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LOWER MANICOUAGAN RIVER AREA (SAGUENAY COUNTY) - FINAL REPORT

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DES MINES

LOWER MANICOUAGAN RIVER AREA

SAGUENAY COUNTY

P. Sauvé

Final report

MINISTERE DES RICHESSES NATURELLES  
EXPLORATION GEOLOGIQUE

LOWER MANICOUAGAN RIVER AREA  
SAGUENAY COUNTY

Final report

by

P. Sauvé

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MAP: 1" = 1 mi. - Lower Manicouagan River Area

LOWER MANICOUAGAN RIVER AREA

Saguenay Electoral District

by

PIERRE SAUVE

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I N T R O D U C T I O N

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Lower Manicouagan River area was mapped by the writer during the 1960 field-season and during a few weeks in 1961 and 1963. The area is on the north shore of the Gulf of St-Lawrence. Highly metamorphosed paragneisses, plutonic rocks and mixed gneisses of the Grenville sub-province outcrop in the central and northern parts whereas the southern part is largely underlain by Quaternary deposits of sand and clay.

Location

The town of Hauterive lies in the southern part of the area and is about 275 miles from Quebec city along provincial highway 15 and 6 miles west of Baie Comeau. The area is bounded on the south by the Gulf of St-Lawrence, on the north by latitude 49°30', and on the east and west by longitudes 69°15' and 69°30'. It includes most of the townships of Eudes and Manicouagan and parts of the townships of Laflèche, Morency, and Ragueneau in Saguenay electoral district. The area comprises approximately 325 square miles.

### Access

Hauterive is easily reached by car, plane, or boat. Baie Comeau airport lies in the area, just north of Hauterive. Boats of all size stop around the year at the deep sea-port of Baie Comeau.

The southern part of the area is accessible by highway 15 and a good network of gravel road. The central and northwestern parts are reached by the Hydro-Quebec road which joins Baie Comeau to the hydro-electric developments of "Manic 2" and "Manic 5". Access to the northeast part is by a gravel road which runs close to the eastern boundary of the area.

Navigation on the Manicouagan river is easy and only interrupted by the two dams. Some parts however are often obstructed by accumulations of pulpwood.

### Field Work

Preliminary topographic maps of the Canadian Department of Mines and Technical Surveys at the scale of 1:40,000 were enlarged to the scale of half a mile to one inch and used as base maps. Vertical aerial photographs, taken by the Royal Canadian Air Force, at the scale of one mile to one inch were used to find linears and rock trends but they proved of little value for location of outcrops in the field. More recent photographs taken by Photo-Air Laurentides at the scale of half a mile to one inch are now available. Pace and compass traverses were run at about half a mile intervals.

Outcrops are abundant but are generally small and thus not too favorable to a good understanding of the highly complex relationships between the rock-types. The largest outcrops are in almost inaccessible cliffs. The best exposed part is the deeply burnt area near Brisson lake, in the north-eastern part of the area.

The depth of weathering is less than one inch at most places but may attain several feet locally. Weathering seems deepest in the green gneiss in the northwest corner of the area where it is impossible to obtain fresh samples with a light hand hammer at many places. Fortunately, fresh rocks are exposed in abundant cuts along the Hydro-Quebec road.

#### Acknowledgements

The writer was ably assisted in the field by J. L. Cabri, graduate student at McGill University, and by Albert Ouellet, J. Gunn, and Michel Hone, all undergraduate students at Laval, McGill and Institut Polytechnique de Montreal respectively. Guy Guimond served as canoe man and Alidor Bouffard as cook.

The writer wished to thank the officers of the Quebec North Shore Paper Co. for providing useful maps of the area and for the use of a small camp.

Mr. Luc Boyer, geologist for H.G. Acres Co. and Mr. Denis Marcil, geologist for Quebec-Hydro-Electric Commission, graciously provided valuable information on the geology near the dam abuilding at "Manic 2". In particular, Mr. Boyer brought to the writer's attention evidence of a late glacial phase.

Dr. Pierre Lasalle was very helpful in the interpretation of various pleistocene features.

Dr. F.F. Osborne, of Laval University, was always willing to discuss geological problems and made numerous useful suggestions.

#### Previous Work

James Richardson (1870) spent four months in 1869 exploring the north shore of the St-Lawrence river from the Saguenay river to Sept-Iles bay. He went up the Manicouagan river for forty miles. In 1895, A.P. Low (1896) travelled up the Manicouagan river and described the rocks along his route. Carl Faessler (1933, 1934) systematically mapped a strip along the north shore. He mapped from the Bersimis river to the Manicouagan in 1932 and from the Manicouagan to the Godbout river in 1933. A small part of these two areas are enclosed in the present one. No published geological work has been done in the area from 1934 to 1959 although the ground has been looked over at different times in search of metals and industrial minerals.

### DESCRIPTION OF THE AREA

#### Settlements

Hauterive is a fast growing town founded less than twenty years ago. It has no large industry but some of its residents work in near-by Baie Comeau. It has a hospital and is a major center of secondary education of the north shore. The bishop's residence is in Hauterive. The village of Chute-aux-Outardes is much smaller than Hauterive and lies 6 miles to the southwest.

There are sparse settlements all along the coast. Prior to 1962, the central and north parts of the area were not settled; only a few temporary lumber camps were found here and there. Since then, accommodation have been set up at "Manic 2" to house several hundred Hydro-Quebec employees and construction workers. Most of these facilities are temporary.

#### Resources

Timber-cutting is by far the most important industry in the region, which is rather heavily forested with spruce, fir, birch, poplar, pine, and tamarack. Most of the area is part of the timber concession of the Quebec North Shore Paper Co. and is under active exploitation. Most of the pulpwood is treated in a paper mill at Baie Comeau. Several lots in the southern parts of the area belong to individuals or have not been allocated but much of this land has been turned into agricultural land or has been devastated by fire. Thus, much of the Manicouagan Peninsula is burnt.

Agricultural possibilities are restricted to the coastal plain in the southern part of the area and to the main river valleys. Farming is mostly centered in Ragueneau township and on the Manicouagan peninsula. Some farms are prosperous but many appear neglected.

The considerable Hydro-electric possibilities of the area are or will soon be used up by Hydro-Quebec.

Fish and game are common in the area. Pike is abundant in the Manicouagan river and in large Salé lake (Rambois). Trout occurs in Brisson and several other lakes and in rivière des Anglais. Several moose were seen during the field-season and their tracks are numerous in abandoned lumber roads. Partridge and bear are also abundant.

#### Physiography

The area is composed of a southern coastal plain which extends northward in the deeper valleys, and of the rocky highlands. The plain is made of Quaternary sand and clay. It rises gradually from sea level at the coast to slightly more than 300 feet above sea-level near the edge of the highlands, and to 400 feet at Manic 2 in the Manicouagan river valley. The lower part consists of well-defined, broad, level terraces with steep banks. The banks are generally lower and less conspicuous in the upper part.

The rocky ground also rises northward but not gradually everywhere. Going from the coast northward, the rock first appears as low, round knobs sticking above the sand plain. Then, the coastal plain ends abruptly 3 miles north of Hauterive. The bedrock summits south of this boundary are less than 300 feet above sea level but rise to 700 feet to the north. This change is less pronounced west of the Manicouagan river. Another jump in summit elevations from about 800 feet to 1000 feet occurs 10 miles north of Hauterive. The change takes place across the broad

valley which runs eastward from Manic 2 to St-Joseph lake. The same change occurs west of the Manicouagan but is 3 or 4 miles farther south at the western boundary of the area. From there, the elevation of the summits rises gradually northward, up to 1500 feet at the northern boundary of the area.

Broad flat summits, characteristic of a former peneplane, are not evident. However, all the highest summits lie at nearly the same elevation within small areas. Also, the northward rise in summit elevations appears gradual except for the two jumps mentioned above. Thus the area is possibly a dissected peneplane. The jumps, which extends at least beyond Godbout, some 35 miles east of the area, must be significant. They may represent the boundaries between old erosion surfaces of different ages and elevations or they may represent differential uplift of some fault blocks.

Cliffs are abundant everywhere. The most rugged areas are not necessarily the highest ones. Thus, the broad plateau rising to 1300 feet northwest of Brisson lake is easily traversed whereas the southernmost occurrences of 1000-foot summits are in rugged country with closely-spaced steep cliffs. A possible explanation is that the latter area was at the edge of an old erosion surface and was therefore more dissected.

The rocky highlands are well drained by the Manicouagan and the smaller Georges-Tremblay and Anglais rivers. Georges-Tremblay river flows parallel to the Manicouagan, 4 or 5 miles to the west. It discharges into the Outardes river. The Anglais river follows a serpentine course near the eastern edge of the area. It flows into Anglais bay in the St-Lawrence near Baie Comeau. All these rivers flow in deep, obviously pre-glacial valleys. The small Anglais river is locally bordered by sheer 300 - to 400 - foot cliffs, and the hills forming a continuous rocky wall on the west side of the Manicouagan rise to 1000 feet above it. Outardes and Amédée rivers drain part of the coastal plain. The plain is poorly drained and contains innumerable marshes, some up to 2 miles long.

The lithology has had little effect on the topography of the rocky highlands except to the northeast of Amédée lake and near Elbert lake where several elongated lakes lie parallel to the trend of the foliation. Far more important from this view point is a system of fractures and dykes directly responsible for the orientation of a great many small and large valleys. The straight stretches of the Manicouagan river trending N20°W and N25°E correspond quite closely with important fracture directions of the system (see "Linears" in Structural Geology below).

GENERAL GEOLOGY

The consolidated rocks of the area are Precambrian in age and belong to the Grenville structural province. They are divided in this report into early gneisses and late igneous rocks but the distinction is dubious in a few cases.

Much of the area is underlain by various types of highly metamorphosed quartzo-feldspathic gneisses. Some gneisses show excellent layering and are probably paragneisses. "Quartzite" or pure quartz rock is probably also of sedimentary derivation. A good part of the gneisses however are moderately well to poorly layered. Some appear igneous but many are of enigmatic origin. Augen gneiss is abundant but is largely restricted to the northern part of the area. Green gneisses are abundant in the western part of the area. Pyroxene occurs among hornblende-biotite gneiss in the northern and western parts of the area but, in contrast, is practically missing in the eastern part. Furthermore, the fold pattern is strikingly more simple in the eastern than in the western and northern parts of the area. A possible explanation to these differences is that the western gneisses are older and underwent at least one more period of folding and metamorphism than the eastern gneisses. Another explanation holds that the western gneisses

Table of Formations

Quaternary	sand and gravel clay and silt till
<u>Age unknown</u>	mica peridotite
<u>Precambrian</u>	
Late igneous rocks	microdiorite meladiorite, diorite, granodiorite, monzonitic granite, pegmatite, green monzonite, minor gabbro
Early paragneisses and orthogneisses	augen gneiss, granite gneiss pink, highly felsic leptite and gneiss with or without garnet and sillimanite, little or no biotite. biotite-hornblende gneiss, biotite-pyroxene gneiss, green gneiss. biotite-garnet gneiss, with or without sillimanite. amphibolite impure marble and calc-silicate gneiss quartzite

NOTE: the rocks are not arranged in chronological order within each group.

are partly equivalent to the eastern ones but are more extensively injected and metamorphosed.

The late igneous rocks occur in four main heterogeneous bodies or "complexes" and several small masses. They range in composition from gabbro to pink granite and include some green rocks of intermediate composition. Almost all of these rocks are believed related in origin. A mafic diorite with relatively sodic plagioclase may represent the parent magma from which many of these rocks are derived.

The quaternary deposits of the area are voluminous. The coastal plain consists of grey silt and clay overlain by sand and is essentially a deltaic deposit formed at the mouth of the Manicouagan and Outardes rivers. The history of deposition is complex in details. For instance, a thick deposit of sand which overlies grey silt and clay of the "Champlain sea-type" near Manic 2 is apparently a valley train formed during a late ice readvance.

#### PRECAMBRIAN

##### Paragneisses and Orthogneisses

Over four fifths of the area is underlain by rocks of this group. Quartzite, impure marble, and amphibolite are the most distinctive rocks in it. The bulk of the group consists of gneisses in which the dominant constituents are quartz and feldspar. Although several varieties may be

distinguished on the basis of color, mineralogy, texture, and structure, their mapping is difficult in many places because the varieties are gradational into each other and because they are intermixed locally. Thus, many of the units shown on the map represent groupings of several varieties and the same variety may be repeated in different units. It follows that the chosen location of the boundary between similar groups is arbitrary in places.

#### Quartzite and Quartz Rock

Coarse quartzite occurs in four large units in the area and an identical quartz rock outcrops in a few isolated exposures. The western unit lies at the western edge of the area at latitude 49°15'. Its core consists only of coarse quartzite whereas its margins include quartzite mixed with biotite gneiss, sillimanite gneiss, and hypersthene-hornblende gabbro and amphibolite. Layering in the surrounding gneiss wraps around the massive core and dips vertically. Thus, it is not known which are the younger rocks. The second or central unit crops out discontinuously for 7 miles along the Manicouagan river in the central part of the area. It apparently forms a continuous layer which generally dips gently to moderately east. It is about 60 feet thick at the Manicouagan 2 dam (Luc Boyer, personal communication) and roughly 300 feet thick four miles farther south.

Detailed mapping near the dam has indicated the possibility of another, lower unit (Luc Boyer). The quartzite includes a minor amount of sillimanite gneiss and other gneisses in layers a few inches to a few tens of feet thick. The southern occurrence is at least one mile long and lies  $1\frac{1}{2}$  mile north of the McCormick or Manicouagan 1 dam. In its western exposures, it consists of 2 quartzite units, each over 250 feet thick, separated by a wedge of nodular sillimanite-biotite gneiss (or of one quartzite unit bent double by isoclinal folding?). It either pinches out or becomes much thinner a short distance to the west. This unit is possibly the direct extension of the central occurrence. The eastern unit occurs in a southwest-plunging anticline at the eastern edge of the area near latitude  $49^{\circ}18'$ . Only the tip of this large occurrence lies in the present area. Two small occurrences of quartz rock are exposed in the anticline north of Amédée lake, halfway between the central and eastern units. An isolated outcrop of quartz rock was found near the east shore of the Manicouagan river, 2 miles south of the northern limit of the area. Another lies  $\frac{3}{4}$  mile southwest of the southern tip of Sewell lake. Two occurrences of quartz rock presumably represent large inclusions within the igneous rocks near the Chute aux Outardes dam.

The quartzite is typically quite massive although some impure varieties show faint to excellent layering. The rock is colorless, milky white, bluish or greenish. It is very coarse with grains up to 2.5 cm. long. The grains are welded and it is generally difficult or impossible to distinguish the individual grain boundary in hand specimens. The rock looks like vein quartz. Much of the

quartzite is quite pure (see silica content in "Economic Geology" below) but may include minute specks of potash feldspar, plagioclase ( $An_{35}$  in one case), biotite, muscovite, garnet, zircon, carbonate, and chlorite. Feldspar increases in size as it increases in abundance and the quartzite locally grades into coarse quartz-feldspar rock with up to 1/3 feldspar. This rock is easily confused with pegmatite.

Very narrow, dark and light lamellae are locally visible to the naked eye in the coarse quartz grains. The orientation of the lamellae diverges only slightly (about  $30^\circ$ ) from grain to grain and defines a "foliation" which can be at wide angle to the layering and foliation in adjacent rock. In one case, this foliation is parallel to a lineation defined by sillimanite needles. As seen under the microscope, some quartz grains are extremely strained and are made up of a very fine mosaic of welded, sub-individual grains whose orientation may differ by as much as  $5^\circ$ . Two sets of extremely fine (so-called "boehm") lamellae with very good preferred orientation may be seen in some slides. The two sets may appear in different parts of the same grain or may even occur together forming a very fine grid similar to microcline twinning. The megascopic lamellae are not parallel to the microscopic ones.

Some of the small, apparently isolated occurrences of quartz rock could be vein quartz. However, the four main units at least are almost definitely of sedimentary derivation as suggested by their large size, apparent continuity (in the case of the central unit), concordant character, and included layers of garnet or sillimanite gneiss parallel to the layering of the quartzite.

Bytownite quartzite and Quartzose Gneiss

This unusual rock was confused in the field with other varieties of quartzose gneiss and its abundance and distribution are unknown. However, its discovery in three thin sections from samples believed representative of local gneiss indicates that it is more than a freak occurrence. The occurrences are on the eastern and on the northern margins of the western unit of coarse quartzite and near the western tip of the lens of quartzose sillimanite gneiss some 5 miles northwest of Manic 2.

