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July 1937

NEW YORK STATE MUSEUM

CHARLES C. ADAMS, *Director*

GEOLOGY OF THE PISECO LAKE QUADRANGLE

BY RALPH SMYSER CANNON JR Ph.D.

Conducted in cooperation with the Department of Geology,
Princeton University

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GEOLOGY OF THE PISECO LAKE QUADRANGLE

BY RALPH SMYSER CANNON JR Ph.D.

INTRODUCTION

LOCATION

The Piseco Lake quadrangle lies within the Adirondack region and close to its southwestern border (figure 1). It includes an area of 217 square miles lying between $43^{\circ} 15'$ and $43^{\circ} 30'$ north latitude and $74^{\circ} 30'$ and $74^{\circ} 45'$ west longitude. Much of the quadrangle is within the borders of Hamilton county; only a few square miles in the southwest corner belong to Herkimer and Fulton counties.

RELIEF

The topography shows much local diversity. In general, the lowlands occupied by the major streams and lakes are separated by much broader highland areas dissected into hills and ridges with imperfectly accordant summits. Although the region is rugged, the relief is not extreme. In few places is the local relief greater than 1000 feet; maximum relief for the entire quadrangle attains 1700 feet. The highest peak, one mile north of the north arm of T lake (n.e.r.)¹, rises to an altitude of 3110 feet. The lowest point lies south of Oregon (s.c.r.)² where East Canada creek leaves the quadrangle at 1420 feet.

DRAINAGE

Although the topographic map shows the quadrangle to have a centrifugal plan of drainage, nevertheless all streams are tributary to the Mohawk-Hudson drainage system. The east third of the quadrangle is drained by the West Branch of Sacandaga river, which flows eastward to join the Hudson at Luzerne. A small area near the north boundary is drained northeastward by Jessup river through Indian lake and Indian river to join the Hudson where it turns sharply eastward in Newcomb quadrangle. West Canada creek drains the northern and western parts of the quadrangle westward and then flows southward to join the Mohawk. The south central drainage is southward by way of East Canada creek, which also discharges into the Mohawk.

¹ The abbreviation *n.e.r.* refers to the northeast 5' rectangle.

² South central rectangle.

CULTURE

Roads and habitation are confined to the major valleys, and the intervening mountainous areas are heavily forested. Much of the quadrangle is made accessible by three main roads. The highway from Utica to Speculator crosses the center of the area from west to east along the Hoffmeister-Piseco Lake lowland. The Gloversville highway follows the Sacandaga-Piseco Lake lowland from Arietta northward to Rudeston. And the Powley Place road joins the Gloversville highway at Piseco outlet after following East Canada creek northeastward from Stratford. There are also several shorter automobile roads and numerous trails and tote roads.

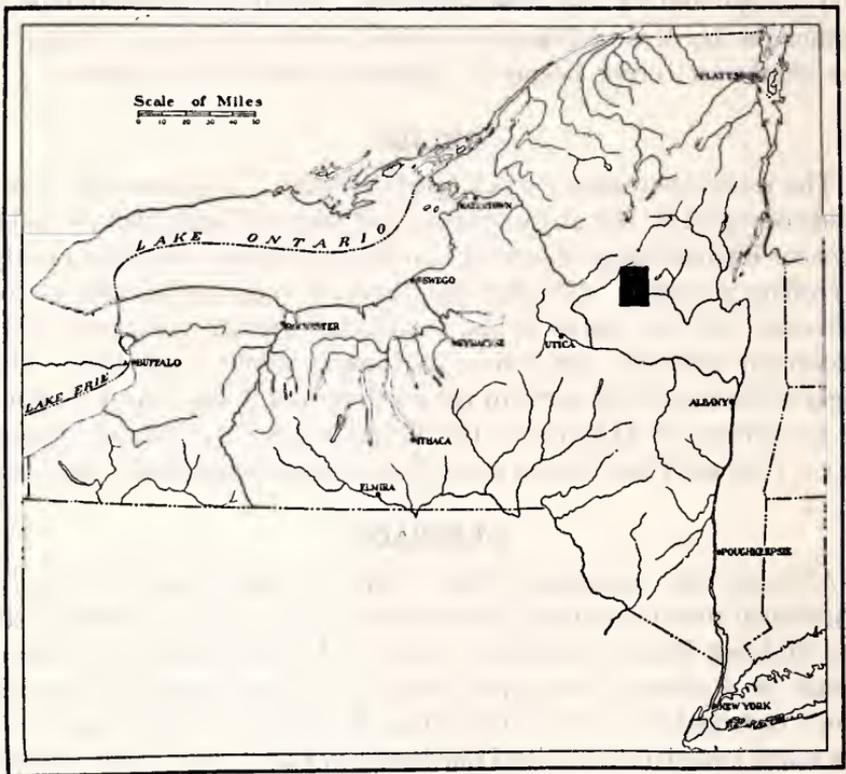


Figure 1 Outline map of New York State showing approximate location of Piseco Lake quadrangle

Population is sparse and the inhabitants are nearly all included in the small villages of Piseco, Hoffmeister, Rudeston and East Piseco (Spy Lake). The livelihood of the inhabitants is largely dependent upon the trade afforded by tourists, summer residents and sportsmen. Farming, hunting and trapping and a sporadic lumbering industry are the other chief means of self-support.

PURPOSE OF THE INVESTIGATION

This study was undertaken for the purpose of making a detailed survey of an area in the Adirondacks by use of modern methods of structural petrology in connection with a thorough study of the petrology. Many quadrangles in the Adirondacks have been mapped and studied according to the established methods of petrology and petrography. Also, structural studies have been made in the north-west Adirondacks by Buddington, Cushing, Dale, Martin, Newland and Reed. Balk has studied in detail the structure of the Newcomb quadrangle and the structure of the Adirondack anorthosite using the methods of Cloos. But the structural problems of the remainder of the Adirondacks have received only scant attention. Obviously more data of this character are necessary. It was hoped that by close correlation of the old and the new methods of approach some progress could be made in the task of unraveling the complex geologic history of the Adirondacks. The Piseco dome was chosen for study because it represents a structural type rather characteristic of the Adirondack Precambrian. Detailed work was confined to the vicinity of the dome from about $43^{\circ} 20'$ north latitude to the latitude of Metcalf and T lakes. The south third of the quadrangle and the part north of Metcalf and T lakes received less careful attention. The field work was done during the summer field seasons of 1933 and 1934. Laboratory studies and preparation of the report were carried on in the Department of Geology of Princeton University.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the constant aid and counsel of Professor A. F. Buddington, whose experience and familiarity with Adirondack geology have proved an invaluable guide throughout the investigation. The writer wishes to express his gratitude to Dr Rudolf Ruedemann for identifying the fossils and fauna of the limestone of the Piseco Lake outlier of Paleozoic rocks. Thanks are expressed to Dr H. H. Hess, who accompanied the writer for several days in the field and who cooperated in the laboratory in making mineralogic determinations. The investigation was made possible by the generous financial support of the Department of Geology of Princeton University.

SUMMARY OF GEOLOGY

The Piseco Lake quadrangle is underlain almost exclusively by rocks of Precambrian age, although these are hidden in many places by a thin veil of later deposits. The oldest of the Precambrian rocks

are the Grenville series, originally sedimentary rocks deposited on the floor of an ancient sea. Beds of limestone, dolomite, sandstone, arkose and shale were deposited in this region. The nature of the floor on which these sediments were laid down is not known, as it has not been found exposed at the earth's surface. The Grenville rocks have been invaded repeatedly by molten magma, whose solidification has yielded a variety of igneous rocks. The oldest of these are a series of feldspathic and mafic rocks including anorthosite, hypersthene gabbro and olivine norite. The solidification of subsequently intruded magmas of different compositions has yielded successively quartz syenite, granite and diabase.

The pregranite magmas forced their way into the sediments principally along bedding planes to form generally concordant tabular bodies, called sills or sheets. The intrusion of granite magma accompanied a period of mountain building, when lateral stresses in the local portion of the earth's crust were compressing the Grenville sediments and the previously solidified sills of igneous rocks into anticlinal and synclinal folds. In large part the granite magma was also intruded concordantly, following bedding planes in the sediments and the contact surfaces of the older sills. Concomitant folding, however, induced a notable thickening of granite sills along the crests of anticlines into saddle-shaped bodies known as phacoliths. In some places or at certain horizons the quartz syenite and granite magmas were intruded in numerous small sills and stringers intimately permeating, disintegrating and reacting with great thicknesses of sediments. Relations of this sort are exhibited throughout a large part of the Grenville and mixed gneiss belts which cross the quadrangle north and south of the Piseco dome. Elsewhere, as in the vicinity of the dome, the magmas were intruded in relatively thick masses largely to the exclusion of sedimentary material. At a much later date in the history of the quadrangle, diabase magma was intruded as small dikes filling fissures in the older rocks.

The original sedimentary character of the Grenville series has been obscured by metamorphism of the sediments to crystalline gneisses. Sandstones have been changed to quartzite; argillaceous sandstone and arkose to garnet gneiss; calcareous rocks to amphibolite; and beds of dolomite to diopside rocks. The recrystallization of the sediments was accomplished by their deformation during the period of mountain building with the cooperation of heat and magmatic solutions given off by magma which had forced its way intimately between the sedimentary beds. During the process of recrystallization magmatic solutions probably effected changes in the composition

of the sedimentary layers by additions and subtractions of material.

Tangential stresses in the earth's crust, acting locally in a north-south direction, compressed the Grenville sediments and the consolidated igneous rocks into folds with an east-west trend and raised ranges of mountains trending across the site of the modern southern Adirondacks. In the Piseco Lake quadrangle this folding, in conjunction with the phacolithic intrusion of granite magma, formed the broad anticlinal dome which lies west of Piseco lake and north of the Hoffmeister valley. As now exposed at the earth's surface, the central part of the dome consists of a complex of igneous rocks with relatively little Grenville material. In general, the north and south flanks of the dome dip away toward broad synclines or synclinoria of Grenville and mixed rocks thrown into minor folds by the same stresses. As these stresses continued to operate after the intrusive bodies of granite magma had crystallized, they deformed all of the Precambrian rocks except for some dikes of granite pegmatite and the younger diabase. Granulation and recrystallization of the constituent minerals of the rocks during deformation gave rise to the foliation and linear structures which they all possess in greater or less degree. Later, when the rocks had cooled and were capable of yielding to stress by fracture, systems of joints were developed by the diminishing forces. At an unknown date before the intrusion of diabase in late Precambrian time, faulting movements occurred along planes parallel to at least one set of these joints. Subsequently, dikes of diabase were intruded along preexisting faults and joints.

The mountains which were formed in this region during Precambrian time were attacked by erosion and were eventually worn down to a relatively smooth and level surface, the pre-Potsdam peneplain. The development of this peneplain continued until late Cambrian or Ordovician time, when the area was again submerged beneath the sea and beds of sandstone and limestone were deposited on the surface of the pre-Potsdam peneplain. Subsequent uplift of the area was probably the occasion of renewed faulting, which displaced both the Precambrian rocks and their thin cover of Paleozoic sediments. As the area emerged from beneath the sea, it was again exposed to erosion, and the thin layer of Paleozoic sediments was slowly removed. The processes of erosion also attacked the Precambrian rocks wherever they were exposed; but the erosion of the resistant crystalline rocks progressed much more slowly than erosion of the sediments. Eventually the Paleozoic sediments were completely stripped off this area, except for a block which was faulted down most deeply and still remains beneath the site of Piseco lake.

Removal of this cover exposed great fault blocks of Precambrian rocks separated from one another by steep scarps. The dislocated fragments of the pre-Potsdam peneplain were preserved as the gently sloping upper surfaces of the blocks. Slowly the topography became adjusted to the character of the Precambrian rocks. The locations of major streams were determined largely by the slope of the pre-Potsdam surface and by zones of weakness along major faults. In addition, shear zones, joints, gneissic structures and the relative resistance of adjacent rocks have had important modifying effects in the development of the present topography.

In the Ice Age, or Pleistocene period, the climate grew cold and continental ice sheets advanced across the area from the north. The movement of the ice eroded the rocks and modified the topography only to a small extent. On withdrawal the glaciers left behind an irregular mantle of *débris* or glacial drift. Deposits of glacial drift are spread over a large part of the area and conceal the bedrock. Thick deposits of drift in the lowlands and major valleys have altered the preglacial drainage and have dammed many streams to form lakes and ponds.

IGNEOUS ROCKS

ANORTHOSITE, HYPERSTHENE GABBRO AND OLIVINE NORITE

At the eastern boundary of the quadrangle in the vicinity of Mud Lake mountain there is an area of rocks in which olivine norite and anorthosite are closely associated with hypersthene gabbro. These rocks occur in such a manner that the succession from the base upward is olivine norite, hypersthene gabbro and anorthosite. The hypersthene gabbro and olivine norite appear to be related as facies of a gravity stratified sheet. The mafic rocks may be intrusive into the anorthosite. The complex has been folded in the Big Bay syncline which pitches 5° to 15° toward the east. To the westward up the pitch of the syncline these rocks have been completely removed by erosion. In the opposite direction they continue for an unknown distance across the Lake Pleasant quadrangle. Although they have been traced toward the east for only one-fourth of a mile beyond the edge of the quadrangle, their continuation is almost certainly indicated by the gabbro and basic syenite areas mapped by Miller ('16, geologic map) along the West Branch of the Sacandaga river.

Anorthosite. Comparatively uniform anorthosite forms the crest of Mud Lake mountain and the knob to the northeast. A short distance west of the latter is a third area, too small to show on the map,



Figure 2 View eastward along Piseco outlet toward Mud Lake mountain, the highest peak. The axis of the Big Bay syncline extends from the position of the observer through Mud Lake mountain, which with the neighboring hills forms a synclinal mountain mass. The two sharp peaks covered with dark evergreen vegetation are anorthosite. The gentler slopes covered with deciduous forest are underlain by quartz syenite and gabbro inter-banded with anorthosite.



Figure 3 Cliff of granite containing sheetlike inclusions of amphibolite on east valley wall of the South Branch of West Canada creek, one and one-half miles southwest of T Lake falls. The amphibolite can be seen as the dark, deeply weathered bands dipping to the left. The linear structure strikes southeast directly away from the observer. The photograph shows a set of nearly vertical joints parallel to the linear structure, and a set of cross joints normal to the linear structure.

capping a small ridge. Each of these anorthosite masses has a synclinal structure. The largest mass at the crest of Mud Lake mountain lies on the major axis of the Big Bay syncline, whereas the two smaller masses to the northeast have been folded down in a subsidiary syncline. In the field these anorthosite areas are sharply set off from the underlying rocks by their abrupt slopes and by differences in vegetation (figure 2). The upper contact of the sheet and the roof rock is not exposed in the Piseco Lake quadrangle but should be found farther east.

Anorthosite of quite similar character occurs interbanded with hypersthene gabbro on the lower slopes of Mud Lake mountain. The vertical continuity of the mass is interrupted by several sills of quartz syenite which have been intruded along gabbro layers.

The anorthosite resembles closely the Whiteface facies of the great anorthosite body of the central Adirondacks. It is a medium to coarse-grained rock, grayish green when fresh and weathering superficially to a gray coat. Because of the paucity of mafic minerals, the foliation and linear structure of the rock are indistinct, even though in many places the plagioclase has been almost completely granulated and rolled out into elongate and flattened lenses. In some outcrops the foliation is made distinct by strings of garnet grains and by flattened plagioclase crystals from an inch to three inches long which lie in the plane of the foliation.

Calcic andesine ($Ab_{55}An_{45}$) is by far the predominant mineral. Some of the plagioclase grains contain a few spindles of potash feldspar in antiperthitic intergrowth. Also the cores of some of the larger grains contain many dark rods and plates of ilmenite and (or) rutile. The mafic minerals are green hornblende and augite, with a little hypersthene. Garnet is also moderately abundant, although it is irregularly distributed and was not seen in thin section. Accessory minerals are ilmenite, titanite and apatite. In areas of intense granulation the original minerals have generally suffered hydrothermal alteration to chlorite, epidote, zoisite, carbonates, sericite, rutile and titanite.

The microstructure of the anorthosite is somewhat variable. In some cases there has been complete granulation and recrystallization of the plagioclase to a rather uniform mosaic with an average grain of 1 mm. In other cases there has been only slight intergranular granulation resulting in an irregular structure of large plagioclase relics with only a small amount of interstitial recrystallized plagioclase. The large relics are usually strained and contain the dark inclusions mentioned above. On the other hand, the recrystallized

plagioclase is generally unstrained and contains no dark inclusions, but grains of ilmenite do occur interstitial to the plagioclase.

This body of anorthosite is of extreme interest from several points of view. It is an additional example of the occurrence of anorthosite in the Adirondacks in small masses far removed from the main anorthosite mass; and moreover it is the farthest southwest of any such occurrence yet reported. It affords a concrete example of the occurrence of Adirondack anorthosite in a floored sheetlike body. A detailed study of the mass and its continuation toward the east would undoubtedly be rewarded by significant structural and petrologic information.

Hypersthene gabbro. The hypersthene gabbro at the Mud Lake mountain locality is the only gabbroic rock in the quadrangle for which an igneous origin is certainly established.

On the lower slope of Mud Lake mountain hypersthene gabbro is interbanded with anorthosite on a coarse scale in bands 50 to 200 feet thick. Structural details have been obscured by the intrusion of quartz syenite sills along the gabbroic layers. Foliation and linear structure are both well developed, and adjacent to the quartz syenite sills the rock has been mashed to amphibolite. The foliation and linear structure lie parallel to similar structures in all adjacent rocks, and likewise are parallel to the gabbro-anorthosite banding and to the quartz syenite sills.

Plagioclase ($Ab_{53}An_{47}$) is the predominant mineral, forming between 50 and 75 per cent of the rock. The remainder of the rock consists largely of hypersthene, augite and green hornblende more or less equally abundant. Ilmenite or magnetite is always present, and in some specimens is a prominent constituent. Garnet is seen commonly in the field. Other accessory minerals include biotite, apatite, and rarely, zircon.

The thin sections examined show complete recrystallization of the plagioclase. The mineral grains are usually of polygonal shape and form an irregular mosaic structure. The average grain size is about 1 mm.

North of Mud lake two gabbroic layers 50 to 100 feet thick were seen interbanded with olivine norite. The rock in these bands is also a hypersthene gabbro, or more strictly norite, as the pyroxene is preponderantly hypersthene. In the single specimen examined microscopically the plagioclase had the composition $Ab_{48}An_{52}$. Apparently the rock contains no garnet. In all other respects this rock resembles the hypersthene gabbro associated with the anorthosite.

Olivine norite. Coarse-grained greenish black olivine norite outcrops in the area between Mud lake and Spy lake. The rock is interbanded with several layers of hypersthene gabbro or norite as noted above. The outcrops are characteristically strewn with great boulders of the olivine norite, ranging in size from a few feet to more than 20 feet. No other outcrops of this rock are known, but large erratic boulders were seen at several places to the southwest.

Foliation, although indistinct, can be seen on weathered surfaces and seems to conform to the regional structure. Although the outcrops are probably separated from the main mass of gabbro and anorthosite by a fault of small throw, the olivine norite is thought to represent the basal part of the Mud Lake Mountain sill. To the north the olivine norite is underlain by fine-grained green granite, which was presumably intruded along the base of the sill, although the contact is nowhere exposed.

Plagioclase is present in the olivine norite to the extent of only about 30 per cent. The plagioclase was determined as andesine ($Ab_{63}An_{37}$). The surprisingly low anorthite content of the plagioclase may be due to some type of alteration. Pyroxene and olivine together constitute perhaps 50 per cent of the rock. Of the pyroxenes, hypersthene is much more abundant than augite. The olivine is rather fresh, generally showing only segregations of magnetite specks along cracks; a few grains are very slightly serpentinized. Rather abundant pale brown hornblende and reddish brown biotite are probably secondary minerals formed during metamorphism. The only additional accessory minerals are magnetite and a green spinel (hercynite?). Garnet was not seen either in thin section or in the field.

Although the microstructure and relations of the minerals as seen in thin section have not been satisfactorily interpreted, some of the facts will be presented. Poikilitic or poikiloblastic textures characterize many of the minerals. Strained plagioclase relics with a maximum size of 1 cm generally have cores dusty with tiny grains of green spinel. Their borders are invariably intergrown with larger grains of green spinel, olivine or pyroxene. The olivine or pyroxene grains of such intergrowths may have a common orientation throughout certain areas. In some cases a zone of clear plagioclase intervenes between the dusty core and the marginal intergrowths. Green spinel occurs also as vermicular growths inclosed in grains of pale brown hornblende. Grains of olivine are commonly inclosed within a single grain of pyroxene. Commonly the olivine is encircled by a narrow rim of hypersthene, which is followed outward by pale

Approximations of variation in mineral constitution of the various rocks of the Mud Lake Mountain sill

	Compo- sition of plagio- clase	Per cent of plagio- clase	Per cent of mafic minerals	Augite- hyper- sthene ratio	Olivine	Horn- blende	Biotite	Garnet	Green spinel	Ilmenite and Magnetite
Anorthosite	Ab ₈₆ An ₁₄	90	10	Au ₉₀ Hy ₁₀		Green		Accessory		Accessory
Hyperssthene gabbro	Ab ₅₃ An ₄₇	65	35	Au ₄₆ Hy ₅₄		Green	Accessory	Accessory		Important in some layers
Norite	Ab ₄₈ An ₅₂	65	35	Au ₉₅ Hy ₇₆		Greenish brown				Accessory
Olivine norite	Ab ₉₃ An ₇	30	70	Au ₂₀ Hy ₈₀	15	Brown	Important accessory		Important accessory	Accessory

brown hornblende that has replaced the hypersthene. Flakes of biotite common in pyroxene and plagioclase are clearly secondary. It is difficult to determine which of these relations are phenomena of the primary crystallization of the rock, and to distinguish them from relations due to subsequent deformation. The existence of a large proportion of the plagioclase as large strained relics indicates, however, that the olivine gabbro has been less deformed, or at least less recrystallized, than the hypersthene gabbro and much of the anorthosite.

METAGABBRO

Gabbroic rocks at several localities other than Mud Lake mountain are probably metamorphosed eruptive rocks. The fact that these rocks are now found only as inclusions in granite and quartz syenite precludes any possibility of proving them intrusive into Grenville sediments, but their homogeneous nature is suggestive of igneous origin.

A paper by Smyth ('94) "On gabbros in the southwestern Adirondack region" describes in detail a fine-grained dark rock forming tabular masses in granite between Wilmurt Lake (n.w.r.) and Morehouseville (Wilmurt quadrangle). This rock is excellently exposed in many ledges on the north side of the Mountain House road along the South Branch of West Canada creek for about a mile west of the Wilmurt Lake road. Perhaps a dozen tabular masses of the dark rock may be seen here with sharp contacts against the country rock of Wilmurt Lake granite. These are interpreted by Smyth as sheets and dikes of gabbro intrusive into the granite ("gneiss").

The rock of these outcrops varies in color from gray to dark bluish gray or black. Weathering is only superficial and produces a dark gray or brown coat. Labradorite with a composition $Ab_{43} An_{57}$ generally forms about half of the rock. Hypersthene and augite are about equally abundant, and the total pyroxene exceeds brown hornblende in amount. The only other constituents are ilmenite and magnetite and sparse biotite, garnet, and apatite. The rock is fine-grained with a granoblastic structure. The mineralogy is described in much greater detail by Smyth ('94, p. 57-60).

A chemical analysis of the rock made by Smyth ('94, p. 61) is given below, together with determinations of TiO_2 and P_2O_5 by R. B. Ellestad. Presumably the analyzed material was taken from the central part of one of the metagabbro bodies.

Chemical analysis and calculated norm of Mountain House metagabbro

<i>Analysis</i>		<i>Norm</i>	
SiO ₂	46.85	Orthoclase	0.56
Al ₂ O ₃	16.34	Albite	18.34
Fe ₂ O ₃	6.16	Anorthite	34.47
FeO	8.76	Diopside	12.20
MgO	8.43	Hypersthene	21.09
CaO	10.17	Olivine	1.82
Na ₂ O	2.19	Apatite	0.27
K ₂ O	0.09	Magnetite	9.00
H ₂ O	0.30	Ilmenite	2.97
TiO ₂	1.54		
P ₂ O ₅	0.12		
	100.95		
Sp. gr.....	3.097		

Analysts: C. H. Smyth jr and R. B. Ellestad

The sheetlike masses of metagabbro range in thickness from two to 25 feet; most of them are four or five feet thick. They have an average strike of about N.45° W. and a dip of about 20° to the southwest. So far as determinable, the contacts conform to the foliation of the adjacent granite, which is extremely weak at this locality. Foliation in the metagabbro also appears to lie parallel to the contacts in the few places where it can be detected. A strong linear structure in the granite pitches 11° to 18° in a direction S.68°W. parallel to the contacts and parallel also to a weak linear structure in the metagabbro. The sheets of metagabbro undulate in broad shallow folds which pitch toward the west-southwest parallel to the linear structure. In addition, the exposed upper surface of one sheet shows flat troughs or flutings about one inch deep and two to five inches wide, with an average spacing of two or three feet, which pitch in the same direction.

