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Geology of the Mistassini River north, Mistassini River south, Peribonca Lake, Pipmuacan Reservoir, Chicoutimi and Baie St-Paul map-areas, Quebec: Grenville project 1965, 1966, 1967

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GRENVILLE PROJECT; MISTASSINI NORTH RIVER TO BAIE-ST-PAUL

A.-F. Laurin

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QUEBEC DEPARTMENT OF NATURAL RESOURCES

Mines Branch

GEOLOGICAL EXPLORATION SERVICE

GRENVILLE PROJECT

1965, 1966, 1967

GEOLOGY OF THE MISTASSINI RIVER NORTH, MISTASSINI RIVER SOUTH, PERIBONCA LAKE, PIPMUACAN RESERVOIR, CHICOUTIMI AND BAIE ST-PAUL MAP-AREAS, QUEBEC

Geological Report

by

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INTRODUCTION

In 1965 the Quebec Department of Natural Resources undertook a project of reconnaissance mapping of the Precambrian Grenville Orogenic Province of the Canadian Shield. The region mapped during the summer of 1965 comprises an area of about 12,500 square miles bounded by longitudes $72^{\circ}00'$ and $74^{\circ}00'$ west and latitudes $49^{\circ}00'$ and $51^{\circ}00'$ north. In 1966 the project was continued eastward and an equal area was mapped between longitudes $70^{\circ}00'$ and $72^{\circ}00'$ west and latitudes $49^{\circ}00'$ and $51^{\circ}00'$ north. The area covered by the 1967 Grenville project is south of that of 1966, covering an area of about 16,000 square miles between longitudes $70^{\circ}00'$ and $72^{\circ}30'$ west and between latitudes $49^{\circ}00'$ north and the north shore of St. Lawrence River. The regions covered for the 1965 project correspond to maps 32I and 32H; for the 1966 project correspond to maps 22L and 22E; and for the 1967 project correspond to maps 21M, 22D, and parts of maps 32A, 31P, 31I, 21L of the National Topographic ~~Series~~ System, produced and printed by the Surveys and Mapping Branch, Department of Mines and Technical surveys.

Mapping was carried out at a scale of 1 inch = 4 miles and was accomplished by a party of about 30 men every summer, during a period of about 3½ months. The area was covered mostly by canoe along lakes and navigable rivers, and by motor-vehicule on various roads. The traversing parties were serviced by a "Beaver" float-plane stationed at the base-camps in Chibougamau, Chute-des-Passes, and Shipshaw during the 1965, 1966, and 1967 summer field-seasons respectively. Foot-traversing was carried out in areas where lakes are not big enough to allow landing of float-planes and to visit significant aeromagnetic anomalies and structural features. In addition, the float-plane was also used to visit small lakes where necessary to fill in gaps.

Considerable use was made of aeromagnetic maps and air-photos in selecting traverse areas and finally in the interpretation of the geology.

ACKNOWLEDGEMENTS

The field mapping party comprised of following geologists in 1965: J.A. Carrier, J.-L. Caty, R. Davies, J.M. DeLammerville, R. Hardy, T. Hashimoto, K. Hendry, M. Hocq, S. Kranck, A.F. Laurin, D.J. Murphy, and V. Tanaka. In 1966 the geologists were: R. Davies, J. D'Cruz, J. Dygas, R.G. Gilmore, J.P. Guelpa, M. Hocq, M.M. Kehlenbeck, A.F. Laurin, K. Mahajan, J.G. Major, and M. Rive. Finally in 1967 the geologists in the party were: K. Arkay, R. Davies, J. D'Cruz, A. Franconi, J.P. Guelpa, M. Hocq, M.M. Kehlenbeck, A.F. Laurin, M. Legrand, K. Schimann, and K.N.M. Sharma. All the members of the group carried out their respective assignments in a satisfactory manner.

We are highly indebted to Dr. T. Hashimoto, and Dr. R. Davies for the great help provided by them during the field seasons and without which this work would not have been possible.

ACCESS

The area of 1965 Grenville Project is rendered accessible by the St-Félicien - Chibougamau highway which passes through the southwestern part of the map-area. The southeastern part is accessible by many roads that connect this part with the towns around the northern part of Lac St-Jean. The big Mistassini and Mistassibi rivers together with several other smaller rivers provide access to different parts of the area. Lake Mistassini with its numerous bays provide an excellent access in the northwestern part. In addition, the area is dotted with lakes of varying dimensions that have served in mapping.

The region of 1966 project is made accessible by two principal roads going north from Chicoutimi to Pipmuacan Reservoir and from Lac St-Jean to Chute-des-Passes. Apart from these the secondary roads and lumber-hauling roads are also serviceable. The access by water is provided, from north to south, by Peribonca river. Other rivers of the area such as Manouane river, Northeast Mistassibi river, parts of Betsiamites river and other smaller rivers are easily navigable. Pipmuacan reservoir, Manouane lake, Peribonca lake, and Onatchiway lake provide access to large parts of the region.

The area mapped in 1967 was the most accessible by roads as compared to the previous areas due to the presence of network of roads connecting various towns around Lac St-Jean and Saguenay valley, and along the southern and western limits of the area. There are lot of secondary roads and lumber roads that are also in good condition.

PHYSIOGRAPHY, GLACIATION, and DRAINAGE

The areas mapped in 1965, 1966, and 1967, as a whole, possess a rather gently undulating topography especially in its northern and northeastern parts where the elevations usually lie between 500 to 1,000 feet above sea level and the maximum relief is generally less than 500 feet. In contrast to this the southern parts of the region possess quite a rugged topography in regions occupied by anorthosites and mangerites. Here the topography rises to more than 3,000 feet above sea level in many places and local reliefs of more than 1,000 feet are present.

The whole area, in general, shows many of the characteristics of continentally glaciated regions, e.g. glacial and glacio-fluvial deposits, glacial striae, and many lakes and rapids resulting from deranged drainage. The glacial features indicate that the region was completely covered by ice during Pleistocene period and that the general direction of flow of the glacier ice was from north and towards S10E to S. Boulders of cryptozoan-bearing limestones of the Mistassini Group are found in the till deposits, especially in the northwestern parts of the region, thus indicating a southward movement. Numerous eskers found in the region have a rather sinuous course from due south to southeastward and occasionally even southwestward. Eskers are composed of sand, gravel, clay, and boulders. In the region of Saguenay-Lac St-Jean there are glacial striae that indicate that the ice here moved nearly parallel to the Saguenay River valley.

In the region occupied by lowlands surrounding Lac St-Jean, there are numerous extensive stratified deposits of marine sand, silt and clay which have been dissected by post-Pleistocene valleys. The occurrence of marine deposits indicates that the lowlands surrounding the Lac St-Jean were occupied by the Champlain sea. The marine nature of these sediments is confirmed on the basis of fossils such as "Saxicava rugosa", "Macoma balthica", "Hiatella arctica", "Portlandia arctica" etc., extensive level terraces and uniform stratification. In addition to these there are also the sand and silt deposits of lacustrine and fluvial origin.

The extreme northwestern part of the region includes a height-of-land from which the drainage goes to Mistassini Lake and westward to James Bay; to lake Chibougamau and westward to Nottaway river and thence northward to James Bay. Lake Mistassini is 1,220 feet above sea level. Southeastward the whole region drains either directly into the St. Lawrence River, or the drainage goes to the Lac St-Jean and Saguenay river and finally to the St. Lawrence river.

The majority of the area mapped in 1966 belongs to the hydrographic basin of Peribonca river which is more than 300 miles long. Peribonca river has a watershed of about 12,000 square miles, whereas the watershed of the Lac St-Jean region as a whole has an area of about 28,000 square miles. Several important dams have been constructed by the Aluminium Company of Canada on Peribonca river (near

Passes Dangereuses) and on Saguenay river (near Shipshaw) to meet the needs of the big aluminium plant in Arvida. Several other cut-off dams have also been constructed to prevent escape of water into different drainage systems.

FLORA and FAUNA

The majority of the region is well wooded, except for some small areas where forest fires have completely burned down the earlier trees and they now have young undergrowths. Black spruce is the most abundant forest tree, and although it has a small butt diameter, it makes excellent pulpwood. White spruce, balsam and jackpine are also present. Jackpine is especially common in areas of considerable glacial drift. At higher elevations birch, poplar, and banksian pine are encountered. Cedar is common along lake shores, whereas tamarack grows mostly along sluggish streams. In some of the low lying areas peat-bogs are present.

The wildlife is represented by fur-bearing animals such as muskrats, otter, racoon, mink, fox, beaver, and by moose, bear, deer, caribou, wolves, and rabbit. These animals are found in varying abundance in different parts of the region. Common loons are quite frequent on many of the lakes. Partridge and ducks are also present. The main fishes that can be caught in the lakes, rivers and streams are pikes, trouts, pickerels, ouananiche etc.

Some farming is carried out in the lowlands along Mistassini river, but many of the farms have been abandoned because of poor soil and unfavourable weather. Farming is also carried out in the lowlands around Lac St-Jean and Saguenay river, and along the St. Lawrence river.

PREVIOUS WORK

Chamouchouane river, Argenson (Chigoubiche) lake and Chamouchouane lake, lying in the area of 1965 Grenville project, formed part of a historic canoe-route from Lac St-Jean to Chibougamau and Mistassini lakes (Richardson, 1872). Richardson surveyed this route in 1870 when travelling north to Lake Mistassini. He noted the presence of "red and grey gneisses", both fine- and coarse-grained, with black hornblende rock and layers of black mica-schist. Many prospectors followed this route in later years, mainly to explore the mineral deposits discovered around Chibougamau lake in 1903. A summary of this early history of exploration is contained in the report of the Chibougamau Mining Commission (Faribault, Gwillin, and Barlow, 1911).

McOuat (1872) reported on the exploration work between Lac St-Jean and the southern part of Lake Mistassini. Galbraith carried out some studies in the region of Waconichi, Chibougamau, and Mistassini lakes in 1881. A.P. Low (1885) provided further information on the geological features of Lake Mistassini region which he visited in 1884. Later on in 1905 (Low, 1906) he carried out a more detailed work in the same region.

In 1919 H.C. Cooke described some of the stratigraphic and structural features of the Precambrian of the northern Quebec. Dresser (1916) and Denis (1934) have also carried out geological studies in the region of Lac St-Jean. Norman (1940) has described the Mistassini series and its inferred fault contact with the gneisses.

In 1915, the Quebec Department of Mines initiated systematic detailed geological mapping of small areas within this region. The mapping was mostly carried out at a scale of 1 inch = 1 mile. The results of these investigations have been published, by the Quebec Department of Mines, and the Quebec Department of Natural Resources, in the form of preliminary and final geological reports. In the area covered by the 1965 Grenville project the following geologists had carried out detailed mapping of small areas (the years referred correspond to the years in which the mapping was done): Neilson, 1948; Longley, 1950; Gilbert, 1950; Laurin, 1955, 1956; Deland, 1956; Sater, 1957; Bergeron and Beal, 1957; Berrangé, 1958, 1959; Moyer, 1959; Benoit, 1960. In the area of 1966 Grenville project Ross studied the geology along the Peribonca river in 1942, and Anderson mapped two 15 minute sheets in 1961 and 1962. Finally, in the area of 1967 Grenville project the earlier geological work was carried out by Bancroft, 1915; Denis, 1932, 1933; Jooste, 1948; Clarke and Lunde, 1949; Philpotts, 1964; Rondot, 1964, 1965; Pyke, 1964; LaSalle, 1964; Chagnon, 1965.

GEOLOGY

Almost all the consolidated rocks of the region are Precambrian, except for the presence of some Paleozoic rocks outcropping along the St. Lawrence River and in the lowlands of Lac St-Jean and Saguenay river; whereas all the crystalline rocks are Precambrian in age. The majority of the crystalline rocks form part of the metamorphics of the Precambrian Grenville Orogenic Province of the Canadian Shield.

Precambrian rocks outcropping in a small area in the northwestern part of the region, west of the Grenville Front, belong to the Precambrian Superior Orogenic Province of the Canadian Shield. The rocks of the Grenville Province are characterized by their higher grade of metamorphism as compared to the rocks of the Superior Province. The most important geological features of the region are the presence of Grenville Front separating the rocks of the Grenville and Superior provinces, and the presence of the largest known Lac St-Jean anorthosite mass in the world.

The last major deformation, metamorphism, and recrystallization took place during the Grenville orogeny around 950 ± 150 million years ago. The effects of major intrusive activity of Elsonian (1,400 million years ago) are the most conspicuous features of this region, as represented by the huge Lac St-Jean anorthosite massif, as well as other smaller bodies of anorthosite and associated gabbro, mangerite, monzonite, syenite and granite. The rocks belonging to post-Grenville orogeny are mainly represented by unmetamorphosed granite-pegmatite, diabase and carbonatite dykes. In general, the grade of metamorphism ranges from upper-Amphibolite facies to Granulite facies, but it goes down to lower-Amphibolite and Greenschist facies, especially in the northern and northwestern parts of the map-area.

DESCRIPTION OF FORMATIONS

For descriptive purposes all the rocks of the region are divided into eight major groups as follows:

I) Rocks of the Superior Province.

II) Gneiss complex of the northern and northwestern parts of the region.

III) Grey, quartz-oligoclase-biotite-hornblende gneisses of the southwestern part of the region.

IV) Metasedimentary rocks (Grenville Group).

V) Charnockitic gneisses.

VI) Anorthosites and associated intrusions.

VII) Dykes - Youngest intrusive rocks.

VIII) Paleozoic rocks.

I) Rocks of the Superior Province

In the northwestern part of the area, covered by the Grenville project of 1965, the rocks of the Superior province outcrop immediately west of the Grenville Front. This area had already been mapped in detail, at 1 inch = 1 mile scale, in the previous years by the Quebec Department of Mines and as such during the course of the Grenville project very little work was carried out in these parts. The rocks outcropping in this area are only very briefly described here.

