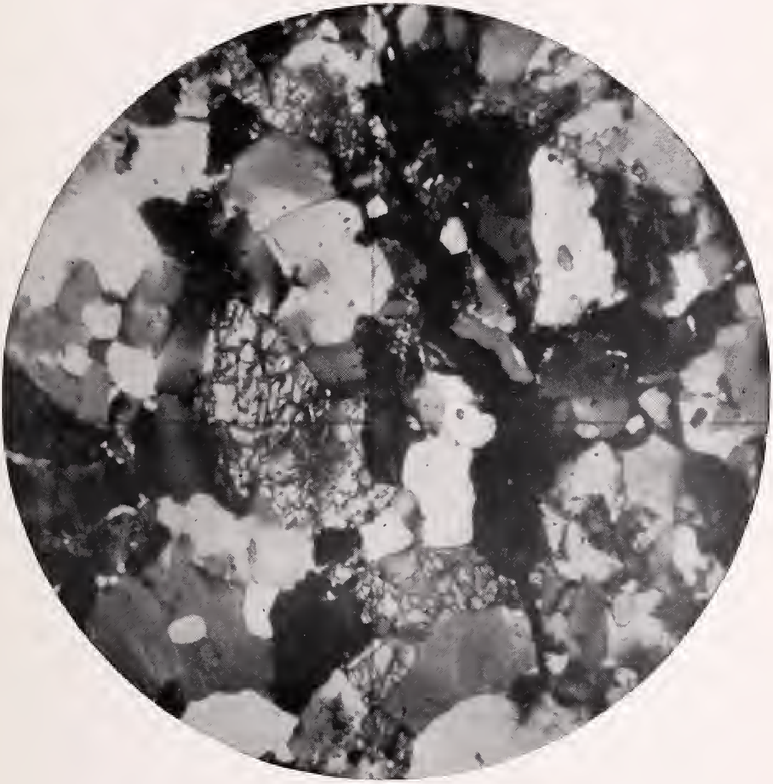


Figure 5 Microphotograph of Grenville pyroxene gneiss from Fine, N. Y. x 27. The lighter colored minerals are quartz and feldspars (orthoclase, albite, microcline and perthite) ; the cleaved and fractured mineral is diopside.

Other bands show less of the crushing and recrystallization phenomena than those just described and apparently are a product of later intrusions, as they are found cutting these finer grained protoclastic rocks in sill-like bodies. The latter are usually somewhat coarser in grain and granitoid with interlocking textures and consist of such essential minerals in descending order of abundance as quartz, orthoclase, albite, microcline and hornblende with magnetite, pyrite, hematite and zircon as accessories. These types are devoid of the crushing effects so characteristic of the former rocks.

In all the types quartz and feldspar are apparently the chief minerals and of these the feldspar predominates over the quartz. Hornblende is the common ferromagnesian mineral of the coarse kinds, but diopside is the common constituent of the fine-grained types, though these very light pink fine-grained rocks appear to have very little of the darker minerals.

One of the best exposures of the pyroxene gneisses is found between Kalurah and the Harrisville road, on the north side, not far from the corners of the Kalurah-Harrisville road. It is referred to by Buddington ('26). All the characteristics mentioned, such as rusty weathering, ribbed and corrugated surface and highly injected condition, are noticed here.

Another outcrop of the same gneisses, but widely separated from the main occurrence, is found about one and three-fourths miles northwest of South Creek lake and not far from the syenite gneiss and granosyenite contact. Here a ledge measuring some 75 feet long in a north-south direction and not over 200 feet thick lies intercalated between the westerly dipping sills of syenite gneiss. The rock is dominantly quartzose, but shows disseminated coccolite and less frequent garnets, with many intersecting quartz veins. It is a light and dark banded rock which weathers to a sandy granulated material.

Following the strike N. 50° E. to a small gap in the series, the west wall continues to be of pyroxene gneiss but strongly pegmatized by medium-grained pegmatites and aplites. As a result of pegmatization this type changes from a fairly coarse granulated rock to one which is extremely fine grained, the changed condition being brought about undoubtedly by excessive contact metamorphism produced by intruding aplites and pegmatites. The series recurs in all probability on the west side of the gorge of Cold Spring creek though it was not possible to trace it uninterruptedly. Its strike is N. 10° E. and the dip 72° W. Here, within 50 or 60 feet of the west edge of the gorge is a vari-colored greenish gray and brown-banded formation made up largely of pyroxene, quartz, feldspar and garnet with sills and seams of pink aplite. These two bodies, occurring as they do so far away from the main mass of Grenville, rather indicate that they are part of a large inclusion which had been torn off from the main mass during the intrusion of the syenite and the granite gneiss complex and had remained here as a root pendant of the shouldering process. The east slope of the gorge has only a veneer of this series, much injected by pegmatitic material. Erosion apparently has taken advantage of this weaker series of rocks and has been responsible for the making of the gorge.

In the gneiss area just east of the bridge over the Oswegatchie and east of the Harrisville road the rock outcrop presents more of a lit-par-lit appearance than elsewhere, but upon close inspection this effect is produced largely by injections of pegmatite in seams from five to one mm wide, rimmed by green augite, the latter mineral frequently appearing as segregations within and without the area of the bands. Under the microscope this rock is essentially orthoclase, albite, quartz, microcline, augite and hornblende, in descending order of abundance; magnetite grains with pyrite centers, both altering to limonite, make up the chief accessory. This rock is characterized more by the interlocking textures than is usually observed.

In the bed of the Oswegatchie, east of the new Brown's Falls power plant, ledges of banded mica gneiss showing differential solution pits on the surface consist of a dark gray rock made up essentially of feldspar and biotite, with injections of quartz, orthoclase, biotite, and garnet.

The origin of these masses is generally thought to be traceable to contact metamorphism or replacement of Grenville members. As shown by Adams and Barlow ('10) and Buddington ('29), it is probably the limestones that have been subjected to these influences.

Closely associated with both the pyroxene gneisses and the hornblende syenites are sill-like bodies of a rock that consists almost entirely of either light-colored or green pyroxene. Several occurrences of the lighter pyroxene rock are found associated with the hornblende syenite on the House property not far from the Red School. The association of this light type, which is probably diopside, with syenite and pyrrhotite is brought out in figure 6. Owing to the proximity of the pyrrhotite, the pyroxene weathers a rusty brown. The fresh rock is light greenish gray in color, massive in appearance and of granitoid texture, fine to medium grain. Under the microscope white diopside and phlogopite were the only minerals observed. Other variants of this lighter pyroxene rock are found,

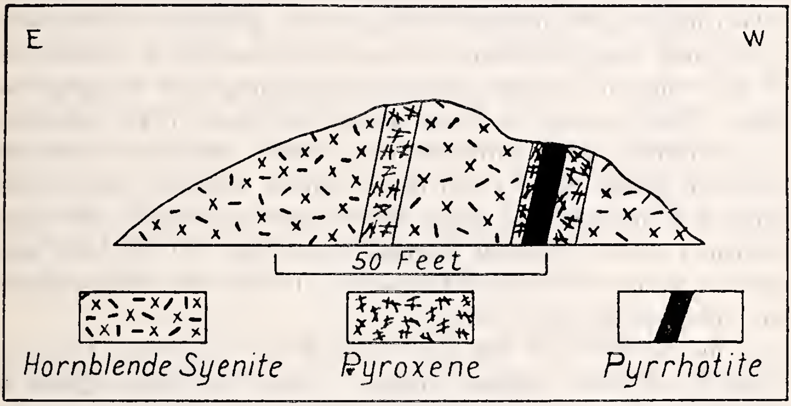


Figure 6 Geological occurrence of pyrrhotite, near Red School.

but essentially they are all of the same type. Near Greenwood creek, south of Portaferry lake, this same type is associated with syenite-intruded marble and quartzite. A light green variety occurs across from the House property and will be described later on as a molybdenite occurrence.

The green pyroxene rock is much more common than the white and is usually associated with the pyroxene gneisses, although it has been found in proximity to the hornblende syenite. In the course of the field work many occurrences of this type were noted, but only near Benson Mines is it found in a substantial body. A conspicuous, though small, outcrop is east of the bridge over Yellow creek in the south extension of the banded pyroxene gneiss series south of Fine. Here a body of pink and green pyroxene gneiss extends nearly 500 feet from west to east; the rock weathers to a decidedly green color in the western part but is lighter toward the east. The change from the green to the lighter color is clearly brought about by the greater development of feldspar in the gneiss series to the east. This series has apparently been soaked with pegmatitic material which has crystallized out as diopside and orthoclase. This occurrence perhaps is not as typical as some where the pyroxene is practically massive; but it shows something of the nature of its origin and its relation to the pyroxene granite gneisses.

Another occurrence of this rock associated with the mica and hornblende and pyroxene gneisses is south of Star lake on the

Kinney farm. On the south slope of the upper, or 1600-foot terrace, occurs a sill of banded augite-garnet rock measuring 15 feet thick striking northwest and dipping 60° to 70° north. This body consists largely of pyroxene and garnet with injections of quartz.

Two miles south of Scott's bridge and a quarter of a mile west of the road is an occurrence of pyroxene gneiss, with segregations or injections of massive pyroxene paralleling and crossing the gneiss. The pyroxene is found around the border of the pegmatite or as isolated crystals within the mass itself. Whether or not the more acid granite rock, which lies in contact with the main syenite series, is a differentiated phase of the latter or whether both have originated from a common magma, is not clear, but the basic pegmatite is seen to cut both rocks showing it to be of a later sequence than either of the other two.

To the northwest of this occurrence, within a quarter of a mile, is the Frank Scott feldspar prospect, where the granite gneiss is intersected by pyroxene-orthoclase pegmatite which shows in good development such materials as augite, apatite, wollastonite, calcite, fluorite and quartz. Wherever the dike material comes in contact with the country rock the pyroxene appears as a series of parallel stringerlike hosts, indicating a later age of the pegmatite.

At the Hurlburt feldspar prospect in the village of Oswegatchie, associated with the pyroxene gneisses and not far from the contact of the Grenville with the granite gneiss, is a pegmatite zone consisting essentially of feldspar, green diopside, and some other minerals which will be described later. Here the pyroxene gneisses are cut by a sill or dike of pegmatite running N. 70° E., consisting largely of feldspar, quartz, scapolite, titanite, pyrite, pyrrhotite, epidote and fluorite. Under the trestle on this property the pegmatite appears to be very coarse in the center, becoming finer grained and banded where in contact with the gneiss. Apophyses from the pegmatite body cut the banded gneiss series. In the more pyroxenic portions of the occurrence a small dike of coarse grained augite rock is found to cut the pegmatite itself, evidencing apparently a later intrusion.

The largest and the only substantial occurrence of this diopside rock occurs just off the state road about one mile east of the village of Star Lake and within one-eighth of a mile north of the road. The situation in the field is somewhat as follows: A rusty outcrop of augite contains here and there small segregations of magnetite, with the greater portion of augite at the south, whereas at the north it becomes particularly feldspathic, as shown in the fine banded pyroxene gneiss series at the base of the small hill to the east. In the more basic part of the occurrence toward the state road, the injected rock belongs to the banded pyroxene gneiss series as does the more acid lighter series to the north; but the hill directly west of the one just referred to, some 40 or 50 feet in elevation, appears to consist almost entirely of augite with zones of phlogopite and biotite mica as shown by a cliff section of 40 or 50 feet, indicating that this hill may be a metasomatized limestone body resulting from a replacement of the limestone by magmatic material emanating from the nearby syenite body. As no traces of the limestone in this pyroxene hill were seen, its origin can not be demonstrated, but it is the general opinion among Adirondack geologists that such bodies derive originally from Grenville limestone.

VARIOUS BANDED GNEISSES

In the Oswegatchie area occur several gneisses of sedimentary aspect, such as garnet gneiss, cordierite gneiss and sillimanite gneiss. Whether they may be correlated under a single term indicating they belong to the same formation can not readily be determined from the work on this sheet. The gneisses are largely present in the northwest corner of the Oswegatchie area, where they are found as continuations from outcrops on the Bonaparte area. To the field observer they appear as feldspathic or garnet-mica gneisses which have a strike N. 10° E. and nearly vertical dip and all are supersaturated with acid pegmatitic material both along the major foliations and across them. At no other place in this whole area does there appear to be such fine examples of pegmatization. Within the same area occur amphibolitic lenses, usually gray or rusty in color, and showing visible quartz and mica or hornblende, the lenses frequently cut by pegmatites. The main rock is usually gray, weathering to brown, and has visible quartz, garnet, mica and feldspar, with sillimanite along the foliation planes. Under the microscope garnet and calcite are sometimes observed along with pyrite, magnetite and limonite among the important ore minerals.

A conspicuous cliff, 250 or 300 feet high, of these gneisses occurs to the south of the area just west of Snyder lake, where injections parallel to and across the major foliations are plainly visible. The face of the cliff follows approximately a foliation N. 60° E., which is also the direction of a main joint plane cut by cross joints, but the cliff is so penetrated and permeated by pegmatitic intrusions that divisional planes are difficult to make out for the most part. These rocks have been assigned to the Grenville by Buddington as undivided gneisses, with which opinion the author is in complete agreement. In alignment with the foliation plane occur lenses of amphibolite. In one instance the amphibolite is intruded by a pegmatite dike, made up of quartz, orthoclase, biotite and black tourmaline. In this particular instance the dike trends N. 35° W., approximately parallel to one of the major joint planes.

Quartz-mica-garnet-gneiss. East of Oswegatchie village are several localities where the occurrence of Grenville metamorphic sedimentaries have been noted; one on the south side of the Oswegatchie river at the south end of the new dam of the upper Brown's Falls power plant; another just east of Lower Oswegatchie near the esker; and the third north of the deserted village of Anderson where there are distinct ledges of the gneiss. In the Anderson locality cliffs of banded and corrugated pinkish and grayish rock occur with a strike of N. 40° W. and a dip of 25° W. The dominance of quartz as well as the stratified and banded appearance lead one to include this rock among the Grenville sediments.

Sillimanite gneiss. This rock is distinguished by the presence of fiberlike sillimanite crystals in bundles or as reticulated masses along the foliation planes; it is closely associated with granite. Occasionally the sillimanite occurs in segregations of quartz, the segregations arranged rather close together.

On the top of the hill (elevation 1680 feet) north of Anderson is an outcrop of gneiss carrying sillimanite and quartz in curious blotches that resemble somewhat the remnants of truncated and plicated veins in part, or as segregations of quartz and sillimanite. The sillimanite itself forms reticulated and feltlike fibrous masses in quartz.

The largest body of sillimanite gneiss is that just west of the Benson Mines ore-bearing gneiss. Here the sillimanite occurs in the strong puckerlike foliation planes. Along with the sillimanite are present feldspar, quartz, biotite, and magnetite. The mineral association in all these occurrences suggests a metamorphosed sedimentary material, because of a similar mineral development in characteristic Grenville. Martin ('16) and Newland (Cushing and Newland, '25) have both suggested this origin. In any event the presence of so much sillimanite is strong evidence of the metamorphism of some preexisting aluminous rock.

In the biotite-garnet gneiss here described, sillimanite is found as seams between laminae of biotite and magnetite. Again, it occurs with light green and colorless apatite in pegmatitic injections which appear also in the pink granite gneiss at the same locality. In the granite gneiss below the upper Brown's Falls dam and in the bed of the abandoned Oswegatchie river sillimanite forms ramifying bands along the foliation planes and at slight angles thereto, but generally along foliation planes which have taken part in movement. As this area occupies a contact zone between the pyroxene gneisses to the south and the granite gneisses to the north I can not help but agree with Buddington ('29, p. 99) "that the development of the garnet-sillimanite gneiss is at least indirectly connected with the association of the ferromagnesian gneisses." Whether or not the sillimanite has been due to alteration of the pyroxene in part, is in doubt, and those who may be interested in a more thorough discussion of the subject are referred to the above study.

