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LAC SAINT-JEAN AREA, SOUTHERN PART

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GEOLOGICAL REPORT 140

LAC SAINT-JEAN AREA

(Southern Part)

by
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INTRODUCTION

Location and Extent

The present map-area covers 2,000 square miles adjacent to the south shore of Saint-Jean lake. It is bounded by latitudes 48°00' and 48°30' and by longitudes 71°30' and 73°00'.

Several villages are located in the northeast part of the area. They include Hébertville, Saint-Bruno, Larouche, Saint-Gédéon, Lac-Sainte-Croix, Saint-Jérome, Desbiens, Chambord, Val-Jalbert, Sainte-Hedwidge, Lac-Bouchette, Saint-François-de-Sales and Saint-André. The town of Roberval is located about 1 mile north of the area.

In order to record the geological data, the map of the area was divided into the following sheets:

Sheet	Latitudes	Longitudes
I - Goélands Lake Sheet	48°00' to 48°15'	72°30' to 73°00'
II - Commissaires Lake Sheet	48°00' to 48°15'	72°00' to 72°30'
III - Chambord Sheet	48°15' to 48°30'	72°00' to 72°30'
IV - Huard Lake Sheet	48°00' to 48°15'	71°30' to 72°00'
V - Hébertville Sheet	48°15' to 48°30'	71°30' to 72°00'

The east part of the Goélands Lake sheet (Map No. 1524) is included in preliminary Report No. 515, entitled: "Geology of the Trenche River Headwaters Area".

Means of Access

The area is easily accessible by means of several roads. Highway 54A, which links Quebec City with Hébertville, crosses the Laurentides National Park in the east part of the area, and secondary roads lead from the interior villages to Highway 55, which connects all the villages bordering Saint-Jean lake.

The central part of the area may be reached by means of the road leading to La Tuque, Lac-Bouchette and Chambord, which is jointed by several roads of hunting and fishing clubs, old logging roads and waterways from some of the larger lakes, such as Ecarté lake and Commissaires lake.

The Canadian National railway line, which passes through Chambord, Lac-Bouchette and Rivière-à-Pierre, crosses the area in a north-south direction to the east of the La Tuque - Lac-Bouchette road.

Translated from the French.

Several roads built and maintained by lumber companies provide access to much of the west part of the area. These include the road connecting Roberval, Sainte-Hedwidge and Brûlé lake, the one connecting Sainte-Hedwidge, Ross lake and Brûlé lake, which joined the road to La Tuque and Lac-Bouchette in the fall of 1966, the road which follows the upper course of the Croche river, and the one which joins Sainte-Hedwidge to La Tuque, which follows the terrasses of Trenche river at the western boundary of the area. Secondary roads branching off from these routes lead to the camps of hunting and fishing clubs or to old logging camps.

This network of roads, along with the waterways and portages, makes the entire region easily accessible.

Field Work

F. W. Benoit studied the Lac Saint-Jean area during the four field seasons, as follows:

in 1961, the Goélands Lake sheet (western half);
in 1962, the Commissaires Lake sheet;
in 1963, the Goélands Lake sheet (eastern half) and the Chambord sheet; and
in 1964, the Huard Lake sheet and the Hébertville sheet.

Part of the area was mapped by means of traverses spaced about one-half mile apart. The Huard Lake and Hébertville sheets were covered with a less systematic traverse network, the density of study depending on the outcrop concentration and the topography.

All the rock exposures alongside the roads and main lakes were examined. Pace-and-compass traverses were run with the aid of aerial photographs at a scale of one-half mile to the inch, and the information was later transferred to topographic base maps on the same scale.

Previous Work

Although F.D. Adams studied the anorthosites of Lac Saint-Jean area near the end of the last century, the only work of importance in the southern part of the area was that of Dresser (1916). This work, however, was confined to "an area of approximately 200 square miles around the south half of the lake ..." Dresser's map, in fact, does not show the geology to the south of latitude 48°20'.

During the summers of 1958 and 1959, J.-Guy Bray mapped a 400-square-mile area adjacent to the northwest part of the present map-area. This work resulted in two preliminary reports (Nos. 387 and 421). A final report will be published soon.

DESCRIPTION OF THE AREA

Topography

The underlying bedrock of the area is reflected in the topography. Bordering Saint-Jean lake, where the bedrock is made up chiefly of Paleozoic shales and limestones, the terrain is flat and supports the most fertile arable land in the area.

Away from the lake valley, the landscape is typical of the Laurentians, with undulating plateaus elongated in a vaguely apparent pattern. The depressions are filled by numerous lakes of all sizes. Highly irregular in outline, they are encircled with rock exposures, such as those at Commissaires lake, or are rimmed with sandy beaches, such as many of the small lakes visited by tourists along the road connecting Sainte-Hedwidge, Ross lake and Brûlé lake.

Elevations range from 340 feet, which is roughly the level of Saint-Jean lake, to 1,750 feet north of Honorat lake, in the southeast corner of the Commissaires Lake sheet. The Huard Lake area is an exception, with a few peaks rising to 2,000 feet, but the local relief is rarely more than 700 feet.

Drainage

The entire area is drained through a widespread network of major rivers. Within the Goélands Lake sheet, Trenche and Croche rivers, augmented by several tributaries, flow south into Saint-Maurice river. Ouiatchouaniche, Ouiatchouane, Métabetchouane and La Belle rivers flow into Saint-Jean lake. Ecorces river, which drains the southeast corner of the area, empties into Kenogami lake.