The samples collected near the coarse quartzite are of fine-grained ( $\frac{1}{4}$ -1mm.) quartzite with a sugary texture. Grey and pale grey layers only  $\frac{1}{2}$  to 1 cm. thick are straight and persistent. The rock consists of quartz (75 to 80%), bytownite ( $An_{70}$  and  $An_{85}$ , 15-20%), brown biotite (1-5%) and minor apatite, zircon, and iron ore (magnetite-martite in one case). One sample contains microcline (5%), the other carries hornblende (1%). Secondary minerals include muscovite, chlorite, and carbonate. The third sample is slightly coarser and consists of quartzose biotite gneiss with conspicuous garnet crystals. It contains quartz (about 50%), bytownite  $An_{80}$  (30%), biotite (20%), garnet, apatite, zircon, muscovite, and chlorite.

These rocks may be derived from impure calcareous sandstones.

Impure Calcareous Rocks

The only important unit of calcareous rocks is exposed in several small outcrops scattered over a strike-length of half a mile along the western road, near latitude 49°17'. Its thickness is unknown but exceeds 20 feet. Its southwestern exposures consist of white or pale grey, calcite-rich bands mixed with white, calcite-poor, plagioclase-quartz-microcline bands. The carbonate bands are well-layered and foliated and may be several feet thick. The northeastern exposures show well-layered, pink to light green, calcite-scapolite-diopside-quartz rocks. The crystalline limestone is very impure and calcite makes up less than 2/3 of most layers. The calcareous rocks are locally cut by an unusual, white, pyroxene-bearing pegmatite as well as by the common pink type. The former contains in order of decreasing abundance: microperthite, clinopyroxene, quartz, and minor dark green hornblende, sphene, myrmekite, and apatite.

Another occurrence of carbonate-bearing rocks is exposed in a cut along an abandoned part of the western road, one mile north-northwest of Donlon lake. (Occurrence not shown on the map). The rock is well layered with green and pink colors dominating. Few layers contain more than 25 per cent carbonate. This calcareous rock occurs among very felsic pink gneiss.

The calcareous rocks are commonly medium to coarse-grained and poorly foliated or unfoliated (though well layered). The silicate minerals, one to three millimeters in size, tend to be round in calcite-rich layers. However, some rather pure (90% calcite) limestone layers in the southwestern part of the main unit are both fine-grained and well foliated. The calcite crystals here are only 0.1 mm. in size and show numerous bent twin lamellae. The foliation is defined by large, elongated calcite grains and by flat lenses of extremely strained quartz. Mechanical deformation is much more obvious here than in the coarse-grained rocks.

Calcite, scapolite (0-30%), quartz (traces to 20%), clinopyroxene (0-15%), and sphene are generally present in the calcareous rocks whereas epidote, plagioclase, microcline, and hornblende are abundant in some samples but missing in others. Scapolite is slightly to completely altered to messy patches of carbonate, sericite, chlorite, feldspar, and possible clinozoisite. It is partially rimmed with epidote, especially at the contact with carbonate. The crystal faces of epidote are developed against carbonate but not against scapolite. Plagioclase (sodic andesine in part) or microcline are commonly, but not always, missing or in only minor amounts in calcite-rich or scapolite-bearing rocks. Oligoclase (about  $An_{20}$ ) is abundant in the plagioclase-microcline-quartz gneiss of the main calcareous unit. Quartz occurs in equant grains a few millimeters in size and in minute specks

within or at the border of pyroxene and hornblende. Diopsidic pyroxene is in part almost colorless but is more commonly slightly to moderately pleochroic from bluish green (X and Y) to pale or moderate brown-green (Z). Absorption is  $X = Z$  to  $X = Y > Z$  and dispersion is strong,  $v > r$ . This pleochroic clinopyroxene is uncommon in the quartzo-feldspathic gneisses. Strongly pleochroic, blue-green hornblende occurs both in equant grains and as partial rim between pyroxene and carbonate. It is in part complexly intergrown with fine-grained quartz. Some rocks carry a small amount of chlorite but no pyroxene or amphibole. Sphene is a minor but persistent accessory mineral. It is up to a few millimeters in size and is visible in many hand specimens. This sphene is quite distinct from that found in the quartzo-feldspathic gneiss: it is less birefringent, is more deeply colored in brown, has weak to moderate pleochroism, and adjacent chlorite shows pleochroic haloes around it. Perhaps it includes some keilhauite component, a rare earth variety of sphene. Other accessories include zircon, apatite, allanite, pyrite, phlogopite, and graphite.

These rocks have a low magnesium content and may be derived from dolomite-poor calcareous sedimentary rocks.

#### Scapolite-Pyroxene-Gneiss, Epidote-Scapolite Quartzite

These rocks are intermediate in composition between impure calcareous rocks and clinopyroxene-bearing quartzo-feldspathic gneiss. They commonly contain a few thin, calcite-rich layers.

All occurrences found are units only a few feet thick and are not shown on the map. They occur at several places within a few miles of Sewell lake near the western boundary of the area. Only three or four other occurrences were recognized elsewhere in the area.

The rocks are well layered and are commonly medium to coarse-grained. Visible epidote may distinguish these rocks from quartzo-feldspathic gneiss with a high pyroxene to biotite ratio. The mineralogy is the same as in the calcareous rocks except that calcite may form only 1 or 2 per cent of the rocks. Pleochroic pyroxene and pleochroic sphene are common as in the more calcareous rocks.

Beds, up to a few feet thick, of epidote-scapolite quartzite or quartzose gneiss occur among amphibolite and felsic pyroxene-bearing gneiss south of Sewell lake. The rock is in part fine-grained with a sugary appearance. Quartz and epidote are conspicuous on the white weathered surface. Two thin sections of this rock contain quartz (about 60%), andesine (10-15%), scapolite (15-20%), epidote (5%), pleochroic clinopyroxene (5%) and minor amounts of calcite, hornblende, microcline, pleochroic sphene, iron oxide, apatite, zircon, and andradite-grossularite garnet. The garnet is almost black in hand specimen and is brown in thin section. Its refractive index is appreciably higher than 1.85 and its cell edge of  $11.99 \text{ \AA}$  in one case suggests a composition closer to andradite than to grossularite. This

garnet is possibly widespread in the epidote quartzite but it was not detected in the other rock-types of the area, except in a narrow calcite-rich veinlet. The scapolite-epidote quartzite is not far in chemical composition from the bytownite quartzite described above. It may be derived from a calcareous sandstone.

### Amphibolite

The large body of amphibolite shown near the western boundary of the map at latitude 49°17' consists almost exclusively of this rock-type. It is up to 4 miles long and half a mile wide. Foliation in it is well developed almost everywhere and is generally parallel to the trend of the unit. Locally however, it is thrown into small folds. The folding may partly explain the great variations in width of the unit. Many outcrops of amphibolite show no compositional layering whatever but others may show all stages between poorly and well developed layering. In a few places the amphibolite is interlayered with hornblende-bearing feldspathic gneiss and, more rarely, with the highly quartzose epidote-scapolite gneiss mentioned above. Interlayered amphibolite and gneiss appear especially common near the western boundary of the unit. At one place, mixed amphibolite and gneiss are separated from the main amphibolite unit by several hundred feet of felsic gneiss. Thus, the boundary of this unit is not sharp at this place even if sharp contacts

between gneiss and amphibolite are numerous. These contacts appear concordant in small exposures. The amphibolite is cut locally by numerous quartz-epidote veinlets parallel or oblique to the foliation. The amphibolite is also heavily injected by granitic material near its southern tip. As the contact is approached, the amphibolite becomes more and more contorted and cut up into blocks by pink, quartz and microcline-rich veinlets. The fragments then change gradually from amphibolite to a complex mixture of amphibolite and more or less felsic hornblende gneiss as if the amphibolite was injected and replaced to a variable degree by felsic material. This grades into pink, heterogeneous, hornblende-bearing granitic gneiss. The passage from amphibolite to granite takes place within a few hundred feet.

Another occurrence of amphibolite is shown on the map just north of the main unit. Several other occurrences were found but they are small, many are only a few feet thick, and they are volumetrically insignificant in the area. They occur among pink, grey, and green gneiss but those in the green gneiss differ slightly from the others in mineralogical composition and are not treated in this chapter.

Many amphibolite occurrences are apparently in sill-like masses with sharp, concordant contacts and they contrast sharply in composition with surrounding rocks. On the other hand, some amphibolite units lie among well layered, somewhat mafic gneiss (about 15 to 35% mafic minerals) containing thin amphi-

bolite layers. Here, the distinction between amphibolite and surrounding rock is not sharp. An example of this feature is seen  $1\frac{1}{2}$  mile west of Amédée Lake. Transgressive dykes of fine-grained amphibolite occur in rare places, notably where highway 15 crosses the Manicouagan river. The dykes are a few feet wide and their contacts are quite sharp. They may be a metamorphosed facies of the pyroxene microdiorite mentioned below and are described with them.

The amphibolites are dark grey or greenish grey rocks with a grain size commonly between  $\frac{1}{2}$  and 3 mm. The texture is commonly gneissic. Plagioclase is xenoblastic, hornblende may be xenoblastic or may show prismatic faces, and biotite is more nearly idioblastic. In some cases, clinopyroxene has curved, concave sides against plagioclase and tends to be interstitial. Plagioclase, biotite, and other minerals may be poikiloblastically included in hornblende or pyroxene. The bulk of the amphibolite varies in composition between the following limits: 40 to 55 per cent plagioclase ( $An_{30}$  to  $An_{45}$ ); 25 to 45 per cent yellow (X) to brownish green (Y) to green or bluish green (Z) hornblende;  $\frac{1}{2}$  to over 20 per cent red-brown or brown biotite; 0 to 10 per cent clinopyroxene; 1 to 8 per cent iron-titanium oxide minerals; traces to 2 per cent apatite. The ferromagnesian minerals total 45 to 65 per cent of the rock. Quartz and potash feldspar are missing or in small amounts. Zircon is common, sphene, garnet, pyrite and chalcopyrite are rare. Alteration of the amphibolite varies from

slight to complete. The secondary minerals include chlorite, carbonate, muscovite and epidote.

Fresh, pyroxene-free amphibolite seems common in the main amphibolite unit. All other thin sections of amphibolite collected in the western half of the area contain clinopyroxene or sharply-defined chlorite-carbonate patches. These patches may occur in proximity to fresh hornblende and biotite and strongly suggest the former presence of pyroxene. A few fresh, pyroxene-free amphibolites were found in the eastern and south-eastern parts of the area, but pyroxene may have been present in some of the altered amphibolites.

The amphibolite from the eastern occurrences and from the main unit contains both ilmeno-magnetite grains (nomenclature of Buddington et al, 1963) and hemo-ilmenite (hematite very minor) in the few polished sections examined. In contrast, a few sections from the other western occurrences contain ilmeno-hematite (60-80% hematite) as well as dual or composite grains of magnetite and ilmenite. A relationship possibly exists between the presence or absence of pyroxene and the types of iron-titanium oxides.

The unlayered amphibolite must represent metamorphosed gabbroic or basaltic rocks, the layered ones may be derived from basic intrusive, extrusive or pyroclastic rocks.

#### Other Mafic Gneisses

A green, mafic rock with abundant, coarse (up to 1 inch across), green clinopyroxene occurs in the northeastern exposures of the main band of impure calcareous rocks described above. It is quite distinct from the common amphibolite

in texture, color, and abundance of pyroxene, and it may well have a different origin.

Another unusual mafic rock rich in garnet occurs one to two miles north-northeast of Caouette lake. It lies at or near the contact between augen gneiss and layered pyroxene gneiss. The garnet content varies widely but can make up to 1/3 to 1/2 of some samples. One thin section contains approximately: garnet 50%, biotite 38%, opaque oxides 6%, apatite 3%, green spinel 2%, greenish brown hornblende 1%.

#### Biotite-Garnet and Biotite-Hornblende Gneisses

Grey biotite-garnet and biotite-hornblende gneisses make up the bulk of the rocks east of the Manicouagan river and south of the Brisson Lake igneous complex. Near the St. Joseph Lake complex, they occur with only a small amount of pink or white, very felsic, biotite gneiss. Elsewhere, the felsic pink gneiss becomes more abundant but is commonly subordinated to the gray gneiss. At places, biotite-hornblende gneiss occurs with little or no garnet. Elsewhere, biotite-hornblende and biotite-garnet gneiss are intermixed in layers of variable thickness, some of which may be only one inch or so thick.

Layering in these rocks is generally readily visible and is locally excellent. It is commonly, though not always, more conspicuous in the more mafic rocks. At many places, the layers do not merely consist of a repetition of only two rock-types but are of varied composition. Some layers are persistent and

of even thickness even around the nose of tight folds. Locally, pale quartzose layers up to two feet thick alternate with thinly layered grey biotite gneiss. From a distance, they look like a sequence of interbanded sandstone and shale. Doubtless, part of this excellent layering represents preserved bedding.

The grain size of the gneisses is  $\frac{1}{2}$  to 2 or 3 mm. although flat quartz lenses up to 5 mm. long occurs in some rocks. The texture is gneissic and xenoblastic; crystal faces are seen only on some mafic grains. The modal composition of the rocks follows:

	garnet-bearing	hornblende-bearing
plagioclase	30 - 45%	30 - 70%
quartz	20 - 35%	15 - 30%
potash-feldspar	15 - 30%	0 - 20%
biotite	3 - 20%	5 - 15%
hornblende	-	traces - 15%
garnet	up to 5% (generally)	-
Total mafic minerals	3 - 20% (less than 1%)	5- 30%

Biotite is predominant over hornblende or is in equal amount. Garnet or hornblende are always present except in some very felsic layers but these minerals seldom occur in the same thin-section. Accessory minerals include pyrite, iron ore, apatite, zircon, allanite, and rarely graphite, sphene and tourmaline. Chlorite, muscovite, and epidote are minor secondary constituents. Carbonate occurs in small amounts but is more abundant and more common in the hornblende-bearing than the garnet-bearing rocks. The plagioclase usually ranges in

composition from An<sub>16</sub> to An<sub>35</sub> but some go up to An<sub>45</sub>. Its calcicity increases with the color index. It is rimmed with albite at the contact with potash feldspar in many cases. Myrmekite is present. Potash feldspar is in part finely perthitic. It shows all gradations from good grid-twinning to wavy extinction. The latter is probably due to submicroscopic twinning as very fine grid-twins can be seen at the edges of some crystals. Quartz may be highly strained and shows numerous lamellae. Biotite is greenish brown, reddish brown, or red. Hornblende is pale green, green, or blue-green.

#### Green and Grey Pyroxene-bearing Gneisses

A characteristic, green pyroxene-bearing gneiss occurs in the northwestern part of the area as well as in the southwestern part about one mile north of the Outardes river. It is locally mixed with a considerable amount of grey hyperstene-free and hyperstene-bearing gneisses. Because of weathering, all these rocks may be undistinguishable in the field. Thus, the units indicated on the map represent groupings of different rock types with ill-defined boundaries. Still, the units are considered significantly distinctive from the others.

The rocks of the northwestern unit vary much in appearance and only their broader aspects are given here.

The rock is moderately felsic (10-25% mafic minerals), grey, and excellently layered on the east shore of the Manicouagan river. Some layers contain hyperstene, clinopyroxene and biotite; others contain biotite with or without hornblende. Farther east, a similar gneiss locally contains much mafic gneiss or pyroxene amphibolite as lenses, sills, or fragments (boudins?) of all sizes. The amphibolite is usually gneissic but unlayered and has sharp contacts. The amphibolite fragments are possibly more abundant near the contact with the augen gneiss. Still farther east, near the indicated anticlinal axis, occurs a rather homogeneous, well-layered, felsic, two-pyroxene gneiss deeply weathered in pale brown. Northwest of Cacouette lake, pyroxene-bearing gneiss is locally predominant, locally subordinate to pink acidic gneiss and augen gneiss. South of the same lake, green and grey hyperstene-bearing gneisses contain a few lenses of unlayered, almost massive dark green mafic gneiss or pyroxene amphibolite. They are locally mixed with very felsic, white or pink, biotite-bearing gneiss. Some pink granitic material definitely cuts the dark grey gneiss locally. Some of the green rocks west of Cacouette lake are lean in quartz and are of monzonitic or dioritic composition. Locally they contain green or white microcline phenocrysts or porphyroblasts and thus grade into augen gneiss. Layering is poorly developed or missing in some places.

The southern occurrences consist of medium to coarse-grained, grey or green layered gneiss grading into unlayered, in part nearly massive, green gneiss. These rocks are mixed with very felsic, pink or pale grey, medium to fine-grained granoblastic gneiss with some garnet near the old road, and with rather coarse, granitic gneiss south of the road. The grey or green gneiss varies from very felsic to mafic but is generally moderately felsic. These rocks apparently cut the pale felsic gneiss in rare places but they are cut in turn by pink pegmatite. Numerous hyperstene-bearing microdiorite dykes transects both the pale gneiss and the green rocks but they are apparently much more common in the latter as if there was a genetic connection between them. Some dykes are straight but many are crooked or irregular and pinch out within short distances in the green rock.