The same systems of joints are present in both metagabbro and granite. There are four main sets of steeply dipping joints, all of which bear definite relations to the linear structure. Because of the flat attitude of the foliation, it is uncertain whether the orientation of these joints is essentially vertical or essentially normal to the foliation. The joints of one system strike parallel and at right angles to the linear structure. There is also a system of diagonal joints which strike at angles of nearly 45° from the linear structure. These systems are developed unequally in the two types of rocks; in general the diagonal joints are developed best in the granite, the other system best in metagabbro. Joints are spaced less closely in the granite than in the metagabbro. These facts point to the conclusion that

the joints in the two rocks were produced by the same forces, probably, a continuation of the forces which produced the linear structure and the shallow folds in the metagabbro sheets.

Vane sheets¹ of quartzose lenticular granite with a maximum thickness of several inches cut the metagabbro at several places and are fairly common in the granite. The dominant set of vane sheets strikes about east-west and dips 35° to the south. A minor set which dips more gently toward the northwest was seen only in the granite. The vane sheets which cut diagonally across the sheets of metagabbro were apparently interpreted by Smyth (p. 55) as slabs of granite country rock, split off and included during the act of intrusion of the gabbro magma. They are, however, certainly intrusive vane sheets of granitic material with the same habit of occurrence as is common throughout a large part of the quadrangle. One such vane sheet was observed which widens out into an irregular knot near which the linear structure of the adjoining metagabbro curves irregularly. At another locality on the east shore of Piseco lake, two vane sheets in similar metagabbro cross one another at right angles. The metagabbro sheets at the Mountain House locality are also cut by dikes of granite pegmatite from one-fourth of an inch to five inches wide oriented at right angles to the linear structure.

In the field one sees apparent fine-grained borders on the metagabbro sheets. These would normally be interpreted as chilled borders indicating intrusion of the gabbro into older granite. Six sheets which were examined from this point of view all show fine-grained borders against both the upper and lower contacts. For example, one sheet three feet thick shows a six-inch zone at the top and a four-inch zone at the bottom. Microscopic comparison of thin sections of specimens taken from the center and the border of this same sheet shows that the apparent differences in grain size are due merely to differences in microstructure. In the border facies, grains of feldspar and the mafic minerals are distributed with almost geometrical regularity. The central portion of the sheet is composed of grains of essentially the same size, but grains of mafic minerals are more or less aggregated into clusters which give the megascopic illusion of coarser grain.

¹ The term "vane sheets" is used in this report to designate sheets of intrusive material whose attitude is parallel to the linear structure of the country rock, but not necessarily concordant to the foliation, in analogy with a weather vane which rotates around an axis. Compare p. 57.

A large thin section cut from the contact of one of the metagabbro sheets shows many interesting features. The granite for a distance of 1 cm from the contact reveals no variation referable to the contact. The granite contains, however, grains of altered pyroxene and rather calcic plagioclase, apparently xenocrysts derived from the nearby metagabbro. In addition, myrmekite is an important constituent, present in much greater quantity than in specimens of the adjacent granite. The contact is remarkably straight and sharp. The metagabbro is minutely banded in a narrow zone parallel to the contact.

One other feature of this locality deserves mention. The granite contains locally, in addition to the sheets of metagabbro, irregular masses and remnants of gray to brown material generally strongly injected and granitized. The sheet of metagabbro which outcrops farthest west at this locality is in sharp contact with such material, which is interpreted as Grenville country rock into which gabbro was intruded as sheets. This was the first event in the supposed history of the metagabbro. The next event was the intrusion of granite magma, disintegrating much of the Grenville material but producing only slight contact effects on the compact gabbro. Folding of the sheets to conform to the nose of Piseco dome and the deformation of granite and gabbro which produced their gneissic structures were probably contemporaneous in a broad sense with the intrusion and crystallization of the granite magma. At a late stage in the crystallization abundant myrmekite was formed in the granite adjacent to the metagabbro sheets, the metagabbro was injected by cross-cutting vane sheets of quartzose granite, and at a still later stage by dikes of pegmatite. Deformation continued throughout these events, so that gneissic structures were produced in all of the rocks. There is some question whether the mechanical deformation has not produced, or at least helped to produce, some of the mineralogic variations observed adjacent to the contacts between granite and metagabbro.

Fine-grained metagabbro or amphibolite occurs at many places in the quadrangle; but without making a special study of the problem, it is difficult to decide how much of it is similar to the Mountain House metagabbro. Possibly some of the inclusions in the Piseco dome granite have had a similar history. Several sheets of fine-grained metagabbro which are exposed on the east shore of Piseco lake at about $43^{\circ} 20'$ north latitude, included in the Spy Lake granite, are believed to correspond to the Mountain House rock. Several slight differences are noted. Garnet is here a more abundant con-

stituent. Also, the attitude of one sheet well exposed along the shore is discordant to ghostlike bands of disintegrated Grenville in the granite, thus suggesting that the gabbro was originally intruded discordantly into Grenville sediments. This zone of metagabbro sheets in the granite continues toward the east where many of the hilltops of the Spy Lake granite area are capped by similar metagabbro sheets. The credibility of a correlation of this rock with the Mountain House metagabbro is strengthened by the fact that the Spy Lake granite and its included sheets of metagabbro occupy a position on Piseco dome symmetrical with respect to the Wilmurt Lake granite and the Mountain House metagabbro.

A rock rather similar to the Mud Lake Mountain hypersthene gabbro outcrops on the west slope of Stacy mountain (n.e.r.) 0.7 mile west of Piseco mountain. Its relations to adjacent quartz syenite could not be precisely determined, although it seems to conform to the foliation of the latter. This metagabbro is homogeneous, medium to coarse-grained with barely discernible gneissic structure. A thin section shows a mosaic of grains of hypersthene, augite and calcic andesine ($Ab_{55}An_{45}$) with an average diameter of 0.8 mm. There are scattered grains of garnet and rare patches of carbonate, quartz, chlorite, and chalcedony. Hydrothermal alteration of pyroxene is common adjacent to such patches.

QUARTZ SYENITE

Quartz syenite includes such rocks as consist predominantly of alkalic feldspars with moderate amounts of quartz and small amounts of ferromagnesian minerals. Except for a rare local facies described below, the rocks mapped as quartz syenite characteristically carry two pyroxenes, hypersthene and augite, in addition to hornblende. It is possible to make a distinction in the field between porphyritic quartz syenite and equigranular quartz syenite. The quartz syenite occurs generally as intrusive sills.

The principal occurrence of quartz syenite is in a position peripheral to the Piseco dome. A compound sill of quartz syenite outcrops in oval belts outlining the dome. Just south of the dome is the broad Morehouse Mountain quartz syenite band, which crosses the central part of the quadrangle in an east-west direction. On the continuation of this band near the east edge of the quadrangle, a sill or compound sill outcrops in the vicinity of Mud Lake mountain. Quartz syenite is an important constituent of the mixed rocks in the bands north of Metcalf and T lakes. Two major bands have been mapped separately from the mixed rocks, and there are in addition

many smaller bands which have been included in the mixed rocks. On the other hand, quartz syenite is a very minor element in the mixed rocks of the south half of the quadrangle.

Equigranular quartz syenite. The oval bands of quartz syenite which nearly encircle the Piseco dome are the outcrops of two closely associated sills, or of a compound or divided sill. Essentially there are two sills separated by a thin septum of amphibolite and bands of granite. The thickness of each of the sills varies between 1000 and 2000 feet. The salient of quartz syenite projecting into the central granite area south of Twin lakes (n.c.r.) is merely due to the combined effect of topography and structure, and does not indicate a discordant relationship.

The rock forming these sills is a fine-grained equigranular pyroxene-hornblende-quartz syenite. Where fresh, the rock is dark green, but in most outcrops a superficial gray to white coat is underlain by a brown weathered zone one or more inches thick. Foliation is shown by thin layers alternately rich and poor in mafic constituents, giving the rock a finely banded appearance. A linear streaking of the dark minerals on foliation surfaces can be seen under favorable conditions. Shreds of amphibolite generally less than one inch thick, and concordant pegmatite seams or lenses of the same order of size and abundance as the amphibolite remnants, are extremely characteristic of this rock. These two elements are present in considerable amount in nearly every outcrop. Joint planes are generally widely spaced and outcrops characteristically have a smooth, rounded, massive appearance.

Microperthite is generally more abundant than plagioclase. Normally orthoclase free of plagioclase intergrowth forms only a small percentage of the groundmass. Small amounts of myrmekite are present as borders fringing the larger microperthite relics. The plagioclase is oligoclase ranging from $Ab_{80}An_{20}$ to $Ab_{75}An_{25}$. Of the mafic minerals green hornblende is generally most abundant or at least equally as abundant as pyroxene. The pyroxene includes both hypersthene and augite, which form parallel growths in some specimens. Magnetite or ilmenite, apatite and zircon are constant accessories. Garnet, pyrite, ilmenite, titanite and rutile occur sporadically. Along the borders of pegmatite lenses, pyroxene is commonly altered to hornblende. Biotite is a sparse local alteration product of hornblende or pyroxene.

The equigranular quartz syenite of the Piseco dome sills possesses a granoblastic structure. Locally the mosaic is so fine-grained as to approach mylonitic structure. Quartz occurs both as small round

or polygonal grains in the groundmass and as flat blades parallel to the foliation. Grains of microperthite averaging about 1 mm diameter are scattered commonly throughout the rock. They appear to be relics of small primary phenocrysts which have escaped complete crushing.

Similar equigranular quartz syenite intrudes the gabbro of the Mud Lake Mountain sill and also forms a mass at the east edge of the quadrangle north of Rudeston.

The same rock forms numerous sills throughout the mixed gneiss areas north of the Piseco dome. In addition to the two major quartz syenite bands shown on the map in this northern part of the quadrangle, many other masses have not been portrayed because of their small size. In the field these rocks are indistinguishable from the equigranular quartz syenite of the Piseco dome sills, but minor differences can be seen in thin section.

The texture of the equigranular quartz syenite shows systematic regional variation within the limits of the quadrangle. The size of the polygonal feldspar grains in the groundmass of this rock increases in general from south to north. In the quartz syenite sill on the south side of Piseco dome the size of this granulated material averages about 0.15 mm.; in the outer sill on the north flank of the dome, for example on T Lake mountain, the average grain size is 0.3 mm. This northward increase in grain size continues to a maximum of about 0.5 mm. near the northwest corner of the quadrangle.

Porphyritic quartz syenite. The broad Morehouse Mountain band which trends east and west across the center of the quadrangle contains a type of quartz syenite whose occurrence is largely confined to this single body. In composition it resembles the equigranular quartz syenite; but instead of the finely banded appearance of the latter rock, it possesses a lenticular structure due to pods of feldspar which are outlined by ferromagnesian minerals and leaves of quartz. The lenticles or pods have been formed by the granulation and mashing of feldspar phenocrysts. However, the granulation has been so nearly complete that feldspar relics remain in relatively few of the lenticles, so that the present structure of the rock is now actually blastoporphyratic rather than truly porphyritic.

The Morehouse Mountain band of porphyritic quartz syenite widens westward and continues into the Wilmurt quadrangle. Toward the east the band continues certainly as far as the Piseco Lake fault. On the east side of this fault the quartz syenite areas north and south of Big Bay are presumably a continuation of the same band.

At its north contact the porphyritic quartz syenite is underlain by granite, both rocks dipping about 40° to the south. On the knob east of Morehouseville (Wilmurt quadrangle) the basal contact zone can be seen in excellent exposures. Smyth ('94, p. 55-61) has described a thin septum of metagabbro which intervenes between syenite and granite at this locality. From the north contact the southward dip of the foliation steepens rather uniformly to an average of 80° or 85° at the south contact. This fact alone would seem to indicate a simple homoclinal structure. However, the quartz syenite just east of the Piseco Lake fault is a single sill, folded into a syncline along the Big Bay axis and an anticline less than a mile to the south. Many lines of evidence indicate that this is a continuation of the Morehouse Mountain porphyritic quartz syenite. Consequently, it seems probable that the Morehouse Mountain quartz syenite has the form of a relatively thin sill, folded isoclinally into a syncline, and anticline overturned toward the north.

The porphyritic quartz syenite is remarkably uniform and homogeneous. The rock is completely free of contamination of any kind, unless sparse scattered crystals of andesine represent xenocrysts. Pegmatite was seen only in a one-inch dike near the center of the band, and in rare thin concordant seams within several hundred feet of the main contacts. The porphyritic quartz syenite differs greatly in this respect from the dirty pegmatite-seamed equigranular quartz syenite. In regard to color and mode of weathering, the porphyritic quartz syenite resembles the equigranular quartz syenite. Its outcrops appear even more massive than those of the equigranular rock because of greater homogeneity and weaker foliation. Linear structure and foliation are shown by the elongation and flattening of the feldspar lenticles and by the interstitial mafic layers and quartz leaves. Foliation is generally overshadowed by a stronger linear structure. In many places the rock with this type of structure passes gradually into a pencil gneiss in which no trace of foliation can be detected.

In mineral composition this rock does not differ greatly from the equigranular quartz syenite. The potash feldspar is dominantly microperthite which is only slightly perthitic. Some specimens contain orthoclase or microcline quite free of intergrowth. Potash feldspar is about equally as abundant as oligoclase ($Ab_{75-80}An_{25-20}$). Relics of primary oligoclase grains generally show antiperthitic intergrowth of potash feldspar, whereas much of the granulated and recrystallized oligoclase is free of such intergrowth. Large scattered plagioclase crystals, with a composition of calcic andesine

($Ab_{57}An_{43}$) may be either phenocrysts crystallized from the quartz syenite magma or xenocrysts derived from older anorthosite. Hypersthene, augite and green hornblende are ubiquitous mafic constituents. In addition, garnet is present in nearly all specimens as grains embedded in plagioclase. In a few specimens garnet occurs also as reaction rims on magnetite, pyroxene, or hornblende, especially at contacts with plagioclase. Ilmenite or magnetite, apatite, zircon and titanite are accessory minerals. The specific gravity varies between 2.70 and 2.78.

Thin sections of the rock are dominated by lenticular areas of granulated and recrystallized feldspar. In some lenticles granulation has been complete; in the center of some there remains a rounded relic of the feldspar phenocryst whose mashing and granulation has produced the lenticle. Crystalloblastic leaves of quartz, together with a fine mosaic of feldspar and the mafic minerals, form a network which weaves between the feldspar lenticles.

Several outcrops of a rather similar porphyritic quartz syenite may be seen along the Gloversville road about a mile south of Rudeston. The linear structure of this rock is so strong that single feldspar lenticles or single quartz leaves commonly appear to have a length of several feet. The relations of this rock to the near-by granite were not satisfactorily determined.

At several localities in the Morehouse Mountain band the dark green porphyritic pyroxene-hornblende-quartz syenite seems to grade into porphyritic hornblende-quartz syenite of variable pink or green color. In texture and structure this rock seems identical with the pyroxene-bearing facies. In some cases it can be distinguished in the field by its color. Thin sections show the absence of pyroxene and garnet, common presence of biotite, and extensive hydrothermal alteration of the mafic minerals. The specific gravity ranges between 2.67 and 2.70, values considerably lower than those of the normal pyroxene facies.

The significance of this hornblende facies is uncertain. All known occurrences lie in the northern half of the Morehouse Mountain quartz syenite band; several outcrops can be seen along the main highway between Hoffmeister and Piseco lake. The differences between the hornblende and pyroxene facies may have resulted by differentiation from a common magma, or the hornblende facies may have been formed by local hydrothermal alteration of the pyroxene facies. As a third possibility, this hornblende-quartz syenite may be a facies of the granite. Structurally it seems to be an integral part of the Morehouse Mountain quartz syenite band.

Andesine crystals in quartz syenite. The presence of large crystals of calcic andesine in the porphyritic quartz syenite deserves special consideration. The crystals are conspicuous only on ice-polished surfaces, where their presence is indicated by shallow pits. They are known to occur at three widely separated points on the Morehouse Mountain band, but the uniformity of their distribution is uncertain. They were seen along the main highway three miles east of Hoffmeister at the crest of the hill just west of Alder brook, and at the quarry just east of Morehouseville (Wilmurt quadrangle). A thin section of a specimen taken one mile west of the head of Morehouse lake cuts one of the phenocrysts. A glaciated ledge at the Alder Brook locality shows crystals ranging from one-fourth of an inch to one and one-half inches long, with a distribution of approximately one in every square yard of surface. Some are mashed and granulated, but most of them show surprisingly little granulation, even those oriented across the foliation.

Analogous cases of labradorite crystals in syenite close to the borders of the central anorthosite body have been described by Balk ('31, p. 384-88, 394-96) and interpreted by him as phenocrysts formed in equilibrium with the syenite magma. In this instance there is a very poor approximation to the requirements for equilibrium between the phenocrysts and the plagioclase of the groundmass. An interstitial liquid containing $Ab_{75-80}An_{25-20}$ (composition of plagioclase in the quartz syenite groundmass) would be in equilibrium with plagioclase phenocrysts with an approximate composition $Ab_{35-40}An_{65-60}$. However, the crystals in the Morehouse Mountain quartz syenite have the composition $Ab_{57}An_{43}$.

In a recent paper Grout and Longley ('35, p. 133-41) have presented the view that such crystals are xenocrysts picked up by syenite magma intruding anorthosite. The evidence favors this explanation for the andesine crystals in the Morehouse Mountain porphyritic quartz syenite. This band of quartz syenite bears a close structural relationship to the Mud Lake Mountain anorthosite-gabbro sill. It is possible that the quartz syenite which intrudes the Mud Lake Mountain anorthosite and gabbro is the eastward continuation of the Morehouse Mountain quartz syenite, although the intervention of faults and drift-covered areas prevents complete confidence in such a correlation. Thus an anorthosite source for andesine xenocrysts is close at hand. The plagioclase of the anorthosite was determined as $Ab_{55}An_{45}$; the crystals in the quartz syenite as $Ab_{57}An_{43}$. Numerous dark inclusions, characteristic of the plagioclase of the anorthosite, were also present in the single andesine crystal seen in

thin sections of the quartz syenite, but were not seen in any of the oligoclase grains nor in the plagioclase of any other rock.

GRANITE

Granite is more abundant and is distributed more widely throughout the quadrangle than any other rock. The geologic map may fail to give an adequate impression of the quantitative importance of granite, as it occurs not only in separate bodies but also as a major constituent of the mixed gneiss areas. Granites of two or more distinct ages have been recognized in some parts of the Adirondacks. In the Piseco Lake quadrangle there are several distinct facies of granite. The writer has found no evidence, however, which might indicate distinctly different periods of intrusion of the facies. Indeed, the several facies occur almost invariably closely associated with one another.

Many characteristic features are common to all facies. Weathering tends to produce a pink coloration regardless of the color of the fresh rock. The depth of weathering, generally less than one-half an inch, is shallower than in the quartz syenite. Color of the fresh rock is variable, ranging from pink through grayish green to a dark green color like that of typical quartz syenite. In some cases variations in color can be correlated with local conditions; green color may be related to the proximity of mafic inclusions, pink color to quartzose areas. The granite characteristically possesses a strong jointing or sheeting parallel to the foliation. Also, linear structure is generally strongly developed, in part because of the abundance of quartz which forms long leaves or spindles. Sheetlike inclusions of fine-grained metagabbro or amphibolite are common, and in many places abundant. Many inclusions show sharp contacts with granite; others have gradational contacts and are so disintegrated by the granite that the original nature of the material is indeterminable. Aplite, with its characteristic vane sheet form of intrusion, is almost ubiquitous in the granite areas.

Porphyritic granite. The granite possesses both porphyritic and nonporphyritic or equigranular facies which are analogous in appearance to the facies of the quartz syenite. The porphyritic facies is a hornblende-biotite granite which closely resembles the porphyritic hornblende-quartz syenite. The hornblende is variously pleochroic in shades of olive green, pale green and bluish green; apparently there is much variation in its chemical composition. Quartz is a prominent constituent. In most specimens plagioclase is less abun-

dant than potash feldspar. Microperthite generally predominates over minor interstitial orthoclase or microcline. The plagioclase feldspar, oligoclase with a composition of about $Ab_{80}An_{20}$, commonly contains spindles of orthoclase in antiperthitic intergrowth. The occurrence of myrmekite is widespread but never of quantitative importance. Magnetite or ilmenite, apatite and zircon are found in all specimens. Muscovite, garnet, perovskite, rutile, titanite and pyrite occur with erratic infrequency. The mafic minerals, especially hornblende, are commonly altered to one or all of chlorite, biotite, and carbonate.

The rock is dominated by lenticles or pods of feldspar in the same fashion as the porphyritic quartz syenite. Many lenticles of granular microperthite contain a central relic of the original phenocrysts ranging in size from one to 30 or 40 mm. Myrmekite may form a lacelike fringe around the borders of the microperthite grains. Equally as common are smaller lenticles of granular oligoclase in which granulation of the phenocryst has been complete. Apparently at the time of original crystallization the porphyritic granite contained large phenocrysts of microperthite and smaller ones of oligoclase. Granulation and recrystallization of the phenocrysts during subsequent deformation of the rock has produced the lenticular structure. Quartz occurs as thin leaves curved around the feldspar lenticles, as ovoid grains, or as irregular, slightly elongate lobate grains. The remainder of the rock consists of the mafic minerals together with quartz and feldspar forming a granoblastic or less regular crystalloblastic structure.

The common association of porphyritic granite with granitized remnants of Grenville sediments suggests a possibility that the development of the porphyritic facies is dependent on the intrusion of granite magma into sedimentary material. This relation is considered more specifically in a subsequent discussion of the mixed gneisses.

Equigranular granite. The porphyritic granite is commonly interbanded with an equigranular facies. In many outcrops the porphyritic granite seems to pass into equigranular granite either by decreasing abundance of the lenticles or by gradual decrease in their size. Sharp contacts between the two facies are equally common. The equigranular granite is also a hornblende-biotite granite, very similar in mineralogic composition to the porphyritic granite. Muscovite and garnet are more common than in the porphyritic rock. The feldspars are similar to those in the porphyritic facies except

that microcline relatively free of perthitic intergrowth is more abundant. Alteration of hornblende to chlorite, biotite and carbonate is widespread, as is also the alteration of ilmenite to leucoxene and titanite or rutile.

The microstructures suggest crushing and recrystallization. Grains of feldspar and the mafic minerals form a granoblastic pattern between long straight leaves of quartz. The mafic minerals are generally somewhat segregated into streaks. On recrystallization of the rock their presence seems to have induced a smaller grain size in the feldspar of the mafic streaks than was formed in the clean feldspar streaks. From this type there is a gradation to a more irregular type of crystalloblastic structure in which the quartz individuals are smaller, less elongate and more evenly distributed through the rock. In general the size of feldspar grains in the groundmass of the equigranular granite increases from the center to the northwest corner of the quadrangle. This textural variation in the granite accompanies a similar gradation in grain size in quartz syenite.

Granite aplite. The granites and some of the mixed gneisses are cut by vane sheets of aplite. The aplite bodies may grade locally into pink granite pegmatite. There are also vane sheets of quartz, generally less than two inches thick, which are commonly associated with the aplite, although not necessarily so. Obviously these three rocks are genetically related to one another, and to the granite in or near which they occur. It is not clear, however, whether they have been generated within the local mass of granite in which they are now found, or whether they represent material derived from the same general source as the granite magma but injected after the crystallization of the granite.

The aplite is a homogeneous fine-grained rock, generally pink in color but locally gray or grayish green. Linear structure is shown well, foliation less clearly, by the elongation and flattening of small quartz leaves. Thin sections show between the quartz leaves a mosaic of feldspar and quartz with generally less than 5 per cent of mafic minerals. The feldspar includes plagioclase and microperthite, with more or less microcline or orthoclase. Biotite and magnetite are constant minor constituents. Chlorite, muscovite, apatite and zircon may be present. Thin sections reveal that despite the fine-grained appearance of hand specimens, the aplite has a granoblastic structure, with individual grains comparable in size to the granulated feldspar in adjacent granite.

Piseco Dome granite area. The central part of the Piseco dome is occupied by a large area of granite whose periphery is bounded and overlain by the Piseco Dome equigranular quartz syenite sills. The foliation of the granite seems to conform everywhere to the contact with the overlying quartz syenite. The probable structure of this granite body will be considered in a subsequent section. The Piseco Dome granite outcrops over an area of about 13 square miles, about seven miles long and three and one-half miles maximum width.