A prominent chain of lakes, including Ecarté lake, Lizotte lake and Commissaires lake, constitutes a large water reserve, the level of which can be controlled by means of a dam between Commissaires lake and Bouchette lake. These waters follow the course of Ouiatchouane river, which includes a 245-foot fall near Val-Jalbert.

Resources

The cultivated lowlands bordering Saint-Jean lake are the most fertile in the area. A few farms have been established away from the lake valley, such as at Saint-André, Saint-François-de-Sales and along the La Tuque and Chambord road as far as south of Bouchette lake, but much of this land, generally silty and not too fertile, has been abandoned and returned to fallow, particularly alongside the railway line to the southeast of the village of Lac-Bouchette.

The uncultivated land supports a flourishing lumber industry. The large-scale woodcutting operations have now moved toward the south, to Van Bruyssel, and toward the west, to the northwest of the Commissaire Lake quadrant, where Consolidated Paper Company has established important logging camps.

The tourist industry has also been of value to the area, and numerous private clubs hold hunting and fishing rights in the vicinity of the woodland roads in the west part of the area. The Laurentides National Park encroaches on a large part of the Huard Lake sheet. Here, hunting and fishing have been placed under special restrictions.

GENERAL GEOLOGY

All of the rocks of the area are Precambrian in age, with the exception of a remnant of Ordovician rocks along the south shore of Saint-Jean lake.

The Precambrian rocks can be divided into three types: the clearly sedimentary and mixed gneissic rocks, the pyroxene-bearing plutonic rocks and the granitic rocks.

The rocks of sedimentary origin, generally considered as belonging to the Grenville Series, are the oldest of the area. They include layered gneiss, with silicated limestones, pyroxenites, quartzites, sillimanite gneiss and amphibolites. These rocks are intimately associated with mixed gneiss, and the whole assemblage shows evidence of later injection and granitization.

The pyroxene-bearing plutonic rocks are made up of basic rocks, from anorthosite to anorthositic gabbro to gabbro, and of pyroxenic intermediate and acidic rocks, including diorite, monzonite, syenite, granite, etc. These pyroxene-bearing rocks were emplaced later than the gneisses of the Grenville Series.

The granitic intrusives form widespread variable-textured massifs throughout the area and seem to have played a role in the enrichment in pink potash feldspar that characterizes certain facies of the earlier series.

During the Paleozoic, Ordovician rocks were deposited on the Precambrian basement. A remnant of these rocks has been displaced downward by a system of faults and protected from erosion. The southern part of this remnant outcrops along the shore of Saint-Jean lake.

TABLE OF FORMATIONS

CENOZOIC	RECENT	Stream and lake deposits; gravel, sand, mud, clay and organic deposits.	
	PLEISTOCENE	Glacial and fluvioglacial deposits; moraines, eskers, till, sand and gravel.	
DISCONFORMITY			
PALEOZOIC	ORDOVICIAN	Utica Group	
		Trenton Group	
DISCONFORMITY			
PRECAMBRIAN		Dikes	Diabase and basic rock
		Granitic rocks	Pegmatite Porphyritic granite Alaskite
		Pyroxene-bearing rocks	Intermediate and acidic: green gneiss in contact with paragneiss mixed green rocks containing hornblende and pink feldspar green hypersthene - microperthite rocks Ultrabasic and basic: gabbro anorthosite
		Meta-sedimentary rocks	Mixed gneiss Gray gneiss Layered gneiss Amphibolite Sillimanite gneiss Quartzite Pyroxenite Silicated limestone

Metasedimentary Rocks

The metasedimentary rocks comprise layered gneiss associated with silicated limestone, pyroxenite, quartzite, sillimanite gneiss, amphibolite and gneisses of uncertain origin that have been termed mixed gneiss.

The layered gneiss and mixed gneiss are quite widespread throughout the area, and are particularly abundant in the center of the Commissaires Lake sheet. The assemblage of layered gneiss interstratified with silicated limestone, pyroxenite, quartzite and sillimanite gneiss underlies about one-fifth of the west half of the Goélands Lake sheet, as well as a small area in the southwest part of the Huard Lake sheet. Smaller lenses have also been noted within the Commissaires Lake sheet.

Silicated Limestone

Two main types of silicated limestone, one containing scapolite and the other containing scapolite and diopside, occur as interbeds within the other metasedimentary rocks. The beds range from a few inches to almost 5 feet in thickness, and the rocks are medium to coarse grained.

The *diopside-scapolite rock* is light green on fresh surface and greenish gray on weathered surface. It is generally made up of 60 to 95% diopside, with scapolite and calcite as the main accompanying minerals. The accessory minerals include quartz, feldspar, phlogopite and zircon. Veins of milky quartz generally accompany this diopside-bearing rock, and locally make up as much as 20% of the beds.

The *scapolite-bearing rock* is light gray, with a faint bluish tinge on fresh surface and dark gray on weathered surface. It contains from 50 to 80% scapolite. The main accessory minerals are quartz, calcite and garnet.

Pyroxenite

A few bands of pyroxenite, from 1 inch to 2 feet thick, are intercalated within the metasedimentary rocks. They are dark green on fresh surface, weathering to black. In addition to the dark green pyroxene, these rocks contain 5 to 15% calcic plagioclase.