The green color of the rock is mainly due to green plagioclase or potash feldspar or both. On slight weathering, the green color is typically replaced by a pale brown or yellow-brown color. Unfortunately, the alteration may penetrate to several feet, as seen in road cuts, and fresh green samples cannot be obtained with a small hammer in some areas. Thus, some rocks are only surmised to be green. Deep weathering seems rare in the other rock types and this is of some help.

Grain size of the green rock is mainly  $\frac{1}{2}$  to 2 or 3 mm. but quartz and potash feldspar may exceed 3 mm. in rare cases. Pyroxene may also exceed this size in the mafic types. The rock is generally gneissic but locally may be more nearly granoblastic than gneissic. The texture is commonly xenomorphic.

Biotite, rarely plagioclase, and even more rarely hypersthene may have straight boundaries.

The bulk of the green gneisses are quartzo-feldspathic with plagioclase the dominant mineral, quartz second in abundance, and with 5 to 30 per cent mafic minerals. Abundance of the main minerals in the thin-sections examined is the following:

	generally	extreme observed
Plagioclase	30 - 60%	
Quartz	15 - 30%	traces - 60%
Potash feldspar	traces - 10%	traces - 25%
Biotite	1 - 20%	
Orthopyroxene	0 - 7%	
Clinopyroxene	0 - 4%	
Hornblende	traces - 10%	

The composition of plagioclase varies within narrow limits: it is between An<sub>26</sub> and An<sub>31</sub> in most samples and the maximum range observed is from An<sub>20</sub> to An<sub>35</sub>. It is rarely anti-perthitic; the potash-feldspar inclusions are not abundant and tend to show a stubby rectangular cross-section. Potash-feldspar is finely perthitic and the amount of exsolved plagioclase is small. Some grains show grid-twinning but most show only undulose extinction (possibly due to sub-microscopic twinning). Brown to red-brown biotite is always present and is commonly the dominant ferromagnesian mineral. In a few sections, biotite and quartz (?) form a vermicular intergrowth similar to myrmekite but on a finer scale. This is restricted to sharply-defined segments of otherwise fresh biotite crystals. Of the pyroxene-bearing sections examined, about

one third contains orthopyroxene, one third clinopyroxene and one third contains both. Orthopyroxene is slightly to intensely replaced, commonly by a platy mineral with parallel extinction, birefringence about 0.020, and yellow to green pleochroism. Green or blue green hornblende is missing or occurs only in small amount (1%) in orthopyroxene rocks free of clinopyroxene but is more abundant in clinopyroxene-bearing rocks. It occurs partly in small secondary grains at the rim of clinopyroxene but also occurs in larger grains apparently in equilibrium with pyroxene. A colorless amphibole (cumingtonite?) occurs in a few rocks free of orthopyroxene and it may have replaced the latter. Primary accessory minerals include apatite, zircon, allanite, pyrite, and opaque oxides. Carbonate, muscovite, and chlorite are rare in the hypersthene-bearing gneiss, but are more common in hypersthene-free gneiss.

A sample of a rather massive green rock found west of Caouette lake differs from the common, quartzose green gneiss described above. It consist essentially of plagioclase ( $An_{35}$ , 75%) and orthopyroxene (20%) with only minor biotite, hornblende, opaque minerals, and apatite. It is quite fresh. Subhedral plagioclase, in marked contrast to the anhedral or xenomorphic plagioclase of the common green gneiss, suggests that the rock is igneous and less affected by metamorphism than some others. It is not known if this rock is a fair sample of the quartz-poor rocks which abound at this locality.

The mafic rocks mixed with the green gneiss consist essentially of plagioclase, pyroxene, amphibole, and biotite. The ratio between the mafic minerals varies widely. In the sections examined, pyroxene constitutes up to 30 per cent of the rock, hornblende up to 50 per cent, biotite up to 20 per cent, total ferromagnesian minerals from 40 to 75 per cent. Clinopyroxene is always present, orthopyroxene nearly always. The former is also more abundant than the latter. All sections contain a little quartz, some contain potash-feldspar. Primary accessory minerals and secondary minerals are the same as in the felsic gneiss but opaque oxides are more abundant here. Plagioclase composition is between  $An_{29}$  and  $An_{35}$  except in one massive rock where it is  $An_{40}$ . These rocks differ slightly from the amphibolites described previously in the following features: no hyperstene, commonly less clinopyroxene, and a slightly greater range in composition of plagioclase ( $An_{30}$  to  $An_{45}$ , most  $An_{35}$  to  $An_{40}$ ) in the common amphibolite.

A short discussion of the origin of the green gneiss will be found at the end of the following chapter.

#### Green Gneiss without Pyroxene

This rock is identical in color, texture, and grain size to some of the green hyperstene-bearing gneiss but pyroxene is generally missing in the moderately felsic rocks (5-20% mafic minerals) which makes up the bulk of it.

Like the pyroxene-bearing rocks, it is locally mixed with grey or pink gneiss and the limits of its occurrences are poorly defined. It occurs in a large unit to the west of Manic 2 and in a small one south of Hauterive. Both occurrences are not far from coarse quartzite and underlie it apparently.

The green and grey gneiss on the shore south of Hauterive shows excellent layering in many places. It generally contains minor graphite and many layers are garnetiferous. Inland, the gneiss is still graphitic but is more poorly layered, is coarser-grained and contains less garnet than near the shore. The green gneiss is cut by green pegmatite as well as by pink pegmatite and granitic material.

The green gneisses of the western occurrence vary much in content of mafic minerals and in development of layering although the bulk of the gneiss is well layered. Somewhat mafic gneiss occurs about 2 miles north and  $1\frac{1}{2}$  mile south of Donlon lake. Their content of mafic minerals range mainly between 15 and 35 per cent of the rock but they also include amphibolite layers a few inches thick. Thicker units of amphibolitic or gabbroic rocks carrying in part two pyroxenes are also present but the nature of their contacts and relationships to the more felsic gneiss are unknown. Some of the mafic rocks are almost massive and it is not clear whether they should be grouped with the green gneiss or the late igneous rocks. Some green gneiss is graphitic. Garnet is not common although a grey gneiss found with the green gneiss one mile southeast of Donlon lake carries abundant garnet crystals

over  $\frac{1}{4}$  inch across. Along part of Hydro-Quebec road, the green or grey gneiss is mixed with a considerable amount of very felsic (2-5% mafic content) white or pink gneiss. In part, these rocks are interlayered at their contacts and appear conformable in small outcrops. On the other hand, some pink granitic material, as well as pink and green pegmatites, definitely cut the green or grey rock locally. In one place, a green gneiss grades into a grey one near a transgressive pink rock.

The green gneiss free of pyroxene is commonly less deeply weathered and without the typical yellow-brown alteration of the pyroxene-bearing one. Under the microscope, the two rocks differ in that the pyroxene-free rocks consistently contain more secondary or alteration minerals. Their content of feldspar, quartz, biotite, and primary accessory minerals are the same. In the sections examined, plagioclase commonly varies in composition between  $An_{24}$ , and  $An_{32}$ , but is as sodic as  $An_{11}$  in a rock rich in potash-feldspar. Plagioclase is quite altered in some rocks. Hyperstene and clinopyroxene occurs in the mafic or amphibolitic rocks in the large occurrence of green gneiss west of Manic 2 and in a few felsic rocks at the northwestern limit of this occurrence. Bluish green hornblende occurs in small amount in some samples. Chlorite and carbonate are present in all thin-sections examined, muscovite in many. In most

cases chlorite or a mixture of chlorite and carbonate form sharply-defined patches obviously pseudomorphous of another mineral. These patches may occur in contact with fresh hornblende and are probably derived, in part at least, from pyroxene. Sphene occurs in a few thin sections; it was not detected in the pyroxene-bearing green rocks.

The similarities of the pyroxene-free and pyroxene-bearing green rocks and the clear increase in amount of alteration minerals from hypersthene-bearing rocks to pyroxene-free ones strongly suggest that the latter is only a retrogressively metamorphosed facies of the former.

A minor part of the green rocks (with or without pyroxene) are almost massive and are almost certainly igneous as indicated previously. On the other hand, the well layered, garnetiferous and graphitic rocks may well be of sedimentary derivation. The origin of the bulk of the quartzose green rocks however is still a problem. Furthermore, the green rocks are not necessarily all of the same age. For instance, the rocks most clearly igneous could just as well be grouped with the "late igneous rocks". In fact, very similar green rocks in the Chutes aux Outardes and George Lake igneous complexes are classed as such.

The green gneisses of the area may not be strictly identical to the "green rocks" (Osborne and Morin, 1962, p. 119 and 124) so common in the Grenville subprovince. They are devoid of the characteristic "mesoperthite" in which comparable amounts of plagioclase and potash feldspar are intergrown. Also, their

layering is better developed, they are more quartzose and perhaps richer in biotite than the green rocks of the Labrieville (Morin, 196 ) and Windigo (Laurin, 196 ) areas for instance. Quartzose green rocks do occur however in some other areas (R. Beland, 1960, Schriver, ).

Grey Gneiss, partly with Pyroxene

This group includes all the quartzo-feldspathic gneisses which are not green or dominantly pink in the northeastern and western parts of the area.

The rocks are commonly medium-grained. They are possibly slightly coarser-grained, on the average, than the biotite-hornblende and biotite-garnet gneisses which occur in the eastern part of the area. Layering is easily visible and can be excellent. The mineralogical composition of a large part of these rocks is very similar to that of the grey biotite-hornblende and biotite-garnet gneisses except that garnet is less common and that clinopyroxene is locally present here. Many thin sections contain sharp chlorite-carbonate patches presumably derived from pyroxene. Biotite is commonly the dominant ferromagnesian mineral. Orthopyroxene rarely occurs in grey gneiss in the vicinity of orthopyroxene-bearing green ones. Hornblende is commonly present in small amounts but is missing in some injected gneiss. Exceptionally, garnet is relatively abundant (locally up to a few per cent) southeast of Donlon lake.

Gneiss with a high clinopyroxene to biotite ratio (for instance 20% pyroxene and 2% biotite) are common in the west-central part of the area in the general vicinity of the calcareous and scapolite-pyroxene rocks. Similar rocks, without known scapolite or calcite rocks near-by, occur near the northeastern corner of the area. Clinopyroxene and sphene are in part pleochroic and thus identical to the varieties found in scapolite-bearing rocks. This gneiss is obviously gradational in composition into scapolite-pyroxene rocks.

As indicated above, the local presence of pyroxene distinguish the western grey gneisses from the eastern ones. Unfortunately, pyroxene is seldom distinctive in the field and it is relatively easily altered. For these reasons, it is not known if pyroxene is or was present in the felsic gneiss which occurs west and northwest of the Brisson Lake igneous complex and east and north of Salé (Rambois) Lake. If present, it is not common. It is not clear if such rocks should be grouped with the eastern or the western gneisses.

Some pyroxene-bearing grey gneiss is probably derived from green gneiss as indicated by the gradation from green gneiss, to grey gneiss to highly contorted grey gneiss injected by pink granitic material. On the other hand, the gneiss which occurs west of the Brisson Lake complex is apparently the direct extension of the biotite-hornblende

and biotite-garnet gneiss which occurs south of the complex. It is not clear however if the bulk of the pyroxene-bearing grey gneiss is genetically related to the green gneiss, to the eastern metasedimentary gneiss, or, for that matter, to any of these two rock-types.

Pink, Highly Felsic Gneiss and Leptite, Nodular Sillimanite Gneiss

The pink gneisses of the area are divided into three groups: a) partly fine-grained gneiss and leptite described in this chapter, b) medium-grained granite gneiss and mixed gneisses, and c) augen gneiss. Some of these rocks are quite similar and they locally grade into each other.

Highly felsic leptite is abundant near the central and southern occurrences of coarse quartzite. Alone, it underlies large areas north of Hauterive but it also occurs mixed with grey, felsic biotite-garnet and biotite-hornblende gneisses in layers or units ranging from one inch or so in thickness to several hundred feet.

The rock is generally pink or red but a minor part is white. The characteristic leptite is fine-grained, from  $\frac{1}{2}$  to 1 mm. in size, with a sugary appearance but this fine-grained rock is always mixed with medium and coarse-grained pink gneiss. Layering is missing or faint. In the latter case, the layers differ only in grain size or in variable proportions of garnet or sillimanite. Many rocks

show little or no foliation as they are practically devoid of platy minerals. White quartz-sillimanite nodules and lenses stand out sharply against the pink feldspathic groundmass in a minor part of the gneiss and leptite. The nodules are ellipsoidal and up to 6 inches long but more commonly are 2 inches long. They occur generally a few inches to several feet apart. Rarely, they constitute over 25 per cent of the rock. The lenses are schistose and up to 1 foot long and  $\frac{1}{4}$  inch thick. They may be deformed nodules. Quartz and sillimanite also occur in wavy, narrow schistose zones only a few millimeters thick. The nodules are common in the southern exposures of pink rocks whereas the flat lenses are abundant in the northern ones, near Manic 2. Further slight differences seem to exist between the southern and northern occurrences: the massive, fine-grained sugary leptite is common in the southern part whereas the northern rocks may carry a little more biotite, have a better foliation or gneissic structure and appear slightly coarser-grained on the average.

Quartz and feldspar make up more than 95 per cent, in many cases more than 98 per cent, of this granoblastic rock. Microcline-perthite is the most abundant mineral and makes up 40 to 55 per cent of the few thin-sections examined. Quartz is second in abundance (about 35 per cent) and albite is commonly third (0-25 per cent). In many cases, the albite is zoned from  $An_{10-12}$  at the core

to  $An_{03-05}$  at the rim. Garnet is common but garnet-free rocks are probably dominant. It generally makes up less than 1 per cent of the rock but is in conspicuous grains locally up to 5 mm. across. Brown or greenish brown biotite in grains less than 0.5 mm. long may constitute only a small fraction of 1 per cent of many rocks. It becomes coarser where more abundant. Opaque oxides and pyrite are the most abundant accessory minerals in many samples. Other accessories include zircon, apatite, sphene, and allanite. Muscovite, chlorite, and perhaps sphene, are secondary minerals and are scarce. Rarely, muscovite forms a few large flakes visible in hand specimens.

Sillimanite ranges in size from extremely fine fibers up to prism 3 mm. long and 0.2 mm. wide. The quartz-sillimanite nodules consists essentially of these two minerals with small amounts of opaque oxide, garnet, zircon, sphene, biotite and, in one case, green spinel. The main accessories, iron ore and garnet, appear on visual examination to be equally abundant in nodules and country rock and no garnet occurs in the nodules of garnet-free rock. Furthermore, the garnet in the nodules and country rock is of comparable size. In contrast, no feldspar occur in the nodules and no sillimanite outside of them except for minor interpenetration at the nodule boundary. Study of two nodules has shown the presence of about 20-25 per cent by volume of sillimanite (the margin of error is large because of the small size of

some sillimanite crystals). Thus, except for the alkalis, the chemical composition of the nodules and country rock is probably very close. The occurrence of quartz and sillimanite in "shear zones" indicates a late crystallization or recrystallization of these minerals but it may possibly be explained by deformation of quartz-sillimanite nodules. Somewhat similar quartz-sillimanite nodules in granite of the Haliburton and Bancroft area of Ontario have been described by Adams and Barlow (1910). However, they are not absolutely identical to those of the present area as their core contains much tourmaline and muscovite and some nodules contain feldspar. Also, they have a sharp boundary and break cleanly from the enclosing granite.

In the field, the characteristic leptite is distinguished from the pink granitic biotite gneiss by its fine-grained sugary texture, extremely low biotite content, lack of foliation, and local presence of sillimanite and garnet. However, these characteristics may be lacking, especially in the northern occurrences, and the distinction becomes difficult or impossible at many places. Also, the rock may grade laterally into other type as, for instance, north of Hauterive where typical leptite passes gradually southward into granitic biotite gneiss with a few augen. Further characteristics of these rocks may be seen under the microscope: they have the highest potash feldspar to plagioclase ratio (excepting scapolite-bearing gneisses), and the most sodic plagioclase of all the rocks of the area. They also have the lowest calcium and magnesium contents of all the gneisses.

Other Sillimanite Gneisses

The sillimanite gneisses of the area are of three types: (1) the very felsic pink gneiss or leptite described in the preceding chapter; (2) a quartz-rich schistose rock found as layers within or very near the central occurrence of coarse quartzite; (3) a biotite-rich gneiss with or without garnet.