Probably related to the quartz-mica-garnet gneisses are the biotite and biotite-garnet gneisses near the upper Brown's Falls dam which show injections of quartz and feldspar pegmatite, with garnets developed along the foliation planes. Because of movement following the period of injection, some of the injections have been pinched or stretched so as to have the appearance of augen gneiss.

Quartz-magnetite gneiss. This is the ore-bearing gneiss of Benson Mines and might be so termed although it seems simpler to name rocks by their dominant minerals. Because of presence of pyroxene the rock might be classed with the pyroxene gneisses, yet it is so different in every way from the pyroxene gneiss just described that there is good ground for placing it in a separate class. In hand specimen it is a rusty brown gneiss with the planes of foliation accentuated by coarse grains of disseminated granular magnetite.

The rock varies in composition over the face of the mine pit, as well as along the foot and hanging walls, both as to magnetite content and other minerals. In all the specimens examined quartz, magnetite and orthoclase feldspar are dominant. Under the microscope appear, also, pyroxene, garnet, phlogopite, hornblende, cordierite, muscovite and scapolite, with abundant secondary minerals such as chlorite, kaolin, limonite and accessories like pyrite, graphite, apatite and zircon (figures 7 and 8). Sillimanite and martite are also reported as coming from here. The pyrogenic character of certain of these minerals, such as garnet, augite and zircon, is sufficient to establish the igneous metamorphism to which this series has been subjected.

Banding, the most conspicuous structural feature of this occurrence, is brought out at the northwest end of the mine where there is a very fine glaciated surface showing grooves and polishings almost parallel with the direction (N. 60° E.) of the foliation planes. Here the magnetite is most conspicuously displayed in disseminated grains parallel with the bandings and injections. Some of the bands are rusty from the alteration of pyrite into limonite and others are lighter colored through predominance of feldspar and quartz or of quartz alone. The percentage of magnetite varies markedly in the bands, which often show a concentration of that mineral on the outside but have more quartz in the interior. Still others reveal a fairly uniform mixture of magnetite. Another variation has large crystals and phenocrysts of feldspar and quartz, simulating porphyritic textures. Pegmatitic veins and lenses up to one inch in thickness parallel the foliation rather frequently. Bands made up of orthoclase, magnetite and quartz may resemble granite so closely that one might be inclined to class them as such. The banded structure in this series is undoubtedly ascribable in part to inherited sedimentary structures and in part to igneous injection phenomena. The foliation planes previously established would naturally aid in distributing the ore-bearing solutions or gases emanating from the invading and cooling syenite; thus, there might result such a composite rock type as we find today.

It was hoped that definite evidence of the derivation of the gneiss might be gained by studying the texture. In some examples the magnetite occupies such a large proportion of the rock that the other minerals behave like inclusions; in other words the phenocrysts of magnetite would appear to have developed later. As a matter of fact, reaction rims of chlorite are found between the host magnetite and the guest orthoclase and scapolite, which indicates that the magnetite was of later crystallization than the included minerals. In most of the sections examined it was impossible to form any definite opinion as to the relations of the magnetite to the other minerals. On the whole it seems that texture alone will not throw much light on the origin of these rocks. The minerals are arranged in a mosaic pattern in which the grains of magnetite differ greatly in size from the other minerals and their shape is most irregular, euhedral crystals being rarely present. So far as can be determined the structures and textures indicate, if anything, that some magnetite has been introduced or has crystallized after the other minerals or at least most of them. Just when and how that took place can not be definitely stated, but probably the magnetite accompanied the ascension of the syenitic and granitic magmas and found lodgement in the Grenville by hydrothermal processes.

Figure 7 Microphotograph of magnetite gneiss; Benson Mines. x 27. The black is magnetite which appears to be replacing quartz, the lighter mineral resulting in the formation of garnet reaction rims between them. The garnet in places has altered to chlorite.

Figure 8 Microphotograph of magnetite gneiss; Benson Mines. x 24. The black is magnetite; the gray is feldspar; the white is quartz. Blades are biotite.

The following chemical analyses taken from the report by Newland ('08, p. 136) give details of the composition of the ore at Benson Mines. No. 1 represents the composition of a sample of the ore exposed in the workings, the sample selected so as to represent an average for the entire face of the quarry. Analyses No. 2 and No. 3 represent the composition of the concentrates obtained by magnetic treatment of the crushed ore.

	1	2	3
Fe_3O_4	49.43	88.08	85.94
FeS_2	1.61	.864	.....
SiO_2	33.32	5.97	5.91
TiO_2	1.07	.....	1.06
P_2O_5	.43	.086	.11
Al_2O_3	6.92	2.26	3.63
MnO	.32	2.04	.43
CaO	1.42	.28	.68
MgO	.91	.18	.08
K_2O	2.77	.....	.87
Na_2O	.58	.....	
CO_2	.68	.....	.42
H_2O	.35	.....	.42
	99.81	99.76	99.55
Iron	36.56	64.18	62.24
Phosphorus	.186	.037	.048
Sulphur	.86	.461	.37
Manganese	.246	.158	.33
Titanium	.64	.....	.64

The chemical composition of the gangue, which may be considered closely analogous in all respects to the country rock, is given in the following analysis taken from the same report (p. 137). The analysis is based on a sample of mill tailings produced during the regular course of milling operations.

SiO_2	67.18
Al_2O_3	17.97
Fe_2O_3	1.02
FeO	6.13
CaO	1.84
MgO	1.50
Na_2O	.44
K_2O	1.12
P_2O_5	.36
MnO	.30
S	2.06
	99.92

In default of other definite evidences of the parentage of the Benson Mines gneiss it is interesting to examine the above analyses for any light that can be cast upon the problem. The greatest difficulty in finding a solution rises from the fact that the rock has been profoundly affected by dynamic and contact metamorphism, with the injection of igneous material in a very intimate way. With this in mind it is interesting to interpret these analyses on the basis of chemical criterions. The first analysis, which is the result obtained from a composite and representative sample of the mine, contains more than 5 per cent alumina. In the tailings the alumina content runs up to 17.97 per cent, which is quite suggestive of a sedimentary origin for not over 10 per cent only is required by the proportion of alkalies present. Also, it is noted that the lime is greater than the magnesia, as is the case usually in acid igneous rocks; but on the other hand, the relations of the potash and soda are not in accord with those in granites. In the case of silica the composite tailings sample is of very little value due to the high iron content, but when the analysis of the tailings is recalculated on the basis of no iron, there is a fair excess of silica beyond the critical point.

The Benson Mines quartz-magnetite gneiss is confined to a body whose structure is imperfectly known because of the scanty surface exposed by reason of forest cover and glacial drift. In a general way the magnetite rock is limited by granite gneiss south of the mine and sillimanite gneiss to the west, although syenite gneiss lies between the granite at the extreme north and the magnetite zone not far from the road. It would appear that the major structure of the body is in the nature of an asymmetrical anticline rather than a monocline. Northeasterly strikes and southeasterly dips prevail at the west end of the mine but at the east end the body seems to pitch 20° NE. To the north of the mine the dips are very low, but to the west in the sillimanite gneiss they are seen to be to the northwest; in the adjacent igneous gneisses on the east, the west of the road and to the south the dips are high to the southeast or are vertical. In such circumstances it seems that the major structure is necessarily anticlinal with the axis of the magnetite body trending northeast-southwest. As can be seen from the areal map the magnetite body extends to the northeast and off the area. Further details on the structure of this deposit are given by Newland ('08, p. 133).

Observations of the dip of the ore and inclosing strata show a monoclinal arrangement for the central and northern parts of the ore belt. The gneiss on top of the ridge lies nearly flat. Across the strike to the southeast the dip increases gradually until at the pits it is about 45° SE. This inclination is maintained with little variation for 1000 feet along the outcrop of the ore to the south-

Figure 9 Outcrop of gneissic grit; southwest of Benson Mines.

Figure 10 Microphotograph of gneissic grit; southwest of Benson Mines. x 24. Largely quartz and microcline.

west. At the bend or fold in the deposit where it swings toward the northwest, the dip is 60° SE. Beyond the bend there is a flattening of the dip, and over the remaining distance in which the ore can be traced the outcrops show the strata lying nearly horizontal or slightly inclined to the northwest. The change in the dip takes place within an interval of 100 feet and would seem to indicate a structural break, though there has been no discernible displacement of the ore by faulting.

Besides the deposit described, according to Newland (*op. cit.*) there are indications of another belt of ore to the north of Benson Mines that has never been explored or developed. The belt lies to the east of the first and higher up in the gneiss. It begins on the south, according to magnetic readings, nearly opposite the north end of the pits and on line with the railroad. It extends in a northerly course toward Newton Falls, in which direction it has been traced for nearly two miles. This seems to be borne out by this present survey and that area has been included in the ore zone as shown by the areal map.

Other phases of this occurrence at Benson Mines will be considered under economic geology and mineralogy.

Gneissic grits. South of the Benson Mines-Star Lake road and east of the Star and Streeter Lake road is a conspicuously jointed exposure (figure 9) of a gray banded rock consisting largely of quartz with very subordinate feldspar (perthite, microcline and albite) and more abundant hornblende and magnetite (figure 10). The entire exposure is permeated along the foliation planes by pegmatite which lends to the surface a banded or corrugated appearance. The marked foliation planes accentuated by these injections cause the rock to simulate a sedimentary type. Across the valley and on the next ridge a different exposure of the series occurs, much more thoroughly pegmatized with knots of orthoclase five to ten feet in length and five feet in width. It is quite possible that along this narrow valley some eastward faulting of slight throw has taken place as evidenced by the smooth vertical east-west joint planes. At the very top of the series and farther to the east the rock has a more varied composition, characterized by quartz, feldspar, hornblende, garnet and sillimanite. The entire series measures 570 feet in thickness. It is cut off on the north by syenite. The swamp through which Little river flows on the southeast may possibly overlie other members of the same series. No definite outcrops of this series were seen either to the west or the southwest.

The dominance of quartz in the rock which, according to microscopic analysis, contains 83.2 per cent of quartz and 15.5 per cent of feldspar, indicates that it belongs to the sedimentary class and perhaps rightfully between the quartz-magnetite gneiss described above and the gneissic grits, as indicated also by its areal relations. The lack of any great amount of magnetite may be explained by the absence of contact metamorphic effects. In other words, the gneissic grits may very well have been the prototypes of the magnetite gneiss, which, because of its favorable situation with respect to the invading and differentiating syenite at the Benson Mines became metamorphosed.

SYENITE AND SYENITE GNEISS

The most conspicuous area of syenite found on the sheet occurs just east of the Grenville series in the northwestern area as a large curving and tapering body of hornblende syenite gneiss. This body of syenite, undoubtedly a part of the monzodiorite-syenite-granite complex on the Lake Bonaparte sheet described by Smyth and Buddington ('26), is distinctly different in outward physical characteristics and composition from most of the grano-syenite and granite gneissic rocks to the east.

The syenite in the area mentioned consists mostly of a coarse hornblende variety and extends onto the Bonaparte area to the west and the Russell sheet to the north. The body is by no means uniform in its composition, although, on the basis of microscopic analyses of a few selected rocks of this area as well as from field observations, it would appear that the greater part of the dark minerals is hornblende. Acid feldspar predominates as the light colored mineral. The best examples of the syenite may be seen along the road west of Kalurah on Grass Pond trail, and along the Northern New York Utilities power line. In all these places the rock has the same general external characteristics, namely, that of a dark or drab-colored rock, medium to coarse in grain with augen of feldspar. The feldspar, generally orthoclase or microperthite, occurs in stretched phenocrysts or augen with a groundmass of hornblende, pyroxene and variable amounts of quartz in finely divided condition or squeezed into thin lenticles. The accessory minerals, which amount to not more than 5 per cent of the aggregate, consist of magnetite, pyrite and hematite.

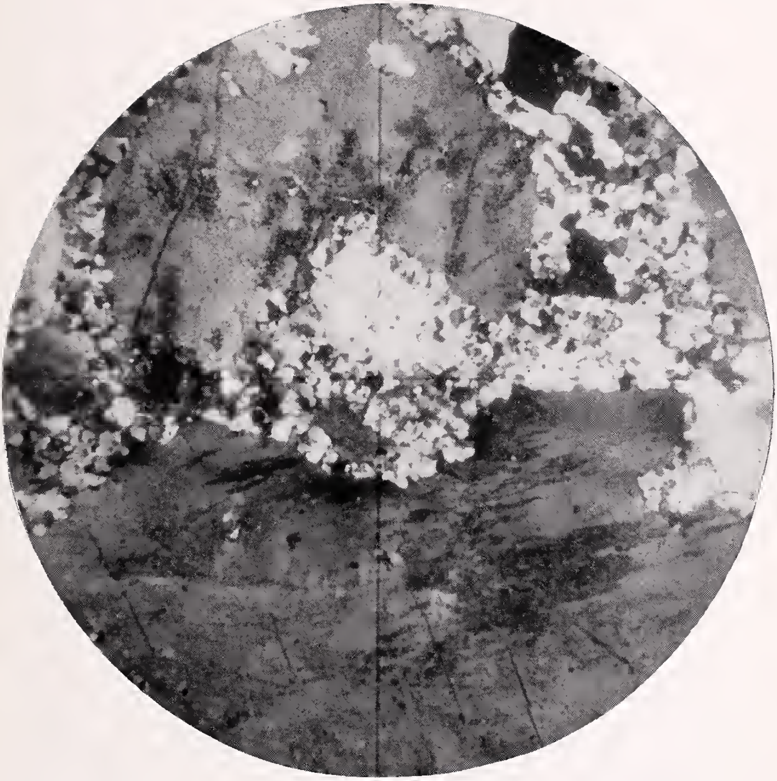


Figure 11 Protoclastic and cataclastic structures in augite syenite, at Kalurah. x 27.

Below is a table showing the mineral composition of a few of the characteristic types of this area, the figures representing the relative percentages:

Slide	Ortho-clase	Micro-perthite	Micro-cline	Plagio-clase	Quartz	Horn-blende	Magne-tite	Zircon
172	20.8	9.5	4.4	....	17.8	46.7	.1	.7
$201A_3$	57.6	....	...	2.9	26.8	12.4	..	..
$201A_3$	....	....	...	80.8	....	10.4	8.7	..
$203A_1$	45.4	....	...	13.9	40.0	....	..	..
$203A_2$	19.2	43.9	...	....	18.8	17.8	..	..

Although these analyses show no pyroxene, it should not be assumed that it is absent in the rocks as a whole. Yet pyroxene is not a prominent mineral except in a few places (figure 11) and for that reason it does not seem wise to include it among the components of the syenite body as a whole. In the above analyses Nos. 172 and $203A_2$ approach the nearest to normal syenite with the latter, perhaps, closer to the type than the former. No. $203A_1$ represents a fine-grained pink rock of granitic appearance occurring as an injection in the coarser grained types represented by $203A_2$. Their locality is near the eastern limits of the syenite body, where such types might be expected. Farther within the syenite, and about three-quarters of a mile west of Cold Spring creek is a sill of more acid protoclastic rock, like No. $201A_3$, consisting of hornblende and quartz drawn out in thin lenticles. Granite pegmatites make their appearance at this latter place and from that point to the east where the syenite is in contact with granite gneiss they become increasingly abundant.

West from Kalurah along the northern edge of the syenite body to the south of the Harrisville-Kalurah road, and also south and southeast from Kalurah to the eastern border of the syenite mass, there outcrops a coarse gneissic hornblende syenite in a composite sill-like body which strikes N. 30°–40° E. and dip 40°–50° W. Sills of finer grained syenite gneiss are occasionally found within the larger body. Conspicuous joint planes characterize the syenite in this region. In the finer grained and protoclastic type of rock hornblende and feldspar predominate with a little quartz; in the coarser types quartz is not a conspicuous element. The general relations of the syenite gneisses are shown in figure 12, herewith.

