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RAWDON AREA, MONTCALM AND JOLETTE ELECTORAL DISTRICTS

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GEOLOGICAL SURVEYS BRANCH

GEOLOGICAL REPORT 92

RAWDON AREA

MONTCALM AND JOLIETTE ELECTORAL DISTRICTS

by

RENÉ BÉLAND

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MAP AND ILLUSTRATIONS

MAP

No. 1264 Rawdon area .... (In pocket)

PLATES

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B. - Valley of Assomption river, northwest of Sainte-Béatrix.

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Joints normal to the lineation.

VIII- Pit exploited by Brouillette Sand and Gravel, at Hamilton, near Rawdon.

RAWDON AREA[x]

Montcalm and Joliette Electoral Districts

by

René Béland

INTRODUCTION

Location and Extent

Rawdon area, mapped during the summer of 1948, covers 210 square miles between latitudes 46°00' and 46°15'N. and longitudes 73°30' and 73°45'W. The area straddles the boundary between Montcalm and Joliette electoral districts. It includes part of Rawdon township, in Montcalm electoral district, and most of Kildare township, the Augmentation of Kildare, and part of Cathcart township, in Joliette electoral district. Eight villages lie within the area, namely: Rawdon, Saint-Alphonse, Saint-Jean-de-Matha, Sainte-Marcelline-de-Radstock, Saint-Ambroise-de-Kildare, Sainte-Mélanie, Sainte-Béatrix, and Saint-Liguori. There are also several hamlets and summer resorts such as Dupont on Français lake, Camp Marcel, Pied-de-la-Montagne, and others.

Means of Access

The southern boundary of the area is only 45 miles northeast of Montreal and less than 10 miles west of Joliette. The area is crossed by several provincial highways interconnected by a close network of secondary roads. No point within the area is more than three miles distant from a road that can be travelled by automobile. Only one railway, with terminal at Rawdon, penetrates into the area. Another line that cuts across the southeast corner of the area just north of Saint-Liguori was abandoned and dismantled about 1945.

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[x] Translated from the French.

Field Work

Most of the geological mapping is based on east-west traverses spaced half a mile apart. In the southeastern part, which is a low cultivated plain, all rock exposures and stream beds have been examined. Traverses and many rock exposures were located directly on aerial photographs. All the information thus gathered was plotted on a half-a-mile-to-the-inch base map which had been prepared from the photographs. The latter, because they showed the general structural trends, were of great assistance in planning the traverses.

Paul L. Derome, a student at Ecole Polytechnique in Montreal, proved a very capable assistant.

Previous Work

The first geological description of the area was prepared by F.D. Adams and published in 1896 by the Geological Survey of Canada, together with a large-scale map. In this report Adams mentions several reconnaissance trips in the area by early officers of the Geological Survey.

Recent reports on the geology of nearby areas similarly located at the edge of the Morin anorthosite have been prepared by F. Fitz Osborne and published by the Quebec Department of Mines. In 1947, P.-E. Coté (1959) mapped the Chertsey area west of and contiguous to Rawdon area.

GENERAL DESCRIPTION

Topography

Two major physiographic provinces meet within the Rawdon sheet: the Saint Lawrence Lowlands, to which belongs the vast plain forming the southwestern part of the area, and the Canadian Shield to the north with its more rugged topography. The escarpment that separates these two provinces is so regular and straight between Rawdon and Sainte-Mélanie that it is thought to be a fault scarp.

Near the village of Saint-Ambroise-de-Kildare, the table-like surface of the Lowlands is broken by a wooded ridge, some six miles in length, which rises between 50 and 75 feet above the plain. The ridge, elliptical in plan as shown on the map by the distribution of water courses around it, is an outlier of crystalline rocks protruding through the Lowland silts and clays. If the escarpment that separates the Lowlands from the Shield is really a fault scarp, the Kildare ridge marks the top of a down-faulted block. The clays and silts surrounding the ridge must be very thick because streams have cut down 50 feet through them without exposing any bedrock.