The Piseco Dome granite consists almost equally of the porphyritic and equigranular facies which are generally interbanded on a coarse scale. Although one or other of the facies generally predominates within any small area, there seems to be no regularity in the distribution of the two facies. Aplite is widely distributed in typical vane sheets which are much more common in the porphyritic facies than in the equigranular facies. Vane sheets of quartz are commonly associated with the aplite, but pegmatite is rarely seen. Inclusions of fine-grained metagabbro or amphibolite and granitized Grenville sediments are abundant, but irregularly distributed; over large areas they are completely lacking. The metagabbro or amphibolite characteristically occurs in thin sheets oriented parallel to the foliation of the inclosing granite. The sheetlike inclusions are commonly cut by vane sheets of aplite or pegmatitic granite. They are particularly well exposed in a great cliff on the east valley wall of the South Branch of West Canada creek one and one-half miles southwest of T Lake falls. A vertical face more than 100 feet high shows innumerable sheets of fine-grained amphibolite with an average thickness of several inches and an average vertical spacing of one or two feet, dipping 10° or 15° to the north (figure 3). In addition to the amphibolite sheets, the granite at this locality contains inclusions of granular diopside rock (metamorphosed limestone) in the form of stout lenses several inches long.

Wilmurt Lake granite area. Conditions are not markedly different in the crescent-shaped granite area, which extends around the west end of the dome just west of Wilmurt lake from Metcalf lake to the Hoffmeister valley. Porphyritic granite predominates west and southwest of Wilmurt lake, and seems to continue along the central portion of the belt which extends toward Metcalf lake. Elsewhere within the area the equigranular facies occurs almost exclusively. These relations within the Wilmurt Lake granite area suggest that the equigranular granite is a fine-grained chilled border of the porphyritic granite. The intimate interbanding and irregular

distribution of the two facies in other granite areas, however, discourages such an interpretation.

The presence of inclusions of metagabbro and amphibolite is an important feature. The inclusions of metagabbro along the north side of Hoffmeister valley have been described. These inclusions extend from West Canada creek toward the northwest for at least one and one-half miles. With the metagabbro there occur shreds and irregular bands of granitized and disintegrated mafic material which supposedly represent remnants of Grenville sediments. Along the northwest boundary the granite is considerably contaminated, and the boundary between granite and mixed gneiss has been drawn somewhat arbitrarily. Aplite and quartz vane sheets are common but not abundant. Vane sheets of quartzose lenticular granite commonly cut inclusions and adjacent granite. Small, sharply defined dikes of late pegmatite, oriented at right angles to the linear structure of the granite, are more abundant than in any other of the granite bodies.

Piseco Mountain granite area. This wedge-shaped mass of granite has apparently been injected along a septum of amphibolite separating the Piseco Dome quartz syenite sills. In the narrow western extremity of the area the granite alternates with amphibolite in a rather intimate manner, which is generalized on the geologic map. In the wider eastern part, however, inclusions of amphibolite are limited to a narrow zone along the south border, and the remainder of the area is occupied by remarkably clean granite.

Porphyritic and equigranular facies of the granite are equally abundant. Their mutual relations, as well as those of aplite, pegmatite and quartz, and the mode of occurrence of the vane sheets, can be seen in excellent exposures along Warner Pond outlet and on the southeast slope of Piseco mountain. Much of the rock shows intimate artieritic injection by aplite. On the east face of Piseco mountain there is an apparent transition from the artieritic granite to equigranular quartz syenite free of injected material. These two facts at first suggested to the writer that the Piseco Mountain hornblende-biotite granite had originated by alteration of the pyroxene-hornblende-quartz syenite as a result of intimate injection by aplite. This possibility was given serious consideration, both in the field and during petrographic studies. Much evidence has accumulated, however, to show such an origin of the granite highly improbable.

Hoffmeister Valley granite area. The few granite outcrops on the south side of Hoffmeister valley are interpreted as a part of

the Wilmurt Lake granite. These are probably separated by a fault from the patches of granite exposed along the north side of the valley from Irondequoit bay to West Canada creek, which represent the continuation of the granite belt east of Signal mountain. This belt of granite occupies an intra-syenite position on the west and south sides of the dome similar to the position of the Piseco Mountain granite on the northeast side. This granite is similar to the Piseco Mountain granite except that it has apparently suffered greater deformation, so that feldspar lenticles are flatter and the grain is in general finer. Dense mylonitic bands are common close to its north contact against the quartz syenite. The granite east of Signal mountain is involved with amphibolite, but no inclusions were seen east of West Canada creek.

Spy Lake granite area. The granite mass which lies principally between Spy lake and Piseco lake is composed dominantly of the equigranular granite. A belt a mile wide, from the latitude of the north shore of Spy lake to the south boundary of the area, consists exclusively of green and pink equigranular granite, cut by a few vane sheets of aplite and quartz but containing essentially no inclusions. From Spy lake northward the porphyritic facies also occurs locally and much metagabbro and remnants of Grenville are present. The inclusions consist of remnants of granitized Grenville sediments and sheets of fine-grained metagabbro like that at the Mountain House locality. Throughout this area most of the hilltops are capped by sheets of metagabbro, which in some cases must have a thickness of at least 50 feet. The metagabbro is commonly cut by vane sheets of aplite and porphyritic or pegmatitic granite.

Rudeston granite area. The relations of the Spy Lake granite to the small area of granite northeast of Rudeston are uncertain. Along the highway at Rudeston only the equigranular facies outcrops. Farther north near the contact with quartz syenite, however, there are some ledges of the porphyritic granite. Several sills of granite less than 100 feet thick intrude the syenite near the contact. At the "rotten rock" quarry along the highway near the edge of the quadrangle the granite contains pegmatites with relations generally characteristic of pegmatites in the equigranular quartz syenite and rarely seen in the granite of this quadrangle. The pegmatite forms concordant seams and poorly defined discordant streaks which are associated with swirls and irregularities in the foliation. The pegmatite carries rare allanite. Sheetlike inclusions of fine-grained amphibolite or metagabbro up to five feet thick are shown well in

the large road metal quarry on the hillside northeast of the highway at Rudeston.

Other granite areas. The small areas adjacent to Fall stream in the northeast corner of the quadrangle are principally pink porphyritic granite with associated aplite. Gradations to a green color and to the equigranular facies occur locally, however, as well as scattered inclusions of amphibolite.

The granite in the extreme northwest corner of the quadrangle is nonporphyritic, but appears to have somewhat coarser grain than any other equigranular granite in the quadrangle. Color is generally pink. The linear structure is not strong; foliation commonly can not be detected.

The widespread occurrence of granite in the mixed gneiss areas is discussed in a subsequent section.

DIABASE

Ten outcrops of diabase were encountered within or very close to the limits of the quadrangle. The diabase occurs as dikes in all cases in which the relations can be seen. The smallest of these dikes has a width of six inches. The greatest established width for any dike is 75 feet, although others may be wider up to a maximum limit of several hundred feet. Five dikes, whose contacts with the country rock are exposed, strike between N-S and N.40°E. and dip within 10° of vertical. All but one of the ten diabase outcrops are in the south half of the quadrangle. The presence of diabase in the northeast corner of the quadrangle, however, is indicated by the common occurrence of diabase float in the glacial drift around the head of Piseco lake. Nevertheless, there seems to be a valid indication of regional variation in the distribution of the diabase. The geologic map of the Lake Pleasant quadrangle (Miller, '16) shows only one diabase dike in the north half as compared with five in the south half.

The diabase has a dark massive appearance, weathering to a dull gray color. It is the only rock of the quadrangle that shows no trace of gneissic structure. Thin sections of specimens from the borders of a dike do show, however, a parallel arrangement of minerals or flow banding parallel to the wall of the dike. The larger dikes are medium-grained, commonly porphyritic with large labradorite phenocrysts. Smaller dikes have fine-grained or aphanitic centers and dense to glassy borders. One fine-grained dike contains a few phenocrysts and many spherical filled vesicles or miarolitic

cavities. As close jointing is a common feature especially of the smaller dikes and promotes their rapid erosion, the diabase dikes are generally poorly exposed.

Extensive hydrothermal alteration of the diabase prevents a satisfactory study of its mineralogy. The principal constituent is plagioclase, apparently labradorite. Relics of augite and rarely hornblende can be identified; if other primary mafic minerals were present originally, they have been altered to chloritic aggregates. Interstitial granophyre is prominent in all of the dikes studied microscopically. Magnetite or ilmenite and apatite are the only accessory minerals. The apatite forms long thin needles which seem to penetrate grains of the other minerals.

The dense chilled border of the 18-inch dike 0.7 mile west of the G Lake road on the north side of Hoffmeister valley (c.r.) was studied in thin section. The texture is porphyritic with scattered small phenocrysts of plagioclase, chlorite secondary after mafic minerals, and ore in a dense groundmass crowded with acicular micro-lites. Tiny grains of quartz may be a result of devitrification. The elongate and tabular phenocrysts show excellent orientation parallel to the wall, and their size seems to decrease slightly toward the contact.

The dike in the Notch (c.r.), whose probable width is between 40 and 150 feet, is medium to coarse-grained with greenish plagioclase phenocrysts one-half to one inch in length. The greater part of the rock consists of interlocking laths of plagioclase. The mafic minerals (apparently mostly pyroxene altered to chlorite and biotite) are principally confined to the triangular interstices, as are also tablets of orthoclase, micropegmatite, and apparent late cavity fillings of primary chlorite.

A dike or multiple dike extends from House pond (s.w.r.) in a direction S. 35° W., and is fairly well exposed on the Lassellville quadrangle 0.2 mile south of the quadrangle boundary. Outcrops show both a medium-grained porphyritic diabase like that at the Notch and a fine-grained sparsely porphyritic facies studded with spherical filled vesicles or miarolitic cavities. The groundmass of the latter facies is essentially a small scale replica of the groundmass of the Notch diabase, except that the plagioclase laths and elongate chloritized mafics seem to form irregular patterns of flow lines. The supposed flow lines curve around the spherical filled cavities; these areas are encircled by concentric rows of the elongate minerals of the diabase in tangential arrangement. Exactly the same sort of

arrangement is seen about rounded plagioclase phenocrysts. The diameter of the circular areas (as seen in thin section) generally falls within the range between one and five millimeters. Some of the circular areas consist entirely of orthoclase and interstitial micropegmatite. In the majority of the areas, however, orthoclase and micropegmatite form only an outer rim; the central portion is filled with grains of quartz and primary chlorite. Evidently vesiculation of the diabase magma occurred at a stage when the magma was still largely liquid. Small crystals in the magma flowed around the gas bubbles just as around solid phenocrysts. The cavities persisted until a late stage in the crystallization of the diabase, when they were filled or lined with orthoclase and micropegmatite from the residual granophyre liquid. The final filling of quartz and chlorite was probably deposited from hydrothermal solutions which were the last residual liquid from the crystallization of the diabase magma.

AGE RELATIONS

After the many years during which geological investigation has been carried on in the Adirondacks, there is still a lack of uniformity of opinion among the various investigators as to the relative ages of some of the rocks. The present study contributes little to the solution of these problems, except perhaps in regard to the age of the gabbroic rocks. Nevertheless, the pertinent data bearing upon the probable age of each group of igneous rocks will be summarized. Before passing on to a discussion of the ages of the igneous rocks it will be recalled that the Grenville sediments, now metamorphosed, are the oldest rocks exposed in the Adirondacks.

Anorthosite, hypersthene gabbro and olivine norite. The rocks forming the Mud Lake Mountain sill are thought to have originated essentially contemporaneously by differentiation in place from a small body of magma. The relations of quartz syenite at this locality are known only with reference to the hypersthene gabbro, which it intrudes. Although the contacts between quartz syenite and hypersthene gabbro are conformable, the intrusive relation is shown by contamination of the quartz syenite near the contacts by amphibolitic material torn off from the intruded gabbro. These relations are well exposed on the west face of Mud Lake mountain. The small outlier of anorthosite northeast of Mud Lake mountain is underlain by quartz syenite with which it is probably in contact, but the narrow critical zone around the foot of the hill is covered. There is no reason to doubt, however, that the quartz syenite is younger than

the anorthosite and intrusive into it. There is similarly a lack of direct evidence with respect to the relations of quartz syenite to olivine gabbro.

Metagabbro. Other gabbroic rocks of igneous origin are thought to have been formed during the same general period of intrusion as the Mud Lake Mountain sill, although in no other case can a pre-syenite age be definitely established. Although the Stacy Mountain metagabbro lies within an area of quartz syenite, the nature of its contacts is not known. Detailed data have been presented which indicate that sheets of metagabbro near the Mountain House and on the east shore of Piseco lake are apparently intrusive into Grenville sediments, and are themselves definitely intruded by granite.

Quartz syenite. The porphyritic quartz syenite and equigranular quartz syenite are thought to have crystallized from similar magma and are thought to be of similar age. Evidence bearing on this point includes the apparent similarity of their structural relations, their close mineralogic similarity and the apparent gradation of porphyritic quartz syenite to an equigranular facies from Morehouse mountain eastward to Big bay. It is believed that a porphyritic facies was developed where uncontaminated quartz syenite magma was intruded in thick sills, that an equigranular facies resulted where the magma was intruded in thinner sheets or was appreciably contaminated with inclusions.

Equigranular quartz syenite is known to intrude older hypersthene gabbro on Mud Lake mountain.

On the other hand, its relations to granite are more obscure in spite of the many miles of boundary between quartz syenite and granite, as the contacts between the two rocks are generally occupied by stream valleys or small gulches. The single locality at which a definite contact was seen exposed is at the crest of Pine mountain (c.r.), where granite below is conformable to quartz syenite above but is separated from it by a five foot band of pegmatite of uncertain origin. At some other places where the contact zone is exposed there is seemingly a transition between the two rocks, as at the locality on the east face of Piseco mountain described above. In the adjoining Lake Pleasant quadrangle Miller ('16, p. 23) notes that transitions from syenite to granite are the rule, and the geologic map invariably shows a belt of intermediate rock separating them. He is thus led to conclude that "there is no evidence for different ages of normal syenite, granitic syenite, and pink granite, but rather there is much

evidence that these types grade into each other and are really only different phases of the same great plutonic body." It has been the experience of the present writer, however, that granite and quartz syenite may be exceedingly difficult to distinguish in the field except on the basis of certain structural characteristics (type of gneissic structures, mode of occurrence of pegmatite etc.); that within a narrow zone adjacent to the contacts the diagnostic structural features commonly disappear or show modifications; and that in many places where a small gulch occupies the contact a change from granite to quartz syenite is effected within a narrow covered zone only ten to 50 feet wide.

Several lines of structural evidence point to the older age of the quartz syenite. At several places close to contacts with granite the quartz syenite is cut by small vane sheets of aplite. As the aplite is almost certainly related in origin to the granite, this fact implies a post-syenite age of the granite. Furthermore, the phacolithic form of the Wilmurt Lake and Piseco Mountain granites is taken to indicate intrusion of the granite magma contemporaneously with the major folding and deformation. On the other hand, the quartz syenite was apparently intruded under quiescent conditions, as the Piseco Dome sills show no thickening in the axial region of the dome. And yet several lines of evidence converge to indicate that these sills have been involved in the folding together with the granite. Apparently the deformation which was accompanied by the formation of granite phacoliths was preceded by the intrusion of quartz syenite sills. Consequently, the granite is the younger rock.

Granite. The preceding pages have been devoted to a presentation of the evidence on which is based the writer's opinion that the granite of the Piseco Lake quadrangle is younger than metagabbro, hypersthene gabbro and anorthosite, and quartz syenite. There is little more to add to the discussion of the relations of granite to quartz syenite. Miller ('16, p. 23) has implied a belief that basic syenite, normal syenite, granitic syenite and granite have crystallized from a common magma by differentiation in place attended by more or less assimilation of Grenville material. The evidence from the Piseco Lake quadrangle seems to indicate rather that the act of intrusion of the granite magma occurred at a time subsequent to the crystallization of the quartz syenite. The writer knows of no evidence, however, which might preclude a possibility that the quartz syenite and granite magmas differentiated from a common magma at depth prior to intrusion.

Diabase. The latest igneous activity in the history of the quadrangle was the intrusion of dikes of quartz diabase. A complete lack of induced gneissic structures in the diabase indicates a date of intrusion subsequent to the cessation of regional metamorphism. Glassy chilled borders on the smaller dikes are evidence of intrusion of the diabase magma into a cool environment. One dike was intruded at shallow depth and under sufficiently low pressure to permit vesiculation of the magma. Clearly the dikes were formed under quite different conditions and at a much later date than the granite, quartz syenite and older basic rocks. The diabase was probably intruded in late Precambrian time.

METAMORPHIC AND MIXED ROCKS

AMPHIBOLITE

In this report amphibolite designates any dark granular metamorphic rock of basic composition, without specific implication of its origin. In such amphibolites the dominant mineral is generally a plagioclase within the range andesine to labradorite. The remainder of the rock may consist of augite, hypersthene, hornblende, biotite, garnet and ilmenite or magnetite. The proportions of these constituents vary widely from one mass to another, and commonly some one of the mafic minerals is absent.

The amphibolite in this quadrangle may well include rocks of the three diverse modes of origin recognized by Adams ('09, p. 3-4) in the Laurentian area of Canada and by Cushing ('10, p. 33) in the northwest Adirondacks: (1) by metamorphism of basic igneous rocks or (2) of impure calcareous sediments, or (3) as a replacement of limestone through the action of intruding granite. Those rocks described elsewhere in this report as metagabbro have probably been formed by metamorphism of basic igneous rocks, and have been removed from this classification only because their mode of origin can be predicated with a fair degree of confidence. Undoubtedly some of the rocks here designated as amphibolite have had a similar origin. Others characterized by banding and intercalated with banded Grenville rocks have probably been derived from calcareous sediments.

Several large masses of amphibolite are included in the quartz syenite sills on the north flank of Piseco dome. Excellent outcrops on the west side of Panther mountain expose a mass of amphibolite with the shape of a stout blunt lens, to which the foliation of adjacent quartz syenite conforms. Schlieren of similar amphibolite sev-

eral inches thick are common in the adjacent quartz syenite. The amphibolite is either uniform or banded, generally nearly black in color, and medium to coarse-grained with scattered garnets generally less than two inches in diameter. A thin section of the rock shows large grains of garnet with interstitial aggregates of hornblende and an opaque ore. The garnets are bounded by either crystal faces or irregularly curving outlines and are studded with inclusions, generally of quartz. The interstitial mafic material is dominantly hornblende and ore with minor hypersthene and augite; some of the aggregates have the appearance of intergrowths. Plagioclase is definitely a minor constituent, most of which occurs as narrow but continuous rims inclosing the garnets. Abundant apatite and common titanite are accessory minerals.

Sheets or lenses of amphibolite surrounded by quartz syenite outcrop on the south side of Twin Lakes mountain and on the hill 0.8 mile north-northeast of the crest of Piseco mountain. The rock at Twin Lakes mountain is nearly identical with the Panther Mountain amphibolite. It is cut by several dikes of white pegmatite about one foot wide composed largely of coarse graphic granite and minor magnetite. The amphibolite of the lens north of Piseco mountain is more typical of the amphibolites of the north half of the quadrangle. The dominant constituent is plagioclase, which forms about half of the rock. Garnet is less abundant and occurs in smaller grains than in the Panther Mountain rock. Other mafic minerals include pyroxene and hornblende in equal amounts, biotite and ore.

A thin sheet of amphibolite forms a more or less continuous septum between the two Piseco Dome quartz syenite sills from the south side of T Lake mountain around the north and west sides of the dome to Signal mountain. The septum is composed of variable amphibolite, generally banded, and more or less similar in character to the amphibolites previously described. In addition, it is commonly associated and interbanded with Grenville sediments, including quartz-feldspar-biotite gneiss, diopsidic quartzite and garnet gneiss. The derivation of this amphibolite from impure calcareous sediments is assured.

Similar amphibolite is a major element in the mixed gneisses north of Piseco dome. Evidence from interbanded sediments, particularly diopside and diopside-carbonate bands, indicates that much of the amphibolite has originated by alteration of impure limestones. On the other hand, there are several masses of homogeneous fine-grained amphibolite which are possibly metagabbro. In some places lit-par-lit injection of amphibolite by granite or syenite has formed arteritic

gneisses, as, for example, along T Lake outlet 0.3 mile west of T lake. Generally, however, the amphibolite is not strongly granitized but merely alternates with small intruded sills of granite or syenite from a few feet to perhaps several hundred feet thick. Large areas which are comparatively free of intruded material are shown as amphibolite on the geologic map.

In the mixed gneiss areas of the south half of the quadrangle amphibolite is much less abundant. It is characteristically fine-grained and rather homogeneous, commonly lacking the banding which is characteristic of the amphibolite north of Piseco dome. Also, these southern amphibolites have not been observed in close association with Grenville sediments of demonstrable calcareous nature. However, there are probably representatives of both altered basic igneous rocks and altered calcareous sediments. In the few thin sections of the southern amphibolites examined the amount of hypersthene exceeds the amount of augite. In the northern amphibolites these relations are reversed. Garnet and hornblende are notably subordinate in amount to pyroxene and biotite. Indeed, garnet is commonly absent. Amphibolite occurs in the south half of the quadrangle also as abundant bands in garnet gneiss.

QUARTZITE, DIOPSIDIC QUARTZITE AND DIOPSIDE-CARBONATE ROCKS

Bedded white quartzite of considerable purity is a notable, though sparse, member of the metamorphosed Grenville sediments. Generally, bedding in the quartzite is still apparent due to the presence of impure layers. At one place east of Redlouse lake (s.c.r.), however, a band of white quartzite 20 feet thick is sufficiently pure and massive so that it has the appearance of vein quartz. The quartzite is coarsely recrystallized and possesses foliation and linear structure which are obvious only where impurities are present. A thin section of one specimen contains more than 98 per cent of quartz; most specimens are less pure. Sections of the rock contain, in addition to quartz, microcline, diopside, garnet, sericite, biotite, chlorite, carbonate, zircon, apatite, titanite and opaque ore. Perovskite is present in quantity in a single specimen.

At several localities quartzite containing grains and lenses of diopside is interbanded with a white to green, massive, granular, diopside or diopside-carbonate rock. The diopside rocks are even more sparsely distributed than the quartzite. They were not found in bands of greater thickness than 20 feet, and generally only a single band was seen at any one locality. In most cases grains of diopside appear

to compose the bulk of the rock. The carbonate is interstitial and very subordinate in amount, or completely lacking. Where interbanded or associated with quartzite, these rocks commonly contain small quartzite lenses. Although the rocks were not studied in thin sections, diopside from many specimens was identified in index of refraction liquids. The identification of carbonate was confirmed by testing with hydrochloric acid.

The granular diopside rocks are present north of the axis of Piseco dome as sparse layers interbanded with amphibolite, rarely also with quartzite. Only one band of diopside rock was noted in the area of metamorphic and mixed rocks which occupies the south half of the quadrangle. An outcrop of garnet gneiss near Loomis pond (s.e.r.) contains a layer of this rock together with amphibolite and quartzite bands. On the other hand, no quartzite was seen north of the Piseco Dome axis except at the two localities where diopsidic quartzite is interbanded with granular diopside rock. In the south half of the quadrangle the occurrence of quartzite is widespread. Bands of quartzite, generally less than three feet thick, occur scattered throughout the garnet gneiss and mixed gneiss areas. Masses of relatively pure quartzite of appreciable magnitude were encountered only within a radius of 1.5 miles of Oregon (s.c.r.). In order to indicate these masses on the geologic map it has been necessary to exaggerate their areal extent.

The composition of the diopside and diopside-carbonate rocks, their association with sedimentary amphibolites on the one hand, and their gradation to diopsidic quartzite on the other, suggest their origin by recrystallization of arenaceous dolomite or limestone; whereas the pure bedded quartzites are obviously recrystallized quartz sandstones. The gradational series of quartzite, diopsidic quartzite, and diopside and diopside-carbonate rocks suggests the former presence of original sedimentary Grenville beds with a range in composition from pure quartz sandstone through dolomitic sandstone to sandy dolomite. Metamorphosed Grenville sandstones which apparently contained impurities of a different type are represented in the garnet gneisses. The accession of material from magmatic sources during the recrystallization of these rocks is a possible factor which can not be evaluated on the basis of the data obtained.

