Geology of the Ohio Quadrangle Southwestern Part of Adirondack Mountains New York

GEOLOGICAL SURVEY BULLETIN 1251-F

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By ARTHUR E. NELSON

CONTRIBUTIONS TO GENERAL GEOLOGY

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A description of the petrology and structure of the metamorphic rocks in the southwestern part of the Adirondack Mountains

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CONTENTS

ILLUSTRATIONS

TABLES

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGY OF THE OHIO QUADRANGLE, SOUTHWESTERN PART OF ADIRONDACK MOUNTAINS, NEW YORK

By Arthur E. Nelson

ABSTRACT

Bedrock in the Ohio quadrangle consists of Precambrian paragneisses and orthogneisses that have been subjected to regional metamorphism. The oldest of these are metasedimentary rocks of the Grenville Series. Igneous and plutonic rocks are, in order of decreasing age, anorthosite, metagabbro, a quartz syenite complex, quartz diorite gneiss, oligoclase gneiss, pink granite gneiss and associated aplite, pegmatite and quartz bodies, and diabase dikes. Pleistocene and Recent deposits, estimated to be more than 150 feet thick locally, form a veneer over a large part of the quadrangle.

The parent sediments of the metasedimentary rocks were probably mixtures of graywacke, quartz sand, clays, and tuffs. The rocks derived from these sediments were reconstituted and recrystallized to produce the Grenville rocks. Some of the reconstituted rocks were later subjected to sodium, potassium, and silica metasomatism and were converted to granite gneiss.

The anorthosite, metagabbro, and rocks of the quartz syenite complex are probably of igneous origin, but the origin of quartz diorite and oligoclase gneisses is unknown. Some quartz bodies and pegmatites are of igneous origin. Some pink granite gneiss was formed by emplacement of a granite magma, and some was formed by granitization of Grenville rocks.

All the Precambrian rocks except the diabase and some of the pegmatites were plastically deformed during the late stages of regional metamorphism, and most of them have prominent gneissic structures. The plastic deformation obliterated most of the former structures and produced the present folds. These folds trend essentially east and include both small- and large-scale folds that range from open to isoclinal and from asymmetric to overturned. The largest fold is the Twin Lakes basin, in the northwestern part of the quadrangle. Locally, north-trending cross folds of limited magnitude and extent were produced presumably after the main deformation. In places, the rocks have been intensely sheared and faulted; the Hoffmeister Valley fault, a large fault which traverses the quadrangle in an east-west direction, is a prominent structural feature that crosses several quadrangles.

INTRODUCTION

The Ohio quadrangle (pl. 1) is in the southwestern part of the Adirondack Mountains in New York and is centered about 30 miles northeast of Utica (fig. 1). The quadrangle, most of which is in Adirondack State Park, includes an area of approximately 217 square miles. Most of the area is in Herkimer County, but part is in the southwest corner of Hamilton County. New York Highway 8 crosses the quadrangle in an east-west direction. Most of the improved roads are in the southwest corner of the quadrangle. Lumbering trails provide access by car to some other parts of the quadrangle. There are no railroads.

The area is sparsely settled, and about 90 percent of it is heavily forested. It is a popular recreational area, especially during the hunting and fishing seasons. Lumbering and dairy farming are the principal activities, and the farming is confined to a relatively small area in the southwestern part of the quadrangle.

The terrain is fairly rugged and has parallel ridges and valleys, but the relief is not great. The maximum altitude is 2,669 feet on Polack Mountain, and the lowest is 1,236 feet at the west edge of the quadrangle adjacent to Black Creek. The altitudes of hills range

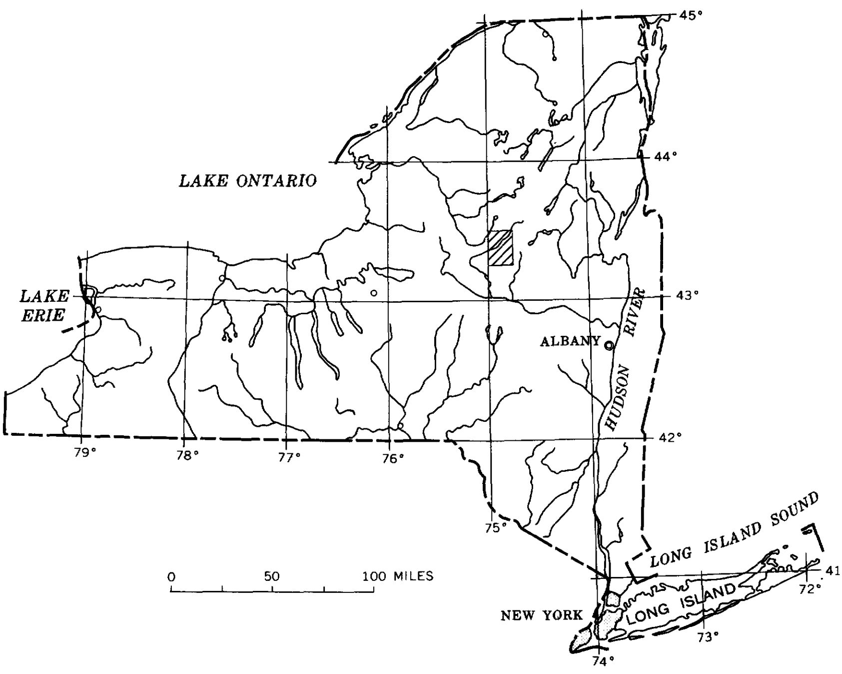

FIGURE 1.—Location of the Ohio quadrangle (striped area), New York.

from about 1,800 to 2,500 feet; hills in the southern part of the quadrangle are generally lower than those in the northern part. Ridges in the southern half of the quadrangle trend approximately east, whereas those in the northern half generally trend northeast. Part of the southwest quarter is less rugged and is underlain by a thick partly eroded sequence of unconsolidated Pleistocene and Recent deposits that in places form kame plains and several kame terraces. Depressions presumed to be the result of eolian erosion or of the melting of glacial-ice blocks are common.

In this report, grain-size determinations are based upon the following scale of grain diameters: Coarse, greater than 5 mm; medium, 1 to 5 mm; fine, less than 1 mm.

Several geological studies have been made in the southwestern Adirondacks. Cushing (1905) mapped the geology of the Little Falls quadrangle, which is directly south of the Ohio quadrangle; Miller (1909) mapped the Remsen quadrangle, which is directly west; and Smyth (1894) studied the gabbros in the southwestern Adirondack Mountains. More recently Cannon (1937) mapped the Piseco Lake quadrangle, which adjoins the Ohio quadrangle on the east. Kay (1943) reported on the stratigraphy of the Paleozoic rocks along West Canada Creek in an area southeast of the Ohio quadrangle.

Some geologic generalizations were necessary in the mapping, especially in the northwestern part of the quadrangle, where there are extensive areas of blowdown trees.

ACKNOWLEDGMENTS

Appreciation is expressed for the help and advice given by the late A. W. Postel, U.S. Geological Survey, and to W. L. McIntosh, U.S. Geological Survey, for his help in the mapping during the season of 1956. Acknowledgment is also made of the cooperation of the residents in the Ohio quadrangle, particularly Mr. John Haskell and Mr. Jay Jones, both of Ohio, N.Y.

GENERAL GEOLOGY

All exposed crystalline rocks in the area correlate with rocks of Precambrian age elsewhere in the Adirondacks, and, with the exception of some diabase dikes, all are metamorphosed igneous or sedimentary rocks. The metamorphic rocks are at the amphibolite or the granulite facies, but some have been retrogressively metamorphosed, and locally minor amounts of sericite, albite, and chlorite occur. Sodium, potassium, and silica metasomatism has affected some of these rocks. The original sedimentary rocks were reconstituted, intruded several times by magma, and in places granitized. Subsequently, all these rocks were plastically deformed. This deformation destroyed the previously existing structures and produced the present ones. As a result, it is difficult to establish the original stratigraphic relationships between these rocks, especially within the limits of a quadrangle. The general age relations that are accepted elsewhere in the Adirondacks are believed to apply in the Ohio quadrangle. In order of decreasing age, the rocks are metasedimentary rocks of the Grenville Series; anorthosite, metagabbro, and amphibolite; quartz syenite complex; quartz diorite gneiss; oligoclase gneiss; pink granite gneiss: migmatite; aplite dikes and pegmatites; and quartz bodies and diabase dikes.

Nearly all the rocks are well jointed and, except for some of the pegmatites, aplites, and diabase dikes, have planar and linear structures that were developed along with folds during regional deformation (fig. 2). The joints have a systematic angular relation to the fold axes. Attitudes of foliation and the presence of minor folds help to delineate major folds. In the apical areas of some folds, lineation is well developed, and the rock is a pencil gneiss without planar structure. In the southern part of the quadrangle the folds are generally isoclinal, and their axes plunge east. In the northern part the folds are more complex; both upright and overturned folds whose axes plunge west or southwest are present. In general, the magnitude of the folds appears to be greater in the northern part of the quadrangle than in the southern part.

Small cross folds trend normal to the main regional east-west structure. A large west-trending fault or fault zone is in the valleys of South Branch West Canada Creek, in the eastern part of the quadrangle, and West Canada Creek, in the western part of the quadrangle. Two smaller faults are also shown on plate 1.

Paleozoic rocks are not exposed in the quadrangle but are presumed to have once covered the area. The Lowville Limestone and overlying rocks of the Black River Group of Ordovician age are exposed a few miles southwest of the quadrangle, between the villages of Poland and Newport along West Canada Creek. Miller (1909) and Cushing (1905) both regarded these rocks as units of the Trenton. The Trenton Group is exposed a few miles west of the Ohio quadrangle. The Trenton, as well as the Beekmantown Dolomite, which is in contact with the underlying Precambrian rocks, is exposed in the Little Falls quadrangle.

Mapping by Miller and Cushing suggests that Paleozoic rocks may occur under a mantle of unconsolidated Pleistocene and Recent deposits in the southwest corner of the quadrangle. The area immediately southwest of the Ohio quadrangle, as mapped by Kay (1943), is underlain entirely by unconsolidated glacial deposits.

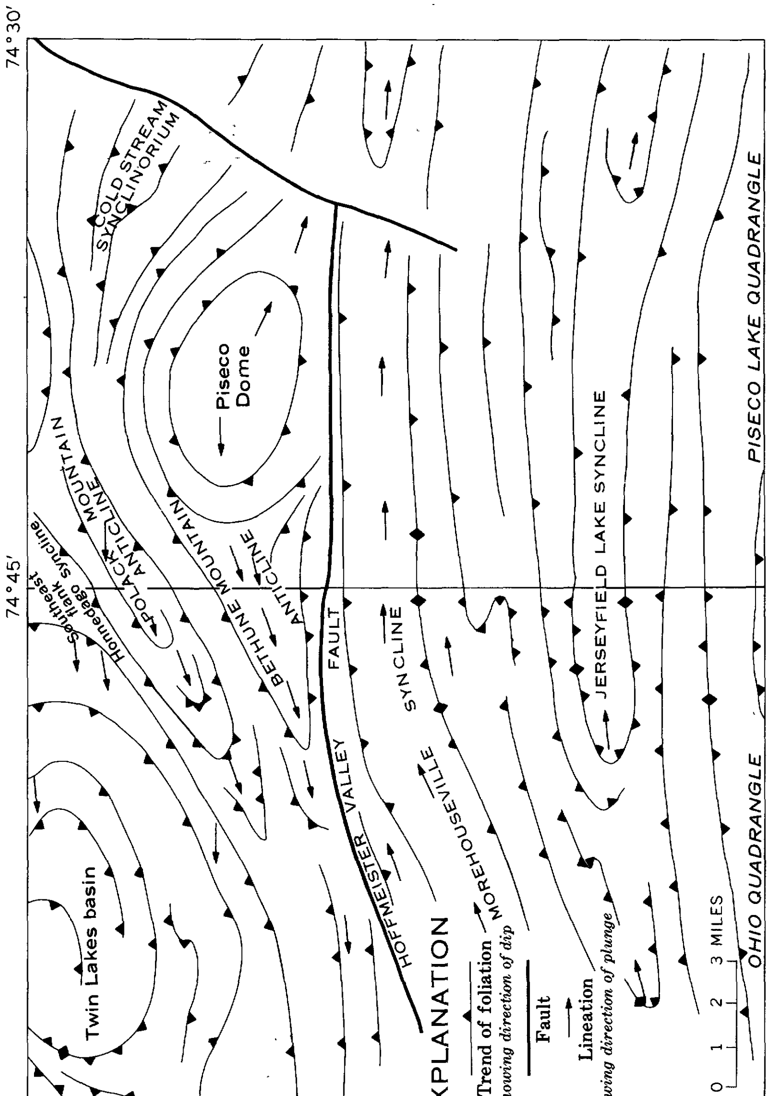

FIGURE 2.—Generalized trends of foliation and lineation in Ohio and Piseco Lake quadrangles.

A veneer of unconsolidated Pleistocene and Recent deposits conceals much of the bedrock, especially at lower altitudes. Therefore, most contacts between rock units are not easily observed.

GRENVILLE SERIES

In the report area the Grenville Series is a heterogeneous assemblage of layered quartz-feldspar gneiss, biotite-plagioclase gneiss, amphibolite, quartzite, and skarn. These rocks, which are well foliated, are mostly equigranular and fine grained, but in some places they range to coarse porphyroblastic gneisses. The Grenville rocks are intercalated in lenses and layers that generally range from 1 inch to 25 feet or more in thickness.