Quartzite

Quartzite occurs in beds up to 10 feet, although generally less than 3 feet, in thickness. The rock is medium to coarse grained, light gray on fresh surface and dark gray on weathered surface, and made up of more than 95% quartz, with accessory feldspar, garnet, biotite and opaque minerals.

Sillimanite Gneiss

A gneiss which weathers to an amber color has been noted near the beds of silicated limestone. It is fine to medium grained, and contains tiny needles of yellowish sillimanite showing a linear orientation. The other constituents of the rock include quartz, plagioclase, potash feldspar and biotite.

East of Huard lake, garnet-rich paragneisses and lenses of a paragneiss containing quartz, potash feldspar and sillimanite have been noted. The latter rock locally exhibits granules of dark green spinel intimately associated with the sillimanite. The spinel is rimmed with

cordierite and is thus isolated from the quartz. The cordierite also contains prisms of sillimanite and is easily identified by the pleochroic halos surrounding tiny inclusions of zircon.

Some garnet-sillimanite gneiss and some cordierite-sillimanite gneiss are intercalated within the layered gneiss in outcrops along the north shore of Carpe lake, in the northeast part of the Huard Lake sheet.

Amphibolite

Amphibolite, which outcrops in only a few places, is intimately associated with the paragneiss. It occurs as bands or lenses up to several tens of feet thick, and makes up 5 to 40% of the outcrops in which it is exposed.

The rock is dark green to black on fresh surface and dark gray on weathered surface. It is medium to coarse grained, and well foliated. These amphibolites contain up to 75% hornblende, with plagioclase and accessory biotite, magnetite and apatite.

Bands of similar composition are intercalated within the layered gneiss, but they are rarely more than 3 inches thick and have been mapped as hornblende gneiss.

Layered Gneiss

The layered gneiss is composed of alternating gray, dark gray, black and pinkish bands, generally altering to a black weathered surface. The rock is medium grained and usually well foliated.

A hornblende-biotite gneiss is most typical. It makes up, in fact, almost 95% of the metasedimentary rocks of the area. This is a banded rock, with the bands rarely more than 1 foot thick and usually ranging from a fraction of an inch to 3 or 4 inches across. Variations in the hornblende-biotite content, which ranges from 5 to 80%, are responsible for the variable composition of the bands. In addition to hornblende and biotite, the gneiss contains plagioclase, potash feldspar, and quartz, as well as minor amounts of iron oxide, apatite, zircon and garnet.

Some of the bands are exceptionally rich in plagioclase and quartz. Locally, the gneiss contains up to 30% garnet.

Gray Gneiss

A zone of gray gneiss, trending northeast, is apparently confined to the southeast corner of the area, within the Huard Lake sheet. Locally characterized by a well-marked regular foliation, it is light gray

and medium grained, and composed mainly of quartz, plagioclase (sodic andesine) and biotite.

Typical exposures of this rock have been observed alongside the road through the Laurentides National Park, about 2 miles south of the bridge across Ecorces river. Here, the gray gneiss contains concordant lenses of hornblende gneiss. A related rock type, seen in some of the outcrops, contains variable amounts of hornblende.

This gray gneiss is quite widespread in other areas within the Grenville province.

Mixed Gneiss

Almost all of the outcrops of layered gneiss include some pink, generally concordant, granitic material. Medium to coarse grained, this material is distributed in several forms: as individual crystals of pink feldspar making up augen gneiss, or as lenses, sills or locally pegmatitic dikes.

The granitic material generally makes up 3 to 40% of the exposures of mixed gneiss, although there are rare occurrences of migmatite in which the granitic content is as high as 60%. In several places, augen gneiss grades into a porphyritic granite described later in this report.

Field observations suggest that most of the mixed gneiss has resulted from the action of later granitic intrusions on the metasedimentary bedded gneiss.

Where these mixed, lit-par-lit and augen gneisses are seen, in the field, to contain more than 20% potash feldspar, they have been mapped as a separate unit.

Pyroxene-bearing rocks

The pyroxene-bearing rocks of the Lac Saint-Jean area consist of a series of intrusives that have been subdivided into two principal members: ultrabasic and basic pyroxenic rocks, and intermediate and acidic pyroxenic rocks. These two members embrace numerous facies, and the most widespread will be described.

ULTRABASIC AND BASIC PYROXENIC ROCKS

The ultrabasic and basic rocks of the pyroxene-bearing series comprise anorthosite, gabbroic anorthosite, anorthositic gabbro and gabbro,

generally within the same intrusive mass. Although exposures are discontinuous around these basic massifs, it appears that there is a gradual transition from one facies to another, and that, in general, the more gabbroic facies are confined to the border zones.

The largest massif is located in the northeast part of the area, near the villages of Saint-Gédéon, Hébertville, Saint-Bruno and Larouche. Three smaller massifs are also of interest. One is located south of Desbiens, another about 1 mile east of Brûlé lake and the third near Bouchette lake.

Massif in the Northeast Part of the Area

The anorthosite of the massif in the northeast part of the area is characteristic of the rock that has been quarried and marketed as the "black granite" of Lac Saint-Jean. Anorthosites occur at Saint-Gédéon, Saint-Bruno, Larouche and Hébertville, but are particularly abundant along the road between Saint-Gédéon and Larouche, where a series of blackish gray outcrops gives the cultivated fields a hummocky appearance.