GARNET GNEISS

In the Grenville and mixed rocks north of Piseco dome, garnet gneiss is very subordinate, outcropping only in a narrow zone not far south of the band of syenite that swings across the northern part

of the quadrangle. Yet garnet gneiss underlies more than one-third of the Grenville belt which crosses the south half of the quadrangle. The western two-thirds of this belt is traversed from west to east by three well-defined bands of garnet gneiss, each of which averages more than a mile in width. The manner of continuation of these bands toward the east can not be stated with confidence, as mapping was not done in sufficient detail to overcome difficulties introduced by greater complexity of structure.

There are no essential differences in the garnet gneiss of the various areas. The most constant feature is the presence of garnet as scattered grains or crystals generally less than one-fourth of an inch in diameter. The garnet gneiss is typically a banded rock consisting of layers which differ widely from one another, both in composition and thickness. On a mineralogic basis the layers can be roughly classed as quartz-feldspar-garnet gneiss, quartz-feldspar-biotite-garnet gneiss, quartzite of several types, and amphibolite. The garnet gneiss exhibits more irregularity of structure than any other rock of the region. Single layers can seldom be traced for any considerable distance; they are commonly contorted or thrown into small folds, and are interrupted here and there apparently by the invasion of igneous material. Although these features of irregularity seem most characteristic of the amphibolite layers, this may be in part attributable to the fact that their dark color is in strong contrast with the surrounding gneiss and permits them to be traced most easily. Wherever foliation can be detected, it seems essentially parallel to the banding. The foliation is commonly too weak, however, to be determined with confidence, so that the structural data for the garnet gneiss areas are based largely on banding rather than foliation.

Bands of quartz-feldspar-garnet gneiss make up a dominant proportion of the rock and are present in nearly every outcrop. In outcrops, these bands typically have a white frosted appearance. This white surface is generally underlain by less than an inch of yellow or dirty brown weathered material, whereas the fresh rock is white to green. In structure the rock is somewhat similar to the granites of this quadrangle; spindles and leaves of quartz, which separate layers of granular feldspar or curve around garnets or feldspar augen, impart to the rock a strong linear structure and locally a weak foliation. The feldspar augen, which range widely in size from one-eighth of an inch to three or four inches long, are distributed through the rock with extreme irregularity. Proportionately large relics of the feldspar crystals remain in the cores of the augen.

Quartz and feldspar, together with subordinate garnet, compose the rock. Although the feldspar generally predominates, there is much variation in the proportions of the major constituents, even in different parts of a single hand specimen. There is similar wide variation in the proportions of the different feldspars, which include either microperthite or microcline and a plagioclase. Sparse accessory minerals may include biotite, chlorite, an opaque ore and zircon.

Bands of moderately pure white quartzite are scattered sparsely through the garnet gneiss. There are also bands which represent transitions from pure quartzite to garnetiferous quartzite or to feldspathic quartzite. These bands could be considered as extreme variations of the quartz-feldspar-garnet gneiss.

Most of the remaining bands other than amphibolite are quartz-feldspar-biotite-garnet gneiss. These bands are gray to nearly black in color and are rarely more than a few inches thick. In the field they appear homogeneous and fine-grained due to the usual absence of large quartz leaves or feldspar augen. In mineral composition they differ from the quartz-feldspar-garnet gneiss in the abundance of biotite and chlorite, in the marked subordination of potash feldspar to intermediate plagioclase, and in the relative paucity of quartz. In addition, some of them carry graphite, or more commonly pyrite, due to which the bands weather to a rusty brown color. Titanite is a common accessory mineral.

The amphibolite bands of the garnet gneiss have only one characteristic which might serve to distinguish them from the other fine-grained amphibolites of this quadrangle: the absence of hypersthene in all thin sections examined. Plagioclase, augite and hornblende predominate. Garnet and opaque ore are present in smaller amounts; minor accessory minerals include biotite, apatite, and rarely zircon.

The evidence bearing on the origin of the garnet gneiss is confusing. Certainly a considerable portion of the garnet gneiss has been derived from Grenville sediments. The presence of graphite and pyrite is characteristic of the Grenville series, and is taken to indicate the sedimentary origin of the bands of quartz-feldspar-biotite-garnet gneiss. The derivation of the amphibolite bands in the garnet gneiss is less certain. In other parts of the Adirondacks they have been interpreted both as altered basic igneous rocks and as altered sedimentary rocks. The writer favors the latter interpretation because of their distribution, which is widespread although in relatively small quantity and commonly in thin bands. The quartzites are clearly recrystallized sandstones, some of which were apparently argillaceous, others arkosic. The origin of the quantitatively impor-

tant quartz-feldspar-garnet gneiss is the major problem, and one regarding which the writer has not formed a definite opinion. It seems assured that some layers of the garnet gneiss are recrystallized arkosic sediments, and it is possible that an origin of this kind may apply to all of the quartz-feldspar-garnet gneiss. The variation in the composition of these bands favors this hypothesis. On the other hand, this is also the rock which has apparently invaded and attacked the amphibolite bands. In addition, except for the presence of garnet, it does not differ greatly from the porphyritic granite of this quadrangle in composition and appearance. Also the local coarse crystallization of feldspar augen might be considered indicative of magmatic activity. Perhaps a hypothesis which postulates the recrystallization of arkosic sediments at high temperature in the presence of injected magma and magmatic solutions, will reconcile the apparently conflicting data.

GRANITE-SYENITE-GRENVILLE MIXED GNEISSES

The mixed gneiss symbol has been used to designate on the geologic map those areas in which Grenville sediments and probably mafic igneous rocks are so intimately involved with siliceous intrusives that an attempt to separate them into various rock types would have necessitated mapping on a smaller scale. These rocks are all migmatites in a broad sense of the term, and indeed injection gneisses and reaction gneisses are fairly abundant. In many places, however, sediments and amphibolite have been merely intruded by small sills of granite or syenite. Commonly in such areas successive outcrops consist alternately of host rock and intrusive, so that separate mapping of them is impossible.

The mixed gneiss area along the north edge of the quadrangle might well have been mapped as granite, dominantly a pink equigranular facies. Outcrops of injection gneiss, amphibolite, granular diopside rock and syenite, however, were observed at scattered localities within the area. As the extent of these rocks and their relations to the granite were not determined, the entire area has been designated as mixed gneiss.

Typical equigranular quartz syenite is an important constituent of mixed gneisses only in the large area north of Metcalf lake and T lake. Equigranular pink granite is also abundant. The host rock is largely amphibolite, with which are associated sparse acidic layers, diopside rocks and a zone of garnet gneiss near the north boundary of the area. Although lit-par-lit injection of the sediments is not exceptional, the invading syenite and granite magma has been largely



Figure 4 Mixed gneiss in Morehouse Lake area. Banded amphibolite (upper half) and porphyritic granite (lower half) are crosscut by vane sheets of pink aplite.

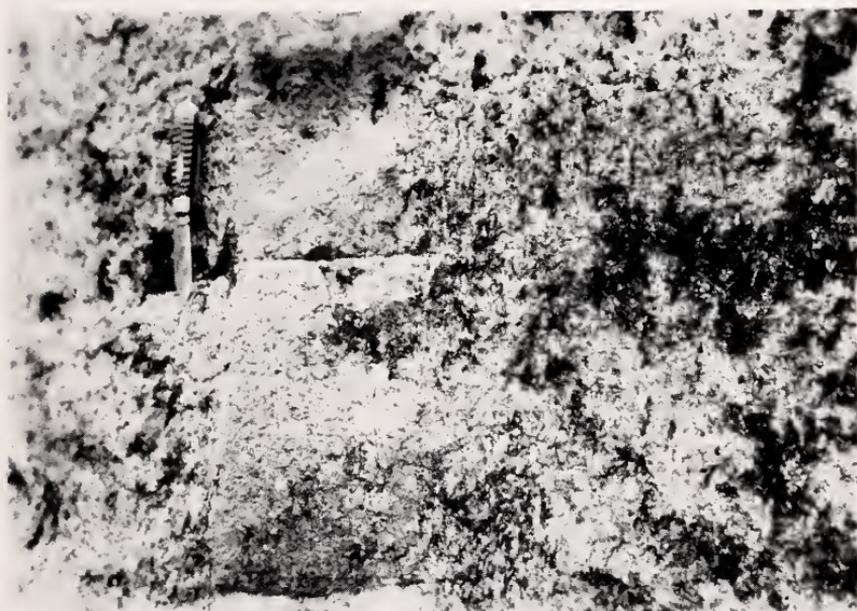


Figure 5 Banded porphyritic granite whose origin is attributed to replacement of Grenville sediments. The tabular feldspar crystals, thought to be porphyroblasts, are crushed much less than is usual in this quadrangle. In this exposure one of the feldspar crystals lies at an angle to the banding and cuts directly across the sharp contact of the fine-grained band.

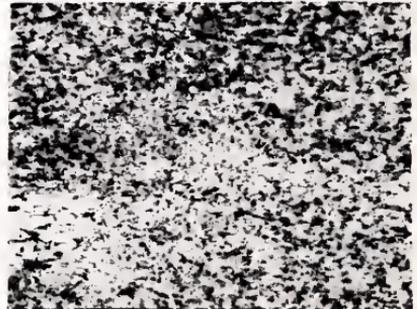
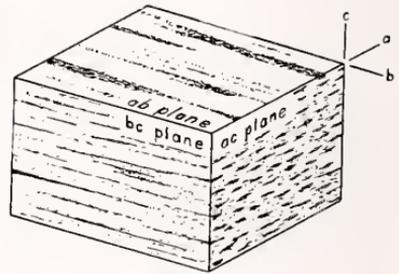
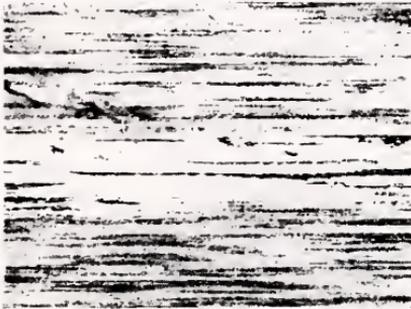


Figure 6 A block of equigranular granite polished on three sides at right angles to one another to show the gneissic structures. The diagrammatic sketch at upper right illustrates the relations of the three photographs. Specimen from Spy Lake granite mass. About two-thirds natural size.

intruded as innumerable small sills ranging in thickness from a few inches to several hundred feet. Considerable areas of amphibolite and smaller areas of garnet gneiss which are relatively free of the acid intrusive rocks have been mapped separately.

Throughout the mixed gneiss areas of the southern Grenville belt porphyritic and equigranular granites predominate. Fine-grained syenitic rocks are also present in small quantity, but these differ from the typical equigranular quartz syenite, both in structural and mineralogical characteristics. They are thought to have formed by reaction between granite magma and intruded Grenville rocks. Amphibolite is relatively and quantitatively much less abundant than in the areas north of Piseco dome. Other Grenville rocks include quartzites, quartz-feldspar-biotite gneiss and garnet gneiss.

The south contact of the Morehouse Mountain porphyritic quartz syenite is marked by a more or less continuous band of amphibolite and granite-amphibolite injection gneiss several hundred feet wide. The remainder of the Morehouse Lake mixed gneiss area is composed of alternating amphibolite, injection gneiss, and porphyritic granite. Some bodies of amphibolite are large enough to be mapped separately. Common vane sheets of aplite cut all the other rocks (figure 4). In part the granite is clearly an intrusive rock similar to the porphyritic granite of the vicinity of Piseco dome. In places, however, it is remarkably banded and variable in composition (figure 5). In the banded facies the large feldspar crystals are much less crushed than is usual in this region. It is believed that at least a part of the "granite" was originally sedimentary in nature, and that the large feldspar crystals are porphyroblasts. In one outcrop of fine-grained granitic rock a zone of feldspar porphyroblasts, not a dike, is seen to cut across the banding. Similar mixed gneisses composed dominantly of porphyritic granite underlie the area from Big Alderbed to Notch mountain and outcrop in the uncovered portion of the area east of Sand lake and south of Mud Lake mountain. The small areas on Chub Lake mountain and south of State brook (s.e.r.) are occupied by dark green coarsely porphyritic granite which contains bands of amphibolite.

In the large areas (s.c.r. and s.w.r.) which extend east and west through Oregon and the Powley Place, the intrusive material is largely fine-grained granite which seems to grade locally to fine-grained syenitic rocks of the type mentioned in an introductory paragraph. These syenitic rocks commonly appear to grade into large masses of amphibolite with which they are involved. Much of the fine-grained gneiss adjacent to amphibolite masses in the region

around the Shaker Place (s.e.r.) has the composition of syenite. This rock in turn commonly appears to grade into granite. The fine-grained granite is also involved with much amphibolite in distinct bands. In the Powley Place area of mixed gneiss, recognizable sedimentary bands other than amphibolite are unusual. In the Oregon area, however, bands and relatively large masses of quartzite and garnet gneiss are much more abundant than amphibolite. Porphyritic granite is of minor importance in these areas except in a band passing through Sugarbush and West Creek mountains.

UNDIFFERENTIATED PRECAMBRIAN

As the principal objective of this investigation has been a study of the petrology and structure of the igneous rocks, the writer did not make a detailed field study of the southern Grenville belt. Fairly careful work was done adjacent to the three roads which cross the belt: the Gloversville road (s.e.r.), the Powley Place road (s.c.r.), and the Jerseyfield road just west of the quadrangle boundary; but several large areas of less accessible territory were not visited. These areas are shown on the map as undifferentiated Precambrian in preference to projecting across them hypothetical geologic boundaries which might easily carry false implications of geologic structure.

STRUCTURAL GEOLOGY

GNEISSIC STRUCTURES

Many of the Precambrian rocks of the Piseco Lake quadrangle possess banded or platy gneissic structures which are referred to by the general name of "foliation." They possess commonly also a parallel linear arrangement of individual mineral grains or aggregates of grains which is here referred to as "linear structure." Foliation and linear structure have been found in all the Precambrian rocks of the quadrangle except the diabase of late Precambrian age. A particular specimen may show a development of either one of these structures alone, or may display a prominent development of both of them (figure 6). Where the two are present together, they are always parallel to one another: the linear streaks always lie in the planes of foliation. The term "gneissic structures" is used in this report to designate collectively these two types of structure, which in many cases are genetically related and which are so commonly associated with one another.

In a recent publication, Buddington ('34, p. 139, 141-42) reviews the progress which has been made in the interpretation of the folia-

tion in the rocks of the northwest Adirondacks. In an earlier paper, Smyth and Buddington ('26, p. 48-78) made a thorough study of the manifold origin of foliation in the Lake Bonaparte quadrangle. These two papers give a comprehensive picture of the problems which arise in connection with the origin of foliation in the northwest Adirondacks. Alling ('24, p. 13-22) has discussed certain phases of the origin of foliation in other parts of the Adirondacks. These discussions are applicable also to the problems of the foliation in the rocks of this region. Balk ('31, p. 317-23, 334-37; '32, p. 24-36) has recently attributed the origin of all gneissic structures in the rocks of the central Adirondacks to the magmatic forces accompanying the intrusion of magma, when flow planes and flow lines were developed by differential flowage movements in the magma, while similar structures were developed in the Grenville country rocks by drag of the magma against the retarding walls and by active thrust of the magma against them. Only one other interpretation for the linear structures of the Adirondack Precambrian has been suggested. In the Canton quadrangle, Martin ('16, p. 106-7) has noted the parallelism of linear structure to the pitching axes of isoclinal folds; he refers to both features by the common name of "pitch." He believes the mineral elongation to have formed under strain and recrystallization accompanying the regional compression which produced isoclinal folding.

An advance statement of the writer's conclusions regarding the origin of gneissic structures in the Piseco Lake quadrangle will serve to integrate them with the opinions of geologists who have worked in other parts of the Adirondacks. The igneous and mixed rocks of the Piseco Lake quadrangle possess important primary foliation structures developed during the intrusion and consolidation of magmas. All the gneissic rocks of the quadrangle, however, whether of igneous, sedimentary or mixed derivation, possess also secondary foliation and linear structures which are here interpreted as structures formed during regional deformation of the rocks. Compression of the earth's crust, which accompanied the intrusion of granite magma and continued after its consolidation, gave rise to folds. Dynamic metamorphism, produced by shearing stresses set up in the solid rocks, which effected the rotation, deformation and recrystallization of their constituent particles, gave rise to secondary foliation and linear structures systematically related to the folds.

Gneissic structures of the igneous rocks. In the igneous rocks of the Piseco Lake quadrangle several types of foliation have been

formed during the emplacement of the magmas. Banded structures developed during the magmatic history of the rocks seem to include primary flow banding, injection banding, banding due to reaction with or replacement of Grenville sediments, and possibly banding due to the repeated injection of magma. These different types of banding or foliation have been formed essentially parallel to one another largely because of the generally concordant mode of intrusion of the magmas into the Grenville rocks. Different types of foliation have been formed in the various intrusives. For example, in the Mud Lake Mountain sill of feldspathic and mafic rocks, the primary banding seems to be a result of gravity sorting of crystals from the magma. The magma of the Piseco Dome equigranular quartz syenite sills acquired a banded character by the disintegration of large amounts of amphibolite, now present in the rock as innumerable bands, schlieren and minute shreds, which have retained or acquired a mutual parallelism during the intrusion of the magma. On the other hand, there is no banding or foliation in the porphyritic quartz syenite of the Morehouse Mountain belt whose origin can confidently be referred to this time of intrusion. Primary foliation in the granite bodies of the region can be detected in some places by the parallel orientation of xenolithic bands and sheets of metagabbro and amphibolite (figure 3), or by the parallel orientation of tabular feldspar phenocrysts, and commonly by variations in the composition and texture of adjacent layers of the granite. Such variations in different bands of the granite may be due to flowage movements of the magma and the injection, assimilation, disintegration or replacement of Grenville sediments.

Dynamic metamorphism of the consolidated rocks, however, has superimposed a new foliation on the old, thus accentuating the older structures, but at the same time obscuring their primary character and mode of origin. The new, or secondary, foliation has been induced by dynamic metamorphism through granulation and recrystallization of the constituent minerals. This secondary foliation is shown in the rocks by flattened lenticles of granulated feldspar, by thin sheets of granulated mafic minerals, and by platy crystalloblastic mineral individuals, especially leaves of quartz and flakes of biotite. Concordant seams of pegmatite, which accentuate the foliation of the equigranular quartz syenite, probably originated at the time of this metamorphism. As a general rule, the secondary foliation is parallel to the older banded structures of the igneous rocks, although certain possible exceptions have been noted. This parallel relation of the

older and younger foliations makes it impossible to discriminate between them positively in many cases.

Linear structures in the igneous rocks definitely attributable to the flow of magma during the period of emplacement and consolidation are extremely rare. Masses of amphibolite or metagabbro, with a crudely cylindrical rather than a sheetlike form, were seen at several places in the Wilmurt Lake and Spy Lake granite phacoliths. These log-shaped masses have apparently formed by the breaking up of bands or sheets included in the granite magma, and are now oriented in accord with other linear structures in the adjacent granite. Cases of this sort are extremely exceptional, however, and for the most part the linear structures in the igneous rocks are attributable to the same dynamic metamorphism which produced the later foliation. The linear structures are shown most commonly by the elongation of mineral individuals recrystallized under stress, for example, spindles or leaves of quartz, and by streaks of mineral aggregates formed by granulation of the mineral grains of the original rock, as in the case of the elongate or pencil-shaped lenses of granular feldspar derived by the granulation of a feldspar phenocryst. Other types of linear structures include grooves, flutings and fine striae on the contact surfaces of minerals and rock bands. These are commonly seen on the surfaces of quartz vane sheets, quartz leaves, granular feldspar lenticles and metagabbro sheets.

The foliation and linear structures here ascribed to dynamic metamorphism are the structures which cross the aplites and some of the pegmatites which were formed after the consolidation of the quartz syenite and granite magmas. Consequently, they can not be attributed reasonably to flowage movements of the magma. The dynamic origin of these structures is also attested by their correspondence to similar structures in the Grenville rocks. A relation noted by Balk ('31, p. 335), that the strike of the linear structures varies much less than the strike of the foliation, is easily understood when one appreciates that the linear structures are parallel to fold axes, whereas the foliation outlines the limbs of pitching folds.

Gneissic structures of the Grenville rocks. The foliation of the Grenville rocks is dominated by the original bedding of the sediments. In many places the metamorphosed sediments, including quartzite, amphibolite and garnet gneiss, where not invaded by significant amounts of magmatic material, have preserved distinctly the structure of the original stratification. In other places where the sediments are involved with much magmatic material, the struc-

ture and composition of the sedimentary layers have been inherited to some extent by the resultant mixed rocks throughout the processes of injection, assimilation and replacement. Foliation and banding of this sort is comparable to the primary foliation of the igneous rocks.

Dynamic metamorphism imposed on the Grenville rocks secondary foliation and linear structures similar to those in the igneous rocks. In the Grenville belts north and south of Piseco dome, however, the secondary foliation is in general only weakly developed. Consequently, the foliation readings for the Grenville belts indicated on the structural map are based chiefly on the older banded structures. In places where both primary and secondary foliation can be identified with confidence, the two structures are essentially parallel to one another. In many places foliation is not discernible, and the Grenville and mixed rocks may be spoken of as "pencil gneisses." In such cases the mafic rocks, metagabbro and amphibolite, show an elongation of aggregates of granulated feldspar or mafic minerals into streaks. In rocks of granitic composition the quartz forms long spindle-shaped grains. In more siliceous rocks, such as impure quartzites, the quartz may occur in honeycomb form separating pencils of feldspar, diopside, or garnet.

STRUCTURAL RELATIONS OF THE IGNEOUS ROCKS

The shapes of the igneous bodies, their relations to intruded country rock and the mutual relations of gneissic structures in intrusive and country rocks provide some basis for interpreting the magmatic and dynamic history of the region. This section is devoted to a consideration of these features, which necessarily involves the repetition of much material presented in previous parts of the report.

Anorthosite, hypersthene gabbro and olivine norite. The structural and mineralogic relations of these three rocks at Mud Lake mountain suggest the origin of these rocks by gravity differentiation from a common body of magma. All the field data procured, as well as analogy with small bodies of closely associated mafic and feldspathic rocks elsewhere, point to the conclusion that their parental magma was intruded as a sill with essentially horizontal attitude. This body of rocks has been separated from its original floor of Grenville sediments by the intrusion of granite magma. No remnant of the original roof was seen in this quadrangle, although it may still remain farther to the east in the Lake Pleasant quadrangle. The primary banding of the rock is parallel to the secondary foliation and conforms to the synclinal structure shown

by granite, quartz syenite and mixed gneisses to the north, west and south of Mud Lake mountain. Linear structures pitch toward the east essentially parallel to the axis of the syncline. The field data which favor the interpretation of a sill-like form of intrusion include the gravity relations of the rocks, the conformity of the attitude of their primary banding to the Big Bay syncline, and the manner in which their areal distribution conforms to the pitching synclinal structure.

Sheets of metagabbro, now included in the Wilmurt Lake granite near the Mountain House, were apparently intruded concordantly into Grenville sediments which have been largely disintegrated by younger granite. Similar bodies of metagabbro along the east shore of Piseco lake show at one place slight evidence of a discordant relation to granitized Grenville sediments. The structural relations of a body of metagabbro surrounded by quartz syenite on the west side of Stacy mountain are uncertain.

Quartz syenite. All bodies of quartz syenite whose form and structural relations are known with reasonable certainty are sills. This form of intrusion is shown unequivocally by the Piseco Dome sills. The inner sill outcrops in a band about 17 miles long from Panther mountain to Irondequoit mountain, which almost completely encircles the dome. Throughout this distance the thickness of the sill is remarkably constant; calculations indicate a limited range in thickness from 1000 to 2000 feet. The outer sill, which outcrops only to the north and west of the dome, is similar in regard to magnitude and regularity of thickness. The variations in thickness, which in part may be only apparent and due to inaccuracies in mapping, show no systematic relation to the structure of the dome.

The Piseco Dome quartz syenite sills were intruded into Grenville sediments. Amphibolite occurs as several large masses included in quartz syenite on the north flank of the dome, elsewhere as ubiquitous shreds and schlieren. A more or less continuous septum of Grenville country rock which separates the inner and outer sills is composed principally of amphibolite interbanded with other types of Grenville sediments. Amphibolite, more or less injected by granite, forms the roof of the outer sill along the north flank of the dome. Wherever such remnants of Grenville sediments are found close to a contact of the sills, the attitude of the contact is concordant to the structure of the sediments. Moreover, the gneissic structures in the quartz syenite are parallel to the contacts and to the gneissic structures in the Grenville country rock.

A small sill of quartz syenite intrudes hypersthene gabbro and anorthosite at Mud Lake mountain. The contacts of the quartz syenite are essentially concordant to the structure of the country rock. Gneissic structures in the quartz syenite are conformable to the contacts and are in harmony with the gneissic structures of adjacent anorthosite and gabbro. The quartz syenite and its host rocks lie on the axis of the Big Bay syncline and have been folded together into a synclinal structure.