All the rocks of the Superior province outcropping in this region are Precambrian in age and are separated by an unconformity into Early Precambrian and Late Precambrian. The early Precambrian rocks are characterized by the presence of a gneiss complex, the Keewatin-type volcanic and sedimentary rocks, together with some intrusive rocks; whereas the late Precambrian comprises of Chibougamau group and Mistassini group of sedimentary rocks, and intrusive rocks probably belonging to Keewenawan. In general, the early Precambrian rocks have been much more intensely deformed as compared to the late Precambrian rocks.

Table I summarizes the rocks of the Superior Province encountered in this region.

For further details concerning the geology and the detailed descriptions of various rock types outcropping in this region west of the Grenville Front, the reader is advised to refer to the works of the following geologists, published by the Quebec Department of Mines: Longley (1958, Map No. 1210, Final Geological Report No. 81); Gilbert (1958, Map No. 1180, Final Geological Report No. 79); Deland (1957, Map No. 1158, Preliminary Report No. 331); Sater (1957, Map No. 1209, Preliminary Report No. 356); Moyer (1960, Map No. 1337, Preliminary Report No. 427); and Neilson (1953, Map No. 918, Final Geological Report No. 53).

Table I

ROCKS OF THE SUPERIOR PROVINCE

LATE-PRECAMBRIAN	Keewenawan (?)	- Diabase, olivine diabase dykes.
	Mistassini Group	- Cherty iron formation, cherty iron carbonate, banded iron formation. - Pink dolomite with some grey dolomite and sandy beds. - Grey dolomite, arenaceous dolomite, shaly dolomite. - Basal conglomerate.
	Chibougamau Group	- Arkose, graywacke, argillite, impure quartzite, interbeds of conglomerate. - Boulder conglomerate.
EARLY PRECAMBRIAN		- Diorite, gabbro, pyroxenite, granite, syenite. - Feldspathic graywacke, some arkose & argillite, with interbeds of volcanic rocks and tuffs. - Basaltic and andesitic lava, some trachyte, with interbeds of tuffaceous and sedimentary rocks. - Gneiss complex comprising of biotite gneiss and various granitic gneisses.

Rocks of the Grenville Province

II) Gneiss Complex of the Northern and Northwestern Parts of the Region

A major portion of the areas mapped during the Grenville projects of 1965 and 1966 is occupied by a complex of gneisses that are homogeneous to heterogeneous in character, generally fine- to medium-grained and in places coarse grained, well foliated to banded, light grey to dark grey to nearly black in colour, and composed predominently of quartz, plagioclase, biotite, and hornblende. Garnet and epidote may appear in appreciable quantities in some places. They tend to be more heterogeneous in the northern parts as compared to the southern parts that are in the vicinity of the Lac St-Jean anorthosite massif. These gneisses occupy more than 60% of the area mapped in 1965, and about 40% of the area mapped in 1966.

These banded gneisses possess good layered structures that are probably relics of original bedding. In general, these gneisses can broadly be divided into the biotite-rich and the hornblende rich varieties. The biotite-rich varieties usually contain an appreciable amount of quartz and in places garnet. The hornblende-rich rocks rarely contain quartz or contain quartz in very minor quantities and contain a high percentage of hornblende. Layering is less conspicuous in hornblendic rocks and it is probable that these rocks were derived mainly from volcanic rocks. These two varieties are described below.

Hornblende-rich Gneisses

The rocks included in hornblende gneiss group show a wide range of compositions and a diversity of textures. Some consist almost essentially

Table II

Rocks of the Grenville Province

Quaternary	Fluvial Deposits Marine Deposits Glacial Deposits	Sand, Gravel and Clay Sand, Silt, and Clay Moraine, Boulders, Sand
Paleozoic	Sedimentary Rocks	Limestones and Shales
Proterozoic	Dykes	Diabase, Granite-Pegmatite, Carbonatite
	Migmatites and Younger granites	Migmatites after the gneisses of the gneiss-complex, and migmatites after paragneisses. Younger undeformed granites
	Plutonic Rocks	Granite, with some pegmatite Syenite Monzonite Diorite Mangerite-Jotunite, with charnockite and Hypersthene-syenite Gabbro, Norite, Mafic gabbro, troctolite, amphibolite and metagabbro Anorthositic gabbro Gabbroic anorthosite, Noritic anorthosite Anorthosite
	Metasedimentary Rocks	Quartzite, Mixed paragneisses, Crystalline limestone, Calc-silicate rock, Amphibolite
Archaean(?)	Gneiss complexes	Hornblende-rich gneisses, Biotite rich gneisses, amphibolites, Grey quartz - oligoclase - biotite - hornblende gneisses, Charnockitic gneisses

of amphibole, others of amphibole and plagioclase, and still others of amphibole, plagioclase and minor quartz. Texturally, the different varieties are fine to medium grained, occasionally coarse grained, equigranular or porphyroblastic, schistose or gneissic, well foliated, rather homogeneous and sometimes heterogeneous. The foliation is marked by hornblende needles. Compositionally they consist of more that 40% hornblende, less than 50% plagioclase (An_{28}), and less than 5% quartz. In some varieties garnet may be present up to 5%. Biotite, sphene, magnetite and apatite form the important accessory minerals. The hornblende is strongly pleochroic from light green to dark green, moderate to high birefringence, optically negative, and with a 2V of about 80°. The plagioclase is in small anhedral grains, both as twinned and untwinned grains. Quartz occurs as clear anhedral grains. Garnet occurs as anhedral porphyroblasts, characterized by numerous inclusions of quartz, plagioclase, hornblende and magnetite. It is red in hand specimens and pinkish in thin section. The hornblende rich gneisses grade into amphibolites with an increase in its hornblende content.

According to Laurin (1960), some of the better layered varieties of the hornblende gneisses and amphibolites could possibly have been derived from the metamorphism of graywacke or calcareous sediments, whereas the majority of the rather homogeneous varieties are believed to be derived from three different types of rocks listed below:

(1) Andesite and basalt flows or tuffs

(2) Gabbro-diorite sills

(3) Ultrabasic intrusives.

(1) Andesites and basalts are common Keewatin-type rocks and they are believed to account for most of the amphibolites of the area. By metamorphism, these lavas give rise to chlorite schist, to hornblende schist, and finally to hornblende gneiss and amphibolite. The transition from one end member to the other can be seen more easily where it takes place within a short distance, for example, within half a mile. Thus, near the contacts of the granite on the shore of La Dauversière lake in Imbault's Queylus area (1959), and southeastward in Ducharme-Mignault area (Laurin 1955), the progressive change of the lavas into hornblende gneiss and amphibolite can be followed without difficulty. The same gradation between chlorite-schist, hornblende-chlorite-schist, and hornblende gneiss can also be observed around Au Couteau lake in Dollier-Charron area (Neale, 1959) which lies just outside the western limit of the region of the Grenville Project and northwest of Migneault-Aigremont area.

(2) Practically all the sills of gabbro-diorite associated with the volcanics have been metamorphosed to amphibolite. The field relations and the occasional preservation of the original ophitic texture leave little doubt as to the origin of these amphibolites.

(3) Some very coarse grained amphibolite found in this region is believed to be derived from an ultrabasic intrusive. The great abundance of amphiboles, together with the very low content of plagioclase are highly suggestive of an original ultrabasic intrusive. According to Williams, Turner, and Gilbert (1954), the abundance of light-coloured, magnesium rich amphiboles is also an indication of a derivation from ultrabasic rocks.

The problem of determining the origin of an amphibolite or hornblende-plagioclase-gneiss becomes increasingly difficult as the grade of metamorphism increases and as the original features of the rock become obliterated. The original nature of the hornblende gneisses and amphibolites found as inclusions cannot be ascertained with certainty. Many geologists have considered them to be either basic differentiation products from the acid magma or as fragments of foreign rock caught up by the granite.

Biotite-rich Gneisses

The biotite-rich gneisses and garnet-biotite gneisses underlie much larger areas as compared to the hornblende-rich gneisses, in this region of the map-area. This group of rocks also includes graphitic, and garnetiferous quartzo-feldspathic gneiss, some quartz-biotite gneiss and some biotite schist. Wherever possible, these later rocks are mapped as distinct map units, as for example, east and northeast of Lac Chigoubiche (Argenson lake). Other smaller bodies of garnetiferous biotite-gneiss occur here and there in this part of the map.

The biotite gneiss is generally a fine- to medium-grained, biotite-feldspar-quartz bearing rock. The regular alternation of bands rich in biotite, while others rich in leucocratic minerals is an indication of relic bedding. Often a faint lineation is generally visible on the foliation plane of individual layers. Minor-folds are present at many places in biotite- and hornblende-gneisses, and having northeasterly, northerly or southerly plunges. In a few places, alternating garnet-rich bands with garnet-poor bands make concentrations along certain layers, whereas elsewhere in other layers garnet is inconspicuous. Epidote has commonly been observed in northern and northwestern parts.

These gneisses vary in composition, texture, and colour within short distances. These variations are seen between the graphitic gneisses, the garnetiferous quartzo-feldspathic gneisses, and the proper biotite gneisses. In the graphitic gneisses, the rock is white to light grey, rusty weathered, and composed of quartz, plagioclase, up to 5% graphite, and some garnet. The garnetiferous quartzo-feldspathic gneiss stands out in larger bodies, but with more garnet. It contains quartz, plagioclase, about 20% biotite and hornblende in nearly equal proportions, and about 15% garnet. The biotite gneiss contains quartz, plagioclase, up to 25% biotite and variable quantities of garnet. Foliation is shown by orientation of biotite or by streaks of mafics.

Thin-section study of the biotite gneiss indicates that the rock has a gneissic structure and or granoblastic texture. Quartz and plagioclase (An_{27}-An_{31}) which make up about 75% of the rock occur as anhedral equigranular grains. Plagioclase is generally untwinned, though fine albite twins can be seen in some sections. It is sericitized to varying degrees. Biotite is oriented parallel to foliation in the rock. Light straw yellow to dark greenish-brown pleochroism is seen in the biotite. In some places it is partly altered to chlorite. Accessory minerals are mainly magnetite, sphene, apatite, clinozoisite, sericite, zircon, and pyrite. In garnetiferous varieties, the garnet porphyroblasts although highly irregular tend to be rounded and characteristically have inclusions of all the other minerals of the rock, but mostly of quartz and feldspar.

The mineralogy of these gneisses suggests that they belong to the Almandine Amphibolite Facies grade of regional metamorphism.

In the present area, no gradation from slightly metamorphosed sedimentary rocks through fine-grained schists to garnetiferous biotite gneisses was observed. However, near the western limit of the region, Gilbert (1959) reports that the main belt of biotite gneisses in the northern part of Rohault area is along the strike of a belt of sedimentary rocks farther to the west between Caopatina and Surprise lakes of which it could easily be the more metamorphosed equivalent. Then, Deland (1959) observed the transition rocks in the Surprise lake area, and after comparing both specimens and thin sections, they showed so much similarity that it is more than probable that much of the biotite-gneisses are the metamorphic equivalents of sedimentary rocks found within the belt of Keewatin-type rocks. Sedimentary rocks of graywacke, arkose, or shale composition could give rise to similar gneisses by metamorphism.

These gneisses usually contain variable amounts of coarse, pink, granitic-pegmatitic material (mobilizate) mostly in lit-par-lit fashion, but also as irregular veins and patches. With an increase in the amount of mobilizate present in the rock, the gneisses pass into migmatite and finally to pink, medium-grained granitic gneisses that are either homogeneous or banded. West of the northwestern part of Lac St-Jean anorthosite massif i.e. in the southeastern part of the 1965 Grenville project, big areas of migmatite have been mapped. Here it is not uncommon to observe the unmigmatized original biotite gneisses and other paragneisses.

In the southern parts, i.e. near the northern limits of the Lac St-Jean anorthosite massif, the biotite-gneisses contain lesser amounts of amphibolite and they are more homogeneous.

The region occupied by all these gneisses is easily distinguishable on aeromagnetic maps by low magnetic relief.

Nature of the Grenville Front

The area covered by the 1965 Grenville project consists of a part of the boundary between the Grenville and the Superior tectonic provinces of the Canadian Shield. This boundary is widely known as the Grenville Front. Along its course, this boundary manifests itself by various features such as faults, shear zones, lithological changes, changes in the grade of metamorphism, changes in K/Ar dates etc.

In the present map-area, east of Lake Chibougamau, the northwestern limit of the Grenville province (Grenville Front) is placed at the contact between the biotite-hornblende gneisses outcropping east of the front and the hornblende schists that outcrop west of the front. These later rocks are believed to represent the metamorphic equivalents of Keewatin-type volcanic and sedimentary rocks. The hornblende schist varies in texture from very fine grained to coarse grained, well foliated, having a good compositional banding. Epidote forms a major constituent of some of the bands. Accessory minerals include biotite, garnet, epidote, magnetite, chlorite, zircon and titanite. The hornblende schists found associated with the biotite-hornblende gneisses southeast of the front and the hornblende schists that occur northwest of the front are quite similar in character, with the only difference that the schists found southeast of the front are somewhat of higher metamorphic grade. The contact between the biotite-gneiss and the hornblende schist is marked by some shearing in places. Minor folds are present at many places in the biotite-hornblende gneisses and schists. The minor folds in schists are isoclinal with southerly plunges and vertical axial-planes.

In the region east and southeast of Lake Mistassini, the limit of the Grenville province is marked by Mistassini Lake fault that has a general northeast trend. Along most of its course the fault is indicated by a pronounced depression. Southeast of lake Waconichi the eastern margin of this fault zone is marked by a 100 feet high cliff in sheared greenstones. Along the Bignell river it is marked by sheared or mylonitized zones a few tens of feet wide. The steep shear zones dip constantly to the east.