Approximately 35 percent of the bedrock in the quadrangle consists of layered gneisses and related rocks of the Grenville Series. The most extensive outcrop area of Grenville rocks is in the southern half of the quadrangle. A belt of these rocks 4–5 miles wide extends westward across the quadrangle from a point about 3 miles north of the center of Jerseyfield Lake. Approximately 2 miles south of Wilmurt Corners, a smaller body of Grenville rocks parallels the main body. A belt in the northern part of the quadrangle extends from the adjoining Old Forge quadrangle in a modified arc southwestward across the north-central part to just south of Forty Mountain, at the west border. A narrower belt, extending west-southwest from the Piseco Lake quadrangle, enters the quadrangle approximately 0.8 mile southeast of Polack Mountain. In addition, Grenville rocks are mixed with, and occur as, inclusions in the younger gneisses.

The thickness of the Grenville Series and the sequence of individual units within it could not be determined owing to the lack of exposures, distinctive marker horizons, and stratigraphic control, as well as the complexity of structure. Where the scale of mapping would permit, however, individual lithologic types were mapped separately, but in most of the area the Grenville rocks are undivided. The two most common lithologic types of Grenville are quartz-feldspar and biotite-plagioclase gneisses. In decreasing order of abundance, the other types are amphibolite, quartzite, and skarn.

With the exception of the skarn, all Grenville rock types contain garnet. In places as much as 30 percent of a given rock is reddish-brown almandite, but commonly the garnet content is much lower; in some places garnet was not observed. The garnet crystals range from 1/4 to 3/8 inch in diameter, but some are more than 2 inches in diameter.

Grenville rocks are of relatively high metamorphic grade, ranging from amphibolite to granulite facies. The original sediments—probably graywacke, quartz sand, clay, and tuff—were reconstituted during regional metamorphism. Some of the reconstituted rocks were later subjected to replacement by potassium, sodium, and silica.

QUARTZ-FELDSPAR GNEISS

Well-defined layers of leucocratic quartz-feldspar gneiss, generally several feet thick, are widely distributed in the Grenville rocks. The gneiss consists of quartz and widely varying proportions of potassium feldspar and plagioclase (table 1). Generally, these gneisses are somewhat thicker than other units in the series with which they are interlayered. Contacts with other gneisses range from sharp to gradational. As far as could be determined, the foliation is parallel to the layering, which presumably represents bedding. The mineral aggregates range in grain size from fine to coarse but are mostly in the fine- to medium-grained range. The fresh rocks are light gray to very light green; the weathered rocks are brown; and the outermost weathered surfaces are light gray.

The quartz-feldspar gneisses include both potassium feldspar- and plagioclase-rich varieties. Table 1 shows modes of some quartz-feldspar gneisses.

Equigranular grains range from 0.25 to 0.5 mm in diameter. Granoblastic and cataclastic (submylonitic, mortar, and microbreccia) textures are predominant in the quartz-feldspar gneisses. Less commonly, xenomorphic granular textures also occur. In this report the term "xenomorphic granular" refers to a texture produced when

TABLE 1.—*Modes of some quartz-feldspar gneisses of the Grenville Series*

[Tr., trace; C, cataclastic; G, granoblastic; X, xenomorphic granular; var., variable; n.d., not determined]

	85	79	101	151B	172A	131	173F
Potassium feldspar		31	19	57	4	Tr.	8
Plagioclase	56	43	56	17	57	59	62
Quartz	44	26	25	20	35	18	7
Amphibole							9
Biotite	Tr.			3	3		
Clinopyroxene						14	9
Orthopyroxene						2	Tr.
Garnet	Tr.	Tr.	Tr.	1			
Accessories [1]	Tr.	Tr.		2	1	7	5
Size (mm)	var.	0.2–0.4	0.1–0.2	±0.5	0.5±	0.3	0.2–0.4
Texture	C	G	G	X	G	G	G
Plagioclase composition	An_{22}	n.d.	n.d.	An_{25}	An_{26}	An_{43}	An_{28}

[1] Accessory minerals include zircon, apatite, sphene, and magnetite.

SAMPLE LOCALITIES

85. Quartz-plagioclase gneiss collected on north slope of hill 1.1 miles north of east end of Potter Pond.
79. Quartz-feldspar gneiss collected on hill 0.9 mile south of Comstock Vly.
101. Quartz-feldspar gneiss collected on south slope of hill 0.25 mile west of Mounts Creek Lake.
151B. Quartz-feldspar gneiss collected on Breezy Knoll.
172A. Quartz-plagioclase gneiss collected on south slope of hill east of Jerseyfield Lake.
131. Pyroxene bearing quartz-feldspar gneiss collected on southeast slope of hill 0.6 mile from Beaverdam Pond at an altitude of 1,900 ft.
173F. Pyroxene bearing quartz-feldspar gneiss collected 0.75 mile northeast of Cold Spring Lake on small hill.

minerals in a rock recrystallized nearly simultaneously without the formation of crystal faces, in the sense defined by Johannsen (1939, p. 39).

Plagioclase is commonly sericitized and displays curved twin lamellae. It ranges in composition from oligoclase to andesine. The potassium feldspars include microperthite, microcline, and minor amounts of microantiperthite. Microcline, in clusters or patches, fills spaces between larger grains and commonly replaces plagioclase. Quartz is commonly strained. Other minerals present are garnet, zircon, apatite, biotite, chlorite, and magnetite. Locally, clinopyroxene, hypersthene, and amphibole are also present. Magnetite and chlorite are associated with biotite and are probably alteration products. Some myrmekite occurs locally on the borders of plagioclase grains that are adjacent to microperthite.

BIOTITE-PLAGIOCLASE GNEISS

Biotite-plagioclase gneiss is widely distributed in the Grenville Series. It consists mostly of plagioclase, quartz, and biotite, and generally contains a considerable amount of potassium feldspar. Layers are variable in thickness, and contacts with other units are generally sharp, but some are gradational. These rocks are mostly fine to medium grained and range from dark greenish gray to pinkish gray, depending upon the minerals present. Weathered surfaces are brown.

Two types of biotite-plagioclase gneiss occur: one is equigranular and consists mostly of plagioclase (and some potassium feldspar); the other contains porphyroblasts of pink microcline. The change from biotite-plagioclase gneiss to the microcline-rich variety is gradational. Where the microcline content is high, the rock has an overall pinkish-gray color, but it is darker where the microcline content is low and the biotite content is high. Microcline porphyroblasts, which occur either parallel or traverse to the foliation, are occasionally more than 2 inches long and locally form augen. Quartz, plagioclase, and biotite make up the groundmass. Contacts of the microcline-rich phase are poorly exposed but seem to be gradational, especially where it is adjacent to the younger, pink granite gneiss. Table 2 shows the modes of some of the biotite-plagioclase gneisses.

Most of the biotite-plagioclase gneisses have cataclastic textures that range from incipient microbreccia, through mortar, to mylonitic. Some plagioclase twin lamellae are bent. Quartz shows strain shadows and commonly has sutured boundaries. Some thin sections contain mosaics of equigranular polygonal grains that are probably due to recrystallization. Xenomorphic granular textures also occur.

TABLE 2.—*Modes of some biotite-plagioclase gneisses of the Grenville Series*

[Tr., trace; C, cataclastic; G, granoblastic; X, xenomorphic granular; var., variable]

	46	147A	193D	139H
Potassium feldspar	13	20	29	
Plagioclase	36	46	42	51
Quartz	32	22	19	20
Amphibole				
Biotite	18	11	10	22
Clinopyroxene				
Orthopyroxene				
Accessories [1]	1	1	Tr.	1
Garnet				6
Opaque				
Size (mm)	0. 2–0. 4	0. 2–0. 5	var.	0. 3
Texture	C	X	C	G
Plagioclase composition	An_{23}	An_{25}	An_{25}	An_{40}

[1] Accessory minerals include zircon, sphene, and apatite.

SAMPLE LOCALITIES

46. Biotite-plagioclase gneiss collected at side of road 1.65 miles north of Dairy Hill Road on Teacup Road.
147A. Biotite-plagioclase gneiss collected in stream valley 0.75 mile west of Little York Vly.
193D. Biotite-plagioclase gneiss collected in saddle between two hills located 0.8 mile north-northwest of McCauley Mountain.
139H. Biotite-plagioclase gneiss collected 0.7 mile south-southwest of Baldface Mountain at an altitude of 2,000 ft.

The principal minerals are plagioclase, potassium feldspar, quartz, and biotite. Garnet is locally abundant, and in places clinopyroxene and chlorite are present. Calcite is rare, but where it does occur, it appears to replace plagioclase. Magnetite, zircon, apatite, and sphene are common accessory minerals. Most of the plagioclase is oligoclase, but some andesine is present. Most of the potassium feldspar is microcline, but microperthite and microantiperthite are also present. The microantiperthite, which is not common, consists of plagioclase grains containing numerous patches of potassium feldspar or grains of potassium feldspar that are rimmed and strongly embayed by sodic plagioclase.

Oligoclase is commonly sericitized in patches. Tiny clusters of microcline occur between larger mineral grains and are probably secondary. Porphyroblasts of microcline, which commonly occur in crushed zones, locally have a sieve texture and are also probably secondary. Microcline forms embayments in oligoclase and in places has replaced the oligoclase, which forms similarly oriented islands in the enclosing microcline. Microantiperthite has a replacement relation opposite to the above—that is, potassium feldspar is replaced by plagioclase. This suggests that replacement was the result of localized enrichment in sodium that probably followed potassium enrichment. Some plagioclase grains contain inclusions of quartz and, in turn, are surrounded and embayed by quartz, which suggests that quartz enclosing the plagioclase is due to late enrichment in silica. Biotite is generally reddish brown and is locally broken, twisted, and crushed; it generally cuts across other minerals. In places, biotite is found with magnetite replacing pyroxene. Locally it is closely associated with garnet porphyroblasts and some is altered to chlorite.

AMPHIBOLITE

Layers of dark-gray amphibolite are commonly interlayered with other rocks of the Grenville Series. Although most of the amphibolite occurs in thin discontinuous layers in other metasedimentary rocks, it also forms inclusions, commonly schlieren, in the younger igneous rocks. Only a few bodies in the northeastern part of the area on the east-southeast flank of Twin Lakes basin (pl. 1) are large enough to be shown separately on the map. Contacts with other rock types are generally sharp, and the layering seems to be parallel to the regional foliation. Some amphibolite layers, especially those containing a higher percentage of felsic minerals, have gradational contacts. Foliation in the amphibolite is evident because of well-developed planar orientation of tabular plagioclase and mafic minerals. Alternate layers of felsic and mafic minerals are not distinct, but locally weathering reveals thin discrete bands or layers having different proportions of these components. At some localities the foliation is obscure. The amphibolites are mostly fine to medium grained.

Most amphibolites contain nearly equal amounts of amphibole and andesine, but locally clinopyroxene, orthopyroxene, biotite, and quartz are present. Quartz, however, does not exceed 10 percent. Biotite-rich amphibolites occur locally where biotite has replaced amphibole and pyroxene. Amphibolites in the southern half of the quadrangle contain less pyroxene and more amphibole than do those in the northern half; minerals in these rocks are recrystallized and are equigranular.

QUARTZITE

Small layers and lenses within the Grenville gneisses are feldspathic quartzite containing 75–85 percent quartz. One mappable quartzite unit extends northwest from Jerseyfield Mountain; elsewhere, quartzite occurs as thin discontinuous bodies that are interlayered with other rocks of the Grenville Series. Quartzite is a light-gray medium-grained rock that is generally stained brown on weathered surfaces.

The quartz is coarsely recrystallized and shows strain shadows; the grains are highly irregular. The quartzite also contains small amounts of microcline, plagioclase (oligoclase?), biotite, and chlorite. Trace amounts of garnet, zircon, magnetite (or other opaque iron minerals), pyroxene, and graphite (?) are present.

SKARN

Coarse granular dark-green indistinctly foliated skarn crops out on a ridge east-northeast of Baldface Mountain. The skarn is apparently a small lens in mixed equigranular granitic and pink granite gneiss. The enclosing rocks strike northeast and dip northwest on the southeast limb of the overturned Polack Mountain anticline (pl. 1). Irregular coarse clots of dark-green clinopyroxene (probably diopside) compose 80 percent of the skarn; most of the remainder consists of nearly white plagioclase and quartz. Small grains of sphene are scattered throughout the rock.

ORIGIN OF ROCKS OF GRENVILLE SERIES

The rocks of the Grenville Series were probably derived from sedimentary rocks, such as graywacke, tuff, shale, quartz sandstone, and calcareous variants of these, but such sedimentary features as graded bedding, ripple marks, and crossbedding were not observed. If these features were once present, they were destroyed during regional metamorphism as the rocks were deformed, recrystallized, reconstituted, and, in places, metasomatized to such a degree that they resemble igneous rocks. However, a sedimentary origin is suggested by several lines of evidence, chief of which is the conspicuous and persistent compositional layering in many outcrops, in which light-colored felsic gneisses and quartzites alternate with darker rocks. This suggests that the rocks were originally stratified. The layering is believed to represent bedding and is therefore probably the only sedimentary structure to survive metamorphism. Little flakes of graphite, which occur locally in the rocks, may represent original organic material. The carbon of the graphite, however, could have formed by the reduction of CO and CO_2. The quartzite layers probably represent original quartz sandstone beds. The darker rocks, chiefly amphibolite, are inferred to represent impure calcareous beds or tuff beds.

