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SUMMARY GEOLOGICAL INVESTIGATION OF THE AREA BORDERING MANICOUAGAN ET MOUCHALAGANE LAKES, SAGUENAY COUNTY

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RENÉ LÉVESQUE, MINISTER

P.-E. AUGER, DEPUTY MINISTER

GEOLOGICAL SURVEYS BRANCH

H. W. McGERRIGLE, CHIEF

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SAGUENAY COUNTY

BY

JEAN BÉRARD

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by

Jean Bérard

INTRODUCTION

During the summer of 1961, the author mapped geologically the area adjacent to Manicouagan and Mouchalagane lakes which is to be inundated on completion of the Manicouagan power project. The dam for this project, with a planned height of 650 feet, is 20 miles down-stream from the junction of the two lakes.

The area mapped comprises 850 square miles and extends from the present lake level to the 1,200-foot contour line. It is contained in an area bounded by longitudes 68°15' and 69°15' and latitudes 51°00' and 51°45'. Kish (1962), in a concurrent program during the summer of 1961, mapped an area bounded by longitudes 68°15' and 68°30' and latitudes 51°30' and 51°45', at a scale of ½ mile to the inch.

Means of Access

A well maintained 135-mile-long gravel road links Baie Comeau, on the north shore of the St. Lawrence river, with the dam-site. From here, a secondary road extends as far as the southern end of Mouchalagane lake. In addition, roads are presently under construction to permit the cutting of the timber on land to be flooded. One of these roads will lead to the east shore of Manicouagan lake.

Access by water, along the Manicouagan river from the dam-site to the junction of the two lakes, is also possible. Only one portage is necessary, though a fairly powerful outboard is needed to combat the strong current.

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* Translated from the French.

Beyond the junction of the lakes, two portages are necessary in order to reach the main body of Mouchalagane lake. These portages, which cover distances of 1,000 feet and 1 mile respectively, by-pass two sets of falls. The secondary access road, mentioned above, goes only as far as the base of the falls.

The area may also be reached by chartered float plane from Louise lake. This lake, at which the Hydro-Quebec dam-workers are housed, is about 5 miles west of the dam-site.

Field Work

The area mapped by the writer includes most of the ground which is to be flooded on construction of the Manicouagan dam, Traverses were run, at intervals of about 2 miles, from the shores of the two major lakes to the 1,200-foot contour. Excepted from this program of systematic mapping were the areas of very low ground, which are devoid of outcrop, and some of the long valleys, which are filled with glacial debris.

The mapping of the area was carried out in three months. This period of time permitted only a preliminary study and, mainly because of the diverse rock types and complex structures encountered, was not long enough to establish definitely lithologic divisions.

Topography

Mouchalagane and Manicouagan lakes are deeply entrenched in the gneissic Precambrian rocks of the area and, together, form an almost complete circle with a diameter of about 40 miles. This circular feature has aroused the curiosity of students of both tectonics and geophysics. The former explain it on a structural bases; the latter invoke meteoric causes. The merits of these two hypotheses are discussed later in this report.

Mouchalagane lake is 740 feet above sea-level. After falls of 45 and 25 feet, and many rapids, its waters join Manicouagan lake at an elevation of 645 feet. Manicouagan river, which flows in a deep valley as far as the St. Lawrence, drains all the waters of the area.

Manicouagan and Mouchalagane lakes, and the Manicouagan river, are all very deep. Although the present beds of these bodies of water vary considerably in elevation, their ancient rocky floors are either even with or below the present sea-level.

It seems probable that Mouchalagane lake has been diverted from its original pro-glacial course at its southern end. In effect, the lake waters are presently held back by rocky shoals which are responsible for the two sets of falls. Farther to the west, a steep-walled valley, strewn with debris, apparently represents the former course of the lake.

The lakes are bordered by hills and cliffs, up to 700 feet high, which are especially prominent adjacent to the southern portions of the two lakes.

The highest elevations in the area are at the centre of the circular structure (3,110 feet) and east of the mouth of the Hart-Jaune river (3,350 feet).

Lavas cover most of the area between the two lakes. Wave-cut cliffs facing the lakes mark the base of the lava section and are easily recognized from the air.