Within the area of Grenville limestone south of Snyder lake occur several coarse porphyritic syenite intrusions, one of them more than 20 feet in thickness, apparently conforming with the prevailing structure of the region and consequently sill-like in occurrence.

Although the contacts at this locality are concealed, the syenite appears at some distance both above and below it. Because of differential weathering and erosion a part of the wall of limestone is free from intruding syenite, but the contact is indicated by the

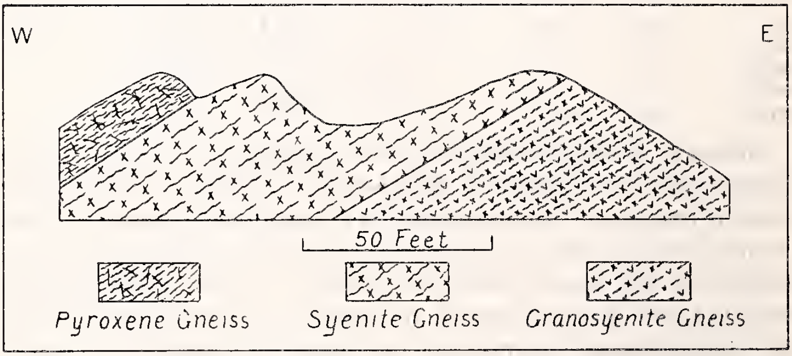


Figure 12 Sill structure of granosyenite and syenite gneiss; Kalurah.

presence of numerous metamorphic minerals. Pegmatitic facies of the syenite are also found in this same area inclosing zones of calcite which may be recrystallized inclusions of the nearby Grenville limestone. A very irregular and disconnected sill of syenite is developed here along a course N. 80° E. It appears to consist of a series of surficially disconnected bodies, branching and bifurcating along the solution joints. Within this body occur segregations of quartz. Apparently the disconnected bodies are caused by the splitting off from some larger body by orogenic movement. Other pegmatitic facies of the syenite cutting the Grenville near its contact will be considered later under contact metamorphism.

An interesting syenite intrusion south of this locality exhibits spheroidal weathering (figure 13), brought about by differential weathering of the corners produced by intersecting joint planes, the corners weathering most rapidly, the edges next and the faces least. Owing to the fact that the newly weathered material in the corner zones is far bulkier than the unaltered material the former falls away from the latter, thus transforming what was once a rectangular block into one of somewhat rounded or spherical form.

OTHER SYENITES AND THEIR VARIANTS

Several small syenite bodies are found in the great granosyenite gneiss complex that spreads over three-quarters or more of the sheet and undoubtedly are related to the syenites just considered—

Figure 13 Spheroidal weathering in syenite; East Pitcairn.

at least magmatically. They are to be seen at the following localities: On Bald mountain, on the Massawepie trail between Wolf and Massawepie ponds, on Streeter mountain, and again on the 1880-foot hill southwest of Little Otter pond and west of the Post Henderson trail. As the last one is of small measurement and underlies a garnet gabbro sill attention will be given only to the other syenite occurrences.

Bald mountain, the most important prominence of the quadrangle (1975 feet a.t.) and a fire station, has many fine exposures of coarse porphyritic syenite gneiss. The following microscopic analysis shows its mineral composition: microperthite, 61 per cent; plagioclase, 19.3 per cent; quartz, 5.4 per cent; hornblende, 8.7 per cent; and magnetite, 5.2 per cent. It was not determined just how far this syenite extends beyond the mountain, although on the map it is indicated by a small lens about a mile in length north and south. The rest of the mountain consists largely of granosyenite gneiss in which there is more quartz visible.

Streeter mountain, just east of Streeter lake, is essentially a composite mass; made up at the base of granite gneiss in which quartz is a conspicuous element, higher up, of granosyenite in which quartz is less conspicuous and at the summit, of hornblende syenite with little or no quartz. Pegmatites both follow and cut across the foliation planes which have a strike N. 40° W. These rock variations are especially conspicuous on the steep eastern slope. Near the eastern base of the mountain, also on the eastern slope nearly 100 feet below the summit, parallel injections of fine-grain pink aplite are seen, apparently a part of the same formation that occurs to the east in the bed of Tamarack creek. The sudden change in composition of these rocks leads one to explain their origin by magmatic differentiation as evidenced in the various elements from the base to the top of the mountain. A quantitative microscopic analysis of the rock at the top shows oligoclase, 75.6 per cent; orthoclase, 2.7 per cent; hornblende, 13.6 per cent; and quartz, 7.6 per cent.

Another syenite body of somewhat indeterminate area, but probably lenslike, is found between Wolf and Massawepie ponds and on the Massawepie trail. No extensions of this body were noted on either side of the trail for any great distance, nor on the trail outside of the outcrops investigated. This was a gneissic gray weathering rock consisting of perthite, 70 per cent; quartz, 17.4 per cent; hornblende, 9.4 per cent; and oligoclase, 3.1 per cent.

This rock is a medium-grained gneissic rock and does not show any of the usual crushing effects seen in the larger bodies to the west.

Diorite. Another variant of the syenite and possibly related to the monzodiorite described by Smyth and Buddington, occurs on the east slope of Panther mountain and south of Bryant bridge on the very western border of the area. This rock has a fine-grained, gneissic texture. It consists largely of plagioclase, orthoclase, hornblende and phlogopite, with the hornblende and phlogopite usually aligned along schistosity planes. It resembles diorite and is cut by a coarser rock that consists of anorthite, albite, microcline, quartz, hornblende and biotite, with accessory zircon. The larger fine-grained body overlies pink hornblende granite gneiss, both rocks preserving a northeasterly foliation and southeasterly dip. This same rock may be found to the southwest of Bryant bridge on the main road and is apparently a continuation of the Panther Mountain sill.

Gabbro. An outcrop of garnet gabbro is found topping a small hill (1740 feet a.t.), one mile southwest of Little Otter pond and from a quarter to a half mile west of the Post Henderson trail. It is dark reddish brown in color, massive in appearance, and interlocking granitoid texture. It consists in descending order of abundance of andesine, labradorite, augite, hornblende biotite, garnet, and of magnetite and pyrite as rather abundant accessories. The relationship of the gabbro to the underlying syenite can not be established on the basis of field evidence, but on the basis of the occurence of syenite and granite gneisses on Streeter mountain and from their sill structure a similar structure and origin may be reasonably conjectured for this occurrence.

Dikes. West of the corners of the Harrisville-Fine and South Edwards roads is a small body of hornblende syenite which shows intrusive relations with the underlying granite gneiss, sending off small dikes and sills into the latter. Many of the dikes are of finer grain at their contacts with the granite, conclusively proving the later age of the syenite. The rock is somewhat dioritic in appearance, containing equal amounts of hornblende and feldspar, but is cataclastic in texture. Under the microscope it is seen to be strongly gneissic and composed of orthoclase, oligoclase, albite, hornblende and biotite, the two last showing strong alignment with the foliation planes. This same intrusive relationship is brought out as one approaches the banded syenite series to the northeast.

GNEISSOID GRANOSYENITE-GRANITE COMPLEX

More than three-quarters of the Oswegatchie sheet is underlain by members of this great complex. Because of the heavily wooded and morainic character of this area, it is impossible to give more than an approximation of the surface occupied by the various components of this great complex. Near the contact with the syenite rocks, particularly the pyroxene gneisses, the complex appears generally somewhat finer grained and lighter in color. Whether this great body is a composite sill in structure or a concordant batholith or a combination of both types it is difficult to say on the basis of the evidence; but the writer was very much impressed with the monotonous ridge and sill-like structure from west to east.

In composition the rocks seem to range between a massive granite and a gneissoid granosyenite. These rocks weather gray, but on the fresh surfaces they are pink. In texture the rocks are coarse, fine-grained or porphyritic; the latter texture was particularly noticeable in the southern part of the quadrangle though some coarse-grained types were found elsewhere, especially westward from the tunnel.

As the rocks appear to be finer grained near the contacts with intruded rocks, it is not likely that they are older than the syenites and in all probability they must have followed closely upon the latter, if they are not to be considered differentiates of the syenite magma.

Some of the types found in this complex show the following percentage composition by microscopic analyses:

Slide	Orthoclase	Plagioclase	Perthite	Quartz	Hornblende	Biotite	Microcline	Garnet	Magnetite
$193A_1$	6.4	26.7	....	60.8	7.5	....	....	....	....
$219A_5$	21.5	....	19.9	54.2	4.3	....	....	....	....
292	.34	13.8	....	55.1	29.9	....	....	....	....
$93A_2$	....	....	54.9	45.7	....	....	....	....	....
256	....	....	17.6	79.8	2.6	....	....	....	....
221	....	17.9	40.6	22.1	6.9	....	12.5	....	....
$192A_5$	....	68.9	....	25.5	5.5	....	.6	....	....
$192A_1$	9.37	....	....	76.3	....	5.7	....	3.8	4.6

The most characteristic and abundant type of rock is represented by Slide $193A_1$ which formed very conspicuous cliffs along the abandoned Aldrich railway and also along the New York Central railroad as far as Briggs. In the field it appears as a medium to coarse hornblende granite gneiss of pinkish color and with abundant quartz. The rock weathers to gray, sometimes separating in great spalls five or six feet in diameter, as shown on the top of Vrooman ridge. The series shows textural variations from porphyritic to fine grained, but on the whole the prevailing type is medium to coarse-grained hornblende gneiss.

Vrooman ridge is made up essentially of porphyritic hornblende granite gneiss and hornblende biotite granite gneiss, with ledges on the top near the east end of the mountain and on the lee south slope. Pegmatitic injections are common. Undoubtedly the largest area on the map is underlain by this variant of the complex.

A characteristic type, found just to the east of the northwestern syenite area, occupies a belt about one and a half miles wide and of indeterminate length extending in a general north-south direction. It belongs to the protoclastic varieties described by Smyth and Buddington ('26). In this type the feldspars are very much granulated and the quartz occurs as long, irregular bifurcating and anastamozing lenticles. It is probably a granosyenite although no quantitative microscopic analysis could be made to determine its relations. To the east of this area the gneisses are free of protoclastic structure, except for a small zone on the eastern edge of the map near Little Otter pond. Here the rocks are characteristically granulated, so far as the feldspars and ferromagnesian minerals are concerned, with the uncrushed quartz drawn out in lenticles. In the interpretation of these gneisses, Smyth and Buddington conclude that the dominant element in the gneissic structure of these rocks is a primary foliation, with a cataclastic texture superimposed upon it; the latter is of minor importance so far as the actual foliation is concerned, but is significant for its indications of a continuance of the rock. Under the microscope the characteristic type of this series contains orthoclase, albite, quartz and hornblende in descending order of abundance, with some magnetite and pyrite grains associated with the hornblende.

To the east of this belt is a large body of gneiss dominantly of granitic composition, but there are several other types which call for consideration. In the railway cuts just east of Jayville is an area of more than two square miles characterized by very coarse pink porphyritic granite which appears to be different and of later age than the country rock of the region, as shown by the relations just north of the Jayville mines, where, according to Newland ('08, p. 137), "Outcrops of the granite occur to the north and east within short distances where they break through and cut off the gneiss area in such a way that their intrusive character is plainly evidenced. In some of the openings, the granite can be seen in immediate contact with the ore." One analysis of the granite taken not very far from the mine gives quartz, 76.3 per cent; orthoclase, 9.37 per cent; biotite, 5.7 per cent; garnet, 3.8 per cent; and magnetite, 4.6 per cent. Another specimen from an outcrop more nearly in the center of this body shows plagioclase, 68.9 per cent; quartz, 25.5 per cent; hornblende, 5.5 per cent; and microcline, .6 per cent.

Another example shows microcline, quartz, hornblende and biotite as essential minerals in descending order of abundance with some magnetite grains altering to limonite along the mineral contacts.

A chemical analysis of this very coarse granite from near Jayville, as given in New York State Museum Bulletin 181 (p. 86), is shown under No. 1, below. Analysis No. 2 from the same report (*id.*) is based on the massive granite of finer grain from a locality three miles to the east of the Jayville locality.

	No. 1	No. 2
SiO_2	75.01	72.69
Al_2O_3	12.88	14.11
Fe_2O_3	.02	.26
MgO	.41	.28
CaO	1.10	.64
Na_2O	3.67	2.37
K_2O	4.16	5.16
H_2O+	.32	.24
H O	.08	.02
	99.66	98.66

In the Jayville mine area the characteristic rock is gneissic hornblende granite, showing strong alignment of the hornblende and with injections of pegmatite consisting largely of orthoclase or pink microcline. In proximity to the ore there appears to be a marked gradation from less basic to more basic banding. Under the microscope the characteristic normal type shows an interlocking sutured and crushed texture.

The area about Oswegatchie village is underlain by hornblende or hornblende-biotite granite gneiss for the most part. Generally, it is a fine to medium-textured uncrushed rock of gneissic appearance brought out by the alignment of the ferromagnesian minerals. In places, as shown in the road metal quarries operated during the construction of the state road from Fine to Benson Mines, the rock appears as a banded or lit-par-lit gneiss, the bands made conspicuous by the dominance or absence of the dark minerals. The rock south of the Oswegatchie river and east and west of the Grenville banded series near Fine is a medium grained pink hornblende or hornblende-biotite granite gneiss.

The road cuttings east of Fine give an excellent chance for studying the fresh surfaces of the granite gneiss. Undoubtedly it is younger than the pyroxene gneiss which it cuts and older than the pegmatites found within it. The rock is generally massive in structure and granitoid in texture with orthoclase, quartz, hornblende, biotite, garnet and fluorite, though the two last minerals are not always present. The lighter pink granite prevails on the east of the cut and the darker pink at the west, although the latter is also found across the river just east of the syenite series.

To the north of the road and west of Welch creek the granite is coarse almost porphyritic in texture. It appears that there are different types of granite, a light pink and a dark pink, and that both apparently are apophyses of larger bodies to the north. Just what relationship there is between these two and the bodies north and south of the river could not be determined. The granites of the Fine area represent in all probability two ages; the larger bodies of the gneissic type to the north and the south being older; the more granitoid types are of later date.

The rocks north of the Oswegatchie river between Newton Falls and Flat rock are the characteristic pink hornblende gneissic types, intruded by pegmatites of orthoclase and quartz.

In the lower part of the Oswegatchie area as well as south of Star Lake village the rocks appear to be of two ages; the main body consists essentially of a coarse to medium hornblende granite gneiss or granosyenite gneiss, in which occur sills of a more granitoid type of later age, both rocks being cut by pegmatites. This relationship is well brought out by the many exposures along the Middle branch of the Oswegatchie river. Here gneisses of the hornblende-biotite granite type are cut by more massive rocks of hornblende biotite composition. Along the southern part of the map near the No. 4 area the outcrops show a medium to coarse grained hornblende granite gneiss as the prevalent formation, with fine-grained types as occasional variations.

LATER GRANITES

Massive granites are found cutting the gneisses as sills or dikes within the great granosyenite gneiss complex or in places as intrusions within the syenite. They are particularly evident along the Middle branch where they show fine to coarse textures. In nearly all occurrences the rock is prevailingly pink in color and is characterized by abundant quartz and feldspar accompanied by hornblende or biotite or both. The fine-grained types are usually intrusions in the form of sills. One type already referred to which occurs both north and south of the Oswegatchie river is a dark pink granite with quartz, albite, orthoclase, microcline, perthite, with rare hornblende, as essential minerals, with pyrite enveloped by magnetite altering to limonite. The characteristic interlocking texture prevails in this type.