Chemical analyses of some of these rocks (table 3) suggest that they are derivatives of graywacke and associated sedimentary rocks. Samples 153752 and 153753, given in table 3, are biotite-plagioclase gneiss from the Grenville Series. These rocks are essentially unmetasomatized. However, typical outcrops occasionally contain a few thin granite and pegmatite layers and may contain a few randomly scattered microcline porphyblasts. These biotite-plagioclase gneisses are believed to have been derived from sedimentary rock, with little or no addition of extraneous material during metamorphism. The analyses show these gneisses have a composition within the range of rocks classed as graywacke by Pettijohn (1957, p. 306–307).

TABLE 3.—*Chemical compositions of biotite-plagioclase gneisses and a pink granite gneiss*

[Samples analyzed by rapid methods similar to those described by Shapiro and Brannock (1956). Results are in percent. Analysts: Paul L. D. Elmore, Ivan H. Barlow, Marvin D. Mack, and Samuel Botts of U.S. Geol. Survey]

	Biotite-plagioclase gneiss	Biotite-plagioclase gneiss	Microcline porphyroblastic phase of biotite-plagioclase gneiss	Pink granite gneiss
Lab. No	153752	153753	153754	153751
SiO_2	66.3	67.8	72.3	73.5
Al_2O_3	15.5	16.2	14.7	14.3
Fe_2O_3	1.9	1.1	.8	.9
FeO	3.3	2.7	1.7	1.4
MgO	1.2	1.2	.49	.31
CaO	2.3	3.1	1.2	1.0
Na_2O	3.6	4.4	3.5	3.3
K_2O	4.3	2.2	4.6	5.5
H_2O	.83	.76	.72	.50
TiO_2	.80	.55	.23	.19
P_2O_5	.30	.18	.05	.04
MnO	.06	.07	.04	.04
CO_2	.15	.06	.12	.09
Sum	101	100	100	101

SAMPLE LOCALITIES

153752. Collected north of Frenchs Vly about 250 ft below the ridge of Bethune Mountain.
153753. Collected about 80 ft above the level of West Canada Creek 1½ miles west of the east boundary shown on plate 1.
153754. Collected in the Ohio Gorge on West Canada Creek.
153751. Collected on the east slope of Fort Noble Mountain about 150 ft above the level of Bethune Vly.

The microcline porphyroblasic phase of the biotite-plagioclase gneiss is believed to be the result of alkali and silica replacement by fluids that entered the rocks along crush zones. A similar phenomenon has been described by Postel (1940) in schists near Philadelphia, Pa. The evidence in support of a metasomatic origin of the porphyroblastic gneiss in the Ohio quadrangle may be summarized as follows:

1. Rocks where microcline porphyroblasts are well developed have cataclastic textures and crush zones.
2. Replacement textures show that the rocks were enriched in potassium and silica, and locally in sodium.
3. Chemical analyses (table 3) show that the microcline porphyroblastic phase is slightly richer in total alkalies and silica than is the normal biotite-plagioclase gneiss.
4. Contacts between biotite-plagioclase gneiss and its porphyroblastic phase are gradational.
5. Large microcline grains have replaced other minerals in the crush zones, and locally large microcline grains protrude into the crush zones. This seems to show that potassium enrichment occurred after, or at least during, the late stages of deformation.

6. In some outcrops, the long dimensions of some of the large microcline grains are almost perpendicular to the trend of foliation, which suggests that the microcline grew as a result of potassium metasomatism after the development of foliation.

Reddish-brown biotite, which is common in the microcline-rich phase of the biotite-plagioclase gneiss, may also be a result of granitization. In the northwestern Adirondack Mountains, Engel and Engel (1953, p. 1064) noted that reddish-brown biotite is associated with extensively granitized rocks.

PLUTONIC ROCKS

Plutonic rocks in the Ohio quadrangle include anorthosite, metagabbro, the quartz syenite complex, oligoclase gneiss, pink granite gneiss, and dikes of pegmatite, aplite, and diabase. All these except some pegmatite and diabase have been deformed. Rocks of the quartz syenite complex and the pink granite gneiss are the most abundant igneous rocks in the quadrangle. In the following discussion the plutonic rocks are described in order of presumed age.

ANORTHOSITE

Anorthosite occurs in only three places in the quadrangle. The largest mass crops out along the west border and extends into the adjoining North Wilmurt quadrangle. This relatively massive body occurs in a mixture of pink granite gneiss and equigranular quartz syenite. Thin layers of coarse-grained amphibolite, probably metagabbro, occur in the anorthosite. The other two occurrences are small lenses in the northern part of the quadrangle; one is a little north of Pooler Vly in pink granite gneiss that is closely associated with bands of Grenville rocks. The other lens is on a small ridge southeast of Polack Mountain in mixed equigranular quartz syenite and pink granite gneiss. Amphibolite (probably metagabbro) is in contact with the anorthosite near Pooler Vly.

As in other parts of the Adirondack Mountains, two facies of anorthosite are present. They are similar to the two facies of anorthosite in the Saranac quadrangle in the central Adirondacks, where Buddington (1953, p. 33–61) mapped and described a mafic-poor type called the Marcy facies and a mafic-rich type called the Whiteface facies. In the Ohio quadrangle, one type is pyroxene rich and the other is pyroxene poor. The anorthosite on the west edge of the quadrangle is pyroxene rich; the lenses near Pooler Vly and Polack Mountain are pyroxene poor. The pyroxene-rich anorthosite is coarse grained, is pale green, and weathers dark gray. The plagioclase grains are as much as 1½ inches long and have a green tint. Other minerals present include quartz, biotite, and an unidentified black opaque mineral. In the pyroxene-poor type, only a few grains of pyroxene are visible in hand specimen; this anorthosite is medium to coarse grained and is milky white or yellow. Weathered surfaces are dull grayish white. Plagioclase grains are commonly less than 1 inch long. In general, the foliation is indistinct in both types of anorthosite but is well developed in the adjacent rocks.

One thin section of pyroxene-poor anorthosite was studied. The rock has a cataclastic texture, and the plagioclase displays undulatory extinction. Granulated plagioclase rims are common, and many of the twin lamellae in the plagioclase are bent. The plagioclase is andesine which contains patches of sericite. The rock also contains clinopyroxene, some of which has been chloritized. Other minerals present include magnetite, garnet, zircon, apatite, and quartz. Minor amounts of potassium feldspar occur as intergrowths in the andesine grains. Modal analyses were not made, but it is estimated that more than 90 percent of the rock is andesine.

METAGABBRO

Three small bodies of metagabbro occur in the northeastern part of the quadrangle; all three are lenses in mixed equigranular quartz syenite and pink granite gneiss. Several other layers of metagabbro, too small to be shown on the map, crop out on Bethune Mountain, and some metagabbro also occurs north of Morehouseville near the base of the porphyritic quartz syenite. Other metagabbro bodies probably exist, and possibly some of the amphibolites included with the rocks of the Grenville Series should be classified as metagabbro.

The metagabbro is a mottled dark-gray to black fine-grained rock. It appears to be massive because gneissic structures are not well developed; however, a faint foliation is parallel to that of the surrounding rocks. The central parts of the larger bodies appear to be coarse grained because they contain clusters of mafic minerals among plagioclase grains. Actually, however, the average grain size is approximately the same as in the border areas. In the border areas the minerals in the metagabbro are more uniformly distributed, and the overall color of the rock is darker because the black mafic minerals tend to mask the brown of the weathered plagioclase. The mafic clusters in the central parts of metagabbro bodies may outline a primary texture, and the rock may originally have been coarse grained, for a few large subhedral grains of pyroxene devoid of inclusions can be seen in thin sections. These mafic grains have some crystal faces and also do not contain inclusions; they are probably relict phenocrysts rather than porphyroblasts. Most of the original large grains may have been crushed to produce the present clusters in which the large pyroxene grains are porphyroclasts. Cannon (1937, p. 19) discussed similar features in the metagabbro of the Piseco Lake quadrangle. The metagabbro generally weathers to shades of brownish black. The weathered fine-grained rock of the border areas is more uniformly dark gray to black, and the weathered coarse-grained parts are brown. The plagioclase on weathered surfaces is brown and imparts a brown appearance to the rock in outcrop.

Textures in thin sections are variable; ophitic, cataclastic, mosaic, and poikilitic or poikiloblastic textures have been observed. In certain zones, polygonal grains of plagioclase and amphibole have regular or slightly irregular mosaic structures which suggest that the grains have undergone crushing and subsequent recrystallization.

The principal minerals are plagioclase, green to dark-green amphibole, clear to pale-green clinopyroxene, and pale yellow to red biotite. Less common minerals are hypersthene, garnet, apatite, and magnetite. Small grains of magnetite are commonly mixed with larger grains of amphibole and biotite. Magnetite may also occur as dustlike particles in larger grains of pyroxene. Pyroxene occurs in large clusters and in crushed aggregates, and some grains have reaction rims composed of polygonal grains of amphibole and minor amounts of biotite and magnetite. Some of the amphibole in the reaction zones is in irregular wisps and is believed to be a retrograde product derived from pyroxene during regional deformation and metamorphism. Plagioclase (labradorite, An_{52-58}) commonly contains tiny inclusions of other minerals. It is generally enveloped in a groundmass of pyroxene, as in an ophitic texture, and has both simple and complex twinning. Locally, the labradorite has curved lamellae and undulatory extinction. In some areas, however, the labradorite is recrystallized and has uniform extinction.

A complete modal analysis was not made of this rock; but in one thin section, 60 percent of the rock consists of pyroxene, amphibole, biotite, and magnetite. The remaining 40 percent is mostly labradorite.

QUARTZ SYENITE COMPLEX

A widely distributed complex of felsic granitic gneisses, characteristically dark green, composes a large part of the bedrock in the quadrangle. Three facies occur; equigranular quartz syenite, porphyritic quartz syenite, and hornblende gneiss. These rocks are present in relatively large bodies that parallel the regional structure; they also occur as lenses in the Grenville Series and as inclusions in younger, pink granite gneiss; in places, they are complexly mixed with younger gneisses. Except where they are cut by a few veins of quartz and pegmatite, these rocks have a uniform, and locally somewhat massive, appearance.

The quartz syenite complex is correlative with rocks that Cannon (1937) mapped as equigranular and porphyritic quartz syenites in the Piseco Lake quadrangle. Actually, the rocks of the quartz syenite complex are a part of a series of genetically related igneous rocks that have been called syenites and quartz syenites and occur throughout the Adirondack Mountains (Buddington, 1939, p. 73–134). They range in composition from mafic syenite and quartz syenite to quartz monzonite, granite, and alaskite.

EQUIGRANULAR QUARTZ SYENITE

The equigranular facies of the quartz syenite complex is a pyroxene-bearing hornblende-quartz monzonite or granite gneiss that is widely distributed in both the northern and southern parts of the quadrangle. The largest body trends west-southwest and is centered in the McCauley Mountain area. Smaller lenses of this rock also have been mapped in both the northern and southern parts of the quadrangle. These gneisses commonly occur as small lenses in the older metasedimentary rocks and as inclusions in the younger, pink granite gneiss. In the Twin Lakes basin area (pl. 1) and in the Polack–Baldface Mountain area, equigranular quartz syenite is the dominant rock type in a mixture that also contains pink granite gneiss and minor metasedimentary rocks.

The equigranular quartz syenite is a fine- to medium-grained well-foliated gneiss that consists of feldspar, quartz, amphibole, and pyroxene. In fresh exposures the rock is dark green; on weathering, however, the color changes to "maple-sugar" brown. The outermost weathered surfaces are chalk white. Adjacent to pink granite gneiss the rock is locally pink or red, instead of the normal dark green.

Modes of the equigranular quartz syenite (table 4) indicated that the rock ranges in composition from quartz monzonite to granite.

The equigranular quartz syenite has xenomorphic granular, cataclastic, and mortar textures. Mosaics of polygonal grains are common and suggest recrystallization. Quartz grains have been crushed and recrystallized, and some have undulatory extinction. The plagioclase twin lamellae are curved.

The principal minerals are microperthite, plagioclase, quartz, amphibole, clinopyroxene, and orthopyroxene; the less common minerals are biotite, microcline, magnetite, garnet, apatite, zircon, and clorite. Myrmekite occurs in plagioclase grains bordering microperthite but is not extensively developed. The microperthite is slightly more abundant than plagioclase. A dark-green amphobile (probably hornblende) is the commonest ferromagnesian mineral but does not occur in all

TABLE 4.—*Modes of equigranular quartz syenite*

[Tr., trace; B, microbrecciated; O, mortar texture; X, xenomorphic granular]

	203D	204A	199A	137D	134D	200E	14	15	16	72	96
Potassium feldspar	35	57	39	39	50	39	39	49	48	35	41
Plagioclase	19	14	25	19	16	32	22	21	20	39	33
Quartz	31	23	30	31	29	22	24	19	26	18	25
Hornblende	11	2	6	8	5	6	8	10	3	8	Tr.
Biotite	3	1	Tr.		Tr.	Tr.		Tr.	Tr.		
Pyroxene		3		3			4		2		
Chlorite										Tr.	
Accessories [1]	1	Tr.	Tr.	Tr.	Tr.	1	3	1	1		1
Magnetite					Tr.						
Texture	X	X	X(B)	X	X(B)	X	X	X	X(B)	O	X
Size (mm)	0.8	1	0.5–0.7	0.5	0.2	0.2–0.3	0.5	0.5	0.5	0.5±	0.5±
Plagioclase composition	An_{24}	An_{25}	An_{22}	An_{22}	An_{20-22}	An_{23}	An_{20}	An_{20}	An_{21}	An_{23}	An_{25}

[1] Accessory minerals include garnet, apatite, and zircon.