These generally massive anorthosites are composed of large black plagioclase crystals up to several inches long. Dark brown hypersthene crystals up to 1 foot in length have been noted in outcrops along the road between Saint-Bruno and Larouche. Deformation has affected these hypersthene crystals, and curving crystal faces are commonly observed.

Most of the anorthosite can be seen, under the microscope, to be made up of more than 90% of a plagioclase that is clouded with opaque dust-like material. The composition of this plagioclase ranges from 48 to 50% anorthite (measured by immersion techniques).

The irregularly distributed hypersthene is characterized by a strong pleochroism and by a refractive index, $M_Z = 1.696 \pm 0.002$, which indicates the approximate composition $Em_{75}Fs_{25}$.

Two chemical analyses, reported by Bertrand (1963), of a sample of similar hypersthene obtained from a quarry to the north of Saint-Gédéon show an alumina content of 6 to 8%.

The hypersthene crystals are also clouded with opaque dust-like material, and contain lamellae of plagioclase with a more calcic composition (75% anorthite) than that of the plagioclase which forms the main body of the rock.

Olivine-bearing Anorthosite

The anorthosites which outcrop 2½ miles south of Saint-Gédéon, along the road following La Belle river, contain crystals of clear green vitreous olivine up to ½ inch across. Under the microscope, these olivine crystals are seen to be surrounded by reaction rims of orthopyroxene and clinopyroxene. The clinopyroxene is locally associated with light green biotite.

The opaque minerals also show reaction rims of biotite, clinopyroxene and, in places, hornblende. A few grains of primary hypersthene have been noted.

Banded Anorthosite

A clearly banded anorthosite has been noted in several outcrops between Larouche and Saint-Bruno. The purplish to light gray bands are up to 2 inches thick. This anorthosite contains 1-inch-long lenticular crystals of hypersthene, generally rimmed with biotite and hornblende. Under the microscope, the ferromagnesian and opaque minerals show a definite orientation.

The hypersthene is covered with opaque dust-like material and is generally surrounded by remnants of hornblende and biotite. The opaque minerals, magnetite-ilmenite, are bound to dark green grains of spinel. The plagioclase, with a composition of 50% anorthite, is clouded with opaque granules.

Locally, the anorthosite grades into a basic olivine-bearing rock. For example, a modal analysis, carried out by means of an integrating ocular (Zeiss), on a massive, fine-grained rock from west of Cascouia lake gave the following results:

olivine	10%
clinopyroxene	36%
plagioclase	45%
opaque minerals ..... (magnetite-ilmenite)	7%
biotite	2%
apatite	traces
calcite	traces

The plagioclase, as determined by immersion in oils, has a composition of 40% anorthite.

About 1 mile from the above-mentioned locality, near the cottages along Cascouia bay, the anorthosite is brecciated and injected by pegmatite. The rock is fine grained, well foliated and purplish.

The plagioclase of this rock type is an antiperthite in which some of the grains have been replaced by scapolite. In addition, grains of perthitic microcline and, associated with the opaque minerals, crystals of hornblende and biotite have been noted.

A dike of fine-grained pink granite, at least 10 feet thick, horizontally intrudes the black anorthosite at the west end of Kenogami lake. The contact, well exposed on the side of an escarpement, is quite sharp. There is no trace of a reaction zone in the anorthosite, but the granite is greenish gray for about 6 inches from the dike walls. Minor sulfide concentrations have developed in this contact zone.

Anorthosite South of Desbiens

The anorthosite to the south of Desbiens has been subjected to considerable late granitic intrusion, and thus has a widely variable composition. In certain places, toward the center of the massif, the rock has similar characteristics to the previously described anorthosite. The border zones, however, have a completely different composition, particularly where the granitic intrusions are abundant. The southeast part of the massif, in particular, is made up of a hornblende- and biotite-rich rock which does not have any of the hydrophobic characteristics of the original anorthosite.

Anorthosite of Brûlé Lake

The anorthosite which is exposed 1 mile to the east of Brûlé lake, west of Commissaires lake, takes the form of a circular body about 2 miles in diameter.

The core of this body is made up of coarse-grained gray to white anorthosite. The rock is composed of more than 90% antiperthitic plagioclase (An_{45}), in crystals which are locally up to 4 inches in length. In addition, it contains disseminated grains of opaque minerals, accompanied by hornblende, as well as interstitial perthite, the latter separated from the plagioclase by a fringe of myrmekite. Accessory minerals include biotite, calcite, apatite, sericite, epidote and, locally, concentrations of garnet.

This anorthosite gives way to basic and acidic pyroxenic rocks to the northeast of the massif. The change occurs over a short distance and, based upon discontinuous exposures, appears to be gradational. East of the massif, a dike of hypersthene diorite, about 8 inches wide, is intrusive into the coarse-grained white anorthosite. This dike rock will be described later in this report.

Anorthosite of Bouchette Lake

The anorthosite at Bouchette lake forms the south part of a tongue of pyroxene-bearing basic rock, trending north-northeast, which disappears beneath the Trenton near Val-Jalbert. Typical exposures of this rock can be seen alongside the Lac-Bouchette and La Tuque road, to the south of Bouchette lake and at the south extremity of the island in Ouiatchouane lake.

South of Bouchette lake, along the road which leads to Grêle bay on Commissaires lake, the anorthosite has, in several places, been injected by pegmatite dikes and quartz veins. Hornblende and biotite have been noted in the anorthosite bordering these intrusions.