According to Gilbert (1958), in the Bignell area, there are good evidences of thrusting along this fault, with the east side moving westward and upward, although the actual displacement in the vertical sense may not have been great.

East of Lake Mistassini this fault marks the contact between the rocks of Mistassini group to the west and the granitic gneisses to the east. Here the disturbed Mistassini dolomites were noted by Gilbert (1958) less than 500 feet west of the sheared gneisses. The effects of deformation in the Mistassini series are shown by overturned folds, drag folds, shear zones etc. In general, the dolomitic rocks of Mistassini group are only slightly disturbed and the degree of disturbance increases near the fault zone. Similarly, the fault truncates the rocks of Chibougamau group and the Keewatin-type greenstones.

In addition, several other faults of variable extensions have been observed near the Grenville Front by various workers. These faults either branch out from the Mistassini lake fault or are parallel to it, e.g. Waconichi fault. These faults also have affected both the early and the late Precambrian rocks.

The grade of metamorphism in the Keewatin-type volcanic and sedimentary rocks is higher near the Mistassini lake fault and it decreases gradually westward. Near the fault the lavas are highly recrystallized and contain numerous injections of granitic-pegmatitic material. In places there is development of garnet porphyroblasts. The pillow structures are rare and very poorly preserved.

III) Grey, quartz-oligoclase-biotite-hornblende gneisses of the southwestern part of the region

These gneisses are found mainly in the southwestern part of the region. Compositionally, the rock has a grano-dioritic to quartz-diorite composition and consists mostly of quartz-oligoclase-biotite and/or hornblende. The quartz content is less than 15% and the mafic content is usually between 10 to 20%. It also contains variable amounts of pink potash feldspar. The rock is medium grained, occasionally fine or coarse grained, generally homogeneous but becomes rather heterogeneous when slightly banded due to the presence of mafic-rich and mafic-poor bands. The rock is well foliated, the foliation being shown by the preferred orientation of biotite flakes or by occurrence of mafics in lenticular streaks. These gneisses are almost invariably associated with varying amounts of mobilizate, present either lit-par-lit parallel to foliation or in the form of irregular veins and patches. With an increase in the amount of mobilizate, the rock passes into a migmatite and finally to a granitic gneiss. The pink granitic gneisses posses a texture similar to that of the grey gneisses. Wherever possible, these migmatized grey gneisses and granitic gneisses have been mapped as separate map-units. In places near the mangerite and anorthosite bodies these gneisses contain green feldspar and pyroxenes. This is believed to be due to the thermal effect caused by the intrusions of mangerite and anorthosite.

IV) Metasedimentary Rocks (Grenville Group)

The various rock types belonging to the Grenville group of metasedimentary rocks are quartzite, mixed-paragneisses, crystalline limestone, skarn, and amphibolites. All these different units may occur either interlayered or as separately mappable bands. The rocks of this group occur mostly in the Lac St-Jean - Saguenay area, and in the southern parts, but even in these places they do not occupy extensive areas.

Quartzite

Quartzite is a well bedded, homogeneous to heterogeneous rock, white to grey in colour and composed of glassy quartz with varying amounts of feldspar, mica, hornblende, pyroxene, garnet, magnetite, etc. Graphite has been frequently seen associated with quartzite. The pure varieties of quartzite generally contain more than 80% of quartz. Good cross-bedding has been observed in many outcrops. Quartzite does not form bands of enough thickness that can be mapped at the present scale of mapping, but instead it forms bands interlayered with the mixed-paragneisses.

Mixed-Paragneisses

The mixed paragneisses are generally very well layered as a result of variations in the percentage of micaceous minerals in different layers. The layering is supposed to be relic of the original sedimentary bedding. The layering is rather continuous and varies in thickness from a fraction of an inch to several feet. The paragneisses are characterized by the presence of pole-violet to red garnet porphyroblasts. The mineralogy is extremely varied. Quartz occurs throughout and together with plagioclase constitutes the chief leucocratic mineral. The other minerals present are biotite, hornblende, sillimanite. Graphite is frequently observed. Photo 1 shows a typical layered, fine-grained paragneiss containing graphite and pyrite.

Quite often the rocks have typical rusty weathered surface. The quartzo-feldspathic layers stand higher in relief than the biotite-rich layers on the weathered surface. Foliation is nearly always parallel to layering. The gneisses often possess good mineral lineation and micro-corrugation lineations on the foliation plane. Minor folds and gentle-warps are also present. In case of minor folds the foliation is bedding-plane foliation. Thin bands of quartzite, calc-silicate rocks, crystalline limestone and amphibolites are associated with these gneisses.

At places, in the vicinity of anorthosite and mangerite, the paragneisses contains micro-perthites, antiperthites and pyroxene. The feldspar acquires a greenish tinge and alters to brownish or buff colour.

The paragneisses have been migmatized to varying degrees as evidenced by numerous thin granitic-pegmatitic and quartz veins either parallel to layering or cutting across layering in various directions. Ptygmatic folding is commonly seen. Even at places where the rock is highly migmatised, the original paragneisses can still be seen in minor amounts in the form of bands and patches. Usually it is the biotite-rich bands of the paragneisses that survive migmatization. Where the rocks are highly granitized and no biotite gneiss lenses are seen, the presence of a faint layering inherited from the earlier paragneisses is quite evident. In general, compositionally every gradation from a good paragneiss to a good "igneous" looking pink granite can be observed in some parts of the map-area.

Crystalline Limestone

The crystalline limestone or marble is a white, friable rock composed predominently of calcite. The rock weathers easily. It forms bands that are only few feet in thickness interlayered with the mixed-paragneisses. It is only in few places that it attains enough thickness to be mapped individually at this scale of mapping. Graphite is commonly present. Other minerals present in small amounts may be tremolite, actinolite, diopside, scapolite, feldspar, quartz, pyrite, sphalerite, magnetite, phlogopite, muscovite, biotite, etc. The bands of crystalline limestone behaved rather incompetently during deformation and as such show thinning and thickening of calcite rich layers.

Calc-Silicate Rocks and Skarn

Calc-silicate rocks and skarn are rather rare in the map area and are seen mostly as thin layers interbedded with the mixed-paragneisses and marble. They are composed of varying proportions of calcite, diopside, scapolite, biotite, sphene, feldspars etc. Photo 2 shows layers of calc-silicate material and marble interbedded with the mixed paragneisses.

Amphibolite

Bands of amphibolite are frequently observed interlayered with the paragneisses. They may result as a consequence of enrichment in mafics of some of the bands or by metamorphism of sills of diabase and gabbro. In general they are fine to medium grained, equigranular, well foliated rocks. They are dark greenish to black in colour and are composed essentially of amphibole and plagioclase in nearly equal proportions or with amphibole in access of plagioclase. Biotite is usually a minor constituent.

V Charnockitic Gneisses

The rocks belonging to green charnockitic gneisses occupy a large area north of the Lac St-Jean anorthosite massif. In addition, they occur rather irregularly over wide areas surrounding the various

Photo 1 - Layered, fine-grained, mixed-paragneisses containing graphite and pyrite.

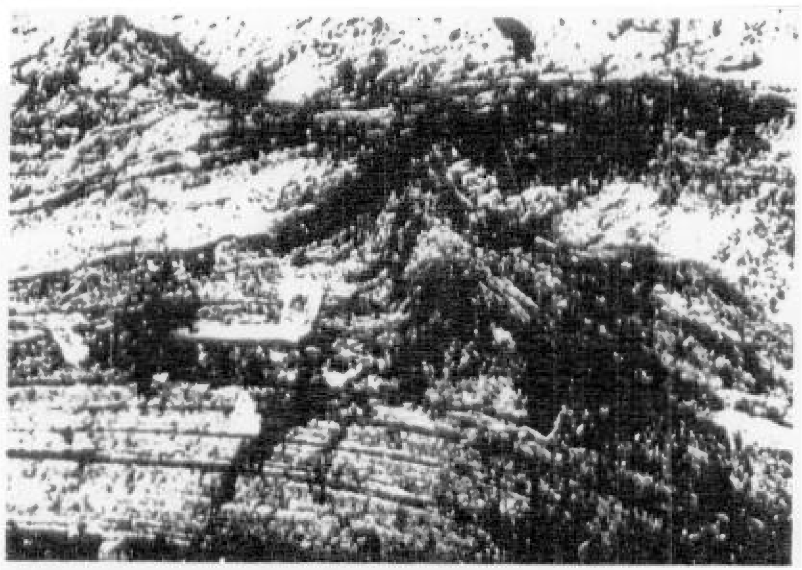


Photo 2 - Layers of crystalline limestone and calc-silicate rocks interbedded with the mixed-paragneisses. Note the flow in pure calcite layers giving rise to boudins of the more competent layers.

anorthosite and mangerite bodies of the region. Most varieties of the green charnockitic gneisses are medium grained, olive-green to grey-green in colour, and composed predominently of green feldspars with some quartz and mafics. The main mafic minerals present are ortho- and clino-pyroxenes with hornblende and/or biotite. In places red garnet is also present. The mafic minerals are commonly arrayed in lenticular streaks. Quartz frequently occurs in ribbons. The rock weathers easily and is only in fresh surfaces that the characteristic green colour is observable. In the weathered zones the rock is cassonade brownish to buff in colour and highly friable. The deep weathering of these gneisses leads to their being poorly exposed.

The green charnockitic gneisses comprise of the original grey quartz-oligoclase-biotite-hornblende gneisses, granitic gneisses, and metasedimentary rocks that have acquired vestiges of the rocks of the granulite facies due to their proximity to the anorthosite and mangerite masses of the region. Mineralogically, the charnockitic gneisses are identical to their parent rocks of which they represent higher metamorphic equivalents; the only difference being that the charnockitic gneisses contain pyroxenes and show the development of microperthites and anti-perthites in their feldspars. Texturally also the rocks resemble the earlier rocks, but now the streaky and ribbon textures are more commonly present. In these gneisses dark amphibolite bands are commonly encountered forming continuous to discontinuous bands parallel to foliation.

During the course of reconnaissance mapping, in the absence of detailed information, all these green charnockitic gneisses were mapped as a single map-unit characterized by their green colour, mineralogy, brownish weathering, texture and structure. It would be possible to separate all the varieties of charnockitic gneisses only in the course of detail mapping.

VI Anorthosites and Associated Intrusions

The areas mapped during the Grenville projects of the years 1965, 1966, and 1967 provide an excellent insight into the phenomena of emplacement, crystallization, deformation, and metamorphism of anorthosite masses and other bodies of plutonic rocks such as mangerite, monzonite, hypersthene-syenite, syenite, charnockite, granite associated with the anorthosite. The structural pattern of this area has been greatly influenced by the presence of Lac St-Jean anorthosite massif which is the largest known anorthosite mass in the world and other plutonic rocks. This anorthosite mass is more or less completely enveloped by mangerite that is rather more pronouncedly developed in the southeastern part of the anorthosite and forming a broad belt. Other plutonic rocks that occur in this border zone consist of monzonite, hypersthene-syenite, syenite, charnockite, and granite that form masses of much smaller dimension compared to the anorthosite and the mangerite. All these plutonic rocks in turn are surrounded by charnockitic gneisses that merely represent the high-grade metamorphic equivalents, in the granulite facies, of similar gneisses found elsewhere in the Grenville province. This is believed to be due to the emplacement of anorthosite and related plutonic rocks.

In general, the parts of the Lac St-Jean anorthosite massif that are near the margins of the mass exhibit numerous features of cataclastic deformation acquired in going through the Grenville orogeny. It, however, preserves the undeformed varieties of anorthosite at many places, both in the central parts and in the marginal parts. When unaffected by deformation, the anorthosite is massive, coarse to very coarse grained, of hypidiomorphic texture, and usually dark in colour-varying from dark grey to blue grey to purple to black. The black variety is a characteristic feature of this mass. Where there are sufficient mafic minerals present to make the rock an anorthositic gabbro to gabbro compositionally, an ophitic to sub-ophitic texture may be observed. In addition, undoubted igneous lamination has also been noted in places. Even in areas where the anorthosite has been unaffected by cataclasis, it shows minor effects of protoclasis where the big plagioclase crystals show bending and breaking caused during emplacement and crystallization. The uncrushed, massive varieties of anorthosite typically have the mineralogy of the granulite facies, in that they contain orthopyroxene and clinopyroxene as the only ferromagnesian minerals present.

The crushing effects due to cataclasis during the Grenville orogeny exhibit a complete range from only slight crushing of the originally very coarse grained anorthosite to a well crushed gneissic anorthosite. The least deformed rocks are characterized by the presence of a mortar texture around the big plagioclase crystals of the coarse anorthosite. As the cataclasis becomes more and more pronounced, the anorthosite progressively contains less and less identifiable original phenocrysts of plagioclase in the crushed ground mass. The crushed material shows the effects of recrystallization to varying degrees. The end-product of this cataclastic deformation is characterized by a white, equigranular, well foliated rock with a typical sugary texture.

The cataclastic deformation and the accompanied recrystallization also affect the ferromagnesian minerals, present in the anorthosite, in a variety of ways. In the earliest stages of deformation there is development of corona of amphibole around the pyroxenes. In the advanced stages of crushing and recrystallization the pyroxenes show a complete transformation into hornblende, biotite, and garnet at the expense of pyroxene and plagioclase. The development of hornblende at the expense of orthopyroxene and plagioclase is sometimes accompanied by very small grains of free quartz in the symplectite. The release of potassium during crushing and recrystallization goes to form biotite and in some cases small grains of microcline associated with biotite. The completely crushed varieties of anorthosites contain only biotite as the main mafic mineral present. Scapolite, sericite, chlorite also occur in minor amounts, at places, in the crushed varieties.