SAMPLE LOCALITIES

203D. On east slope of hill 1 mile east of Wells Vly.
204A. From top of hill 0.6 mile north-northeast of Forty Mountain.
199A. On south slope, but near the top of hill 0.8 mile northwest of Beaverdam Pond.
137D. From outcrop in valley located 0.6 mile east-northeast of the top of Baldface Mountain
134D. On north slope of Polack Mountain.
200E. Due north of Spruce Mountain, near the Indian River.
14. Near crest of hill 0.5 mile northwest of White Lead Lake.
15. On southwestern part of a hill 0.3 mile northeast of Pooler Vly.
16. In stream valley on west side of McCauley Mountain at an altitude of 1,620 ft.
72. On southwest side of holl 0.6 mile southeast of Lafe Hall Clearing.
96. Near south end of Thorp Vly.

thin sections. Pale-green to colorless clinopyroxene (probably augite) and lesser amounts of orthopyroxene (hypersthene) occur in some thin sections.

Replacement textures were observed, but nowhere are they extensively developed in the equigranular granitic gneiss. Hornblende and pyroxene are locally altered to chlorite. Biotite and magnetite are closely associated with hornblende and less commonly with pyroxene; they may have been derived from hornblende and pyroxene during metamorphism. Plagioclase generally contains patches altered to sericite; and where it is bordered by microperthite, the plagioclase commonly contains myrmekite. Locally, microcline replaces plagioclase and forms intergrowths within it. Microcline also occurs as interstitial grains that are irregularly distributed or that form small clusters.

Several atypical varieties of the equigranular facies occur, but they do not form mappable units. One variety is more mafic and contains as much as 10 percent magnetite and as much as 25 percent hornblende and pyroxene. Both clinopyroxene and orthopyroxene are present. Generally, plagioclase is more abundant than potassium feldspar and in some rocks potassium feldspar is absent. Another variety contains 11 percent hypersthene, 5 percent clinopyroxene, 3 percent quartz, and 6 percent accessory minerals. The mineral assemblage plagioclase-orthopyroxene-clinopyroxene-quartz is indicative of the granulite facies of regional metamorphism (Turner and Verhoogan, 1951, p. 473–477).

A single outcrop of quartz-diorite gneiss near the southwest end of Baldface Mountain occurs entirely within an area of much equigranular quartz syenite and pink granite gneiss. The rock is gray, medium to coarse grained, and somewhat massive. Float from similar rock was seen at several nearby localities, suggesting that a larger body may be present. The foliation conforms to that of the adjacent rocks but is not well developed.

Modal analysis shows that the rock contains 51 percent plagioclase, 32 percent hornblende, and 15 percent quartz, and has a xenomorphic granular texture. The plagioclase (oligoclase An_{23-25}), has some curved lamellae, contains local intergrowths of microcline, and is sericitized in patches. The green to greenish-brown hornblende appears to have been altered locally to yellowish-brown or brown biotite and magnetite. Quartz is included in some plagioclase grains and encloses others. Microperthite, biotite, and associated magnetite, apatite, and zircon are present in minor amounts.

PORPHYRITIC QUARTZ SYENITE

Two large bodies and several small lenses of porphyritic pyroxene- and hornblende-bearing quartz monzonite gneiss are shown on plate 1. The broad band of porphyritic gneiss in the central part of the quadrangle is well exposed in an abandoned quarry just east of Morehouseville. This band is a continuation of the porphyritic quartz syenite mapped by Cannon (1937) in the Piseco Lake quadrangle. The other large body of this rock is exposed in the northern part of the quadrangle. It strikes essentially west and dips northward into the Twin Lakes basin (pl. 1). The phacoidal texture of the rocks in the Morehouseville band is best seen in weathered outcrops. In the Black Creek Lake area, phacoidal texture is less well developed, but the rocks are coarser grained. Postel, Dodson, and Carswell (1956) mapped two similar types of phacoidal gneiss (Hawkeye Granite Gneiss) in the Loon Lake quadrangle, New York.

Generally, the rock is moderately foliated and coarse textured, especially where the phacoids are well developed, but locally, where the phacoids are sparse, the rock is medium grained. The foliation, which is generally the dominant gneissic structure, is less well developed than lineation in parts of the Morehouseville band. As far as could be determined, contacts with other mapped units parallel the trend of foliation.

The porphyritic facies differs from the equigranular gneiss mainly in its texture. The phacoids, some more than 1½ inches long, are lenticular aggregates of feldspar grains that have been crushed and recrystallized and are enveloped by leaves or recrystallized quartz and layers of grains of feldspar and mafic minerals. In some places a single large grain of feldspar occupies the core of the phacoid. Where phacoidal texture is not well developed, the quartz characteristically forms flat, somewhat lenticular leaves whose long dimension is parallel to the foliation.

Xenomorphic granular and mortar textures most commonly occur in these rocks. Potassium feldspar, including intergrowths in plagioclase, occurs in amounts nearly equal to plagioclase; microperthite is the principal potassium feldspar, and oligoclase (An_{24-26}) is the main plagioclase, although andesine (An_{32}) is present locally. Modes of representative samples are given in table 5.

TABLE 5.—*Modes of porphyritic quartz syenite*

[Tr., trace; C, cataclastic; G. granoblastic; M, Mortar texture; X, xenomorphic granular]

	158B	28	49	36	55	146	144B	140A	191A	Average
Potassium feldspar	27	31	27	29	32	26	45	24	32	30
Plagioclase	38	37	47	37	37	38	11	43	21	34
Quartz	17	19	15	20	19	18	28	27	26	23
Hornblende	8	4	7	2	4	------	14	2	20	7
Biotite								1	T	Tr.
Pyroxene	7	7	Tr.	9	6	Tr.	------	3	------	3
Accessories [1]	1	2	3	3	1	Tr.	2	Tr.	1	3
Chlorite	Tr.	------	1	------	Tr.	18	------	------	------	------
Garnet						Tr.	------	------	------	Tr.
Opaque	2	------	------	------	1	------	------	------	------	Tr.
Texture	G	M	C	M	C(M)	X	M(X)	X	X	------
Size (mm)	0.3	0.5	1	0.9	0.2	------	0.3—0.5	1.0-2.0	0.5±	------
Plagioclase composition	An_{24}	An_{25}	An_{23}	An_{24}	An_{24}	An_{24}	------	An_{25}	An_{21}	------

[1] Accessory minerals include apatite and zircon.

SAMPLE LOCALITIES

158B. On south slope of hill north of Jones Creek about 0.7 mile from mouth of Jones Creek.
28. Near east edge of quadrangle 0.3 mile north of Bochen Lake.
49. On hill 0.5 mile from south end of Erb Road.
36. On small hill 0.2 mile south of Morehouseville.
55. On hill 1 mile east-southeast of New Holland Clearing.
146. On hill 1½ miles west of Little York Vly.
144B. On north slope of hill 1½ miles east -southeast of Wilmurt Corners.
140A. From top of hill that is on a line and equidistant from Cotton Lake and Mill Creek Lake.
191A. On Southern part of hill 0.2 mile west of Black Creek Lake.

HORNBLENDE GRANITIC GNEISS

Although not widely distributed in the quadrangle, several bodies of hornblende-bearing granitic gneiss were mapped. These rocks most commonly occur in and near areas of porphyritic quartz syenite; in some places, these rock types are intermixed. The largest body of hornblende gneiss occurs in the band of porphyritic quartz syenite south of Morehouseville. Two smaller east-trending lenticular bodies occur in the southern part of the quadrangle, one just south of Richards Vly, and one near the south boundary. A small lens is present in the southwest-trending band of Grenville rocks in the northern part of the quadrangle.

The hornblende gneiss is coarse grained and ranges in composition from biotite-hornblende quartz monzonite to biotite-hornblende granite. It is commonly red, but in some places it is pale green. Where this rock lacks phaciods, it is difficult to distinguish from pink granite gneiss.

The texture of the hornblende gneiss is similar to that of the associated porphyritic quartz syenite; the difference between the two is principally mineralogical: pyroxene does not occur in the hornblende gneiss but is common in the porphyritic quartz syenite. The close spatial association and similarity of textures observed for these two rock types suggest that the hornblende granitic gneiss may be a variant of the porphyritic gneiss. On the other hand, where the hornblende gneiss is devoid of phacoids, its mineralogic similarity to the supposedly younger pink granite gneiss suggests that it may instead be a variant of this younger gneiss. Modes of the hornblende gneiss are given in table 6.

Cannon (1937, p. 27) described hornblende granite gneiss in the Piseco Lake quadrangle. He did not know whether it was a facies of the quartz syenite or of younger pink granite and suggested that it may have formed by hydrothermal alteration of pyroxene-bearing quartz syenite.

OLIGOCLASE GNEISS

Oligoclase gneiss occurs in an east-tending lenticular or tabular body along the south edge of the quadrangle. Near Crosby Vly the oligoclase

TABLE 6.—*Modes of hornblende granitic gneiss*

[Tr., trace or present; C, cataclastic; X, xenomorphic granular]

	144	144A	145	59	34	178D
Potassium feldspar	44	40	43	37	48	42
Plagioclase	9	22	26	31	[1] 18	24
Quartz	28	28	24	28	25	22
Hornblende	10	6	3	------	9	3
Biotite	6	2	2	3	------	6
Magnetite	Tr.	--------	1	------	Tr.	Tr.
Accessories [2]	3	2	1	1	Tr.	3
Chlorite	Tr.	------	------	------	------	Tr.
Texture	X	X	X	C	C	X(C)
Size (mm)	0. 3–0. 5	0. 8	0. 9	0. 5	0. 4	0. 5
Plagioclase composition	An_{24}	An_{23}	An_{25}	An_{24}	------	------

[1] Includes 5 percent microantiperthite.
[2] Accessory minerals include apatite, zircon, and sphene.

SAMPLE LOCALITIES

144. On north slope of small hill 0.5 mile south from southwest shore of Atwood Lake.
144A. 0.15 mile east of sample locality 144.
145. From small hill 0.1 mile south of "C" in the name "Wilmurt Corners" on plate 1.
59. On south slope of valley 1.3 miles from mouth of Jones Creek.
34. About 0.5 mile south of Route 8 on east side of French Road.
178D. On top of hill 0.6 mile northwest of Richards Vly.

gneiss is intimately interlayered with metasedimentary rocks of the Grenville Series, and locally it occurs as lenses in rocks of the Grenville Series.

The oligoclase gneiss has a well-developed gneissic structure. It is a fine- to medium-grained green gneiss that is commonly very uniform in appearance. It consists principally of sodic plagioclase (oligoclase), quartz, and minor amounts of potassium feldspar, some of which occurs locally as intergrowths in the plagioclase. The content of ferromagnesian minerals averages less than 3 percent. The less common minerals include microcline, magnetite, apatite, and zircon. Sericitization of plagioclase and chloritization of ferromagnesian minerals is common. The modes of a representative group of these rocks are given in table 7.

In the field, oligoclase gneiss can be distinguished from equigranular quartz syenite by its lighter green color and by the absence or low content of ferromagnesian minerals. In quartz syenite, microperthite occurs in amounts equal or nearly equal to the plagioclase whereas in the oligoclase gneiss, oligoclase is the predominant feldspar; and in some thin sections potassium feldspar is absent.

PINK GRANITE GNEISS

The most widely exposed rock in the quadrangle is a pink granitic gneiss that ranges from biotite-hornblende granodiorite, to quartz monzonite, to granite. The largest body of pink granite gneiss, a con-

TABLE 7.—*Modes of oligoclase gneiss*

[Tr., trace or present; C, cataclastic; G, granoblastic; B, microbrecciated; M, mortar; X, xenomorphic granular]

	63	94	93	154	161G	18b	20	22
Potassium feldspar	2				14	13	3	7
Plagioclase	62	56	62	60	55	50	62	55
Quartz	32	39	33	37	23	31	23	35
Hornblende		Tr.			5			
Biotite	[1] 4				1	[1] 4		
Clinopyroxene		Tr.	Tr.		2	1		
Accessories [2]	Tr.	0.5		Tr.	Tr.	1	3	Tr.
Chlorite		4	5	2			9	3
Opaque		0.5	Tr.	1				
Texture	C	X	X(B)	X	G	M	G	G
Size (mm)	0.3	0.5			0.2–0.5	0.2	0.2	0.2–0.3
Plagioclase composition	An_{24}	An_{25}	An_{25}	An_{23}	An_{24}	An_{25}	An_{25}	

[1] Chloritized.
[2] Accessory minerals include apatite and zircon.

SAMPLE LOCALITIES

63. On south slope of hill 0.1 mile west of Jerseyfield Road and 1.4 miles south of the southern tip of Jerseyfield Lake.
94. From top of hill 1.8 miles east of Hedgehog Mountain.
93. At Bull Hill.
154. On hill 0.7 mile east of Bull Hill.
161G. On California Trail 0.55 mile west of the county line.
18b. On Jerseyfield Road 0.3 mile south of quadrange.
20. On south slope of hill 0.15 mile north of south boundary of quadrangle and 0.1 mile east of Jerseyfield Road.
22. On small hill 1.25 miles west from the southeast corner of map.

tinuation of granite gneiss from the Piseco Lake quadrangle (Cannon, 1937), occurs in the area around Fort Noble, Bethune Mountain, and Morehouseville. A body of pink granite gneiss extends westward for about 8 miles along the east edge of the quadrangle from near Bochen Lake. This body is on the south limb of the Morehouseville syncline (pl. 1); it is apparently continuous with the pink granite gneiss exposed just north of Morehouseville. Pink granite gneiss is also exposed in an area slightly north of McCauley Mountain and westward to the edge of the quadrangle. Other, smaller bodies of pink granite gneiss were noted in the quadrangle, but most were too small to be mapped. Most of the Grenville outcrops contain extremely thin layers of pink granite gneiss, and lenses of this gneiss are common in the other rocks as well. In the Fort Noble Mountain area, pink granite gneiss is locally intimately mixed with biotite-plagioclase gneiss and amphibolite of the Grenville Series.