Development of the Area

The Manicouagan basin, consisting mainly of Manicouagan and Mouchalagane lakes, is to serve as a reservoir for a hydro-electric plant that is being constructed 20 miles south of the junction of the two lakes. The anticipated level of the reservoir will correspond to the 1,200-foot contour. This means a rise of 555 feet for Manicouagan lake and of 460 feet for Mouchalagane lake. In addition, these lakes will merge at their northern ends, and the Hart-Jaune, Racine-de-Bouleau, Seignelay and Mouchalagane rivers will be inundated for considerable distances up-stream. The lavas in the central part of the area will form a large island with steep cliffs facing out over the waters of the new-formed lake.

The area to be flooded has been withdrawn from staking, except on special authorization of the Lieutenant-Governor in Council, as it is classified as land assigned by the Crown for the development of hydraulic power (Chap. 196, sect. V, art. 33d; Quebec Mining Act).

Lumbering activities were accelerated at the beginning of the summer of 1961 in an effort to recover the 3 or 4 million cords of wood that would otherwise be submerged. The most abundant tree is good-quality black spruce. Fir and tamarack are present, and birch and aspen are abundant on burnt-over ground.

Roads already built as well as those planned are laid out with the recovery of the timber resources in mind. They will be useful for other purposes also, as they follow the edge of the area to be flooded.

GENERAL GEOLOGY

Precambrian and Paleozoic rocks, with a capping of later effusive rocks, underlie the Mouchalagane-Manicouagan lake area. The Paleozoics, however, are confined to small, widely distributed remnants. The bedrock is mantled with fairly thick unconsolidated Pleistocene deposits and minor stream deposits.

Precambrian rocks occupy most of the area immediately surrounding the two lakes. They are made up of various types of orthogneiss and paragneiss that are so extensively intermixed as to preclude grouping into distinct lithologic units. On the map accompanying this report, however, the rocks are grouped according to the predominance of one type over another. Thus, rocks classified as "paragneiss" may contain variable proportions of granitic or monzonitic gneiss and, on the other hand, the latter rocks may contain remnants of paragneiss. The paragneisses are similar in appearance to the rocks of the Grenville series, and have been referred to this series in several instances.

Recorded geological history of the area began with the deposition of sedimentary rocks, including limestone, quartzite and various types of sandstone. During the Precambrian, these rocks were highly metamorphosed as a result of several periods of folding and intrusion.

A succeeding long period of erosion resulted in the development of a peneplane. A circular depression was then formed, either by tectonic means or through the impact of a meteorite, which permitted Ordovician seas to invade the area. Later, after a period of erosion, lavas were poured out over most of the circular basin. These effusive rocks, along with a few intrusives, now cover the Precambrian basement and the few Ordovician rocks which were not eroded away.

During a later period of erosion, the plateau-like lava was eroded at its periphery, thus exposing the remnants of Paleozoic rock.

<u>Table of Formations</u>

Cenozoic	Sand, gravel, boulders; till and stratified drift
Mesozoic?	Lavas, volcanic breccias, tuff
	Anorthosite-essexite
Ordovician	Limestone, shale, dolomite
Precambrian	Diabase dykes
	Grey or pink granite gneiss, syenite, granodiorite, pegmatite
	Gabbro, anorthosite, diorite
	Charnockitic gneiss, amphibolite
	Metasedimentary rocks

PRECAMBRIAN

Paragneiss

The paragneisses are confined principally to the borders of Mouchalagane lake, where they make up more than 70% of the bedrock. A few fairly thick but isolated inclusions of paragneiss were also mapped near Manicouagan lake. The banding of the paragneisses closely reflects the original bedding.

One of the principal types of paragneiss is made up of hornblende or biotite or both these minerals, along with plagioclase, garnet and quartz. Another is composed of sillimanite or kyanite, with biotite, plagioclase and garnet. Quartzites and crystalline limestones are also present.

Granitic, syenitic, monzonitic and dioritic gneisses, as well as pegmatites, are associated with the paragneisses.

Amphibole-pyroxene-plagioclase-garnet Paragneiss

The most common of the paragneisses within the area is the amphibole-pyroxene-plagioclase-garnet type. Many varieties, differing slightly in mineralogy, have been observed. They generally occur as bands from 6 inches to several tens of feet thick, alternating with bands of quartzite, crystalline limestone and grey or pink granite gneiss.