The sequence of cataclastic deformation, metamorphism, and recrystallization as observed in the anorthosite is similarly represented in the mangerite, which also in the undeformed state is a coarse grained, porphyritic rock with a hypidiomorphic texture. The phenocrysts present in this rock are mostly of potash-feldspar and some of plagioclase. The main mafic minerals present include orthopyroxene, clinopyroxene, and hornblende. The first visible effect of cataclasis in mangerite is exhibited by the development of mortar texture around the big phenocrysts of mesoperthitic potash-feldspar and plagioclase. As the degree of crushing goes up, the phenocrysts are reduced to augen and flaser shapes, and they define a foliation in the rock by the alignment of their long dimension. The crushed material in the rock shows effects of recrystallization during deformation by the presence of a well developed polygonal texture. Foliation is also marked by the arrangement of mafic minerals into lens shaped streaks. The pyroxenes show transformation into olive green to brownish green hornblende and/or biotite. The extreme cataclasis and recrystallization reduces the rock to a medium to fine grained, equigranular, well foliated charnockitic gneiss, green in colour and showing the typical rusty brown weathering. Thus, in the absence of any visible and identifiable remnants of phenocrysts, it becomes rather difficult to distinguish it from other gneisses of the region that also have acquired the characteristics of the granulite facies due to their proximity to the anorthosite-mangerite masses.

The other plutonic rocks of the area-monzonite, hypersthene-syenite, syenite, charnockite, granite - form masses of much smaller dimensions as compared to the anorthosite and mangerite. These rocks also are coarse grained, in general porphyritic, and possess a hypidiomorphic texture. The deformation and recrystallization trends observed in these rocks repeat those observed in the anorthosite and mangerite. However, in these smaller bodies of plutonic rocks, it is not uncommon to observe good, undeformed, porphyritic igneous textures, especially in the central parts of the masses.

Hence, the main effects of cataclasis, metamorphism, and recrystallization, to which these plutonic rocks have been subjected during the Grenville orogeny, is to impart various metamorphic fabrics to the originally massive, coarse-grained, porphyritic rocks.

The anorthosite and associated intrusive rocks are described in detail as follows.

Anorthosites

As mentioned earlier, the main anorthosite mass in the region is the Lac St-Jean massif. Its major part lies in the areas mapped in 1966 and 1967, and only a small northwestern part lies in the area mapped in 1965. In addition, there are several much smaller bodies of anorthosite scattered in the map-area. For mapping purposes the rocks of the anorthosite group were divided into five major rock types based on the percentage of mafic minerals present:

Anorthosite	- 0 to 10% mafics
Gabbroic anorthosite	- 11 to 20% mafics
Anorthositic gabbro	- 21 to 35% mafics
Gabbro	- 36 to 65% mafics
Mafic gabbro	- > 65% mafics.

It is possible to observe the different rocks of the anorthosite group even in the same outcrop.

Away from its contact with the other rocks of the region, the Lac St-Jean anorthosite is a coarse-grained rock in general and becomes extremely coarse-grained in its central parts, consisting of plagioclase and pyroxene crystals up to several inches in length. The grain size distribution is quite heterogeneous. Generally it contains more than 90% plagioclase. Orthopyroxene and clinopyroxene are the main mafic minerals, but other mafics such as hornblende, biotite, and rarely chlorite are also present. Other minerals that may also be present include garnet, apatite, magnetite, ilmenite, sphene, etc. In places, within the main mass, the plagioclase has good irridiscent crystals. The anorthosite shows a variety of colours in different parts of the mass. The black variety is quite common near Alma and St-Gédéon area, whereas the purple and dark grey variety is common in Chicoutimi and Kénogami area.

The massive varieties of anorthositic rocks usually contain very small percentage of mafics, although there are massive rocks of gabbroic anorthosite to anorthositic gabbro composition. In the massive varieties mafics often occur in clots or segregations (Photo 3) and as big individual crystals. Within these mafic patches in the anorthosite and in the mafic varieties of the anorthosite an ophitic texture can often be seen (Photo 4). Here the pyroxenes occupy interstices formed by well shaped lathes of plagioclase and as such possess irregular outlines. The development of ophitic texture in this manner indicates that the crystallization of mafics in their present location took place after the plagioclase crystals had already developed.

Good compositional layering has also been observed in several places in the anorthosite. The layering may either be shown by slight changes in the mafic content or by alternance of very mafic and leucocratic layers. This phenomenon is believed to be due to primary igneous lamination.

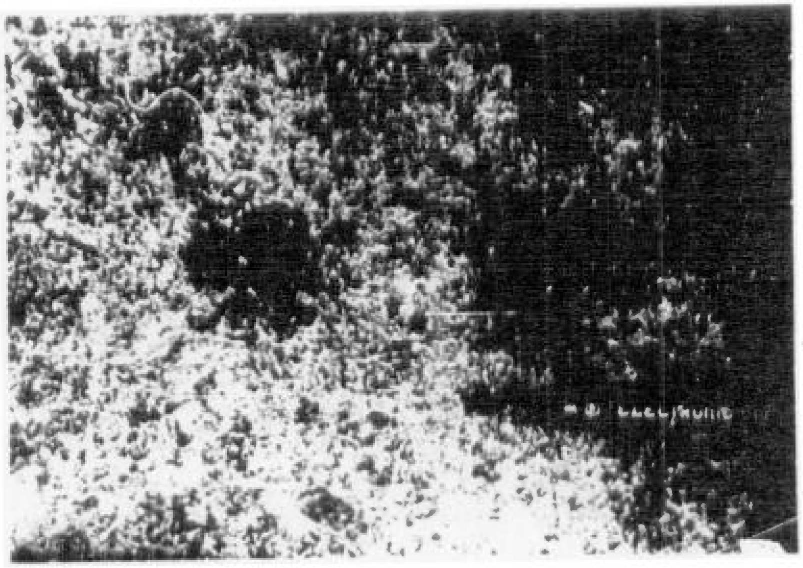


Photo 3 - Mafic minerals occurring in clots or segregations in coarse grained anorthosite.

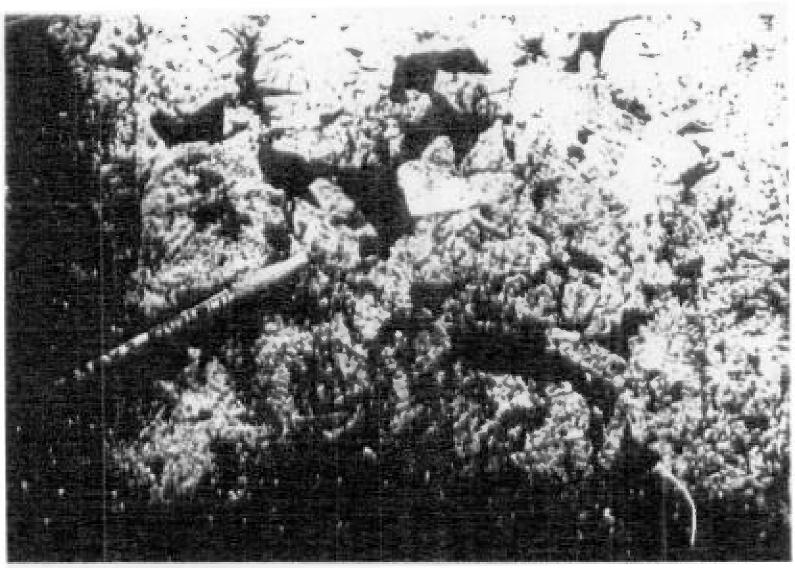


Photo 4 - Ophitic texture in anorthosite. Clinopyroxene (dark) and plagioclase (light).

Photo 5 shows an example of a kind of layering seen in the anorthosite. In few places the foliation developed in the anorthosite was seen to cut the compositional layering. In addition, parallel alignment of plagioclase lathes giving rise to trachytoidal texture, with varying degrees of perfection, has also been observed in some places and is believed to be a primary igneous feature.

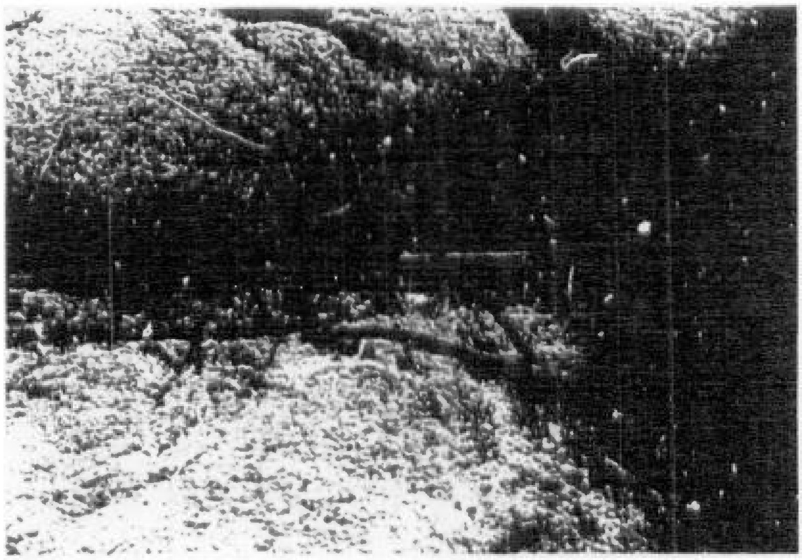


Photo 5 - Layering in anorthosite. Note the concentration of mafics towards the bottom of the upper layer. This concentration of mafics gradually decreases upwards.

Magnetite and ilmenite concentrations occur at many places within the anorthosite mass, especially near the border zone and associated with the gabbroic varieties of anorthosite. The gabbroic and noritic rocks at places contain pyrite and pyrrhotite disseminations.

Some medium-to coarse-grained, noritic to gabbroic varieties of anorthosite are seen associated with, but intrusive into the anorthosite, thus indicating that the mafic-poor parts of the anorthosite had attained a crystallized state while the mafic portions were still in a mobile condition. Photo 6 shows norite cutting the anorthosite and Photo 7 shows the mafic variety of anorthosite containing xenoliths of less mafic anorthosite.

Some small bodies of troctolitic anorthosite have also been mapped in this region. The rock is dark grey to black in colour and contains olivine as the chief ferromagnesian mineral, accompanied by varying amounts of augite, hypersthene, hornblende, ilmenite and magnetite. Spinel and apatite are accessories. The plagioclase is grey to dark grey in colour. Some olivine grains also possess corona of hypersthene and hornblende around it. Olivine is dark green and rusty weathering. These rocks often have an ophitic to subophitic texture.

In places, the anorthosite contains inclusions and roof-pendants of metasedimentary rocks.

The first signs of mechanical deformation, both protoclastic and cataclastic, in an anorthosite are manifested around the edges of big plagioclase crystals where the crushed plagioclase, broken up into smaller grains, is white in colour as compared to the dark colours of the big plagioclase crystals. Photo 8 shows a good example of this phenomenon. This change in colour of plagioclase may be explained as follows. The dark colour in plagioclase is probably imparted by the

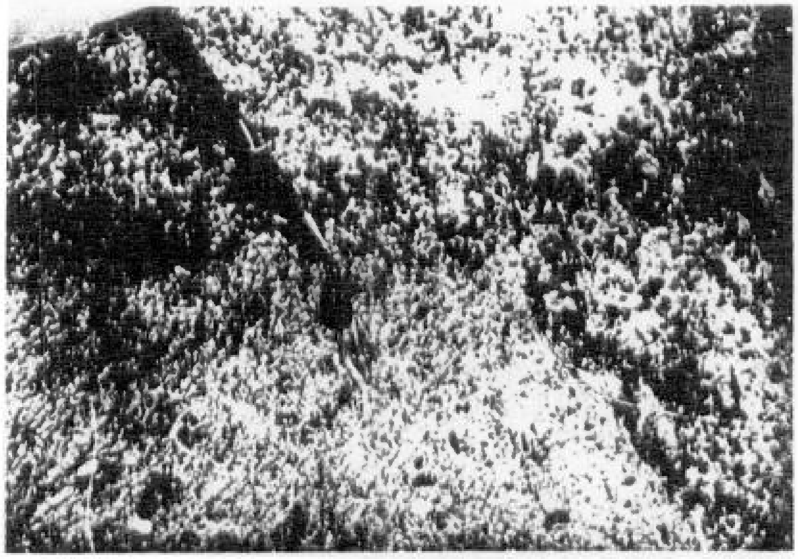


Photo 6 - Medium grained norite cutting coarse anorthosite. Note the concentration of mafics at the contact. The pencil points a garnet porphyroblast.

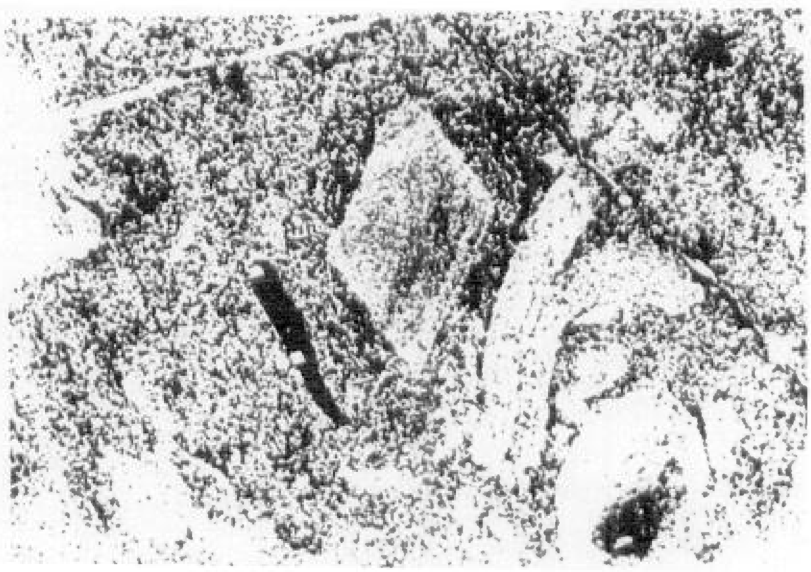


Photo 7 - Xenoliths of leucocratic anorthosite in mafic variety of anorthosite.

presence of numerous minute inclusions of iron-titanium oxides, as can be seen under the microscope in plagioclase phenocrysts. During crushing and recrystallization these oxides are separated from the plagioclase and become concentrated in small irregular clots and patches in the rock. The recrystallized plagioclase thus is a clean mineral with no inclusions in it.