The quartz-rich sillimanite gneiss is well layered and may be schistose. Three thin-sections of this rock contain quartz (50 to 65%), microcline-perthite (traces to 15%), plagioclase (nil to very little), sillimanite (10-15%), biotite (4-8%), garnet (0-3%), and minor muscovite, zircon, and opaque minerals. A very fine white phyllosilicate, forming up to 30 per cent of one section, has pseudomorphously replaced sillimanite plus a little quartz. Secondary chlorite is a minor constituent. This rock has many of the characteristics of the pink leptite: a high potash-feldspar to plagioclase ratio and very low plagioclase content. It differs from it mainly in its layering and gneissic texture.

Biotite-rich sillimanite gneiss occurs at several places in the northeast quarter of the area. Although, they are shown in short lenses on the map, some occurrences may well form thin but persistent units. The rocks are mainly pinkish grey to dark grey. Some show rust-colored weathering. Compositional layering is excellent locally and almost certainly reflects original bedding in some cases. The mineralogy of

this gneiss is quite different from that of the other sillimanite gneiss and more akin to biotite-garnet gneiss in which it occurs. Plagioclase (An<sub>18</sub> to An<sub>35</sub> in four thin-sections) is the dominant mineral. Quartz and potash-feldspar form only a minor amount of some rocks. Red or brown biotite makes up more than 10 per cent, sometimes more than 25 per cent, of the rock. Sillimanite (up to 15%) may occur in narrow shear zones with quartz or may be disseminated through the sample. Garnet forms up to 5 per cent of some samples, is missing in others. Accessories include pyrite, iron ore, zircon, graphite, muscovite, chlorite, and possibly rutile.

#### Pink, Medium-grained, Granitic and Mixed Gneisses

Pink gneisses are common throughout the area. They may be mixed in variable proportion with almost any other type of gneiss. They also occur alone or in greatly dominant proportions in large tracts of ground, especially north of Hauterive, north of the Chute aux Outardes igneous complex, east of the main amphibolite unit, and west of the Brisson Lake complex. The pink gneisses are indicated separately on the map only where they are greatly dominant.

This group includes several varieties of pink to white, highly felsic (commonly less than 5% biotite) quartzofeldspathic gneiss rich in potash-feldspar. Much of the rock consists of rather poorly layered granitic gneiss of even composition which may grade into garnetiferous layered gneiss or into gneiss devoid of layering. Rarely,

the rocks show an excellent lineation but no foliation. The mixed gneisses consist of interlayered pink and grey gneisses which may be extremely contorted and cut by abundant, transgressing granitic veinlets. This contorted, injected gneiss seems especially abundant north of the Chute aux Outardes complex and in a small lens 4 miles northwest of the Manic 2 dam. Granitic gneiss with elongated inclusions and contorted mixed-gneisses grade within short distance into a massive granite with angular inclusions of grey biotite and hornblende gneiss on the east shore of the river 3 miles upstream of Manic 2.

The pink gneisses have a xenoblastic texture. Quartz, microcline-perthite, and plagioclase individually make up commonly 20 to 40 per cent of the rock. Any one of these minerals may be dominant. Microcline can be twice as abundant to only half as abundant as plagioclase. In some cases, it is more abundant than in some grey gneisses. Plagioclase range from  $An_{16}$  to  $An_{31}$  in the sections examined. It may have sharp albite rims against microcline-perthite. This albite is clearly exsolved from microcline as albite rims also occur between microcline grains and, less commonly, at the boundary of microcline and quartz grains. Plagioclase is partly myrmekitic against microcline. Biotite commonly makes up 2 to 5 per cent of the rock. It is brown to brownish green in contrast to the brown or red-brown biotite commonly found in the grey gneiss. Hornblende apparently occurs only

in the vicinity of amphibolite and calcareous rocks. Garnet, where present, forms less than 1 per cent of the rock. Iron ore, apatite, zircon, and in some cases, allanite and sphene occur as accessories. Secondary minerals include chlorite, muscovite, and rarely, epidote.

Some of the well-layered garnetiferous pink gneisses may be sedimentary in origin. On the other hand, the granitic gneiss with inclusions must be of igneous derivation. For the most part, however, the origin of the granitic gneiss is not clear. The cross-cutting veinlets of the mixed gneisses have obviously formed late. In rare cases, for instance at the southern tip of the main amphibolite unit, it is clear that this granitic material has been largely added to the rock, presumably in the liquid form. This may apply also to mixed gneisses in which the pink material increases in abundance near a granitic body. However, transgressing granitic veinlets are so common throughout the area that many of them may well have been generated by local secretion during metamorphism.

#### Augen Gneiss

The augen gneisses may be divided into three groups according to their manner of occurrence. The first group consists of small units found here and there at the periphery of the main igneous complexes. These occurrences are presumably a contact effect and their field relationships are described with the igneous rocks. Augen gneiss of the second

group makes up large and small masses in the northern part of the area. It is not visibly associated with younger igneous rocks and is mixed with pyroxene-biotite quartzo-feldspathic gneiss. The contact between these rocks can be rather sharp as, for instance, near the nose of the syncline about one mile east of the Manicouagan river. Here the composition of the two rock-types is quite distinct and the contact is concordant. At other places, on the other hand, the contact may be gradational either through development of scarce, small augen in the transition zone or through alternance of augen-free and augen-bearing layers. The third group occurs in the southern part of the area. Here the augen gneiss constitute a relatively small part of large, rather homogeneous masses of pink granitic gneiss. The most notable occurrences are west of Lac Salé (Rambois) and northeast of the McCormick dam. No obvious mineralogical difference exists between granitic gneiss and augen gneiss and all gradations can be observed between augen-free gneiss, gneiss with scarce and small augen, and coarse augen-rich gneiss.

Foliation or gneissosity is generally well-developed in the augen gneiss but layering is seldom marked. A lineation defined by elongate augen is conspicuous in some rocks, especially in the northwestern part of the area. Excellent lineation may occur in rocks devoid of gneissosity.

The augen are  $\frac{1}{2}$  to 2 inches long. They are commonly pink or white but some are light grey or even pale green. Some augen consist of single microcline crystals but most are aggregates of a few medium to coarse microcline crystals. The microcline is microperthitic and includes small grains of the other minerals. It includes subhedral crystals of plagioclase in some rocks.

The mineralogy and composition of these rocks are very similar to that of the other pink gneisses. Microcline makes up about 40 to 50 per cent of the few thin sections of augen gneiss examined. This figure, which does not necessarily reflect the true composition of this coarse-grained rock, is higher than the corresponding figure (20-40%) given for the medium-grained pink gneiss and is about the same as that (40-55%) of the fine-grained leptite. The ferromagnesian minerals make up 5 to 20 per cent of the rocks. Dark green hornblende occurs in many rocks but is always subordinate to biotite. Clinopyroxene was detected in a pale green augen gneiss from the northwest part of the area. Garnet occurs in minor amount in some rocks, especially in the comparatively felsic, hornblende-free ones.

#### Stratigraphic Correlation

Any correlation between the paragneisses of the area must be based on correlation of the quartzite units as it is the only rock sufficiently distinctive for this purpose.

Lithologically, the different quartzite units are identical, which is remarkable in view of their high purity. Structurally, the central, southern, and eastern occurrences (and perhaps the two small occurrences near Amédée Lake) either belong to a single formation or else they lens out within the gap of a few miles separating them if no important fault is present. In the second case, they may lie within a restricted stratigraphic interval. The western occurrence of quartzite may also lie at this stratigraphic level but there is little structural evidence for or against this (i.e. it is not known if it lies in a basin or in a dome).

Most of the paragneisses lying east of the Manicouagan river and south of the Brisson Lake igneous complex apparently overlie the quartzite whereas the gneisses occurring west of the river, including the green gneiss, generally lie below it. The relationship between the gneisses from the northern part of the area and the quartzite is not clear but most of the gneisses may lie below the stratigraphic level at which the quartzite occurs.

#### Metamorphic Grade

The gneisses of the area belong to the highest part of the amphibolite facies or to the lower part of the granulite facies. Perhaps they may be placed into the hornblende granulite subfacies of Turner (Fyfe, Turner and Verhoogen, 1958). This is shown, in part, by the abundance of coexisting microcline and sillimanite. Muscovite is not rare but it generally

occurs in minor amounts. Much of it is fine-grained and may well be secondary or retrograde. Large muscovite flakes, which may be primary, are scarce and seem restricted to sillimanite gneiss and associated pegmatite.

Hyperstene and clinopyroxene are common in the green gneiss of the northern and western parts of the area whereas only clinopyroxene occurs rarely in the eastern part. However, the relationship between the two regions is not a simple gradational change. Hyperstene-clinopyroxene gneiss is not everywhere present within the western part and it occurs with abundant hornblende-biotite gneiss free of pyroxene. As mentioned above, the pyroxene gneiss gives way to hornblende-biotite gneiss near pink granitic injections. Thus the hyperstene may well be anterior to many of these injections and some hornblende-biotite gneiss may be retrogressive. In the eastern region, the clinopyroxene is largely restricted to amphibolite and to a few calcareous layers. Chlorite-carbonate patches believed largely pseudomorphous after clinopyroxene are fairly common between the two regions. In summary, the abundance of hyperstene and clinopyroxene in the northern and western parts indicates a higher metamorphic grade in this area but it is not clear if these minerals (and the green gneisses which contain them) belong to the metamorphic period which has affected the eastern part of the area or to an earlier one. This pyroxene assemblage may also represent an early-formed magmatic assemblage partly preserved during a later period of intense metamorphism.

Biotite is ubiquitous throughout the area and it must have been stable under most metamorphic conditions. However, it is scarce or missing in some microcline-garnet-sillimanite leptytes north of Hauterive. Perhaps an unfavorable chemical composition, such as a high iron to magnesium ratio, has rendered it unstable in this case. A hypersthene-microcline-bearing green gneiss from the northwestern corner of the area is free of biotite. It is fresher and its grains are more nearly euhedral than the other green gneisses. This raises the possibility that biotite is retrogressive in many green gneisses, especially since pyroxene has apparently been changed to hornblende in some cases. This is purely speculative however.

The lack of sphene in hypersthene-bearing green gneiss also suggests that these rocks belong to the granulite facies. On the other hand, sphene is present in the pyroxene-free green rocks which appear to have undergone retrogressive metamorphism.

Other interesting minerals characteristic of very high metamorphic intensity are scapolite, andradite-grossularite, bytownite, perthitic microcline, and green spinel. Epidote is scarce and is largely secondary except in scapolite-bearing rocks. Cordierite is present in a sillimanite-garnet gneiss which occurs a few hundred feet west of the highway bridge over the western branch of the Outardes river. It may be the result of contact metamorphism as it occurs near the contact or within an inclusion in the Chutes aux Outardes igneous complex.

### Conclusions

The gneisses of the area may be divided into two groups (hereafter termed "eastern" and "western" groups). Those which occur in the eastern part of the area between the Brisson Lake igneous complex and the green gneiss near Hauterive are commonly well layered. They include quartzite and sillimanite-garnet gneiss and are presumed to be mainly paragneisses. The origin of the gneisses in the rest of the area is a more difficult problem. Some green gneisses appear derived from igneous rocks; other gneisses are excellently layered and may be paragneisses. For the most part however, their origin is uncertain.

The two groups of gneisses show differences other than unequal development of layering and presence of green gneiss in one group. These distinctions follow.

1) Augen gneiss is common in the western group but it is scarce in the eastern group where it occurs only at the periphery of the main igneous masses.

2) The metamorphic grade is slightly higher in the western part.

3) Small bodies of pre-or synkinematic granitic material are more abundant in the western group than in the eastern one.

4) Folding is relatively simple in the eastern group whereas the structure is quite complex in the western one (see Structural Geology below). These differences are slight in some cases but, taken together, they appear significant enough to justify the division of the gneisses into two groups.

The boundary between the two groups is gradational and its location is not shown on the map. It is assumed to lie "stratigraphically" below the quartzite and sillimanite gneiss. This location coincides approximately with the two-fold division on Faessler's map (1933) into "Grenville paragneisses" and younger orthogneiss.

More than one hypothesis may be advanced to explain the relationships between the two groups. It may be argued that the western gneisses consist in part of the same sedimentary sequence represented in the eastern gneisses but much more injected by granitic material. The abundant injections would have caused the more complex structure in the western part. The presence of pyroxene may be due to a slight increase in metamorphic grade in the western and northern parts of the area, but cannot be explained by contact metamorphism of the granitic injections since the mineral appears degraded to amphibole in their vicinity.

A second explanation assumes that the eastern group represents a sedimentary sequence which was deposited over a highly metamorphosed "basement complex" now represented by the western group. This hypothesis fits with the inference that the eastern group apparently overlies the western one and it explains the differences in structure, metamorphism and abundance of injection between them. The pyroxene in the western rocks may have formed in a metamorphic period anterior to the deposition of the eastern group and its great alteration near

the eastern rocks may be due to retrogressive metamorphism near the "wet" sediments during the younger metamorphic period.

The almost complete obliteration of the sedimentary features by the intense metamorphism has left little evidence to choose between the two hypothesis. The first explanation, that the two groups include the same sedimentary sequence, is strengthened by their ill-defined boundary but it dismisses as somewhat accidental their aforementioned differences. On the other hand, the hypothesis of a discordance between the two groups is based on the assumption that the differences are significant. For this reason, it is slightly preferred by the writer although the evidence is inconclusive.

#### Late Igneous Rocks

This chapter deals with igneous rocks which may be considered syn- or post-tectonic since they are partly massive, especially in the central part of the masses, and partly gneissic. They range in composition from basic to acidic but are all considered related in time and origin except for a distinctive mica peridotite. The latter may or may not be Precambrian and is treated separately at the end of the chapter.

The late igneous rocks occur in four main bodies or "complexes", in small satellitic masses, and in several small independent masses.

St. Joseph Lake Complex

This complex occurs a few miles south of St. Joseph Lake, in the east-central part of the area. It is about five miles long and up to two miles wide. Its long dimension is parallel to the axis of the syncline in which it lies. The complex has been divided into five units. Two of these units are of uniform composition, the others are heterogeneous.

(1) A homogeneous mass in the central part of the complex is made up of ortho- and clinopyroxene meladiorite (or andesine gabbro). The rock is generally black, coarse-grained, and unlayered but shows a slight gneissosity due to the parallel arrangement of the tabular plagioclase crystals. Andesine is black on the fresh surface but weathers with a mauve color. The modal composition is listed in the first column of table 1.

(2) A mass of acidic quartz diorite and granodiorite lies at the southern end of the complex. It is 2 miles long and  $\frac{1}{2}$  mile wide. It is of rather uniform composition. (Table 1, no. 5 and 6). The rock is generally light grey but may be pinkish in the western occurrences. It is commonly medium-grained but is locally coarse. The rock shows a slight gneissosity but is unlayered.

(3) Another unit, lying roughly  $\frac{1}{2}$  mile north of the aforementioned granodiorite mass, consists of quartz-bearing hornblende diorite with a lesser amount of more acidic rocks. The hornblende diorite is gneissic, medium-grained, medium to dark grey. Much garnet is present locally. The more acidic rocks

have compositions of granodiorite and quartz monzonite. They are coarse-grained, light grey, partly massive, and carry conspicuous coarse quartz and, occasionally, garnet. At places, the acidic rock cuts the garnet-bearing hornblende diorite. Dark, pyroxene microdiorite occurs at a few places in the mass but its relationship to the other rocks is unknown.

(4) An area, about one mile long and lying north of the pyroxene meladiorite mass, is underlain by a complex mixture of several rock types. Medium to coarse-grained hornblende diorite and quartz diorite are possibly the most abundant rocks. They locally contain much garnet. Some porphyritic or porphyroblastic rocks carry large crystals of red or brown feldspar. Gradations are found from granodiorite with few phenocrysts to monzonitic granite rich in them. Stringers of porphyritic granite, a few inches wide, cut diorite in a few places. Also present are white to light grey felsic gneiss. This rock is medium-grained, partly garnet-bearing and layered. In rare instance, the gneiss appears invaded by diorite and it may be a paragneiss engulfed in the igneous mass. Pyroxene microdiorite is again a minor constituent. The contact between these rocks and the pyroxene meladiorite mass was not observed.