Contacts of the pink granite gneiss with other rocks were nowhere observed except near Fort Noble Mountain, where both sharp and gradational contacts can be seen. In this area some outcrops in the transition zone between the Grenville Series and pink granite gneiss contain streaks or screens of Grenville rocks that may be skialiths in the pink granite gneiss. In other areas there appears to be a gradation from biotite-plagioclase gneiss through biotite-plagioclase gneiss rich in microcline porphyroblasts into pink granite gneiss. In places the microcline-rich rock grades into pink granite gneiss within a distance of 2 feet.

Foliation, defined by alternating felsic and mafic-rich layers, is well developed in the pink granite gneiss. Lineation, defined by needles of quartz (fig. 3), by pegmatites, by linear quartz segregations, and by streaks of ferromagnesian minerals, is also exceptionally well developed in highly sheared zones. The pink granite gneiss is fine to medium grained and is generally characterized by a pink color on both fresh and weathered surfaces. Where it is close to amphibolite, the gneiss is commonly green; rarely, it is grayish white.

Xenomorphic granular textures are most common; but some textures suggest replacement, crushing, and recrystallization; and in some specimens, the feldspars are interlocking.

Feldspar, quartz, hornblende, and biotite are the principal minerals in the pink granite gneiss. Pyroxene and garnet occur rarely. Microperthite is the most common potassium feldspar, and thin sections reveals some interstitial microcline. Locally, there are some microcline-rich granite gneisses. Oligoclase (An_{18-27}) is the principal plagioclase, but locally some granite gneisses contain albite.

Oligoclase commonly contains patches of sericite; hornblende and

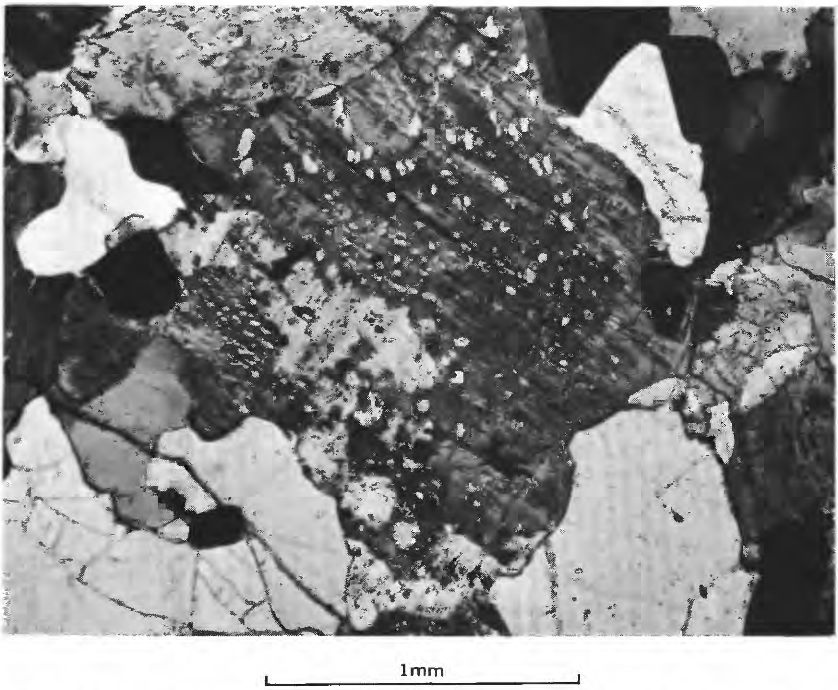

FIGURE 3.—Photomicrograph of sheared pink granite gneiss showing prominent needles of quartz that define the lineation (crossed nicols). Section cut parallel to foliation.

biotite are altered to chlorite, and calcite occurs locally. Microcline commonly replaces plagioclase (fig. 4) and, in places, occurs as an irregular or patchy network of small grains between larger mineral grains. Microperthite, in places, has rims of sodic plagioclase with fingers or lobes that penetrate the potassium feldspar. A little myrmekite occurs in plagioclase grains adjacent to some microcline and commonly the microcline partly encloses some of the plagioclase and myrmekite.

Modes of typical pink granite gneiss are given in table 8, and table 9 gives the modes of pink granite gneiss from the Fort Noble–Bethune area, where the pink granite gneiss is mixed with biotite-plagioclase gneiss of the Grenville Series. These tables show that the granite gneiss from the Fort Noble–Bethune area has, on the average, about 10 percent more plagioclase and less mafic minerals than does the other granite gneiss.

There are small but noticeable mineralogic differences between the granite gneiss in the mixed area near Fort Noble Mountain and certain closely associated rocks of the Grenville Series. The biotite content of the granite gneiss ranges from a trace to 6 percent and averages

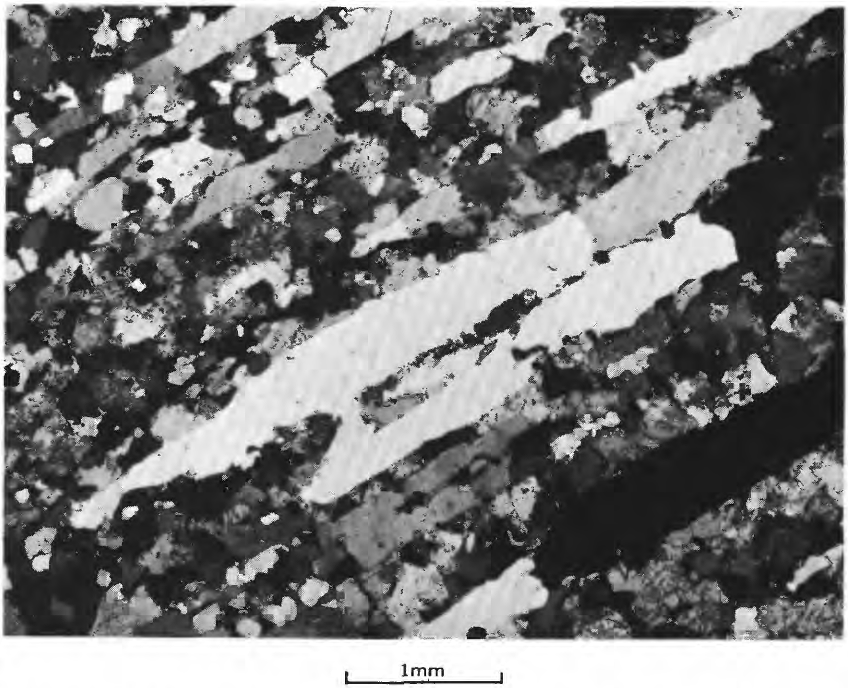

FIGURE 4.—Pink granite gneiss, showing a microcline grain containing numerous inclusions of plagioclase. Plagioclase grains are light colored, and all have the same orientation. Microcline has almost completely replaced the plagioclase (crossed nicols).

TABLE 8.—*Modes of typical pink granite gneiss*

[Tr., trace or present; G, granoblastic; X, xenomorphic granular]

	137C	139A	139E	202E	207B	198E	208E	181A	158A	52	196A
Potassium feldspar	44	40	44	24	40	38	20	32	37	28	51
Plagioclase	14	21	19	45	23	23	32	19	35	34	18
Quartz	31	26	32	16	25	25	38	34	26	35	26
Hornblende	9	10	4	6	5	12	8	10			
Biotite	1	2	Tr.	1	6	1	1	4	2	3	5
Magnetite				6	1	Tr.		Tr.			
Accessories [1]	1	1	1	2	Tr.	1	1	1	Tr.	Tr.	Tr.
Chlorite	Tr.										
Pyroxene		Tr.									
Texture	X	X	X	X	X	X	X	X	G	G	X
Size (mm)	0.3–0.7	0.6±	0.5±	0.3–0.5	0.5±	0.5±	0.4–0.6	0.3	0.2–0.3	0.3	0.5±
Plagioclase composition	An_{23}	An_{22}	An_{22}	An_{18}	An_{24}	An_{23}	An_{23}	An_{24}	An_{22}	An_{24}	An_{24}

[1] Accessory minerals apatite, zircon, and sphene.

137C. From south slope of hill between Polack and Baldface Mountains.
139A. From side of hill 0.7 mile north of the mouth of Betty Green Brook.
139E. On bank of small stream at an altitude of about 1,700 ft, 1.5 miles southwest of Baldface Mountain.
202E. From outcrop on east bank of West Canada Creek 0.35 mile north of Betty Green Brook.
207B. From top of hill 1 mile east of Twin Lakes.
198E. From southeast slope of hill east of Baby Lake.
208E. From northwest slope of hill about 0.2 mile northwest from that point on the jeep trail that touches the "W" in the name "Whiskey Spring Vly" on plate 1.
181A. From west side of hill 0.7 mile west of Pooler Vly.
158A. On south slope of hill 1.1 miles northeast Atwood Lake.
52. On south side of a hill that is 1.1 miles west-southwest from the center of Bochen Lake.
196A. From south part of hill that is 1 mile west-southwest of the mouth of Twin Lakes.

TABLE 9.—*Modes of pink granite gneiss of the Fort Noble–Bethune Mountain area*

[Tr., trace; G, granoblastic; M, mortar; X, xenomorphic granular]

	61F	39	67B	2	1	3
Potassium feldspar	21	33	54	33	36	39
Plagioclase	51	39	21	27	33	34
Quartz	22	24	24	38	28	26
Hornblende	Tr.					
Biotite	5	3	0.5	1	2	0.5
Accessories [1]	1	1	0.5	1	1	0.5
Chlorite	Tr.			Tr.		
Pyroxene	Tr.					
Size (mm)	0.2–0.3	0.2	0.3–0.5	0.3–0.4	0.2–0.5	0.3–0.6
Texture	G	M	G	G	G	X
Plagioclase composition	An_{28}	An_{23}	An_{27}	An_{27}	An_{24}	An_{27}

[1] Accessory minerals include apatite, zircon, magnetite, and sphene.

SAMPLE LOCALITIES

61F. From outcrop located near bridge on West Canada Creek 0.2 mile south-southwest of Wilmurt School.
39. At the east end of Ohio Gorge on West Canada Creek.
67B. Due north 0.3 mile from the bridge on the Fayle Road over West Canada Creek.
2. On east end of ridge on top of Fort Noble Mountain.
1. From north side of West Canada Creek 50 ft. west of trail to Fort Noble Mountain.
3. Just a little east of county line on south side of Fort Noble Mountain at an altitude of about 1,940 ft.

about 2 percent; in the biotite-plagioclase gneiss of the Grenville Series, the biotite content is between 10 and 22 percent and averages 15 percent. Potassium feldspar, on the other hand, is more abundant in the granite gneiss than in the biotite-plagioclase gneiss, and plagioclase is, on the average, about 10 percent less abundant in the granite gneiss than in biotite-plagioclase gneiss.

MIGMATITE

Migmatites consisting of alternating layers of light-colored granitic and darker, more mafic materials occur locally in the quadrangle but are not shown separately on plate 1. Most of them occur in the Fort Noble Mountain area, where they are closely associated with pink granite gneiss and metasedimentary rocks of the Grenville Series. Individual layers range from a quarter of an inch to almost 1 foot in thickness and are parallel to the foliation in the adjacent rocks. The dark layers are Grenville rocks and range in color from green to dark gray or black; the granitic layers are light pink. Contacts between layers are generally sharp, but some boundaries are indistinct and gradational. Some metasedimentary rocks adjacent to the migmatites contain porphyroblasts of microcline with their long dimensions parallel to the layering in the migmatites. In places small concordant thin layers of pink granitic material, generally less than one-fourth of an inch thick, extend outward for several inches into the metasedimentary rocks from the ends of the microcline porphyroblasts.

Migmatite consisting of alternating bands of pink granite material and gray granulated felsic gneiss that contains pink porphyroblasts of microcline is exposed in an abandoned quarry by the road 0.7 mile north of Nobleboro.

APLITE

Sheets or dikes of light-pink aplite approximately 1–2 inches thick are widespread, especially in the pink granite gneiss. Many of the aplite sheets intersect the foliation in a line parallel to the lineation, but some aplites are parallel to the foliation. An idealized section normal to lineation would show aplite sheets as spokes of a wheel and the lineation at the wheel axis. This suggests that aplite emplacement was tectonically related to the formation of lineation. Cannon (1937, p. 58) attributed similarly oriented aplites to contemporaneity of deformation and aplite formation.

PEGMATITES AND QUARTZ

Pink to white pegmatite and white quartz veins, stringers, eyes, and blebs occur in most of the igneous and metasedimentary rocks except metagabbro. Three general types of pegmatite occur in the quadrangle: those that have boudinage structures; the small irregular pegmatites that are discordant to the planar structures; and the pegmatites that have intruded along cross and diagonal joints. Commonly pegmatites and quartz bodies are oriented parallel to the lineation, and some are similar in orientation to the aplite sheets. Contacts of pegmatites with the country rock range from sharp to indistinct, but the contacts of quartz bodies are always sharp.

Those pegmatites occurring as boudins have a faint foliation that parallels the boudin outline, but most pegmatite and quartz bodies are not foliated. Although no detailed study was made of the pegmatites and quartz bodies, one thin section of a pegmatite in pink granite gneiss was examined. It contains the same minerals as the pink granite gneiss, but the pegmatite is coarse grained. Pegmatites in the equigranular quartz syenite contain the same minerals as the host rock.