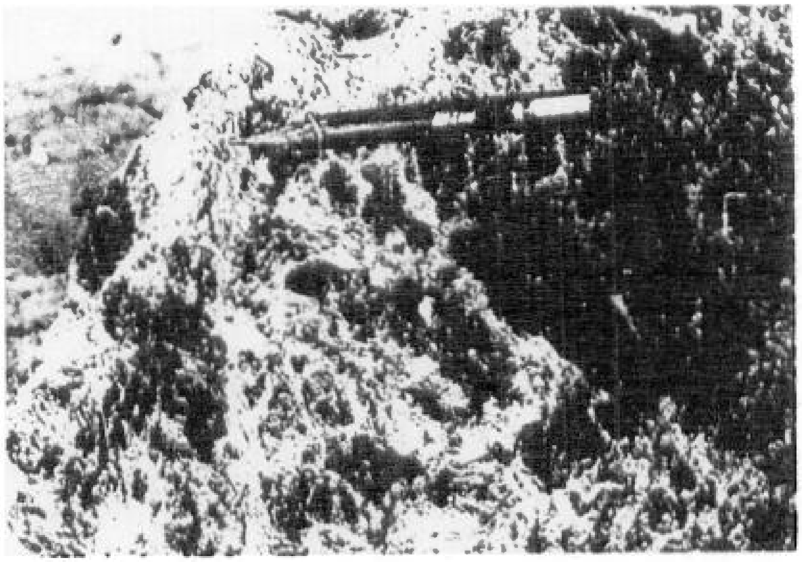


Photo 8 - Partly crushed coarse-grained anorthosite, showing the light coloured crushed crystal boundaries and dark coloured uncrushed cores.

The strongly sheared varieties of anorthosite are gneissic in character. The foliation becomes more conspicuous in the more mafic varieties of the anorthosite. The strongly sheared and crushed varieties are usually found near the margins of the massif, although local shear zones have been observed well within the main mass. These features are illustrated in photos 9, 10 and 11. Some highly sheared mafic varieties of anorthosite appear to be folded as well, as shown in photo 12.

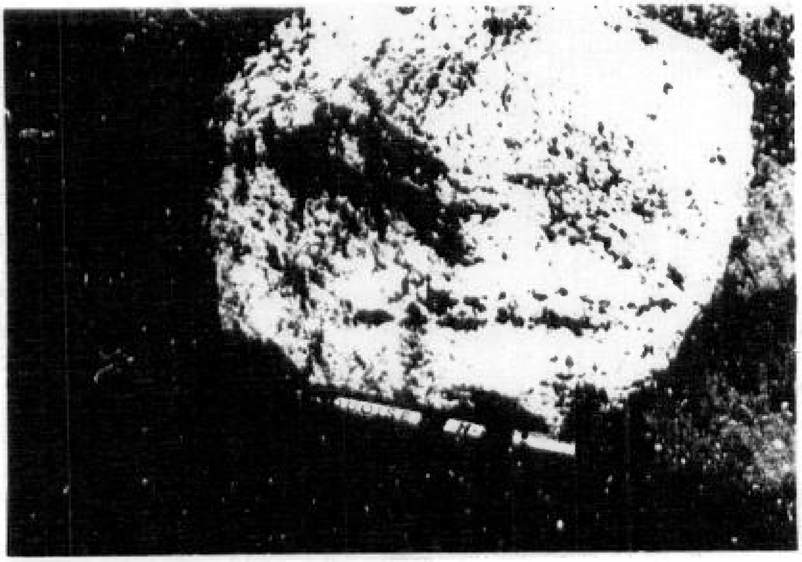


Photo 9 - Medium grained, foliated, strongly sheared anorthosite. Biotite is the main mafic mineral.

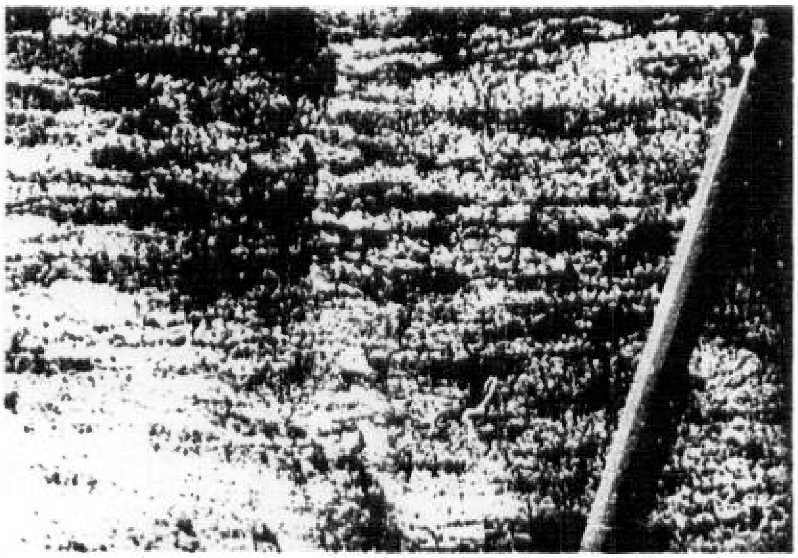


Photo 10 - Strongly sheared gabbroic anorthosite. The pyroxenes have been streaked out parallel to foliation.

Photo 11 - Gneissic anorthosite showing the development of a good foliation and some segregation of mafics (mostly biotite) into discontinuous bands and lenses.

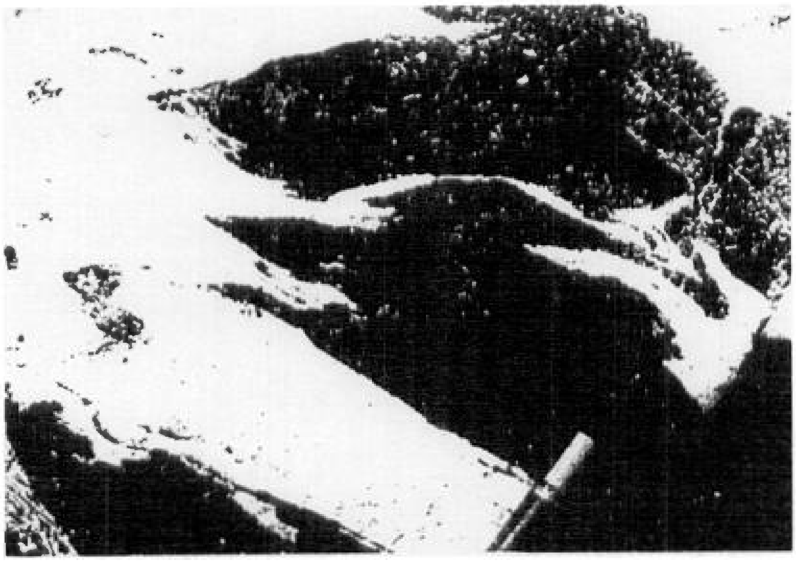


Photo 12 - Strongly sheared gabbroic anorthosite, exhibiting folding.

At places, in shear zones in the anorthosite, the plagioclase has been altered to clay minerals probably kaolinite. These alterations are generally ¼ inch to 6 inches thick. Kaolinite has also formed on a large scale in the Château-Richer anorthosite as a result of surficial weathering of the anorthosite. Here many remnants of unaltered anorthosite, in the form of blocks of varying sizes, are still recognizable in many places. Also, the veins and bands rich in magnetite-ilmenite have been preserved.

The anorthositic gabbro has also been observed intruding the green charnockitic gneisses in the form of sills, as observed near Chute-des-Passes anorthositic gabbro mass (Photo 13). The anorthosite here is highly crushed.

In the gabbroic or noritic mass, west of Rivières des Aigles, there is a gradational zone consisting of an amphibole-plagioclase rock (metagabbro) within which there are segregations of pink syenitic material (Photo 14). It is believed that the residual liquid from the magma that gave rise to the noritic rocks was the pink syenite and green monzonite (mangerite) which are here seen closely associated. In the areas of 1966 and 1967 Grenville projects, in some places gradations have been observed from gabbroic anorthosite to mangerite to syenite and granite, thus indicating these rocks to be comagmatic.

Inclusions of anorthositic rocks have been observed in syenite-monzonite-granite rocks in St-Ambroise-Chicoutimi area lying in the map-area of 1967 Grenville project. Photos 15, 16, and 17 show the xenoliths of anorthosite seen in monzonite near Rivière à la Hache. Inclusions of anorthosite-gabbroic anorthosite in mangerite have been reported by Berrangé (1960) from a region north of Lac St-Jean. Near the Labrieville anorthosite mass, Anderson (1962, 1963) has also reported the presence of inclusions of anorthosite, from few inches to few miles in size, found in monzonite, syenite and granite. The inclusions have sharp contacts with the enclosing rock. The contact between the anorthosite and the green monzonite is exposed near the Shipshaw power station.

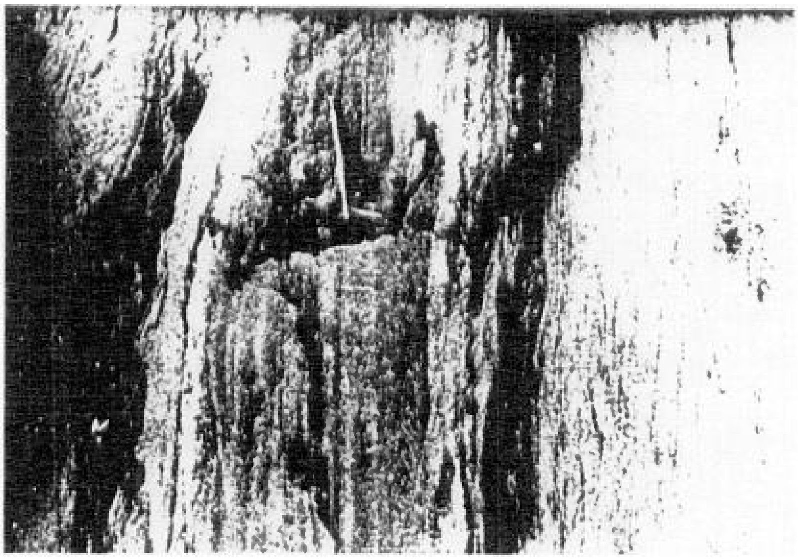


Photo 13 - Strongly sheared anorthosite (light, on the right hand side) intruding the green charnockitic gneisses in the form of sills.

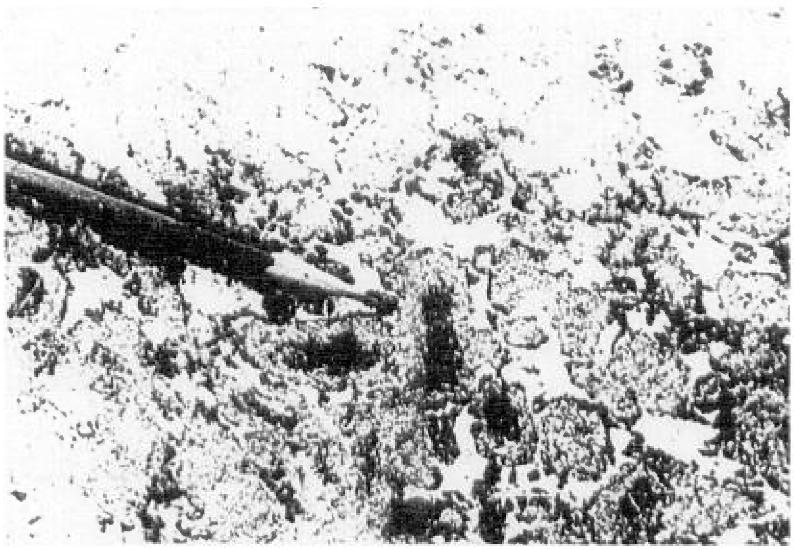


Photo 14 - Amphibole-plagioclase rock i.e. metagabbro (dark) with interstitial syenite material.