(5) The remaining and largely peripheral part of the St. Joseph Lake complex differs from the previous unit only in the relative abundance of the same rock types. It is domi-

nated by gneissic, coarse, porphyritic or porphyroblastic monzonitic granite with minor hornblende diorite and quartz diorite. The coarse granite locally occurs in large, homogeneous units but it is also mixed with medium-grained, pink or grey granitic gneiss similar to those which occur in force around the complex. Apparent interlayering of these two rock types was noted at several places at the boundary of the complex. However, a different picture is suggested in a road cut at the western limit of the complex. Here, a vertical section perpendicular to the strike of the gneiss shows a deeply-interpenetrating or exaggerated "saw-tooth" contact between the coarse granite and medium-grained gneiss. The contact is transgressive in this section but in smaller exposures or in differently oriented ones it could appear as an interlayering of the two rock types. If this feature is general, then the complex which appears concordant in plan would be discordant in section. Unfortunately, the evidence is inconclusive.

#### Brisson Lake Complex

This complex lies south of Brisson lake in the northeastern part of the area. It is elongated in a direction slightly north of east and is more than 5 miles long by 3 miles wide. Two small satellitic masses occur south of its west end. The bulk of the complex consists of monzonitic granite and augen gneiss but dioritic rocks are also common.

Diorite occurs in the central part of the complex in a body 2 miles long by  $\frac{1}{2}$  mile wide. The north-south elongation of this body is nearly perpendicular to that of the main complex. The rock is devoid of gneissosity. The dominant rock type is a medium to coarse-grained, grey, quartz-bearing oligoclase diorite, (no. 9-, table 1). Plagioclase forms tabular crystals commonly 4 to 8 mm. long but up to 3 centimeters long in some porphyritic diorites. It has a dark grey to purplish core and a light grey rim. A small body of medium-grained, black, pyroxene-bearing meladiorite, (no. 8, table 1) occurs in the northern part of the diorite body. It is cut by minor granite and pegmatite. The west-central part of the main dioritic body contains abundant, angular inclusions of diorite and microdiorite. The enclosing diorite is less mafic than the inclusions. All these rocks, as well as a few aplitic stringers, are in turn cut by irregular dykes of microdiorite. At the southern tip of the body, dykes of biotite-pyroxene microdiorite (no. 25, table 1) cut medium-grained, quartz-bearing, biotite-hornblende diorite, and are in turn cut by narrow dykes of pegmatite. The boundary between the diorite mass and the surrounding granitic rocks varies from abrupt and brecciated to gradational. At the southern limit of the mass, diorite and microdiorite appear brecciated and are complexly injected by pegmatite and granitic material. The bordering granite east of the mass contains sharp, angular inclusions of microdiorite. In the southeastern part, a grey, massive diorite grades imperceptibly into massive quartz diorite and pinkish granodiorite and then pass suddenly into a complex mixture of granite and augen gneiss with large, irregular lenses of gneissic dioritic rocks.

At the northern limit, diorite grades into granodiorite and then, into a complex mixture of medium and coarse-grained massive quartz monzonite, granodiorite, and felsic diorite.

Coarse diorite and quartz diorite occur in another mass  $\frac{1}{2}$  mile long near the western end of the Brisson Lake complex. They apparently grade into the surrounding granodiorite and granite. The mass is cut by a microdiorite dyke along a small, straight valley near its eastern limit.

Diorite, quartz diorite, and granodiorite also occur in several smaller masses or in isolated outcrops among the granitic rocks as, for instance, about one mile east and also, one mile southeast of Brisson Lake. The two satellitic masses south of the west end of the main complex consist of diorite, pyroxene microdiorite, granodiorite and quartz monzonite.

The rocks making up the remaining and largest part of the complex have mainly an oligoclase quartz monzonite (or monzonitic granite) composition but vary much in texture. Four main rock types or end-members are recognized but intermediate types are common.

(1) A medium-grained pinkish grey monzonitic granite contains a moderate amount of biotite and hornblende (no. 12, table 1). It is massive to slightly gneissic.

(2) A coarse-grained massive pink granite is more felsic than the previous one and is locally porphyritic. It carries abundant potash feldspar crystals;  $\frac{1}{4}$  inch or larger, which appear euhedral in hand specimens.

(3) Augen gneisses have a composition similar or slightly more mafic than the monzonitic granites. Some augen consist of single

crystals of potash feldspar and the rock is essentially a gneissic porphyritic or porphyroblastic granite. More commonly, the augen are aggregates of medium to coarse feldspar and quartz crystals. The augen are pink, less commonly white, and are up to 2 inches long. The percentage of augen is uniform in some rocks, variable in others which may have augen-rich layers alternating with augen-poor ones.

(4) The remaining type groups together several varieties of ordinary gneisses. Some are granitic gneiss with low color index and free of layering whereas others are well layered. Some carry a moderate amount of garnet. They look like the common gneisses which surround the complex. It is not clear if they are invaded country rocks or if they are deformed igneous rocks of the complex and they may not all have the same origin. These four main rock-types occur alone or together. Some stretches of ground are made up of a complex mixture of 2 or 3 rock-types. Amphibolite lenses are locally abundant in these mixed rocks.

The medium-grained monzonitic granite is common in the northeastern part of the complex. Alone, it forms homogeneous masses more than  $\frac{1}{2}$  mile long in some cases. It locally contains numerous small inclusions rich in hornblende and biotite. It may grade into the coarse granite or may be in sharp contact with it. In this case, the medium-grained granite is apparently cut by the coarse one but the reverse is occasionally found. About  $\frac{1}{2}$  mile southwest of Brisson Lake, a 15 foot dyke of medium-grained granite cuts clearly across a complex of microdiorite, diorite, augen gneiss, and coarse gneissic granite. The dyke carries angular inclusions of all the invaded rocks.

Coarse, massive, pink granite is abundant and occurs alone over large areas in the southwestern part of the complex. It also occurs mixed with porphyritic granite and augen gneiss east of the southern tip of the main diorite mass. It is cut by narrow dykes of augen rock in a few places but these augen are single crystals. At one place, a sharp contact between coarse granite and augen gneiss cut at an angle the gneissosity of the gneiss. The granite, which is almost massive, is probably later than the augen gneiss in this case.

Augen gneiss is commonly mixed with other granitic rocks. It occurs throughout the complex but is especially abundant near the borders. The contact of the complex with the surrounding gneisses is not sharp as some augen gneiss lies outside the complex among the common gneisses. At places, the passage is rather abrupt from gneisses with a few augen here and there or with few augen-bearing layers to augen-rich gneiss. However, it may be difficult to decide if an isolated exposure belongs to the complex and the position of the contact is in doubt in poorly exposed areas, as at the northwest border of the complex.

Common felsic gneiss occurs in isolated outcrops at several places. Mixed with augen gneiss and minor coarse granite it underlies a rather large area east of the main dioritic mass.

#### Georges Lake Complex

This complex lies at the western border of the area a short distance south of Georges lake (or Georges-Tremblay Lake). Rocks of intermediate composition occur in the western part. In this complex, as in the other ones, granitic rocks tend to surround

the dioritic ones. Thus, acidic rocks occur in force at the southern and eastern borders of the complex. The northern border is poorly known and the western border lies outside the area.

The rocks of intermediate composition are massive or almost massive, medium to coarse-grained. They are deeply weathered. Partially weathered rocks are brown and it is suspected that the fresh rocks are green. They consist of pyroxene-bearing diorite, quartz diorite and porphyritic granodiorite with minor meladiorite and quartz monzonite. Changes in composition, easily detected in the uneven distribution of the microcline phenocrysts, take place within rather short distances but the passage is gradational. A porphyritic granodiorite near the eastern limit of the dioritic rocks show a Rapakivi texture and the phenocrysts are slightly concentrated into faint layers. Two dykes of pyroxene microdiorite, a few feet wide, and two narrower dykes of monzonitic rocks were observed to cut the dioritic rocks.

The contact between the dioritic and bordering granitic rocks is largely unexposed except at the eastern limit of the dioritic rocks. Here a porphyritic granodiorite grades eastward into rocks of varied composition but more acidic on the average. The change is easily detected in the microcline phenocrysts which become more abundant eastward although their distribution becomes much more uneven.

The acidic rocks consist of granitic biotite gneiss and of massive, pink biotite-hornblende granite. The massive granite is medium to very coarse-grained and, in part, is very poor in ferromagnesian minerals. The gneiss is much like the acidic types of common gneisses and is free of good layering. Its gneissosity appears roughly parallel with that

of the surrounding rocks. Some gneisses show poorly developed augen. The massive granite apparently cuts the gneiss in a few places. Massive granite partly occurs in very small bodies among the gneiss but also makes up sizable bodies several hundreds of feet wide. In the eastern part of the Georges Lake complex, homogeneous massive granite passes eastward into mixed granite and gneiss and then into gneiss with very little granite. The boundary of the complex, as indicated on the map, lies near the easternmost occurrences of massive granite. Elsewhere, the boundary of the complex is unexposed or has not been visited.

#### Chute aux Outardes Complex

The Chute aux Outardes igneous complex is the largest one of the area. It is exposed discontinuously over an area of about 25 square miles in the southwestern part of the area. Its southern part is concealed by the coastal plain and its western extension lies outside the area.

This complex is composed of rock types largely similar to those of the other complexes but it differs from them in the relative proportions of these rock types. It is characterized by a great predominance of pink monzonitic granite over dioritic rocks.

A pink porphyritic granite is abundant in a belt some 2 miles wide in the northern and eastern part of the mass. This rock contains abundant microcline phenocryst one inch to 2 inches long and with a sub-rectangular cross-section. It may be massive or may show a preferred orientation of the elongated phenocrysts. The porphyritic granite occurs alone over large areas but also occurs mixed with non-porphyritic, massive or gneissic granite. Dykes of porphyritic gra-

nites carrying inclusions of diorite cut gneissic granite in rare instances.

The porphyritic granite gives way to the southwest to massive or slightly gneissic granite with only minor porphyritic granite. This changes farther southwest into a more gneissic granite and a pink granite gneiss becomes abundant in the southwesternmost exposures of the complex. The gneiss is locally distinctly layered and, perhaps, it should be excluded from the igneous complex. Augen gneiss also occurs in minor amount in this part of the complex. The "eyes" may consist of aggregates of fine-grained quartz and feldspar crystals, of a few medium-grained microcline crystals, or, less commonly, of single microcline crystals.

Rocks ranging in composition from gabbro to green monzonite to pink porphyritic monzonitic granite are exposed on the shores of the Outardes river between the dam and the bridges on highway 15. The intermediate green rocks are dominant in these outstanding exposures. A description of the complex relationships between them follows.

Hornblende gabbro is medium-grained, black to dark grey, massive to gneissic, and hyperstene-bearing in part. It occurs in two main bodies over 100 feet wide near the dam and west of the eastern bridge as well as in a few smaller bodies. The northern mass carries a few very narrow, straight dykes of very mafic biotite-hornblende rock.

All transitions exist from meladiorite, to diorite with scarce or moderate amounts of green perthite phenocrysts, to green monzonite with abundant phenocrysts. These rocks make up the bulk of the area concerned. The different rock types may merge almost

imperceptibly into each other or they may be bounded by sharp contacts. At several places, medium-grained meladiorite clearly shows chilled edges, a few inches wide, of very fine-grained microdiorite against porphyritic monzonite. On the other hand, the same diorite may be cut in turn by narrow veinlets of green porphyritic rock. A zone of monzonitic rock always separates meladiorite from large paragneiss inclusions near the central part of the dam. Abundant, angular inclusions of hornblende gabbro up to several feet in size may be seen in monzonite at the northeastern part of the dam. Both monzonite and gabbro inclusions are cut by a dyke of microdiorite.

A few dykes of quartz-rich, pink porphyritic monzonite granite definitely cut clearly across the green rocks in the gabbro-diorite-monzonite center near the dam. Here, the green monzonite is strikingly similar to the pink monzonitic granite in grain size and abundance of phenocrysts although the pink rock carries more quartz. On the other hand, the green monzonite appears to grade into pink granite near highway 15 as some discontinuous exposures suggest a gradation over a wide zone from green to brown and from brown to pink perthite.

What appears to be very large inclusions occur in the complex near the dioritic center. A mass of quartzite and paragneiss 200 feet long by 30 feet wide is completely surrounded by massive monzonite and granite near the dam. Two much larger masses of pure quartzite are exposed near-by. A well-layered garnet-sillimanite-cordierite paragneiss which outcrop a few hundreds of feet west of the bridge may also be surrounded by rocks of the complex. Smaller inclusions of gabbro have been described above and it is possible that the larger

gabbro masses are also inclusions as they appear lenticular.

Aside from this main dioritic center, twelve other bodies of diorite and granodiorite were found throughout the Chute aux Outardes complex and many more certainly exist. Only the largest masses are indicated on the map. The shape and size of the bodies are generally unknown. The rocks vary in appearance from place to place. They may be porphyritic or not, massive or gneissic. Some rocks have a green fresh surface, others are grey or pink. The massive granodiorite is presumably younger than adjacent granite gneiss but its relationship to massive porphyritic granite is unknown.

The contact of the complex is largely unexposed but appears approximately concordant with the foliation of the surrounding gneiss. On the other hand, small bodies of massive, coarse pink granite, which appear satellitic to the main complex, are clearly transgressive into the gneiss. These bodies occur up to a few miles north and northeast of the complex.

The isolated, easternmost exposures of porphyritic granite on highway 15, two miles east of the Outardes river, may be part of the main complex or may belong to a small satellitic mass.

#### Other masses

A fifth complex is exposed three miles north-northwest of St. Joseph lake at longitude  $68^{\circ}17'$ , latitude  $49^{\circ}22'$ . It appears concordant and may be sill-like. If so, it may be far less voluminous than the other complexes. It consists largely of massive to gneissic meladiorite, diorite, and granodiorite, with local development of augen rock, especially near its periphery. Many of the rocks are deeply weathered in brown and their fresh surface may well be green.

Microdiorite was seen in a few places but its relationship to the other rocks is unknown. Small satellitic masses of mafic diorite cut by felsic rocks occurs east of this mass.

Massive, coarse, mottled hyperstene-hornblende gabbro occurs in small masses, perhaps as dykes, near the western occurrence of quartzite. More altered but apparently similar gabbro also occurs near the central and southern occurrences of quartzite.

As mentioned previously, some of the green dioritic and granodioritic rocks which occur a few miles north of the Chutes aux Outardes complex are quite massive, they are accompanied by microdiorite, and they are similar to the green rocks of the complex. Although described with the green gneisses, they are partly syn- or post-tectonic.

Several small bodies of pink monzonite granite occur here and there. Some are massive, others are gneissic. On the map, the less gneissic ones have been grouped with the late igneous rocks, the more gneissic ones with the common gneisses. The division is arbitrary and probably separates some genetically related rocks.

#### Pegmatite

Pegmatite is common throughout the area but seems especially abundant a few miles southwest of the Georges Lake complex and south of Blanche river, about 1½ mile north of Chutes aux Outardes complex. It occurs mainly as irregular stringers and small dykes but also as dykes a few tens of feet wide. The largest body encountered in the area makes up a high cliff 4 miles northwest of the Manic 2 dam. Pegmatite was followed for 500 feet at the

north end of the cliff but the body may be much longer since the same cliff half a mile farther south is also largely composed of pegmatite. The body is at least several tens of feet wide.

Pegmatite is white or pink but it may also be green among the green gneisses. It generally consist of quartz, plagioclase (near  $An_{20}$ ), microcline or perthite, and minor biotite. Hornblende, garnet, zircon, apatite, and magnetite may or may not be present. Secondary minerals include muscovite, chlorite, epidote, and carbonate. The mineralogy of the pegmatite may be related to that of the country rock. For instance, hornblende is abundant in some pegmatite in calcic or calcareous gneiss. Similarly, a pegmatite within the main calcareous unit contains such diopside and hornblende but no mica. Also, conspicuous muscovite seems restricted to pegmatite within sillimanite gneisses.

#### Microdiorite

This is a dark, very fine-grained, partly pyroxene-bearing meladiorite. Many samples have a diabasic look due to their dark color and fine, lath-shaped plagioclase.

As mentioned previously, microdiorite is common as dykes and irregular masses in each of the complexes. It cuts every other type of igneous rocks but it may also be cut by them.

Microdiorite dykes were observed in at least 15 other places outside of the complexes. These localities are scattered throughout the area. Several of these occurrences are in narrow, straight depressions or linears and it is quite possible that microdiorite dykes are common under the numerous linears of the area (see Structural Geology below).

The dykes are generally a few feet to 10 or 20 feet wide. Their length is unknown but some linears in which dykes have been found were traced for a few miles on aerial photographs. The contacts are sharp and chilled in many cases. Narrow felsic stringers about one inch wide may occur at the contact of the dyke as if the wall-rock had melted slightly against the dyke. Sometimes, the felsic stringers occur in the central part of the dyke or may inject it irregularly.