The quartz syenite which outcrops north and south of Big bay is also a sill folded along the same synclinal axis. The sill is underlain by granite which dips beneath the north contact. It is overlain to the south and along the axis of the Big Bay syncline by granite-amphibolite mixed gneiss. The Morehouse Mountain band of porphyritic quartz syenite, which extends from the Piseco Lake fault westward into the Wilmurt quadrangle, is presumably a continuation of the same folded sill. Although most of the north contact is covered by glacial drift, at a few places granite can be seen dipping southward beneath the quartz syenite. On the knoll east of Morehouseville (Wilmurt quadrangle) quartz syenite and granite are separated by an intervening body of metagabbro. Amphibolite and granite-amphibolite injection gneiss, which dip steeply southward along the south contact of the Morehouse Mountain quartz syenite, form the roof of the sill.

The areas of quartz syenite which are shown on the geologic map in the northern Grenville belt have not been sufficiently studied to permit a detailed discussion of their structural relations. For example, the mapping of the narrow band which appears to cross the northern part of the quadrangle is greatly generalized, and the band may not represent a single continuous sill. No evidence was observed, however, which might controvert a conformable sill-like mode of occurrence of the quartz syenite in the area north of Piseco dome.

Granite. In the northwest Adirondacks, Buddington ('29) has recognized the phacolithic nature of certain granite bodies occurring on anticlinal folds. Intrusions of granite magma on the Piseco dome have clearly assumed this shape in several cases. The Wilmurt Lake granite is a saddle-shaped body occupying an axial position on the west end of the dome. The crescent-shaped area of outcrop continues westward into the Wilmurt quadrangle for at least one mile and probably much farther. The floor of the phacolith is formed by the outer quartz syenite sill, which is smoothly rounded except

for minor crenulations that appear to parallel the pitch of the major fold. On the contrary, the roof seems to pinch to a peaked fold toward the west in Wilmurt quadrangle. In the Piseco Lake quadrangle the roof is known certainly only along the north contact, where it is formed by a belt of mixed gneiss. On the axis of the fold, one mile west of the edge of the quadrangle, the calculated thickness of the granite is about 2500 feet. From the axis of the fold the granite swings around toward the northeast in the form of a tapering sheet which essentially pinches out in the vicinity of Metcalf lake. Its continuation on the south side of the dome is somewhat uncertain because of glacial drift and probable faulting along the Hoffmeister valley. It is believed, however, to continue as the granite which underlies the Morehouse Mountain quartz syenite along the south side of Hoffmeister valley.

In the sheetlike limb of the phacolith which extends toward Metcalf lake a fairly strong secondary foliation conforms to the attitude of floor and roof. In the broader axial portion of the phacolith, this type of foliation is extremely weak and difficult to detect. However, sheetlike inclusions in the granite swing around the nose of the dome in essential conformity with the nearest part of roof or floor. Linear structures, which are strongly developed throughout the mass, seem to conform in a general way to the poorly defined pitch of the fold, although they diverge somewhat toward the west.

The Piseco Mountain granite is the remnant of a phacolith cut away on the axis of the dome by erosion and to the east by the Piseco Lake fault. This remnant outcrops in a thin band south of T Lake mountain, flaring widely toward the east in the direction of the east end of the dome. The granite has been inserted between the Piseco Dome quartz syenite sills along the amphibolite septum, in part injecting and distintegrating the amphibolite. As in the case of the Wilmurt Lake granite, the floor of the granite dips less steeply than the roof, thus indicating decreasing thickness in depth or increasing thickness toward the axis of the dome. This relation must be somewhat discounted, however, because of the general increase in dip away from the dome axis; an indiscriminate application of similar reasoning would indicate a downward thinning of the quartz syenite sills.

The contact of the Piseco Dome granite with the overlying quartz syenite sill is everywhere concordant to the structure of the quartz syenite. The westward-dipping upper contact and foliation of the granite swing around the west end of the granite area in a smooth

curve that indicates a broad axial region of the dome. The granite area narrows toward the east, and just west of Piseco lake the limbs of the dome, as shown by the upper contact and foliation of the granite, rise uniformly to a sharp anticlinal crest. Although erosion has not cut deeply enough into the center of the dome to expose the floor of the granite, there can be no doubt that the granite is a floored concordant intrusive body, either phacolith or folded sill. A comparison of its structural relations with those of the Wilmurt Lake and Piseco Mountain granite phacoliths leads to the conclusion that the Piseco Dome granite is a large phacolith.

The Spy Lake granite is presumably analogous in its position and general structural features to the Wilmurt Lake granite at the opposite end of the dome. Consequently, it is considered a phacolithic body, although the evidence from this granite area alone is not conclusive. A strong linear structure is present throughout the Spy Lake granite area. Primary and secondary foliations are weakly developed, dip with extreme irregularity, and at a few places a weak secondary foliation appears to cross the primary banding at an angle. Scattered sheets of metagabbro included in the granite afford the only reliable evidence of the attitude of primary banding; elsewhere the granite contains disintegrated remnants of Grenville sediments which are commonly contorted in a complicated fashion. The secondary foliation of the granite is shown only by very slight flattening of quartz spindles. The structure of the granite is in general anticlinal, with an axis trending east-southeast parallel to the linear structure. This is believed to be a continuation of the Piseco Dome axis. The location of the axis, which the structural map indicates is not trustworthy, however, because of the questionable reliability of many foliation readings in the granite area north of Spy lake.

The small band of granite between the quartz syenite sills, at the west end of the dome just east of Signal mountain, appears from the geologic map to be a folded sill. Although this granite band has been mapped less accurately than any other granite area on the dome, the field data are sufficient to indicate that there is no significant thickening of the granite body toward the axis of the fold.

With regard to the structural relations of the granite of the mixed gneiss areas, the data obtained permit only the statement that the intrusion of granite magma appears to have been everywhere essentially concordant, and that no definite evidence points to a phacolithic rather than a sill form of intrusion.

Aplite. Aplite occurs in small sheetlike bodies in granite, or cutting other types of rocks adjacent to granite. The orientation of these sheets is essentially parallel to the linear structure of the inclosing rock. Although perhaps a majority of them are parallel also to the foliation of the country rock, many are discordant, intersecting the foliation at various angles. For these bodies the writer proposes the term "vane sheet" in recognition of their orientation parallel to an axis, the tectonic axis or linear structure of the country rock. The analogy is with the weather vane, whose orientation must conform to an axis of rotation and is further determined by local dynamic conditions. Vane sheets of aplite are com-

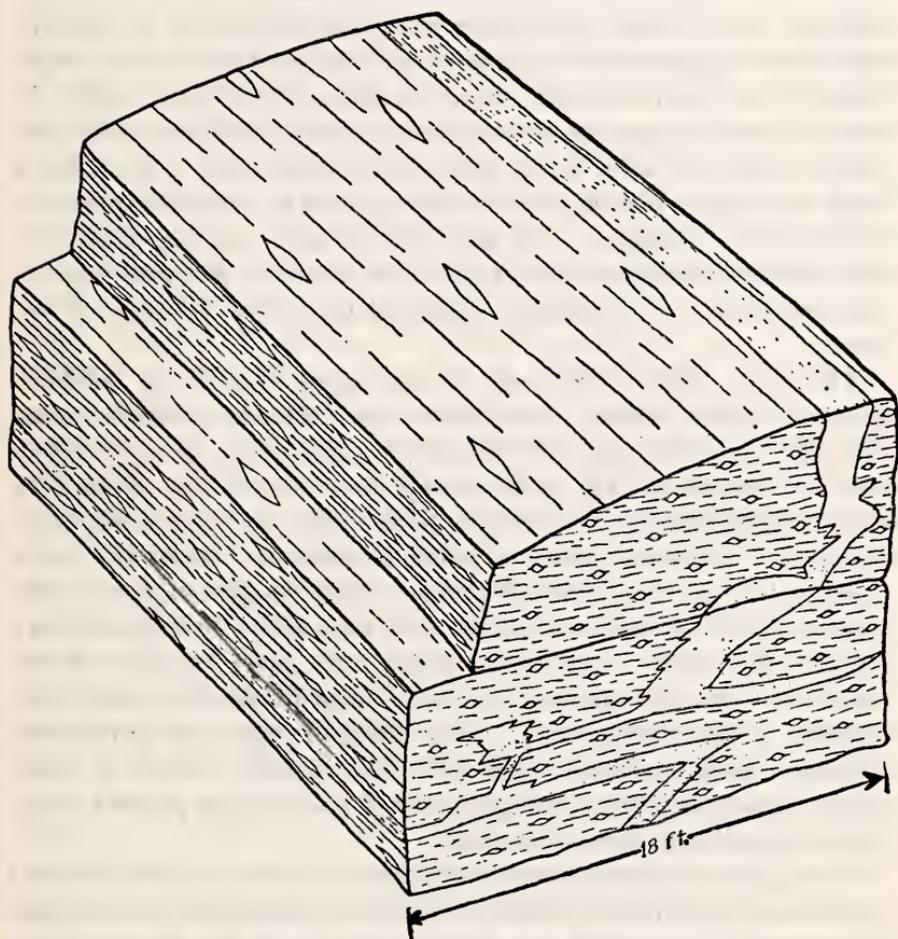


Figure 7 Irregular vane sheets of aplite cutting porphyritic granite. Note parallelism of vane sheets to structure of host rock on joint faces parallel to linear structure. Piseco Dome granite area.

mon in many of the granite and mixed gneiss areas; but especially in the granite phacoliths along the axial portion of Piseco dome they are most abundant, and many of them show well a discordant relation to foliation. Quartz and deformed pegmatite or quartzose lenticular granite also occur as vane sheets. Generally they are only an inch or two wide, and are much less abundant than the aplite with which they share a common distribution.

A majority of the vane sheets are regular tabular bodies with considerable continuity. Others bifurcate, curve irregularly or show marked variation of width (figure 7). Generally at a single locality the vane sheets occur in one or two sets. Examples of two intersecting sets of vane sheets have been described from several localities (p. 19). Where vane sheets cross the foliation of the country rock, there is generally no discernible offset of bands which might indicate shearing movements along the plane of the vane sheet. In the Wilmurt Lake granite area at the west end of the dome where the granite generally lacks visible foliation, in some cases it possesses a weak secondary foliation adjacent and parallel to vane sheets regardless of their orientation. An east-west foliation reading plotted on the structural map, near the axis of the dome at the west edge of the quadrangle, was obviously measured on a local foliation of this sort.

The vane sheets have been formed along fissures in solidified granite or older rocks. The country rock already possessed foliation and linear structures in some degree at the time of aplite intrusion. Consequently, the aplite magma was injected and crystallized during the period of deformation, because the aplite itself has been deformed. A strong linear structure is generally shown by quartz spindles in the aplite, oriented parallel to the linear structure of the country rock. Where the country rock possesses a strong secondary foliation in addition to linear structure, the quartz spindles of the aplite are generally flattened to form a weak foliation parallel to the foliation of the country rock. Vane sheets of pegmatitic granite and of quartz have also been deformed. The contact surfaces of many quartz vane sheets are strikingly grooved and striated parallel to the local orientation of linear structure.

Although the exact dynamic significance of the fractures followed by the vane sheets is uncertain, there are two factors which may have cooperated in controlling the axial orientation of the fractures. In the concomitant period of deformation, the country rock had already acquired a linear *structure*, whose presence would favor fracture along any planes parallel to it. The fractures were apparently devel-

oped in response to a change in the intensity of the forces which folded the rocks and produced in them gneissic structures both before and after the time of formation of the vane sheets. Consequently, there may have been also a dynamic control along a principal *direction of stress*, the tectonic axis, which occupies a position parallel to the local orientation of linear structures.

Pegmatite. Sharp-walled bodies of pegmatite of at least two different ages, which are found cutting granite and adjacent rocks, were formed after the consolidation of the granite. The Wilmurt Lake granite and included sheets of metagabbro are cut by thin vane sheets of quartzose lenticular granite, supposedly pegmatitic material which has been strongly deformed so that it now possesses a strong linear structure parallel to that of the inclosing gneiss. In this same granite area pegmatite dikes occupy a cross-joint position normal to the linear structure of the adjacent gneiss. In most cases these pegmatites have been deformed together with the country rock, so that the quartz forms leaves or spindles and the feldspar crystals are somewhat granulated. The pegmatite, however, is decidedly less deformed than the country rock; for example, phenocrysts in granite may have been completely reduced to lenticular aggregates of granular feldspar, whereas the feldspar in adjacent pegmatite may show only incipient granulation. In the body of metagabbro on the knoll east of Morehouseville (Wilmurt quadrangle) coarse pegmatite dikes normal to linear structure are accompanied by a series of vane sheets (or dikes parallel to linear structure) of similar coarse pegmatite, which also display a weak linear structure. Clearly these pegmatites have been deformed together with the granite or other gneiss which they cut, although deformed in smaller degree.

Pegmatites of later age are somewhat more widely distributed throughout the north half of the quadrangle. These dikes occupy diagonal positions with respect to linear structure, with which they make angles of approximately 45° . The pegmatite of the diagonal dikes is massive and shows no sign of foliation or linear structure. In a number of cases, however, the linear structure in the country rock for a width of an inch or more along either side of the dike is dragged as though by differential movement along the fissure adjacent to which the country rock had somehow been rendered plastic.

Concordant seams of pegmatite are characteristic of the equigranular quartz syenite and occur also at some places in equigranular granite. The concordant seams are in some places accompanied by

ragged discordant pegmatite veins with indefinite boundaries against the host rock. Irregularities of foliation are commonly associated with these veins. Balk has figured apparently similar phenomena from the Newcomb quadrangle ('32, figs. 2 and 3). The foliation and linear structures of the country rock appear not to cross the discordant pegmatite veins. Some of the concordant seams, studied in thin section, show very slight dynamic effects, such as granulation of feldspar. Although the discordant bodies have not been studied petrographically, they are apparently similar.

These facts do not seem in accord with other data which suggest that the quartz syenite magma had consolidated prior to the major deformation. It may be that during deformation pegmatitic liquid was formed by partial anatexis of adjacent quartz syenite, was segregated into veinlets and crystallized toward the end of the period of deformation. This suggestion gains some credibility from the fact that concordant pegmatitic seams of coarse-grained aggregates of minerals indigenous in the host rock are common also in several other types of rock, for example, in metagabbro and even in amphibolites to which a sedimentary origin is assigned. A metamorphic origin, however, is suggested for these seams and veinlets of pegmatite in the quartz syenite and other rocks of the Piseco Lake quadrangle, less because of petrologic evidence than because it appears to be the only explanation consistent with the structural data.

Diabase. Vertical dikes of diabase, the youngest of the Precambrian rocks, cut across the structure of all the older rocks. The dikes have been intruded along preexisting joints and faults. All observed diabase-country rock contacts trend between northeast and north. Topography indicates a similar trend for other dikes whose contacts are not exposed; for example, the diabase outcropping along the Powley Place road at the Notch (c.r.). In the adjoining Lake Pleasant quadrangle, five of six dikes strike in a northeast direction (Miller, '16, p. 30). Apparently a tensional stress in the local crust in late Precambrian time acted in a west to northwest direction and favored the intrusion of diabase magma along north to northeast fissures.

FOLDS

In the Piseco Lake quadrangle, the belts of Precambrian rocks and the gneissic structures of the rocks trend in general from west to east. The linear structures depart from this direction only in exceptional cases by as much as 30° . On the other hand, trends of foliation and of the Precambrian formations deviate much more widely from

this direction, especially around the noses of pitching folds, where they swing 180° through a north-south direction. The fold axes share a general east-west strike and gentle eastward pitch with the linear structures.

The major structural feature is the Piseco dome, an anticlinal dome whose axis crosses the quadrangle in a general east-west direction in the vicinity of $43^\circ 25'$ north latitude. Smaller folds, the Big Bay syncline and a parallel anticline, flank the dome on the south. To the south of this anticline lies the southern Grenville belt with a general synclinorial structure. In the southern two-thirds of the quadrangle, south of the axis of the dome, the foliation dips predominantly toward the south. On the north side of the dome is the northern Grenville belt, also with a general synclinorial structure. In the northern third of the quadrangle the foliation dips predominantly toward the north.

Piseco dome. The axis of this major anticlinal dome is indicated both by a zone of reversal of foliation dips and by the trend and pitch of the linear structure. The axis trends in a general east-west direction, but is triply curved with a central convexity facing north and distal convexities facing south. From the apex of the dome the axis pitches gently westward; it next turns toward the southwest, steepening to a pitch of about 25° ; and near the edge of the quadrangle returns to a westward trend and a gentler pitch of about 10° . In the opposite direction the axis pitches gently east-southeastward from the apex of the dome; turns slightly toward the southeast with a pitch steepening to nearly 10° ; and on the west shore of Piseco lake returns to its former direction and nearly horizontal attitude. On the east side of the lake, the continuation of the axis is offset nearly one and one-half miles to the north. Evidence of major faulting along Piseco lake, cited elsewhere in this report, indicates downthrow of the east side without important horizontal movement. Consequently, the northward shift of the axis of the dome on the east side of the lake, if accomplished by dominantly vertical differential movements on faults trending north-northeastward, should indicate a southward dip of the axial plane of the dome. It is notable that the relations between curvature and pitch of the axis described in this paragraph suggest the same relation.

Because of the variation in shape of the various granite phacoliths, the configuration of the dome is different at various "stratigraphic" horizons. The details of form of the various phacoliths have been presented, and will not be repeated here. Ignoring for the moment

the effect of the shape of the phacoliths on the configuration of the dome, we can draw some generalizations from the orientation of foliation alone. Throughout a large central area surrounding the apex of the dome foliation dips are gentle, generally less than 20° . South of the apex the southward dips increase uniformly to 35° on the north side of Hoffmeister valley at a distance of three miles from the axis. Toward the north, the northward dips of the foliation steepen to about 50° at a distance of two miles from the axis. This is another independent indication of asymmetry of the dome, suggesting again a southward-dipping axial plane. The orientation of foliation on the north limb is much less regular than on the south limb, in part due to curving about lenticular masses of amphibolite, and possibly in part due to minor cross folds. Along the axis of the dome, and especially at the ends of the dome, foliation in the granite phacoliths is extremely weak, very irregular, and is apparently folded into minor crenulations. It is considered advisable to summarize the salient features of the dome:

1 The dome is underlain by granite and quartz syenite, with very little Grenville in comparison with the Grenville belts.

2 The structure of the dome is remarkably regular in comparison with the structure of the Grenville belts.

3 The axial uplift of the dome is a result both (*a*) of the folding of consolidated rocks as shown by the quartz syenite sills, and (*b*) of the intrusion of granite magma as phacoliths thickest along the axis of the fold.

4 A broad, flat, axial region at the apex of the dome pinches to anticlinal folds toward the east and the west (figure 8).

5 Strike and pitch relations of the axis, an apparent offset of the axis by vertical movement on a normal fault or faults, and asymmetric dips on the limbs indicate an asymmetric dome with southward-dipping axial plane.

6 Linear structures in the gneisses are essentially parallel to the axis of the dome, both as to strike and pitch.

7 There is a general parallelism between primary and secondary foliation and the contacts between different types of rocks, with possible exceptions only at the pinched ends of the dome.

8 Linear structures are especially strong along the axial region; for example, a large majority of all readings of linear structure made in the Piseco Dome quartz syenite sills are from the west end of the dome where the sills swing around the end of the fold.

9 Foliation is weak along the axial region, especially in the pinched granite phacoliths at the ends of the dome.

10 Where the foliation is discernible in the granite phacoliths at the ends of the dome, it is commonly irregular and folded in minor crenulations parallel to the major fold.

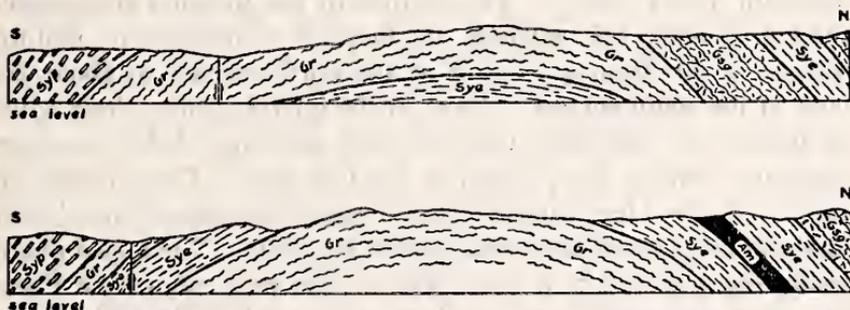


Figure 8 Structure sections across Piseco dome. The lower section from Sheriff Lake outlet north to the triple peak north of T Lake outlet crosses the flat apical region of the dome and shows the Piseco Dome granite mass. The upper section, which extends from Fourmile brook north along the west edge of the quadrangle nearly to Metcalf brook, shows the pinching at the west end of the dome; the granite body in this section is the Wilmurt Lake phacolith underlain by the upper Piseco Dome quartz syenite sill. Vertical scale not exaggerated. Legend: Gr = granite; Sye = equigranular quartz syenite; Syp = porphyritic quartz syenite; Am = amphibolite; Gsg = granite-syenite-Grenville mixed rocks.

Big Bay syncline and anticline. A synclinal axis extending through Big bay, Mud lake and Mud Lake mountain, from the Piseco Lake fault in a direction S. 80° E. into the Lake Pleasant quadrangle, is indicated by foliation and by the areal distribution of the rocks on Mud Lake mountain and of the quartz syenite north and south of Big bay. The foliation and outcrop pattern of these rocks also indicate that the axis pitches 5° to 15° toward the east parallel to the linear structure. Although only meager data are available for the south limb, the fold is apparently symmetrical, with both limbs dipping about 30° and flattening toward the axis.

The Big Bay syncline is paralleled by an eastward-pitching anticline less than three-fourths of a mile to the south. The anticline is decidedly asymmetric. Its north limb has been described above as the gently dipping south limb of the Big Bay syncline. For two and one-half miles east of the Piseco Lake fault its south limb dips from 85° to 65° south, although a few measurements made near the east edge of the quadrangle apparently indicate that the angle of dip decreases toward the east. The quartz syenite of Big bay shows no discernible foliation where it is folded into this sharp anticlinal structure.

The Morehouse Mountain quartz syenite west of the Piseco Lake fault can scarcely be interpreted otherwise than as the continuation of

the quartz syenite sill east of the Piseco Lake fault, which is folded along the axis of the Big Bay syncline and anticline. It is evident, then, that these fold axes must continue toward the west in the Morehouse Mountain quartz syenite. The attitude of the foliation alone would scarcely indicate this relation, as there is a moderately uniform increase in dip from 40° south at the north contact to about 80° south at the south contact. Zones in the quartz syenite along which the foliation is extremely weak or even indistinguishable, however, apparently indicate the position of the fold axes. The syncline and anticline in the Morehouse Mountain quartz syenite are nearly isoclinal and overturned somewhat toward the north. The folded quartz syenite sill is eroded to a lower level on the west side of the Piseco Lake fault than on the east, due both to the pitch of the folds toward the east and to downthrow of the east side of the fault. An attempt to check the structure of the Morehouse Mountain quartz syenite belt by specific gravity profiles, using methods recently developed by Buddington in the northwest Adirondacks, was unsuccessful, as gravity variations in the quartz syenite are insufficient to overshadow irregularities and inaccuracies. The results do show, however, an asymmetric variation of specific gravity from north to south across the quartz syenite in a manner not inconsistent with the writer's interpretation of the structure.

Southern Grenville belt. The cursory field examination of the Grenville belts has provided some structural data on which may be based a few broad generalizations. In the southern Grenville belt, for five miles south of the Morehouse Mountain quartz syenite, the foliation dips are uniformly southward, in general steeper than 60° . This steeply dipping belt of Grenville and mixed gneisses is either a homocline dipping toward the south or a belt of isoclinal folds overturned toward the north. The latter interpretation seems the more probable one, in view of the isoclinal folding in the adjacent Morehouse Mountain quartz syenite and on the basis of drag folds seen in the Grenville rocks.

In a belt two to three miles wide across the south end of the quadrangle, similar rocks are folded in fairly open anticlines and synclines, whose limbs dip generally less than 45° and which pitch 5° to 20° toward the east. It is believed that there is a transition from this zone of relatively open folding northward into the zone of supposed isoclinal folding. There are indications that the southernmost of the major garnet gneiss belts (s.w.r. and s.c.r.) has a synclinal structure, tightly folded toward the west but opening up toward the east. The

great north-south extent of garnet gneiss from Avery's Place to State brook (s.e.r.) is thought to be the eastward continuation of this belt involved in a series of rather open folds which pitch toward the east.