A sand and gravel terrace, from 100 to 500 feet wide and from 40 to 50 feet high, runs along the foot of the escarpment from Rawdon to Pied-de-la-Montagne. From the latter point eastward the terrace widens into a sandy plateau, the southern embankment of which swings southeastward along a circular arc, passes through the village of Sainte-Mélanie and extends to the eastern map boundary.

Two miles north of Sainte-Mélanie, the sandy plateau has been cut by now-abandoned meanders of Assomption river. These old meanders are at present occupied by small streams, which appear as small concentric circular arcs near the eastern boundary of the map. The bottom of the meanders are at the same elevation as the plain of the Lowlands, which must have been their base level.

According to the few elevations given on Map 31 1/4 East Half (see Bibliography) and a few measurements made with an aneroid barometer, elevations in the Lowlands vary from 170 feet at Saint-Liguori bridge to 350 feet at the summit of Kildare ridge. Sainte-Mélanie plateau stands at 450 feet above sea-level.

The part of the area that lies on the edge of the Canadian Shield is more rugged and shows greater elevations. Rocky hills, linked into north-south chains parallel to the trend of the folding, rise some 300 to 600 feet above the narrow valleys that separate them. The chains of hills are interrupted by the valley of Assomption river and by two sets of long, narrow valleys trending east-west and northeast-southwest respectively. These transverse valleys suggest transverse or oblique faulting, but no displacement or offsetting of formations have been observed.

Where seen from a good vantage point, this whole hilly country (Plate IA) appears as a rejuvenated and dissected peneplain sloping down towards the south and the east.

The photograph reproduced in Plate IA was taken from a hill in "Concession Rouen" at an elevation of 1,600 feet. The divide between Ouareau and Assomption rivers does not rise beyond 1,200 feet. The village of Sainte-Marcelline has the same elevation as the town of Rawdon, i.e. 500 feet. The village of Saint-Jean-de-Matha stands at 700 feet. The elevations of the lakes and valleys around Saint-Alphonse vary between 800 and 900 feet.

At the edge of the Shield, the valleys are choked with sands and alluvial deposits; valley floors are much closer to bedrock in the northwestern part of the area. On ranges VI and VII, Cathcart township, Assomption river flows on bare rock in a steep-walled gorge. Near Sainte-Béatrix the same river meanders in a wide, alluvium-filled and terraced valley (Plate IB). Similarly, the Rouge river valley, which is a rocky gorge at the latitude of Vert lake, becomes a sandy plain at Rawdon. Because of widespread alluvial deposits, the lake country around Saint-Alphonse is less rugged than the upper part of the Rouge river valley. The village of Saint-Jean-de-Matha, built on a rocky pedestal, is surrounded, like the town of Rawdon, by a sand plain. All the valleys immediately north of Rawdon and the ones located east of Français lake have been broadened by thick alluvial deposits sufficiently to be farmed.

Drainage

Two good-sized rivers cross the area from west to east: the Ouareau and the Assomption. The Ouareau, cascading down the rocky ledges that protect the Rawdon plain, has cut, across the Lowlands, a deep trench in which Paleozoic rocks are exposed. The Assomption river valley across the Precambrian Highlands has been described above. The Assomption reaches the Lowlands outside of the map-area, but one of its meanders re-enters the area at Pointe-à-Neuf-Pas. The divide between Ouareau and Assomption rivers snakes between the numerous lakes in the Precambrian Highlands; in the Lowlands, it follows Sainte-Mélanie plateau.

Rouge river is the main affluent of the Ouareau. The Rouge enters the area near Bouleaux lake, which it drains, goes over a rocky sill at Rawdon, and thence cascades down to the Lowlands in a beautiful gorge. A small dam, built on the uppermost rock ledge at Rawdon, causes Rouge river to flood the trench that it has cut through the Rawdon sands, thus forming a small artificial lake. In the Lowlands, Rouge river is joined by Blanche river, so named because of the light grey silt with which it is loaded. Blanche river flows along the foot of the Rawdon - Pied-de-la-Montagne escarpment and receives as tributaries, besides numerous rivulets and torrents, the discharges of Français and Rocher lakes. Kildare, or Grand Ruisseau, brook, which drains the Lowlands south of Kildare ridge, is also an affluent of Rouge river.