The rock is generally mesocratic to melanocratic with a dark greenish to reddish tinge. The grain size is medium to coarse, in places very coarse. The principal amphiboles are hornblende and actinolite. Enstatite, bronzite, clinoenstatite and augite are the most common pyroxenes. Certain facies of the rock are made up almost entirely of bronzite and graphite. The main accessory minerals are graphite, quartz, biotite and zircon.

These rocks outcrop extensively around the central portion of Mouchalagane lake. They also occur to the north of the central portion of Manicouagan lake, where they are associated with granitic and monzonitic gneisses.

Sillimanite or Kyanite, Biotite-garnet-feldspar Paragneiss

Paragneisses containing sillimanite or kyanite, along with biotite, garnet and feldspar, are less abundant than those just described but form marker horizons that can be quite easily followed in the field. They are mesocratic and medium to coarse grained. Sillimanite, or kyanite, makes up 5-25% of the gneiss. Clear garnets are also abundant. The biotite and plagioclase together make up more than 50% of the rock. Secondary minerals include quartz, microcline, chlorite and epidote. This rock-type is generally associated with the paragneisses described above.

Biotite-hornblende-plagioclase-quartz Paragneiss

This paragneiss is associated with the two varieties described above. An abundance of quartz and feldspar gives the rock a granitic appearance. A characteristic banding, due to the distribution of the ferromagnesian minerals, is also a feature. In colour, the rock ranges from light to dark grey, depending upon the relative abundance of the mafic constituents. This type of paragneiss is exposed mainly along the Mouchalagane river. Some has also been noted among the mixed gneisses of Manicouagan lake.

Quartzite

Vitreous or sugary-textured quartzites form beds from 6 inches to several tens of feet thick. They are either grey or pink, depending upon the amount of garnet present, and vary considerably in grain size. The main accessory minerals are graphite, chlorite, apatite and clinozoisite. Except for a few isolated beds observed here and there in the mixed gneisses alongside Manicouagan lake, the quartzites are confined to the paragneisses of Mouchalagane lake. Here, they make up about 2% of the rock.

Crystalline Limestone

The crystalline limestones form beds of variable thickness. They are dark grey on the weathered surface and alabaster white to pale grey on the fresh surface, and fine to coarse grained. A few bands and small "pockets" of a tremolite-diopside-rich facies are more resistant to erosion and stand out in relief.

In addition to calcite, the principal minerals of the limestone are dolomite, radiating tremolite, diopside, phlogopite, quartz, actinolite and graphite. Talc is abundant in zones where some crushing of the rock has occurred.

Crystalline limestone is fairly common within the paragneisses of Mouchalagane lake. In the northwestern corner of the area, large patches of acicular tremolite were noted in a limestone band about 200 feet thick. In the mixed gneisses bordering Manicouagan lake, it occurs in very narrow, isolated bands.

Mixed Gneiss

Grouped under this term are rocks so intimately intermixed as to make separation into distinct units, on the scale of mapping, quite impossible. Thin bands of paragneiss, making up about 20% of the assemblage, alternate with bands of amphibolite, grey or pink granite and granitic or charnockitic gneiss. The main rock-types in this group are described individually in the sections on paragneiss, charnockitic gneiss and granite gneiss.

A characteristic type of mixed gneiss was, however, observed within the area. It is in grey to pink bands ½ inch to 15 inches thick which, although with rather diffuse borders, can be traced several feet before disappering, perhaps to reappear farther on. The pink bands have a granitic composition, whereas the grey bands are granodioritic. Biotite, hornblende and garnet are common accessory minerals.

Charnockitic Gneiss

In the southern portion of the Manicouagan - Mouchalagane lake district, charnockitic gneiss underlies the more prominent hills and forms cliffs up to 700 feet in height. A few bands of this gneiss have also been seen in the mixed gneisses and in the gabbroic anorthosite massif to the south of the Hart-Jaune river. Though massive in places, the charnockitic gneiss generally exhibits a vague gneissosity caused by the parallelism of granitic and amphibolitic bands and the alignment of mafic minerals.

The rock varies in colour from dull green, through various intermediate shades, to brown. It is medium to coarse grained. Granitic, granodioritic and dioritic gneisses, as well as bands of amphibolite, are commonly found in the midst of these charnockitic gneisses. A few widely distributed bands of paragneiss were also noted.