An interesting feature was observed near the northern border of the area. A dioritic dyke within granite gneiss is locally thoroughly brecciated and injected by granite. The dyke obviously cuts the granite but is injected by it. Yet, an almost parallel dyke of microdiorite about one thousand feet away has very sharp contact against the granite gneiss and is undeformed. According to Krank (1962) Sederholm has described "basic dykes with sharp contacts cutting granite, but occasionally intruded by the same granite. This, according to Sederholm, proves that the granite subsequent to the intrusion of the basic dykes was brought down to the depths where remelting took place". In our case, it is believed that remelting occurred after intrusion of the first dyke but it was only local and not volumetrically important. Also, if the two dykes are not greatly different in age, they may have been injected in hot but solid, or perhaps rheid granite.

#### Petrography

##### Volumetric Analysis, Differences between complexes

Each of the four main igneous complexes varies in composition from pyroxene meladiorite to monzonitic granite but the Chutes

aux Outardes complex also includes hypersthene-hornblende gabbro. Modal composition of some representative samples from the different complexes are listed in table 1. The listed composition of some acidic rocks is not accurate because of their very large grain size. The color index commonly ranges from about 45 in meladiorite to 5 to 20 in monzonitic granite and monzonite with much potash feldspar. Quartz is scarce or absent in meladiorite and some diorite, and increases in amount to 15-30 per cent in pink monzonite granite but makes up to 40 per cent of some quartz-rich granite. The green monzonite of the Chutes aux Outardes complex is leaner in quartz (4-8%) than comparable pink rocks. It also contains less quartz than some pyroxene-bearing green rocks of the Georges Lake complex (no. 23, table 1). The total feldspar content is less than 40 per cent in some gabbro but is commonly near 45-55 per cent in meladiorite and 55-75 per cent in the other rocks. This consists entirely or almost entirely of plagioclase in the mafic rocks. Potash feldspar is generally only slightly more abundant than plagioclase in the most acidic rocks and "true granite" is probably rare, if present. Because they commonly contain oligoclase instead of andesine, some would object to naming these rocks "quartz monzonite". Following Jung (1958) they are here termed monzonitic granite.

Rocks of similar color index may show differences in composition from one complex to another. However, the differences, which are indicated next, are slight and must be regarded with caution as they are generalisation based on few samples. The main differences may be in the abundance of pyroxene in the mafic and intermediate rocks. The Georges Lake complex with a fair amount of orthopyroxene and clinopyroxene in an intermediate rock, may have the highest pyroxene content

Table 1

Modal Composition of Igneous Rocks

Lake St. Joseph Complex

	1	2	3	4	5	6	7
Sample no.	115	C-21	48	47	155	43	112
Quartz	-	7	8	18	20	22	19
Plagioclase	56	47	35	40	59	50	36
Potash feldspar	-	-	10	28	2	10	20
Orthopyroxene	6	-	-	-	-	-	-
Clinopyroxene	19	-	-	-	tr	-	-
Hornblende	5	35	20	8	9	5	7
Biotite	10	10	-	5	10	12	18
Opaque	4	1	3	tr	tr	tr	tr
apatite	tr	tr	1	1	tr	1	tr
Others			23				
Plagioclase comp.	An <sub>45</sub> -An <sub>35</sub>	An <sub>28</sub>	An <sub>32</sub>	altered	An <sub>35</sub>	An <sub>32</sub>	An <sub>27</sub>
Color index	44	46	47	14	19	18	25

- 1- Pyroxene meladiorite, hornblende secondary after pyroxene; from pyroxene meladiorite unit.
- 2- Quartz-bearing meladiorite, from basic to acid mass.
- 3- Basic hornblende rock (metagabbro?), basic to acid mass. Others: 9% stilpnomelane, 7% chlorite and actinolite, 7% garnet.
- 4- Quartz monzonite cutting no. 3
- 5 & 6 - Quartz diorite and granodiorite; from southern, homogeneous quartz diorite-granodiorite mass.
- 7- Porphyritic granodiorite (mode inaccurate as rock is very coarse).

(Cont'd)

## Modal Composition of Igneous Rocks

## Brisson Lake Complex

	8	9	10	11	12	13	14
Sample no.	126	127	82	125	88	406	79
Quartz	6	7	4	11	23	33	39
Plagioclase	43	68	55	39	27	27	26
Potash feldspar	tr	5	5	21	30	30	28
Orthopyroxene	-	-	-	-	-	-	-
Clinopyroxene	2	-	tr	-	-	-	-
Hornblende	21	7	19	tr	7	tr	2
Biotite	16	9	9	18	11	10	5
Opaque	7	2	7	5	1	tr	tr
Apatite	5	2	1	1	1	tr	tr
Others				5			
Plagioclase comp.	An <sub>33</sub> -An <sub>27</sub>	An <sub>26</sub>	An <sub>19</sub>	An <sub>19</sub> -An <sub>16</sub>	An <sub>22</sub>	An <sub>21</sub> -An <sub>17</sub>	An <sub>21</sub>
Color index	51	20	36	29	20	10	7

8- Meladiorite, main diorite unit.

9- Feldspathic diorite, typical of a good part of main diorite unit.

10- Oligoclase diorite, southern border of main diorite unit.

11- Medium-grained, oligoclase granodiorite, northern boundary of main diorite unit.  
Others: 5% sphene.

12- Medium-grained monzonite granite, northeastern part of the complex.

13 & 14 - Coarse, pink, acidic monzonite granite, central and northeast part of complex respectively.

Table 1

(Cont'd)

Modal Composition of Igneous Rocks

## Chutes aux Outardes Complex

	15	16	17	18	19	20	21	22
Sample no.	8-61	448	3-61	5-61	447	323	446	1-61
Quartz	-	-	3	8	6	11	15	33
Plagioclase	37	44	49	39	39	54	30	25
Potash feldspar	-	-	3	34	36	12	43	38
Orthopyroxene	6	-	6	-	-	-	-	-
Clinopyroxene	-	tr	16	-	-	-	-	-
Hornblende	52	37	-	5	11	12	5	3
Biotite	1	6	11	7	4	7	5	tr
Opaque	3	$\frac{1}{2}$	10	4	3	3	1	1
Apatite	1	tr	2	1	1	1	tr	tr
Others		12		2			1	
Plagioclase comp.	An <sub>70</sub> -An <sub>50</sub>	An <sub>75</sub> -An <sub>55</sub>	An <sub>40</sub> -An <sub>28</sub>	An <sub>23</sub>	An <sub>20</sub>	An <sub>27</sub>	An <sub>19</sub>	An <sub>15</sub>
Color index	63	56	45	19	19	23	12	4

15- Hyperstene-hornblende gabbro, Chutes aux Outardes dam.

16- Cummingtonite-hornblende gabbro. Others: 12% cummingtonite. Near highway bridge over Outardes river.

17- Hyperstene-augite meladiorite, Chutes aux Outardes dam.

18- Green porphyritic monzonite. Others: 2% chlorite and carbonate. Chutes aux Outardes dam.

19- Green porphyritic monzonite, on highway near Outardes river.

20- Porphyritic granodiorite, southwestern part of complex.

21- Porphyritic, pink monzonite granite. Others: 1% sphene. On highway, half-way between Manicouagan and Outardes rivers.

22- Medium-grained monzonite granite, western part of complex.

Table 1

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(Cont'd)

Modal Composition of Igneous Rocks

	Georges L. Complex			Microdiorites			
	23	24	25	26	27	28	29
Sample no.	164	113	81	4-61	C-103	192	274
Quartz	9	2	2	tr	tr	1	4
Plagioclase	47	58	58	55	44	59	55
Potash feldspar	21	tr	3	tr	-	tr	1
Orthopyroxene	8	-	-	5	5	9	-
Clinopyroxene	3	15	9	20		10	-
Hornblende	9	24	1	tr	24	12	13
Biotite	1	-	21	5	20	8	18
Opaque	1	1	5	12	5	tr	6
apatite	1	tr	1	3	1	1	3
Others					1		
Plagioclase com.	An <sub>28</sub>	An <sub>35</sub>	An <sub>30</sub> -An <sub>19</sub>	An <sub>43</sub> -An <sub>26</sub>	An <sub>35</sub>	An <sub>31</sub>	An <sub>35</sub>
Color index	23	40	37	45	56	40	40

23- Hyperstene-augite diorite-granodiorite, dioritic part, Georges Lake complex.

24- Augite microdiorite, Lake St. Joseph complex;

25- Microdiorite, Brisson complex.

26- Microdiorite, chilled border of diorite, Chutes aux Outardes complex.

27- Microdiorite, in small complex, 3 miles NNW of St. Joseph Lake. Others: 1% carbonate.

28- Microdiorite, on Hydro-Quebec road, 1 mile northeast of Georges Lake complex.

29- Microdiorite, on riv. Blanche, one mile east of Rambois Lake.

of all the complexes. It is followed in order by the Chutes aux Outardes, St. Joseph, and Brisson Lake complexes. Orthopyroxene was not seen in the latter and clinopyroxene occurs only in some mafic microdiorite and meladiorite. Hornblende is more abundant or equal to biotite in many acidic rocks of the Chutes aux Outardes complex, especially in the green ones, whereas biotite is generally the most abundant of the two minerals in the acidic rocks of the St. Joseph and Brisson Lake complexes. Other differences in the calcity of plagioclase, pleochroic formula of hornblende, and amount of exsolution in perthite are mentioned below under mineralogy.

The microdiorites (no. 24-29, table 1) have a rather constant plagioclase content (near 55-60%) and have a color index near 40. Their mafic minerals consist mainly of pyroxene or of hornblende and biotite. Opaque mineral content is also variable and may exceed 10% of the rock in some cases. The microdiorites are similar in composition to many medium-grained meladiorite but they may contain more pyroxene than the medium-grained rocks. Judging from the modes, the microdiorites from different parts of the area may have a fairly constant chemical composition except for their potassium content. They may have a rather high sodium to calcium ratio for a sub-basic rock as suggested by the low calcity of their plagioclase. Their  $TiO_2$  and  $P_2O_5$  content is also variable but generally high.

### Texture and Grain Size

In many diorite, meladiorite, and hornblende gabbro, plagioclase occurs in euhedral tabular crystals 3 or 4 times longer in the a and c crystallographic directions than in the b direction. This gives the rock a characteristic look, somewhat like a diabasic texture but much coarser. The flat crystals are commonly oriented at random but they show a sub-parallel arrangement in the St. Joseph Lake meladiorite. The ferromagnesian minerals are in subhedral to euhedral grains between the plagioclase crystals. In some other diorite and hornblende gabbro, the plagioclase and ferromagnesian minerals occur in equant, subhedral crystals. All these rocks range in grain size from medium-fine, with crystals 0.5 to 2 mm., to coarse or even very coarse. A rare, pegmatic facies with crystals  $\frac{1}{2}$  inch to 2 inches long occur in the western part of the St. Joseph meladiorite.

The texture of the intermediate rocks is commonly hypidioritic granular. Some rocks are glomeroporphyritic with the coarser plagioclase and ferromagnesian grains segregated into light and dark patches up to 1 cm. across. The matrix surrounding the patches may be fine-grained. Plagioclase is mainly subhedral but may be anhedral. Rarely, it occurs in "battered phenocrysts" as described below. Potash feldspar phenocrysts or porphyroblasts are common in diorite, granodiorite and the more acidic rocks of the Chutes aux Outardes and Georges Lake complexes but they are mainly restricted to monzonitic granite in the other complexes. The rocks rarely contain phenocrysts of both plagioclase and potash feldspar.

The acidic rocks are allotriomorphic to hypidiomorphic. The massive rocks tend to be hypidiomorphic, the gneissic ones are allotriomorphic. In some rocks only biotite shows some crystals faces but, in others, hornblende and, more rarely, plagioclase may be subhedral. Quartz and potash feldspar are anhedral. Some large potash-feldspar crystals appear euhedral with a smooth rectangular cross-section in hand specimens but their borders are actually irregular when seen under the microscope. The crystals must have been euhedral but were deeply indented by post-magmatic or metamorphic reactions. The monzonitic granites vary in grain size from medium-fine ( $\frac{1}{2}$  - 2 mm) to very coarse. The porphyritic granite and monzonite of Chutes aux Outardes complex contain potash feldspar crystals up to two inches long in a medium-grained groundmass. These phenocrysts may have a rectangular cross-section. Some very large phenocrysts (up to 3 inches long) in the St. Joseph complex are well rounded, others are rectangular. A Rapakivi or pseudo-Rapakivi texture (see mineralogy below) is developed locally in the porphyritic rocks of the St. Joseph complex and at the eastern border of the Georges Lake dioritic rocks.

The augen gneisses have been described with the common gneisses. Textural gradations exist between slightly gneissic porphyritic granite and augen gneiss.

The microdiorite is partly porphyritic or microporphyritic. The phenocrysts are not abundant and consist of lath-shaped to stubby euhedral plagioclase crystals up to 1 cm. long. Biotite and orthopyroxene phenocrysts may also be present. The groundmass is hypidiomorphic to allotriomorphic-granular and 0.05 to 0.5 mm

in size. Biotite-hornblende microdiorite free of pyroxene are allotriomorphic and may have suffered more recrystallization than pyroxene-bearing microdiorite. Rarely, the groundmass plagioclase of pyroxene-bearing microdiorite is lath-shaped with a texture tending to pilotaxitic or intergranular.

Mineralogy  
Plagioclase

Plagioclase commonly shows normal zoning in microdiorite and mafic rocks. It is less commonly and less strongly zoned in intermediate rocks, and, except for a sharp, secondary albite rim, it shows no zoning in the acidic rocks. Plagioclase composition differs slightly in rocks of similar color index taken from different complexes. Plagioclase from the St. Joseph Lake complex is zoned from  $An_{45}$  to  $An_{35}$ \* in a sample of pyroxene meladiorite, it is commonly near  $An_{35}$  in other sub-mafic and intermediate rocks, and is near  $An_{30}$  in the acid quartz monzonite examined. Except in one meladiorite ( $An_{47-42}$ ), the Brisson Lake complex has consistently more sodic plagioclase. The mineral is zoned  $An_{33-27}$  in a meladiorite and has an An content from 31 to 18 in several dioritic rocks and 23 to 17 in monzonitic granites. Two augen gneisses from the northern and eastern limits of the complex have more calcic plagioclase,  $An_{31}$  and  $An_{28}$ , than comparable massive granites. The Chutes aux Outardes complex shows the widest range in plagioclase

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\* Practically all plagioclase determinations were done by the method of symmetrical extinctions on albite twins on sections oriented perpendicular to 001 and 010.

The results are reproducible to within 01 or 02 An content but the accuracy is unknown.

composition. Its gabbro contains labradorite and even sodic bytownite ( $An_{75}$ ). A meladiorite and a microdiorite show zoning  $An_{43-25}$  and  $An_{40-25}$ . Determinations on three green monzonite gave  $An_{25}$  to  $An_{20}$  and  $An_{20}$  to  $An_{15}$  on a few pink monzonitic granite. Thus, the plagioclase of these acidic rocks appears just as sodic as that of the Brisson Lake complex. Plagioclase from satellitic masses is comparable to that of the main complex in a few cases at least. Plagioclase in the groundmass of microdiorite is commonly between  $An_{25}$  and  $An_{35}$ . The most sodic plagioclase in microdiorite ( $An_{19}$  and  $An_{22}$ ) was found in the Brisson complex. Thus, plagioclase is relatively sodic in all the sub-basic rocks of the area,

Albite twinning is developed in almost every plagioclase grain and may be accompanied by pericline and carlsbad twinning.

Calcic andesine in the St. Joseph pyroxene meladiorite is deeply clouded except at the rim or around fine (0.005 to 0.02 mm) inclusions composed, in part, of pale green clinopyroxene. The plagioclase phenocrysts in some microdiorites may also be cloudy.

Plagioclase in the intermediate and acid rocks may contain a small proportion of potash-feldspar inclusions. These may have a rectangular outline, and are especially common in large plagioclase grains. They are commonly lacking in small grains or near the border of large ones. Their even distribution in some rocks suggests that they are due to ex-solution. Myrmekite occurs in nearly all rocks which contain potash feldspar and is absent in the others. Its abundance is roughly proportional to that of potash-feldspar at least in the intermediate rocks. It is largely restricted to plagioclase grains in contact with potash feldspar.

Oligoclase in many acidic rocks is bordered by a narrow, sharply-defined rim of albite in crystallographic continuity with it. This rim occurs only against potash feldspar. Since a similar rim is seen occasionally between two grains of potash feldspar, the albite is presumably exsolved from the potash feldspar.

What appears as a single, large plagioclase phenocryst in hand specimen can be made up of several medium-sized grains with sub-parallel orientation. The twin lamellae bend slightly from one grain to the next but there is no fine granular plagioclase bordering the grains, as in a typical protoclastic texture. Such strained plagioclases are common in the Chutes aux Outardes diorite and granodiorite.