APLITES

Closely associated with the Grenville quartzites and syenites of the East Pitcairn and Portaferry Lake areas are exceedingly finely textured rocks which occur as sills. Some of these intrusions in the quartzite are so fine grained and so like the quartzite in general appearance that without the closest observation they are hard to identify. A very typical area for the aplites is along Greenwood creek and between it and Portaferry lake. The rock here is dominantly feldspathic with negligible ferromagnesian minerals. So irregular is the contact between the aplite and the intruded rocks, particularly the gneisses, that the latter for some distance away from the contact are practically in the condition of a relict gneiss. Other aplites also appear to resemble relict gneisses and to have preserved the gneissic structure of the intruded rock. These injections of more or less sill-like characteristics range in width or thickness up to four feet and generally lack sharp contacts because of the resorption of the gneiss at the contact. The main body of aplite is seen in the zig-zag road southwest of Portaferry lake and east of East Pitcairn corners. Here it measures some 300 to 400 feet in thickness and is very conspicuous by contrast with the darker color of the intruded rock. In figure 14 is shown a cascade along the course of Greenwood creek through the jointed aplite gneiss region.

Likewise in the quartzite of this same general region occur aplitic injections which are difficult of identification in the field although on microscopic examination they are found to consist largely of feldspar (perthite and albite) and quartz, besides augite, titanite, zircon and magnetite. They are more or less schistose in appearance. Most of the so-called aplitic injections in the quartzite group are apparently microperthitic granosyenites, granite gneisses or micrograniti gneisses. These rocks are so very fine grained that they are almost indistinguishable from quartzites proper.

Along the north shore of Greenwood creek and beyond Peabody farm is a roof pendant or inclusion of what appears to be quartzite in the syenite. The contact between it and the syenite from all viewpoints is so striking that one's attention is immediately attracted to it. The rock is pink in color, of exceedingly fine texture, (the grains measuring less than .1 mm in diameter) and of dominantly feldspathic composition. Under the microscope there appears twice as much feldspar as quartz, the phenocrysts of perthite occurring in a groundmass of fine crystals of orthoclase, perthite, albite, quartz, augite, hornblende and magnetite and hematite grains. Owing to protoclastic, mosaic and sutured textures, it is difficult to decide as to the real nature of the rock, whether it is a feldspathic quartzite, microgranosyenite, or an aplite. Although definite evidences for its sedimentary origin are obviously withheld at present, the observed dominance of feldspar over quartz has inclined the writer to regard it either as a microgranosyenite or an aplite, in which case what appears to be a roof pendant or inclusion is a sill-like body.

PEGMATITES

The coarse-grained injections found so frequently near contacts or within the formations, either paralleling the foliation planes or cutting across them, are classed as pegmatites. They are generally of massive structure and of granitoid texture and in exceptional cases show deformational characteristics so common to the intruded rocks. In one case described (see p. 17) a pegmatite vein appears as a series of disrupted or disconnected fragments, undoubtedly once a continuous body but now torn asunder through strong earth movements subsequent to its intrusion.

The composition of pegmatites in this area shows a considerable range. In general quartz and feldspar with or without augite, or feldspar and augite together with certain accessory minerals, make up the pegmatites. One of the outstanding characteristics of the pegmatites is the close relation they bear to certain rock formations. The more quartzose types of pegmatite are frequently associated with the more acid rocks, such as the granite gneisses; the pegmatites in which augite and feldspar make up the composition are closely associated with the syenites; and, in one instance, a pegmatite consisting almost entirely of plagioclase is seen to cut a diorite.

One of the most important pegmatite developments occurs near the west contact of the granite gneiss and the banded augite syenite series between Fine and Star Lake village. On the L. V. Hurlburt

Figure 14 Cascade over aplitic gneiss; in Greenwood Creek, East Pitcairn.

prospect east of the state road in the village of Oswegatchie, near the contact of the banded pyroxene gneiss and the granite gneiss series, is a pegmatite body which consists principally of augite and orthoclase with microcline, albite, quartz, scapolite, titanite, pyrite, pyrrhotite and epidote. The pegmatite occurs within about 100 feet of the line of contact, the longer axis of the body taking the direction N. 40° E., parallel to the strike of the region. The mottled character of the deposit arising from the intermixtures of green pyroxene and feldspar is particularly noticeable. In the prospect pit opened some years ago, evidently for developing a feldspar supply, areas of feldspar measuring five by six feet and almost free of augite are occasionally seen. Here and there is apparent a certain rhythmical banding of the augite and feldspar in bands about an inch wide. The same body continues on through to the top of Bear mountain on the north shore of Star lake more or less following the contact between the banded pyroxene gneiss and the granite gneiss. Although concealed for the most part between Oswegatchie and Bear mountain, this pegmatite shows evidence at the surface of much larger development than appears to be the case at the Hurlburt prospect.

A pegmatite zone in the banded pyroxene gneiss occurs across the bed of a tributary of Little river, one mile east of the state road. It is a feldspar-augite pegmatite, 10 to 15 feet wide and with walls 10 to 15 feet high, forming the confines of the cascading stream. The smoothness of the walls and the high western dip indicate a small keystone fault. During the course of erosion the pegmatite has weathered into large blocks which now fill the bottom of the small gorge. To the south of this occurrence pegmatite occurs in the granite gneiss, here showing a banded structure by the parallel arrangement of the orthoclase, quartz and pyroxene. The same pegmatite, consisting largely of augite and feldspar, may be followed up to the top of Bear mountain, where it occurs between the hornblende granite gneiss and the banded syenite gneiss. The latter in contact with the pegmatite takes on a pink color for a considerable distance from the contact as a result of injection by the pegmatitic magma. The pyroxene gneiss underlying the pink syenites is also pegmatized with augite and orthoclase. In fact cliffs of massive pegmatite consisting of very large areas of orthoclase and pyroxene crystals occur in this region. Pyroxene crystals measuring four or five inches in diameter have been observed here. Farther north nearer to Fine along the same zone much larger crystals have been observed.

The pegmatites of the road cuttings just east of Fine all indicate a later age than any of the other rocks in that region, such as augite syenites, granites, granite gneisses or the Grenville limestone. A light-colored pegmatite of medium to coarse grain, consisting of plagioclase, quartz, augite and amethystine fluorite, with vugs lined with crystals of quartz, orthoclase and black tourmaline, is found here. Veins of augite, pyrite and calcite occur both in the granite gneiss and the syenite as well, while fluorite is found in the pegmatite.

At Jayville pegmatites are of considerable importance and will be described in greater detail later on.

Below the Flat Rock power house and the dam and in the banded augite syenite gneiss are found two small dikes of light-colored pegmatite of massive structure, and made up largely of quartz, orthoclase and acid plagioclase with very little hornblende, some zircon and alteration products of kaolin and sericite.

It would appear not only from a survey of these localities but from others as well that the pegmatites are the latest rock formation in this region; but there is little evidence so far bearing upon the sequence among the different types of pegmatites.

BASIC DIKES

No dikes of trap or diabase have been noted anywhere in the quadrangle, if exception be made of the occurrence of a dark fine-grained rock associated with syenite occurring on the Peabody farm south of Portaferry lake. It is not determinable from the surroundings whether this represents an intrusive dike or a dark basic phase of the syenite. Diabase dikes occur abundantly in the eastern Adirondacks, but are not so common on the west side. They are the latest of the Precambrian intrusions, cutting all the formations up to the Potsdam sandstone.

ABSENCE OF PALEOZOIC ROCKS

During late Precambrian times this region was a land area, exposed to powerful erosive forces which resulted in the development of a more or less even surface. Evidences of this eroded surface or peneplain are shown in the hill tops which rise to a more or less common level. How long this erosion went on we have no means of knowing, but certainly it operated during a very long period in Precambrian time.

In early Paleozoic time much of the Adirondack region was depressed so as to be invaded by the sea. Sediments were then

Figure 15 Pyroxene gneiss of mottled appearance, slightly folded; Fine, N. Y.

deposited over the surface of the crystallines. In the Oswegatchie area no direct evidence of the existence of the Potsdam sandstone or of any later member of the Paleozoic series has been discovered, although remnants of such beds are present on the Lake Bonaparte and Gouverneur quadrangles to the west and northwest. Whether the Cambrian sea ever transgressed the Oswegatchie area, can not be stated therefore on the basis of the direct evidence. It is quite probable, however, in view of the existence of the outliers of the Cambrian on the nearby areas to the west and northwest, that the sea may have covered this quadrangle. In that event the excessive erosion which this region has suffered through many millions of years has served to remove all traces of the sediments.

STRUCTURAL GEOLOGY

Over much of the Oswegatchie quadrangle the strikes of the formations are in general accord with the trends of the foliation on both the Bonaparte and the Russell sheets.

In the northwestern part of the area next to the Bonaparte quadrangle the Grenville formations, represented by gneisses, limestone and quartzite, have northeasterly strikes but they swing around to the north and the northwest as they continue toward the north end of the sheet. Moderate westerly dips in the quartzite and pyroxene gneisses on the east side of the belt to high western and vertical dips in the limestones and the mixed gneisses to the west show that the effects of the earth movements found their culmination in the rocks on the west. The same bowing out of the formations is seen in the syenite gneisses to the east of the Grenville belt as well as in the western part of granosyenite-granite gneiss complex. In the eastern part of the complex the strikes are generally accompanied by moderate westerly dips. In the southern part of the area northeasterly strikes are found as a rule, though occasionally the strikes are nearly east and west.

Rapid departures in strikes are sometimes evidenced in the field by structures which resemble zones of ptygmatic folding and which because of their intricate character can not be indicated adequately on the map. There are several of these areas between Benson Mines and Fine.

Foliation of the Grenville limestone. Limestone or its derivatives when subjected to forces from crustal movements yield to such forces by rock flowage and generally show this by recrystallization and multiple twinning, not by dimensional rearrangement or realignment of the discrete particles. As a matter of fact, calcite is not at all a favorable substance to reflect such earth stresses by dimensional rearrangement because of the rhombohedral shape of the grains.

In the many exposures of the Grenville limestone around East Pitcairn and just north of Fine, the strike and dip measurements are obtained largely from the banded structure caused by alternations of different colors or different sizes of grain. For example, in the Fine area fine-grained almost compact limestones alternate with exceedingly coarse marbles, the grain of the latter measuring three to four inches in diameter. The compact limestones in addition to calcite contain coccolite, phlogopite and orthoclase and have a well-developed schistosity parallel to the banding. Protoclastic and cataclastic structures are developed in the limestones, not unlike those produced and observed in the igneous gneisses of the region. Multiple twinning is also observed in the calcite grains. In other words, in this fine-grained marble the effects of regional metamorphism may have been responsible for the granulation, recrystallization, multiple twinning and schistosity of the rock. The marble near the contact, that is, within three feet or so of the pyroxene gneisses, is a much coarser rock than that found at a considerable distance. Generally, however, the marble is free from foliation and has only a coarse banding distinguished by variations of grain or color which may be indicative of the original bedding. It is along this structure that occur some of the inclusions of rusty gneiss observed on the western contact where they are roughly aligned along the schistosity planes, dipping steeply to the west. Furthermore, wherever the Grenville limestone is intruded by syenite, the latter rock appears in sill-like bodies conforming to the foliation.

Foliation in other Grenville rocks. Whatever foliation is present in the quartzites is made evident by exceedingly thin or narrowly spaced schistosity planes, along which are aligned the various included elements, also injections of aplites and other igneous rocks. The included bands in the quartzite measure, say, 2 mm to 7 mm in width, and the finely gneissic structure is made evident by the dimensional alignment of the constituent minerals, which are always parallel to the banded or bedded structure of the quartzite. In places this structure is accentuated by an injection of pink aplite of contrasting color to the quartzites.

In some of the purer types of quartzites, such as occur for example on the west shore of Portaferry lake, closely spaced schistosity planes are present and the rock exhibits protoclastic, sutured and mosaic structures. Stretched quartzes, feldspars and zircons are arranged parallel to their longer axes and to the schistosity. There are some very fine-grained rocks in this series in which we might expect the schistosity resulting from shear as between competent and incompetent members to develop at an angle to the bedding, but still the schistosity is parallel with the bedding.

In the pyroxene gneisses elongated augite grains in both narrow and somewhat coarse bands alternate with bands of exceedingly fine-grained quartzite, an arrangement that accentuates the schistosity of the series. The coarse bands of the gneiss show phenocrysts of quartz and orthoclase and are characterized by granulated borders. The pyroxene of the narrow bands appears to be dimensionally arranged, but in the wide bands the pyroxene is apparently uncrushed and shows no dimensional arrangement. The arrangement of the pyroxenic parts may be explained by the feature that they have been introduced later in the form of an injection contemporaneously with deformation.

In some aplitic quartzites exposed near Greenwood creek the structure is massive, but in others an alignment is brought out by the quartz, feldspar and zircon. In still others a decidedly protoclastic texture prevails, phenocrysts of feldspars with crushed borders occurring in a ground mass of finely divided quartz and feldspar. Although they have the appearance generally of either aplites or quartzites, it is recognized that some of these rocks may have been superpegmatized by feldspathic juices.

In the mica-garnet-sillimanite gneisses schistosity is shown by the strong dimensional arrangement of the micas and sillimanite and again the arrangement is parallel to the bedding.

In the pyroxene gneisses a variety of types are found, ranging from those in which there is no marked foliation to those with protoclastic texture and those with well-developed foliation. The development of the foliation appears to have been coincident with the orogenic uplift of the formations since there is a parallelism between its direction and that of the banding.

Foliation of igneous rocks. Foliation of igneous rocks in the Lake Bonaparte area, according to Smyth and Buddington ('26), is most marked in the granosyenite complex to the northwest where protoclastic textures prevail, and is not so well shown to the southeast where the characteristic interlocking textures are noted. In the areas here described all graduations from protoclastic and cataclastic textures to massive granitoid types are present.

In the hornblende granosyenite and granite gneisses a marked foliation may be brought about by a strong alignment of the hornblende element. In some phases of the complex, however, there is a noticeable lack of any foliation, as instanced for example by the syenite on top of Bald mountain which is quite massive. The more gneissic types found north of the Oswegatchie river reveal under the microscope some cataclastic textures and alignment of ferromagnesian minerals. The alignment appears to be parallel to the sill structure of the region. This parallelism of the foliation with the sill structure may be explained as the result of an earlier period of metamorphism, for otherwise we should expect a greater divergence of strike of the foliation from that of the major structure of the sill or other body of rock. This conformity between the major foliation and the sill structure has been explained by R. A. Daly ('17) as possibly the effect of load metamorphism:

A third reason for crediting the great efficiency of load metamorphism is the exceedingly common parallelism between foliation or schistosity and the stratification. This fact is abundantly illustrated in the Canadian shield, in the Adirondacks of New York State, and in the Precambrian of the North American Cordillera, Scotland, Scandinavia, Finland, et cetera. Löwl ('06) has given a good statement of it in the following passages (translated): "The great majority of the crystalline schists are foliated, not across the bedding, but parallel to it. Their parallel texture must have been developed when the rocks lay undisturbed, and thus only because of the downward pressure of the overlying rocks, exactly as in the case of shale and most clay-slates, among which, indeed, traverse cleavage is not the rule, but the exception. It is not merely a case of the condensation of the buried rock by the dead weight of its cover. The load also causes foliation. Its effect is not hydrostatic, but, even if there be pressure on all sides the pressure in the vertical direction is the strongest. Lateral thrust may develop still greater inequality of pressure, especially at small depth; yet an essential difference between the effects of load and lateral thrust is not to be assumed." Parallelism of schistosity and bedding, to the degree observed in the crystalline schists, is truly inexplicable by pure dynamic metamorphism. The parallellism is found, whether or not the dips are persistently low or high or persistently changing cross country. Since new metamorphic minerals seem to be regularly elongated at right angles to the metamorphosing stress, the schistosity produced by intense orogenic movements (tangential force) will be parallel to bedding only in comparatively rare and narrow belts. Prevailing parallelism in a terrane of variable dip is therefore a good indication that dynamic metamorphism has not controlled the recrystallization. Elementary as it is, this principle has been wonderfully neglected in most of the recent discussions of regional metamorphism.