Northern Grenville belt. From the Wilmurt Lake granite phacolith to the northwest corner of the quadrangle, a succession of Grenville and mixed rocks, quartz syenite and granite strike northeast and dip 50° to 30° northwest. This is the southeastern part of the Honnedaga syncline, a large structure comparable in size to the Piseco dome. A reconnaissance survey of this corner of the quadrangle revealed no positive evidence of isoclinal folding.

The major structure to the northeast of Piseco dome is the Cold Stream synclinorium. From T lake northeast to Fall stream, the Grenville and mixed rocks are folded in a broad synclinal structure which trends in general east-west and narrows toward the west. The rocks occupying the trough of the syncline are folded into minor open folds whose trend varies from east-west to east-southeast.

Even less is known of the structure of the area between the Honnedaga syncline and the Cold Stream synclinorium. Throughout this area gneissic structures are only weakly developed, the reliability of determinations of foliation and linear structure is uncertain, and many apparent discrepancies among the meager structural data obtained remain unexplained. Apparently there are two possible interpretations of the character of the transition from synclinorial structure in the east to homoclinal structure in the west corner of the quadrangle. Either the Cold Stream synclinorium becomes more tightly compressed toward the west, and passes into isoclinal folds overturned toward the Piseco dome; or else the synclinorial structure plays out toward the west and gives way to a more regular homoclinal structure dipping uniformly toward the Honnedaga syncline.

JOINTS

The north-south compression of the local portion of the earth's crust, which folded the rocks of the quadrangle into east-west folds and which induced in them secondary gneissic structures, did not cease abruptly. Late in this period of deformation, as the stresses decreased and the temperature of the rocks declined, there came a time when the rocks could no longer yield by movements and rearrangements affecting the individual mineral grains. Instead, the rocks yielded by fracturing along sets of parallel joint planes. In many cases systematic angular relations of joints to gneissic structures and folds permit an interpretation of the stresses which produced the joints.

There may have been a period of transition during which the rocks yielded alternately, first in one way and then the other. Joints formed during this period would be destroyed as a rule by renewed dynamic metamorphism of the rocks. Joints of this stage are apparently represented by the aplite, pegmatite and quartz vane sheets. Fractures developed parallel to the linear structure were filled with these materials. No barren joints have been definitely identified with the fractures occupied by the vane sheets. Unfortunately, as no statistical study of the vane sheets was made, it is uncertain whether they show any systematic relation to stress directions or structures other than the parallelism to linear structure.

Cross joints oriented normal to the local trend of linear structures are probably next in age. These joints dip steeply but with sufficient irregularity to make it impossible to decide whether they tended to form vertically or perpendicular to the generally gentle pitch of the linear structures. Cross joints are common, and a large majority of them are barren. Some of them, however, are occupied by dikes of granite pegmatite. In some cases the pegmatite dikes are crossed by the local gneissic structures. The deformation of the pegmatites, which produced in them gneissic structures parallel to the gneissic structures in adjacent country rock, indicates that these joints were developed in part before the cessation of dynamic metamorphism. The cross joints are interpreted as local tension joints formed parallel to local compression of the crust.

On the other hand, diagonal joints, which are rather common and are oriented at angles 45° or more from the linear structure, are in some places occupied by dikes of pegmatite which have not been deformed. The diagonal joints also appear to dip nearly vertically. These joints apparently occupy shear plane positions at angles of approximately 45° from the local direction of compression of the crust. In few cases, however, is there any evidence to indicate shearing movements along them. Differential movement along some which are now occupied by dikes of massive pegmatite has resulted in drag of the gneissic structures in the walls.

Common joints oriented approximately parallel to the linear structure form a set essentially complementary to the cross joints. Their significance and relative time of origin are uncertain. They may be closely related to the fractures occupied by the vane sheets, although these joints generally dip more steeply than 60° , a condition which the vane sheets do not fulfill in many cases. At the locality east of Morehouseville, joints which apparently belong to this set contain slightly deformed granite pegmatite similar to that in adjacent cross

joints, and consequently may have been formed essentially contemporaneously with the cross joints. The relations of the four sets of vertical joints, cross joints, diagonal joints and joints parallel to linear structure, are displayed best in the Wilmurt Lake granite and may be easily seen in the outcrops along the road west of the Mountain House (compare p. 18).

A set of joints is commonly developed parallel to the foliation. It is difficult to evaluate the significance of these joints, as the foliation is naturally the direction of greatest weakness of the rocks. Furthermore, they are most abundant in those places and in those rocks in which foliation is most strongly developed, as is well illustrated in the granites. Consequently, it seems possible that many of the foliation joints may be of recent origin, formed by unloading and weathering of the rocks. Nevertheless, the common occurrence of pegmatitic seams parallel to the foliation of quartz syenite and other rocks indicates that the foliation was a potential direction of fracture early in the period of joint formation. As they would only tend to confuse the picture, these joints have been omitted from the joint map of the quadrangle, except in cases where only one other set of joints occurs, especially in the zone of steeply dipping foliation south of Piseco dome.

The orientations of all joints mentioned heretofore bear systematic angular relations of some sort to the local gneissic structures. As the orientation of the gneissic structures varies from place to place in the quadrangle, one should not expect regional joint directions to show up very strongly. There is, however, one direction prominent throughout a large part of the quadrangle. From the northeast corner in a wide zone south-southwest across the quadrangle, there appears to be a distinctly preferred joint direction between north and northeast. There are many possible interpretations which might explain this regional joint direction, but the writer feels that the data from so limited an area do not afford a basis sufficient to favor any one hypothesis. Two points of tangible evidence bearing on this problem may, however, be cited: (1) north-northeast has been a direction of normal faulting at least twice in the history of the quadrangle, in Precambrian time and again in post-Utica time; and (2) locally this has been a favored direction for the intrusion of diabase dikes in late Precambrian time.

FAULTING

Piseco Lake outlier of Paleozoic rocks. In the glacial gravels around the head of Irondequoit bay pebbles of Paleozoic limestone and sandstone are common. They are especially abundant in the large

gravel pit on the northwest side of the main highway at the end of the bay (figures 9 and 10). A statistical study of 300 pebbles in this pit gave the following results: Paleozoic sandstone, 12 per cent; Paleozoic limestone, 22 per cent; Precambrian rocks, 66 per cent. Farther to the south and west a few pebbles of sandstone and chert were found only at several localities in Hoffmeister valley. The source of this material must be sought toward the northeast, the direction from which the ice sheet advanced. In the gravels around the north end of Piseco lake, however, pebbles of Paleozoic sandstone are moderately common, but no limestone is present. Careful search in many gravel pits throughout the quadrangle failed to discover the presence of any pebbles of Paleozoic rocks, except at localities in the Piseco Lake lowland and the Hoffmeister valley.

This evidence clearly indicates the presence of an outlying patch of Paleozoic limestone and sandstone somewhere between Irondequoit bay and Piseco village, presumably concealed beneath the waters of Piseco lake. Also, patches of sandstone must remain in the lowland which extends northeast from Piseco village. These outliers are comparable to the Wells and Hope outliers of Paleozoic rocks studied by Miller ('16, p. 32-45; geologic map) in the Lake Pleasant quadrangle to the east.

Many of the limestone pebbles from the gravel pit at the head of Irondequoit bay are fossiliferous. Dr Rudolf Ruedemann has kindly examined a small number of specimens containing graptolites from this locality and has communicated the following information:

The limestone pebbles from Piseco lake which you sent to me contain (see N. Y. Mus. Bull. 162):

Diplograptus (*Mesograptus*) *mohawkensis* Rued.

Diplograptus (*Amplexograptus*) *amplexicaulis* (Hall), small variety.

Rafinesquina, fragments.

Dalmanella, fragments.

Calymene, fragments.

Primitiella unicornis Ulrich

Ulricha? *bivertex* Ulrich

That is a lower Canajoharie fauna, of Trenton age. It seems that the pebbles represent a transition from the Trenton limestone to the Canajoharie beds, comparable to Cushing's Dolgeville beds.

It should be pointed out, however, that only those specimens were sent to Doctor Ruedemann for examination which contained graptolites. Hence, they are not truly representative of all the limestone pebbles derived from the Piseco Lake outlier, and it is possible that



Figure 9 Gravel pit along main highway near head of Irondequoit bay (c.r.) in which approximately one-third of the pebbles are Paleozoic limestone and sandstone



Figure 10 Detail of figure 9, showing one of the gravel lenses in Pleistocene kame or delta deposits which contain the pebbles of Paleozoic sediments



Figure 11 View of Panther mountain looking westward from the east side of Piseco lake. The low lying area at the extreme left is granite, overlain to the right by the sill of quartz syenite which constitutes Panther mountain. The gentle northward slope and the steep southward slope of the mountain are respectively dip and scarp slopes controlled by the northward dip of the sill and its foliation



Figure 12 View of Panther mountain looking southeastward from T Lake mountain, showing the well-developed dip and scarp slopes

the outlier contains other limestones in addition to the transition beds.

The sandstone of the Piseco Lake outlier is not fossiliferous, and its age is uncertain. Analogy with near-by Paleozoic sections and the occurrence of sandstone pebbles at the head of Piseco lake unaccompanied by limestone, suggest that the sandstone underlies the limestone and is the oldest of the sediments deposited in this quadrangle in early Paleozoic time. Lithologically it is similar to typical Potsdam sandstone. However, it may be either of late Cambrian or of Ordovician age.

Evidence of faulting. Many lines of evidence indicate the presence of normal faults of important magnitude in the Piseco Lake quadrangle. The outlier of Paleozoic limestone and sandstone in Piseco lake, lying about 1200 feet below the level of neighboring peaks formed of Precambrian rocks, can be explained only by normal faulting. An important fault, occupied by a large dike of diabase, is exposed at one place just beyond the edge of the quadrangle. Large diabase dikes elsewhere may indicate the location of fault planes. In the glacial deposits of the Piseco Lake and Hoffmeister Valley lowlands, erratic boulders of diabase and fault breccias occur in much greater abundance than one would anticipate from the limited exposures of these rocks. Shear zones, areas of shattered bedrock and zones of fault breccia are found in outcrops close to probable faults. Changes in structure and abrupt changes of bedrock along the strike are coincident in some cases with locations of probable faults. The topography of the quadrangle affords evidence of fault lines and fault blocks. In some cases a fair estimate of the direction and magnitude of fault movements in post-Utica time can be obtained from the topography. Specific details of the evidence of faulting are cited below in the descriptions of individual faults. A detailed discussion of the pertinent physiographic evidence is included in a subsequent section which deals with the physiography of the quadrangle.

Age of faulting. An exposure in the Lassellville quadrangle one mile S.35°W. from House pond (s.w.r.) affords some indication of the age of faulting. A large diabase dike trending N.35°E. occupies a fault along which there has been sufficient movement to bring different kinds of rock into juxtaposition. Movement occurred along this fault before the intrusion of the dike and occurred again afterward, shearing and brecciating the diabase. In one exposure a fault breccia has been cemented by the penetration and solidification of diabase magma; subsequent movements have shattered the healed breccia,

both the fragments of gneiss and the interstitial diabase. The only other evidence of the age of faulting is derived from displacements of the Paleozoic sediments. In the Piseco Lake quadrangle, limestone of Trenton age is the youngest rock involved in fault movements, but related faults in the Little Falls quadrangle to the southwest cut the Utica shale. This evidence indicates that fault movements occurred at least once in Precambrian time before the intrusion of diabase, and occurred at least once after Utica time. There is no evidence which determines whether there have been more than two periods of faulting.

Character of faulting. The fault pattern, shown by the faults on the geologic map, is apparently related to the major fold axes and trend lines in a manner analogous to the relation of joint sets to local linear structures. A northeast to north-northeast set of diagonal faults is represented by the Piseco Lake fault and the West Canada Creek fault. A northwest to north-northwest diagonal direction of faulting is shown by the Clockmill Corners-Kennels Pond fault and by the Brayhouse Brook fault. The Hoffmeister Valley fault trends east-west essentially parallel to adjacent fold axes. Although the Big Alderbed-Jockeybush Lake fault cuts at a small angle across the trend of the rock belts, its trend is essentially parallel to the strike of linear structures in adjacent gneisses. These three sets of faults appear comparable to three of the four sets of local vertical joints. There is no indication, however, of a set of cross faults trending at right angles to the fold axes.

Direct evidence of fault movements in Precambrian time has been discovered only in the case of the House Pond fault, and even in this case it was found impossible to determine the direction of movement. There is direct evidence, however, of the character of the fault movements which have occurred since Utica time. Physiographic evidence indicates that the post-Utica fault movements consisted essentially of a vertical shifting of small fault blocks, commonly only a few miles in diameter. The movements at this time resulted generally in downthrow of the east side of the faults. There was much irregularity of movement, however, and in a number of cases adjacent blocks which lie on the same side of a fault behaved quite differently. Presumably, in such cases the long straight faults which form a common boundary of several fault blocks are older faults developed before the post-Utica faulting. This suggestion implies that the essentials of the fault pattern were developed by the Precambrian faulting. Little more can be learned of the faulting, and of the forces which caused it, from the study of so small an area.

Piseco Lake fault. This fault is indicated from the northeast corner of the quadrangle to Mud pond (c.r.) by a well-developed trough line¹ which separates highlands to the west from a relatively low-lying area to the east. These topographic relations indicate that in post-Utica time the east side has moved downward with respect to the west side. The evidence of the Piseco Lake outlier necessitates a minimum throw at one place of about 1200 feet. Down-faulting of the east end of Piseco dome has displaced the axis northward and has brought down the Spy Lake granite, analogous in its structural position to the Wilmurt Lake phacolith, to a position opposite the Piseco Dome quartz syenite sills. Relations at the south end of Piseco lake are obscure; the fault here may intersect a continuation of the Hoffmeister Valley fault, or it may branch (compare Miller, '16, p. 56-57), sending a fork northeastward along the east side of Piseco lake through Rudeston. The upper contact of the quartz syenite sill on the axis of the Big Bay syncline has been brought down in juxtaposition with a lower horizon in the folded sill on the west side of the fault. The steeply dipping south contact of the quartz syenite sill has been offset more than two-tenths of a mile to the north on the east side of the fault. This offset is accounted for in part by the vertical movements, but apparently it implies in addition a slight shift of the east side northward. A small fault breccia zone in garnet gneiss exposed in the road north of Mud pond is considered an auxiliary fault adjacent and parallel to the main fault. Apparently the Piseco Lake fault ends abruptly to the south against the Clockmill Corners-Kennels Pond fault.

Notch fault. This fault is parallel in orientation to the Piseco Lake fault, and possibly a continuation of it. Its interpretation is based solely on the trough line which extends from Clockmill Corners to Brayhouse brook, and on the outcrops of a large diabase dike along the Powley Place road. Topographic indications of downward movement on the east side of the fault are much less marked than in the case of the Piseco Lake fault. To the northeast the Notch fault may end abruptly against the Clockmill Corners fault, or it may continue to join the Piseco Lake fault. Its intersection with the Big Alderbed-Jockeybush Lake fault is the locus of an important topographic depression filled with lake beds; consequently, the relations of the faults at the intersection are not known.

House Pond fault. This fault is in line with the Piseco Lake fault to the northeast, and lies approximately along the extension of that

¹ A relatively straight line of topographic depression; compare p. 85.

part of the Little Falls fault which has been mapped in the Little Falls quadrangle. Its presence has been established in the Lassellville quadrangle by actual observation of the fault zone. Elsewhere its presence is indicated by a trough line and by outcrops of the diabase dike which occupies it. Two periods of movement, before and after the intrusion of diabase, have been established for this fault. Although its termination against the Brayhouse Brook fault is hypothetical, no indication of it has been found northeast of this line.

West Canada Creek fault. The presence of this fault is indicated entirely by a striking trough line with northeast trend. South of its intersection with the Hoffmeister Valley fault, the topography indicates that post-Utica movement has downfaulted a block on the west side of this fault where the Hoffmeister valley widens southward at the west edge of the quadrangle. A low-lying triangular area in the northeast angle between these two faults is probably also downfaulted. From the center of Piseco dome northeastward, the continuation of the rectilinear valley affords the only evidence for a fault line. The altitudes of the highlands on either side of the fault are approximately equal, and there is insufficient offset of the Piseco Dome quartz syenite sills to be detected with certainty by mapping on this scale.

Mud Lake fault. The presence of a fault of rather small throw trending northeastward through Mud lake (e.c.r.) is suggested by an apparent offset of the lower contact of the Mud Lake Mountain sill with underlying granite, and is corroborated by topographic evidence. However, there is no appreciable lateral offset of the axis of the Big Bay syncline.

Clockmill Corners-Kennels Pond fault. The northwesterly trough line which indicates this fault follows the northeast foot of a steep fault line scarp from Clockmill Corners to Avery's Place, whence it passes between Sherman mountain and Trout Lake mountain to the southeast corner of the quadrangle. The valley of the West Branch of the Sacandaga river, south of Avery's Place, may occupy a branch of this fault. At no place along its course have lateral offsets been definitely established, although a probable displacement of amphibolite and garnet gneiss at the southeast end of Kennels pond has been indicated on the geologic map.

Brayhouse Brook fault. This fault also is postulated because of the evidence of a trough line. The character of the topography indi-

cates relatively downward movement on the east side of the fault, from its intersection with the House Pond fault northwestward to the Big Alderbed-Jockeybush Lake fault.

Hoffmeister Valley fault. Bedrock evidence for this fault is more clear-cut than the physiographic evidence. In this case the mere presence of a large rectilinear valley can not be considered evidence of faulting, as the valley is crudely parallel to the strike of the bedrock. Nevertheless, it is significant that each of the two low-lying triangular areas mentioned in connection with the West Canada Creek fault is bounded on one side by this trough line. At the west edge of the quadrangle there is striking discord in the orientations of the gneissic structures on the north and south sides of the valley. On the north side foliation strikes about N.55°W., linear structure pitches 10° to 15° in a direction S.68°W. On the south side of the valley, foliation strikes slightly north of east, linear structure pitches a few degrees toward the east. Further evidence is afforded by the abrupt disappearance of the outer Piseco Dome quartz syenite sill at the intersection of this fault with the West Canada Creek fault. As this sill is continuous for about 13 miles around the north and west sides of the dome without marked variation in thickness, an abrupt lateral pinching out of the sill fortuitously coincident with the intersection of two faults is improbable. Obviously the sill has been cut out along the south side of the dome by relatively downward movement on the south side of the Hoffmeister Valley fault. The granite exposed at a few places along the south side of the valley is the continuation of the Wilmurt Lake phacolith on the south side of the fault.

Big Alderbed-Jockeybush Lake fault. The continuity of the Big Alderbed-Jockeybush Lake trough line across the entire width of the quadrangle strongly suggests the presence of a fault. As there is in this case, however, little evidence for vertical faulting since Utica time, the fault movements must have occurred largely in Precambrian time. At the west edge of the quadrangle, a large diabase dike of undetermined trend outcrops in the bottom of the trough line valley. This dike may have been intruded along the fault plane, even though following a direction unusual in this quadrangle. Critical points near Big Alderbed, where evidence of displacements of bedrock might be obtained, were not studied in sufficient detail. The relations shown on the geologic map near Avery's Place, involving displacements of amphibolite and garnet gneiss and of the Clockmill Corners-Kennels Pond fault, are somewhat hypothetical. The assumption

of these relations, however, does explain satisfactorily the field data obtained in this area.

MICROSTRUCTURE

In addition to the customary petrographic examination of the rocks, a qualitative examination of the orientation of the dimensional and crystallographic axes of the constituent minerals of several specimens was attempted. This procedure was suggested by work which has been carried forward in Europe in recent years, especially by the Austrian geologists, Sander and Schmidt. Petrofabric analysis¹, the name by which their method for interpreting the structural history of a rock or region is commonly known, is based on statistical analysis of megascopic and microscopic structural data. The writer has not attempted a statistical petrographic analysis of the rocks of the Piseco Lake quadrangle. It was hoped that examination of carefully oriented thin sections might yield merely a qualitative indication of mineral orientation which might be compared with the statistical results of petrofabric investigators.

For this purpose an examination was made of three different kinds of rocks; a porphyritic granite from Notch mountain (c.r.), an equigranular granite (figure 6) from the Spy Lake granite mass (e.c.r.), and a lenticular quartz syenite from the small area one mile south of Rudeston (n.e.r.). In each case three thin sections were taken from the same specimen: one parallel to the foliation (*ab* plane), another normal to the foliation but parallel to the linear structure (*bc* plane), and a third normal to both structures (*ac* plane). The foliation and linear structure here referred to are in all cases the secondary gneissic structures whose origin the writer attributes to dynamic metamorphism. The results which are obtainable by this method are essentially the same for all three rocks.

The grains of some of the minerals are elongated and oriented with systematic relations to the gneissic structures. Much of the quartz in these rocks forms leaf-shaped grains which afford the most striking example of orientation of dimensional axes. Even in hand specimens the quartz leaves are obviously flattened parallel to the foliation, and are remarkably elongated and ribbed or fluted parallel to the linear structure. In the thin sections oriented parallel to the *ab* plane the quartz leaves appear as broad bands parallel to the linear structure. In the other two sections they appear as narrow bands, remarkably straight, continuous and parallel in the

¹A recent paper by Fairbairn ('35) has made available in English a comprehensive survey of the fundamentals of this method.

bc sections, but wavy and rather discontinuous in the *ac* sections. The orientation of biotite and chlorite flakes is analogous. The flakes have a general orientation parallel to the foliation, but much greater regularity of orientation is seen in the *bc* sections than in the *ac* sections. Other minerals of note in this connection are the uniaxial accessories, zircon and apatite, whose elongation (parallel to the *c* crystallographic axis) is essentially parallel to the linear structure. In the *ac* sections these minerals generally appear equidimensional and nearly isotropic; in the other two sections they show maximum elongation roughly parallel to the linear structure.

It is possible to estimate also the preferred orientations of the crystallographic axes of these same minerals. In the case of the zircon and apatite, both dimensional and crystallographic orientations are the same; that is, their *c* crystallographic axes are roughly parallel to the linear structure. Also, the orientation of the dimensional axes of the biotite and chlorite flakes indicates the approximate orientation of their crystallographic axes. Apparently the poles of these flakes are concentrated in a girdle or partial girdle parallel to the *ac* plane with a maximum concentration approximately normal to the *ab* plane.

An appraisal of the approximate orientation of quartz axes by mere inspection is somewhat more difficult and could be attempted only in the case of the relatively large quartz leaves. Although the quartz leaves appear externally to be single individuals, each leaf is seen in thin section to be composed of a number of distinct segments, each with an independent crystallographic orientation. The walls of the segments are more or less normal to the *ab* plane, so that the *ac* and *bc* sections show the quartz leaves as long narrow ribbons divided into elongate segments, whereas the *ab* sections show them as much wider bands composed of a mosaic of grains. In all three rocks a large proportion of the quartz in the *bc* sections appears isotropic or nearly so. In the *ab* and *ac* sections very few grains show an approach to isotropism. This indicates a preferred orientation of quartz grains with their *c* crystallographic axes approximately parallel to the plane of foliation and approximately normal to the linear structure. In other words, there is a maximum clustering of quartz *c* axes more or less parallel to the *a* fabric axis.

It is of interest in this connection that the quartz of the vane sheets and of the Grenville quartzites has also been deformed and recrystallized. Although thin sections of these rocks show apparent orientation of the quartz axes, it is not known whether the orientation is the same as in the quartz leaves of granite and quartz syenite, as the orientation of the sections is uncertain.

Four sets of microscopic joints are seen in the quartz leaves in these sections. All of the sets appear roughly normal to the local foliation planes, although this relation is difficult to check merely by inspection. At any rate, the *ab* sections show a strong set normal to the linear structure and a weaker set parallel to the linear structure. In the *ab* section of the porphyritic granite, these sets are subordinate to two sets of diagonal joints which form angles varying from 45° to 60° with the linear structure. These four sets apparently correspond to the four sets of local vertical joints observed megascopically in the field.

The writer's interpretation of the dynamic history of the gneissic igneous rocks of the Piseco Lake quadrangle is based on evidence independent of the method of petrofabric analysis. Consequently, it is extremely interesting that this interpretation and the data obtained by this cursory examination of the rocks are not inconsistent with the results so far obtained by the petrofabric investigators. The apparent orientations of biotite and quartz axes in the Piseco Lake rocks are consistent with the statistical orientations commonly found in tectonites which have been subjected to regional dynamic metamorphism. Other important features common both to such tectonites and to the rocks of the Piseco Lake quadrangle include (1) the parallelism of linear structures and fold axes, and (2) the elongation of quartz grains parallel to linear structures and normal to the preferred orientation of the quartz axes. As the present study has not been placed on a statistical basis, the writer does not intend to imply that the comparisons noted above necessarily prove a dynamic history of the rocks of the Piseco Lake quadrangle similar to the history of apparently similar tectonites which have been statistically investigated.