Generally, the Bouchette Lake anorthosite is a fine-grained rock, with a saccharoidal or granular texture. The color varies from pure white to light or dark gray, depending on the ferromagnesian content. A characteristic foliation is generally visible, and may be quite distinct in places. South of Bouchette lake, the foliation is accentuated by a linear arrangement of ferromagnesian minerals (hornblende and biotite), concentrated in lenses from 1 inch to 4 inches long or in slender, discontinuous lenticular bands which range to more than 1 foot in length.

The anorthosite at the south end of the island in the north part of Ouiatchouane lake has been so badly sheared that it exhibits a granularity and sharp foliation that could be mistaken for that of a paragneiss. Some of the anorthosite bands, in addition, contain nodular crystals of pink feldspar, 1 inch in diameter, which later laboratory studies revealed to be porphyroblasts of plagioclase (An_{45}).

In the hilly country to the north of Ouiatchouane lake, the white granulated anorthosite grades into a gray rock and into a grayish white and black banded rock. The dark bands are rich in ferromagnesian minerals, which, within the shear zones, comprise hornblende and relicts of pyroxene. Several samples contained crystals of hypersthene, locally deformed, which were filled with exsolution laths of clinopyroxene. A few crystals of orthopyroxene were also noted. The fractures in this mineral were filled with finely twinned needles of cummingtonite.

This interbanding of the hornblende-bearing rocks and the grayish anorthosite can be easily seen on the grounds of the sanctuary of Notre-Dame-de-Lourdes, at the foot of the statue of Saint-Antoine. Farther to the west, however, these rocks are locally intercalated with layered biotite gneiss, and their identification becomes almost impossible if one has not observed the gradual transition from granular anorthosite.

Within the Chambord sheet, north of Bouchette lake, the anorthosites resemble those at Brûlé lake, except that they have been subjected to granulation near the fault zone which extends north from Bouchette lake to west of Chambord.

Several samples of plagioclase from the granular anorthosites of the Bouchette Lake area were studied by immersion techniques and, on the universal stage, by the Rittmann zone method. They are composed of anorthite, between 50 and 55%, except for the nodular pink plagioclase of Ouiatchouane lake, which has a composition of 45% anorthite. Several of the plagioclase grains show signs of deformation, as evidenced by the presence of marked curves in the albite twins.

The following is a modal analysis of a sample of banded anorthosite taken at the foot of the statue of Saint-Antoine in the sanctuary of Notre-Dame-de-Lourdes at Bouchette lake:

Plagioclase	55% (An_{47})
Hypersthene	18%
Clinopyroxene	10%
Hornblende	9%
Biotite	6%
Opaque minerals ..... (magnetite, ilmenite)	2%

This analysis is evidently not characteristic of the entire assemblage, because locally the pyroxenes occur only as relicts in the center of large amphibole crystals. However, it shows that the banded rock definitely belongs to the series of hypersthene-bearing basic rocks.

INTERMEDIATE AND ACIDIC PYROXENIC ROCKS

Although exposures are discontinuous, it would appear that there is a gradual transition, particularly evident within the Commissaires Lake sheet, between the basic pyroxenic rocks and the intermediate to acidic pyroxenic rocks. In fact, all the intermediate facies between anorthosite and hypersthene granite have been observed. Nevertheless, local intrusions of the intermediate pyroxene-bearing member have been observed in the anorthosite, particularly to the east of Brûlé lake.

Elsewhere, the massifs of intermediate and acidic pyroxenic rock have been intruded, in several places, by dikes and massive bodies of granitic rock and, in places, contain inclusions of metasedimentary rock.

As a useful field classification, the intermediate and acidic pyroxenic rocks have been divided into three groups. The first, which includes several facies of variable composition, comprises the green

hypersthene and microperthite rocks. The second group embraces the mixed green rocks containing hornblende and pink feldspar, and the third group includes the green gneiss in contact with paragneiss.

The names given to these subdivisions indicate that they are only intermediate facies between the intrusive pyroxene-bearing rocks and other series of rocks, either later intrusive or earlier metasedimentary. It must be emphasized, therefore, that contacts drawn on the geologic maps between these facies are strictly arbitrary. Even in the field, and with a fairly continuous suite of outcrops, it is almost impossible to determine where one facies ends and another begins.

The principal massifs of intermediate and acidic pyroxenic rock are located:

1) adjacent to the northwest end of Commissaires lake;
2) east of Bouchette lake, where the massif straddles the boundary between the Chambord and Hébertville quadrants; and
3) in the southeast corner of the area, where rock-cuts have been made for the road through the Laurentides National Park.

A few smaller massifs have been noted within the gneiss in the vicinity of the village of Sainte-Hedwidge-de-Roberval, as well as in the northwest and north central parts of the Goélands Lake quadrant.

Characteristic intermediate and acidic pyroxenic rocks are best exposed in several sections along Highway 54A, in outcrops of the Sainte-Hedwidge massif, some of which can be seen in the center of the village, and in certain facies of the massif to the west of Commissaires lake which can be reached by the Sainte-Hedwidge and Brûlé Lake road.

These rocks are deeply weathered and are covered with a thin white film, hiding an alteration which ranges from 6 inches to 5 feet in depth. This alteration is buff (chamois to olive-brown in the acidic facies and dark brown in the intermediate facies. The fresh surface of the rock, seen only in road-cuts along the main highways (54A), is light to dark green. It quickly loses its fresh appearance on exposure.