DIABASE

Two diabase dikes were observed in the quadrangle. They are dark gray and massive and have no gneissic structures. One dike of fine-grained diabase about 2 inches wide cuts oligoclase gneiss in the southern part of the quadrangle. A dike of medium-grained diabase, estimated to be nearly 50 feet wide, is partly exposed along the valley wall of Fourmile Brook. Although only a small part of the dike was observed, it is believed to follow the stream valley. Cannon (1937) mapped diabase near the west edge of the Piseco Lake quadrangle along a continuation of the trend of the Fourmile Brook fault. This fault may have been intruded by a large diabase dike, but no outcrops of diabase were observed between Fourmile Brook and the dike mapped in the Piseco Lake quadrangle.

Diabase from Fourmile Brook has a subophitic texture and consists mainly of andesine (An_{45-50}), clinopyroxene, and an opaque iron mineral. Interstitial granophyric textures occur but are not common. Diabase near the fault zone in Fourmile Brook has clinopyroxene grains that are crushed to aggregates of small granules, apparently relics of original large crystals. Andesine laths are not deformed. Brecciated diabase from the fault zone shows that some of the angular fragments were finely crushed and that the spaces between fragments were later filled with quartz, most of which has an undulatory extinction. Part of the quartz filling has a mylonitic texture—particularly in the narrow contact areas between quartz and diabase breccia fragments—which suggests that the quartz was also crushed and later recrystallized.

Alteration is extensive in the diabase; the andesine is highly sericitized and the clinopyroxene chloritized. Sericitization and chloritization are less extensive in the adjoining country rock.

Postel (1952, p. 21) mentioned that many diabase dikes occur in Clinton County, in the northeastern Adirondack Mountains; Postel, Nelson, and Wiesnet (1959) reported that only two have been observed in the Nicholville quadrangle in the northwestern Adirondacks.

ORIGIN OF PLUTONIC ROCKS

The origin of many of the plutonic rocks is not clearly established by the available data. Scattered evidence presented below indicates an igneous origin for at least some of the rocks, particularly the anorthosite, metagabbro, and quartz syenite complex, and some of the pink granite gneiss. However, some of the pink granite gneiss probably formed by granitization. The origin of the oligoclase gneiss and the diorite gneiss is problematic.

The anorthosites in the Ohio quadrangle are believed to be igneous because they are similar to the large anorthosite bodies, presumably of igneous origin, of the central Adirondack Mountains. The metagabbros are believed to be igneous rocks because they have ophitic textures.

Rocks of the quartz syenite complex have a uniform mineralogical composition and generally lack replacement textures. In places, septa of amphibolite and lenses of other Grenville rocks indicate that quartz syenite is intrusive into the Grenville Series. Gneissic structures in some of the inclusions do not have the same orientation as similar structures in the host quartz syenite; the difference suggests that the inclusions were rotated before consolidation of the magma.

Some of the pink granite gneiss probably represents crystallized magma, but some appears to be the result of metasomatism of biotite-plagioclase gneiss of the Grenville Series. The magmatic origin of some of the granite gneiss is suggested by its relation to the intrusive rocks of Piseco dome (Cannon, 1937). Much of the pink granite gneiss is folded into an anticline that is the westerly extension of Piseco dome, and some can be traced laterally into similar granite gneiss of Piseco dome. Therefore, they presumably have the same origin.

Field and laboratory studies suggest that part of the pink granite gneiss resulted from reactions of potassium- and silica-rich solutions with the Grenville paragneisses. Outcrops in part of the Fort Noble-Bethune Mountain area show that gradational contacts that have minor compositional changes between Grenville rocks and granite gneiss occur both along and across the strike of the rock units. Transitional zones of granite gneiss contain screens of Grenville rocks that are highly suggestive of replacement of Grenville rock by granite. Replacement textures and crush zones in the pink granite gneiss are similar to those of the biotite-plagioclase gneiss rich in microcline porphyroblasts. If the microcline-rich rock is the result of alkali and silica metasomatism, as suggested previously, some of the nearby granite gneiss is likely also the result of replacement. Modal analyses show that plagioclase and biotite are less abundant in pink granite gneiss than in the rocks of the Grenville Series, but that the potash content is higher in the granite gneiss.

Figure 5 shows changes in chemical composition in the postulated progression from unaltered biotite-plagioclase gneiss without microcline to porphyroblastic gneiss and pink granite gneiss. Data are from table 3. There is a progressive increase in silica and alkalies and a decrease in iron, magnesium, calcium, and aluminum. These data are interpreted to indicate that the gradual change from biotite gneiss through porphyroblastic gneiss to granite gneiss was due to introduction of alkali- and silica-rich materials.

In summary, it is believed that metasomatic changes that converted the paragneiss to pink granite gneiss were caused by alkali- and silica-rich fluids that permeated the rocks through channelways in shear and crush zones that developed during deformation. As some of the granite gneiss is intrusive and is undoubtedly related to the igneous rocks of nearby Piseco dome, it is suggested that the alkali- and silica-

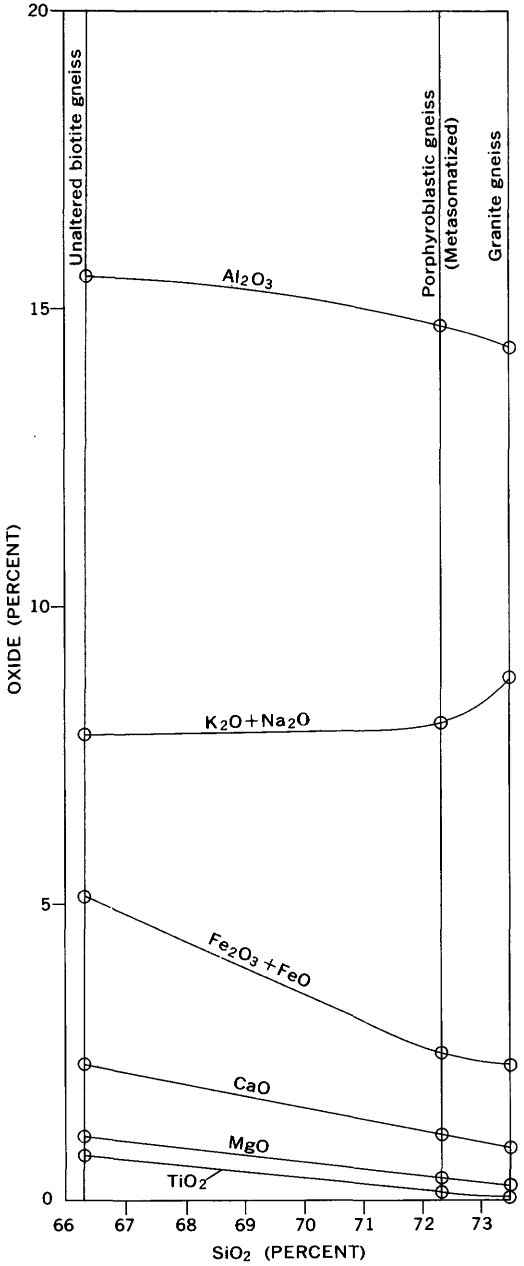

FIGURE 5.—Interpreted compositional trends from rocks of Grenville Series to pink granite gneiss.

rich solutions originated in the magma that produced the rocks of Piseco dome.

The migmatites probably formed by the reaction of invading granitic material that penetrated the rocks of Grenville age along bedding or other structural planes.

The age and genetic relations between the pegmatite and quartz bodies are unknown because contacts between the bodies have not been observed. Faintly foliated pegmatites, occurring as boudins, are believed to be the oldest pegmatites in the quadrangle. They probably existed prior to the plastic deformation that produced the boudins. It is conceivable, however, that the boudins formed during the period of plastic deformation. Geometric relation between some of the pegmatite and quartz bodies and the lineation suggests that they may have formed by local anatexis during the final stages of metamorphism and deformation, when the lineation developed, as suggested by Postel (1956, p. 22) for silexite and pegmatite in Clinton County, N.Y. The small irregular discordant dikes are believed to be the youngest pegmatites. Many of them occur in the pink granite gneiss, and at least some of them may be genetically related to it.

AGE SEQUENCE OF THE PLUTONIC ROCKS

Evidence of the relative ages of the rocks in parts of the Adirondack Mountains is meager and in some areas is insufficient to establish a complete geologic succession. Throughout the years several workers (Buddington, 1939, p. 197–234; 1953, p. 14–20; Cannon, 1937, p. 35–38; Postel, 1952, p. 18; Postel and others, 1956) have accumulated evidences of relative ages, and the following age sequence is generally accepted for the Precambrian rocks in the Adirondack region. The rocks of the Grenville Series are believed to be the oldest; they are followed, in order of decreasing age, by anorthosite and metagabbro, the quartz syenite complex, quartz diorite gneiss, oligoclase gneiss, pink granite gneiss, aplite and pegmatite, and diabase dikes.

Little field evidence for the relative ages of the Precambrian rocks was obtained in the Ohio quadrangle. Many inclusions and septa of rocks of the Grenville Series occur in the orthogneisses and are believed to show that the Grenville rocks were intruded by the igneous rocks. The relative ages of the anorthosite and metagabbro could not be determined, nor could their relationship to the other rocks be established. No evidence for the relative ages of the pink granite gneiss, oligoclase gneiss, and quartz syenite complex was obtained.

The equigranular and porphyritic quartz syenite are believed to be contemporaneous and to have been derived from the same magma. They look alike, especially where the phacoidal structure is not well developed. Mineralogically they are similar; they are present in the same areas and, hence, are involved in the same structures. Apparently some unknown local factors caused the difference in texture. Cannon (1937, p. 35) believed that similar rocks in the Piseco Lake quadrangle are probably different phases of the same magma.

In the northern Adirondack Mountains, rocks similar to parts of the phacoidal granitic gneiss have been mapped by Postel, Nelson, and Wiesnet (1959) as Hawkeye Granite Gneiss and have been considered to be older than the equigranular quartz syenite. Postel, Nelson, and Wiesnet (1959) indicated, however, that where phacoids are not well developed, the Hawkeye Granite Gneiss closely resembles the equigranular quartz syenite, just as it does in the Ohio quadrangle.

The undeformed diabase dikes are clearly the youngest Precambrian rocks in this area. Similar dikes in the northern Adirondack Mountains also intrude the older gneisses, but do not cut the overlying Cambrian sedimentary rocks.

In summary, it is believed that igneous rocks of the Ohio quadrangle were formed during four main periods of igneous activity. During the first period the anorthosites and associated mafic rocks were emplaced. This was followed by the intrusion of the quartz syenite complex, and still later by the intrusion of the pink granite gneisses and associated rocks. After deformation ceased the diabase dikes were intruded.

PLEISTOCENE AND RECENT DEPOSITS

Pleistocene deposits comprising ground moraine, outwash sand and gravel, and kame deposits cover most of the quadrangle. Recent alluvial gravels of limited extent and thickness are present along the streams, but have not been differentiated in mapping.

Much of the bedrock throughout the quadrangle is mantled by ground moraine consisting principally of large boulders of a wide variety of Precambrian rocks found here and elsewhere in the Adirondack Mountains. The maximum thickness of the deposits is not known, but it cannot be very great, perhaps only a few tens of feet.

Large and fairly extensive deposits of partly stratified and locally crossbedded sand occur throughout the southwestern part of the quadrangle. Deposition of this material in delta and kame terraces has left a marked effect on the topography there. Most of the sand is medium to coarse and is interlayered with fine sand that is less widely distributed. In places the coarse sand is interbedded with gravel and contains deposits of clay.

Deposits of finely laminated clay occur in the drainage basin of West Canada Creek in the western part of the quadrangle. This clay, seen at places along West Canada Creek and in Black Creek valley, is probably continuous with the clay in the Remsen quadrangle to the west (Miller, 1909, p. 43).

Several terraces in the glacial sand and gravel are present in the West Canada Creek drainage basin. A large kame plain, about 150 feet above the surrounding area, can be seen west of Gray along Hurricane Road. Other smaller kames are in the southwestern part of the quadrangle. In the kame moraine areas, erratics are not as common as elsewhere, apparently because of concealment by younger sand and gravel.

STRUCTURE

The Precambrian rocks have been folded, faulted, and sheared, and most have several sets of joints. Folds strike generally east to northeast and are mostly isoclinal and locally overturned. In the southern part of the area the fold axes plunge to the east, but in the northern part they plunge to the west and southwest. Locally, cross folds plunge gently to the north.

Lineation and foliation, occurring separately and together, are present in all the major rock types. Figure 2 shows the generalized trends of foliation and lineation in the Ohio and Piseco Lake quadrangles.

The following discussion is based on a study of many widely scattered outcrops, but the interpretation of field data is believed to be consistent with that made in other areas in the Adirondack Mountains for which subsurface data are available.

MINOR STRUCTURES

Foliation.—The most common structure in the Precambrian rocks is foliation. It is observed in all the Precambrian rocks except the diabase dikes and some pegmatite and quartz veins that crosscut the regional foliation. Foliation is defined by parallel planar arrangement of the long and intermediate axes of nearly all constituent mineral grains. In gneisses high in ferromagnesian minerals, the foliation is accentuated by alternating laminae of light-colored felsic minerals and dark-colored mafic minerals that were segregated during metamorphism. The contacts between the laminae are commonly indistinct, and each lamina contains some minerals that are dominant in the adjoining one. Trends of foliation in rocks on opposite sides of contacts are parallel to each other and, with few exceptions, are also parallel to trends of contacts. Compositional layering, presumed to represent bedding, in the Grenville series is parallel to the foliation except locally on some plunging folds, where it is cut by foliation.