The principal constituent minerals are oligoclase-andesine and perthitic microcline. Secondary minerals include quartz, hypersthene, augite, apatite and magnetite.

Basic Igneous Rocks

Anorthosites and their associated gabbroic and dioritic rocks outcrop over a large area adjacent to the northern portion of Manicouagan lake, south of the Hart-Jaune river. This assemblage has also been observed in a separate massif at the north end of Mouchalagane lake.

At the former place, the rock is either massive or gneissic. In the massive type, the plagioclase gives the rock a dark green colour, tinged with maroon. The texture is ophitic, with grain size varying from medium to very coarse. The gneissic type displays alternate light and dark grey bands, depending upon the relative abundance of the plagioclase and ferromagnesian minerals. Bands containing 60% plagioclase, 25% hornblende and 15% combined pyroxene, quartz and biotite alternate with lighter-coloured bands made up of 80% plagioclase, 10% rusty brown garnet and 10% hornblende and pyroxene.

About 85% of the rock is gabbroic or dioritic in composition. The remainder is anorthositic.

Shear zones, containing pyrite and a small amount of chalcopyrite, occur at many places in the gabbroic anorthosite. Elsewhere, faults have been observed along which considerable metasomatic replacement has taken place; in fact, the rock immediately adjacent to these faults has been changed into a chloritic red granite.

The southern contact of this intrusive massif is exposed alongside Manicouagan lake. Here, the gabbroic anorthosite is bordered by an ebony-black amphibolite about 200 feet thick and made up of 90% coarse black hornblende, with some garnet.

The anorthositic rocks are apparently younger than the rocks around them. Inclusions and other large remnants of the graphitic paragneiss and mangerite host rocks, in places making up a considerable portion of the mass, are present within the anorthositic gabbro.

The anorthositic and gabbroic rocks north of Mouchalagane lake and west of the Racine-de-Bouleau river differ in appearance from the rocks described above. The massive facies is white and spotted with tiny garnets and crystals of augite, fine to medium grained and equigranular. It is made up of 90% plagioclase, 3% augite, 3% garnet and a small amount of calcite, hornblende and sericite.

The border facies of this massif is gneissic and has a composition close to that of gabbro or diorite. A few light-coloured anorthosite bands are included within the gabbroic rocks. Bands of pink or grey granite gneiss, quite rich in garnet and ferromagnesian minerals, were also noted. The gabbroic gneiss is made up essentially of 60% zoned plagioclase, 20% actinolite-hornblende, 10% garnet, 5% biotite and 5% hypersthene. The rock is medium grey with a vague pinkish tinge due to the presence of garnet.

Five miles northeast of the junction of the Mouchalagane and Seignelay rivers, white anorthosite underlies a hill with a prominent south-facing cliff. The cliff may be seen from 20 miles away, especially when the sum is shining on it.

The two anorthosite massifs are apparently quite distinct. The Mouchalagane Lake massif is more granular and homogeneous, especially to the east of Seignelay river. The Manicouagan Lake massif, on the other hand, is coarser grained and more variable in composition.

Acidic Igneous Rocks

Small masses of grey or pink granitic and syenitic gneiss are exposed throughout the area. Alongside Manicouagan lake, they occur as lit-par-lit injections and, rarely, as separate bodies in both the mixed gneiss and the charnockitic rocks. At Mouchalagane lake, on the other hand, these rocks are more abundant and are more easily separable from the paragneiss host-rock.

The granitic and syenitic gneisses are outwardly similar and contain small amounts of hornblende or biotite. Other massive or gneissic granitoid rocks, including granodiorite, quartz monzonite and monzonite, are associated with these gneisses.

Pegmatites and pegmatitic granodiorites cut all the

Precambrian formations of the area except the diabase dykes, including the quartzite and crystalline limestone. Pegmatitic veins, containing crystals which range in length from ¼ inch to more than 1 foot, intersect the mixed gneisses to the north of Manicouagan lake. The giant-sized crystals of these pegmatites include pale green, twinned plagioclase, pink, red or grey microcline and flakes of biotite and muscovite, as well as hornblende and pyroxene. These crystals are quite easily separated from their friable matrix.