However much this portion of load metamorphism may be responsible for the production of the foliation planes in the Grenville, it is more than probable that the major portion of the complex in which the foliation is found paralleling the sill structure as well as the bordering Grenville may have been produced concomitantly with the intrusion. As Cushing suggests, "It is quite possible the inclusion of the Laurentian granites was responsible for a certain amount of the folding as shown by the Grenville rocks and it is quite probable that the granite intrusions occurred while the side pressures were in operation and the folding was going on. It is also in the highest degree probable that folding continued long after the granite injections had ceased." (Cushing and Newland, '09, p. 55).

In this part of the Adirondack province it seems probable that the movements operated during the intrusion of the magma as well as afterward, but especially in the earlier period, when the conditions are viewed in the light of occurrences elsewhere as well as of certain rocks found in this region. Weinschenk and Johannsen ('16), in explaining the phenomenon of piezocrystallization in relation to the separation of minerals from a magma as applied to the granites of the Central Alps, make the statement that both orientated and unorientated minerals are present; the latter occur near the central portion of the Alps and the former near the contact zones. The behavior of a cooling magma under intense strain developed during its solidification is explained by them as follows:

> Orogenic pressure, acting in a definite direction, compresses the molten mass, so that mica flakes, growing in the border zone of the viscous magma, will develop with their long directions at right angles to the pressure. Pressure in the melt, however, does not remain orientated to a great distance but soon becomes a directionless stress. At some distance from the border, therefore, the parallel arrangement of the mica flakes is lost, and the rock acquires a haphazard (richtungslose) texture.
>
> The great pressure upon the cooling mass tends, under the given conditions, to produce minerals of the smallest possible molecular volumes. In spite of the high temperature, a part of the water with which the melt is saturated goes into the constitution of minerals which would not be stable in the melt under normal pressures, and the plagioclase material crystallizes into specifically heavy calcium-aluminum silicates surrounded by a border of calcium-poor feldspar. In this way there is gradually formed a connected framework whose interstices contain the still fluid mother liquor of the granite. Readjustments, caused by the pressure, now fracture the brittle constituents, and the mother liquor is forced into the cracks thus formed, crystallizing in fine veins and as granular quartz-feldspar aggregates.

This principle would seem to apply equally well in the formation of some of the structures found in the Oswegatchie area already described—notably the protoclastic, cataclastic, dimensional ferromagnesian minerals and the absence of strong foliation planes away from the contact toward the central mass of some of the igneous bodies. This latter condition may be illustrated by the hornblende syenite on the top of Bald mountain, which was practically devoid of foliation planes, whereas the syenite on the flanks of the mountain is more gneissic.

Definite proof that the foliation of the igneous gneisses is not secondary and therefore was produced by dynamo-metamorphism long after solidification is shown by the aplites between Portaferry lake and East Pitcairn where specimens of massive aplite clearly prove it has been injected into the already schistose syenite gneiss. In fact, small inclusions of the syenite gneiss are found in the aplite near the contact.

Buddington interprets the uniformly parallel relationship between foliation and bedding in the Grenville formations "as resulting from deformation of a system partly solid (Grenville) and partly liquid (magma and magmatic solutions), and is not necessarily the result of load or static metamorphism, as so commonly inferred."

It is well known that when sediments are folded the folding must have taken place under such burial by other rocks as to render the sediments sufficiently pliable to bend rather than fracture. Another observation is that the folded strata once deeply buried eventually are exposed and only the roots of the original folds remain. In the region under discussion the dominant type of fold has its limbs nearly parallel and rather gently inclined. This type of folding in the region is so prevalent as to become monotonous. Such folds with wings approximately parallel to the axial plane are known as isoclines. They may not involve great thicknesses of sediments, though when truncated through the process of erosion they may appear to possess great dimensions, a fact which must be borne in mind when estimating the thicknesses of formations. This is particularly applicable to the Grenville series between the Fine and East Pitcairn districts, where prevailing westerly dips indicate inclined isoclinal folds. The more quartzose beds between the syenite and granite gneisses, separated widely in some instances from their mother areas, may result from infolding and a pinching out of the series, or they may represent roof pendants as a result of magmatic stoping. It would seem likely, however, in view of the post-Grenville intrusions exemplified by the syenites and granites, that a process of magmatic stoping would bring about a real discordance in the dips of the strata, which is not always the case. At some localities we find approximate parallel and conformable dips between the isolated areas and the nearest main bodies. In such occurrences the conformability of the latter with the original bodies, as well as with the sill structure of the intruding bodies, argues for a directional control provided by the Grenville in the path of the invading magmas. This same control is conspicuously and frequently shown by the smaller injections of aplites and micropegmatites in both the Grenville quartzites and the gneisses; and what is true in the smaller occurrences is likely to be so for the larger bodies of rock.

Complex folding is found at Benson Mines where the banded magnetite gneiss is the predominant formation and the wall rock of the ores. On plotting the strikes and dips on a large scale field map, it is found that the magnetite series is structurally a part of a pinched out southwesterly pitching asymmetrical anticline, whose axis follows a general northeast-southwest direction. The strike of the gneiss changes, however, from a northeast direction to N. 60° E. at the mines and then to a northwest direction west of the mines and finally north of the mines to a north direction. On the north limb at the northeast end of the fold, sillimanite gneisses are present, with a northeast strike and a northwest dip. If these are conformable with the magnetite series they would seem to overlie the latter. Just north of the village of Benson Mines and to the north and east of the Carthage & Adirondack Railway occur intruded sills of granite gneiss and augite syenite gneiss; whether the sills are themselves folded or were intruded subsequent to the deformation can not be determined at present, owing to the forested and morainal character of much of the terrane north of the mines. One very noteworthy fact brought out from the field studies is that wherever the strike changes as it does in the vicinity of the mines—and these same changes have been noted in the region about Fine—areas of strongly foliated, plicated and banded sillimanite and pyroxene gneisses are found. The folding in places appears more in the nature of a puckering of certain types of strongly foliated gneisses while these rocks were trying to accommodate themselves to other rocks which are likewise undergoing deformation.

The dominant structure of the igneous gneisses in the area is that of a composite sill, as illustrated by many localities, particularly in the southern part, where the contacts between the pyroxene gneisses and the granosyenite gneisses are revealed. Such structure holds not only for the syenites and the more acid gneisses, but for all other bodies, including the diorites on Panther mountain and the more granitic bodies which intrude the gneisses along the Middle branch of the Oswegatchie and elsewhere.

Although no contacts between the garnetiferous gabbro which caps the 1920-foot hill southeast of Mud pond and the adjacent syenite are in evidence, it is believed that the gabbro, also, is sill-like in shape. Many of the granite bodies showing little or no structure have apparently invaded older gneisses—gneisses which were already in a tilted attitude—and therefore the granites inherited the latter structure. The same structure is particularly characteristic of the bodies of syenite and aplite which have invaded the Grenville between Portaferry lake and East Pitcairn corners. Here, the steep zig-zag road cuts through the series and shows the structure particularly well. Such hills as Vrooman ridge, Maple mountain, Streeter mountain, Maple hill and Bald mountain are essentially composite sills in outline. Along the cuts made by the Middle branch of the Oswegatchie the same relation is illustrated time and again.

The association of the syenite, granosyenite and granite gneiss in sills which frequently overlie each other, suggests a common source for the magma and indicates that the magma became differentiated through its ascent in the earth's crust. According to Shand ('27) it is to be accepted that "The syenites are either marginal modifications of great bodies of granite, or else they rise, in the form of dykes, stocks, or cupolas, from the roof of a granite batholith."

So far as observed it would appear that magmatic differentiation is not so well defined along the sills as across them; sharp lines of demarcation exist, to be sure, between the different sills but such changes as are shown in several typical cases indicate a gradation in a broad way. For instance, Streeter mountain consists on top of coarse basic syenite gneiss, in which hornblende is a dominant mineral, whereas below there appears to be a gradual diminution of the hornblende and an increase of the quartz indicative of a change to granosyenite. At the base of the mountain and for some distance away the rock is granite. In such circumstances it is necessary to conclude that differentiation started where the magma first came under sill control.

Faulting. No displacement or faulting of any great importance was discovered in this area, although evidences of movement were observed in various places. In the Benson Mines series a slight displacement appears on the south wall of the mine along a N. 80° E. trend where a slickensided fault plane inclined 80° to the north is found. This plane could not be traced farther than in the confines of the mine opening.

Where the South Edwards-Harrisville roads corner, the Grenville limestone here intruded by pink granite shows a slight east-west normal fault with a throw of a few feet.

At the railway cut just east of Jayville the coarse porphyritic granite is fractured in the direction N. 10° E. and the fracture plane has a slickensided appearance.

Some slight movement in the Grenville limestone west of Snyder lake is observable in a north-south direction, manifested by the slickensided quartzite inclusions.

Perpendicularity of the cliff of mixed gneisses west of Snyder lake, which appears to coincide with the N. 60° E. schistosity plane, is suggestive of faulting, although no actual evidences otherwise were found to substantiate the presence of such displacement.

Shearing and slickensided surfaces along the gneiss-pyroxene rock contact east of the railway and parallel with the longer axis of Bear lake suggest faulting in the direction of N. 10° E.

Slickensides on some of the surfaces at the Jayville magnetite mine, at the southwest end of Vrooman ridge, as well as at other places, all give evidence of faulting.

Jointing. In the Grenville series, particularly in the quartzose pyroxene gneisses and the mixed gneisses, the jointing was mostly in the directions N. 85° E., N. 60° E. and N. 35° W. In the igneous gneisses there is a wide range of trend with the major joints following in descending order of frequency the directions: N. 30° E., N. 80° W., N. 40° E., N. 75°–80° E., N. 85° W., N. 45° W., N. 85° E. and N. 30° W. Along the Middle branch and Fish creek, which are for a considerable distance in this area west-flowing streams and consequently cut the formations, the conspicuous joint planes trend as follows: N. 62° E., N. 75° E., N. 45° W., N. 5° E., N. 25° W., N. 30° E., NS., N. 75° W., N. 15° E., N. 65° E., N. 60° W., N. 40° E., N. 50° W., N. 85° W., N. 40° W., N. 10° W., E.-W., and N.-W. East of the Alder beds the following conspicuous joint planes were noted: N. 40° E., N. 53° W., N. 80° E., N. 62° E., N. 85° E., N. 10° E., N. 35° W., N. 20° E., N. 25° E., N. 70° E., N. 85° W., N. 43° E., N. 4° E., N. 60° W., N. 12° W., and N. 70° W. In the Aldrich-Vrooman Ridge district the following joint planes are conspicuous: N. 50° E., N. 50° W., N. 75° E., N. 30° E., N. 30° W., N. 85° W. and N. 5° E.

Jointing in igneous rocks is generally supposed to be the result of contraction during consolidation. It appears probable that the various igneous bodies of this area were erupted under compression. If the pressure responsible for the folding came from the southeast, as has been suggested by various Adirondack geologists, it is quite conceivable that some of the jointing originated from this movement, particularly those of the northeast-southwest and east-west types. It is out of the question to find a satisfactory explanation for the other joint directions.

CONTACT METAMORPHISM

Where igneous rocks have intruded other rocks, or even other types of igneous rocks, the effects of their intrusion are frequently observable for a greater or less distance on either side of the intrusions if not within the intrusions themselves. If the intruded rocks themselves have undergone change, we refer to the effects as exomorphic contact metamorphism; whereas any change observed within the intrusions we designate as endomorphic contact metamorphism.

In the vicinity of Fine the pyroxene gneisses in contact with the Grenville limestone contain fragmentary bodies of fine-grained pink limestone unevenly coated with secondary lime silicates. These inclusions or xenoliths are elliptical or round in shape and measure from less than a foot to many feet in length. Their longer axes are generally parallel with the foliation planes of the pyroxene gneisses. Frozen to their surface occur pyroxene and scapolite in irregular crystalline aggregates, which have resulted from the reaction between the invading magmatic juices and the limestone. These inclusions are particularly abundant north and south of the Oswegatchie river, where they appear somewhat corroded and embayed as the result of assimilation and differential chemical weathering.

At Manchester school white pyroxene, calcite and feldspar are developed along the contact of syenite and its pegmatite facies with the Grenville limestone. This occurrence is found as a conspicuous rusty colored knoll, resembling the capping of an ore body.

At North Fine the Grenville limestone near its contact with the banded syenites is fine grained and schistose and carries phlogopite, coccolite and orthoclase, as secondary minerals. In places, also, the limestone carries tremolite in crystal aggregates in which the individual crystals measure three or four inches in diameter, undoubtedly an exomorphic effect.

East of Manchester school a contact metamorphic phase of the Grenville shows alternating bands of coarse white diopside and massive quartz (figure 16). The whole ledge, a hundred feet wide,

Figure 16 Modified pyroxene gneiss showing bands of quartz and pyroxene; Manchester School.

is characterized in parts by conspicuously involved folding; the individual bands measure less than an inch to an inch in width for the quartz and less than that for the pyroxene. The rhythmical banding is similar to the wall rock found at the feldspar mine near DeKalb Junction and where the wall of the mine consists of contorted bands of quartz and diopside. According to Shaub ('28), "The deposition of the bands would be roughly normal to the direction of the motion of the solutions which probably came from fractures dipping to the south. In this process the solutions would not be expected to advance as a single wave, but instead they would deviate to follow the most permeable parts of the rock first and then advance from these new centers, and thus produce the irregular pattern of bands found in the wall rock." In this occurrence there is evidence of enlarged quartz grains indicating secondary silication. It would also appear most probably that this deposit represents a phase of contact metamorphism which resulted in the silication and the pyroxenization of the country rock brought on by the invading pegmatites subsequent to the intrusion by the syenites.

Associated with the xenoliths of Grenville limestone in the Fine area and with the magnetite gneisses in the Benson Mines area may be noted the occurrence of abundant scapolite minerals, evidently derived by contact influences from the plagioclase feldspar. In the Benson Mines series these crystals have diameters as much as two or three inches and appear like large phenocrysts. They are white and colorless silicates of lime and sodium.

In places within the Oswegatchie quadrangle, particularly at Fine and along Greenwood creek, the quartzose rocks have been very much altered through superpegmatization in which quartz has played a very important part, thereby making these exceedingly fine grained rocks very difficult of interpretation. Some of the rocks have undergone granulation, evidenced by protoclastic and cataclastic textures, and then by the process of pegmatization the quartz has been recemented along the granulated periphery of the larger grains.

A deposit of talc, of no importance commercially, was found east of Portaferry lake above the east tributary of Cold Spring creek. The mineral occurs in concretionary form, enveloping dolomite. The concretions average from six inches to a foot in diameter. They are yellow in color and the tâlc is granular in texture, lacking the foliated or fibrous quality of the Edwards talc. There is little evidence as to the direct origin of the talc, but very likely the mineral has been produced by solutions emanating from the syenite, which outcrops in the vicinity, and interacting with the dolomite.

Evidences of endomorphic metamorphism are noted mostly in pegmatitic injections in which are found pyroxene, calcite, plagioclase, quartz, muscovite, amethystine fluorite and garnet. Some of these minerals already have been discussed in connection with the Manchester School occurrence. Another dike north of Fine carries pyroxene, orthoclase, quartz and calcite, indicative of the influence of the nearby Grenville limestone. Amethystine fluorite and tourmaline are noted among the minerals of the Fine dikes along the state road.

Blended contacts of gray syenite with pegmatite, south of Fine, are characterized by pyroxene, garnet, amethystine fluorite and calcite, and are indicative of the relative heated condition of the syenite rock at the time of its intrusion by the pegmatite.

The granite gneiss in contact with the augite syenite, along the State road north of Oswegatchie, is of a decidedly lighter color, indicating a salic border to the intruding granite.

The banded syenite area in the village of Star Lake shows in a conspicuous manner how the feldspathic juices have invaded the country syenite, in places the injection is so thorough as to give rise to a relict gneiss.

