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NIPISSIS RIVER - NIPISSO LAKE AREA, SAGUENAY COUNTY

DEPARTMENT OF NATURAL RESOURCES

MINES BRANCH

GEOLOGICAL EXPLORATION SERVICE

GEOLOGICAL REPORT 142

NIPISSIS RIVER - NIPISSO LAKE AREA

Saguenay County

by

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INTRODUCTION

In 1951, the Quebec Department of Mines commenced a program of geological mapping along and adjacent to the Quebec North Shore and Labrador railroad. In 1951, P.-E. Grenier, with the writer as assistant, mapped the Nipissis River area, and, in 1952, the writer mapped the Nipisso Lake area. These two areas are combined in this report.

Location and Access

The Nipissis River area is bounded by longitudes 65°52'W. and 66°07'W. and by latitudes 50°30'N. and 50°45'N.; the Nipisso Lake area by longitudes 65°45'W. and 66°00'W. and by latitudes 50°45'N. and 51°00'N. The southwest corner of the Nipissis River area is 24 miles northeast of Sept-Iles, on the St. Lawrence shore. Each map-area covers approximately 200 square miles.

The Quebec North Shore and Labrador railroad provides the easiest means of access to the region. Numerous large lakes in both areas provide landing points for hydroplanes. Temporary landing strips were constructed at two localities within the areas but these will not be kept in repair when construction of the railroad is completed.

In addition to these means of access, a canoe route, interrupted by two portages, one 6 miles long and the other half a mile, may be followed from the mouth of Moisie river to the map-areas. In spite of a strong current, the Moisie and Nipissis rivers are easily travelled by motor-driven canoes.

Field Work

The field mapping of the areas was done on a scale of two inches to one mile and was based on systematic traverses spaced at intervals of half a mile. Aerial photographs were used to locate and control these traverses. Preliminary base-maps were supplied by the Quebec Department of Lands and Forests and the final base-map of the Nipisso Lake area was prepared from aerial photographs by Canadian Aero Service Limited.

Previous Work

In 1939, Carl Faessler (1945) mapped an area south of the Nipissis River area, and, in 1940, E.W. Greig (1945) mapped the geology of an area immediately to the east of that mapped by Faessler. The Iron Ore Company of Canada has done reconnaissance geological mapping and prospecting near the railroad. Acknowledgement is due this Company for permission to examine the unpublished maps and reports of this survey.

Vegetation and Animal Life

Black spruce, balsam, birch, poplar and tamarack are the common trees within the areas. The black spruce and the balsam are the most common, and at many places good stands of these trees, suitable for logging, were observed. With the exception of the Nipissis valley, most of the areas covered with trees of economic size are too inaccessible for lumbering operations.

Beaver, otter, caribou, black bear, muskrat, rabbit and partridge were seen.

Nipissis river is a salmon stream. Speckled trout are abundant in the Nipissis and Nipisso rivers and in Nipisso, Cacaoni and Pérusse lakes.

PHYSIOGRAPHY

General

The map-area lies near the southern border of the Canadian Shield and show the characteristic rugged topography of the borders of the Laurentian Plateau. As is common in other shield areas, general accordance of summit levels indicates a former peneplane at or near the present summit levels.

Maximum relief is about 2,100 feet and the average local relief about 500 feet. The elevation* of the upland ranges from 1,200 to 2,450 feet above sealevel. The northern part of the area is slightly higher than the southern part.

In general, the region is a rolling to rugged upland, sloping gently from north to south. It is deeply dissected by the Nipissis-Wacouno valley and by its triburary valleys, the Nipisso and "upper" Nipissis. Lake Nipisso occupies a former deep valley that parallels the Nipissis-Wacouno valley.

The nature of the underlying bedrock has had a pronounced influence on the development of the topography of the region. Areas of high elevation but of gentle relief are underlain by granitic rocks. The lower terrain is for the greatest part exceedingly irregular, and the underlying rock is more mafic, being either strongly foliated and banded or well jointed.

Jointing and foliation appear to be the dominant factors governing the development of the characteristic valley and ridge topography of the area.

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* Determined with calibrated aneroids.

Plate I

A - Nipissis river; view northward from south end of Nipisso Lake area.

B - Nipisso lake; view northward from south end of lake.

The Nipissis-Wacouno valley transects the area and is deeply incised within the Laurentian plateau. Where the river has cut through the augen gneiss the valley is narrow with very steep walls, but elsewhere it is relatively broad and the slopes are steep but not cliffed. Along the southern part of Nipissis river, where it occupies the contact zone between granitic rocks and more mafic rocks, the granite forms cliffs and the mafic rocks form steep to gentle slopes.

Structural control of the valley is well illustrated below its junction with Nipisso river. Here the river flows along the contact between the granitic rocks and the more mafic paragneisses and intrusives. Above the junction, the valley is incised at right angles or at a steep angle to the structure of the underlying bedrock. Evidence of structural control of this upper portion of the valley is lacking. It is possible that the river, flowing on a tilted peneplane surface, utilized weaker zones wherever possible but was forced locally to cut across the structure.

The Nipissis flows and meanders upon a bed of sand and gravel. This material is the remains of a much thicker deposit whose former presence is recorded by rock-defended terraces on the valley walls. At the south end of Nipissis river area the terraces are composed of well-sorted sand and gravel beds. Northward, the unconsolidated deposits are progressively less well sorted and stratified until, near the north edge of the Nipisso Lake area, they are composed of boulders and pebbles erratically distributed in a matrix of silt and sand. This suggests that the original valley fill was glacial, and that subsequent reworking by the present stream has produced the well-sorted and stratified deposits found in the lower parts of the valley.

With the exception of the basin of Tchinicaman and Tchinicamas lakes, which drain into the St. Lawrence through Tchinicaman river, the region is part of the drainage basin of Moisie river.

Swamps are rare but lakes are abundant. The main valleys are fed by numerous, small, turbulent streams that have their origin usually in one or more lakes on the upland.

Glaciation

Both erosional and depositional features point to the former presence of glaciers in the region. Glacial striae, crescentic gouges, grooves, and polished surfaces are present in outcrops and on the walls of the Nipissis-Wacouno valley.

The Nipissis River area shows intense glacial erosion but very little glacial deposition. Lake shores lack debris, and the upland areas have few glacial erratics and only thin, scattered patches of sand and gravel. The same is true of the southern part of the Nipisso Lake area. However, north of latitude 50°50' increasing amounts of glacial debris are

Plate II

A - Nipissis River valley, north of Nipisso river.

B - Nipissis river; view southward from Nipisso river.

found; there are many sand plains and the valleys contain large amounts of sand and gravel. Immediately east of the north end of Nipisso lake,three crescentic ridges of sand and gravel lie with their long axes approximately at right angles to the direction of glacial movement in the area. These ridges are approximately 1,000 feet long, 40 feet wide, and 20 feet high. They may be recessional moraines.

A cluster of drumlinoids is found east of the junction of Nipissis and Wacouno rivers. The drumlinoids are low sand and gravel ridges, rising 10-20 feet above the general surface and separated from one another by long, very straight valleys. A section of a drumlinoid in contact with the valley wall showed scattered boulders and cobbles in a silty matrix and steeply inclined bedding. It could not be determined whether the steep dip was original or was due to slumping on the valley slope. The upper portions of the drumlinoids are composed of sand and gravel with scarce, large boulders. Locally isolated patches of bedrock protrude through the drumlinoids.

In the south of the Nipisso Lake area, where the Nipissis-Wacouno valley cuts through the augen gneiss, there are several cirque-like forms on the east side of the valley. These are semi-circular gouges in the cliff wall with a vertical back wall and near-vertical side walls. Their average dimensions are 3,200 feet wide, 1,500 feet deep, and 800 feet high. One consists of two basins, one above the other, with a 700-foot-wide and near horizontal surface separating the two vertical walls. These basins may have been formed by small local glaciers that fed the glacier that occupied the main valley soon after the retreat of the continental ice sheet.

The direction of movement of the ice sheet in the region was determined from glacial striae, grooves, crescentic gouges and the elongation of drumlinoids. All determinations were within 10° of S.10°E.

ACKNOWLEDGMENTS

In 1951, Dr. P.-E. Grenier, with the writer as assistant, mapped the Nipissis River area, and, in 1952, the writer mapped the Nipisso Lake area. Dr. Grenier's guidance in the field and his help in the preparation of this report are gratefully acknowledged. Dr. H.P. Eugster acted as senior assistant during 1952, and his help in the field and laboratory proved invaluable.

In 1951, additional party members were D. Pollock and F. Benoit, junior assistants; L. Tanguay and F. Cassivi, canoemen; and R. Campeau, cook. In 1952, they were A. Auclair and R. Kelly, junior assistants; L. Tanguay and R. Tanguay, canoemen; and R. Gallant, cook. All performed their pespective duties in a highly commendable manner.

This report was written at McGill University, and the writer is indebted to J.S. Stevenson for his helpful aid and criticism.

GENERAL GEOLOGY

The rocks of the two map-areas include paragneisses and acidic and basic intrusives. More than three-quarters of the rocks are of igneous origin; granitic types predominate.

In the Nipissis River area granitic rocks are found west and north of Nipissis and Nipisso rivers, whereas basic intrusives are found east and south of the two rivers. A narrow band of paragneisses and migmatites separates the two main rock groups.

In the Nipisso Lake area, granitic rocks occupy the southern third, except for the southeast corner, and most of the northern quarter. Paragneisses and numerous basic sills underlie the intervening area. This central part includes also a band of granitic gneiss and granulite.

The paragneisses, as outlined on the accompanying maps, are in part composed of igneous rocks. The latter are either too small to be shown as separate units or are exposed as widely separated outcrops in localities where the structure is too little known to allow the exposures to be joined together on a map. The granite gneiss-granulite zone also contains other rock types.

The age relationships shown in the following table of formations are based on contact features and, where these were not available, on the comparative degree of deformation and (or) recrystallization of the various rock units. These relationships are corroborated by mineralogical, petrographical and structural evidence which suggests that the hypersthene-bearing rocks (norite, gabbro, diorite, hornblendite, pyroxenite) are derived from the same parent magma and that the granitic gneiss around Hogan lake correlates with the main body of augen gneiss.