As most foliation and layering observations were made on the fold flanks, it is not known how much of the foliation is a superimposed axial-plane foliation. An outcrop about 1½ miles north of Gray contains a plunging isoclinal fold. On the fold nose, an indistinct mineral foliation parallels the axial plane and cuts the layering. Foliation parallel to the layering was not observed except on the flanks of the fold, where the layers merge with the axial-plane foliation, and the two are parallel and indistinguishable.

In the southern half of the quadrangle, the foliation trends essentially east-west and dips either north or south (fig. 2). Some deviations, however, are due to local complexities of structure. The foliation in the northern half is more variable, though it generally strikes east-northeast and dips northwest. The change in trend from the southern part of the quadrangle to the northern part is due to the effect of the Piseco dome, on the east, and the Twin Lakes structural basin, on the northwest.

Lineation.—Linear features are present in all the major rock types and usually occur in the foliation planes. The principal kinds of linear features are defined by the long axes of mineral grains, streaks of mineral aggregates, grooves, elongated bodies of pegmatite and quartz, and fold axes. An alinement of the long axes of minerals in the foliation plane is the most common type of lineation. Spindles, needles, rods, and blades of recrystallized quartz are abundant. The alinement of mafic constituents in streaks and the parallel arrangement of linear aggregates of ground-up feldspar form the lineation in the coarser grained rocks. In the porphyritic quartz syenite gneiss the long axes of phacoids locally define the lineation. Lineation may be outlined by streaks of pegmatite and by linear grooves on the surfaces of tabular bodies of quartz and aplite; the lineation in these bodies is parallel to that of the enclosing rocks. In the apical areas of some isoclinal folds, the rock is a pencil gneiss. The pencils consist of crushed aggregates of quartz, feldspar, and some mafic minerals. At places, lineation is defined by the axes of minor folds in the foliation.

In the Ohio quadrangle the lineation trends east-northeast and plunges both eastward and westward (fig. 2). South of West Canada Creek most lineations plunge about 20° E.; north of West Canada Creek the lineation plunges 15°–20° W. (fig. 6). Lineations are generally parallel to fold axes and are presumably "b" lineations. No "a" lineations (perpendicular to "b") were seen in the Ohio quadrangle.

Boudinage.—Boudinage is widespread. The boudins are cigar- or barrel-shaped bodies or irregular elongated lenses and blebs. Some of the boudins are connected; others are separated. They are generally composed of amphibolite or pegmatite which can commonly be traced to a layer or band of the same material. Their longest dimension appears to parallel the east-west-trending folds and lineation. Foliation

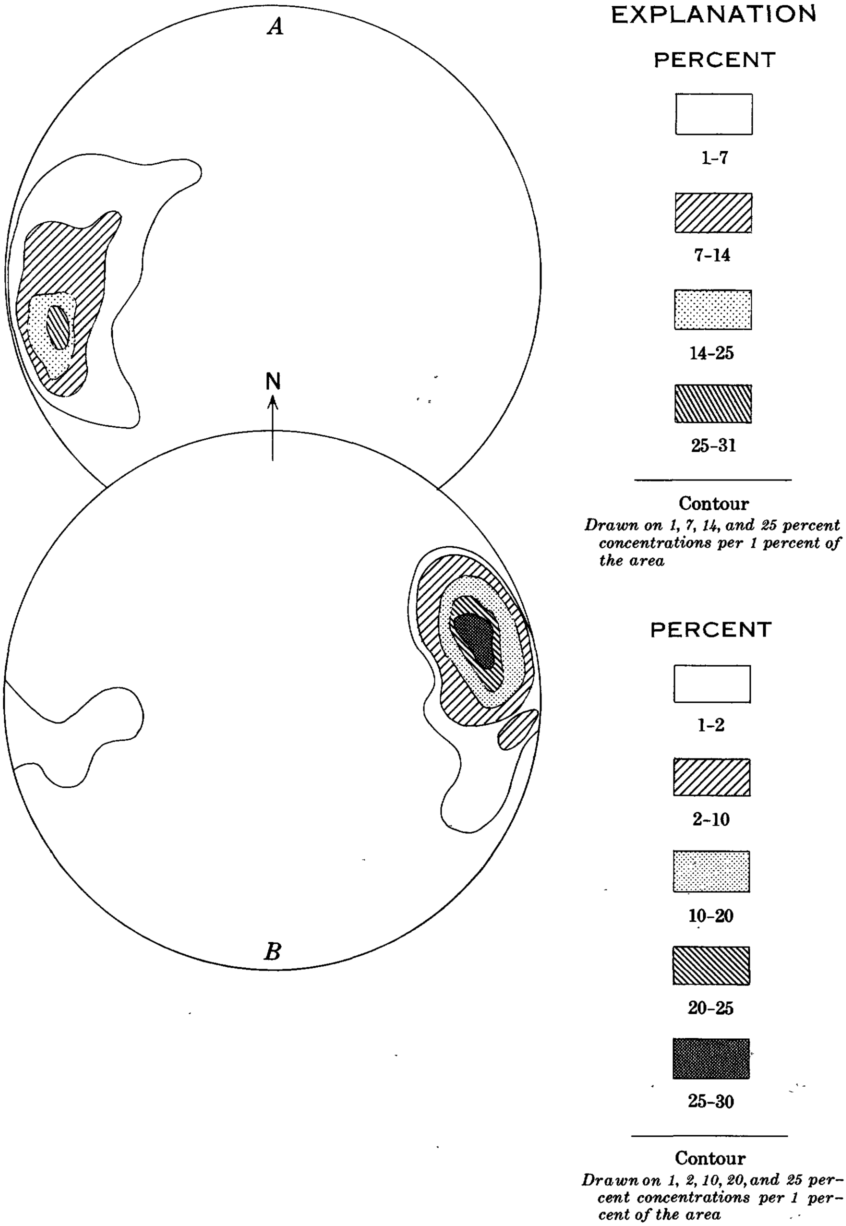

FIGURE 6.—Orientation of "b" lineations in the Ohio quadrangle, plotted on lower hemisphere of equal-area net. *A*, Orientations of 78 "b" lineations in the northern half of the quadrangle. *B*, Orientations of 96 "b" lineations in the southern half of the quadrangle.

in the boudins is parallel to their walls and to the foliation of the enclosing gneiss. Where the boudins are separated, the foliation of the enclosing gneiss parallels the configuration of the boudins, which may indicate that the enclosing rocks flowed into the spaces between them. Locally little pegmatite knots and stringers are present between boudins.

Inclusions.—Many inclusions occur in the plutonic rocks of the Ohio quadrangle. Most of the inclusions are amphibolite, and their long dimensions as well as their foliation are most commonly parallel to the foliation of the enclosing gneiss. However, some exceptions occur. In a stream valley about 1 mile northeast of Gray, the foliation in several large inclusions of amphibolite trends as much as 60° across that of the enclosing equigranular quartz syenite. Apparently, two ages of foliation are represented. The foliation of the enclosing gneiss was produced during regional metamorphism, but the foliation of the inclusions may be a rotated earlier structure.

FOLDS

Foliation and compositional layers in all the Precambrian rocks except the diabase dikes have been folded. The folds range in size from small crinkles and minor folds complete in individual outcrops to large ones that were determined by attitudes at widely scattered places. The minor folds, whose maximum amplitudes are estimated to be 15–20 feet, parallel the larger folds. The larger folds are mostly isoclinal; some are overturned, and others are probably asymmetric. South of the Hoffmeister Valley fault, the fold axes plunge east to east-northeast, whereas north of the fault the plunges are more variable and are generally to the southwest. Some minor cross faults oriented perpendicular to the regional strike were observed.

Great complexity of structure is suggested by variations in the intensity of folding. Some exposures show the rocks to be highly contorted, some have small regular overturned isoclinal folds, and others show no folds. Commonly, the direction of dip of the foliation reverses along strike in an outcrop, and many pegmatites are ptygmatically folded. Complexity is also suggested at some localities where the small isoclinal folds are overturned to the north, and at other nearby localities where the folds are overturned to the south. An example of this was observed in the vicinity of Jerseyfield Lake, where the small folds north of the lake are overturned to the north, and those south and southwest of the lake are overturned to the south. Because the minor folds apparently reflect the attitude of the larger structures, the small-scale folding in the area north of the lake indicates that the major structure there is probably an isoclinal fold overturned to the north.

Similarly, the larger structures south and west of the lake are probably overturned to the south. Many outcrops within these areas, however, do not show small folds, only steeply dipping foliation and east-trending layers.

Five major folds were mapped in the quadrangle. They are the Jerseyfield syncline, the Morehouseville syncline, the Bethune Mountain anticline, the Polack Mountain anticline, and the Twin Lakes basin (fig. 2).

Jerseyfield Lake syncline.—Jerseyfield Lake, in the southeastern part of the quadrangle, is in the trough of the Jerseyfield syncline. This fold crosses the southern part of the quadrangle, plunges east, and extends into the adjoining Piseco Lake quadrangle. It occurs in rocks of the Grenville Series that locally contain lenses of younger rocks. The rocks in the syncline are complexly deformed and are commonly overturned.

Morehouseville syncline.—The Morehouseville syncline folds porphyritic quartz syenite and trends across the central part of the quadrangle. It is the westward continuation of a structure described by Cannon (1937, p. 64) in the Piseco Lake quadrangle (fig. 2). Cannon also described an east-plunging anticline south of the syncline, but the anticline is not obvious in the Ohio quadrangle perhaps because it is complex and more tightly folded.

Foliation in porphyritic quartz syenite on the north flank of the Morehouseville syncline has relatively low to moderate southerly dips, whereas the south flank dips at high angles and is locally vertical or overturned to the north. The axis of the syncline trends east just south of Morehouseville. A short distance to the west it trends southwest and almost parallels Two Mile Brook. At many exposures along the fold axis, the foliation is indistinct, and the rocks are pencil gneisses.

Bethune Mountain anticline.—The Bethune Mountain anticline is a west- to southwest-plunging fold in pink granite gneiss that is mixed in some places with Grenville paragneisses. Its axis passes through Bethune Valley. The anticline is a westerly extension of Piseco dome (fig. 2) and is slightly asymmetric toward the north. Its axial region is readily recognized because of the strong development of linear structures there.

Polack Mountain anticline.—The Polack Mountain anticline is in equigranular quartz syenite that is highly mixed with pink granite gneiss north of the Bethune Mountain anticline. It is overturned to the southeast and plunges southwest. This fold, like the Bethune Mountain anticline, has its greatest width along the eastern part of the quadrangle; it gradually narrows to the southwest.

The foliation pattern is that of an anticline overturned to the southeast, and linear structures indicate that the fold plunges southwest. Small-scale folds on the northwest flank of the fold are also overturned to the south; hence, it is inferred that the rocks of the Polack Mountain anticline were overturned toward the south against the Bethune Mountain anticline. The axial plane of the Polack Mountain anticline dips steeply to the northwest and strikes approximately N. 60° E.; the fold axis strikes about N. 80° E. and has a plunge of 15°–20° SW.

Rocks of the Grenville Series between the Bethune Mountain anticline and the Polack Mountain anticline probably lie in a southwest-trending syncline that is overturned to the southeast. This structure, which is not obvious in the Ohio quadrangle, is an extension of the Cold Stream synclinorium of the Piseco Lake quadrangle (fig. 2). Cannon (1937, p. 65) stated that the Cold Stream synclinorium narrows westward and that the rocks north of the synclinorium strike northeast and dip northwest and are a part of the Honnedaga syncline. In the Ohio quadrangle these two synclines are separated by the Polack Mountain anticline, whose eastward continuation in the Piseco Lake quadrangle is not well defined.

Twin Lakes basin.—Twin Lakes basin, the largest structure in the quadrangle, occupies a large part of the northwest quadrant and extends northward into the adjoining Old Forge quadrangle. Bedrock throughout most of the basin is equigranular quartz syenite intermixed with pink granite gneiss. The Twin Lakes basin appears to be of the same magnitude as Piseco dome 12–14 miles away in the Piseco Lake quadrangle. The basin is asymmetrical. Dips along the north, northeast, east, and southeast sides are relatively gentle, whereas the dips along the northwest, west, and southwest sides are steep and locally overturned. In plan view, the basin is elliptical with its long dimension essentially east-west. Foliation is well defined throughout the basin, but lineation is sparse. The structure Cannon (1937, p. 65) interpreted as the Honnedaga syncline is probably the easterly extension of the Twin Lakes basin of this report.

Cross folds.—Cross folds were observed at several locations in the quadrangle, and one example can be seen high on the south slope of Fort Noble Mountain. The rocks there are on the north flank of the Bethune Mountain anticline, where the foliation and layering dip north and strike east. The foliation and streaks of quartz which define the regional lineation have been folded into north-trending folds whose amplitudes are generally less than 10 feet. This folding postdates the formation of the major structures, but its total effect on the regional structure is not great.

Minor folds.—On a hill north of Whiskey Spring Valley, a layer of amphibolite is folded into a series of sinistral folds (fig. 7). The folds are on the northwest flank of the southwest-plunging Polack Mountain anticline at the southeast margin of the Twin Lakes basin. The long limb of the folds is subparallel to the regional foliation, and the short limb is transverse to the foliation. If the crests of the folds were connected, they would trace the trend of the amphibolite layer, which at this locality is at an angle of 20° from the regional foliation. During regional plastic deformation the amphibolite layer, together with other rocks of different competence, was involved in the development of the major folds in the quadrangle. The small folds in the amphibolite formed during development of the major structures and are therefore oriented parallel to the major folds.