GEOLOGIC HISTORY OF THE REGION

Precambrian time. The oldest rocks in this region, as well as in other parts of the Adirondack province, are represented by a series of crystalline limestones, schists and gneisses, designated as the Grenville. Their basal character has been made evident by studies carried out in different parts of the Adirondacks by a number of geologists. Not only do they rank as the oldest rocks in the Adirondack province, but they are among the oldest in all probability of the Precambrian formations found anywhere in the world. It is clear that these rocks have lost most of their primary characteristics. Some of them are so altered from their original condition that it is quite impossible to state definitely what their immediate ancestors or prototypes were. The marbles and quartzites, it is clear, were originally laid down in the ancient Precambrian seas as lime oozes and sand. In the field the metamorphosed sedimentary rocks as a rule present certain differences in their mineral and chemical composition, in textural and structural features so that they can be distinguished from other rock groups. Because of their folded character and the particular type of folding present, known as the inclined isocline for much of their extent, it is not possible at present to estimate the thickness of the sediments in the Oswegatchie area. There is almost certain repetition of beds across the strike in this sort of structure. Nor would it be possible to indicate in this series which is the bottom and which is the top. The patchy character of the Grenville along the Oswegatchie river and to the south, owing largely to partial envelopment and possibly to assimilation by the various igneous rocks, as well as to contact metamorphic section, the effects of differential erosion, folding and glaciation make it extremely difficult to arrive at any satisfactory stratigraphical sequence applicable to all of the Grenville. To be sure in the northwest part of the area there appears to be a sequence between the limestone, pyroxene gneiss and quartzites; but as to which is the bottom and which is the top of this small sequence it is difficult at present to decide.

With the absence of exact knowledge of the top and bottom of the series we are hardly in a position to recognize the basement complex upon which the Grenville was deposited. It seems most likely that we are unable to identify the basement rocks in the Adirondack region because of the profound effects of metamorphism upon the formations or their disruption and assimilation by invading magmas either of pre-Grenville or post-Grenville date. The inclusions of syenite, amphibolite and quartzose rocks within the Grenville limestone, though very inconspicuous in amount in this quadrangle, seem to point to incorporation of other materials in the Grenville, perhaps of rocks antedating the Grenville; but so far as observations within the Oswegatchie area are concerned we are unable to point to any definitely proved rock older than the Grenville.

Certain silicate materials are classified as Grenville because of their field occurrence and composition, such as the magnetite gneisses of Benson Mines, mica-garnet gneisses and mica-garnet-cordierite-sillimanite gneisses, amphibolites and arkosic gneisses. Where quartz is dominant as in such rocks as arkosic gneisses, magnetite gneisses and mica-garnet gneisses, no other classification seems at present to fit these rocks however much they may have been altered through magmatic influences. In classifying the mica-garnet-cordierite-sillimanite gneiss as Grenville it seems best to follow the plan set forth by the authors of the Lake Bonaparte quadrangle, because in that area more of this formation is found than on the Oswegatchie sheet. Small bodies of amphibolites from five to 250 feet in length and consisting largely of hornblende, biotite and feldspar occur with the mixed gneisses as well as with the granite gneisses. Wherever found they appear to lack cross-cutting relations but are concordant with the country rock and generally are intersected by pegmatites.

Because of the limited number of amphibolite occurrences on this sheet it is difficult to give any satisfactory explanation of their origin other than that they apparently antedate the country rock. Rocks that resemble amphibolites are found in some cases to be related to diorite or syenite in composition, clearly of igneous origin and older than the rocks with which they are associated or by which as usually happens they have been intruded. This is well shown by the diorite on Panther mountain, which is distinctly intruded by the associated granite gneisses though concordant with them; outcrops of the rock on the road just west of Bryant bridge has more the appearance of an amphibolite inclusion yet is distinctly a part of the same body that outcrops on Panther mountain. For a fuller discussion of amphibolites the reader is referred to J. C. Martin ('16) and Buddington ('31).

No definite basis for estimating the age of these ancient metamorphic sedimentaries has come to light other than that they may range through an interval as long as subsequent geological time to a period as short as any two later geologic eras. During the period of deposition of the Grenville, it is necessary to postulate a synchronous subsidence to account for the accumulation of between 20,000 and 25,000 feet of strata, which Cushing estimates to be the thickness of the Grenville. Surely such a subsidence with the weight of the overlying thousands of feet of rock upon the deeply buried formations must have brought on many changes. Included within the original Grenville there may have been also considerable thicknesses of igneous rocks, although of this matter we are not absolutely certain. Under the load of thousands of feet of rock there is very little possibility of the lowermost strata escaping changes in composition, texture and structure.

While the lowermost and oldest rocks were deeply buried, they were intruded by molten magmas which eventually differentiated into the various types of gabbros, diorites, syenites, granites and their pegmatites as we find them today. These intrusions apparently invaded the Grenville contemporaneously with the regional pressures exerted upon the magmas but not necessarily or probably all at once. The great pressures were in operation approximately coincident in time with the intrusions, in consequence of which we find the various textures and structures present that have been described in earlier parts of this report. The folding in the region exemplified by the Grenville in which the isoclines are tipped over to the east and the limbs dip to the west and the general sill-like structure of the igneous gneisses covering most of the sheet were undoubtedly produced in this period of compression. At the time these beds were being compressed and folded and intrusions were making their way into them, differentiation of the syenites and the granites took place with more or less variation in periods of intrusion. The general uniformity of conditions is evidenced by the unity in the major structural control, as a result of which there is a broad concordancy throughout the different members of the great complexes.

After this period of uplift and intrusion there was a prolonged interval of erosion. There is no way of estimating the amount of material removed from this portion of the Adirondacks because of the uncertainty as to the existence of any great thicknesses of Cambrian sediments or, possibly, later sediments covering the crystallines. Nor can we definitely state how many stages of uplift and erosion there were, although it is a fair inference that the stages were a multiple succession, because of the mass of material removed from the original land surface. The general level-like nature of certain parts of the Oswegatchie area may have been brought about partly through the erosion in the early or Precambrian period and partly through that of Mesozoic time, both of which were very long in duration; but it is generally supposed that Precambrian erosion outlasted that of any later period. Undoubtedly, the level-like surface which is indicated by the general even skyline viewed from such mountains as Streeter Lake mountain and the high land around Aldrich resulted from the wearing down of what was once a very rough topography, largely during Precambrian time. Upon such a surface a heavy accumulation of residual soil might be expected to exist like that occurring farther south beyond the reach of the Pleistocene ice-sheet; but of such soil there is now little evidence anywhere on the quadrangle.

In late Precambrian times occurred the intrusion of many dikes of diabase and pegmatites which are found in nearly all parts of the Adirondacks. The intrusions followed joint planes that had previously been formed through stresses set up perhaps when the magmas were in the process of intrusion, but it is certain that further stresses were caused by the invasion of these lesser igneous bodies which took the shape of dikes and more rarely that of sills. Although diabase dikes are extremely rare in the Oswegatchie quadrangle, it is known from conditions elsewhere that they are a product of late Precambrian time. Many of the pegmatites in this area most certainly belong to a relatively younger series, for they are devoid of gneissic structure and are found cutting all members of the great complex of igneous gneisses. These pegmatites are generally associated with the mother rocks from which they originated, having intruded themselves through crevices or joint planes formed after the consolidation of the magmas. Besides the pegmatite intrusions, note may be made of the presence of veins or dikes made up almost entirely of vein quartz with very minor feldspar which characterize the final stage of igneous activity. These bodies generally parallel the foliation planes. Miller, in his Adirondack work, has given the name "silexite" to this rock. It seems appropriate because of the abundance of such bodies. They represent the last differentiate of the granite magmas. One of the noteworthy occurrences of silexite is in the arkosic gneisses southeast of Star lake where it is injected along the foliation planes of the gneiss to such an extent that from a distance the material resembles a stratified rock.

Later history. Following the intrusions of the late Precambrian it is estimated that between 3000 and 5000 feet was eroded from the surface of the Adirondacks before deposition of the first of the fossiliferous sediments in the region. As a consequence a broad peneplain was developed before the deposition of the Potsdam sandstone, the earliest of the fossiliferous formations. Outliers of Potsdam sandstone occur in the Lake Bonaparte and Gouverneur quadrangles and increase rapidly in number and area to the west; their presence indicates that following the long period of subaerial erosion there must have been extensive subsidence, since it is believed that the Cambrian sea covered a considerable portion of New York State. There are great thicknesses of lower and middle Cambrian strata in New England and along the eastern border of New York State, but only the upper Cambrian is found in the northern and western Adirondacks. The absence of any Potsdam on the Oswegatchie sheet is likely to be explained by erosion of these sediments after deposition although the area may have been very close to the old shore line and, consequently, the accumulation of Potsdam was not very thick. In the central and southwestern Adirondacks there is no evidence of the existence of a Cambrian sea and it is reasonable to conclude that those parts formed an island during that time. Not only did this island persist during the Cambrian but throughout all the succeeding Paleozoic periods with the seas retreating farther and farther to the south and west.

At the close of the Ordovician and again following Carboniferous time mountain-making movements brought about the formation of the Taconic range and the Appalachians proper. There is little definite information to be had of the effects of these uplifts upon the Adirondacks. A broad-scale uplift with little or no differential movement may be postulated as the probable outcome of these disturbances upon the region. The slight evidence of faulting found in the Oswegatchie area, faulting on too small a scale to be responsible for any marked topographic feature, can be regarded as related to the Precambrian disturbances. But such a profound and widescale movement as the Appalachian would certainly have involved more or less reelevation of the Adirondack province, if not the freshening of old faults and the making of new ones; but no definite knowledge of these matters is to be derived from conditions in the area under consideration.

During the succeeding Mesozoic era when uplifts in regions not remote from the Adirondack province took place, such as the Triassic lowlands of southeastern New York and the Connecticut valley, the Oswegatchie area was likely affected by another elevating movement with renewal of erosional activities which, perhaps, contributed to the further development of the peneplain originating in late Precambrian time. Just what share the various periods of accentuated erosion had in contributing to the present topography is difficult to state, although it is believed from studies to the west and north that the present Adirondacks represent a compound peneplain involving several stages of active erosion from the Precambrian up to the Mesozoic and Cenozoic eras. In the last-named era came the ice invasion which left its impress upon the whole Adirondacks and upon the entire State, for that matter.

Glacial history. Direct evidences of the destructive effects produced by the ice sheet are seen occasionally on such steep lee slopes as the south side of Vrooman ridge, the hills south of Aldrich and the drumloidal, hogback hills northeast of Jayville. As marks of the movement of the ice rock striations may be noted in all parts of the quadrangle. These follow generally a north to northwest direction though the anomalous N. 60° E.–S. 30° W. striation and grooving at the west end of the mine opening at Benson Mines indicate a secondary movement or current in the ice controlled by the higher land to the north at a time when the ice was apparently much reduced in thickness.

Features arising from subglacial stream drainage are exhibited in several places on the sheet. Notable are the eskers in the village of Oswegatchie (see figure 17); also, the multiple eskers of Star lake, and the bifurcating ones of Rock and Sand lakes. Other smaller eskers occur at Twin lakes and on the north shore of Streeter lake. The Oswegatchie eskers apparently occur in twin forms; the north one, bounded by Twin lake stream, may have a rock nucleus as inferred from the outcrop of Grenville strata at its western tip. Their upper portions, however, are made up of moraine of which the materials are conspicuously rusty. The Star Lake multiple eskers, taken in connection with the kettle holes of Readway ponds to the south, indicate that there was formerly a more complicated drainage system than now obtains and that there may have been a local halting of a tongue of ice either in the general advance or retreat of the ice sheet, more probably at the latter time. The bifurcating eskers of Rock and Sand lakes consist of a main esker, N. 40° E. traceable for more than 1000 feet rising to 30 feet in height, which separates Rock lake from Sand lake. The main esker is joined by a smaller tributary one pursuing a north-south trend, which eventually makes a juncture with the west bank of Sand lake. The main esker is continued in a southerly direction for an additional 500 feet, with a bend to the southeast, followed by the outlet stream. Inconspicuous and intermittent as these eskers are, when the whole of the sheet is considered, they do show something of the nature of the subglacial drainage. They represent the material as it accumulated in the bottom of the stream bed without any confining walls of ice, consequently this fill-like mass has assumed its own angle of repose.

Worthy of some notice are the kettle holes of Twin lakes, Star lake, Readway ponds and Tamarack creek. Their shapes differ considerably from the usual circular outlines in that most of them are much more irregular and are bounded by eskers on one or more sides. This irregular outline is particularly observable in the examples found at Readway ponds and Tamarack creek. The Tamarack creek hole has a slightly crescentic shape with a northwest trend; it measures three-quarters of a mile long by an eighth to a sixteenth of a mile wide. It is situated at the base of an outwash plain and has a well-marked esker on the northeast rim. The esker, 60 feet high and about a half mile long, is covered with boulders of granite and diorite gneiss. It is forested with poplars, birch, spruce and hemlock. At present three diminutive circular ponds occur in the kettle hole, the main floor of which is a cranberry bog. The kettle holes of Readway ponds are bounded in somewhat similar fashion by eskers. The topography of the district, in fact, is essentially composed of esker, knob and kettle moraines.

The Twin lakes kettle holes are about 100 feet below the surrounding outwash plain or terrace north of Star lake and at levels of 89 feet and 94 feet respectively, below the level of the lake.

Figure 17 Twin Lake creek eskers; Oswegatchie.

They have conspicuous eskers on the east sides and are similar to the depressions so frequently associated with outwash plains in other well-known glaciated districts.

Star lake has no surface outlet but may drain underground into Twin lakes to the north, which lie at a lower elevation in glacio-lacustrine or fluviatile deposits so as to make such underground flow a possibility. The topographical conditions certainly favor this explanation of the lack of surface outlet for Star lake, but it would require exploration by well drilling to establish the matter beyond doubt.

Conspicuous terraces of glacial sands (figure 18) indicate levels of glacial waters both below and above the present surface of Star lake in the period following glaciation in this district. They range from 1420 feet to 1540 feet. Lower terraces at 800 feet mark the position of glacial waters in the East Pitcairn valley.

Other effects of the Labrador ice sheet are the drift and till which overlie most of the area, inclusive of many glacial erratics and boulders, some of which are surprisingly large, like Kelly rock near Tunnel camp on the Middle Branch, with dimensions of 15 feet in the shorter axis by 20 feet at right angles. The source of this boulder is probably local as it consists of granite gneiss, not unlike the rock of the immediate neighborhood, and is quite angular in shape.

The general effect of the continental glacier upon the Oswegatchie area has been a modifying one either by glacial wear, as shown in the overdeepening of the valleys where lakes and ponds have been formed and where cliffs have been oversteepened on their lee side, or by glacial deposition which characterizes the greater part of the area, particularly in the hills, where drift is the characteristic deposit overlying bed rock and in the filling and choking of the valleys by stratified deposits. These latter deposits are not unusually large or uniformly distributed. Most of the stratified deposits seem to have been deposited during the ice advance. Since the ice left the Adirondack province (perhaps 20,000 or 25,000 years ago) the streams have been engaged in cutting out a new topography which had been considerably modified by the glacial occupancy. It is believed that no great divergences took place in the drainage as a result of the glacial incident and the present streams were operative in base-leveling when interrupted by the oncoming of the ice. This work has been somewhat accelerated in later time because of reelevation of the surface.

ECONOMIC GEOLOGY

Deposits of magnetic iron ore occur at Benson Mines, Jayville and on the Green place two miles south of Fine, and are indicated on the geologic map by appropriate symbols. Since Mr Newland has reported on these mines in New York State Museum Bulletin 119, p. 128–39, no attempt will be made to duplicate his work so far as relates to the descriptions of the occurrences. It is thought best, however, to include in this place such information resulting from a more extensive survey of the region as may throw additional light upon the genesis of the ore bodies.