Table of Formations

Quaternary		Sand, gravel, till
PRECAMBRIAN		Diabase dikes
	Post-Moisie intrusions	Lamprophyre dikes Pegmatite and aplite Biotite granite Hornblende granite Anthophyllite gabbro Granite gneiss and granulite Augen gneiss and granite gneiss
	Moisie Group	Hypersthene pegmatite Amphibolites Hypersthene granite Pyroxenite and hornblendite Diorite Gabbros Norite
	Grenville-type paragneisses	Migmatites Garnet-hypersthene gneisses Quartzites Amphibolites Schists Quartzofeldspathic gneisses

If the assumptions made above are correct, then the basic rocks are older than the granitic gneisses, as the latter intrude the norite around Hogan lake. Also, east of Nipisso lake, the large inclusions of metasedimentary rocks in the augen gneiss contain several small sills of gabbro and amphibolite. Granite gneiss similar to that found in the granite gneiss-granulite zone occurs as dikes in the augen gneiss. The large gabbro dike in the east central part of the Nipisso Lake area cuts the augen gneiss and in turn is intruded by small dikes of granite which resemble the biotite granite. The hornblende and biotite granites are the youngest major intrusions in the area. Contact features show that they are younger than the augen gneiss and the gabbroic rocks. The hornblende granite is believed to be the older of the two granites as it is strongly lineated and generally gneissic, whereas the biotite granite is only locally gneissic.

Because the paragneisses are the oldest in the area, and because they resemble rocks that elsewhere have been assigned to the Grenville series, they are here also believed to be of Grenville age.

Grenville-type Paragneisses

Paragneisses similar to those found in the Grenville province of the Precambrian Shield north and northwest of Montreal outcrop in both map-areas. Wide variations in mineral composition were observed, especially in the rocks of the Nipisso Lake area. Metasedimentary rocks are sparsely distributed throughout the eastern half of the Nipissis River area, where they occur mainly as inclusions in the basic intrusive rocks. Good exposures are present along the east side of the Nipissis River. A band of paragneisses, averaging a mile in width, extends from the south boundary to approximately 2 miles below the junction of Nipissis and Nipisso rivers.

In the adjoining area to the north, metasedimentary rocks underlie the greater part of the area north of latitude 50°50'. The width of this belt cannot be determined, as there are numerous basic and acidic rocks injected parallel to the strike of the formations.

In decreasing order of abundance the Grenville rocks consist of quartzofeldspathic gneisses, schists, quartzites, amphibolites, and hypersthene gneisses. Garnet has been seen in all types with the exception of the biotite and hornblende schists.

A strong foliation or banded structure characterizes the metasedimentary rocks of the region. The bands range from 1/16 inch to several inches thick and they may be traced without change in thickness or composition across tens of feet. Individual outcrops usually contain two or more rock units, and it is impossible to divide the Grenville on the accompanying maps into separate zones.

Quartzofeldspathic Gneisses

At least three-quarters of the metasedimentary rocks of the area are gneisses containing abundant quartz and feldspar. The gneisses are fine to medium grained*, strongly crystalline, and gray or green. Foliation is distinct, with light and dark bands alternating, and lineation may be seen in most hand specimens.

Key minerals are biotite, hornblende, sillimanite, graphite, muscovite, cummingtonite and epidote. Many of these minerals occur together in the same gneiss. Quartz has been strained and displays undulose extinction. Microcline is common, some resulting from the original composition of the sediment, but much was introduced.

Biotite Gneiss - Gneisses containing biotite and hornblende in varying proportions are very abundant in the region. The basis of separation of these gneisses is as follows:

Biotite gneiss contains biotite in excess of two-thirds of the total biotite-hornblende content.

Hornblende gneiss contains hornblende in excess of two-thirds of the total biotite-hornblende content.

Intermediate types are biotite-hornblende gneisses.

Under the microspope, the foliated character of biotite gneiss shows up as an alternation of felsic and mafic bands. The grains are equigranular and granoblastic, with sutured contacts. A preferred orientation of the quartz grains is readily seen, and the biotite flakes are elongated in the same direction. Quartz is present in amounts up to 60%. Oligoclase-andesine makes up 10-50% of the grains and shows only slight alteration to white mica. The feldspar is strongly twinned according to the albite law and rarely displays pericline and carlsbad twinning. Biotite is everywhere pleochroic in shades of yellow and brown. Additional minerals observed in the 10 thin-sections examined are hornblende, microcline, graphite, garnet, sillimanite and muscovite. Locally the biotite gneiss contains abundant pink garnets, probably almandine. Apatite, sphene, magnetite, and zircon are accessory minerals.

Hornblende Gneiss - The color of the hornblende gneiss depends upon the percentage of mafic minerals; outcrops with a low amphibole content are light gray, whereas amphibole-rich varieties are dark greenish gray. Grain size ranges from fine to coarse, with most rocks being medium-grained.

The study of five thin-sections revealed that all have a granoblastic to nematoblastic, equigranular texture; the grain contacts show evidence of resorption. The mineral composition of the rock is variable with regard to actual minerals present as well as to the percentages of the mineral components. Maximum hornblende content in thin-sections was 55%. Plagioclase ranges from An_{27} to An_{35}. It shows diffuse zoning, the borders being about 50% more sodic than the core. Alteration is very slight and, where present, consists of sericite, clinozoisite, epidote, and calcite. Small amounts of biotite and epidote are occasionally seen. Garnet is seen. Accessory minerals are sphene, apatite, magnetite, zircon, and pyrite.

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* Coarse grained - greater than 5 mm. Medium-grained - 5 to 1 mm. Fine grained - less than 1 mm.

Biotite - hornblende Gneiss - Twelve thin-sections of this rock type were examined. All showed the same textural and structural properties as described for the previous two gneisses.

Biotite, hornblende, plagioclase, and quartz, in varying proportions, are the essential rock-forming minerals. Plagioclase has the composition of oligoclase-andesine with extreme values of An_{15} and An_{35}. Two slides contained a low percentage of epidote (pistacite?) as yellowish green, anhedral to subhedral grains. Accessory minerals are sphene, apatite, magnetite, zircon, and pyrite; the first two minerals may be fairly abundant.

Sillimanite Gneiss - Sillimanite, muscovite, and graphite gneisses occur as isolated outcrops or bands in both areas. They are especially abundant along the northern border of the augen gneiss. This zone can be traced across the width of the Nipisso Lake map-area.

The sillimanite gneisses are light gray, fine to medium grained, and well foliated. Sillimanite occurs in clusters of very fine needle-like grains and rerely as distinct crystals; the needles may by up to ½ inch long. Locally garnetiferous gneisses are abundant. The rock contains quartz, biotite, plagioclase (An_{15} to An_{20}), microcline, muscovite, graphite, and garnet. Accessory minerals are zircon and sphene. Garnet (almandine) contains inclusions of sillimanite and was probably the last mineral to form.

Graphite Gneiss - A rusty weathered surface and finely disseminated graphite flakes characterize this rock type. Weathering destroys the adhesive bond between grains and the rock disintegrates readily from a hammer blow. The color of fresh specimens varies from light to dark gray. Grain size is variable, although most specimens are medium grained.

Microscopical examination reveals a granoblastic texture with the grains more or less equigranular. Biotite is pleochroic in yellow and brown. Quartz is a major component forming up to 40% in the thin-sections examined. Sodic andesine is present in appreciable amounts and usually has a diffuse normal zoning. A potassic feldspar with very fine grid-twinning is also present. The feldspar is cryptoperthitic to microperthitic and is probably microcline. Zircon, pyrite and magnetite are accessories and, locally, there is abundant garnet.

Although graphite locally may make up to 10% of the minerals present, the small size of the grains, usually less than 1/8 inch, would appear to discourage economic exploitation of the graphite gneiss.

Muscovite Gneiss - Fine-grained muscovite gneisses are intimately associated with the sillimanite gneisses. Generally they contain a small amount of sillimanite. Essential components are quartz, muscovite, biotite, plagioclase, and microcline. The biotite has a colorless to pale brown pleochroism. Zircon and sphene are rare.

Cummingtonite Gneiss - A few narrow bands of cummingtonite gneiss are interbedded with biotite gneiss. The rock is brownish gray and medium grained, and shows a crude foliation. In hand specimens, quartz, feldspar, and a yellowish brown amphibole are easily recognized. The feldspar is calcic oligoclase.

A small percentage of biotite is also present. Magnetite and zircon are accessory minerals.

Epidote Gneiss - One outcrop containing the mineral assemblage epidote, manganiferous pyroxene (hedenbergite or schefferite), plagioclase, and quartz was found along the west boundary of the Nipisso Lake area, half a mile north of the augen gneiss. The rock is fine grained and strongly foliated, and has a pitted weathered surface. Plagioclase has an anorthite content of 90%. Accessory minerals are sphene and zircon.

Schists

Schistose rocks in which the quartz content is less than 10% outcrop sparingly in the region. Biotite-rich varieties predominate. The amount of plagioclase is variable but never exceeds 60% in the biotite schists. The schists are medium to coarse grained and dark colored, and form bands up to several inches thick in the surrounding paragneisses. Locally they weather rusty.

Only one thin-section of biotite schist was examined. The rock is medium grained, nematoblastic, and free from alteration. Biotite is the predominant mineral, with plagioclase (An_{25}), quartz, hornblende, and sphene also present. Well-developed pleochroic haloes around zircon grains are abundant in the biotite flakes. Apatite, magnetite, and zircon are the accessory minerals.

Hornblende and hornblende-biotite schists have the same appearance as the biotite schists, but hornblende is present in amounts greater than, or equal to, biotite.

One thin-section of a hornblende paragneiss has five distinct bands of different mineralogical composition. The thickness and estimated mineral composition of the bands are as follows:

Inches		Composition
3/8	-	hornblende 90%, diopside 10%
1/8	-	hornblende 100%
1	-	hornblende 45%, plagioclase 35%, biotite 15%, sphene 5%
1/4	-	hornblende 85%, quartz 15%
1	-	hornblende 35%, plagioclase 45%, biotite 15%, microcline 5%

The bands do not grade into one another and the mineral assemblages appear to be the result of different original chemical composition rather than the result of metamorphic differentiation.

Amphibolites

Amphibolites derived from sedimentary rocks outcrop in the Nipisso Lake area. Difficulties were encountered in attempting to distinguish between the para-amphibolites (of sedimentary origin) and the ortho-amphibolites (of igneous origin). The characteristic features of the amphibolites that could be traced into gabbros were compared with those of the amphibolite bands believed to be of sedimentary origin. A list of these features was compiled, and, although it is realized that common characteristics have been observed in both types, the two amphibolites have, nevertheless, distinct diagnostic properties.

Ortho-amphibolites have the following characteristics:-

1. Gneissic structure
2. Relict igneous textures
3. Gradation into gabbro
4. Resistance to migmatization
5. Criss-crossing by hornblende veinlets in places
6. Inclusion of paragneiss
7. Pinching and swelling along strike in places
8. Presence of pyroxene (especially hypersthene and augite) as a relict mineral.

The characteristic features of the para-amphibolites are:-

1. Strong foliation
2. Alternate paragneiss layers in places
3. Easy migmatization
4. Uniform width along strike
5. Presence of quartz as an accessory mineral.