Assomption river has only one important tributary, namely, Noire river, a fast-running stream with many falls and rapids, which double the flow of the Assomption.

Natural Resources

The Lowlands constitute excellent farming country. Tobacco is the main crop on the sandy Sainte-Mélanie plateau. In the rest of the Lowlands, the rich clayey soils are excellent for cereals and cattle fodder. The valley of Assomption river and the other valleys on the border of the Shield are settled by a rural population engaged in mixed and dairy farming. The soil is poorer and more difficult to till than in the Lowlands, and, therefore, with few exceptions, the farms look less prosperous. North of Assomption river, and along the upper part of the Rouge, there are many abandoned farms, and much land, once tilled, is grown over with shrubs and young trees. One is surprised to find in dense maple and birch forests, far from inhabited land, remnants of fences and man-made piles of stones, which indicate that the land was once cultivated. The population of the district, at least within the Shield, appears to have been more numerous than it is today. It is rather curious that, in this country, the Shield area was settled and farmed earlier than the Lowlands; the latter, before they were drained and cleared, were very swampy and did not appeal to the early colonists.

There is no important lumber or pulp wood industry in the area. Each village and hamlet has a small saw will producing for local consumption; small surpluses of lumber may be shipped to Joliette from time to time. Old dams and half demolished lumber camps along the upper Rouge river show that lumber and pulp cutting were once very active. The forests then exploited are now depleted.

There is a small hydroelectric plant on Ouareau river, less than a mile west of Rawdon. The only other suitable locality for such a plant would be the falls at the confluence of Noire and Assomption rivers. The other streams are too small to warrant the expense of building dams and reservoirs. Most of the little saw mills mentioned above were run by water wheels or turbines at one time; all are now powered by internal combustion or steam engines.

The most profitable business in the country around Saint-Alphonse, Sainte-Béatrix, and Rawdon appears to be the tourist trade. Every lake has its rim of summer cottages built for and by city dwellers. Rawdon, long known as a summer resort, is rapidly developing into a skiing centre.

GENERAL GEOLOGY

Precambrian

The oldest rocks in the area are the metasedimentary formations of the Grenville series. They consist of glassy metaquartzites, sillimanite-garnet paragneisses, and crystalline limestones containing diopside and serpentine. There rocks were originally sandstones, mudstones, and dolomitic limestones laid down in Precambrian times on a floor which has not been and will likely never be identified. These sedimentary rocks became buried deeply in the earth's crust, and were submitted to high temperatures and pressures. They became plastic, were crumpled and folded, and changed their mineral composition. Many were made into gneisses; all were literally soaked in magmas. The rocks resulting from the crystallization of these magmas were also deformed with the sedimentary rocks. Subsequently, erosion and isostatic uplifting brought this assemblage of paragneisses and orthogneisses to the surface of the earth. No trace is left of the eroded, thick mantle of rock that covered the gneisses previous to their ascension. As the gneisses rose from the deep zones of the crust, they became more brittle. Fissures developed within them and were filled by basic magma; thus diabase dykes were formed, probably near the end of Precambrian times.

Paleozoic

In early Paleozoic time, well stratified sediments were laid down upon the crystalline gneisses. These Paleozoic formations are now exposed in the bed and banks of Ouareau river, near Saint-Liguori. The Paleozoic rocks have remained horizontal and undeformed, except for some normal faulting south and southwest of the area. The rectilinear escarpment located between Rawdon and Pied-de-la-Montagne may have been formed by such a fault. The great regional breaks surmised from topographic features within the Shield area may have formed at the same time. Except for this faulting and fracturing, no record is left of the geological history of the region from the Ordovician epoch to the Quaternary. The peneplained and dissected aspect of the Shield suggests prolonged denudation periodically modified by isostatic movements.