Benson Mines. The ore bodies extend in a belt which begins about one mile west of the hamlet of Benson Mines and follows a general easterly direction to a point near that place where they curve around to the northeast and continue for an indefinite distance toward Newton Falls. In the period of their operation they were connected by a short spur track with the Carthage and Adirondack branch of the New York Central Lines. The highway from Edwards to Cranberry lake and Tupper Lake village is about one-half mile north of the deposits. The ore occurs at the base of a ridge a little above the 1400-foot contour. It has a thin covering of soil where worked and its surface is glaciated (figures 19 and 20). Nearly all of the surface plant had been removed or was torn down at the time of inspection (figure 21). The last operations were carried on in the year 1917 when some 34,000 long tons of nodulized ore were produced and shipped to furnaces. The crude ore is said to average about 30 per cent metallic iron.

The ore was extracted by open-cut methods. Well drills were employed to sink holes for blasting and a steam shovel to load the broken ore. The latter was then run to the mill in cars and there passed into a giant crusher of the jaw type. Two pairs of 36-inch rolls effected a further reduction, after which the material was fed to ball mills for final pulverization. The fine product was then subjected to magnetic separation whereby a concentrate of magnetite and a tailing of nonmetallic minerals were obtained. The magnetite was then dewatered and heated in an inclined kiln at a temperature sufficient to cause partial fusion of the particles, the ore coming out at the lower end of the kiln in the form of nodules an inch or so in diameter—a form most suitable for shipment and reduction in the furnace.

From observation and studies made by Newland in 1907 and by the writer during the field seasons of 1926 to 1929, the Benson

Figure 18 Glacial lake terrace south of Star Lake.

Figure 19 Glaciated surface of magnetite rock; Benson Mines.

Figure 20 Open cut in ore; Benson Mines.

Figure 21 The Benson Mines milling plant used in concentration of iron ore (mill now destroyed).

Mines deposit appears to be in the form of a zone of ore-bearing gneiss made up of a great number of bands which parallel the general foliation of the country rocks. This foliation is not so noticeable in the hand specimens as in the exposed ledges and is particularly conspicuous on a glaciated surface at the western end of the pit. Segregation of the magnetite along the foliation planes is generally characteristic for the district. In composition the ore-bearing rock contains besides magnetite the following minerals: feldspar, quartz, garnet, pyroxene, cordierite, scapolite, pyrite, amethystine fluorite, phlogopite and hornblende besides some graphite, zircon, apatite and such secondary components as chlorite, kaolin and muscovite. In the lighter colored bands feldspar and quartz dominate over the magnetite, such bands measuring about 5 cm in width. In the darker bands with plentiful magnetite the feldspar takes on the appearance of phenocrysts, some of which measure as much as three centimeters in diameter.

Wherever magnetite, scapolite and orthoclase occur together garnet reaction rims are present. In some specimens it is difficult to tell whether the chlorite ingredient is the result of alteration of the hornblende or pyroxene, but in general it is evidently the product of both. Pyrite occurs as rims around magnetite, which it also replaces. In texture the rock for the most part belongs to the granitoid type with interlocking grains and to some extent it has a poikilitic appearance. The banded character and composition of the rock are traceable to the igneous injection and metamorphism of an original sediment or sediments, characterized by considerable change from layer to layer.

It was our conclusion from the study made of Newland's work and our own observations of the district that the magnetite banded gneiss has more in common with the Grenville formations than it has with the igneous rocks, although many aspects of the gneiss today partake of an igneous nature as shown by certain phases or zones which resemble syenite. Still other phases belong to the granitic or pegmatitic class. It has already been remarked that the relations of silica, alumina, potash and soda, as revealed by chemical analyses, point in general to a sedimentary origin.

From the areal map it is seen that the outcrop of the magnetite gneiss is elliptical in outline with the longer axis taking a NE-SW direction. The area is little more than a mile and a quarter in length and about three-eighths of a mile in width. On the west the gneiss is succeeded by sillimanite gneiss, showing some igneouslike characteristics, and this in turn gives way to fine-grained syenite gneiss with injections of biotite-granite gneiss. Still farther to the west is a body of banded pyroxene gneiss from a quarter to three-eighths of a mile wide. To the north of the village of Benson Mines is a sill-like body of granite gneiss, which has a width of a quarter of a mile as a maximum. South of the Benson Mines is an area composed almost entirely of pyroxene gneiss, part of which is formed by a comparatively thick body of pyroxene rock measuring about half a mile in width and consisting almost entirely of diopside with segregations of biotite in some places and in other places small segregations of magnetite. So many of these pyroxene bodies are found associated with syenite and Grenville usually near the contact that we conclude that they probably originated by igneous metamorphism of the sediments, such as impure limestone.

Thus, in view of the generally igneous environment of the Benson Mines deposits, it would seem that the source of the magnetite may be traceable to the more basic differentiates of the igneous series, in all likelihood of the syenite. In connection with the transfer of the iron into the gneissic series it may be remarked that the foliation of the gneiss is such as to offer an easy path for the invading solutions. The absence of magnetite in the arkosic gneisses to the southwest of Benson Mines may very well find explanation in the unfavorable structure of these rocks. The quartz-orthoclase which invades the ore-bearing gneiss is undoubtedly a product of the latter igneous activity. It is believed that the magnetite itself is related to the earlier syenitic intrusion and particularly of the pegmatitic differentiate of the syenite which followed the main intrusion.

The locus of the ore body appears to have been an area of more intense folding than other parts of the quadrangle, a folding which is quite different from the general type of structure so characteristic of the region as a whole. Not only do we have a northeasterly trending fold developed in a broad curve but one which pitches considerably to the southwest, giving it the shape of an asymetrical anticline. To the west and the southwest of the deposit are evidences of very intense crumpling in puckerlike structures of the pyroxene gneisses which evidently thus accommodated themselves to the deformation.

No evidence is at hand of folding subsequent to that produced in early Precambrian time or of later date than the period of main magmatic intrusions. On the other hand, the small differential movement, such as may be seen in the pit at Benson Mines, is perhaps later in origin than the period of folding.

Jayville ore deposit. As D. H. Newland has given the most detailed account of the Jayville mines it seems best to quote him at length from New York State Museum Bulletin 119, pages 137–38:

Jayville is 14 miles west of Benson Mines and 29 miles by rail from Carthage. With the cessation of mining in 1888 the buildings and machinery were removed and the place has since been practically abandoned, leaving only the waste heaps and pits as evidences of the former activity. The mines were last operated by the Magnetic Iron Ore Co., who instituted extensive developments in 1886. The existence of the larger deposits at Benson Mines soon led the company, however, to give up the undertaking in favor of that locality. The mines are credited by Smock with an output of 25,000 tons during the last period of operation.

The ore occurrence presents a phase quite dissimilar from that at Benson Mines and more like the magnetite deposits on the east side of the Adirondacks. There are innumerable shoots, lenses and irregular bunches in which the magnetite is found showing sharp boundaries in contact with the wall rock. The latter is for the most part a hornblende-biotite gneiss of sedimentary appearance. The horizon of the ore lies close to the contact of the gneiss with a red pegmatitic hornblende granite. Outcrops of the granite occur to the north and east within short distances where they break through and cut off the gneiss area in such a way that their intrusive character is plainly evidenced. In some of the openings the granite can be seen in immediate contact with the ore.

The openings are on the northeastern and northwestern slopes of a low ridge of the gneiss that rises just west of the railroad. The pits nearest the station are Hart No. 1 and No. 2, of which the first is said to be 300 feet deep following a shoot 20 feet wide and 10 feet thick. Hart No. 2 is much shallower. At the northeastern end of the ridge where it curves to the west are the pits called New York No. 1 and No. 2, both of inconsiderable depth. Benson No. 1 farther to the west is reported by Smock to have a depth of 350 feet on the incline; of its two levels the upper is about 25 feet long and the lower driven at a point 60 feet from the bottom of the slope runs off in a southerly direction for 160 feet and then north 60 feet. This pit supplied most of the shipping ore. Between Benson No. 1 and No. 2 an adit has been excavated into the hill on a lead which in the interior develops into a lens some 60 or 70 feet long and 20 feet wide. The Fuller and Essler pits are located at the extreme west, the former being opened on a pod of ore 50 feet wide, dipping 45° west.

The distribution of the ore in disconnected bodies which pitch and strike in all directions has probably resulted from the intrusion of the granite. The bodies occupy approximately the same horizon and have the aspect of an originally continuous band which has been disrupted and faulted. The intrusion has exercised, also, a metamorphic influence upon the deposits shown by the abundance of garnet and hornblende that often replace the magnetite almost completely. Well developed titanite crystals of unusual size are found in the contact zone.

The analysis below taken from Putnam's report, gives the composition of the Jayville ore. It was made from a sample of 500 tons mined in 1880 and shipped to the furnace at Alpine. It represents the selected lump ore, sufficiently high in iron to be used without concentration.

Iron	56.72
Titanium	nil
Phosphorus	.009

In the present survey of the district no considerable body of Grenville was seen about the mines, although low places in the near-by region as well as the calcite veins in faulted parts of the ore body, probably originating from some Grenville remnants through solution and recrystallization, would suggest the occurrence of such a body not far away. The main country rock in this region is a grayish pink hornblende granite, more or less gneissic in appearance, but near the ore contact the rock is a distinctly banded gneiss containing microcline, orthoclase, hornblende, biotite, quartz, magnetite and calcite. Locally, masses of nearly pure hornblende with coarse titanite crystals occur. The pinkish granite belongs to the coarse-grained type, characterized by quartz, microcline, orthoclase, oligoclase, hornblende, with zircon, kaolin, chlorite and some magnetite. This rock has the normal granitoid texture characteristic of all granites, but its components show more or less distinctly an alignment from compression or flowage. Pegmatites of varied appearance cut both country rocks and the ore bodies. Associated with them are reaction zones in which such minerals as green pyroxene, hornblende and garnet are prominent. Some idea of the general structure of the deposits may be had by consulting figures 22 and 23. It is observed that the magnetite conforms rather closely to the major foliation of the region. Dips of 55°–58° W. are common throughout the deposits.

Specimens collected from the old dumps indicate a fairly good quality of ore, which is corroborated by the foregoing analysis. The magnetite appears both in coarse and fine condition and carries some disseminated pyroxene; veinlets of pyrite up to an inch across intersect the ore. On exposed surfaces the pyrite is changing to melanterite. Some of the ore shows calcite and dolomite in intimate association with the magnetite. Other examples show banded muscovite not in alignment with the foliation planes but transverse to them. The micaceous bands carry a brick-red alteration pigment and are cut by irregular veins of white calcite. The interstitial matter of the bands is calcareous.

It is believed that the magnetite is a late-stage differentiation product of the syenite which perhaps found lodgment in original beds of Grenville limestone by a process of replacement. Such an origin is suggested by the conditions represented by figure 23 as well as by the presence of calcite in the gangue and in veinlets intersecting the ore.

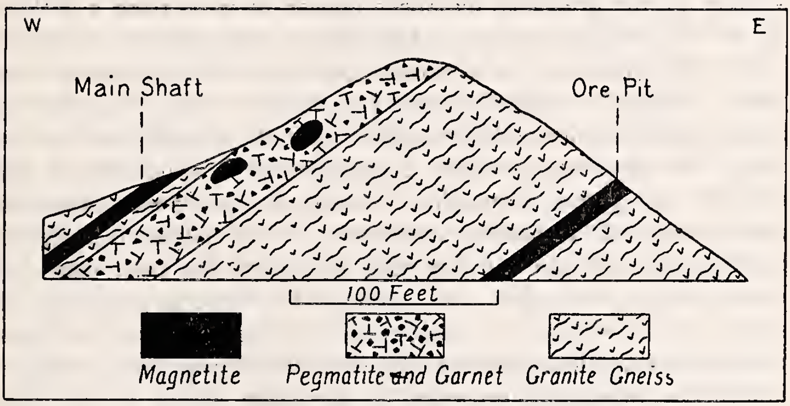


Figure 22 Section through Jayville mine.

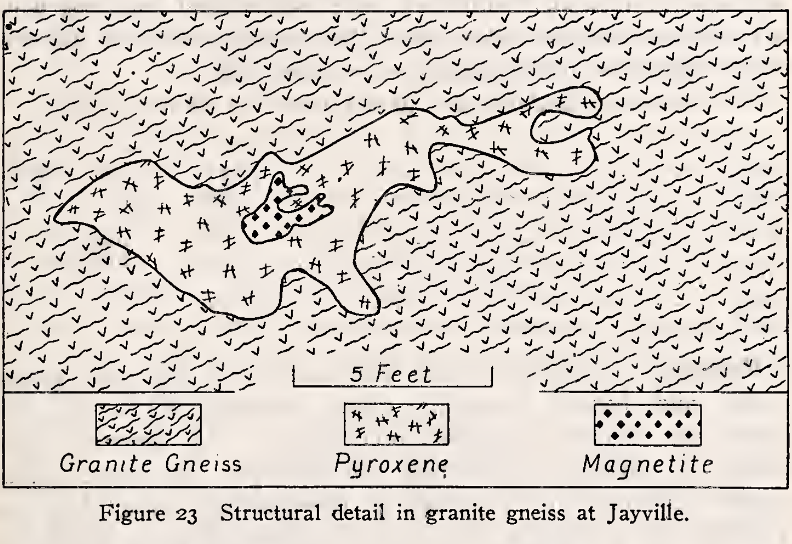


Figure 23 Structural detail in granite gneiss at Jayville.

The Green magnetite prospect. This prospect was investigated and reported upon by Newland in New York State Museum Bulletin 119 ('08). Its location is two miles south of Fine and about a half mile north of School 15 on the east side of the road. The prospect is now indicated by several outcrops and five water-filled pits, one of which is equipped with a small primitive bucket hoist already in decay.

The magnetite here lies between pink granite gneiss and modified Grenville gneiss and consists of both fine and coarse material. The primary foliation of the granite gneiss of the neighboring region strikes about N. 10° E. and dips about 45° W., but in the vicinity of the ore body the rocks appear to vary from a NW. to N. 80° E. trend and to have a high dip of 73° to the west of north. The contact between the Grenville gneiss and the granite is irregular. Within the magnetite there is a distinct change in grain from a fine texture in the center to coarser next the contact with the wall rock. At the contact occurs a considerable development of such minerals as pyrite, serpentine, hornblende, pyroxene, orthoclase, quartz and calcite besides magnetite. Some slight faulting has affected both the ore and the walls and along the fault planes are veins carrying magnetite and calcite. The general nature of the rocks and the mineral associations bring to mind the Jayville deposits and here too it is believed that the ore has originated by aqueo-igneous or pegmatitic processes as late-stage effects of the deep-seated intrusions. Newland ('08, p. 129) states that "the ore deposits are associated with dark pyritic schists and limestone which are doubtless altered sediments." The writer has noted the presence of limestone in the walls of the western pits.

The following analyses are copied from his report (*id.*).

	1	2	3
Fe	71.12	61.46	62.02
SiO_2	.860	.....	6.36
Ti	tr.	nil	.....
S	.005	.025	.03
P	.049	.009	.024
Mn	tr.	.....	.....
CaO	.051	.....	.....
MgO	tr.	.....	.....

Feldspar. Along and near the contact of the pink granite gneiss and banded Grenville gneiss between Fine and Star Lake are many pegmatite occurrences. At several places along the contact, prospecting for feldspar has been undertaken. Just east of the village of Oswegatchie, distant less than a quarter of a mile, is the L. V. Hurlburt property which was worked in 1923 and 1924 with the production of some three carloads of feldspar. The feldspar is reported to have been used for glazing pottery and for the manufacture of scouring soap. Owing to the abundance of pyroxene and the difficulty incurred in separating it cleanly from the feldspar the operations were discontinued. The surface equipment which stands today, although in disrepair, consists of an engine house, trestle, incline, and a 25-foot derrick. The pegmatite zone is from 100 to 150 feet wide measured across the strike which is N. 25°–30° W. At the quarry pit the granite gneiss and the Grenville series are in contact. The pegmatite consists essentially of pink microcline, albite, augite, quartz and scapolite; accessory minerals are pyrite, titanite, pyrrhotite, epidote and amethystine fluorite. The augite and feldspar are in greatest abundance and augite generally dominates at this place. In patches, however, feldspar occurs almost free of admixture with other minerals. In these patches the grain-size averages from one-third to one-half an inch. In other parts of the deposit there are irregular fragments of feldspar and pyroxene which measure more than a foot in diameter and of scapolite only slightly less in size. The coarser pegmatites appear to prevail in the center of the body and the finer at the upper contact.