Under the microscope, the rock is seen to be composed of plagioclase (An_{25}), green magnetite, and apatite. The foliation is clearly discernible and the grains are medium to coarse.

Quartzites

Many of the rocks mapped as fine-grained quartzites in the field were found in thin-section to contain sufficient plagioclase and biotite to classify them as biotite gneisses. However, there are small patches or lenses of nearly pure quartzite in the paragneisses and in the inclusions in the norite. Several bands of quartzite outcrop on the east shore of the northwest bay of Tchinicaman lake. One is approximately 5 feet wide and composed almost entirely of quartz. Another is about 3 feet wide and is interbedded with graphite gneiss. A thin-section of the latter band contained about 80% quartz, plagioclase (An_{30}), and a small amount of pyroxene that appears to be hypersthene. Accessory minerals are graphite, apatite and pyrite.

East of Nipisso lake, the long, folded inclusion of paragneiss that lies near the north border of the augen gneiss contains several outcrops of coarse-grained quartzite. The only other mineral observed in the rock was biotite (never more than 5%).

Garnet-hypersthene Gneisses

Garnet-hypersthene gneisses are exposed in the northwest bend of the large paragneiss inclusion near the north border of the augen gneiss on the east side of Nipisso lake. They occur also on the west side of Nipisso lake, three-quarters of a mile from Debor lake.

These rocks are strongly banded, the individual bands ranging between 1/4 inch and 12 inches thick. Half the bands are coarse-grained quartzite containing up to 15% red garnet. The other layers have varying amounts of quartz, hypersthene, and garnet. The bands are drag folded and pinch and swell along the strike. The oxidation of a small amount of sulfides and the brownish-red weathering of the pyroxenes give the outcrops a deep rust color.

Thin-sections of the pyroxene-bearing bands show that the rock is medium grained and granoblastic, with a few large porphyroblasts of hypersthene. In hand specimens, the hypersthene is glassy yellowish brown. The small percentage of green monoclinic pyroxene present in some slides may be of the diopside-hedenbergite group. Accessory minerals are apatite, magnetite, and iron sulfides. Garnet, which locally is very abundant, has an X-ray pattern similar to that of pure spessartite.

Impure Marbles

No outcrops of marble were observed in either area but in the southeast corner of Yodel island and in the bay west of the island several large angular blocks of impure marble were found along the shore. As these occurrences are nearly on strike with each other and,as the rock is extremely friable, it is believed that the erratics are not far from their source.

The rock is coarsely crystalline and yellowish to pinkish gray. Dark green diopside crystals form up to 10% of the rock and small pale brown grains of titanite are common. Scapolite and orthoclase are also present.

Migmatites

Turner (1948, p. 11) defines migmatites as -

> ".... composite rocks in which the effects of metamorphism have been complicated by soaking of rocks in magmatic fluids, or by the development of lenticles and sheets of liquid magma, either injected from external sources (lit-par-lit injection), or segregated as products of differential fusion of the host rock itself (anatexis)."

Within the area rocks are encountered that present all stages of transition from true paragneisses, through gneisses in which there has been addition of granitic material along the foliation, to extreme types in which there has been complete mixing of the two rocks through assimilation of the gneiss and interchange of the gneissic material with the "magma". Paragneisses are readily migmatized, whereas the gabbroic rocks are altered to hybrid rocks only near the granite contacts.

Two bands of migmatitic rocks outcrop in the Nipissis River area. One, averaging 3,000 feet wide and divided by Nipisso river, strikes southwest from the northeast corner of the area, to a point one mile above the junction of the Nipissis and Nipisso rivers. From there, it swings south for another 1½ miles. Another zone outcrops south of Pollock lake between the granite gneiss and gabbro. These two zones are actually complexes in which several rock types outcrop in bands too small to be mapped separately and in which migmatites are the main rock types. Migmatitic gabbros are found in the Cacaoni Lake area wherever granite is in contact with gabbro. These migmatites appear to be restricted to immediate contact zones, although the complex manner in which the granite has intruded the gabbro prevents accurate determinations of the width of the migmatite bands.

In the Nipisso Lake area migmatites are strongly developed in the northern part, around and between the biotite and hornblende granites. Elsewhere, in both areas, patches of migmatite are found in the paragneisses far from any known granite body.

Biotite gneiss and, to a lesser degree, hornblende gneiss appear to be the most easily migmatized paragneisses. Whether the original host-rock contained biotite as the main mafic mineral or whether the biotite has been formed by potassium metasomatism of other ferro-magnesian minerals is unknown. Several thin-sections showed that biotite formed around hornblende, and this suggests that some of the biotite of the migmatites was formed by alteration of hornblende.

Two main types of migmatites have been observed: banded migmatites and augen migmatites. The more widespread variety consists of bands of introduced quartz and microcline along the foliation of the host rock. The augen migmatites are characterized by the development of feldspar porphyroblasts, with or without bands of granitic material. Migmatization of the gabbroic rocks results in an equigranular, massive rock of the same appearance as the original one but containing quartz and microcline in addition to the original minerals.

In the migmatites, plagioclase is commonly zoned; the grain borders are more sodic than the cores. Apatite and sphene are everywhere present as accessory minerals, in addition to those usually found in the paragneiss. A few slides showed microcline replacing plagioclase. Where microcline is in contact with plagioclase, the border of the latter mineral generally contains tiny eyes or lenses of quartz.

Moisie Group

The hypersthene-bearing rocks of the Nipissis River and Nipisso Lake areas are combined here as the Moisie Group. These intrusive bodies, some of batholithic dimensions, include norite, gabbro, diorite, hornblendite, pyroxenite, and a few small patches of granite. All contain hypersthene. The writer believes that these rocks are from the same parent magma, with composition closely approaching that of the norite, the most abundant rock type of the series.

Table 1 - Rosiwal Analyses of the Metasedimentary Rocks

	Biotite Gneiss GH-168	Muscovite Gneiss E-69	Sillimanite Gneiss E-68	Sillimanite Gneiss N-102	Diopside - Epidote Gneiss H-29	Biotite Gneiss GH-169	Biotite Gneiss H-2	Hornblende Gneiss H-45	Hornblende Gneiss GH-162A	Hornblende Gneiss G-221	Hornblende Gneiss G-40	Hornblende Gneiss H-50	Cummingtonite Gneiss H-101	Para-amphibolite E-100	
Quartz	72.6	59.1	56.6	46.7	36.8	30	20.7	19.7	17.0	14.2	11.8	3.9	3.8		Quartz
Plagioclase	18.8	6.2	1.9	4.4	30.8	35.6	29.9	50.0	56.5	50.5	52.0	36.6	37.0	47.4	Plagioclase
Microcline		11.6	14.5	23.2			34.0	5.3							Microcline
Biotite	6.8	14.5	13.9	13.1		34.2	14.3	4.2	13.2	18.0	2.7	12.8	6.9	7.3	Biotite
Hornblende								20.0	12.7	13.7	32.7	35.1	37.0*	40.8	Hornblende
Garnet				5.3			1.3								Garnet
Epidote					25.4					3.1					Epidote
Sillimanite	1.4	0.5	12.9	5.9											Sillimanite
Diopside					6.5										Diopside
Muscovite		7.9	0.1	1.5											Muscovite
Sphene		+			+			0.1	+	+	+	2.3		1.6	Sphene
Apatite	0.4					+	+	0.3	+	+	+	0.7		0.4	Apatite
Calcite										+					Calcite
Zircon		+	0.1	+	+		+						+		Zircon
Pyrite												2.5			Pyrite
Magnetite								0.3				5.7		2.5	Magnetite
An content	23	17	14	14	90	45	15	27	34	34	27	29	28	25	

* Cummingtonite

Wherever possible the Moisie series is outlined, on the accompanying maps, as separate rock units. Within any one unit different facies may occur, but usually in bodies too small to be outlined. Thus in the main mass of norite, coarse-grained gabbroic, dioritic, and granitic facies are present but the intimate association of one type with another and the scale of the mapping do not allow these "foreign" facies to be shown on the map. Also, outcrops of fine-grained norite are included in the Pollock Lake diorite and the Cacaoni gabbro.

Norite

Johannsen (1937, p. 233) defines norites as -

> "..... plutonic rocks of hypautomorphic to xenomorphic-granular texture, and the mineral combination basic plagioclase and orthorhombic pyroxene. Usually clinopyroxene is accessory so that there are all transitions through augite-norites and hypersthene-gabbros to normal gabbros."

Thin-sections of the norite show that the amount of hypersthene may exceed, equal, or be less than, the amount of augite. Thus, according to the above definition, and,as would be expected in such a large mass, all facies of the norite-gabbro suite are present. Furthermore, in a few places, the pyroxenes have been almost completely uralitized and the rock is composed of uralitic hornblende and plagioclase.

The characteristic feature of the norite is the fine grain. It is upon this feature more than any other that this map-unit differs from the other gabbroic facies of the Moisie Group.

Greig (1945), who mapped the area south of the Nipissis River area, called the rock pyroxene and hornblende amphibolite and suggested that it might have been derived from sedimentary rock. However, as a result of the writer's work in the present areas, the norite is believed to be an intrusive igneous body.

Aerial photographs of the terrain underlain by norite show an extremely rugged topography controlled by strong jointing. This is especially true in the southeast corners of both areas where a distinct rectilinear drainage system reflects the pattern of the underlying joint system. The norite is cut by numerous dikes and irregular bodies of a coarse-grained augen granite believed to be associated with the granite gneiss. Outcrops invariably contain numerous black dikelets of hornblende, which are more resistant to erosion than the host rock and cut the norite in several directions.

In hand specimens, the norite is very-fine to fine grained. Feldspar predominates and a mafic mineral, pyroxene or amphibole, is everywhere present. Typically, the rock is massive, with a salt and pepper appearance in which an ophitic arrangement of the minerals is discernible in many places. Locally, sheared varieties may be common and, in places, the rock is schistose.

Plate III

A - Norite cut by coarse-grained augen gneiss

B - Character of terrain underlain by norite.

Examination of ten thin-sections showed that there are two principal varieties of the norite, one a pyroxene-rich and the other an amphibole-rich facies; the former is the more abundant. Texturally, the rock is of two types, also with an intermediate facies. An equigranular, granoblastic texture is common and a sub-ophitic to ophitic texture was observed in a few thin-sections. The texture is independent of the mineral constituents, as both pyroxene- and amphibolite-rich types show an ophitic arrangement of the grains.

Plagioclase (An_{45}) forms 50-60% of the rock. Augite and hypersthene or hornblende are the other main constituents. Augite is pleochroic in shades of pink and green (perhaps due to a slight titanium content). Brown pleochroic biotite and ilmenite are the most abundant accessories; apatite and zircon are usually present in minor amounts. A small percentage of amphibole is formed around the pyroxene grains in most slides. One specimen taken near the contact with the granite gneiss around Hogan lake showed almost complete replacement of the pyroxenes by amphibole.