Quaternary and Recent

During the Quaternary epoch a continental ice sheet invaded the Shield area leaving everywhere unmistakable traces of its progress. Hill-tops were rounded and smoothed. Craggy rock surfaces became roches moutonnées. Abundant glacial striae are to be found in stream beds and under thin soil; they strike almost due south, and the ice sheet must have advanced in that direction. Ground moraines have been recognized in the northernmost part of the area, and in a few places along the divide between Ouareau and Assomption rivers. As the ice front retreated northward, the moraines were washed and sorted by meltwaters. Most valleys were partly filled with fluvioglacial gravels and silts. The sand plain at Rawdon is an alluvial deposit protected from dissection and erosion by a rampart of rocky ledges. Several mounds of fine sand (Plate IA) near Sainte-Béatrix have shapes that suggest eolian accumulation. It is difficult to estimate to what extent the present relief results from glacial action. Several U-shaped valleys have been widened if not deepened by tongues of ice. But the plastering of hillsides with glacial debris, particularly striking near Rocher lake, the filling of valleys with fluvioglacial alluvia, and the smoothing of hill-tops indicate that the relief has been decreased rather than accentuated by the passing of the ice sheet.

Retreat of the ice from the Saint Lawrence valley was accompanied by a marine invasion. The clays and silts of the Lowlands accumulated in the Champlain sea. The gravelly terrace that clings to the Rawdon - Pied-de-la-Montagne escarpment and the Sainte-Mélanie plateau mark a temporary shore line of this sea. A similar though narrower terrace fringes the Kildare ridge, which must have been an island at one time. Though the unconsolidated sediments of the Lowlands contain no marine fossils, their marine origin is certain because of their geographic position. Their maximum elevation is 300 feet, and the Champlain sea is known to have reached the 600-foot contour near Quebec city and, at least, the 500-foot contour at Saint-Jérôme. There is little doubt that the same sea extended to the Rawdon escarpment. The Rawdon sands, in which some cross-bedding layers dip to the south and others, to the east and south, represent a deltaic fan in the Champlain sea.

Table of Formations

In the following table, the formations mapped in the Rawdon area are listed from top to bottom in descending chronological order.

Table of Formations

Quaternary	Champlain	Clays and silts Sands and gravels
	Glacial	Fluvioglacial gravels, sands, silts Boulder clays
Paleozoic	Ordovician Cambrian	Arenaceous limestones Orthoquartzite (Potsdam)
Precambrian	?	Diabase dykes
	?	Pink granite gneiss
	Morin series	Buff granulite Quartz mangerite Hypersthene gneiss Anorthosite and norite
	Grenville series	Quartzite, sillimanite-garnet gneiss Crystalline limestone Amphibolite

PETROGRAPHY

Grenville Series

Distribution

Grenville paragneisses make up about a third of the crystalline rocks in the area. The main lithologic units are crystalline limestone, glassy quartzites containing disseminated garnets and slivers of sillimanite, and grey yellowish gneisses with augen structures in which large globular garnets are set in foliated mixtures of feldspars, slender crystals of sillimanite, and lenticular blades of quartz. Even in their most homogeneous exposures, these gneisses are interbanded with orthogneisses believed to be igneous and composed of feldspars, quartz, and pyroxenes. The areas of Grenville rocks shown on the map should be understood as areas in which paragneisses predominate over orthogneisses.

Metaquartzite

Quartzites, though abundant in the area, do not form large masses. They outcrop as elongated patches in orthogneisses and as intercalated, discontinuous bands in the paragneisses. The largest exposures are cliffs some 20 feet high of white glassy quartzite in layers from 6 inches to 2 feet thick (Plate IIB), almost flat-lying. The rock resembles vein quartz and contains scattered small garnets and rare feldspars which weather out leaving yellowish cavities.