One of the noticeable features of the occurrence is the rhythmical banding of the green augite, the quartz and the feldspar, simulating stratification.

South of the Hurlburt property the pegmatite zone narrows considerably but outcrops may be found for some distance along the same trend. Near Twin lakes is a body cutting the granite gneiss and made up from west to east of nine feet of pyroxene-quartz-orthoclase pegmatite, followed by a foot or so of orthoclase and quartz and this by two feet of pyroxene with subordinate orthoclase. It would appear that the middle part composed of orthoclase and quartz was a later injection than the rest. Figure 24 shows the relationship of this pegmatitic body with overlying granite gneiss and the underlying pegmatized banded gneisses.

Careful investigation of the area about Oswegatchie village might result in uncovering sizeable bodies of feldspar freer from pyroxene than those described.

South of Scotts bridge on the 1200-foot contour just east of the road there is a sill of microcline and augite pegmatite 12 feet wide occurring between pink granite gneiss and syenite, the pegmatite and the syenite cut by an apophysis of pegmatite which carries augite, quartz and orthoclase. The deposit strikes N. 45° W. and dips moderately to the west. A small amount of feldspar has been taken out. Some disseminated molybdenite flakes occur in the neighboring syenite.

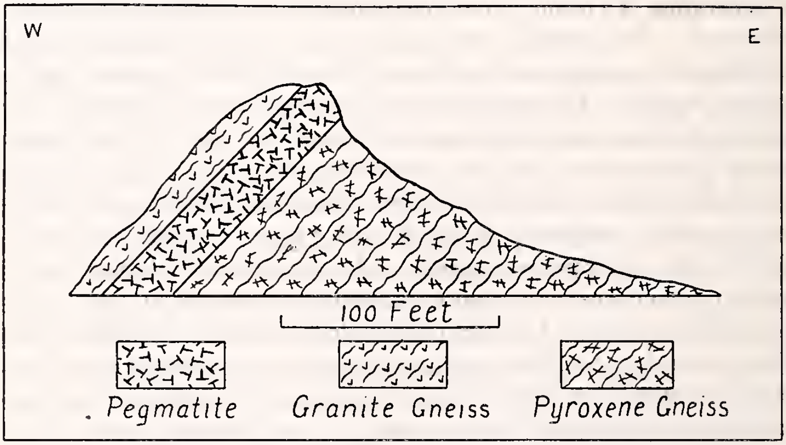


Figure 24 Occurrence of pegmatite near Star Lake.

Pyrrhotite. An abandoned prospect for this mineral is located on Ore Bed hill, a mile south of Red School. The pyrrhotite has for its host a light-colored augite rock and the body intersects hornblende syenite. The outcrop is extremely rusty because of weathering and alteration of the pyrrhotite. The general strike of the body and of the adjacent syenite is about north-south. Not very far away the same pyroxene rock carries mica of the muscovite variety in books measuring five or six inches across and comparatively free from gangue. The strike of the muscovite body is N. 55° W. and the dip is vertical. The general relations of the occurrence are shown in figure 6 on page 25.

Molybdenite. This mineral is found west of Red School as disseminated flakes up to an inch in diameter, usually along minute fissures in a pegmatized pyroxene rock. The latter occupies an area about 225 feet long by 30 feet wide with a general N. 50° W. course. In addition to the pyroxene the rock contains pyrite,—with which molybdenite is usually associated,—muscovite, calcite, serpentine, hornblende, phlogopite, quartz and apatite; an assemblage suggestive of contact metamorphism of limestone.

Building stones. In an area like this made conspicuous by the great dominance of igneous rocks, it seems surprising that no quarrying beyond that necessary for road metal, utilized in the construction of the state road, has been done and yet the granites, syenites and the gneisses would lend themselves to varied employment. Some of the granites have pleasing colors and attractive textural qualities.

Newland ('24, p. 79–89) reports very favorably on the building stone possibilities of the Fine-Pitcairn area between Jayville and Aldrich, which is intersected by the Carthage and Adirondack railroad, a section of approximately eight miles where there are many favorable exposures. In writing of the exposures from west to east he writes:

> The stretch from contact to about milestone 57 on the western border consists of gneissoid granite with a marked parallelism in the arrangement of the light and dark minerals and rather finely granular texture. The ledges between milestones 57 and 60 reveal the granite in thoroughly massive or indistinct gneissoid condition and rather coarse in grain. The color is red, pink or sometimes mottled by the appearance of white feldspar in addition to the colored variety. One phase seen near milestone 59 shows porphyritic red feldspar in white groundmass of feldspar and quartz, specked with black hornblende crystals. . . . The next ledge beyond Jayville consists of the normal red granite which continues to milestone 61 where a white granular gneiss with rusty streaks outcrops for a short distance. On the eastern border between milestone 62 and 64 granite becomes finer in texture, evidently the result of granulation superinduced by pressure metamorphism, but maintains its normal composition and for the most part its massive habit.

For descriptions of the microscopic, chemical and physical characteristics the reader is referred to the text of the above-quoted bulletin.

Limestone. Were it not for the lack of transportation facilities and near-by markets the Grenville limestones in the East Pitcairn district, by reason of their purity and abundant distribution, would have commercial possibilities. The lime kiln on the south shore of Flat Rock reservoir testifies to the economic importance of the Grenville limestone in the past. No use is now made of the carbonate rocks and it is hardly probable they will come into employment in the future, except, perhaps, for the local supply of crushed stone. There are large resources of such rocks, suitable for almost any commercial requirement, in the more accessible districts of St Lawrence and Jefferson counties. Gouverneur, Richville, DeKalb, Natural Bridge and Harrisville may be named as localities which combine both plentiful supplies of similar limestones or dolomites with good shipping facilities and superior conditions for quarry work.

BIBLIOGRAPHY

Adams, F. D. & Barlow, A. E.

1910 Geology of the Haliburton and Bancroft Areas. Geol. Surv. of Canada, Mem. 6: 1–419

Agar, W. M.

1923 Contact Metamorphism in the Western Adirondacks. Proc. Amer. Phil. Soc., 62: 95–174

Alling, H. L.

1918 The Adirondack Graphite Deposits. N. Y. State Mus. Bul., 199: 1–150
1919 Problems of the Adirondack Precambrian. Amer. Jour. Sci. ser. 4, 48: 47–68
1925 Genesis of the Adirondack Magnetites. Econ. Geol., 20: 335–63

Bain, G. W.

1923 Almandite and its Significance in the Contact Zones of the Grenville Limestone. Jour. Geol., 31: 650–68

Balk, R.

1925 Primary Structure of Granite Massives. Bul. Geol. Soc. Amer., 36: 679–96
1930 Structural Survey of the Adirondack Anorthosite. Jour. Geol., 38: 298–302

Bastin, E. S.

1910 Origin of Certain Adirondack Graphite Deposits. Econ. Geol., 5: 134–57

Bowen, N. L.

1917 The Problem of the Anorthosites. Jour. Geol., 25: 309–43
1928 The Evolution of the Igneous Rocks. Princeton Univ. Press. 1–32

Buddington, A. F.

1917 Report on the Pyrite and Pyrrhotite Veins in Jefferson and St Lawrence Counties, N. Y. N. Y. State Defense Council Bul., 1: 1–40
1919 Foliation of the Gneissoid Syenite-Granite Complex of Lewis County, N. Y. N. Y. State Mus. Bul., 207–8: 101–10
1929 Granite Phacoliths and Their Contact Zones in the Northwest Adirondacks. N. Y. State Mus. Bul., 281: 1–107
1931 The Adirondack Magmatic Stem. Jour. Geol., 39: 241–63

Cushing, H. P.

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
1915 Age of the Igneous Rocks of the Adirondack Region. Amer. Jour. Sci., ser. 4, 39: 288–94
1916 Geology of the Vicinity of Ogdensburg, N. Y. N. Y. State Mus. Bul., 191: 64

Cushing, H. P., Fairchild, H. L., Ruedemann, R., & Smyth, C. H. jr

1910 Geology of the Thousand Islands Region. N. Y. State Mus. Bul., 145: 1–194

Cushing, H. P. & Newland, D. H.

1925 Geology of the Gouverneur Quadrangle. N. Y. State Mus. Bul., 259: 1–122

Daly, R. A.

1917 Metamorphism and its Phases. Bul. Geol. Soc. Amer., 28: 375–418

Fairchild, H. L.

1918 Pleistocene Marine Submergence of the Hudson, Champlain, and St Lawrence Valleys. N. Y. State Mus. Bul., 209–10: 1–76

Fenner, C. N.

1914 Mode of Formation of Certain Gneisses in the Highlands of New Jersey. Jour. Geol., 22: 594–612, 694–702

Foye, W. G.

1916 Are the "Batholiths" of the Haliburton-Bancroft Area Correctly Named? Jour. Geol., 24: 783–91

Grout, F. F.

1918 Internal Structures of Igneous Rocks etc. Jour. Geol., 26: 439–58

Harker, A.

1909 The Natural History of Igneous Rocks. New York, 384p.

Kemp, J. F.

1921 Geology of the Mount Marcy Quadrangle, Essex County, N. Y. N. Y. State Mus. Bul., 229–30: 1–86

Kemp, J. F. & Alling, H. L.

1921 Geology of the Ausable Quadrangle. N. Y. State Mus. Bul., 261: 1–126

Löwl, F.

1906 Geologie. Leipzig und Wien. 1–332

Martin, J. C.

1916 The Precambrian Rocks of the Canton Quadrangle. N. Y. State Mus. Bul., 185: 1–112

Miller, W. J.

1910 Geology of the Port Leyden Quadrangle, Lewis County, N. Y. N. Y. State Mus. Bul., 135: 1–62

1914 Geology of the North Creek Quadrangle, Warren County, N. Y. N. Y. State Mus. Bul., 170: 1–90

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

1917 Geology of the Blue Mountain Quadrangle. N. Y. State Mus. Bul., 192: 1–68

1924 The Geological History of New York State. N. Y. State Mus. Bul., 255: 1–148

Newland, D. H.

1916 The Quarry Materials of New York. Granite, Gneiss, Trap and Marble. N. Y. State Mus. Bul., 181: 1–212

Newland, D. H. & Kemp, J. F.

1908 Geology of the Adirondack Magnetic Iron Ores—with a Report on the Mineville-Port Henry Mine Group by J. F. Kemp. N. Y. State Mus. Bul., 119: 1–182

Quirke, T. T. & Collins, W. H.

1930 Disappearance of the Huronian. Can. Dep't Mines, Geol. Surv. Mem. 160: 1–129

Shand, S. J.

1927 Eruptive Rocks. New York. 1–360

Shaub, A.

1929 A Unique Feldspar Deposit near DeKalb Junction, N. Y. Econ. Geol. 24, 1:68–89

Smyth, C. H. jr

1899 Crystalline Rocks of the Western Adirondack Region. N. Y. State Mus. Rep't 51, 2: 469–97

1918 Genesis of the Zinc Ores of the Edwards District, St Lawrence County, N. Y. N. Y. State Mus. Bul., 201: 1–41

Smyth, C. H. jr, & Buddington, A. F.

1926 Geology of the Lake Bonaparte Quadrangle. N. Y. State Mus. Bul., 269: 1–166

von Engeln, O. D.

1930 Private Communication

Wilson, M. E.

1918 Temiskaming County, Quebec. Can. Geol. Surv., Mem. 103: 1–197

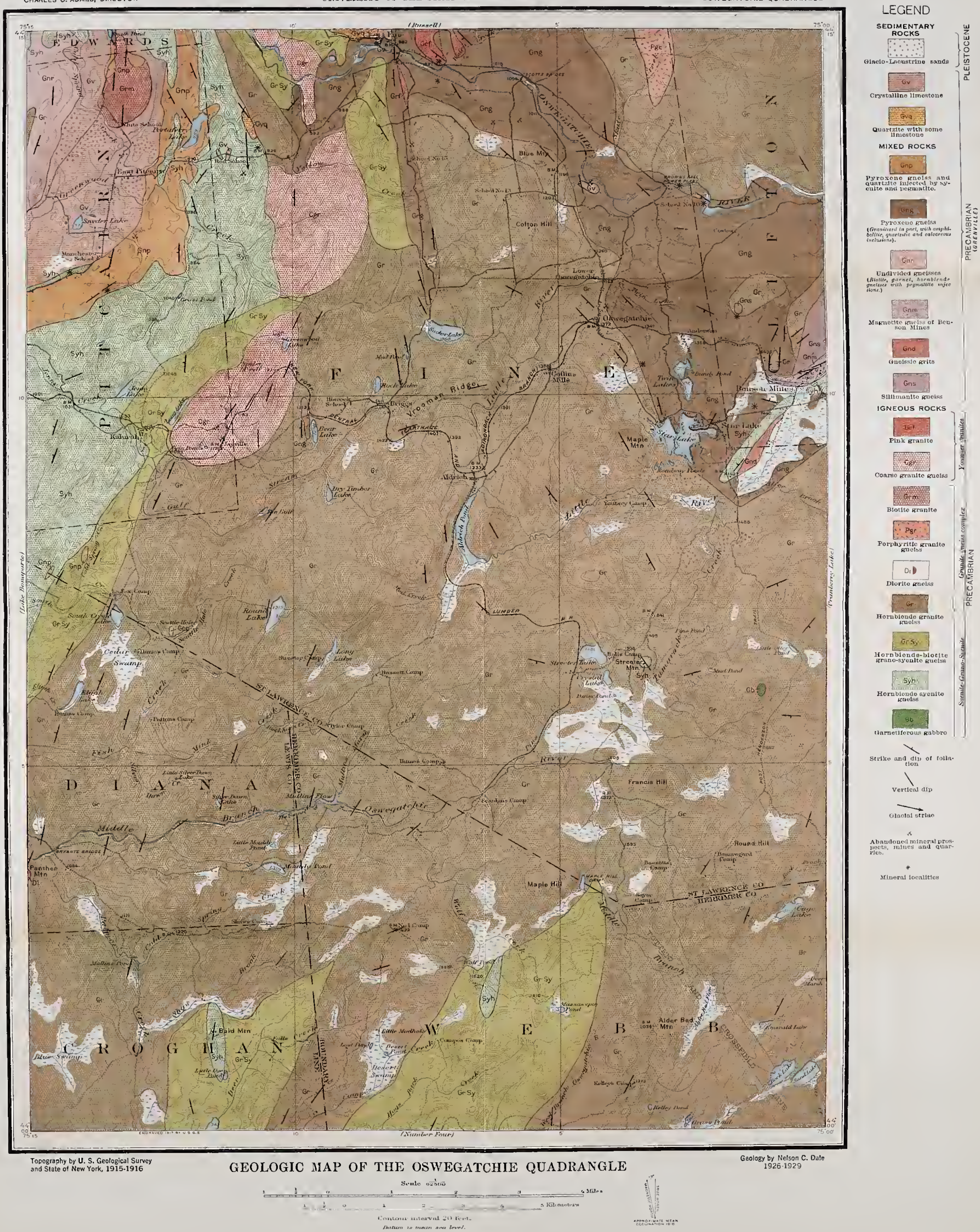
1925 The Grenville Precambrian Sub-province. Jour. Geol., 33: 389–407

Wright, J. F.

1923 Brockville-Mallorytown Map Area. Can. Geol. Surv., Mem. 134: 1–63

INDEX

Geologic Map of the Oswegatchie Quadrangle



Topography by U. S. Geological Survey
and State of New York, 1915-1916

GEOLOGIC MAP OF THE OSWEGATCHIE QUADRANGLE

Geology by Nelson C. Dale
1926-1929