The western boundary of the norite massif is for the most part concordant with the underlying paragneisses. No data are available on the other contacts. Approximate known dimensions of the body are 20 miles east-west and 23½ miles north-south. Greig (1945) reports that the massif extends further eastward and outcrops of norite were observed northeast of the Nipisso Lake area. These outcrops may be part of the main massif.

Table 2 - Chemical analyses of norite and amphibolitized norite

	G-26	GH-171		G-26	GH-171
SiO_2	51.32	48.30	H_2O+	0.72	1.87
TiO_2	1.37	1.26	H_2O-	0.03	0.03
Al_2O_3	15.71	16.05	CO_2	0.11	0.06
Fe_2O_3	1.59	1.64	S	0.08	0.08
FeO	9.78	9.15	Cr_2O_3	0.03	0.04
MnO	0.20	0.21	V_2O_3	0.01	0.03
MgO	6.83	7.52	NiO	0.01	0.01
CaO	8.70	9.93	BaO	0.04	0.03
Na_2O	2.80	2.68	SrO	0.01	0.02
K_2O	0.80	0.80	CuO	0.01	0.01
P_2O_5	0.24	0.22	U_3O_8	0.002 (x)	0.001 (x)
				100.36 (+)	99.91 (+)
				2.999	3.020

(x) Uranium oxide (U_3O_8) equivalent according to beta radiation.

(+) Less 0.03 for O + S

G-26 Norite from Tchinicaman lake. Analyst M. Archambault.

GH-171 Amphibolitized norite from one mile south of Lorna lake. Analyst M. Archambault.

Table 3 - Norms and modes of norite and amphibolitized norite

	G-26	GH-171
NORMS		
Quartz	0.42	
Orthoclase	4.45	4.45
Albite	23.58	22.53
Anorthite	28.08	29.47
Diopside	10.42	14.56
Hypersthene	26.70	10.02
Olivine		11.32
Magnetite	2.32	2.32
Ilmenite	2.58	2.43
Pyrite	0.12	0.12
Apatite	0.67	0.67
Calcite	0.20	0.20
An content	55	57
MODES (approximate)		
Plagioclase	49.4	38.2
Augite	21.1	2.4
Hypersthene	15.0	
Hornblende	-	58.6
Biotite	12.4	-
Ilmenite	1.2	1.7
Apatite	0.8	(+)
An content	48	46

Hypersthene Gabbro

Gabbro sills, ranging from a few feet to half a mile wide, are abundant in the Nipisso Lake area. Only the larger bodies have been outlined on the accompanying map. During the field work, an attempt was made to separate the sills into hypersthene gabbro, anorthositic gabbro, and amphibolite; subsequent laboratory work proved that all the above types were present. Outlining of individual bodies could not be accomplished as metamorphism has changed the original pyroxenes into amphibole and the mineralogical composition of the gabbroic rocks was variable within any one unit. Furthermore, the structure of the area, both regional and local, could not be deciphered satisfactorily to permit correlation of the scattered outcrops.

A large mass of gabbro surrounds Cacaoni lake and extends along the northeast boundary of the Nipissis River area into the Nipisso Lake area. The distribution of the gabbro is extremely irregular owing to the widespread intrusion of pink biotite granite into the gabbro.

The composition of the gabbro is quite variable. Differences in composition can be attributed to variations in initial chemical composition in different parts of the magma, to hybridization by granitic solutions, and to recrystallization due to metamorphism. In general, hand specimens are green to dark green and medium to coarse grained, and have a granitoid or, rarely, an ophitic texture. Here and there the rock is strongly sheared and a gneissic or linear structure is found in place of the more common massive structure.

In the unaltered facies plagioclase is the most abundant mineral. It occurs as lath-shaped crystals, euhedral to subhedral in crystal outline. Normal zoning is common, the core being about An_{55} and the rim An_{30}. Most of the grains are about An_{45}. Hypersthene and augite occur in about equal amounts. The augite is slightly pleochroic in shades of pink and green. Olivine was seen in one slide. Accessory minerals are magnetite and apatite.

The optical properties of the olivine and the hypersthene indicate that they contain about 40% of the ferrous silicate molecule. The olivine is surrounded and replaced by hypersthene.

Reheating and alteration of the gabbros by alkali-bearing solutions derived form the biotite granite has affected the greater part of the Cacaoni gabbro. Texturally, the hybrid gabbros are similar to the purer members. A green hornblende, pseudomorphous after pyroxene, is the mafic predominant mafic mineral. The replacement of pyroxene by amphibole may result in a single grain of the new mineral but usually a mosaic of small hornblende crystals occupies the former position of the pyroxene. Plagioclase partly retains a lath-like appearance; however, the calcium content has decreased considerably, so that the anorthite content is now about 30%. The grains show a diffused normal zoning that is accentuated by clear sodic borders surrounding a core filled with liquid inclusions. Biotite, pleochroic in shades of straw and dark brown, is fairly abundant.

Alkali metasomatism of the gabbro has introduced two new minerals, quartz and microcline-perthite. It is also responsible for the formation of biotite from amphibole or pyroxene. Alteration of the various minerals is common,with plagioclase and hornblende the most susceptible. Sericite, clinozoisite, and epidote are derived from feldspar; chlorite, epidote and magnetite, from hornblende.

Among the accessories, apatite and sphene are abundant, whereas magnetite and zircon are usually present. Sphene may occur as individual grains but is usually found as a rim around magnetite.

Coarse-grained bodies of hypersthene gabbro outcrop around Tchinicaman lake. Most contacts show that the gabbro is younger than the norite but at several places the norite cuts across the gabbro. These relationships would indicate that the two rocks are of the same age and that the maximum development of gabbro followed that of the norite.

Thin-sections show that the gabbro is very similar to the norite and to the Cacaoni gabbro. Pyroxenes are more uralitized and there is a greater percentage of biotite, The plagioclases have a slightly lower anorthite content An_{35-40}.

Olivine Gabbro

The large sill $1\frac{1}{4}$ miles south of Firth lake, several small sills south of Albany lake, and numerous other outcrops are composed of olivine gabbro. The rock is massive, coarse grained, granitic to ophitic, [illegible] dark gray. The pyroxenes have a bronzy luster and the feldspars usually are greenish gray. Pale pink garnets occur throughout.

Table 4 - Rosiwal analyses of norites

	G-7	G-26	GH-104	GH-70
Plagioclase	57.5	49.4	50.0	53.8
Hypersthene	16.2	15.0	15.0	17.2
Augite	21.1	21.1	16.1	
Hornblende			9.2	20.9
Biotite	1.6	12.4	6.0	
Ilmenite	1.0	1.5	3.5	1.3
Apatite	0.8	0.5	0.3	+
An content	40	48	40	40

Table 5 - Rosiwal analyses of gabbros

	G-5	GH-136	G-45
Plagioclase	61.0	58.6	50.0
Hypersthene	8.0	13.2	17.2
Augite	10.0	13.2	20.3
Hornblende	3.5	11.2	
Olivine		2.4	
Biotite	5.5	+	9.7
Magnetite } Ilmenite	9.3	1.3	2.0
Sphene			+
Apatite	2.0	+	+
Zircon			+
An content	37	45	40

G-5 and G-45 are from Tchinicaman lake,
GH-136 from Cacaoni lake.

Only one thin-section was examined. It contained about 25% olivine as large grains showing the characteristic fracturing of the mineral. Minute non-pleochroic grains of hypersthene form rims around the olivine. A few grains of hypersthene and augite are present; these contain numerous inclusions of olivine. Biotite and brown hornblende form clusters of interlocking grains. The composition of the plagioclase could not be determined as the grains are obscured by a bluish green alteration product.

Garnet was the latest mineral to form. It occurs as tiny grains replacing feldspar, especially where the latter is adjacent to olivine. At the contact of olivine and plagioclase, garnet and hypersthene are formed; the garnet replaces plagioclase and the hypersthene replaces olivine.

Anorthositic Gabbro

Anorthositic gabbro was seen at the mouth of Nipisso river and on the tip of the long point northeast of Yodel island. The rock is composed of white plagioclase, An_{47}, with about 30% dark green hornblende. Biotite, pyroxene, and a brownish red garnet are also present. Accessory minerals include ilmenite and pyrite. The grains are medium to coarse and have a very fresh appearance. Outcrops show a strong gneissic structure and the amphibole occurs in clots and streaks that are strongly lineated.

Diorite

The Pollock Lake body is a mica diorite similar to that reported by Greig (1945) in the Matamec Lake area. The rock is brownish gray and coarse grained. It is massive and has a granitic texture. Under the microscope, the texture varies from granoblastic to granitic; most of the minerals have poor crystal outlines. Essential minerals are feldspar, hornblende, biotite, orthorhombic and monoclinic pyroxenes, quartz, and microcline. Magnetite and apatite are abundant accessories; zircon, sphene, pyrite and leucoxene are also present.

This intrusion is characterized by coarse biotite flakes which may make up 20% of the rock. Two of the five thin-sections examined contain green hornblende. The orthorhombic pyroxene is slightly pleochroic and has parallel extinction and polysynthetic twinning. The monoclinic pyroxene is pale green; the dispersion is greater for the optic axis nearly parallel to C and thus is an augite.

Plagioclase forms up to 60% of the minerals. It varies from irregular, nearly equigranular grains to distinct lath-shaped crystals. Albite, pericline, and carlsbad twinning are present and one grain has a baveno twin. It is usually zoned with a core of about An_{38} and a rim of An_{25}. One slide contained lath-shaped crystals of plagioclase An_{38} and small clear xenoblastic grains of feldspar with a composition of An_{25}. The larger grains are usually clouded or "dirty", owing to numerous liquid inclusions and to zoning, where it is especially noticeable; the cores are clouded and the rims clear.

The thin-sections suggest that the Pollock Lake massif may have been a hypersthene gabbro and that biotite, hornblende, quartz, and microcline are newly formed minerals. This change in composition could be the result of autometasomatism or the result of metasomatism by granitic fluids.

Pyroxenite and Hornblendite

In the Nipissis River area outcrops of the ultrabasic facies of the Moisie Group are found in the north end of the Pollock Lake diorite, half a mile south of the former airstrip, and near the east shore of the northwest bay of Tchinicaman lake.

The small intrusion in the northern part of the Pollock Lake diorite is composed mainly of pale green hornblende, pseudomorphous after pyroxene, along with small remnant grains of olivine, hypersthene and augite. The ultrabasic rock south of the airstrip has olivine (5%), hypersthene (15%), and augite (15%). Hornblende (40%) and chlorite (25%) are secondary.

West of Tchinicaman lake, the rock is medium grained and strongly schistose. Mineral composition consists of amphibole (50%), hypersthene (35%), and equal parts of augite and magnetite.