The intermediate and acidic pyroxenic rocks of the area are, for the most part, granular and massive, and characterized in some places by a porphyritic texture. Locally, a preferred orientation of the ferromagnesian minerals gives the rock a gneissic appearance, especially in the contact zones with the paragneiss.

Green Hypersthene-microperthite Rocks

The green rocks containing hypersthene and microperthite range in composition through diorite, quartz diorite, granodiorite, quartz

monzonite and hypersthene granite, and it is difficult to assign a particular rock name to any of the massifs.

To the northwest of Commissaires lake, an unaltered sample was subjected to a modal analysis by means of an integrating ocular (Zeiss). The following composition was determined:

Quartz	16%
Plagioclase	57%
Microcline	16%
Orthopyroxene	7%
Hornblende	2%
Augite	1%
Opaque minerals ...	1%

This composition is that of a hypersthene granodiorite. Nevertheless, rocks of other compositions are found within the same massif.

The plagioclase has a composition of 37% anorthite. The subhedral crystals are locally rimmed by microperthite, with a vermiculated border of myrmekite separating the two minerals in places.

The orthopyroxene, with lamellar and globular intergrowths of clinopyroxene, occurs as relicts within large crystals of dark olive green hornblende. The opaque minerals are generally associated with this hornblende, which has a $2V_x$ angle of 45 degrees. The quartz shows a wavy extinction, characteristic of the mineral in all facies of the pyroxenic series. Zircon and apatite are the main accessory minerals.

A few outcrops, identical in appearance, located 3/4 mile northeast of Brûlé lake, contain fayalite (Fa_{90}) in place of hypersthene. The modal composition of this rock is shown below.

Quartz	9%
Plagioclase (An_{25})	25%
Microcline	53%
Fayalite	4%
Augite	4%
Hornblende	3%
Opaque minerals ...	2%

The fayalite has a $2V_x$ angle of $52^o \pm 2^o$. In order to determine the composition of this mineral, d_{174} and d_{130} were measured on a Debye-Scherrer film and the curves of Jambor (1964) and Yoder (1957) were used. Both methods indicated an approximate composition of 90% fayalite.

The plagioclase of this rock is literally enveloped in microperthite, with myrmekite commonly providing a separation between the two.

A few samples from north of Ouiatchouane lake, in the Chambord quadrant, also contain local fayalite. This no doubt indicates the presence of zones which were rich enough in iron to result in the instability of orthopyroxene under the conditions of formation of the rock.

Intrusives within the Anorthosite - Dikes of intermediate pyroxene-bearing rock within the white anorthosite east of Brûlé lake have been mentioned earlier in this report. An 8-inch-wide dike, its dark green color outlined clearly against the white anorthosite, has been sampled. Its composition is that of a hypersthene diorite:

Quartz	1%
Plagioclase	45%
Orthopyroxene	34%
Hornblende	14%
Apatite	2%
Opaque minerals ...	4%

The plagioclase has a composition of 45% anorthite, and includes a large proportion of laths of potash feldspar. The orthopyroxene has a $2V_x$ angle of $69^o \pm 2^o$, which indicates an approximate composition of En_{75}.

Although contacts between this hypersthene diorite and the anorthosite are very sharp, being clearly visible even in thin-section, the plagioclase has the same antiperthitic texture and the same composition (45% An) in both rocks.

Green Pyroxene-bearing and Green Hornblende-bearing Rocks - The green pyroxenic rocks grade imperceptibly into rocks containing hornblende and microperthite. Good examples of this gradation are seen in the two localities described below.

The green rock which outcrops in the center of the village of Sainte-Hedwidge has the composition of an orthopyroxene-bearing quartz monzonite:

Quartz	10%
Plagioclase	39%
Microcline	20%
Orthopyroxene	14%
Hornblende	7%
Biotite	2%
Clinopyroxene	2%
Opaque minerals ...	5%
Apatite	1%

The plagioclase crystals are zoned, with a composition of 33% anorthite in the center and 24% at the borders. The orthopyroxene has a $2V_x$ angle of $63^o \pm 2^o$, which indicates an approximate composition of En_{70}.

Pyroxene-bearing intermediate and acidic rocks form a large part of the bedrock exposed in outcrops alongside the road through the Laurentides National Park. A sample taken about ½ mile south of the beginning of Sawinne river has the following composition:

Quartz	13%
Plagioclase	35%
Perthite	27%
Orthopyroxene	4%
Clinopyroxene	4%
Hornblende	10%
Biotite	3%
Opaque minerals	4%

The zoned plagioclase has a composition of 42% anorthite in the center and 27% at the borders. The main accessory minerals are zircon and apatite.

The rock is porphyritic, with a few crystals of potash feldspar up to 1 inch in length. Under the microscope, the plagioclase, surrounded by a fringe of myrmekite, is seen to be contained within large crystals of microperthite. In some places, the plagioclase is observed only as small twin planes that are in optical continuity, although they are isolated from each other by microperthite.

The crystals of orthopyroxene have been locally changed to bastite, but the included lamellae of clinopyroxene have remained unaltered. On the other hand, partly altered crystals of orthopyroxene have been observed as inclusions within large hornblende crystals. Locally, a ring of colorless twinned amphibole (cummingtonite) separates the relict orthopyroxene from the hornblende.

In these two localities, at Sainte-Hedwidge and along the road through the Laurentides National Park, the pyroxene-bearing rocks grade into dark green hornblende-bearing rocks without any appreciable change in appearance in the field. In fact, thin-section examination of the green rocks of the area shows that pyroxene-microperthite rocks grade imperceptibly into hornblende-microperthite rocks, the latter having as equally important an area as the former.