Photo 15 -

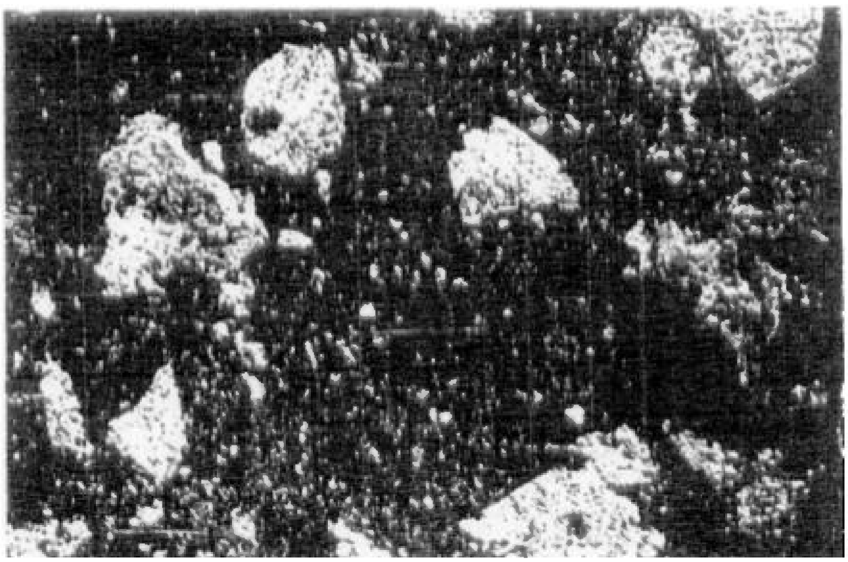
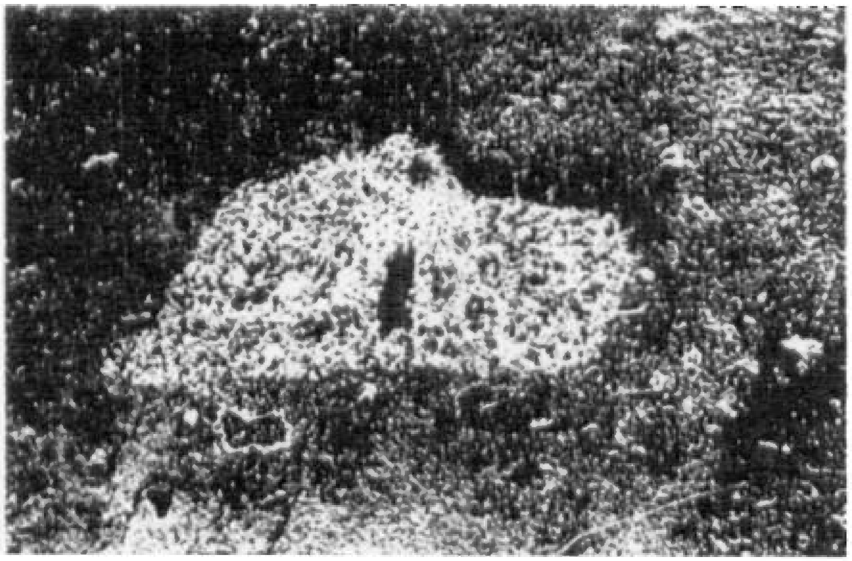


Photo 16 - Anorthosite xenoliths seen in monzonite near Rivière à la Hache.



<u>Photo 17</u> - Close-up view of an inclusion of anorthosite in monzonite, Rivière à la Hache.

Here the monzonite has been observed to intrude the coarse-grained anorthosite.

Apart from the huge Lac St-Jean anorthosite massif there are several smaller bodies of anorthosite mapped in the region. These bodies also possess nearly all the features as those observed in the Lac St-Jean massif.

Anorthosite in the Superior Province

Anorthosite and its related gabbroic varieties have also been reported in the Superior province rocks outcropping west of the Grenville front, in the northwestern part of the region. A U-shaped anorthosite body, about 2 miles in width was mapped, east of Lake Chibougamau, by Longley (1958). It has a core of granite. This body extends further west outside the limits of the mapped region.

Compositionally the rock is an anorthosite, but with enrichment in its mafic content passes into a gabbroic anorthosite or an anorthositic gabbro in places. The mafic varieties are usually seen near the margins. In general the rock is medium-to coarse-grained, containing plagioclase crystals up to½ inch in length, light grey to white in colour, with plagioclase (labradorite) content usually more than 75%. Plagioclase has been saussuritized to varying degrees. Amphibole shows alteration to chlorite. Near the northeastern part of the anorthosite contains large inclusions of volcanic rocks.

Longley also reports the presence of small bodies of anorthosite associated with the hornblende-gneisses found east of Lake Chibougamau, in the Grenville province.

Gabbros

Small lenticular masses of gabbro-metagabbro have been mapped in different parts of the region. Apart from the true gabbro, this group also includes some amphibolites. The rocks belonging to this group are generally medium- to coarse-grained, equigranular, massive to foliated, dark grey to black in colour, and often possess a good ophitic texture. Plagioclase and pyroxene are the principal constituents, but with increasing degree of deformation and metamorphism the pyroxenes are replaced by amphibole and biotite, often with good corona structures. Occasionally there is development of garnet. Magnetite, apatite occur as accessory minerals. Olivine has been observed in a few thin sections. In some cases the core of the gabbro lens consists of massive, ophitic gabbro, whereas the marginal parts possess a good foliation.

The gabbroic rocks have been seen to cut the anorthosites, acidic intrusive rocks, as well as emplaced as sills in the gneisses. These gabbroic rocks vary from a few feet to several hundreds of feet in thickness.

A rather different kind of medium-grained, equigranular gabbro body is mapped in the southwestern part of the region. Compositionally the rock varies from anorthositic gabbro to gabbro depending upon the amount of pyroxenes present. The plagioclase has the characteristic purple colour as seen in the anorthosite. Sometimes the rock shows a good foliation, but in general it is massive. It is traversed by many pyroxene rich veins in various directions. At places it also contains veins, up to 4 inches wide, of coarse grained gabbro containing plagioclase and pyroxene crystals that are bigger than that in the surrounding medium grained rock. Ophitic texture is frequently observable. This gabbro body becomes dioritic near its margins.

Petrography of Anorthosite and Gabbro

The results of petrographic study carried out on different varieties of anorthosite that differ in their physical appearance, texture, and composition are presented below.

The dark grey to black and purple variety of anorthosite is in general inequigranular, coarse to very coarse grained, massive, porphyritic, with a hypidiomorphic texture, containing big well formed crystals of plagioclase and a very small percentage of mafic minerals. They show little effects of deformation, whereas the marginal parts are characterized by a good mortar texture exhibited by the presence of crushed and partly recrystallized plagioclase around the margins and in between the phenocrysts of plagioclase (An_{50}-An_{60}). The phenocrysts are usually well twinned and show bent and broken twin lamellae. The smaller plagioclase grains consist of merely crushed, as well as crushed and recrystallized plagioclase grains. The smaller plagioclase grains that have resulted only by crushing are xenomorphic, and they still preserve the same twinning as in the phenocrysts, whereas the recrystallized plagioclases are generally untwinned and possess a well developed polygonal texture. Hornblende and biotite are the main mafic minerals, derived from alteration of pyroxenes. Relics of pyroxenes, as well as fresh pyroxenes (orthopyroxene and clinopyroxene) are also present. Opaque iron ore is the main accessory mineral. In some cases chlorite is also present and is a product of alteration of biotite.

In places the anorthosite is heterogeneous, segregated, coarse grained, porphyritic, very well foliated rock, varying in composition from anorthosite to gabbroic anorthosite to anorthositic gabbro in different bands parallel to foliation. The variations in the content of ferromagnesian minerals of these bands is believed to be a primary igneous feature, although somewhat modified by later deformation, metamorphism, and recrystallization. The rock vividly illustrates the various effects of cataclasis and accompanied recrystallisation in an anorthosite of varying composition. The anorthosite is white to light grey to blue grey in colour and defines foliation by the alignment of augen plagioclase and by the pyroxene crystals that have been streaked out parallel to foliation.

Petrographically, these augen-anorthosites show a very good example of the development of mortar texture. The cataclasis has resulted in crushing the rock, thereby reducing its grain size. The originally big plagioclase phenocrysts (An_{48}-An_{58}) are reduced to augen shapes, surrounded by crushed margins and set in a matrix composed of medium to fine grained plagioclase. The matrix consists of two types of plagioclases - the first type is the one obtained by simple crushing and breaking up of the phenocrysts of plagioclase. Thus, these plagioclases have bent and broken twin lamellae and are xenomorphic. The second type of plagioclase in the matrix is characterized by the crushed and recrystallized plagioclase that have acquired a good polygonal texture due to recrystallization during deformation. These plagioclases are generally untwinned. Along some narrow zones the crushing effect is much more pronounced resulting in very finely crushed and recrystallized plagioclase grains. Main mafic minerals present include ortho-pyroxene and clino-pyroxene. Hornblende and biotite occur only in minor amounts due to alteration of pyroxenes. In some cases biotite shows slight alteration to chlorite (penninite). Opaque ore is the main accessory mineral.

The completely crushed and recrystallized anorthosite is white in colour, well foliated, medium grained, equigranular and granoblastic. It may either be homogeneous with the plagioclase (An_{45}-An_{50}) and mafics evenly distributed in the rock, or it may be heterogeneous due to segregations of mafic minerals into numerous irregular bands and lenses. They posses a perfect polygonal texture. There is development of garnet and hornblende at the expense of pyroxene and plagioclase. Petrographic study of the completely crushed anorthosite shows that in plagioclase rich zones hornblende and opaque ores occur only at the corners of polygonal plagioclase grains. The mafic bands consist of polygonal hornblende and only some plagioclase. The hornblende is mostly olive green to brownish green, highly pleochroic, and usually with a very small extinction angle. Some of the hornblende found near the contact between plagioclase rich band and mafic band are xenomorphic and have biotite forming around their borders. Some remnants of fresh as well as altered pyroxenes are also present. Garnet is quite clean and xenomorphic. Magnetite occurs either as scattered grains or concentrated in very thin bands. Chlorite, sericite and epidote have also been noted in some thin sections and they represent alteration products of the ferromagnesian minerals of the rock.

Petrographically, metagabbros are granoblastic in texture, composed of polygonal grains of plagioclase and hornblende. Ortho-pyroxene and clino-pyroxene are frequently present, mostly as stubby grains. At places hornblende can be seen as being derived from pyroxene. Slightly lepidoblastic biotite forms individual grains or is associated with hornblende. Zircon, apatite and opaque ores are the main accessory minerals.

Charnockitic Suite of Igneous Rocks - Jotunite, Mangerite, Hypersthene-Syenite and Charnockite:

Jotunite, mangerite, hypersthene-syenite and charnockite are plutonic igneous rocks of diorite, monzonite, syenite and granite composition respectively, and belonging to the charnockitic suite of plutonic igneous rocks by their characteristic olive green to grey green colour and by the presence of ortho-, and clino-pyroxenes. Out of these only the mangerite is most widely developed in this region. As mentioned earlier, it more or less completely envelopes the Lac St-Jean anorthosite mass, with its maximum development to the southeastern part of the anorthosite massif. Apart from this it also forms several smaller, isolated bodies in the region. In many places near its margins, as well as near its contacts with the anorthosite, jotunite has been observed. Jotunite rarely forms separately mappable bodies. The hypersthene-syenite and charnockite form masses of much smaller dimensions as compared to the anorthosite and the mangerite. Mangerite, hypersthene-syenite and charnockite are described separately as follows.

Mangerite

Mangerite is a coarse grained, porphyritic, inequigranular, massive to foliated rock. It is olive green to dark green to grey green in colour when fresh and weathers easily to brownish or rusty weathering. The thickness of weathered zone varies in different outcrops from fraction of an inch to several feet. The weathered surface has a typical white colour, spotted by dark-coloured mafics. In most cases there is concentration of iron at the contact between the fresh and the weathered zones. The main minerals present include green feldspars, quartz and mafics. Quartz content is quite variable, but it is always less than 15%. Mafics are less than 15%. The green feldspar phenocrysts vary in size from ½ inch to 5 inches in length. In some cases the phenocrysts are augen shaped and possess a preferred orientation, presumably inherited during deformation and metamorphism. In places, the phenocrysts of dark coloured, bluish grey, well twinned plagioclase are also seen which have the same appearance as the plagioclase of the anorthosite. This most probably provides an indication to the comagmatic nature of the anorthosite - mangerite rocks of the area.

Locally the mangerite contains gradations into pink to grey-pink monzonite, syenite and granite. The smaller bodies mapped as mangerites may as well include some monzonite, syenite and granite; as it is very difficult to map them separately at this scale of mapping. In places the mangerites contain a rather high percentage of magnetite and ilmenite.

Inclusions of anorthosite and gabbroic-anorthosite in mangerite have been reported by Berrangé (1960) from Antoine area. Similar inclusions have also been observed during the course of 1967 Grenville project. The mangerites are traversed by younger, coarse-grained, pink, granite-pegmatite veins.

Petrographically, the rock has a typical porphyritic texture commonly observed in the mangerites, shown by phenocrysts of potash feldspar and in some cases by phenocrysts of both plagioclase and potash feldspar. The rock is monzonitic in composition. The phenocrysts are set in a matrix composed of plagioclase, potash feldspar, quartz and mafics. The plagioclase phenocrysts are generally well twinned, whereas the potash feldspar phenocrysts are untwinned mesoperthitic orthoclase, with the exsolved material occurring in the form of rod-perthite and string-perthite. The quartzo-feldspathic minerals are highly xenomorphic in form. The cataclastic effect is exhibited by the presence of mortar texture around phenocrysts, as well as around some of the feldspar grains in the matrix. The crushed material has recrystallized to some degree as evidenced by the presence of polygonal texture. In the crushed varieties of mangerite, some of the phenocrysts are augen shaped. Myrmekite is also present near the contact between some plagioclase and potash feldspar grains.

The ferro-magnesian minerals form aggregates and consist mostly of clino-pyroxene, ortho-pyroxene, and hornblende. The pyroxene is rather unstable and is being transformed into hornblende, accompanied by symplectitic texture. Some pyroxene grains have a partial to complete rim of hornblende. The hornblende is olive-green to brownish-green, and highly pleochroic. Zircon, apatite, allanite, and opaque ores are the principal accessory minerals present.

The highly crushed mangerite is a medium grained, equigranular well foliated rock and in the absence of recognizable phenocrysts it becomes rather difficult to distinguish it from the charnockitic gneisses.

Hypersthene Syenite

Hypersthene syenite either forms small individual bodies or occurs as local facies within the mangeritic and monzonitic rocks of the region. A typical hypersthene-syenite is similar to that outcropping in a road cut, half a mile north of traffic circle on Route 54, just south of Chicoutimi. The rock is coarse grained, equigranular, massive to foliated rock, ranging in colour from green in fresh parts to brownish in the weathered zones. Foliation is marked by the alignment of green feldspar augens and by the aggregates of mafic minerals forming streaks. It is identical in texture to the pink syenites of the region, the only difference being that the hypersthene syenite contains many remnants and some fresh ortho-pyroxene and clinopyroxene associated with hornblende and biotite.