Magnetite occurs as distinct grains and as lamellae along the hornblende cleavages. The lamellae also form a right-angled grid in the hornblende grains, suggesting that the amphibole is pseudomorphous after pyroxene.

A thin-section of a similar rock contained also a small amount of plagioclase (An_{35}) and biotite.

Medium-grained, dark green hornblendite forms a needle-like peak about one mile north of the junction of Nipissis and Wacouno rivers. Two miles east of the junction, there is a 10-foot-thick layer in gabbro. The rock is coarse grained, dark brownish green, and slightly sheared.

One mile northwest of Debor lake, a small sill of hornblendite is interlayered with the paragneisses. With the exception of a few grains of magnetite, hornblende is the only mineral present; it is colorless to very pale green.

Hypersthene Granite

The granitic facies of the Moisie Group forms narrow dikelets, dikes, and irregular masses cutting the norite around Tchinicaman lake and east of the south end of Nipisso lake. The rock is yellowish brown, coarse grained and, in many places, gneissic. Thin-sections show microcline and quartz, in addition to hypersthene, augite, biotite and plagioclase. Pyroxenes may be fresh but usually they are uralitized or altered to brown mica. Microcline occurs as fresh anhedral grains which, when closely examined, reveal a sub-microscopic multiple twinning. Grains of microcline cut perpendicular to the obtuse bisectrix show the axial plane at an angle of 8° to the basal cleavage. The potash feldspar appears to be one of the latest minerals to form, since inclusions of quartz, plagioclase, and pyroxene are present in some grains. The anorthite content is variable: 23 to 42%.

Amphibolites

Ortho-amphibolites occur as sill-like bodies and only rarely as narrow dikes and dikelets. Amphibolites are widespread in the Nipisso Lake area but rare in the Nipissis River area, only a few sills being recorded in the latter.

As the prefix "ortho" indicates, these rocks have been formed by the recrystallization of gabbroic or dioritic intrusions. At many places, gneissic amphibolites can be traced across the strike, through sheared gabbros, into massive gabbros that display igneous characteristics. Grain-size ranges from fine to coarse and the texture, from granitic to granoblastic. Gneissic varieties predominate, the massive types being rare. Some outcrops contain up to 25% garnet, which gives a reddish tinge to the usual dark green or gray color.

Sixteen thin-sections of ortho-amphibolite were examined under the microscope. Of these, four contained relict pyroxenes and two may have been hornblende gabbros originally. The pyroxenes include the orthorhombic pyroxene, hypersthene, and two monoclinic types, diopside and augite. Hypersthene and diopside were seen in two slides; hypersthene and augite, in a third.

Hornblende forms 40 to 70% of the amphibolite and has a pleochroism of yellow to grass green. Plagioclase is also very abundant and occurs as small clear xenoblastic grains and as large phenocrysts. The latter are rare and invariably show bent twin lamellae, granulation, and replacement by the smaller feldspar grains. No difference in composition of the two types could be determined. The feldspars are very fresh; only a few grains have a slight alteration to sericite, epidote, and clinoziosite. The composition of the feldspar ranges from An_{30} and An_{43} with the greatest number of values falling between An_{32} and An_{38}. Garnet is a common accessory. In one thin-section porphyroblasts of garnet contain inclusions of hornblende, pyroxene, biotite, plagioclase, magnetite, and apatite. The accessory minerals are magnetite and apatite and rarely sphene, zircon and quartz.

In many places in the Laurentian region of eastern Canada and in the Adirondacks of northern New York, amphibolite has been formed by the metamorphism of pre-existing diorites and gabbro. Buddington (1939, p. 13) says that:

> "Such amphibolite can be proven of igneous origin only by the transitions to rock still preserving typical igneous texture".

Osborne (1936) claims that the amphibolites of the Shawinigan Falls area of Québec were originally volcanic rock, either andesite or basalt. He believes that in some places original volcanic structures are still preserved in the rocks. It is quite possible that some of the narrower amphibolite bodies that have been completely recrystallized may have been originally of volcanic origin. However, there is no evidence to support this hypothesis and, in fact, where original structures and textures have been preserved, the rocks are undoubtedly intrusive.

Hypersthene Pegmatite

The norite surrounding Tchinicaman lake has been intruded locally by medium-grained, light brownish gray, aplitic or pegmatitic dikes containing quartz, feldspar, hypersthene, and garnet. As these dikes have been observed only in this one locality and as they contain hypersthene, it is believed that they are an end-product of differentiation of the norite magma.

Post-Moisie Intrusions

Augen Gneiss and Granite Gneiss

A large massif of augen gneiss extends across the center of the combined areas. The upper contact roughly parallels Nipissis river as far north as its junction with Nipisso river. From this point it strikes northeast, following the valley of Nipisso river, to the east border of the Nipisso Lake area. The lower contact strikes east across the Nipisso Lake area passing half a mile south of Debor lake. On the east side of Nipisso lake it trends northeast until it is cut off by the hornblende granite massif along the east boundary of the area. The augen gneiss extends beyond the east and west boundaries of the area. Locally the massif lacks the augen texture and the rock is a granite gneiss.

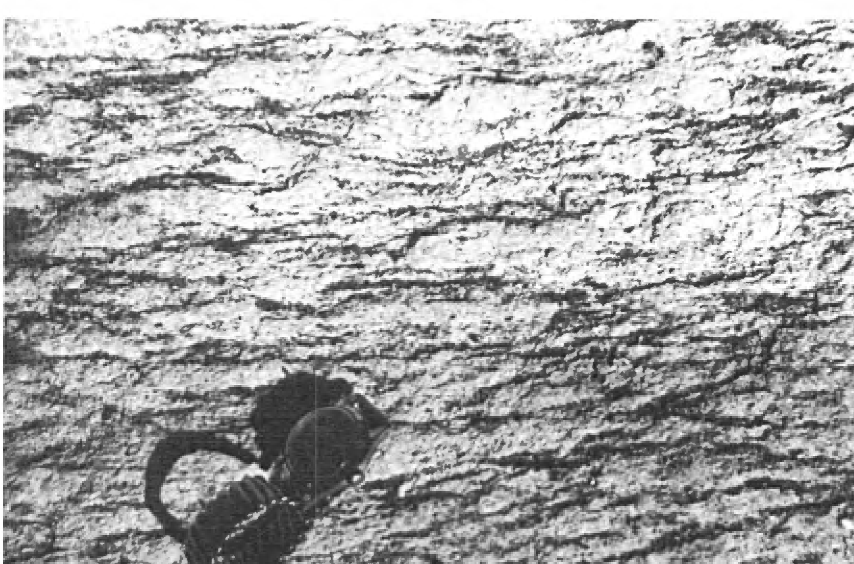
A granite gneiss body which outcrops in the south-central part of the Nipissis River area is similar to the massif described above, except that it lacks the augen texture. These two masses are believed to be of the same age. Outcrops of norite immediately east of the granite gneiss body are cut by numerous dikes and small irregular bodies of coarse-grained augen gneiss. These small intrusions are probably related to a deeper underlying mass, connected to the large body of granite gneiss.

The rock in the augen gneiss and granite gneiss massif is usually pink but may be light gray in places. It is fine to coarse grained and strongly gneissic, and has a pronounced sugary texture. A parallelism of the long axes of feldspar crystals and augen imparts a lineation that can be recognized in most outcrops.

The essential minerals are quartz, microcline, plagioclase, and biotite. Quartz invariably has undulose extinction and contains numerous liquid inclusions. Microcline occurs as small granoblastic grains and as porphyroblasts; it is usually perthitic and contains numerous inclusions of quartz and plagioclase. There are small granulose grains of albite-oligoclase in all thin-sections; these show only slight alteration to white mica. Biotite is in clusters of individual grains and is pleochroic from yellow to brown. Green hornblende was seen in a few thin-sections. Accessory minerals include zircon, apatite, sphene, allanite, and magnetite - the

Plate IV

A - Character of terrain underlain by augen gneiss.



B - Augen gneiss

last with rims of sphene. Garnet and hornblende are abundant in the granite gneiss along the northern and southern contacts respectively.

Microcline porphyroblasts contain numerous fragments of plagioclase, all having approximately the same crystallographic orientation in each augen. It appears that microcline replaces an older plagioclase augen. The neighboring plagioclase grains contain small quartz eyes.

Both the northern and southern contacts, as well as the internal gneissic structure, of the augen gneiss massif are parallel to the foliation or schistosity of the enclosing rocks. Linear structures are also in agreement with those found in the enclosing formations. In plan, the body is "S"-shaped with a synclinal axis to the west and an anticlinal axis to the east. From the lineation of the gneiss and enclosing sedimentary gneisses, the plunge of the folds is about 30° toward S.5°E.

The northern or lower contact of the massif is remarkably sharp. The adjacent graphite and sillimanite gneisses are almost free from migmatization. The presence of garnet in the massif along the contact indicates that it may have absorbed some of the sedimentary rock. The underlying metasedimentary rocks show no brecciation or deformation such as would result from the emplacement of the augen gneiss, and the granite gneiss is remarkably free of inclusions.

The southern or upper contact is a broad zone in which the granite may be traced through migmatite into unaltered metasedimentaries and basic intrusives. At several places along this contact the feldspar porphyroblasts are rectangular and the rock is a porphyritic granite.

On the east side of Nipisso lake, the augen gneiss is intruded by biotite granite, hornblende granite, and gabbro. It also contains two large inclusions of paragneiss. It is believed that the eastern boundary of the augen gneiss is only a short distance outside the area and that these paragneiss inclusions may be large blocks broken off along the margin of the intrusive.

The body of granite gneiss in the south-central part of the Nipissis River area is elongated but is irregular in outline. The gneissic structure trends northeast, parallel to the structure of the enclosing rocks. Inclusions of norite are common.

Granite Gneiss and Granulite

Pink granite gneiss and granulite, with some paragneisses and amphibolites, form a ¾-mile-wide zone, extending across the Nipisso Lake area. The southern contact of this zone lies one mile north of Debor lake and passes through the northern part of Yodel island. A similar granite gneiss occurs as dikes and sills in the augen gneiss.

The granite gneiss is fine grained, pink, and strongly gneissic. Quartz, microcline, plagioclase, biotite, and hornblende are the main constituents. Zircon, apatite, sphene, and allanite are accessory minerals. Both zircon and allanite have developed pleochroic haloes in the mica grains.

The granulite of this zone is pink and fine grained, and shows a higher grade of metamorphism than the associated granite gneiss. It contains stretched quartz lenses up to an inch long and is composed mainly of quartz, microcline and plagioclase (An_{16}). Magnetite and zircon are accessory minerals; a small amount of muscovite occurs as an alteration product of microcline. Pink garnet crystals, up to ¼-inch in diameter, are in narrow layers.