#### Potash Feldspar

The development of twinning in potash feldspar varies from place to place. Good grid-twinning typical of microcline occurs in many rocks, especially within the Brisson Lake complex and in some pink rocks of the Chutes aux Outardes complex. It seems largely missing in the green rocks. In many rocks, especially in the St. Joseph complex, the potash feldspar grains show an uneven or patchy extinction with local development of extremely fine grid twinning at the border or within single grains. The smooth passage from well twinned to untwinned parts suggests that the latter may be sub-microscopically twinned. In some other rocks, the grains show a relatively sharp or even extinction without visible twinning. The optic angle in apparently untwinned grains is commonly large but, in one case, it is

approximately  $35^{\circ}$  (optically negative).

Potash feldspar is commonly perthitic. The exsolved material is disposed in very narrow lamellae and in minute blebs evenly distributed throughout the grains except at their borders. The exsolved part, which constitutes only a small portion of the grains, varies in amount from place to place even within a single complex. It is decidedly more abundant in the Outardes and Georges Lake complexes than in the other ones. It is not markedly more abundant in the green rocks than in some pink ones.

Potash feldspar has been replaced by albite and minor quartz along fractures, at the border of grains, along Carlsbad twin boundaries, etc... The replacement is not extensive however and, in the case of albite, may be partly due to exsolution.

The rare Rapakivi texture mentioned above appears clearly in hand specimens: grey or brown potash feldspar phenocrysts have a white feldspar rim about 1 - 2 mm wide. Under the microscope, the single "phenocryst" is seen to consist of several potash feldspar grains in sub-parallel orientation whereas the rim is made up of small granular plagioclase (and myrmekite) grains about 0.5 mm across. It seems probable that a once-continuous plagioclase rim has recrystallized into this granular aggregate.

#### Quartz

Quartz occurs in anhedral grains. It is interstitial and partly wraps around plagioclase crystals in some cases. Several grains apparently disconnected in thin section show simultaneous extinction under cross-nicols.

Secondary or replacement quartz is not abundant but is quite common. It may be intergrown, often in myrmekitic fashion, with plagioclase, biotite and hornblende, and it is present within potash feldspar. Quartz is commonly strained. It may show rolling extinction, or may be composed of a mosaic of grains whose optic axes differ in orientation by a few degrees.

#### Pyroxene

Orthopyroxene occurs in some microdiorites, in the meladiorite mass of the St. Joseph complex, in gabbro and meladiorite associated with the green rocks of the Chutes aux Outardes complex, and in meladiorite and diorite-granodiorite of the Georges Lake body. The last occurrence is the most acidic rock in which it is found. Orthopyroxene is optically negative and slightly pleochroic in green to pink-brown. It contains numerous, brown, bladed inclusions arranged parallel to (010). In the St. Joseph Lake mass, it occurs in isolated grains about 2 mm. long and in smaller, irregular inclusions in clinopyroxene. All inclusions within a single clinopyroxene grain have the same optical orientation. This is probably not a partial replacement of orthopyroxene by clinopyroxene since the isolated orthopyroxene grains are unattacked. Rather, the orthopyroxene inclusions may have exsolved from augite in a post-magmatic reaction.

Clinopyroxene is present in most microdiorites and meladiorites; it may form up to 20 or 25 per cent of these rocks. It is scarce in intermediate rocks, except in diorite-granodiorite of the Georges Lake complex, and is absent in the monzonitic granite.

Traces of clinopyroxene were detected in an acidic quartz diorite of the Lake St. Joseph complex and in a green monzonite near Chutes aux Outardes. The mineral may have a greenish tint under the microscope. In the Lake St. Joseph meladiorite, it is full of extremely fine, opaque inclusions, minute inclusions of hornblende, a lesser amount of orthopyroxene, and minor plagioclase granules.

#### Amphibole

Hornblende is present in all rocks except in some gabbro and microdiorite. It is most abundant in the intermediate rocks and may form less than 1 per cent of some acidic rocks. In the mafic rocks, hornblende may occur in subhedral grains, as partial rims around pyroxene and opaque oxides, and as inclusions in clinopyroxene. It occurs in subhedral to anhedral grains in the intermediate and acid rocks. It may also show a sieve texture. All gradations are seen from a "common" variety of hornblende with pale yellow (X) to olive or brownish green (Z) pleochroism, to a presumably hastingsitic variety with strong to extreme pleochroism in yellow (X), deep green (Y), and very deep blue-green (Z), with strong to extreme dispersion, and with moderate to small optic angle (2V commonly 40-60°, near 25° in some cases with extreme pleochroism). The common variety occurs in the mafic rocks, in some intermediate rocks, and in green rocks. In the Brisson and Chutes aux Outardes complexes, hornblende becomes more and more blue and dark as the rock becomes more and more felsic. It is only slightly bluish with a wide 2V in the acid rocks of the St. Joseph Lake Complex. The hornblende in augen

gneiss at the periphery of the Brisson mass is not as blue and as dark as that in the massive monzonitic granite of the same complex.

Actinolite or light green or bluish green amphibole may occur with common hornblende but is not abundant. It forms partial rims around clinopyroxene and has obviously formed from it in many cases. It is probably later than hornblende.

Cumingtonite makes up about 10 per cent of a hornblende gabbro containing traces of clinopyroxene near the highway bridge over the east branch of the Outardes river. It is colorless, optically positive, and has rather wide 2V. It partly rims hornblende but is in turn rimmed by the latter against labradorite grains. Cumingtonite is riddled with small, irregular, colorless inclusions probably made up of quartz or feldspar. This contrast with the hornblende which is almost free of inclusions. The even distribution of the inclusions suggest that cumingtonite and the inclusions may be derived from the breakdown of a former mineral, possibly hyperstene.

#### Biotite

Biotite occurs in all rocks except in a few microdiorite and in some deeply-altered, chlorite-bearing rocks. It may be greenish-brown, brown, red-brown, or, rarely, brownish green. Red-brown biotite is common in mafic rock containing pyroxene and common hornblende. Biotite associated with dark blue-green hornblende is commonly brown or greenish brown.

Many biotite grains form a very fine, wormy or myrmickite-like intergrowth with quartz and appear replaced by the latter. The replacement is uneven: it may be restricted to a sharply-bounded area to one side of a single grain. In a few cases, the side of grains in contact with altered hornblende is clearly more replaced.

#### Opaque minerals

Opaque oxides are present in almost all igneous rocks. They commonly make up one to several percent of the mafic and intermediate rocks (maximum measured: 12% in microdiorite) and less than one percent of the monzonitic granites. The opaque oxides in the microdiorites examined consist largely of hemo-ilmanite (up to 1/3 hematite) and very minor titaniferous magnetite.

Pyrite occurs in minor amounts in almost all rocks. Grains of chalcopyrite and pyrrhotite were rarely seen.

#### Other minerals

Apatite, zircon, and allanite are primary accessory minerals. Apatite is probably present in all the rocks and makes up a few percent of some rocks. In some places, as in the southern mass of granodiorite within the St. Joseph Lake complex, apatite is unusual in having weak to strong pleochroic haloes in surrounding biotite and hornblende. Zircon has been detected in all intermediate and acidic rocks and allanite in most.

Scattered specks of garnet occur in some porphyritic granite but the mineral is more common in augen gneiss and other granitic gneisses. It is probably most abundant in the St. Joseph Lake

complex. In this complex, it is also abundant in a mafic hornblende-bearing rock, possibly a metagabbro (no. 4, table ).

Other secondary minerals include stilpnomelane, sphene, possible rutile, chlorite, carbonate, sericite, clinozoisite, clay minerals, and limonite. Stilpnomelane was seen only in the garnet metagabbro mentioned above. Sphene occurs in part as secondary rim around opaque oxides and partly as equant grains in some acidic rocks. In the last case, it is not clear if the mineral is magmatic or not. A dark brownish-red mineral with extreme relief, possibly rutile, was seen only in a narrow zone of deformed rocks near Chutes aux Outardes dam. Chlorite and carbonate are common but seldom abundant.

#### Summary and Conclusions

In summary:

- 1) Each of the four main complexes range in composition from meladiorite or even gabbro to granite although the proportion of acidic to basic rocks differs in the different complexes.
- 2) Green rocks occur with pink ones in three complexes.
- 3) The mafic and intermediate rocks tend to occur well inside the complexes and are surrounded by acidic rocks.
- 4) The mafic, intermediate, and some acidic rocks may occur in homogeneous, unlayered masses with little or no gneissosity. The acidic rocks at the border of the complexes are often gneissic and may grade into augen gneiss and common gneiss.

5) Features indicative of an igneous origin such as chilled edges, angular inclusions of different rock types, and clear cross-cutting relationships occur at several places but are especially common in the dioritic rocks.

6) The intermediate rocks are commonly cut by more acidic rocks but the opposite is also seen on occasions.

7) Each complex has mineralogical characteristics visible in many of its rock-types which distinguish it from comparable rocks of some other complexes.

8) Small satellitic masses near the periphery of some complexes commonly have the mineralogical or textural characteristics of the complex.

9) Microdiorite occurs in dykes throughout the area but seems more abundant in the complexes.

10) Plagioclase is relatively sodic especially in the basic to intermediate rocks. Thus, sodic andesine and calcic oligoclase occur in many pyroxene-bearing microdiorite and meladiorite with color indices near 40.

The following conclusions are offered with reservations because the geologic history of the area is exceedingly complex and the simple hypotheses briefly discussed below may well be in error on many points. In particular, some arguments are based on the assumption that similar rock types within the same complex are of approximately the same age but this may not be always true.

All or almost all the igneous rock of a single complex are probably related genetically and are not due to independent injections widely separated in time. This is suggested by the occurrence of the same suite of diverse rock-types in each of the main complexes, by the gradations between rock-types, and by the mineralogical characteristics mentioned above which suggest consanguinity between different rock-types of the same complex (some of the characteristics may well be due to some post-magmatic reactions however). The fact that acid rocks cross-cut intermediate rocks and vice-versa suggests that both types are closely related in time. Similar type of evidence suggests that the green rocks are genetically related to the pink ones:

- a) both green and pink rocks occur in three of the complexes;
- b) green rocks occur in several places in the Chutes aux Outardes complex and not in a single chance occurrence;
- c) green rocks appear to grade into pink ones with identical texture in one case.

The four complexes are identical in many respects and may be of approximately the same age. Together with many small bodies, they may represent a distinct magmatic period or they may represent only the final part of a long magmatic period whose earlier stages are represented by some of the gneissic igneous rocks which have been grouped with the gneisses.

It seems best to correlate microdiorite with the other massive igneous rocks. Although it is, in part, obviously later than all other igneous rocks, it also appears early in some cases. Furthermore, it is similar in composition to the

meladiorite which is generally early. In any case, it is clear that rocks of this somewhat unusual composition have formed throughout and possibly after the main magmatic stage.

If all the igneous rocks are genetically related, they may have evolved from a parent magma of meladioritic composition. This is indicated by the facts that meladiorite is the most basic common rock of the area, that it is generally earlier than the acidic rocks, and, mainly, because microdiorite dykes of relatively uniform composition are widely distributed in time and space. That meladiorite forms only a small part of the complexes may be only a reflection of the level of erosion. As mentioned before, plagioclase is unusually sodic for such basic or sub-basic, pyroxene-bearing rocks. Judging from published description, this feature seems uncommon in other areas of the Grenville province. All intermediate and many acidic rocks appear truly igneous and may have been derived from meladioritic magma by differentiation or assimilation or both. However, some of the acidic rocks, especially augen gneiss and the rocks bordering the complexes, may have formed through metamorphism or metasomatism of the bordering gneiss. Evidence is seen in the very uneven development of augen in some rocks and the fact that some well-formed augen gneisses are mineralogically closer to common gneiss than to characteristic acidic rocks of the complexes. For instance, plagioclase is more calcic ( $An_{30}$  vs  $An_{20}$ ) and hornblende less pleochroic with wider 2V, in some augen gneiss than in massive granite of the Brisson complex. Furthermore, the acidic rocks forming the peripheral part of the St. Joseph

complex faithfully reflect the major syncline in the surrounding gneiss and, in part, must have evolved from them. Unfortunately, because rocks of varied appearance and, presumably, varied origin can be thoroughly mixed-up and because the texture is seldom distinctive (solid-state recrystallization has affected the igneous rocks), it is difficult to decide if some rocks are of igneous or of metasomatic origin.

#### Mica Peridotite

A mica peridotite occurs at the extreme southwest end of a road-cut about 1300 feet past mile post 12 on the Hydro-Quebec road and about 3/4 mile south of the Manic 2 bridge. This is the only exposure of this rock type found in the area. The shape and size of the igneous mass are unknown.

The rock is magnetic, black, and is characterized by large biotite or phlogopite flakes up to 2 inches across. The flakes appear oriented at random. They are poikilitic and slightly bent.

Under the microscope, olivine and its alteration products is seen to occur in elongate, euhedral or subhedral crystals up to 4 mm. long poikilitically enclosed in large mica or in patches of amphibole and of opaque oxide. The amphibole is almost colorless and is optically negative with wide 2V. Amphibole and opaque oxides are in part at least secondary and may have replaced some poikilitic mineral, perhaps pyroxene. The mica is pleochroic in pale yellowish brown but its edges are locally strongly pleochroic in green and are less birefringent. Accessory minerals include apatite, zircon, carbonate, magnetite, ilmenite, pentlandite, pyrrhotite, and possibly sphalerite.

More than half of the olivine is altered into serpentine and magnetite. The thin section observed contains 25 per cent olivine and alteration products, 35 per cent mica and 35 per cent amphibole. These proportions may not be representative of the rock as the latter is very coarse.

The mica peridotite is quite different and is believed unrelated to the other igneous rocks exposed in the area. It is also believed later than the other rock but its age is unknown. Pleochroic haloes are inconspicuous or missing around zircon which suggests that the rock may be relatively young.

#### QUATERNARY

##### Glacial Features

Glacial striae are not abundant. They are oriented between S 10° E and S 45° E. The late ice movement was thus subparallel to the Manicouagan valley and the ice must have flowed appreciably faster, and for a longer time in this deep valley.

Ground moraine is ubiquitous in the rocky highlands but it is thin at most places. It is best exposed in the burnt area near Brisson lake in the northeastern part of the area. Large boulders several feet in size are locally numerous. They consist of the rock types of the area but also include anorthositic rocks. The latter must be derived largely from a known occurrence of anorthosite 10 miles north of the area (Grove 1962). A striking feature is the abundance of large boulders of white or light-colored, fine grained, bedded or cross-bedded quartzite and "quartz-pebble" conglomerate. These erratics make up one fourth of the large boulders at many places. Many have been

split by fire or frost but they were originally well rounded although the rock is exceedingly hard and tough. They obviously traveled a long distance. The only reported occurrences of similar quartzite to the north are in the Marie-Victorin (Otish) mountains some 225 miles north-northwest of the area, and in the Labrador trough, whose southern tip is 250 miles to the north-northeast.

Front moraines are conspicuous in a belt which extends southwest from Brisson Lake, then veers southward to disappear a few miles north of Manic 2. Probable front moraines are visible on aerial photographs at a few places northwest of Manic 2. They trend southeast on the west side of the river. Thus, the front moraines are distributed in a V-shaped pattern whose point lies near Manic 2. Southeast of Brisson lake, the moraines occur in parallel ridges up to one mile long, 30 feet high, and 200 feet wide. The ridges lie about one quarter mile apart in some cases. They consist of a till rich in cobbles and large boulders. The red brown matrix weathers readily in light brown or ash grey,

Several kettle holes and kettle-hole lakes occur in a high terrace about one mile west of the Manic 2 dam. The largest kettle lake is 1000 feet wide and about 150 feet deep (Luc Boyer, personal communication) for an average bottom slope close to 20°. Some fluvio-glacial features found near-by are described in the next chapter.

Manicouagan Valley Deposits

The highest and widest terrace in the Manicouagan valley lie west and southwest of Manic 2. It stands about 400 feet above sea-level near the dam and its surface slopes southward about 10 feet to the mile. It used to fill the valley from side to side. All other terraces downstream from Manic 2 have obviously been carved from the deposits of the high terrace by stream erosion. The highest terrace upstream from Manic 2 occurs near the northern boundary of the area and lies more than 50 feet below the high terrace.