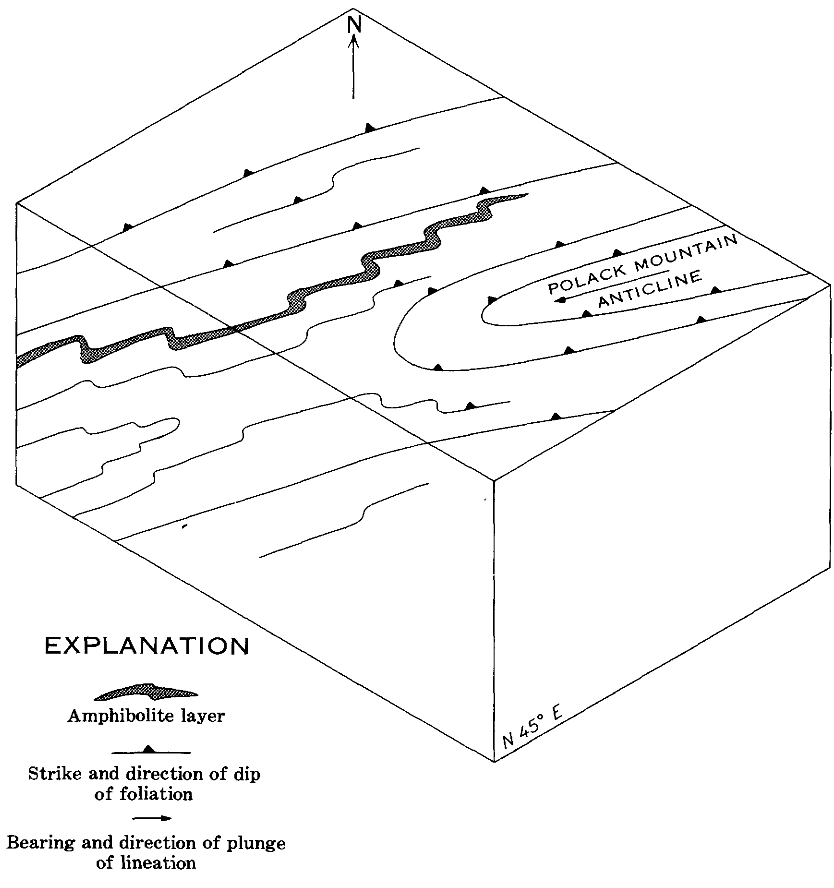

FIGURE 7.—Sinistral folds in an amphibolite layer and their relation to the Polack Mountain anticline. The anticline is overturned to the southeast and plunges southwest; the folded band of amphibolite is on the northwest flank of anticline.

FAULTS

The only faults that are fully exposed in the quadrangle have displacements of only a fraction of an inch to several inches. Direct evidence for larger faults is lacking, and no measurable displacements of major rock units were found. Other evidence, however, such as abrupt changes in trends of foliation, shear zones, breccia, and topographic features, suggest the existence of large faults and fault zones.

Sheared rocks are common, but they alternate with nonsheared rocks and are not continuous along strike. Shearing has produced a sheetlike or flattened form of streaked mineral aggregates. Quartz occurs as flat narrow blades 0.5 cm or less thick in the foliation planes, whereas in other rocks that were not as intensely sheared, the quartz occurs as somewhat wavy and more irregular blebs. Feldspar has flattened finely granular elongated bladelike forms in the highly sheared zones; however, outside the shear zones the feldspar aggregates have a more random distribution, are more lenticular, and are not as finely granular. Foliation surfaces in shear zones tend to be very straight and smooth, whereas outside the zones of highly sheared rock the foliation is wavy or uneven. Linear structures are more prominent in rocks in the shear zones than in rocks outside the shear zones. Strongly sheared blades and streaks of minerals or aggregates of minerals in highly sheared zones are parallel to the "b" lineation in the less deformed rocks. These structures are commonly confined to pink granite gneiss and the biotite plagioclase gneiss of the Grenville Series, whereas adjacent bands of the more mafic rocks in Grenville Series are not as intensely sheared. This indicates that the felsic rocks were probably less competent during regional deformation than the mafic rocks. Because the sheared mineral aggregates are parallel to the "b" lineation and, hence, to the fold axes, the formation of these structures must be related to the folding. These sheared rocks, located on the flanks of iosoclinal folds, were probably formed during the late, brittle stages of plastic deformation. Although the sheared rocks are usually discontinuous, they probably occupy positions along faults; but as most of these occurrences are limited in extent and are erratic, they are not shown on the map. These postulated faults are believed to be the earliest faults to have formed.

Hoffmeister Valley fault.—The general east-trending valley of the south and main branches of West Canada Creek contains a large fault or fault zone that is a continuation of the Hoffmeister Valley fault mapped by Cannon (1937, p. 75). This fault extends east–west across several quadrangles in the southern Adirondack Mountains and is one of the largest structural features in the region. Direct evidence of this fault is in the Piseco Lake quadrangle (fig. 2), where a major rock unit is displaced along the fault. In the Ohio quadrangle the evidence is less direct because of widespread unconsolidated deposits. However, the presence of the fault is confirmed by (1) intensely sheared rocks near the projected fault that have cataclastic and mylonitic textures, and (2) lineation that plunges in opposite directions on opposite sides of the projected fault. The westward plunge of fold axes and lineations north of the fault zone (figs. 2, 7) is probably due to westward tilting of the block north of the fault. Cannon (1937) showed that in the Piseco Lake quadrangle the south side of the fault is downthrown; similar movement seems probable in the Ohio quadrangle.

Along the projected Hoffmeister Valley fault zone in West Canada Creek, near the bridge south of Wilmurt School, a shear zone separates gently north-dipping rocks on the north side from gently south-dipping rocks on the south side. The fractures generally trend east, but some trend northeastward. Foliation in this fault zone is vertical to steep, and the rocks are finer grained than those on either side. Thin sections show localized zones or clusters of finely crushed mineral grains, large grains that have in part been partly crushed along their edges, fractured and shattered quartz grains, small mylonitic zones, and locally some large plagioclase grains that have bent twin lamellae. Granoblastic textures are also present. Lineation is well developed. The deformation that produced these cataclastic textures may have been associated with movement along the Hoffmeister Valley fault, as this shear zone is parallel and close to the Hoffmeister Valley fault.

Fourmile fault.—A part of Fourmile Brook lies along a fault of unknown extent. Topography suggests that the fault is a continuation of the Alder Bed–Jockey Bush Lake fault of the Piseco Lake quadrangle (Cannon, 1937, p. 75). Evidence for this fault can be seen in the steep valley walls about 1½ miles north of Little York Valley. At several places along the valley walls, layers of quartz irregularly alternate with a dense gray claylike material containing angular fragments of brecciated diabase; these layers strike parallel to the river and dip vertically, cutting across the foliation in the adjacent rock. The layers of quartz are interpreted as remnants of quartz-filled fissures in a fault zone, and the claylike material is probably gouge. On both sides of the river, the rocks along the valley walls are more highly sericitized and chloritized than elsewhere. This alteration may have been caused by hydrothermal solutions that were guided by the fault.

The amount of displacement could not be determined but is believed to be small. The valley walls are steep, and the layers of quartz are vertical, which indicates that the dip of the fault is about vertical.

Thin sections of diabase from the fault zone indicate that two phases of movement occurred along the Fourmile fault after emplacement of the diabase. The first movement is suggested by the presence of brecciated diabase; the second movement is suggested by the fact that the quartz which filled the spaces between the brecciated diabase fragments was later crushed and that the contact area between the quartz and diabase has mylonitic textures.

The Fourmile fault may be the same age as the "younger" faults described by Postel (1952, p. 35) in Clinton County in the northeastern part of the Adirondack Mountains, for along Postel's Palmer Hill fault, also, are brecciated fragments of diabase.

Twin Lakes Stream fault.—A fault in the upper part of the Twin Lakes Stream area is indicated by the 90° discordance between the foliation trends north and south of the stream. As the gneissic structures west of the quadrangle and east of Twin Lakes Mountain are concordant, the fault probably dies out near the west edge of the quadrangle and does not extend much beyond Twin Lakes Mountain on the east.

Transverse faults.—A transverse fault probably of limited extent is exposed near the east end of an outcrop near the bridge south of Wilmurt School but is not shown on the map. The fault trends north-northwest, dips west, and cuts across pink granite gneiss mixed with Grenville paragneisses on the south side of the Hoffmeister Valley fault. Drag along the fault indicates that the rocks are downthrown on the west side, but the total displacement is not known. Pegmatitic material was emplaced along the fault, and the rocks in the fault zone were later intensely crushed and converted to mylonite and locally to pseudotachylite. This fault is close to, and has a strike almost normal to that of the Hoffmeister Valley fault. This fault may have formed as a result of movement along the Hoffmeister Valley fault. The regional east-trending foliation close to the fault gradually curves into a position parallel to the fault plane.

Other outcrops in the quadrangle show transverse faults of similar magnitude, but because of the scale, these small faults are not shown on the map.

JOINTS

The Precambrian rocks are generally well jointed, and several joint sets have a systematic angular relationship to the lineation and to the regional folds. The joints are classified as diagonal joints, cross joints, foliation-plane joints, and longitudinal joints. Diagonal joints are the most common and are more uniformly distributed than the other types. They cross linear trends at angles ranging from 30° to 60° and dip steeply or vertically. Cross joints are steep and strike approximately normal to the linear structures. Foliation-plane joints—the least common joint set—are parallel to the foliation and are best seen where foliation has relatively low dips. Longitudinal joints are parallel, or nearly so, to the trends of lineation and dip steeply. In the apical areas of folds, where foliation is commonly lacking and where lineation is the dominant structure, the longitudinal joints are better developed than other types of joints.

Many of the joint sets are expressed by well-developed topographic lineaments, mostly stream valleys. Some lineaments, such as Hurrell Brook valley, represent diagonal joints; others, such as the valley of Mad Tom Brook, represent cross joints; and some, such as the valley of the upper part of Little York Stream, represent longitudinal joints.

ORIGIN OF STRUCTURE

Several hypotheses for the origin of planar and gneissic structures in the Precambrian rocks of the Adirondacks have been advanced. Many of the earlier geologists believed that the parallelism of compositional layering and foliation resulted from the control by previous structure in the Grenville sedimentary rocks on invading magma. Miller (1916), on the other hand, held that the gneissic structure is due to magmatic flowage. More recent geologists believe that the gneissic structures in the Precambrian rocks were formed by the plastic yield and flow of mostly solid rocks during regional deformation. The conclusions of Buddington (1937, p. 51; 1939, p. 301–331), Cannon (1937, p. 49), and Postel (1952, p. 33) on the origin of planar and gneissic structures in the Precambrian rocks of the Adirondacks are summarized as follows. The plastic yield and flow of the rocks is due to stresses imposed upon them during regional deformation. These stresses are primarily resolved in the rocks by shearing, rotation, migration of material, and recrystallization of the rock constituents; and the resultant mineral orientation defines the planar and linear structures. Finally, these structures are directly related to the folds formed during the deformation. It is believed that the previously described structures as well as the textures present in rocks of the Ohio quadrangle also originated the same way.

GEOLOGIC HISTORY

The oldest rocks in the Ohio quadrangle are Precambrian metasedimentary rocks of the Grenville Series. The Grenville rocks were successively intruded during Precambrian time by anorthosite, gabbro, rocks of the quartz syenite complex, quartz diorite and oligoclase-rich igneous rocks, pink granite gneiss, pegmatite and quartz bodies, and diabase dikes. Except for diabase, quartz, and some pegmatites, all the Precambrian rocks are deformed; commonly, these rocks have well-developed gneissic structures which are believed to have formed almost concurrently during the regional metamorphism and plastic deformation. This period of metamorphism is thought to include the times immediately preceding, during, and after emplacement of the pink granite gneiss; deformation ceased prior to the diabase intrusion. The plastic deformation destroyed most of the evidence of former periods of deformation as well as any magmatic-flow structures. Some Precambrian rocks were granitized during regional metamorphism, but the total effect of metasomatism is not fully known. Some faulting occurred before and after the emplacement of the diabase. North-trending cross folds developed probably after the main period of deformation.

Cambrian rocks probably were not deposited in this area, nor are they known to crop out in the surrounding areas; however, Ordovician shale and limestone, and possibly some younger rocks as well, were deposited upon the Precambrian rocks. Subsequent to deposition and lithification of the youngest consolidated sedimentary rocks, the region was subjected to erosion, and the sedimentary rock cover was stripped from all the Precambrian rocks except possibly those in a small area in the southwest corner of the quadrangle. During Pleistocene time a glacial veneer was deposited in the area.

ECONOMIC GEOLOGY

No mineral deposits were being worked in the Ohio quadrangle at the time the fieldwork was done (1954–58) except for the sporadic operation of sand and gravel pits. Cannon (1937, p. 101) reported that diatomaceous earth was extracted on a commercial scale from Whitelead Pond, near Wilmurt school. However, no work has been done on the deposit since about 1941.

Magnetite mineralization is sparse and irregular; some isolated outcrops are slightly magnetic owning to disseminated magnetite and veins of pegmatite that contain magnetite. Areas where some outcrops are slightly magnetic, as determined by anomalous compass readings, are shown by an overprint on plate 1. No magnetite has ever been mined in the Ohio quadrangle.

Garnet which might be suitable for use as an abrasive occurs in the Grenville series. Locally, it amounts to as much as 30 percent of a rock; one such occurrence is on a hill east of Breezy Knoll. However, the garnet deposits have not been developed, and their extent is not known.

Road metal is obtained from numerous pits in Pleistocene and Recent sand and gravel deposits. Abandoned quarries in the quartz syenite complex, pink granite gneiss, and migmatite once provided a source for crushed stone, but these quarries have not been worked for several years. Crushed stone could be obtained at numerous other places.

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INDEX

[Italic page numbers indicate major references]

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