Several specimens of granite gneiss, containing biotite but lacking garnet, show stretched quartz lenses and grains. These are intermediate facies of the granite gneiss-granulite suite and indicate that the two end members were originally the same rock-type.

Anthophyllite Gabbro

A large dike cuts the augen gneiss east of Nipisso lake. The rock is dark purplish gray and massive, and has an ophitic texture. The grain size is predominantly coarse.

In thin-sections, the gabbro does not show any evidence of deformation. The mafic mineral is a fibrous amphibole (anthophyllite) arranged in clusters that have a stubby prismatic outline. Where the anthophyllite is in contact with plagioclase, it has been partly changed to green hornblende.

Plagioclase (An_{40}) is slightly sericitized and contains minute inclusions of an unknown mineral. Colorless to light brown, biotite is in scattered plates. Ilmenite, magnetite, and pyrite are accessory.

Hornblende Granite

There are two bodies of pink hornblende granite. The larger extends from the northeast part of Nipisso lake beyond the north boundary of the area. The other is east of Yodel island along the east boundary, and also extends beyond the area.

The granite is medium to coarse grained, usually strongly lineated and gneissic. In a few places small lenses of dark green hornblende parallel the lineation. Essential minerals are microcline-perthite, quartz, oligoclase, hornblende, and biotite. The biotite is secondary and replaces hornblende. There are minor amounts of apatite, zircon and magnetite.

The east contact of the larger hornblende granite body appears to follow the trend of the overlying paragneisses. Elsewhere the contact is irregular and transgresses the foliation of the enclosing rocks. The smaller body cuts across the structure of the augen gneiss. The northwest border of this massif is a continuation of the contact between the augen gneiss and the paragneisses.

The granite is characterized by a pronounced lineation due to the alignment of hornblende prisms and the long axis of feldspar grains. In both massifs, the gneissic structure is a continuation of the trend of the surrounding rocks. Similarly, the lineation has the same general orientation as the other rocks.

Biotite Granite

Four stocks of granite, in addition to numerous dikes, occur. In the Nipissis River area one stock cuts the gabbro and paragneisses around Cacaoni lake and another cuts augen gneiss west of the airstrip. A small stock cuts augen gneiss east of Yodel island and a larger body outcrops in the northwest corner, and beyond the limits, of the Nipisso Lake area.

The biotite granite is invariably pink or red and grades form fine to coarse grained. It is usually equigranular but, locally, large crystals of microcline give it a porphyritic texture. The granite is massive in general but, locally, it is gneissic.

Under the microscope the granite shows an allotriomorphic, granitoid texture. It has a high percentage of microcline and quartz. Plagioclase (An_{10-15}) is slightly altered to sericite, epidote and clinozoisite. Yellow to brown pleochroic biotite is the main mafic mineral and in a few slides it has been partly or completely altered to light yellowish green penninite. Hornblende, in minor amounts, was seen in two of the six thin-sections. Accessory minerals include sphene, apatite, magnetite, granophyre, epidote, zircon, and pyrite.

The granite stock on the west side of Nipissis river is 5 miles long and 3 miles wide. If the gneissic structure of the augen gneiss along the contact of the biotite granite reflects the trend of the contacts, then the north side of the stock strikes roughly east and dips about 70° south. The south border trends more uniformly northeast, and dips south at about 45°. Because it cuts across the structure of the enclosing granite gneiss, the attitude of the intrusive as a whole is discordant.

The contacts of the large biotite granite mass in the northwest corner of the Nipisso Lake area has been approximately located on the east, but assumed on the south. The contact appears to parallel the foliation or gneissic structure of the enclosing paragneisses. As the trend of these rocks conforms with that of the paragneisses farther south and east, it is assumed that this is a concordant intrusive mass.

The small body of biotite granite in the Nipisso Lake area is an irregularly-shaped mass that intrudes the augen gneiss discordantly.

Pegmatite and Aplite

Pegmatite dikes and sills are abundant. They cut all the rocks except the lamprophyre and diabase dikes. Field evidence suggests that they are of more than one age and that there may be as many as three ages.

Fine- to medium-grained, pink or pinkish gray pegmatitic sills form layers in the paragneisses. The width of the layers ranges from less than one inch to several feet. These sills do not appear to be related to amy one body of granite because contact zones around the various granites show the same type of sills. They are composed essentially of quartz and microcline with some apatite and sphene. The sphene is dark brown to black and probably contains a radioactive element because haloes and radial fractures surround the grains.

Another and more common type of pegmatite occurs as coarse-grained dikes. They are composed of pink potassic feldspar, plagioclase, quartz, biotite, and hornblende. The last two minerals rarely occur together in the same dike. Nodules of magnetite grains, up to an inch in diameter, are common. The minerals are usually well-formed; euhedral crystals of quartz were seen in several dikes. The dikes show sharp contacts and usually no evidence of deformation.

The age of the dikes is not definitely known but their relative undisturbed state indicates that they probably belong to a late stage of the biotite granite intrusion.

Gabbroic pegmatites, containing plagioclase and hornblende, were found in several places in the northeast of the Nipisso Lake area. An outcrop of gabbroic pegmatite, one mile southeast of Albany lake and half a mile east of the boundary of the area, contains large grains of pyrrhotite, pyrite,and chalcopyrite.

Fine-grained aplite dikes are common but not so abundant as the pegmatites. They are composed of quartz, microcline, plagioclase, and biotite. One dike contains pink garnets.

Lamprophyre Dikes

Basic dikes, identified in the field as lamprophyres, cut various rock-types in the region. One, containing plagioclase, biotite, hornblende, and quartz, cuts gabbro and coarse-grained pink pegmatite. Two similar dikes cut the augen gneiss south of Irène lake.

Lamprophyre dikes cutting the augen gneiss and most other rocks of the area have a gneissic structure, whereas the one cutting the pegmatite is massive. Although the evidence is scanty, there is some suggestion that there may be two ages of lamprophyre dikes, corresponding to the two main periods of granite intrusion.

Diabase Dikes

Diabase dikes occur in both areas and cut most of the rock types. They are closely similar to dikes that, in other parts of the Precambrian Shield, are considered to be of Keweenawan age.

The diabase is dense, fine grained and black,and much of it contains feldspar phenocrysts and (or) amygdules of quartz and calcite. It

Table 6 - Rosiwal analyses of amphibolites

	GH-171	G-20	G-173	GH-110
Plagioclase	38.2	29.0	32.4	
Hornblende	56.6	59.0	65.5	59.0
Biotite		12.0	2.1	
Hypersthene Augite	2.4			34.7 3.5
Magnetite	1.7	+	+	3.0
Apatite	+		+	
Sphene		+	+	
An content	46	43	26	

GH-171 and G-20 are amphibolitized norites; G-173 is an amphibolite, and GH-110 is an hypersthene amphibolite.

Table 7 - Rosiwal analyses of granites

	G-126	G-143	GH-125	GH-135
Quartz	44.0	36.5	18.4	53.0
Plagioclase	18.5	28.2	36.8	16.1
Microcline	24.1	30.6	32.0	21.2
Biotite	10.8	4.4	11.8	8.0
Hornblende	1.3			0.8
Epidote			+	+
Magnetite			+	
Apatite	+	+	+	+
Sphene	+		+	+
Zircon	+	+		
An content	18	8	13	10

G-126 and G-143 are augen gneisses; GH-125 and GH-135 are biotite granites.

consists essentially of plagioclase (An_{15}) in a sub-microscopic ground mass of biotite, hornblende, and magnetite. Accessory minerals are calcite, apatite and sphene.

STRUCTURE

The shape of the augen gneiss massif reflects the structural trend of the enclosing rocks; the southern contact trends northeast and the northern contact mainly east. The shape of this massif is a clue to the general structure of the area and to the direction of the forces responsible for the formation of this structure (figure 1).

Foliation, Schistosity, and Gneissic Structure

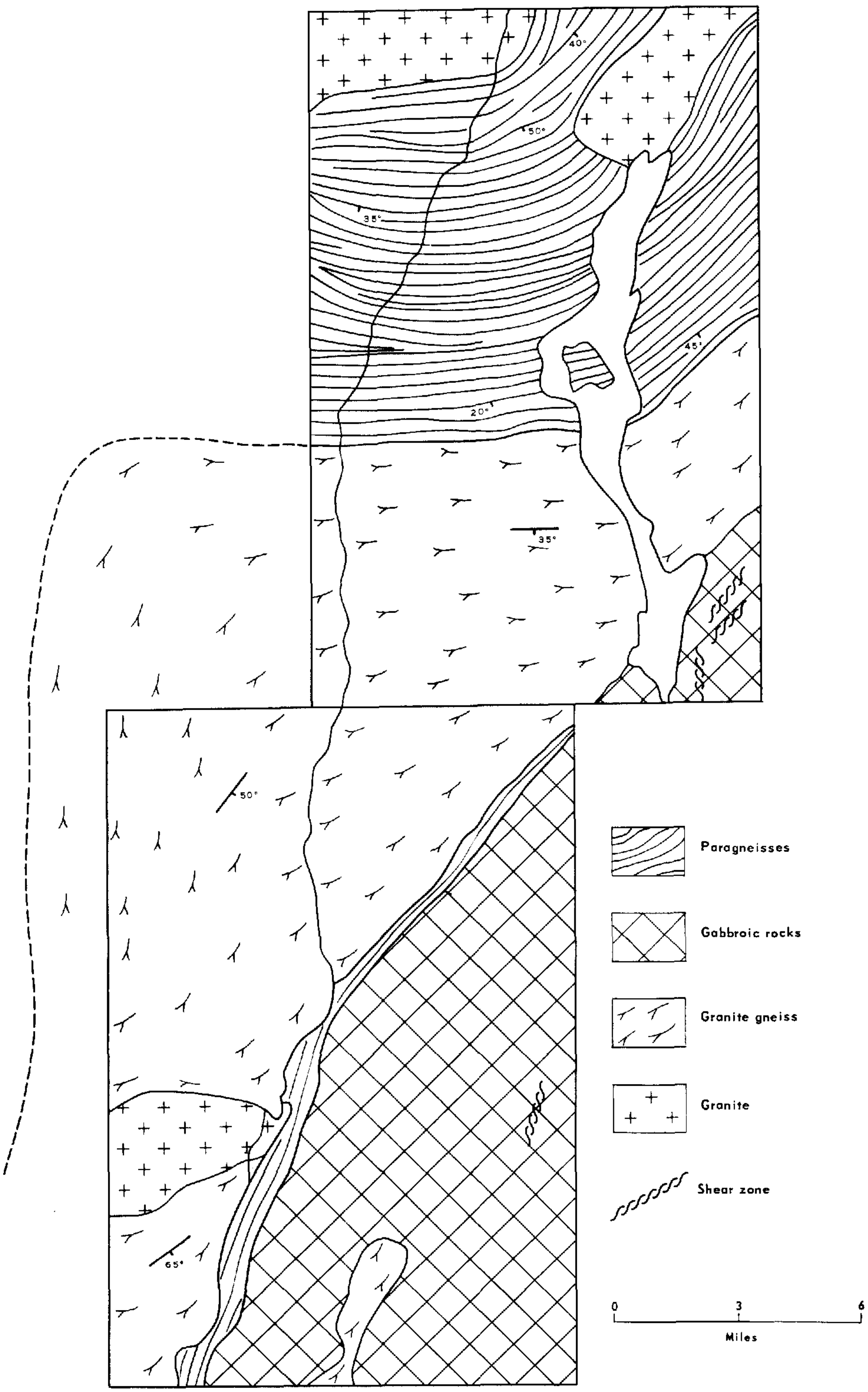
Strong recrystallization induced by regional metamorphism destroyed all primary structures of the sedimentary series. The variety of rock units in the Grenville Series appears to be due to differences of chemical composition in the original sedimentary beds. Considering that the foliation, the schistosity, and the gneissic structure parallel the units, these structural elements may be used in the same way as bedding to interpret the general structure of the area. Except for local variations, the relict bedding dips southward and parallels the adjacent granite contact. The augen gneiss has a well-developd gneissic structure due to the alignment of feldspar grains and to the accompanying parallelism of mica flakes. The contacts of the augen gneiss control also the orientation of the gneissic structure, which parallels the adjacent contact. Near the younger granitic intrusives, especially the biotite granite plug in the Nipissis River area, the gneissic structure of the augen gneiss conforms locally to the trend of the contacts of the younger granites.