The high terrace generally consists of grey silt and clay overlain by yellow sand. The grey silt locally contains marine (or brackish-water) fossils. The deposits are well-exposed in a high bank on the west shore of the Manicouagan river,  $1\frac{1}{2}$  mile south of Manic 2. Here, very fine yellow sand with a few silt beds which occur on the shore (about 125 feet above sea-level), passes upward into grey silt with a few sandy beds (about 175-225 feet above sea-level). This is followed upward by sand with numerous silt beds, then by coarser sand, and, finally, by sand and gravel at the top (about 380 feet above sea-level). The sand of the upper part is very poorly sorted and generally cross-bedded with abundant, conspicuous fore-set beds. The gravel may be coarse and poorly sorted with a hard, silty sand matrix. Pebble, cobble, and even boulder beds become especially abundant in the vicinity of the kettle lakes.

Although very little silt occurs above 250 feet elevation at this locality, it occurs abundantly up to about 370 feet elevation only one mile away near the dam. A few miles downstream, silt and clay occurs at river level. Here again, a thick deposit of silt grades upward into fine sand with silty beds and then into coarser sand and gravel. Thus, the distribution of silt and sand is rather complex.

The flat surface of the high terrace rises suddenly from about 400 feet above sea-level to 460 feet in the small knobs at its northern edge. This slope locally attains 15-20 degrees. The small mounds have all the features of kames. They consist of stratified material ranging from silty sand to boulder gravel. Sorting is very poor and boulders are common in fine-grained beds. Numerous huge boulders, some over 10 feet across, occurs in the kame north of the kettle lakes. Cut-and-fill structures and fore-set beds are conspicuous and some strata dip relatively steeply.

The sand and gravel deposits in the upper part of the high terrace have much in common with, and merge into, the kame deposits. They are thus of fluvio-glacial origin. They overlie some grey silt and are probably younger than all the grey marine silt in the Manicouagan valley but this is not certain in view of the complex stratigraphy and limited work done so far.

The valley train or fluvio-glacial deposits of the high terrace were deposited during a late readvance of the ice which probably stopped near the present position of the kettle lakes near Manic 2. This agrees with the distribution of the front moraines mentioned above and the fact that the high terrace has no counterpart upstream from Manic 2.

### Other deposits

The coastal plain and the deep valley in the southern part of the area contain thick deposits of grey silt and clay overlain by sand and gravel. The grey silt occurs up to about 350 feet above sea level in the Georges Tremblay river valley and in the valley extending eastward from Manic 2 to St. Joseph lake. The silt and clay are hard, sticky, well-bedded and may be interbedded with fine grey sand. The beds dip gently or "sag" at some places. Complexely twisted beds locally occur between undisturbed layers but are not truncated by the upper layers. The deformation is probably due to slumping caused by recent dissection of the deposits.

The coastal plain is obviously an uplifted deltaic deposit formed at the mouths of the Outardes and Manicouagan river. The large size of these river is responsible for the widest coastal plain on the North Shore between the Saguenay river and Sept-Iles.

Much of the silt on the Manicouagan peninsula may have been deposited during and even after deposition of the sand and gravel of the valley train. It thus seems unlikely that the uppermost silt in the Manicouagan valley is contemporaneous with the uppermost silt of the coastal plain.

### Post-glacial Emergence

Post-glacial uplift is indicated by the former shore lines of the St. Lawrence stranded at different elevations on the coastal plain. They are evident on aerial photographs and are indicated on the map. The higher ones consist of sand and gravel beach ridges, with marshy ground on the landward side in some cases. They may occur in groups separated from the next group by a large area of poorly-drained

ground. This is probably due to uneven uplift of the land. The lower shorelines are marked by steep silt banks forming the edges of broad, flat, wave-cut terraces. The silt may be covered by a few inches to a few tens of feet of sand and gravel on the level part of the terraces.

The highest shoreline recognized in the area lies about 350 feet above sea level. Shorelines near elevation 300 feet apparently encroach on the upper surface of the valley train which, in part at least, must have been deposited when the area stood at least 300 feet lower than at present. The most conspicuous terraces are about 165, 100, 75, and 40 feet above sea level.

### STRUCTURAL GEOLOGY

#### Minor structures

The gneisses generally show a conspicuous foliation which is essentially parallel to the compositional layering where the latter is present. Lamination is only locally well-developed. It is most conspicuous near the axial plane of folds to which it is parallel.

Some granitic gneisses near the western margin of the Brisson Lake complex and along the northern margin of the Chutes aux Outardes complex are unusual in containing well-developed lineation with little or no foliation. The absence of foliation here is not due to lack of biotite as may be the case in some granulitic rocks. The plunge of the lineation is very steep. This unusual feature is possibly related to the intrusion of the contiguous complexes. Some augen gneiss in the northwestern part of the area similarly show conspicuous lineation with poorly-formed foliation. The lineation is sub-horizontal in this case.

The foliation is locally thrown into numerous small folds easily visible in single outcrops. In many tracts of ground, however, the trend of the foliation is constant or gently curving with little or no small folds. The axes of the small folds is roughly parallel to that inferred locally for the larger ones. Another type of small folds is more common: it consists of pygmatically folded granitic veinlets partly transgressive to the foliation of the gneiss. The axial planes of these folds may be sub-parallel to the foliation.

#### Folding

The area may be divided into two parts with markedly different fold patterns. Folding is simple in the large area lying east of the Manicouagan river and south of the Brisson complex. The axial planes trend north or northeast, they are steeply-dipping, and can be easily traced for several miles in some cases. The fold axes are horizontal or plunge gently. On the other hand, folding is quite complex and much less regular elsewhere in the area. The axial planes trend mainly north or northeast but they can be traced only for short distances. The plunge of the axes varies from horizontal to vertical and a least one basin-like structure has very steep dips almost all around.

Large parts of the area are characterized by gently dipping foliation. The possibility of large recumbent folds in these parts is suggested by the rare occurrence of recumbent ptygmatic folds but this is uncertain. On the other hand, moderate to steep dips are especially common near the four main igneous complexes and at least two of the complexes (St-Joseph Lake and Brisson Lake) lie in synclinal or synformal structures. Perhaps most of the steep dips are in narrow synclinal zones which interrupt the broad zones of gentle dips. This style of folding has been called dejective by Stille (1917, reported by Goguel, 1952, p. 127).

#### Linears and Dykes

One of the most striking topographic feature of the rocky uplands in this part of the North Shore consists of numerous straight, narrow valleys forming a system of criss-crossing linears. Some linears are up to ten miles long and run in valleys up to a few hundred feet deep. Thus, the major ones are quite obvious on contoured topo-

graphic maps. Aerial photographs reveal a great many more minor ones. These consist of sharp, straight depressions which may be traced for one mile or more yet may be only a few feet deep and a few tens of feet wide.

The major linears east of the Manicouagan river belong mainly to two main trends: one set strikes about N5E to N20E (longest ones at N10E), the other N20W to N40W. West of the river, the major linears may be slightly curved and are more scattered in orientation. The sets found east of the river are possibly repeated here but may be slightly rotated as a few linears strike N20E to N30E and many strike N5E to N40W (the longest one at N15W). A few major linears also strike near N70E and N75W. Some linears of course do not fall into these groups. Figure 1 is a rose diagram showing the orientation of 137 major and minor linears measured on areal photographs. The preferred trends of the minor linears coincide rather well with that of the main ones.

The linears must be due to pre-glacial erosion along some type of fractures but field observations seldom reveal much about them. The wall-rocks on each side of the narrow linears are similar (although often undistinctive) and most linears may result from a fracture with little or no relative movement of the walls. In about half a dozen cases, linears were seen to coincide with steeply-dipping microdiorite dykes. The direction of some dykes correspond with the main trends in linears indicated above. It is not known however if a large or a small part of the linears result from dykes. In two instances where a linear transects flat-lying foliation, the foliation dips very gently from the linear on

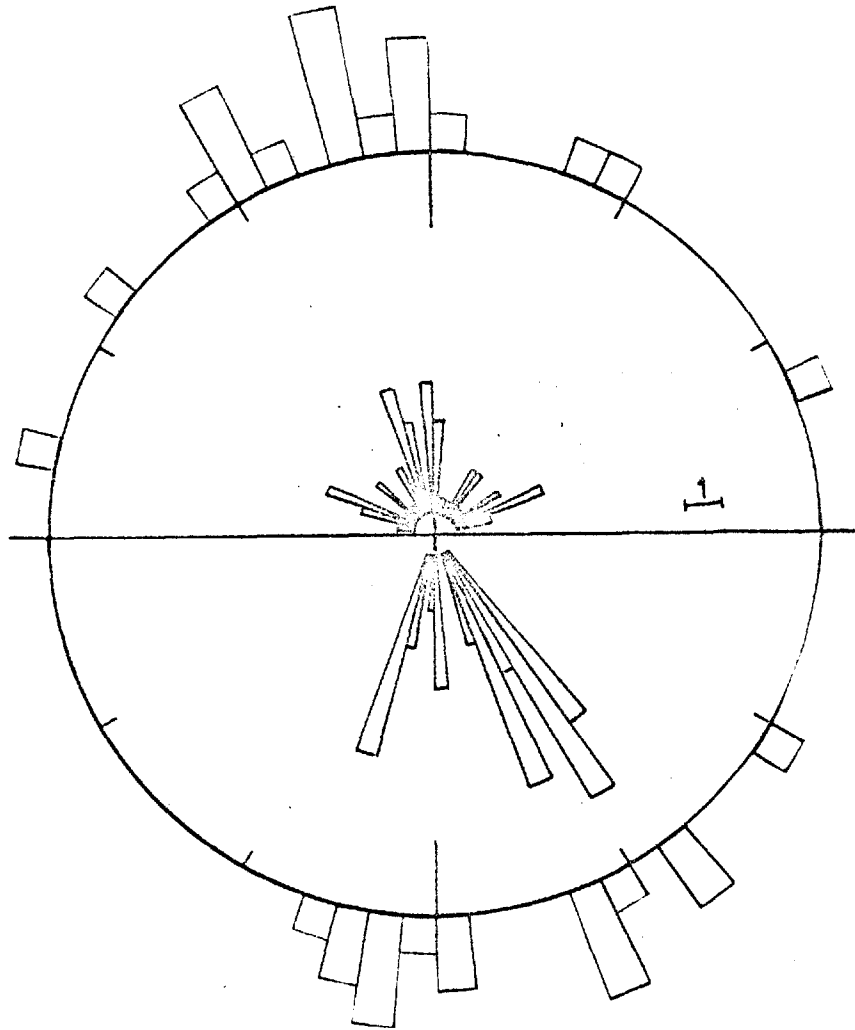


Fig. 1 - Diagram showing azimuthal distribution of linears. Top half: 19 major linears (outer circle) and 46 minor ones (center) from the western half of the area.

Bottom half: 16 major and 56 minor linears from the eastern half of the area.

both walls as if the walls had been heaved up as in doming. The change in dip is very slight however and may be only coincidental. A few shear-zones and breccia zones have been detected in unusually well-exposed places, for instance on the shore of the St. Lawrence south of Hauterive. They were not found in important linears but they may underlie some of them.

The rocks bordering some valleys are altered to characteristic green and red colors. The ferromagnesian minerals are altered to green chlorite and the feldspar is largely altered and stained red. The alteration zone is commonly narrow but may be up to half a mile wide at places. Hydrothermal solutions must have travelled along these linears. Along most linears however the alteration is slight or missing.

The linears cut and are thus younger than the main igneous masses. On the other hand, they are in part at least contemporaneous with, or older than, microdiorite dykes. As mentioned before, the dykes probably formed during and after the intrusion of the main masses.

No spatial relationships is obvious between the linears and the igneous masses or other features of the local geology. This fracture system is more likely a regional feature. For this reason, it would be interesting to know the directions of the forces which caused them; this point is brought up in the next chapter.

### Joints

No joints were measured in the course of the mapping but a detailed study at the Manicouagan 2 dam site has revealed the main sets listed below (L. Boyer, personal communication). They are recorded here because of their importance in such work as dam foundation and because the same trends possibly persist over a large region.

They are:

- set 1, trend N60°E to N70°E, dip vertical, tight joints.
- set 2, trend N20°W to N35°W, dip vertical, tight joints.
- set 3, trend N10°E to N30°E, dip varies from 40°E to vertical to 40°W, the "joints" may show slippage, they are partly "open" and filled with clastic material.

The trends of the joints coincide with those of the major linears although the direction of set 1 is poorly represented among the linears. Hence, the suggestion that the trends of the joints may be regional.

Sets 1 and 2 are about perpendicular to each other, their trend is bisected by the trend of set 3. All these fractures can be explained by a simple system of main compressive forces acting roughly horizontally in a direction N70°W: sets 1 and 2 are then assumed to be conjugate fractures. Shear fractures N20°E / dip 40E and N20°E / dip 40W are also assumed conjugate, and fractures N20°E / dip vertical could be release joints. However, this is highly hypothetical in view of the absence of data on the slip direction. This hypothetical force direction is roughly perpendicular to the axial planes of the folds in the eastern part of the area.

ECONOMIC GEOLOGY

Minor amounts of copper and nickel sulphides were seen in three road-cuts in the area. They were not seen in samples taken from natural exposures and the latter are obviously not representative of the sulphides present. (1) The most interesting samples were collected near mile post 18 on Hydro-Quebec road. A few small chips contain about 1 per cent copper as bornite, chalcopyrite, and malachite. The sulphides fill very narrow fractures, occur at grains contact and replace hornblende in a hornblende-pyroxene pegmatite. (2) A few visible specks of chalcopyrite were detected in meliorite along the abandoned western road, about one mile northwest of Donlon lake. (3) The mica peridotite, whose location is given above, contain a very minor amount of sulphides barely visible to the naked eye. These sulphides consist of pentlandite and pyrrhotite with pentlandite the most abundant of the two.

Black or redish-black, heavy sands rich in titaniferous magnetite, ilmenite, and garnet occur locally on the shores of the Manicouagan river and along the coast. Some deposits are buried in the quaternary sand but others occur right at the surface of the sediments in the tidal zone. Much of the coastal plain was staked a few years ago, probably for the magnetic sands, but most claims have been allowed to lapse.

The quartzite of the area is a possible source of pure silica. The rock is abundant and easily accessible. Content of impurities varies greatly from place to place but is locally very low. Two small grab

samples have yielded on analysis 98.65 and 97.89 per cent silica and 0.11 and 0.13 per cent iron. The samples were not collected because of extra high purity and may be representative of a good part of the quartzite of the area. Faessler (1934) reports 99.71 per cent silica in a quartzite a few miles east of the present area. Many of the impurities are easily detected as scattered grains among the very coarse quartz and a limited amount of field work might rapidly locate some of the purest material.

Sand and gravel are generally abundant in the coastal plain and in the deeper valleys. Some of the old shore-lines shown on the map are beach-ridges and may be a ready source of sand and gravel.

Peat is abundant under the large and numerous swamps of the coastal plain. These deposits, as well as some other deposits, have been described by Faessler (1933).

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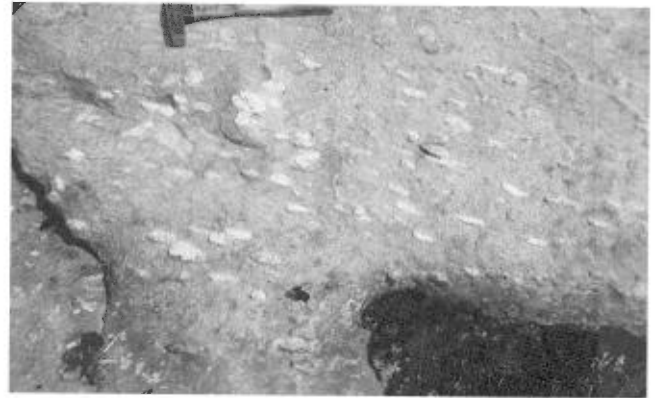
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Hills rising one thousand feet above Manicouagan river,  
northern part of the area.

- 105 -



White quartz-sillimanite nodules in quartz-feldspar leptite or gneiss almost free of ferromagnesian minerals. A few miles northwest of Hauterive.



Banded paragneiss separated from diorite (smooth area to the right) by green porphyritic monzonite (pitted). The three units are cut by pink porphyritic quartz monzonite (rough surface, upper left-hand corner). Chûtes-aux-Outardes.

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Coarse diorite with angular inclusions of meladiorite (darker), both cut by irregular dykes of microdiorite (smooth, grey area, two feet left of hammer). Northeastern part of Brisson Lake complex.



Diorite or amphibolite inclusions in quartz monzonite. Brisson Lake complex.



Microdiorite dyke.



Front moraine in burnt area east of Brisson Lake.



Kame deposit. Large boulders of folded gneiss (one above observer) in bedded fine sand. Stratification dips  $35^{\circ}$  on top of boulder near feet of observer, lies sub-horizontal near his compass. Sand pit  $1\frac{1}{2}$  mile west-northwest of Manic 2 dam.



Superimposed current ripple-mark in sand. In small valley southwest of Caouette lake.