Rocks Containing Hornblende and Pink Feldspar

Along the road through the Laurentides National Park, opposite Clarence Gagnon lake ("Le Gîte"), pegmatitic intrusions can be seen in the pyroxene-bearing acidic rocks. Bordering these intrusions, for a distance of a few feet, the pyroxenic rock contains crystals of pink feldspar disseminated in green feldspar. This would appear to represent a reaction zone between the rocks of the pyroxene-bearing series and the later granitic intrusions.

Similar green rocks containing pink feldspars make up numerous outcrops in the area, even though, in many places, granitic massifs may not be exposed in the immediate vicinity. Generally, however, the spatial distribution of these heterogeneous rocks places them between the pyroxene-bearing rocks and later acidic intrusives.

These brownish-weathering rocks are light green, spotted with pink, on the fresh surface. Under the microscope, it is seen that the crystals of plagioclase and quartz are contained within phenocrysts of microperthite. The inclusions of plagioclase are locally invaded by growths of quartz, and some of the quartz inclusions are isolated from the perthite by a thin coating of plagioclase which is in optical and spatial continuity with the splinters of plagioclase in the microperthite.

The orthopyroxenes are absent from this series, their place being taken by biotite and, above all, by a dark olive green hornblende. Generally, it appears that in this sequence, comprising pyroxene-microperthite rocks, hornblende-microperthite rocks and rocks containing hornblende and pink feldspar, the hypersthene was replaced by dark green hornblende well before the formation of the pink feldspar phenocrysts. In fact, several hornblende-microperthite rocks in which pink feldspar has not formed contain only relicts of orthopyroxene, and some no longer show a trace of the mineral.

Green Gneiss in Contact with Paragneiss

The transition zone between the intermediate and acidic pyroxene-bearing rocks and the metasedimentary rocks is generally gradational and complex. The rocks of this zone belong to the granulite metamorphic facies and are composed of metasedimentary rocks which have been injected and migmatized by dikes and sills of pyroxenic rock. These contact gneisses, along with the other rocks of the area, have been injected in several places by late granitic intrusions that have locally stabilized the component minerals under new physical-chemical conditions. These new conditions, which have been responsible for the disappearance of the pyroxenes, have given the rock the characteristics of the amphibole facies.

GRANITIC ROCKS

The granitic rocks of the Lac Saint-Jean area are intrusive in nature and are younger than the rocks described above. Dresser (1916) applied the name "Roberval granite" to certain facies of these rocks. His description of the relationship between Roberval granite and the Laurentian rocks is similar to our description of the layered gneiss:

> "The relation of the Roberval to the Laurentian is best seen in Ouiatchouane township, especially in range III. Here, stocks of Roberval granite occur within the Laurentian deflecting its strike, and sending off dikes and irregular arms into that formation."

The granitic intrusives have been subdivided into three types: alaskites, massive and gneissic porphyritic granites (which were mapped as separate units), and pegmatites.

Alaskite

The intrusive alaskitic rocks are pink to white on fresh surface and cream-colored on weathered surface. They are massive or gneissic, and range from fine to coarse grained. These rocks are called "alaskite" because quartz and alkaline feldspar are the only essential minerals. In fact, the rocks are made up of 5 to 30% quartz and 65 to 90% microperthitic alkaline feldspar, with less than 5% dark minerals.

The alaskites are particularly abundant in the vicinity of the fault zones. They intrude the other rocks of the area in several places, either in the form of lit-par-lit injections in the metasedimentary rocks or as dikes, sills or irregular bodies within the older rocks.

Massive or Gneissic Porphyritic Granite

Small stocks of porphyritic granite occur in the northern part of the area. The most easily accessible exposure of this granite is at "Mont Plaisant," a tourist landmark near Roberval.

The prophyritic granite is massive or gneissic, and the large crystals of pink feldspar are widely variable in appearance. In an abandoned quarry near Plaisant mountain, for example, the porphyritic granite is locally massive toward the center of the stock, with well-formed crystals 2 inches in length. Only a few feet away, however, the feldspar crystals are deformed and the rock takes on a gneissic appearance.

On a regional scale, it is noted that, between Roberval and Saint-Prime, the deformation becomes more and more intense as one approaches the hill-side at Saint-Prime. The change in elevation which produced this slope is caused by a fault, and, where cuts have been exposed, the rocks indicate a definite increase in the intensity of deformation. Mechanical deformation is, therefore, partly responsible for the gneissosity of these rocks, but it is possible that other factors, may have had an influence on the origin of a local orientation of crystals within individual stocks.

Brown weathering, and pink on fresh surface, these rocks contain 10 to 70% large crystals of potash feldspar set in a medium- to coarse-grained matrix.

The porphyritic granites are made up of 50 to 70% orthoclase and perthitic microcline, 5 to 30% sodic plagioclase, 5 to 30% hornblende and biotite, and 0 to 30% quartz. The percentage of potash feldspar is never less than 50%, and the percentage of dark minerals is always greater than 5%.

Some granitic intrusions have had an influence on the layered gneiss and on the members of the pyroxenic series. Some of the layered gneissic rocks have developed into mixed lit-par-lit injection gneiss; others have developed into augen gneiss in which the "eyes" of potash feldspar make up as much as 50% of the rock and are up to 1 inch in length.