Near Brézel lake, the granite gneiss is equigranular and medium grained and only locally retains an augen texture. The trend of the gneissic structure here is predominantly northward but the dips vary from 35° eastward to 30° westward.

The small bodies of granite gneiss that intrude the augen gneiss have a gneissic structure parallel to that of the surrounding rocks. At several places dikes of this granite gneiss contain angular inclusions of augen gneiss that have been rotated out of the plane of former orientation. The granite gneiss must then have been intruded during a period later than the period of maximum deformation and recrystallization that affected the augen gneiss and paragneisses and before the end of the regional metamorphism.

Lineation

Lineation is especially well developed in the paragneisses and, to a lesser degree, in the igneous rocks. It was caused by the preferred orientation of prismatic or tabular minerals such as hornblende, biotite, and feldspar. Most of the lineations strike between S.10°W. and S.30°E. and plunge 20° to 40° southward.



STRUCTURAL MAP OF NIPISSIS RIVER AND NIPISSO LAKE AREAS

FIGURE 1

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Folds

Northeast of Yodel island the northeast trend of the formations is disrupted by two small open folds. The warping of the lower contact of the augen gneiss imposes a fold-like pattern on this gneiss and on the underlying paragneisses.

The axes of some of the folds in the western part of the Nipissis River area strike northwest; the axes of some in the Nipisso lake area strike north-northwest. These structures cannot be considered true or complete folds as only the lower contact and underlying rocks have been buckled, the upper contact maintaining an almost uniform northeast strike.

Southeast of Yodel island the narrow inclusion of paragneiss and the enclosing augen gneiss have been folded and their axes strike northwest.

Faults

Strong shears are found at several places in the gabbroic rocks. On a small island in the northeast bay of Tchinicaman lake, the gabbro is strongly sheared and the central part of the shear zone is a mylonitic augen gneiss. The rock is composed of finely crushed plagioclase and pyroxene, with porphyroblasts of plagioclase and garnet. Intense movements along a shear or fault zone striking N.15°E. and dipping 70° east have produced a cataclastic texture in the gabbro. The trend of the shear zone coincides with the elongation of the northeast bay of Tchinicaman lake.

Similar shear zones are present in the gabbroic rocks in the southeast corner of the Nipisso Lake area. These zones, a few inches to several feet wide, are composed of rocks that show various degrees of deformation. The most intensely crushed rocks are black, flinty, structureless mylonites containing scattered porphyroblasts of plagioclase. Augen gneisses are common and are intermediate in deformational grade between the mylonites and sheared gabbros. The zones strike northeastward and dip 35° to 50° east. One zone immediately east of the south end of Nipisso lake trends N.10°E. and dips 70° east.

The southern border of the hornblende granite west of the north end of Nipisso lake appears to be offset along a line striking N.15°W. Strong shearing of the granite, the topography, and an abrupt change in strike of the contact suggest the presence of a fault. The south shore of Brézel lake may mark another fault. Along the west border of the Nipissis River area and south of Brézel lake the gneissic structure strikes north and dips east. North of the south shore the strike is the same but the dip is consistently west.

Joints

All of the rocks of the area are jointed. The igneous rocks, especially the more massive gabbroic types, are strongly jointed. In the southeast corners of both areas, aerial photographs show a prominent ridge-and-valley topography that is controlled by jointing. The most conspicuous joints in the norite strike northeast and northwest; the dips are steep and may be either east or west. Shearing is conspicuous where the norite is weakly jointed, and usually trends northward. Dips to the east are more common, and usually less steep than the western ones.

Regional Structure

In order to discuss the regional structure, one must determine the origin of the features described above and their relationship to the deformational forces that affected the area.

Although the augen gneiss has a phacolithic shape, it is not a true phacolith intruding a series of folded rocks, as originally defined by Harker (1909, p. 78). The downwarping of the lower contact is a direct result of the presence of the granite gneiss which was intruded as a sill-like body and attained its present shape either by gravitational settling or by flowage during metamorphism. The latter appears to be more probable.

The high-grade regional metamorphism of the enclosing para-gneisses indicates that the thermodynamic conditions were such that the rocks could flow under stress. One can then think that forces acting from the southeast caused a bulge to develop in the semi-plastic rocks in somewhat the same manner that blocks are torn off and pushed ahead of thrust faults. The ability of the rocks to flow prevented fracturing and a non-disrupted bulge formed in the area of relatively low pressure. Parallelism of the gneissic structure with the contacts ensued or was maintained and the lineations were oriented parallel to the direction of linear flow. The underlying or surrounding rocks, also semi-plastic, were wrapped around the protuberance.

The gabbroic rocks in the eastern half of the Nipissis River area and in the southeast corner of the Nipisso Lake area responded to the regional stresses by shearing, jointing and faulting, Recrystallization and flowage are secondary to fracturing. The relative dryness of the rocks is probably the main factor that forced them to fracture instead of yielding by flowage. The mylonite zones, trending north-northeast to east-northeast and dipping eastwards, indicate also that the origin of the deformational forces was in the southeast.

Both the strike and plunge of the lineations show a variability that can be attributed to different local reactions of the rocks to stress rather than to changes in the direction of the stress. If the stresses came from the southeast, the lineation should be in the movement plane and parallel to the principal direction of movement in the cleavage plane and in the direction of maximum deformation.

Lineation in the area reflects the direction of recrystallization of minerals and flowage of rock induced by stress acting from the southeast. Various factors have been emphasized as controlling the development of bedding foliation; some of these are:

1. Initial anisotropism of the sediments.
2. Incipient recrystallization parallel to bedding under load or geothermal metamorphism.
3. Plastic flowage.
4. Development or rotation of slip surfaces parallel to bedding.
5. Rotation of bedding into the plane of axial cleavage.
6. Bedding acting as channels for escaping fluids.
7. Mimetic crystallization.

Any one or any combination of these factors may cause foliation to form parallel to bedding. At present a lack of knowledge of the mechanical aspects of the problem and a scarcity of field and laboratory data prevent the drawing of any conclusion.

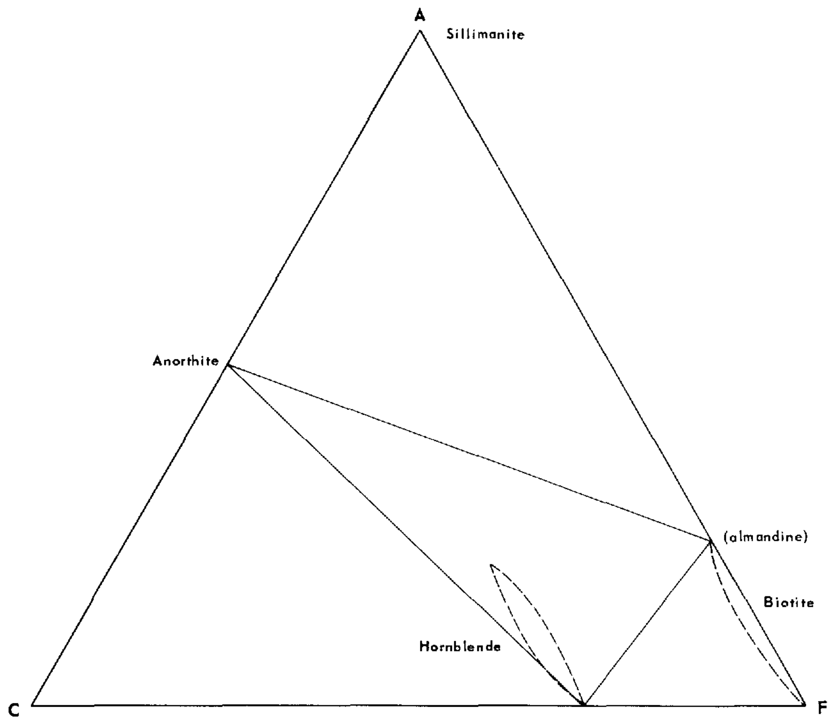
METAMORPHIC GEOLOGY

Application of the facies principle to the rocks of the area indicates that most of them contain mineral assemblages common to the amphibolite facies. Furthermore, the assemblages sillimanite-almandine and hornblende-plagioclase-almandine correspond to typical mineral groups of the sillimanite-almandine sub-facies.

Figures 2 and 3 illustrate stable mineral assemblages for rocks of the area having an excess and a lack of K_2O respectively. Figure 4 is an AKF diagram for rocks with excess Al_2O_3 and SiO_2 that show the effect of potassium on the stable assemblages. Rocks with no water or with a low water content are illustrated in Figure 5.