PHYSIOGRAPHY

TOPOGRAPHY

The Piseco Lake quadrangle affords an excellent example of subsequent topography adjusted to the "grain" of the bedrock. Certain departures from an adjusted condition are attributable to the disturbing influence of Pleistocene glaciation. Many independent factors have contributed to the present character of the topography. On the one hand are qualities inherent in the bedrock: the relative resistance of the various rocks to erosion; the foliation and linear structure of the gneisses; joints, shear zones and faults. On the other hand are the external forces: erosion active throughout long periods of time; faulting, warping and changes in level of the local

portion of the earth's crust; and lastly glaciation followed by a short period of subaerial erosion. All these have contributed to the development of the current land forms.

Bedrock control—influence of lithology. In many parts of the Adirondacks the presence of large masses of Grenville marble has had a notable influence on the topography. Many areas of Grenville marble have been reduced to broad flat valleys, because the marble has offered relatively little resistance to erosion as compared with the other types of Precambrian rocks. As marble is not present in significant amount in the Piseco Lake quadrangle, differential erosion of the various lithologic types of Precambrian gneisses here has accomplished less striking results. Still there has been sufficient contrast in the response of some of the rocks to erosion to cause noticeable modifications of the topography. The Morehouse Mountain and Piseco Dome quartz syenite belts stand up above neighboring areas of granite and mixed gneisses. Another relatively resistant rock is anorthosite, which caps the several hilltops of the Mud Lake Mountain group (figure 2). In the mixed gneiss areas where granite is involved with sheets of fine-grained amphibolite or metagabbro, the mafic rock in many cases forms the higher hills.

On the other hand, granite, mixed gneisses and Grenville rocks seem to offer less resistance to erosion than do quartz syenite or anorthosite.

The most easily eroded of the Precambrian rocks is the quantitatively unimportant diabase. Narrow dikes of diabase are eroded very rapidly because of their close jointing. At the small pond near the quadrangle boundary, one mile south of the French road (w.c.r.) the outlet is by way of a miniature gorge only three and one-half feet wide and ten or 15 feet deep. Only a few fragments of fresh fine-grained diabase that remain frozen to the vertical walls betray its origin by differential erosion. In the bottom of the valley followed by the Powley Place road through the Notch (c.r.) are several outcrops of diabase. At this place, however, factors other than the presence of diabase may have been effective in determining the site of the valley.

In one other connection differential erosion of rocks has had a pronounced effect in shaping the topography. Paleozoic sandstones and limestones are eroded very easily as compared with the Precambrian rocks. The presence of Paleozoic sediments in the basin of Piseco lake has been shown. These rocks were presumably once continuous over the adjacent lowland, and the depressed area has been formed by their rapid removal.

Foliation. The foliation of the gneisses commonly controls the trends of ridges and the steepness of their slopes. This effect is well shown by comparison of the topography of the Morehouse Mountain and Piseco Dome quartz syenite belts. The uniform and rather massive porphyritic quartz syenite of the Morehouse Mountain belt possesses a weak foliation. On this rock is developed a rounded topography with smooth-flowing contours; its hills show only a very slight tendency toward elongation parallel to the strike of foliation. Contrast this behavior with that of the equigranular quartz syenite of the Piseco Dome belt, which has a moderately strong foliation. The topographic map shows an oval of ridges which trend parallel to the strike of the belt; this is also the foliation trend. This development of valleys and ridges parallel to the trend of foliation is characteristic of nearly the entire highland area of the north half of the quadrangle. It is well exemplified by the case mentioned above and by the ridges farther northwest which outline the southeast limb of the Honnedaga syncline.

In most of these ridges the foliation dips are greater than 30° and the slopes of the ridges are more or less similar to one another. Where the foliation dips are less than 30° , however, as at the ends of the elongate Piseco dome, the ridges possess noticeable dip and scarp slopes. This is particularly well shown by the Signal Mountain ridge at the west end of the structure. It is shown also by Panther mountain (figures 11 and 12) at the east end of the structure, although the structural conditions here are more complex. The ridges of Piseco mountain and its neighbor, Stacy mountain, which trend north-northeastward, are controlled by joints. The *ridge crests* have scarp and dip slopes, very abrupt scarp slopes at the southwest end and comparatively gentle dip slopes from the peaks northeastward (figure 13).

Linear structure. Balk ('32, p. 76-77) has shown that certain features of the topography of the Newcomb quadrangle have been influenced by linear structure in the gneisses. In view of the strong linear structure which characterizes much of the gneiss of this quadrangle, there are surprisingly few features which can be attributed primarily to this influence. This factor is most effective where foliation is relatively weak and linear structure correspondingly strong. The best example is in the area south of Wilmurt lake and west of Signal mountain. Here the westerly spurs of the Signal Mountain ridge and a number of hills west of the Wilmurt Lake road trend and decline toward the west-southwest in harmony with the linear structure.



Figure 13 View of the northern highland area looking southwestward across the lowland area from Oxbow mountain (Lake Pleasant quadrangle). The Piseco Lake fault, coincident with the Piseco Lake trough line, follows the base of the straight steep highland front. Piseco mountain (center beyond the island) is a ridge which trends parallel to the highland front. The photograph shows dip and scarp slopes of the ridge crest controlled by the northward dip of foliation.



Figure 14 View of the southeastern highland area looking due east from Tomany mountain. A straight valley, which is a part of the Big Alderbed-Jockeybush Lake trough line, extends across the photograph from left center to center background.

Joints. Joint directions have exerted a very obvious control over the development of valleys and ridges, and the drainage pattern. For the sake of convenience in this discussion shear zones and faults are considered together with joints. The important north-northeast joint direction is reflected in many topographic features: the valley of the South Branch of West Canada creek; the highland front along the west side of Piseco lake; the low ridges and valleys on the east side of Piseco lake from Rudeston to Spy lake; the parallel ridges and valleys from Black Cat outlet (s.c.r.) to Christian Lake mountain (c.r.). Another joint trend is reflected in the line of valleys extending from the southeast corner of the quadrangle north-northwestward through Kennels pond to Big Marsh (c.r.). The line of valleys trending west-northwestward from the south side of North Branch mountain (s.e.r.) through Big Alderbed is parallel to another set of joints. These are only a few of many examples.

Synclinal axis. The shallow but straight east-west valley which contains Big bay, Piseco outlet and Mud lake occupies a synclinal axis. Farther east along this axis the Mud Lake Mountain group is capped by a synclinal mass of resistant anorthosite (figure 2). In other words, a synclinal valley and a synclinal mountain have been formed on the same axis.

Combination of factors. In many cases topographic trends are probably attributable to a combination of several of these factors rather than to a single one. For instance, the series of small east-northeast ridges (w.c.r.) north of Big Alderbed mountain show elongation parallel to the strike of foliation. However, the lithology of the underlying Grenville and mixed gneisses is extremely variable normal to the foliation, but rather constant parallel to the foliation. In addition there is a well-developed sheeting or jointing parallel to the foliation. Finally, the linear structure here makes only a small angle with the foliation strike. Consequently, foliation, linear structure, joints and differential resistance to erosion have probably all contributed to the trend of the ridges.

Drainage pattern. All of these properties inherent in the bed-rock favor the development of rectilinear valleys. The topographic map of the quadrangle shows the drainage systems to consist very largely of a network of streams whose courses follow the favored directions. This phenomenon of common occurrence in the Adirondacks has been variously described as trellised, lattice or rectilinear drainage.

Major topographic units. One of the most striking characteristics of the topography of the quadrangle is its division into rectilinear areas, each of which possesses its own topographic character. Most of the linear boundaries of these areas bear an angular relation to the trend of the rock belts. This character has been pointed out by Miller ('16, p. 46) in Lake Pleasant quadrangle and attributed by him to block faulting of late Mesozoic or even later age.

The *northern highland* area to the north and west of Hoffmeister and Piseco Lake valleys is the highest and most rugged portion of the quadrangle. Although it is deeply dissected, the summit elevations of the peaks are roughly accordant. Details of topography are controlled chiefly by foliation, to a smaller degree by joints.

The *southwestern highland* area is bounded on the north by Hoffmeister valley and on the east essentially by East Canada creek. It is somewhat lower and less deeply dissected than the northern highland area. The heights of its hilltops decrease rather evenly toward the southwest.

The *south central highland* has the form of a triangle whose corners are marked by Oregon, Notch and State Brook mountains. The northeast front of the highland is a straight abrupt slope. The topography is markedly asymmetric with the highest peaks ranged along the northeast side. The hilltops are successively lower to the west in the direction of the valley of East Canada creek. From Notch mountain to Kennels pond the drainage divide lies within one-half a mile of the foot of the steep northeast slope.

The *southeastern highland*, a rugged region lying between the West Branch of Sacandaga river and the east and south boundaries of the quadrangle, is part of a quadrilateral highland area, whose eastern half lies in the Lake Pleasant quadrangle.

Sharply contrasted with the highlands is the *lowland* which occupies much of the eastern part of the quadrangle. Its limits within the quadrangle are confined by abrupt highland fronts on the northwest and southwest and by the gradual rise of the highland area to the southeast. With the exception of that portion occupied by Piseco lake and the swampy area to the northeast, the surface of the lowland is irregular. A number of hills rise above drift-choked valleys to altitudes of 2100 feet. The lowest valley level is slightly above 1600 feet, so that the total relief within the lowland is somewhat greater than 500 feet. Yet in spite of its irregularities and relief, the area is notably lower than the contiguous highlands.

Rectilinear breaks in the topography. The topographic map of the quadrangle shows a number of rectilinear breaks in the topog-

graphy which are notable for their considerable length and many other interesting peculiarities. Their peculiarities will be discussed in the subsequent descriptions of individual examples. Many of them, which are parallel to sets of joints, have been mentioned above in connection with the effects of joints in controlling the development of the topography.

In a discussion of the river system of Connecticut, Hobbs ('01) has emphasized the occurrence of features which, judged by his descriptions, are analogous to these linear breaks in the topography of the Piseco Lake quadrangle. He mentions ('01, p. 478) "approximately rectilinear stretches of river channel, and especially the stretches of neighboring streams which hold approximately to the same line. . . . The term 'trough lines' used to designate these lines, need for the present be given no further signification than lines so favored by nature that the waters of the region have been induced to adopt them for their channels over longer or shorter distances." The present writer has adopted this term to designate the rather similar features here described.

A line of topographic depression, here called the Piseco Lake trough line, extends from Mud pond (c.r.) north-northeastward through Piseco lake to the corner of the quadrangle. From Mud pond to Piseco lake it occupies a small valley, and thence to the corner of the quadrangle it follows the steep front of the northern highland area (figure 14). It is not only the most important trough line of the quadrangle, but also the most impressive feature of this sort in the Adirondacks. From Mud pond this trough line extends for 50 miles in a north-northeasterly direction to Newcomb lake with nearly geometrical straightness. For another 50 miles to the northeast corner of the Adirondacks in Dannemora quadrangle it continues with only slightly less regularity.

In the Lake Placid quadrangle, this trough line is occupied by the Wilmington Notch fault (Miller, '19, p. 68-69). In studying its course through the Newcomb quadrangle (Indian and Hudson River valleys) Balk ('32, p. 63-64) finds several crushed zones but no evidence to indicate faulting of important magnitude. Miller ('17, p. 44) believes that ample evidence of faulting is to be found in the contiguous Blue Mountain quadrangle. In the Piseco Lake quadrangle the trough line is coincident with the Piseco Lake fault whose minimum throw at one place is about 1200 feet. A fault mapped by the writer for a distance of one and one-fourth miles across the south boundary of this quadrangle, and the Little Falls fault mapped for a distance of 14 miles by Cushing ('05, geologic map) fall on the

continuation of this line toward the south-southwest. In summary, we find here a trend line which is expressed variously by both structure and topography across the entire width of the Adirondack region for a distance of 130 miles.

If the projection of the straight valley of the South Branch of West Canada creek be continued south-southwestward across the Hoffmeister valley, it passes along the base of a steep highland front.

A broad linear depression, the Hoffmeister Valley trough line, bears slightly north of west from the head of Irondequoit bay. It is drained both eastward into Piseco lake and westward into West Canada creek.

From the south foot of North Branch mountain (figure 14) a trough line extends in a west-northwesterly direction through Jockey-bush lake, across the Powley Place, through the Big Alderbed, and thence beyond the limits of the quadrangle. The line of topographic depression is locally indistinct. This line is remarkable, however, in that it crosses three of the highland areas mentioned above, that it cuts directly across two major valleys and that it has been sought out by tributaries of three major drainage systems as a locus for the excavation of valleys.

A trough line, most evident as the northeast limit of the south central highland area, appears to continue along minor valleys and cols north-northwestward to Hoffmeister valley and south-southeastward between Trout Lake mountain and Sherman mountain.

The Brayhouse Brook trough line trends in a north-northwesterly direction, following the valley of East Canada creek in the southern part of the area and continuing along Brayhouse brook. A possible northern continuation may follow the valleys of small tributary streams east of the foot of Big Alderbed to Trout lake.

A considerable number of other trough lines are less conspicuously developed or else are shown principally on adjoining maps. Some characteristics of the Piseco Lake trough lines are enumerated below :

- 1 They are of remarkable length and straightness.
- 2 Several drainage systems excavate straight valleys along the same line.
- 3 Most of them separate areas of different topographic character or areas at different elevations.
- 4 A trough line which follows the base of a highland front in one part of its course may occupy a symmetrical valley in another part. Such change of character occurs only at an intersection with another trough line.

5 A trough line may show no change, or may end abruptly, or may show a lateral offset, at an intersection with another trough line.

6 Many are parallel to sets of joints; some are coincident with known faults or diabase dikes; nearly all trend across the belts of Precambrian gneisses.

Hilltop altitudes. The altitudes attained by hilltops increase in general from southwest to northeast across the quadrangle from about 2100 feet in the southwest corner to a maximum of 3110 feet in the northeast rectangle. The average increase in the altitudes of hilltops along north-south lines is about 40 feet to the mile. Cushing ('05, p. 67) has noted a similar situation in the adjoining Little Falls and Wilmurt quadrangles, and has expressed a belief that the accordant hilltops are remnants of an old erosion surface sloping to the southwest. He notes also that the imaginary surface tangent to the Precambrian hilltops is more gently inclined than the slope of the pre-Potsdam erosion surface beneath the Paleozoic rocks of the Little Falls quadrangle. Consequently, he suggests that the surface represented by the hilltops is a peneplain that beveled the Paleozoic strata in the Mohawk valley, cut across the pre-Potsdam peneplain, and eroded the Precambrian rocks of the Wilmurt and Little Falls quadrangles considerably below their former level.

Of the data on which Cushing bases this supposition, his figures for a section along the west edge of the Little Falls and Wilmurt quadrangles (figure 15, upper section) are most reliable, as this section is farthest removed from the influence of known faults. For nine or ten miles from Ilion northward to Middleville, the buried surface of the Precambrian rises about 130 feet to the mile. "Ten miles north of Middleville the pre-Cambrian appears from under the Trenton at 1300 feet altitude, a rise of 80 feet to the mile." From the Precambrian contact northward for 15 miles to the northwest corner of the Wilmurt quadrangle the Precambrian hilltop altitudes rise about 50 feet to the mile.

Essentially from these data Cushing concludes that "they do seem to indicate that one surface falls to the south more rapidly than the other, say from two to three times as rapidly." To the present writer these data suggest that the pre-Potsdam erosion surface rises from beneath the Mohawk valley with a curved profile that is convex upward, flattening gradually to the north to correspond essentially with the accordant hilltops of the Wilmurt quadrangle. In place of Cushing's interpretation of two peneplains, formed respectively before and since Paleozoic time, the writer would offer the alternative suggestion that the surface joining the Precambrian hilltops passes

beneath the Paleozoic rocks of the Little Falls quadrangle to continue as the pre-Potsdam peneplain.

PRE-PLEISTOCENE PHYSIOGRAPHIC HISTORY

On the basis of the data now at hand the writer believes that the following statements are essentially correct:

1 The pre-Potsdam erosion surface on which the Paleozoic sediments were deposited in the southwestern Adirondacks is a well-developed peneplain.

Miller ('13, p. 81) summarizes what is known with regard to this surface:

The peneplain surface of the Precambrian rock under the Paleozoic strata has been carefully studied on all sides of the Adirondacks and it has been fully demonstrated that it is roughest along the northeastern and eastern sides; less rough along the southeastern and southern sides; and very smooth along the southwestern side. Even where roughest the differences of elevation never amount to more than a few hundred feet, while on the southern side Cushing ('05, p. 57-58) and the writer ('11, p. 50-54) have each found knobs or ridges of hard Precambrian rock projecting upward from fifty to eighty feet into the Cambrian strata, though these appear to be extreme cases of ruggedness of the surface of the peneplain. Along the southwestern border of the Adirondacks the writer has shown by his mapping of the Port Leyden quadrangle ('10, p. 37-44) that the surface of the peneplain is there remarkably smooth.

2 The rise of hilltop altitudes in the Piseco Lake, Wilmurt and Little Falls quadrangles is sufficiently uniform to indicate that the summits are remnants of a sloping dissected erosion surface. This erosion surface is essentially the pre-Potsdam peneplain stripped of its Paleozoic cover.

The imaginary surface joining the tops of the Precambrian hills can be traced northward from the Paleozoic contact of the Little Falls quadrangle. Although there are certain abrupt breaks in the continuity of this projected surface, these are due to dislocations by faulting. In the opinion of the writers of all available reports for the southwestern Adirondacks, the hilltops are remnants of a peneplain, which are correlated tentatively with the so-called Cretaceous or Kittatinny peneplain.

In describing the tangential arrangement of the master-streams of the Adirondack drainage, Ruedemann ('31, p. 436-39) pictures the removal of the Paleozoic cover from the Precambrian core of the

Adirondacks as a stripping process accomplished by glint streams¹ which have migrated laterally down the quaquaversal slope of the Precambrian surface. If such a process has actually operated without interruption, certain resultant conditions should now exist in the marginal portion of the Adirondacks. The stripped surface of the pre-Potsdam peneplain, lowered slightly, however, during the lateral migration of the glint streams, should rise from the edge of the Paleozoics toward the center of the Adirondacks as far as this stripping process was operative. Dissection of this surface by subsequent erosion should be progressively more advanced toward the center of the Adirondacks; and consequently the hilltops should fail to rise precisely to the original level of the stripped surface in proportion to the time they have been exposed to weathering and erosion.

Conditions in the Adirondack border adjacent to the Piseco Lake quadrangle seem to answer very closely to this description. The hilltops of the Precambrian area fall only slightly below the projection of the pre-Potsdam peneplain, as shown in the accompanying sections (figure 15). This correspondence is in itself remarkably close, but there is a probable correction which makes the correspondence even closer. Those sections for which more than two points on the pre-Potsdam surface are known show a rapid decrease in the rise of the pre-Potsdam peneplain toward the present edge of the Paleozoic cover. Cushing's tentative interpretation of a Cretaceous peneplain beveling both the Paleozoic and the Precambrian rocks (p. 67, 71) does not seem to be supported by these data.

3 The remnants of the pre-Potsdam peneplain stand at various levels and have various inclinations in each of the major topographic units of the Piseco Lake quadrangle.

This is principally a matter of observation from the topographic map. In the southwestern highland area the hilltops rise uniformly northward from about 2100 feet to 2600 feet. In the south central highland area the remnants of the peneplain rise eastward from about 1700 feet to 2600 feet. Remnants of the peneplain are not easy to

¹"It would seem desirable to distinguish this special form (of *cuestas* and *escarpments*) that surround the Canadian shield and its outlying areas (as the Adirondacks) from the variety of other *escarpments*, as those of the southwest, by the term 'glint' that is used for the same feature in Scandinavia, viz., an *escarpment* of *sedimentaries*, usually Paleozoic rocks, surrounding a Precambrian nucleus. It would then seem logical to use the term 'intra-glint' (or simply 'glint') rivers also for the tangential streams that are now held in their course by the glints that they themselves created surrounding the Adirondacks." (Ruedemann, '31, p. 439-40)

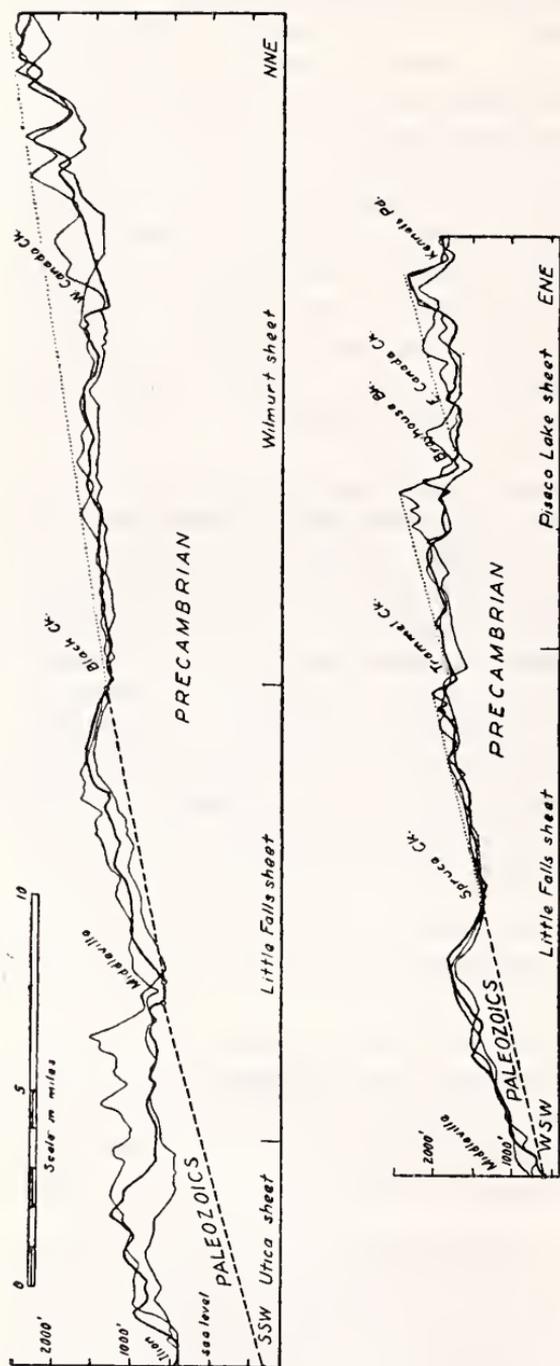


Figure 15 Sections showing the present topography, the position of the pre-Potsdam peneplain beneath the Paleozoic sediments of the Mohawk valley, and its inferred former continuation across the border of the southwest Adirondacks.

Legend: Dashed lines represent the supposed position of the pre-Potsdam peneplain beneath the sediments of the Mohawk valley, based on known points indicated by small circles; dotted lines represent the writer's conception of the approximate former position of the pre-Potsdam peneplain; heavy solid lines are profiles of the topography along the line of section; light solid lines are projected profiles of the topography one mile on either side of the line of section.

Upper section: This section from Ilion north-northeastward to the north edge of Wilmurt quadrangle essentially forms the basis for Cushing's interpretation of a Cretaceous peneplain beveling the pre-Potsdam peneplain. The dotted line is the Cretaceous peneplain of Cushing and the pre-Potsdam peneplain of the writer.

Lower section: This section shows the writer's conception of the former continuation of the pre-Potsdam peneplain from Spruce creek east-northeastward into the Piseco Lake quadrangle, interrupted by dislocations along the trough lines (interpreted as fault lines in this case) of the Piseco Lake quadrangle.

detect in the southeastern highland area because of its narrowness and deep dissection. The broad smooth top of Sherman mountain, however, may be a remnant of the former erosion surface. Thorough dissection also prevents exact identification of the surface in the northern highland area. But many peaks scattered over a large part of the highland stand at altitudes between 2800 and 3000 feet. In the hilly portion of the lowland area the dominant level of hilltops is about 2000 or 2100 feet. The Piseco Lake outlier, possible pre-Potsdam weathering near Rudeston, and the presence of sandstone erratics around the head of the lake afford more direct evidence of the preservation of the pre-Potsdam peneplain in the Piseco Lake valley portion of the lowland. Its altitude here is certainly less than 1700 feet. Fragments of the peneplain have been similarly preserved at low altitudes in the adjoining Lake Pleasant quadrangle, buried beneath the Paleozoic rocks of the Wells and Hope outliers (Miller, '16, geologic map). Other remnants of Paleozoics indicating the position of the pre-Potsdam peneplain occur as far within the Adirondacks as the north edge of the Thirteenth Lake quadrangle (Miller, '29, p. 384-85).