This augen gneiss has a highly irregular structure, with the "eyes" appearing in 1-foot-thick bands which alternate with pegmatitic bands, a few inches thick, and with bands of mixed lit-par-lit injection gneiss.

It is still impossible to determine whether these granitic intrusions, as well as those which affect the pyroxenic intermediate and acidic rocks, are contemporaneous with the so-called "Roberval" granite.

Pegmatite

Dikes, sills and irregular bodies of pegmatite occur throughout the area, but never as large massifs. They have a granitic composition and contain minor hornblende and biotite.

Basic Dikes and Diabase

Numerous dikes and shapeless masses of a fine-grained basic rock, in places varying to medium grained, have been mapped within the pyroxene-bearing rocks. This medium to dark gray rock is made up mainly

of plagioclase and of pyroxenes which have been partly or completely uralitized. In some places, the rock shows less evidence of deformation than the surrounding rocks and is therefore considered as being younger. Age relations with the late granitic intrusives, however, are impossible to establish.

Basic dikes which clearly cut the pyroxene-bearing rocks have also been observed, for example in exposures alongside the road through the Laurentides National Park, 1 mile north of the bridge across the Sawinne river. Here, the rock is definitely a diabase, with an ophitic texture which stands out clearly on the outcrop surface, and is made up of bytownite, olivine, brown hornblende, hypersthene and augite. The olivine is partly serpentinized, and surrounded by successive reaction rims of hypersthene and brown hornblende. The plagioclase is generally peppered with minute transparent inclusions.

ORDOVICIAN

A narrow Ordovician section has been noted in the northeast part of the Chambord sheet, bordering Saint-Jean lake. It is usually covered by 70 to 100 feet of overburden and outcrops in only a few places. The rocks comprise a generally well-bedded, locally fossiliferous, gray limestone of the Trenton Group and a black slate of the Utica Group. The latter also contains a few fossiliferous horizons.

J.A. Dresser (1916) located and described these Ordovician rocks quite adquately.

Four drill-holes within the Chambord sheet give a good indication of the thickness of these sedimentary rocks and of the overburden which covers them. The results are shown below.

Name	Cayouette No. 1	Cayouette No. 2	Chambord No. 1	Saguenay - Lake St.John No. 1
Year	1909	1909	1954	1946
Depth drilled	659'	400'	354'	293'
Overburden	70'	83'	90'	---
Utica Group	60'	60'	50'	93'
Trenton Group	100'	Trenton and PC 257'	185'	152'
Precambrian	429'		29'	48'

STRUCTURE

Gneissosity, Lineation and Folding

The gneissic rocks in the center of the Commissaires Lake sheet have a general north-northeast trend and a predominant east to southeast dip.

The gneisses of the Goélands Lake sheet and the west part of the Commissaires Lake sheet trend northeast and have a predominant southeast dip. In the northeast part of the Goélands Lake sheet and the northwest part of the Commissaires Lake sheet, however, the gneissosity is parallel to the contact with the massif of pyroxene-bearing rocks.

In the Chambord sheet, intrusive rocks cover more than 50% of the surface area, and the gneissosity of the gneissic rocks parallels the contacts with the individual massifs.

The bands of gneiss have been distrubed and show fold axes which plunge to the north or south, more or less parallel to the direction of gneissosity.

Shear Zones, Faults and Joints

Two important fault zones have been mapped in the area. The first, with a north-south trend, appears to the west of the village of Chambord. It then passes through Bouchette lake, Commissaires lake and Ecarté lake in the south part of the Commissaires Lake quadrant. This fault zone, which is locally more than 1 mile in width, is identified by the presence of several subsidiary faults, as well as by mylonites, epidote and the injection of an appreciable amount of late granitic material (alaskite).

The other major fault follows the south shore of Saint-Jean lake. It lies within the extension of the Kénogami Lake fault and forms the escarpment which separates the lowlands of the Lac Saint-Jean valley from the Laurentian Plateau. Movement along this fault took place in post-Ordovician time. It intersects the north-south fault zone to the southeast of Chambord, giving rise to numerous secondary faults, such as the one which follows the Ouiatchouane river in a northwest direction.

ECONOMIC GEOLOGY

Concentrations of magnetite-ilmenite (10 to 20%), confined to the intermediate or basic pyroxene-bearing rocks, have been noted east of

Honorat lake, east of the anorthosite body in the Commissaires Lake sheet and northeast of the Ouiatchouane river. Aeromagnetic maps indicate the presence of other such concentrations, but none have proved to be of economic importance.

A lens of amphibolite alongside the La Tuque and Lac-Bouchette road contains traces of sulfides, notably copper, nickel, molybdenum and iron.

A partly mylonitized pegmatite on the west shore of Bouchette lake, near the granular anorthosite, contains traces of pyrite and of chalcopyrite.

Some of the pink granite in the easily accessible north part of the area could be used as building stone or as ornamental stone.

The black anorthosite in the northeast part of the area is quarried for use as cut stone under the name of "black granite of Lac Saint-Jean."

The Trenton limestone could be used as building stone, as road-bed fill or as a source of calcium carbonate for the cement industry.

The wedge of Ordovician rocks which outcrops alongside Saint-Jean lake is about 25 miles long, 12 miles wide and, locally, 300 feet thick. There has been some interest in prospecting for oil and gas within this Paleozoic remnant, and traces have been noted in the Trenton limestone.

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