Pegmatite veins, 4 to 5 feet wide, cut the crystalline limestone along Mouchalagane river.

Diabase Dykes

Diabase dykes are quite rare in the area covered by this report and, of the six that were mapped, only one appears to have any appreciable width. They trend northeast and east. Other very narrow diabase dykelets cut the bedrock at several places, but are too small to be indicated on the accompanying map.

Care must be taken not to confuse these dykes with the pipes and conduits of post-Ordovician lava which cut both the basement rocks and the Ordovician limestones.

ORDOVICIAN

Grey, fossiliferous limestones make up the bulk of the Ordovician rocks in the area. Shale, dolomitic limestone, conglomerate and argillaceous sandstone also occur; they are generally fossiliferous and, except for the buff-coloured dolomitic rocks, range from black to pale grey.

The exposures of Ordovician rock are confined within the circle formed by Manicouagan and Mouchalagane lakes. It is possible, however, that remnants of the Ordovician are present outside this circular structure, as some angular fragments of fossiliferous limestone were seen on the southeast shore of Manicouagan lake. Actual exposures are, nonetheless, lacking.

Two outcrops of a grey, slightly crystalline, nonfossiliferous Ordovician limestone were found by Kish (1962) in the midst of the lavas. A brecciated limestone, made up of angular fragments of the basement rocks cemented by dolomitic material, has also been noted.

The unconformity between the Ordovician and the basement rocks is visible at three places within the map-area. The Ordovician sequence begins with a few inches of conglomerate with a black, graphite-rich argillaceous matrix. Higher up in the sequence the rock becomes calcareous and quite fossiliferous. The limestone beds range from one inch to 3 or 4 feet thick, and average about 8 inches. They are separated by thin layers of an easily cleavable shale, containing an abundance of fossils.

The Ordovician rocks have been deformed, but are relatively unmetamorphosed, except where directly in contact with the lavas. Here, the limestone immediately adjacent to the volcanic rock has a chalky appearance, and white limestone has been noted as inclusions within the lava. The limestones are, in places, quite steeply dipping and have been cut by minor faults. The resultant shear zones have been filled with large crystals of secondary calcite.

Post-Ordovician Intrusive Rocks (anorthosite-essexite)

An intrusive body west of Memory lake resembles a granulated, dull pinkish grey, cream-coloured or salmon-coloured anorthosite. The rock fractures quite unevenly, without regard to crystal structure, and has a well-developed gneissosity owing to the alignment of the ferromagnesian minerals. The weathered surface is grey and very rough. In places, cliff faces of this rock resemble a conglomerate made up of pebbles and boulders from one inch to one foot in diameter. The talus slopes below the cliffs are commonly strewn with these strikingly rounded products of differential alteration.

This intrusive rock also rises above the black amygdaloidal lavas to the southwest of Memory lake. Here, the surrounding lavas contain angular inclusions of a granular anorthosite similar in appearance to the rocks of the intrusive mass.

The principal constituent of the anorthosite is a well-altered plagioclase (An_{60}). In some places it is completely fractured and brecciated; in others it is altered to a fibrous mineral (oxyhornblende). Other important minerals include garnet, pyroxene and a carbonate, along with small amounts of apatite and rutile.

Several brick-red dykes, from 1 inch to 20 feet wide, cut the anorthosite. They are fine to medium grained and made up of garnet, ferromagnesian minerals and plagioclase. Some of these dykes resemble the red lavas described below.

Anorthosites were mapped both 8 miles to the east and 10 miles to the southeast of Memory lake. These rocks are similar in appearance and almost identical in composition to the anorthosites of the central part of the circular structure. They lie underneath and in visible contact with the volcanic rocks. The chilled border of the lava differs in colour from the main mass and penetrates cavities and fractures in the underlying anorthosite. Also, inclusions of anorthosite have been caught up in the lava. The anorthosites outside the central massif have not been affected by crushing to the same degree as the anorthosites within this structure. The former display a distinctive play of colours on their crystal faces, whereas the latter have a very dull lustre. Moreover, the former contain fresh augite and more hornblende than the latter, resembling in these respects the anorthositic rocks north of Mouchalagane lake.