4 Discordance in altitude and inclination between various units of the pre-Potsdam peneplain in the Piseco Lake quadrangle is a result of block faulting along trough lines.

This statement is easily established with regard to the Little Falls fault. In the northeast rectangle of the Little Falls quadrangle the exhumed surface of the Precambrian is exposed on both sides of the fault (Cushing, '05, geologic map). On the downthrown side this surface is at 1200 feet. The fault-line scarp on the upthrown side rises rather steeply to the same surface at an altitude of about 1600 feet. The Piseco Lake fault also provides well-founded evidence. The Piseco Lake fault separates the known pre-Potsdam peneplain at an altitude of less than 1700 feet from the roughly accordant summits of the northern highland area at an altitude of 2800-3000 feet.

The conclusion that the trough lines of the Piseco Lake quadrangle are topographic reflections of faults is inescapable. The evidence of the Piseco Lake outlier clearly indicates a major fault coincident with the Piseco Lake trough line. Although the other trough lines do not reveal their character by so direct evidence, yet they express in their peculiarities (p. 86) the properties of a group of intersecting faults.

It follows that the five major topographic units of the quadrangle, which are bounded by these faults and surmounted by remnants of the pre-Potsdam erosion surface, are crustal blocks that have been

displaced by post-Cambrian movement. The topographic evidence for post-Cambrian faulting can be applied, however, only to those trough lines that accompany a distinct change in the elevation or attitude of the pre-Potsdam peneplain as indicated by the Precambrian hilltops. Trough lines that do not seem to fulfil this requirement, as for example the Big Alderbed-Jockeybush Lake trough line, may have been excavated along lines weakened by Precambrian faulting.

In conclusion, the downthrown side of the faults of the Mohawk valley (Darton, '95, pls. 2 and 3) is almost generally the east side. The topographic evidence indicates a similar relation for most of the faults of the Piseco Lake quadrangle.

5 Post-faulting erosion has stripped the Paleozoic cover from the surface of the pre-Potsdam peneplain, has dissected this surface, has bared the vertical displacements of the pre-Potsdam peneplain to form fault-line scarps and has attacked the fault-line scarps.

That the Paleozoics have been stripped away since the time of faulting is attested by the preservation of small patches of Paleozoics on downthrown blocks within the Adirondacks and by the character of the Little Falls fault. If the stripping process had preceded the act of faulting, no Paleozoics would have remained on the downthrown blocks. The topographic expression of the Little Falls fault affords corroborative evidence. This fault has a notable effect on the topography only where Precambrian rocks are exposed on the upthrown side. Where Paleozoic rocks equally resistant to erosion are in juxtaposition, the fault is not expressed by the topography (Cushing, '05, p. 71-72). That the scarps on the upthrown sides of the faults are fault-line scarps that owe their origin to denudation of the faulted Precambrian surface is also shown by the Little Falls fault in the northeast rectangle of the Little Falls quadrangle.

Subsequent erosion of the exhumed pre-Potsdam peneplain and fault-line scarps is a matter of observation. The degree to which these features are dissected decreases toward the southwest in the direction of the remaining Paleozoic cover.

Summary of pre-Pleistocene history. During late Precambrian time the Piseco Lake quadrangle stood only slightly above sea level and was worn down to a well-developed peneplain. The stability of the land and the smoothing of the surface continued until late Cambrian or Ordovician time, when the region slowly subsided beneath the sea which advanced irregularly from the east. During late Cambrian and Ordovician time the sea possibly advanced and

retreated alternately across the quadrangle. By the end of Ordovician time the quadrangle was buried beneath a blanket of sediments deposited in the shallow seas.

The Taconic disturbance at the end of Ordovician time resulted in the broad uplift of the Adirondack region, possibly accompanied by faulting. This uplift probably raised the Piseco Lake quadrangle above the sea, and there is no indication that it has ever again been submerged. After emergence the area was slowly eroded without further incident until the beginning of the Appalachian revolution. This crustal disturbance, which gave birth to the Appalachian mountains, raised the Adirondack region and a large surrounding area high above the sea. It is possible that the Adirondacks experienced differential uplift and faulting at this time.

The events of the history of the Adirondack region during Mesozoic and Tertiary time are only poorly recorded. Long-continued erosion had reduced much of eastern North America to a peneplain by the end of Mesozoic time. The Cretaceous peneplain has not been recognized, however, in the Piseco Lake quadrangle. In this connection, the recently published opinion of Newland ('32, p. 20) is of interest:

In the Adirondacks the evidences of base-leveling in Cretaceous time are less apparent, perhaps owing to the marked resistance offered by the massive igneous rocks to erosion and the extreme differences in hardness of the Grenville beds. There is, however, a measure of uniformity in the heights attained by individual groups of mountains in the . . . Adirondacks.

From the evidence found in the Piseco Lake quadrangle it is possible only to say that at some time after faulting had occurred the dislocated pre-Potsdam peneplain was laid bare by erosion of the Paleozoic cover. The processes of erosion attacked the tilted blocks of Precambrian rocks exposed by the stripping, and by Pleistocene time had carved from them the essential features of the present topography. The lines occupied by major valleys were determined chiefly by the slope of the pre-Potsdam peneplain on the various blocks and by lines of faulting. The topography, as developed by the end of Tertiary time, was of a subsequent nature, in close adjustment to variations in the mineralogic, textural, and structural properties of the Precambrian bedrock.

PLEISTOCENE AND RECENT HISTORY

Pleistocene glaciation. In late Pleistocene time the quadrangle was overridden by the Wisconsin ice sheet, which covered much of northern North America, including nearly all of New York State.

In other parts of the United States a succession of glacial deposits shows that the Wisconsin was merely the last of a series of ice caps which advanced and retreated during Pleistocene time. Several of these ice caps spread over greater areas than the Wisconsin, and were seemingly more effective agents of erosion and transportation. In Pennsylvania and New Jersey glacial deposits of older age extend well beyond the terminal moraine which marks the limit of southward advance of the Wisconsin glacier. The Adirondack region was probably glaciated during one pre-Wisconsin stage at least, and in all likelihood was glaciated more severely than during Wisconsin time.

The work of earlier glaciers in the Adirondacks has been obscured, however, by erosion and by Wisconsin glaciation so effectually that only a few fragments of inconclusive evidence indicative of multiple glaciation have been discovered (Cushing *et al.*, '10, p. 164-72; Kemp and Alling, '25, p. 71). In the Piseco Lake quadrangle no tangible evidence of more than one ice advance was detected. Although some of the glacial features of the quadrangle are probably in part the work of earlier glaciers, no means has been discovered whereby these may be distinguished from the effects of the Wisconsin glaciation. This apparent lack of definite evidence of pre-Wisconsin glaciation illustrates how meagerly the history of geologic events is recorded.

Glacial striae and grooves which are found on ice-polished surfaces of exposed bedrock indicate the direction in which the ice was moving when they were made. Postglacial weathering, however, has generally destroyed glacial markings on surfaces which have remained exposed to the atmosphere. Of nine occurrences of striae noted in the quadrangle, all but one were found along roads on surfaces which have been artificially exposed.

Observations indicate a local direction of ice movement varying between S.25°W. and S.50°W. As this is also an important direction of topographic trends, the evidence of the striae must be regarded with caution. Striae that are preserved are necessarily made at a late stage of the glaciation, when glacial movement is comparatively feeble and susceptible to guidance by the local topography. As the local topographic trends at several of the localities are quite discordant to the directions of striae, however, a general movement of the ice toward the southwest may be assumed with some confidence. These observations merely afford additional data in confirmation of the generally accepted belief that the ice currents swept across the Adirondacks toward the southwest.

On the other hand, the evidence arising from the distribution of erratics of Paleozoic sediments in the glacial drift seems to point an exception. As noted before, Paleozoic limestone pebbles were found at a single locality at the head of Irondequoit bay. At only two localities have Paleozoic erratics been found outside of Piseco Lake valley. Pebbles of sandstone and a blue-gray chert which must have been associated with limestone occur in a kame on the G Lake road at the head of Big Marsh (c.r.). Another kame still farther west along the same valley where the road to Mountain House crosses the South Branch of West Canada creek (w.c.r.) also contains pebbles of sandstone. Apparently these erratics have been transported by ice from Piseco Lake basin. Although this evidence is not conclusive, it suggests the existence of a westward-moving ice tongue in Hoffmeister valley at a late stage when the ice no longer covered the neighboring highland areas.

During the maximum stage of glaciation the quadrangle was completely covered by ice. This is indicated by the presence of foreign boulders on many of the higher peaks in the northern part of the quadrangle. There is no reason to believe that glacial erosion has modified significantly the preglacial topography. The bedrock hills show no tendency toward an asymmetric shape attributable to the movement of ice across them. Abrasive action of the ice on the bedrock surface has undoubtedly scoured out local basins. There is evidence that the basins of three of the larger lakes of the area, Metcalf and Big Rock lakes (n.w.r.) and Piseco lake, are attributable in part to glacial scour in preglacial valleys. In the case of Piseco lake, stripping of the Paleozoic rocks by the ice has apparently been a contributing factor.

At least, glacial erosion was sufficiently effective to remove almost completely the mantle of weathered rocks which must have been present before glaciation. Only a single remnant of material showing undoubted preglacial weathering was observed. On the north side of the main highway between Rudeston and Oxbow lake outlet (n.e.r.) is a small road metal quarry in so-called "rotten rock." The exposures show deeply disintegrated granite overlain by bouldery till. That the weathering is preglacial is established definitely by the association of boulders of fresh gneisses in the till side by side with boulders of the weathered granite.

Glacial deposits. Deposits of glacial drift have modified the topography to an extent greater than has glacial erosion. Most of the lakes and ponds owe their existence to the irregular distribution

of till. In general, it is relatively thick in the valleys, thinner on hillside slopes, and consists largely of scattered boulders with little interstitial matrix on the higher slopes. The dearth of finer material on steep slopes is partly due to postglacial erosion. The maximum depth of till in the lowland areas is not known, as road cuts are shallow and well records are not available. The greatest thickness of till shown by road cuts in the Hoffmeister and Piseco Lake lowlands is about ten feet, but the maximum thickness must be many times this figure. No definite morainic belts were observed in the quadrangle.

Kame deposits are common in all the major lowlands of the quadrangle. They are well exposed in gravel pits along the roads where their gravels have been utilized for road construction. Typical knob-shaped kames may be seen just south of Clockmill Corners (c.r.), at Powley Place (s.c.r.), and where the Mountain House road crosses the South Branch of West Canada creek (w.c.r.). The most notable group of kame deposits occurs at this latter locality. For a distance of several miles the north side of the valley here is flanked by a terrace ranging from 100 to 600 feet wide and at an average height of 70 feet above the creek. The terrace consists of lateral moraine and kame terrace deposits formed during retreat of the ice when a small ice tongue in the valley alone remained. The shrinking of an ice tongue in the valley is attested by two observations of kame deposits at higher levels on the valley walls near-by. One of these is on the Wilmurt Lake road at an altitude of 2220 feet; the other lies south of Hoffmeister on the opposite side of the valley at an altitude of 1980 feet.

Glacial lakes and associated deposits. As the ice retreated, drainage channels were sometimes blocked either by the retreating front of the ice or by dams of drift deposited by the ice. In consequence, lakes were important features of the postglacial landscape. There were three major glacial lakes within the quadrangle which have since disappeared or shrunken. Miller ('16, p. 68, 70) has called attention to two of these. His descriptions follow:

Piseco lake. There is positive evidence that the water of Piseco lake formerly stood fully 20 feet higher as shown by the perfectly developed delta sand flats at an altitude of something over 1680 feet in the vicinity of Rudeston and Piseco at the north end of the lake. During this higher water stage, a long arm extended northward to include even Fawn lake. A perfectly continuous swamp (old lake) area reaches from Piseco to Fawn lake and the greater elevation (1695 feet) of Fawn lake is readily explained as due to the Post-



Figure 16 Lake deposits of cross-bedded coarse sand and evenly bedded fine sand, exposed in a sand pit where the Gloversville road crosses Sand Lake outlet at an altitude of about 1700 feet. These lake beds suggest the former existence of a lake stretching from Arietta northward beyond the position of the present Piseco lake.



Figure 17 View southwestward across the sand flats at Powley Place. The level plain is the surface of lake deposits of stratified sand (similar to those in figure 16) formed in a glacial lake.

glacial differential elevation of the land increasing northward at the rate of several feet a mile.

Arietta lake. This long narrow lake occupied the valley bottom of the West Branch Sacandaga river from the Shaker Place (Piseco lake sheet) and eastward past Avery's Place and to the mouth of Silver lake stream (Lake Pleasant sheet) with a branch extending southward from Arietta over the areas of the three Stink lakes (Lassellsville sheet). Excellent sand flats at 1680 along the road a mile north of Arietta and from the mouth of North Branch eastward for a mile, show the former water level.

The evidence cited by Miller undoubtedly indicates the former high level of Piseco lake and the former existence of Arietta lake which are here postulated. Indeed, there is reason to believe that at one time the two formed a single continuous body of standing water (figure 16).

The preglacial and postglacial drainage history of the lowland between Arietta and Fawn lake is, however, a rather intricate problem. As Miller ('16, p. 70-71) points out, the present drainage of this lowland by the West Branch of Sacandaga river through the Gorge probably does not coincide with the preglacial drainage. There are three low passes, all more or less filled with drift, by which this lowland area may have drained. Just north of Mud Lake mountain (e.c.r.) is a divide between Mud lake and a tributary of the West Branch Sacandaga at an altitude between 1680 and 1700 feet. In the adjacent corner of the Indian Lake quadrangle is a divide between the present Piseco and Indian lake drainages at an altitude between 1700 and 1720 feet. And in the northeast corner of the Lassellsville quadrangle a flat swampy divide, slightly higher than 1660 feet separates the West Branch Sacandaga from Stink lakes with their southward drainage. In addition to considering the character of these three possible drainage channels and of their divides, it is also necessary to keep in mind the regional tilting of the land surface due to glaciation and deglaciation (Fairchild, '18, p. 209-10, pls. 3 and 9; Alling, '19, p. 93-95). As the present writer has not made a detailed study of the problem, he hesitates to speculate upon what he believes to be a very complex drainage history.

A third glacial lake of smaller size occupied the valley of East Canada creek at Powley Place. This is shown by the extensive sand flats developed here (figure 17). A sand pit excavated in the surface of the plain provides a section of the upper five feet of the material showing stratified sand and fine gravel of a character indicative of deposition in shallow standing water. Apparently a dam of drift or ice across the creek not far above its junction with Black

Cat outlet caused the ponding. The level of the lake stood originally at about 1680 feet.

Origin of lakes and ponds. With few exceptions, the lakes and ponds of the area are the result of the Pleistocene glaciation. The only exceptions that have come to the writer's attention are beaver dams and areas ponded by man, as for example, the pond shown on the map at Mountain House, which no longer exists. Although all others are attributable to glaciation, individual ponds have had diverse origins.

The suggestion has been offered above that the basins of some of the larger lakes (Piseco, Big Rock and Metcalf lakes) may have been produced in part by glacial scour. There is also a group of small ponds usually situated at the heads of valleys high in the mountainous areas which appear to occupy bedrock basins. Examples of this class are Loomis ponds (s.e.r.), Jones lake (c.r.) and the chain of three ponds at the head of Metcalf lake (n.c.r.). Nowhere has the bedrock basin been established beyond doubt, but in all examples mentioned there is good reason to believe they occupy such basins.

Most lakes seem to have resulted from the irregular distribution of the glacial drift. A large majority have been formed by the deposition of dams of glacial drift across preglacial valleys. Obvious examples are so numerous that there is no need of citing specific cases. Several ponds, although lying in the larger valleys, seem merely to occupy irregularities on the surface of the drift. Examples are Mud pond (c.r.), Mud lake (e.c.r.), the small pond southwest of the highway at Rudeston and several small basins on the surface of the kame terrace along the South Branch of West Canada creek.

Postglacial history. Since the time of deglaciation the forces of normal subaerial erosion have been active at the task of restoring the deranged drainage to an adjusted condition. Ferris lake (s.c.r.) and the extinct Powley Place lake near-by may be used to illustrate.

Ferris lake is an interesting example of deranged drainage. The writer had been informed that the lake possessed two outlets, one flowing west toward Powley Place, and the other flowing south to join Black Cat outlet. When the lake was visited in September 1934, however, it was found that the drainage was not southward to Black Cat outlet but in the reverse direction. The waters of Black Cat outlet were dividing at the junction, a portion of them continuing southward to East Canada creek and a smaller portion of them flow-

ing northward into Ferris lake. Such a condition illustrates the complete lack of adjustment of the drainage subsequent to glaciation.

By way of contrast, the postglacial history of Powley Place lake may be briefly recapitulated to illustrate the reestablishment of adjustment. The stages of the process are: first, ponding due to some upset of equilibrium, followed immediately by concomitant erosional attack on the obstruction and filling of the depression with lake sediments. This continues until the depression is either drained or completely filled. As soon as the lake has been drained, the stream immediately begins to erode the material with which it filled the lake basin. This is the stage of the process now effective at the Powley Place.

ECONOMIC GEOLOGY

GARNET

In the Adirondack region at the present time active mining of garnet for abrasive is confined to Warren county. Although several localities in the Piseco Lake quadrangle apparently merit consideration as possible sources of abrasive garnet, no attempt has been made to develop these deposits. Lenses of amphibolite in equigranular quartz syenite on the west flank of Panther mountain (n.e.r.) and on the south side of Twin Lakes mountain (n.c.r.) contain a notable proportion of garnet. These large inclusions in the quartz syenite are dark, coarse-grained, banded to massive amphibolite with scattered garnets which range in diameter from a fraction of an inch to a maximum of about three inches. The garnet content at some places according to rough estimates exceeds 10 per cent of the rock by volume. Garnet is an important constituent of many of the amphibolite masses in the north half of the quadrangle; but on the basis of accessibility, percentage of garnet and large size of the garnet crystals the two localities mentioned seem to offer the greatest possibility for future development.

DIATOMACEOUS EARTH

Deposits of diatomaceous earth are present in a number of small lakes and ponds especially in the western part of the quadrangle. Metcalf lake (n.w.r.) and Brain lake (w.c.r.) are representative of this group. A deposit of diatomaceous earth in Kennels pond (s.e.r.) is the single occurrence known to the writer in the eastern part of the quadrangle. No attempt was made to determine the extent or purity of these deposits. In the Wilmurt quadrangle to the west a deposit of diatomaceous earth in a pond near Wilmurt is worked on a commercial scale.

GRAVEL AND SAND

The local requirements for sand and gravel are supplied from surficial deposits of Pleistocene age. Kame deposits are the principal source for gravel; sand is obtained from glacial lake deposits.

The gravels are utilized largely for road metal. The kame gravels are satisfactory and available in sufficient quantity for this purpose. The Gloversville highway and the Powley Place road are surfaced with gravel taken from pits principally in kame deposits at intervals along the roads. Although much less abundant, gravel and sand suitable for concrete and construction purposes are adequate to meet the local demand.

ROAD METAL

In addition to gravel, quartz syenite and granite have been utilized for surfacing the roads of this quadrangle. A number of small road metal quarries principally in quartz syenite along the main highway from Rudeston to Hoffmeister have supplied crushed stone for the construction and maintenance of the macadam road. "Rotten rock" from a small quarry in deeply weathered granite east of Rudeston has been employed to a small extent in place of gravel.

Except for syenitic areas in the mixed gneiss belts there is no quartz syenite along the roads in the south half of the quadrangle to supply a possible future demand for crushed stone. The diabase along the Powley Place road and masses of metagabbro or amphibolite which outcrop along the Gloversville highway, however, afford possible sources for road metal of excellent quality.

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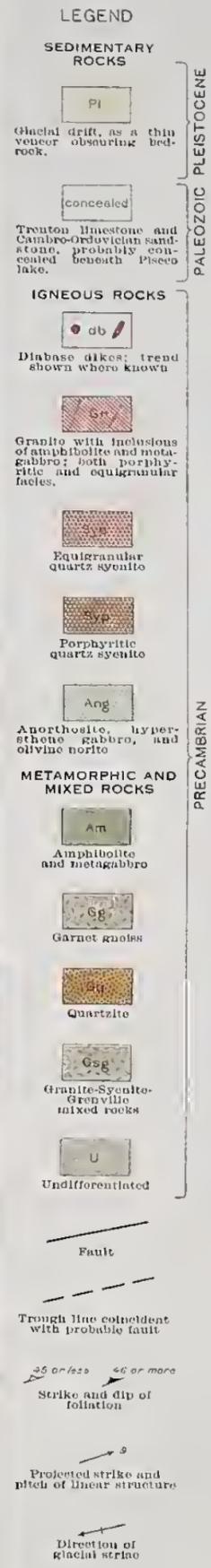


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- Map 1 Map of gneissic structures; Piseco Lake quadrangle
Map 2 Map of joints, shear zones and fault breccia zones;
Piseco Lake quadrangle
Map 3 Geologic and topographic map of the Piseco Lake
quadrangle

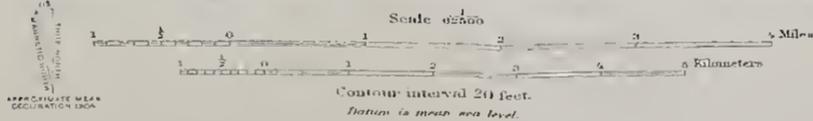




Topography by U. S. Geological Survey and the State of New York, 1902-04

GEOLOGIC MAP OF THE PISECO LAKE QUADRANGLE

Geology by Ralph S. Cannon, Jr., 1933-1934



43° 15' N
43° 30' N
74° 30' W
74° 45' W

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LEGEND

SEDIMENTARY ROCKS

- Pl
 Glacial drift, or a thin veneer obscuring bed-rock.
- concealed
 Trenton limestone and Cambro-Ordovician sandstones, probably concealed beneath Pisco lake.

IGNEOUS ROCKS

- db
 Diabase dikes; trend shown where known.
- Gp
 Granite with inclusions of amphibolite and metagabbro; both porphyritic and equigranular types.
- Ang
 Anorthosite, hypersthene gabbro, and olivine norite.

METAMORPHIC AND MIXED ROCKS

- A
 Amphibolite and metagabbro.
- Gg
 Garnet gneiss.
- Q
 Quartzite.
- Gsg
 Granite-schists, Gneiss, mixed rocks.
- U
 Undifferentiated.

- Fault.
- Trough line coincident with probable fault.
- strike and dip of foliation.
- Protected strike and pitch of thrust or vector.
- Direction of glacial strike.

LEGEND

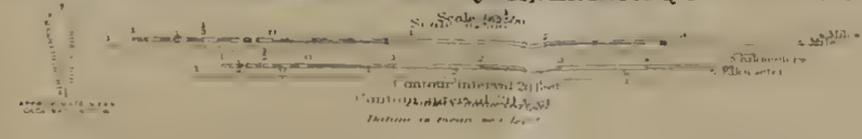
- Strike and dip of joint.
- Vertical joint.
- Strike of joint, dip not determined.
- Strike and dip of shear zone.
- Outcrop of shiftered rock; symbol shows limits of variations of dominant joints.
- Strike of fault breccia zone.
- Fault breccia; strike of zone not determined.

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MAP 2 MAP OF JOINTS, SHEAR ZONES, AND FAULT BRECCIA ZONES;
 GEOLOGIC MAP PISECO LAKE QUADRANGLE

Compiled by Ralph S. Cannon, Jr. 1933-1934

Topography by U. S. Geological Survey
 and the State of New York, 1902-04





LEGEND

SEDIMENTARY ROCKS

Recent drift, or a thin
cover overlying bed-
rock

Clay shale, sandstone,
and siltstone

Shale, sandstone, and
siltstone

Shale, sandstone, and
siltstone

Argillaceous
quartz syenite

Porphyritic
quartz syenite

Amphibole, hyper-
sthene, garnet, and
olivine rocks

Amphibole
and melange

Garnet gneiss

Quartzite

Gneiss-Syenite-
Granite
mixed rocks

Unfolded

Fault

Trough line coincident
with probable fault

Strike and dip of
foliation

Projected strike and
pitch of linear structure

Direction of
glacial striae

LEGEND

32 Foliation dipping gently
(0-15°); numbers show
angle of dip

78 Foliation dipping steeper
than 15°

Vertical foliation

Horizontal foliation

Strike of mineral paral-
lelism, mineral worth-
or linear or platy

12 Projected strike and
downward pitch of lin-
ear structure

Horizontal linear struc-
ture

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MAP 1 MAP OF GNEISSIC STRUCTURES; PISECO LAKE QUADRANGLE
GEOLOGIC MAP OF THE PISECO LAKE QUADRANGLE

by Ralph S. Cannon, Jr., 1933-1934