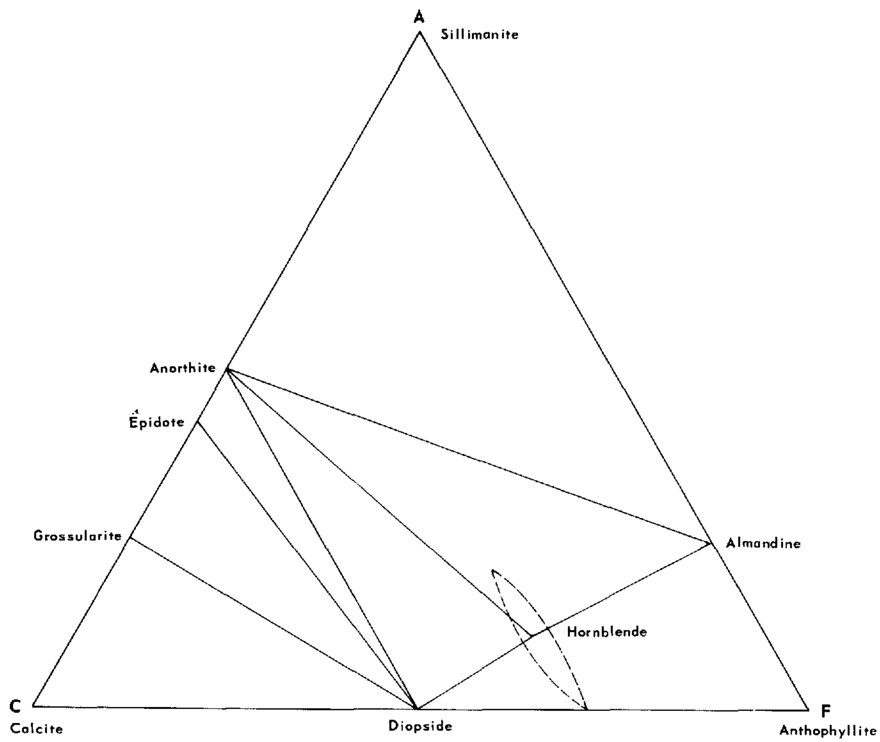
The typical mineral assemblages (plagioclase - hornblende and plagioclase - biotite) are found in all parts of the area. The occurrence of these assemblages suggests that temperature-pressure conditions were uniform for all parts of the area and that differences of mineral associations result from different chemical compositions of the rocks. Of prime importance were the amounts of K_2O and H_2O in the rocks. The effect of shearing stress cannot be evaluated but it appears that, at the great depth of burial (in the zone of flowage), the role of directional pressure in the development of stable minerals may be negligible.

Comparison of the ACF diagrams of Eskola, Barth, and Turner with those of this report show that the sillimanite-almandine sub-facies of the amphibolite facies is represented by the mineral assemblages of Figures 2, 3, and 4. Figure 5 corresponds to the granulite facies of these writers. These petrologists emphasize that the temperature-pressure conditions are higher in the granulite facies than in the amphibolite facies and that the former must be considered as a separate facies. This view is not shared by the writer, who believes that mineral assemblages corresponding to the granulite facies may be stable in the amphibolite grade of regional metamorphism if the rocks are deficient in H_2O.



ACF DIAGRAM FOR ROCKS WITH EXCESS K_2O

FIGURE 2



ACF DIAGRAM FOR ROCKS DEFICIENT IN K_2O

FIGURE 3

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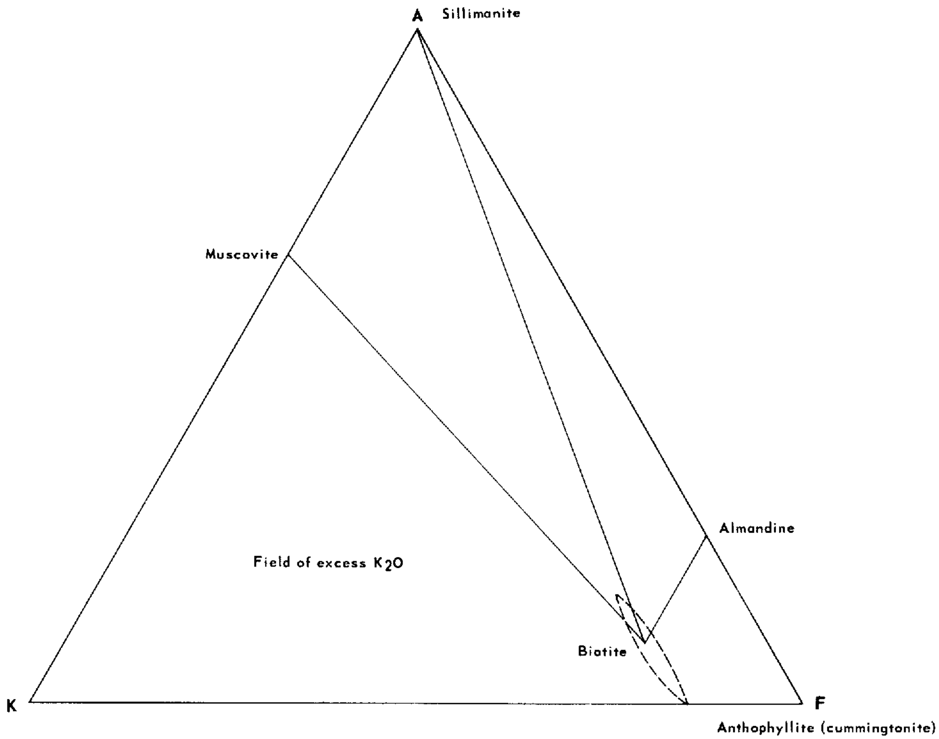
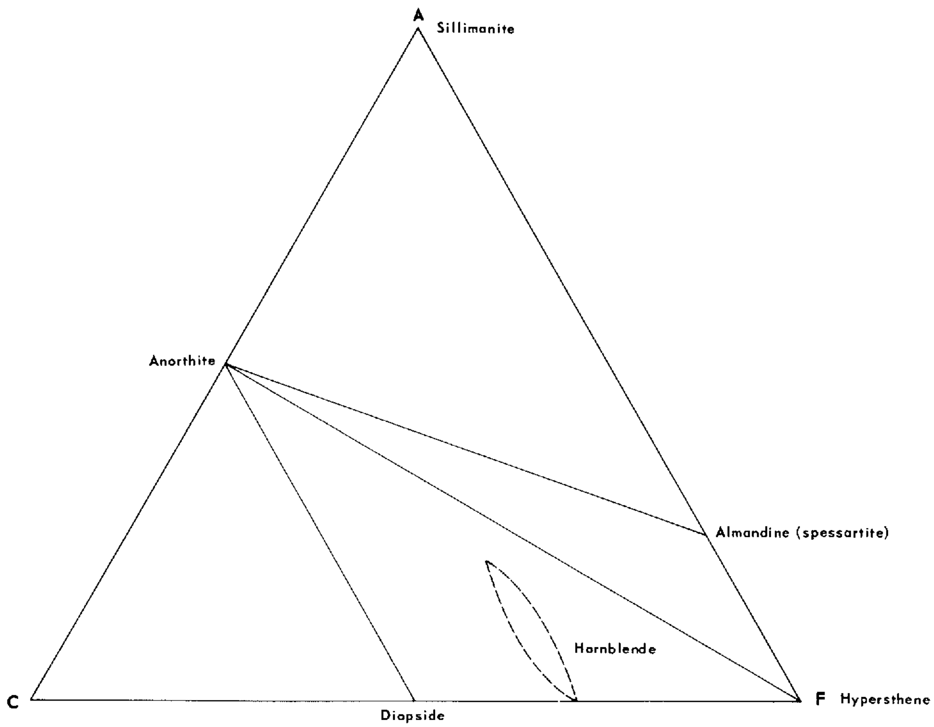


AKF DIAGRAM FOR ROCKS WITH EXCESS SiO_2 AND Al_2O_3

FIGURE 4



ACF DIAGRAM FOR ROCKS DEFICIENT IN H_2O

FIGURE 5

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The writer is of the opinion that if thermodynamic conditions are uniform throughout an area, the presence of amphiboles or pyroxenes in different rock types is determined by the amount of water present during the formation of these minerals. In most of the metasedimentary gneisses water is present in excess and hydroxyl-bearing minerals will be formed. In the gabbroic bodies meteoric water was lacking and, at the high temperatures and pressures of the amphibolite facies, the original "dry" mineral assemblages were stable. Usually narrow sills and dikes and the marginal parts of the larger bodies contain hornblende as the stable ferromagnesian in place of pyroxene. This suggests that the H_2O of the surrounding rocks was able to migrate, for short distances, into the igneous rocks.

If, locally, mineral assemblages corresponding to the granulite facies are found in areas where the regional metamorphism is of the amphibole grade, it does not necessarily follow that the temperature-pressure conditions were different in these localities. Where these "higher" grade rocks are completely surrounded by rocks of the amphibolite facies, it is more probable that temperature-pressure conditions were uniform throughout the region and that the amount of water in the rocks was variable.

The variations in the mineral assemblages can be treated solely from the viewpoint of differences in the bulk chemical composition of the rocks. These differences can be attributed to different original compositions of both the igneous and sedimentary rock groups and, in part, to the addition of material by migmatization. The granitic, gabbroic, and paragneissic rocks contain mineral assemblages stable under the conditions of high-grade regional metamorphism: high temperature, high pressure (hydrostatic), and differential water content.

ECONOMIC GEOLOGY

The object and duration of the writer's work did not permit detailed prospecting. Deposits of sulfides, ilmenite, garnet, and graphite were examined.

Sulfides

Two miles northeast of the junction of the Nipissis and Nipisso rivers, a rusty weathering cliff contains scattered sulfide minerals. A sample taken from here and assayed by the Quebec Department of Natural Resources gave 0.02% nickel and 0.02% copper.

Finely disseminated pyrite, pyrrhotite, and some chalcopyrite were found in nearly every outcrop of the graphite gneiss that lies along the north border of the augen gneiss. A specimen from the rusty weathering cliff, taken half a mile east of the former airstrip in the Nipisso Lake area assayed 0.02% nickel and 0.08% copper.

Approximately one mile southeast of Albany lake and half a mile east of the boundary of the area, coarse grains of pyrrhotite, pyrite, and chalcopyrite were found in a gabbroic pegmatite dike. The 4-foot wide dike, exposed for 25 feet, outcrops in the bed of a stream that drains into Albany lake. Two assays of the mineralized rock gave 1.29% and 0.17% copper, respectively, and traces of nickel and silver.

Ilmenite

The anorthositic gabbro on the long point of Nipisso lake, east of Yodel island, contains minor ilmenite. A dip-needle survey of the point and adjacent mainland failed to show any indications of ilmenite concentrations.

Garnet and Graphite

The only non-metallic minerals that occur in sufficient quantities to merit discussion are garnet and graphite. Garnets are abundant in the paragneisses and amphibolites in the bay west of Yodel island. Gneisses containing up to 10% graphite outcrop along the northern contact of augen gneiss.

Sand and Gravel

Large amounts of sand and gravel from the Nipissis and Wacouna valleys were utilized in the construction of the road-bed of the Quebec North Shore and Labrador Railway.

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