Petrography reveals that the rock is equigranular consisting of big grains of mesoperthitic orthoclase. In between these potash feldspar grains there occur finer grains of potash feldspar and plagioclase that have formed mainly as a result of cataclasis, thus giving rise to an ideal mortar texture in the rock. The big potash feldspar grains have highly serrated margins, whereas the feldspathic material occurring in their interstices shows good polygonal texture as a result of recrystallization accompanying deformation. At places, where the potash feldspar grains are unaffected by deformation, they possess sutured margins. Only a very small amount of myrmekitic quartz is present in some plagioclase grains at the contact with potash feldspar.

Hornblende is the dominant ferromagnesian mineral, accompanied by biotite, ortho-pyroxene and clino-pyroxene. Hornblende is olive green to brownish green, generally fresh, but at places can be seen developing from pyroxene. Remnants of pyroxenes occur as stubby grains. Biotite forms small flakes and has undoubtedly been derived from hornblende. Opaque ores are frequently associated with the mafic minerals. Apatite and zircon are the only accessory minerals.

Charnockite

Charnockite was not observed to form individual bodies in the region. Instead it occurs as local variations within the mangerites and granites, especially in the southern parts of the area.

A typical charnockite is a coarse grained, massive to foliated, porphyritic rock varying in colour from pinkish green to brownish green. Compositionally the rock is a granite, but depending on the rock colour, the nature of the feldspars, and the presence of ortho-pyroxene, the rock varies from granite to charnockite (hypersthene-granite).

Petrographically, the rock is composed of potash feldspar as the dominant mineral, together with quartz, plagioclase, and mafics. Potash feldspar is mostly mesoperthitic orthoclase containing the exsolved material in the form of string or hair-perthite. Plagioclase, present in a very minor amount, forms small grains in the interstices between the big potash feldspar grains. Coarse-grained quartz is quite abundant. The feldspathic material is xenomorphic and shows highly sutured margins. Plagioclase is partly saussuritized. The rock shows little evidence of cataclasis.

The main ferromagnesian mineral present in the rock is biotite. Some of the biotite grains are quite dirty and could have been derived from amphibole or pyroxene. Although fresh orthopyroxene is rarely seen in this rock, the presence of mesoperthitic orthoclase and the rock colour clearly indicate that the rock had crystallized at a very high temperature and belongs to the charnockitic suite of plutonic rocks. Zircon, opaque ores and apatite form the main accessory minerals.

Monzonite - Syenite - Granite

Intermediate to acidic plutonic igneous rocks, represented by monzonite - syenite - granite, form important bodies around the Lac St-Jean anorthosite massif. All these rocks, in general, are coarse grained, massive to foliated, porphyritic, dark grey to grey-pink to pink in colour, and show frequent gradations into one another depending upon the relative abundances of quartz, plagioclase, and potash feldspar. These rocks are described below in detail.

Monzonite

A typical monzonite is a coarse grained, inequigranular, porphyritic rock, dark grey to grey pink in colour. It may be massive or foliated. Photos 18 and 19 show the typical porphyritic massive and foliated monzonites respectively. The feldspar phenocrysts are commonly augen shaped. Petrography reveals that the phenocrysts present in the rock are of both potash feldspar and plagioclase, whereas the matrix is composed of rather smaller size grains of potash feldspar, plagioclase, quartz, and mafics. The quartzo-feldspathic minerals are quite xenomorphic with highly serrated margins. The potash feldspar phenocrysts are orthoclase and commonly possess a good carlsbad twinning. Some of the orthoclase grains are perthitic, the exsolved material occurring as rod, string or hair perthite, with some patch perthite being also present. Plagioclase, mainly twinned, is both antiperthitic as well as with no exsolved material. It shows some saussuritization. Feldspar phenocrysts and the feldspathic material of the matrix, both exhibit effects of cataclasis to varying degrees by the presence of mortar texture around grain margins, and by bent and broken plagioclase twin lamellae. Myrmekite is also present at the contact between potash feldspar and plagioclase grains.

In some varieties hornblende is the dominant ferromagnesian mineral, whereas in rather more deformed varieties lepidoblastic biotite is the dominant mafic mineral. Hornblende is green and

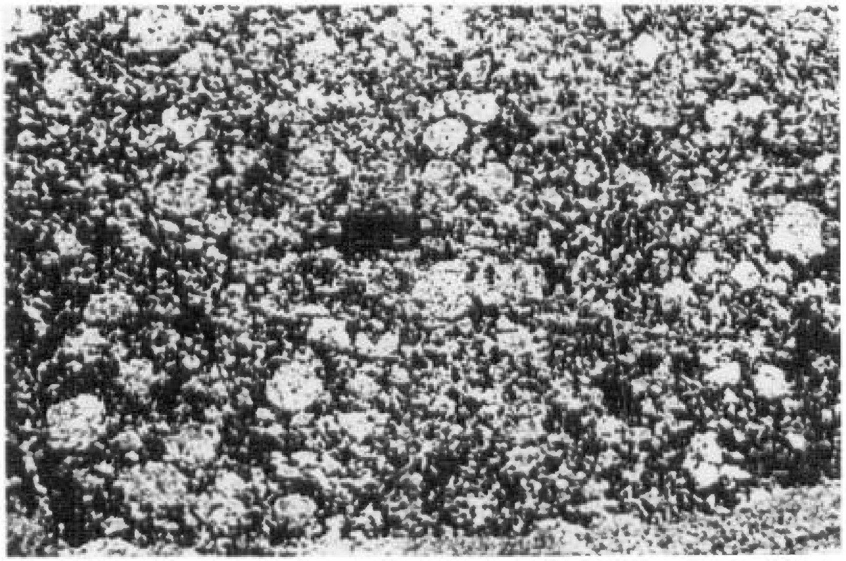


Photo 18 - Typical porphyritic texture of massive monzonites.

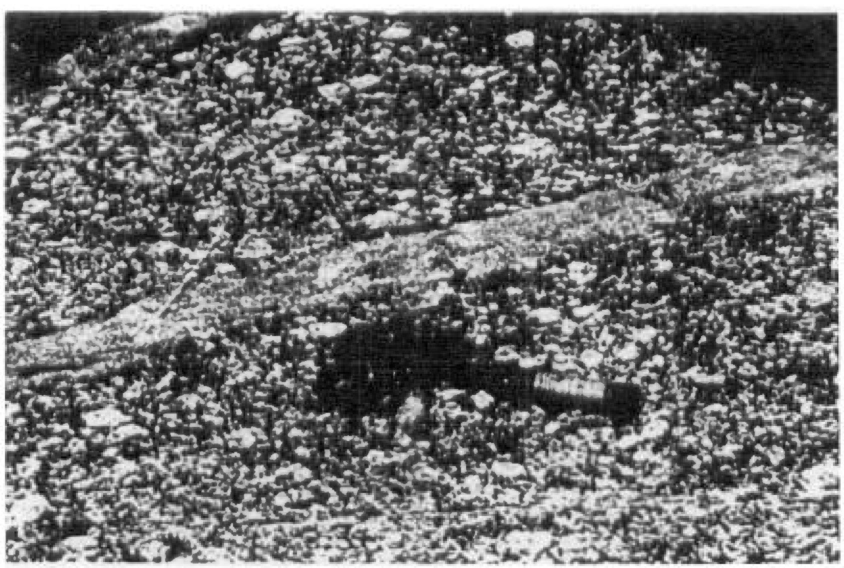


Photo 19 - Typical foliated monzonite showing the development of augen and streaky textures.

highly pleochroic. Some hornblende grains show alteration to biotite. Apatite, zircon, sphene and opaque ores are the only accessory minerals. Sphene either occurs surrounding opaque ores or forming independent grains not associated with opaque ores.

The smaller bodies of monzonite grade into syenite and granite near its periphery.

Syenite

Two principal types of syenites as represented by the porphyritic Shipshaw syenite and the equigranular Laterriere syenite have been recognized in the region.

A quarry near Chicoutimi Nord provides fresh exposures of Shipshaw syenite. It is a very coarse-grained, massive, porphyritic rock, with a hypidiomorphic texture, and varying in colour from pink to pink-green. The syenite has been intruded by numerous dykes of carbonatite, emplaced in a parallel set of joints, parallel to the ground surface. K/Ar age determinations carried out on two samples of syenites of this region, by Doig and Barton (1968) yielded ages of 896 and 937 million years, thus placing them as syntectonic intrusions emplaced during the Grenville orogeny. A third sample of syenite, from near a carbonatite dyke, gave an age of 661 million years. Doig and Barton explain this to be due to the thermal effect accompanying the intrusion of carbonatite dyke.

Petrographically, the syenite is mostly composed of orthoclase mesoperthite, the perthitic material being in the form of string or hair perthite. Only a few small grains of microcline, with good cross-hatched twinning, are present in the rock. Plagioclase also occurs in a very minor amount, usually in grains much smaller than potash feldspar and in the interstices formed by bigger potash feldspar grains. Some of the plagioclase grains are antiperthitic. There is only a slight amount of granulation around the grain margins of potash feldspars. Apart from the granulated grain boundaries, the orthoclase grains are xenomorphic and have sutured boundaries with other potash feldspars. Some potash feldspars have good augen shapes. Myrmekite is rather rare. Plagioclase occurring as individual grains or in the perthites show varying degrees of saussuritization.

The ferromagnesian minerals present in this syenite are clino-pyroxene, ortho-pyroxene, hornblende, and biotite; the latter being derived as alteration products of pyroxenes. The pyroxenes occur as stubby grains. Zircon and opaque ores are the main accessory minerals.

The second type of syenite, Laterriere Syenite, is less coarser grained than the Shipshaw syenite described above. It is a coarse grained, equigranular, well foliated, pink rock. The foliation is defined by alignment of potash feldspar augens, as well as by mafic mineral aggregates forming streaks.

Petrographic study of Laterriere Syenite reveals that it is predominantly composed of big potash feldspar grains. In between these potash feldspar grains there occurs crushed and recrystallized material, resulting from cataclasis during deformation and metamorphism, which is also responsible for imparting a metamorphic fabric to the rock. Almost all of the big potash feldspar grains are mesoperthitic orthoclase, containing the exsolved material in string perthite or hair perthite form. Microcline is present in very minor amounts. The feldspathic material found in the interstices of large potash feldspar grains is composed of orthoclase, microcline, and plagioclase. The margins of larger potash feldspar grains are highly serrated due to strongly developed mortar texture. The crushed material has partly been recrystallized, as evidenced by polygonal texture. Plagioclase that occurs as individual grains or as exsolved material in the perthites has been saussuritized to varying degrees.

Hornblende and biotite are the main mafic minerals in the rock. Hornblende is brownish green to olive green and highly pleochroic. Some of the hornblende is rather dirty and could have been derived from pyroxene. Biotite occurs as individual grains or associated with hornblende. Zircon, opaque ores and apatite are the main accessory minerals.

Granite

Granite is a coarse grained, massive to foliated, hypidiomorphic, generally porphyritic rock, varying in colour from grey-pink to pink. It is composed of quartz, microcline microperthite, albite and mafics. The mafic mineral is mostly biotite, but hornblende may also be present. The quartz content varies from 10 to 30%, whereas the mafics are generally less than 15%. Zircon, sphene, opaque ores and apatite are the common accessory minerals. The deformed and foliated varieties of granite exhibit textures like augen, flaser, streaky, ribbon quartz etc.

The porphyritic pink granite found in the region of Roberval has long been utilized as building stone and tomb-stone because of its property to take good polish and its resistance to weathering conditions. Many of the old churches and houses in this area have been constructed using this granite.

Some granite bodies also occur in the southwestern part of the region. The Rivière à Pierre granite and the other bodies occurring north and west of it are coarse-grained, porphyritic, grey-pink, hornblende granite. There are some quarries in operation in the Rivière à Pierre granite. The biggest quarry belongs to Dumas et Voyer Company. Here, at the top of the mountain, several roof-pendants of well layered paragneiss lenses were seen, sitting right on top of the granite. The paragneiss lenses also contain small lens shaped boudins of quartzite.

The granite forming the core of the anorthosite body, found northwest of the Grenville front, is medium to fine grained, gneissic, containing up to 70% potash feldspar, 10 to 40% plagioclase, and up to 25% quartz. Biotite and hornblende are the main mafic minerals. The products of alteration of minerals are represented by chlorite, epidote, kaolinite, sericite. Apatite, zircon and titanite occur as accessories.

VII - Dykes - Youngest Intrusive Rocks

Diabase

Medium to very fine grained, dark grey to black, unmetamorphosed, aphanitic diabase dykes have been noted in nearly all parts of the region, cutting all the rock types. They vary in thickness from few feet to several hundred feet. They are also present in the anorthosite found northwest of the Grenville front.

Pegmatite

Numerous irregular bodies and dykes of pegmatite cut all the rocks in the region. Most of the pegmatite dykes are characteristically discordant and unmetamorphosed. They vary greatly in size, composition, and texture. Some dykes are distinctly zoned, with the cores usually composed of milky quartz and followed outward by a granitic or aplitic zone, which in turn is followed along the margins by a coarse-grained pegmatitic zone. The pegmatite proper is commonly formed of megascopic graphic intergrowths of quartz and potash feldspar, books of muscovite and biotite, perthitic microcline, sodic plagioclase, and hornblende. Magnetite, pyrite and other sulphides have been noted in various places associated with the pegmatites.

Carbonatite

Carbonatite dykes, varying in thickness from a fraction of an inch to up to 18 inches thick, are common in Kénogami-Chicoutimi area and were observed as far north of the Saguenay river as St-Honoré. There are essentially two varieties of carbonatite dykes: a fairly pure orange to rusty weathering variety and a green variety which often contains biotite, iron oxides and various fragments of surrounding rocks. These dykes were not observed to cut the Paleozoic rocks, but were seen cutting nearly all the other rocks of the region. In places some pyrite is also associated with these rocks. Chemical analyses carried out for these dykes indicate the presence of rare-earth elements. K/Ar age determinations carried out for the carbonatite dykes of this region by Doig and Barton (1968) indicate an average of 564 million years.