Owing to the scarcity of outcrop, it was impossible to establish definite genetic relations between the different types of anorthosite. Nevertheless, the following suppositions may be made:

(a) If it is assumed that the anorthosites to the west of Memory lake lie in actual intrusive contact above the lavas, then these anorthosites are younger than the volcanics. In such case, the inclusions of anorthosite within these lavas would have been derived from the basement rocks.

(b) The anorthosites to the east of Memory lake, close to Manicouagan lake, are identical with the anorthosites of the central core. The lavas of the district would, therefore, lie above these anorthosites. The lavas near Memory lake, which apparently underlie the anorthosite, would thus represent a conduit of extrusive rock. Here, differences in texture and composition of the anorthosite could be accounted for by hydrothermal activity and tectonic forces attendant on the outflow of lava. This hypothesis is supported by the presence of dykes which closely resemble the lavas.

(c) Variations of these two possibilities are introduced if we consider the anorthosites of Mouchalagane lake. These rocks greatly resemble the "islands" of anorthositic basement rocks east of Memory lake. Thus, it is possible that: (1) all three bodies of anorthosite belong to the basement complex; (2) the anorthosites of the central core are actually different from the others, and, so, may be younger than the lavas. These problems are difficult to resolve with the limited amount of information on hand.

Taking into consideration their geographical distribution and their chemical and mineralogical similarity, Rose (1955) postulated that some relationship exists between the essexite-anorthosite and the neighbouring lavas. He also made a petrogenic comparison of the former rocks with the rocks of the Monteregian hills.

Basalt, Felsite, Dacite, Volcanic Breccia, Tuff

Post-Ordovician effusive rocks cover about 75% of the surface area between Manicouagan and Mouchalagane lakes. Excepting the exposures bordering Manicouagan lake, between latitudes 51°15' and 51°30', the nearest outcrops of lava are from ½ mile to 4 miles away from the shores of the lakes. The most common types of lavas are black vesicular or amygdaloidal basalts, mesocratic microcrystalline felsites, and reddish brown dacites. Volcanic breccias and tuffs also occur.

During the field work, only the periphery of the lava plateau was examined. It was thus not possible to obtain a complete picture of the nature, composition, origin and means of emplacement of these lavas. The main types, however, are described below.

Black or green, amygdaloidal or vesicular basalts make up about 65% of the effusive rocks. The basalts contain inclusions, from a few millimetres to several decimetres across, of the basement rocks. Among the inclusions are granite, hornblende-plagioclase gneiss, anorthosite, and some Ordovician limestone. The inclusions have undergone considerable metamorphism, which has changed the plagioclase and the calcite to a chalky white. The amygdules are made up of calcite, chlorite and zeolite, or a mixture of these minerals. The basalt itself is composed of chlorite, plagioclase, a small amount of quartz, calcite, zeolite and extremely fine-grained ferromagnesian minerals.

The felsites comprise the light-coloured, non-porphyritic volcanic rocks of the area. They are similar in appearance and colour to the dacites. Both contain a small amount of quartz, with plagioclase, augite and hornblende. The latter two minerals are generally altered to chlorite. These rocks are commonly pale brown to reddish brown and either vesicular or amygdaloidal. Plagioclase, pyroxene, garnet, magnetite and epidote are visible in the coarser-grained facies. Some of the visicles are lined with calcite or zeolite. The amygdules are made up of calcite, chlorite and zeolite, or a mixture of these minerals in which dark green chlorite is the principal constituent. The felsites are similar in composition to the anorthosites of the central massif.

Massive, vesicular volcanic breccias, nearly 50 feet thick, are well exposed in cliffs at two localities alongside Manicouagan lake. The breccias are made up of sub-angular fragments, from a fraction of a millimetre to at least 3 or 4 decimetres across, of both rocks and minerals. These include quartz, pink microcline, white plagioclase and fragments of diorite, granite, lava and Ordovician limestone. The matrix of the rock is grey or dull green. The fragments of green basic lava are coated with a thin film resulting from a reaction with the matrix. Flow structure is evident in some of the breccias, particularly those containing a large amount of tuff.

Numerous tuffs and other volcanic ash-rocks were noted in the volcanic breccias. Their composition is identical to that of the breccia.