A big dyke of calcite-bearing rock, containing large blocks of anorthosite as inclusions, was observed cutting the anorthosite near Caron Dam on Saguenay river.

VIII) Paleozoic Rocks

Paleozoic rocks are exposed in the southern part of the region, along the St. Lawrence River Lowlands. They consist mostly of Trenton limestone and Utica shales of Ordovician age. In addition, other Paleozoic formations such as Black River, Lorraine, Richmond, Queenston etc. have also been reported.

In the central parts of the region, the Paleozoic rocks are found in the lowlands adjoining the Lac St-Jean. The majority of the rocks belong to Trenton limestone and Utica shale groups. The Paleozoic rocks also occur in the region of St-Honoré, north of Chicoutimi. Here the sequence begins with impure and sandy limestones and thin sandstones followed by highly fossiliferous limestone, and capped by fossiliferous Utica shale. The contact between Paleozoic and Precambrian is exposed in a quarry south of St-Honoré. Utica shale is best exposed at Chute-aux-Galets.

The main fossils found in shales are graptolites and trilobites, whereas in limestones brachiopods, cephalopods and trilobites were observed.

STRUCTURE

Although the scarcity of data collected during the reconnaissance mapping program, for the Grenville Projects that cover this region, prevents any detailed structural analysis to be carried out for the various parts of the map-area, some broad generalizations can, however, be made regarding the structural characteristic of the region.

One of the most important structural feature of the region is the presence of Grenville Front which marks the boundary between the Grenville and Superior tectonic provinces of the Precambrian Canadian Shield. As mentioned earlier, this boundary manifests itself by various features such as faults, shear zones, lithological changes, changes in the grade of metamorphism, changes in K/Ar dates etc.

On lithological grounds the whole area can broadly be divided into two parts. The northern part is underlain by various gneisses in the Grenville province and in the Superior province by the Keewatin-type volcanic-sedimentary rocks and the rocks of

Chibougamau and Mistassini groups; whereas the southern part is occupied by the largest known anorthosite massif of Lac St-Jean and associated plutonic igneous intrusives. Near the Grenville front the gneisses possess a strong northeast structural grain. Away from the Grenville front the two main structural trends observed in the gneisses are east-west and north-south, with occasional north-east structures being also present. On the other hand, the structural pattern of the southern part of the area has been greatly influenced by the presence of Lac St-Jean anorthosite massif and other plutonic rocks. As described earlier, all these plutonic rocks exhibit numerous features of cataclastic deformation, with the accompanying recrystallization, in going through the Grenville Orogeny. In the vicinity of intrusive masses, the foliation in the surrounding gneisses conforms to the outlines of the intrusive masses.

ECONOMIC GEOLOGY

All known mineral occurrences of some significance situated in the areas mapped during the 1965, 1966, and 1967 Grenville projects are briefly described as follows.

1) Occurrence of a magnetite rich rock, on the northwestern shore of Perron Lake (Lac de l'Ecluse), associated with the monzonite-syenite body is reported by Berrangé (1959). A grab sample from this locality gave the following result:

Fe	-	25.16%
SiO_2	-	27.72%
Al_2O_3	-	10.03%
TiO_2	-	8.49%

P	-	1.83%
S	-	1.00%
Mn	-	0.13%
Zn	-	0.03%

2) A brucite prospect is situated east of Larouche creek on lots 12 and 13, Range III, in La Trappe township. It consists of large number of boulders of white brucitic marble in an area 300 feet by 800 feet. The underlying rock is anorthosite and gabbroic anorthosite. The boulders are probably in place and derived from a roof-pendant in the anorthosite. The crystalline limestone contains 22 to 38% brucite with an average of 19% MgO.

3) A sulphide prospect, reported by Berrangé (1959), is located at the intersection of the lines between lots 11 and 12, and ranges II and III in La Trappe township. Anorthosite and gabbroic anorthosite are traversed by granite-pegmatite veins. Sparingly disseminated pyrite and pyrrhotite with minor chalcopyrite occur in the gabbroic anorthosite. Selected grab samples from these showings assayed as follows:

	Cu	Ni	Co	
Lot 11	0.20	0.31	0.02	%
Lot 12	0.40	0.08	0.05	%

4) Berrangé also mapped the mica prospect of "Delisle Mine", north of Noir lake, in Hudon township. Here the diopsidic metamorphic pyroxenite and quartzite are traversed by numerous veins of granitic-pegmatitic material. Large books of phlogopite occur in the pegmatite

and pyroxenite. Biotite and muscovite occur in the pegmatite. Some pyrite and pyrrhotite is also present. The mine produced about 2 tons of mica in 1943.

5) Pyrite and pyrrhotite with minor amounts of chalcopyrite occur in two localities east of Lac Rond in Antoine township (Berrangé 1960). In the western showing massive sulphides and iron-oxides form the cementing material around the fragments of sheared anorthosite included in the monzonite-syenite country rock. Following is the anlysis of a grab sample:

Cu - 0.02%

Co - 0.01%

Ag - traces

6) Ilmenite and columbium-bearing rutile occurs in lots 38-43 and 57, range III; and lots 46-51, range II in Beaudet township (Benoit 1961). The mineralization is confined to narrow, discontinuous pegmatite dykes. Metallic sulphides are also present in these dykes in the form of patches.

7) A few claims had been staked in a mineralized zone containing pyrite, malachite and bornite, southwest of Aigremont lake in Mignault township. The mineralization occurs in a quartz vein in a ¼ mile long shear zone, traversing the hornblende gneisses, with a northeasterly direction. The shear zone is parallel to the gneissosity of the rocks. The vein is about 3 feet thick near the highway and about 20 feet thick a quarter of a mile northeastward. The grab samples collected from this locality assayed as follows (Laurin, 1955):

Au - $0.03 of Au/ton

Ag - $0.12 of Ag/ton

Cu - 0.56%

Zn - 0.01%

Ni - 0.02%

8) The occurrence of disseminated magnetite in hornblende schist and in the anorthositic gabbro in Rinfret township, east of Lake Chibougamau, is reported by Longley (1958). Analysis of a grab sample showed 53.12% Fe and 7.57% titanium.

9) Chalcopyrite occurs in bands and veins of varying thickness associated with the sedimentary and volcanic rocks found northwest of the anorthosite body, west of the Grenville front.

10) Many of the shear zones found in the Keewatin-type volcanic-sedimentary rocks near the France lake granite are sulphide-bearing, containing mostly pyrite-pyrrhotite and occasionally sphalerite and galena (Gilbert, 1958).

11) Disseminated pyrite with some chalcopyrite commonly occurs in the arkose and graywacke of the Chibougamau group, especially west of Waconichi lake.

12) Near the south shore of Waconichi lake, the fault contact between the greenstones and the Chibougamau group rocks contains large quartz-carbonate veins with pyrite and chalcopyrite that carry some gold and silver.

13) Important mineralizations of disseminated chalcopyrite and other sulphides found in the anorthositic rocks north of Nepton river (east of Lake Chibougamau) have been reported by Pouliot (1963) who carried out detailed work on 1 inch = 1,000 feet scale in southwest quarter of McCorkill township. The representative samples from two important locations gave the following results:

Cu - 0.41%	Cu - 0.40 and 0.23%
Ag - 0.092 ounce/ton	No gold or silver
No gold	

In addition, several other occurrences of disseminated pyrite were reported from the Keewatin-type rocks of the area.

14) The occurrences of pyrite, chalcopyrite, galena, sphalerite have been reported by Deland (1957), Sater (1957), Moyer (1960). These occur either as disseminations in the rocks of Mistassini group or associated with shear zones.

15) The iron formations belonging to the uppermost part of the Mistassini group rocks contain magnetite-rich bands. The magnetite occurs either as disseminations or in lenticular bands constituting up to 50% of the rock.

16) The occurrence of magnetite rich monzonite (containing usually < 25% magnetite) is reported from Riverin lake area by Anderson (1963). These rocks may contain magnetite up to 25% and up to 15% apatite.

17) Magnetite-ilmenite rich bands are found in the Lac St-Jean anorthosite body and in the Labrieville anorthosite body, especially in the gabbroic anorthosite and anorthositic gabbro varieties. In addition some pyrite and apatite is also present.

18) Paleozoic limestones and shales occurring in the lowlands of St. Lawrence river and of Lac St-Jean provide a good source of lime and building stones.

19) The Saint-Charles titaniferous-magnetite deposits are situated in Bourget township, north of Saguenay river and about 15 miles downstream from Lac St-Jean. The deposit was first mentioned in 1884 by Laflamme and in 1893 Adams recognized the presence of olivine in them. Further work on this was carried out by Dulieux (1912), Robinson (1926), Waddington (1944), and Jooste (1958). The titaniferous-magnetite occurs in the form of irregular bodies of variable dimensions in the anorthositic rocks. Olivine, pyroxene and apatite are the accessory minerals present. Minor amounts of hornblende, biotite and plagioclase are also found in the ore. The possibility of utilizing the deposit by electric smetting was discussed by Stansfield (1916), and some good quality steel had been produced in pilot-plant tests. The deposits are owned by J.F. Gauthier family of Jonquière, Canadian Javelin Limited and others.

A selected sample analyzed for E.R. Rose by the Mines Branch (Canada) gave the following results:

Fe	-	38.7%
TiO_2	-	14.94% (8.96% Ti)
S	-	0.04%
P	-	3.08%
Cr	-	0.007%
V	-	0.03%

After grinding to-100 mesh and magnetic separation, the magnetic concentrate (titanomagnetite carrying exsolved ilmenite) showed:

Fe	-	60.8%
Ti	-	10.0%
Mn	-	0.22%
Cr	-	$<$ 0.05%
V	-	0.05%

The Fe: Ti ratio of the raw ore material is 4:3 and that of the magnetic concentrate 6:1.

The titaniferous-magnetite contains inclusions of anorthosite and gabbroic anorthosite. The deposit has been divided, on the basis of field observations, into phosphatic and phosphorous-poor titaniferous magnetite deposits, which occur in the northern and southern parts respectively. The phosphatic deposits contain visible apatite.

20) There are many quarries for building-stone and tombstone in the Chicoutimi-Roberval region and near Rivière à Pierre. The rock types exploited for this purpose include - Black anorthosite,

Roberval granite, Rivière à Pierre granite, Diabse, Trenton limestone, Shipshaw syenite etc.

21) At St-Eugène a large quarry exploits white crystalline limestone which is used for chemicals and building materials etc.

22) Numerous carbonatite dykes have been observed in the Chicoutimi area. The chemical analyses indicate the presence of rare-earth elements in it. A carbonatite plug has been located, by drilling, in the region of St-Honoré. The deposit is being explored in detail by Copperfields Mining Corporation and Quebec Mining Exploration Company (Soquem). Their work indicates that the carbonatite plug contains one of the world's largest columbium deposit.

23) The monzonitic rocks found northeast of Réservoir LaMothe are extremely rich in ilmenite and magnite. The mineralization occurs either as disseminations in the monzonite or as discontinuous bands and lenses.

24) A pyrrhotite mineralization is reported from the extreme south-western part of Rouleau township, Range A, Jonquière-Kénogami county. This 20 feet thick mineralization occurs in coarse-grained noritic anorthosite and is traceable up to 300 feet. The sulphides occur as small disseminated patches to small massive bodies, and sometimes enclose the pyroxene and plagioclase crystals of the anorthosite. Results of assays indicate from 0.1 to 0.2% Ni and 0.1 to 0.3% Cu.

25) The occurrence of sphalerite and galena was discovered near Montauban-les-Mines in 1910. Mining was intermittently carried out here until 1955. At present the Ghislau Mining Corporation Limited owns the mineral rights for the southern parts of the ore zone, whereas the Satellite Metal Mines Limited owns the mineral rights for the northern parts of the ore zone. Detailed descriptions of this deposit have been given by Bancroft (1915), O'Neill and Osborne (1939), Wilson (1939), and Smith (1956). The mineralization occurs in calc-silicate rocks in the south and in biotite-paragneisses in the northern parts. In addition to lead and zinc, valuable amounts of gold and silver have also been recovered.

In addition to the deposits of Montauban-les-Mines, there are several other showings of sphalerite, galena, pyrite, pyrrhotite, gold, molybdenum, chalcopyrite, magnetite which have been described in detail by Pyke (1966).

26) Sand and gravel deposits are abundant throughout the region and many are being exploited for road and rail-road construction. Some clay deposits are also present.

27) St-Urbain Hemo-Ilmenite Deposits: J. Rondot has carried out detailed geological study in the region of St-Urbain. The ilmenite deposits associated with the St-Urbain anorthosite body are divided into two groups - the one near the town of St-Urbain and the other east of Lake Ontario. The deposits near St-Urbain

are more important and are associated with a positive magnetic anomaly. The first deposit discovered here was more interesting and was actively exploited. It consists of several lenticular masses of quite pure ilmenite. The other exploited deposits also occur in elongated lenses, but they are rather small. Average composition of the ore from these deposits is as follows:

TiO_2	-	41.13
Fe	-	38.30
S	-	0.28
P_2O_5	-	0.036
SiO_2	-	1.84

According to Rondot these deposits have been affected by a meteoritic impact which resulted in intense fracturing, crushing, mylonitization, and hydrothermal alteration as indicated by the presence of zeolite, prehnite, etc.

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Geochemistry

Another aspect of the Grenville Project involved collecting stream sediments for the purposes of making geochemical studies during the field seasons of 1965, 1966, and 1967. These samples were then analyzed in the laboratories of the Quebec Department of Natural Resources. In 1965 a total of 843 geochemical samples were collected and analyzed for Cu, Zn, Pb and Mo; whereas in 1966 and 1967 the number of geochemical samples collected were 203 and 797 respectively. These were analyzed for Cu, Zn, Pb, Mo, Ni and U. The results obtained are presented as follows. The localizations of each geochemical samples are given on the geological map.