CENOZOIC

During the Pleistocene, the area was subjected to glacial erosion and deposition. Striations, large glacial grooves, drumlins, eskers and crag and tail structures all provide evidence of this. The linear features impressed on the unconsolidated material in the area between the northern extremities of Mouchalagane and Manicouagan lakes all indicate a north to south direction of ice movement.

Several lake terraces and deltas, formed when the level of the lakes was higher, were observed, particularly bordering Manicouagan lake.

The valleys occupied by Manicouagan and Mouchalagane lakes are quite deep. They are believed to represent pre-glacial valleys that were filled with glacial debris and then partly cleared by river action. Considerable debris, however, remains at the bottom of these lakes.

A profile across the valleys of Manicouagan and Mouchalagane lakes is wide at the top, but quite acute at the base. This feature, shown by drilling to the south of the area, gives added weight to the hypothesis that the valleys are pre-glacial in origin and that they had reached a fairly well advanced stage of erosion. Some of the streams and rivers that flow into the two principal lakes have profiles similar to the two lake-valleys. Others are suspended, in places up to several hundreds of feet, above these valleys. The larger rivers have a quite regular long profile, whereas the smaller ones follow a steep course, with many high falls and rapids, into the major lakes. The Seignelay and Racine-de-Bouleau rivers, in particular, are deeply entrenched in very thick alluvial deposits. The terraces formed in the alluvium are at least 150 feet high. They are especially well developed along Racine-de-Bouleau river. The terraces of these two tributaries are apparently at similar elevations, in spite of the difference in present lake-level between Manicouagan and Mouchalagane lake. This implies that, at the time of deposition of the alluvium, both lakes stood at about 900 feet.

STRUCTURAL GEOLOGY

The circular structure which controls the shapes of Manicouagan and Mouchalagane lakes was apparently formed during Precambrian time. The remnants of Ordovician rock indicate the former presence of a large disk-like or ring-like sedimentary basin. This basin could have been formed by meteoric impact, although no direct evidence of this has been found as yet. It could also have been formed by the collapse of a large volcanic caldera, or by simple tectonic collapse along concentric and radial faults. It is also possible that drainage of the area in Precambrian time took on a circular pattern owing to a large polygonal structure developed through the distribution of the joints and faults. The two major lakes, taken together, presently show the broad outline of an octagon.

Post-Ordovician intrusive and effusive rocks later occupied the central portion of the basin which, if it was indeed a caldera, would correspond to the collapsed top of a magmatic reservoir. The caldera theory would thus explain both the circular depression and the subsequent outflow of lava through fissures from the underlying reservoir.

However, with the information presently available, the origin of the circular structure of the Manicouagan-Mouchalagane lake area is still open to question.

Schistosity Bedding

The schistosity of the rocks in the south half of the area parallels the orientation of the lakes. In the northern half, especially in the paragneisses, the schistosity is N.30°E. and, less commonly, N.30°W. Dips are generally towards the east but, because of the many small folds, westerly dips were observed in places.

The bedding of the metasedimentary basement rocks, as seen in the quartzite and crystalline limestones, is parallel to the schistosity. The bedding of the Ordovician rocks is well preserved, despite deformations which, in places, have been quite intense.

Folds, Faults

Minor folds, usually isoclinal and oblique, are abundant in the basement rocks. The rarer folds in the Ordovician limestones are open and relatively small.

Several chloritized zones, rich in secondary granitic material, indicate the presence of faults in the anorthositic gabbros to the east of Manicouagan lake. Numerous faults, too small to be shown on the accompanying map, were noted in the basement and the Ordovician rocks.

Kish (1962) recognized important faults to the northeast of the area accompanied by sharp changes in the schistosity of the rocks.

ECONOMIC GEOLOGY

Traces of copper were noted in the anorthositic gabbros to the east of Manicouagan lake. A sample from the east shore, at latitude 51°27', assayed 1.92% copper and $0.10 worth of gold per ton (value of gold calculated at $35.00 an ounce).

The lavas might also be economically interesting. A small amount of disseminated pyrite was observed, and it is possible that sulphide concentrations could be found in fault zones or at contacts between lava and limestone.

The paragneisses alongside Mouchalagane lake contain several bands rich in pyrite, magnetite, graphite and garnet. These rocks are rusty and readily split apart. Thick, relatively pure beds of crystalline limestone were also observed in places.

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