Under the microscope the quartz, which constitutes between 75 and 90 per cent of the rock, is seen to occur in irregular patches measuring from 0.5 to 20 mm. in their greatest dimensions. The patches contain many crystals which join together along very complex sutures. Between the quartz patches are found rare and much altered plagioclases, tiny slivers of potassic feldspar, minute zircons, globulose garnets with included flakes of biotite, fresh biotite blades pressed against the quartz, small idioblasts of sillimanite, and anhedra of magnetite and pyrite. In a coarse-grained specimen from Pied-de-la-Montagne, the quartz is stuffed with rutile needles arranged in sagenitic webs. Many of the needles extend across the boundaries between adjoining quartz crystals, and, therefore, must be products of recrystallization.

All of the quartz shows a wavy extinction which in every thin section takes a definite pattern. In some sections, the extinction proceeds in bands, as if the quartz had been cut into slices. In other sections, two sets of such slices produce quadrangular patterns, as if one set of slices had been stretched and broken up into rectangular fragments. Tension cracks in the garnets are normal to the axes of the "extinction waves" in the quartz. The quartzites evidently possess a linear structure which marks a direction of stretching. In many exposures this structure can be detected by the unaided eye. Freshly broken pieces have a coarsely fibrous structure in which the quartz fibres or pencils are parallel to one another and to the layering or bedding of the rock.

Some of the quartzites contain abundant garnets, feldspars, sillimanite, and biotite, and thus grade into well banded quartzose paragneisses.

Sillimanite-garnet Paragneisses

The sillimanite-garnet gneisses constitute the most homogeneous masses of Grenville rocks in the area. The two largest of these masses outcrop along Rouge river and near Rocher lake respectively. The Rouge river mass is about a mile wide; the other one, nearly half a mile. Other masses, almost as large, occur in the northern part of the area. Very few inclusions or shreds of the sillimanite-garnet gneisses have been seen in the orthogneisses. The reason perhaps is that paragneisses of that composition were easily assimilated by the magmas from which the orthogneisses were descended.

There are two main types of sillimanite-garnet paragneisses: one coarse-grained, grey or yellow, with large augen of garnets; the other medium-to fine-grained, more feldspathic, easily mistaken at first sight for a pink granite gneiss. The coarse-grained type is much more abundant than the other, which may be a granitized facies of the former.

The coarse-grained augen gneiss is grey, somewhat reddish where it contains much garnet and biotite, rather yellowish and rusty where the latter minerals are less abundant and where the gneiss is pyritic and graphitic. The grain is coarse enough for most of the mineral constituents to be identified with the help of an x6 pocket lens. The most conspicuous minerals are reddish brown or pink garnets, which occur as augen and as ill-defined small crystals in layered arrangements. All the garnets are fractured, and show plane parallel fractures, resembling cleavages, which are normal to the foliation of the rock. The other mineral constituents are molded on the garnet augen. Any freshly broken surface reveals pearly flakes or blades which are cleavage faces of sillimanite crystals. These crystals have their long axes (c-axes) in the plane of the foliation, and bend with it around the large garnets. The sillimanite crystalloblasts are rather large; lengths of 5 mm. to 1 cm. are common, and, in a road-cut along the south shore of Français lake, sheaves of crystals measuring 4 inches in lengths were collected. The other minerals recognized in these gneisses are quartz in thin lenticular plates, dull feldspars in elongated, ill-defined crystals, graphite flakes, and irregular clusters of red biotite.

In thin sections the outlines of the garnet porphyroblasts appear much indented. In some sections, the garnets have poikilitic cores, studded with round grains of quartz, altered perthites and plagioclases, small biotite flakes, some with pleochroic haloes and zircons, tiny rutile crystals, and magnetite. In other sections the garnets are of the "sponge" type; their centres are clear but their outer margins are ramified into tentacles that are wrapped around crystals of quartz, feldspars, and sillimanite. The sillimanites, like the garnets, are cut by tension fractures that are normal to the foliation. Many crystals of sillimanite are altered at their periphery and along their cracks and cleavages into a pale green mineral with low birefringence.

The manner of occurrence of quartz in these rocks is interesting. The quartz forms thin lenses parallel to the foliation. Seen on edge, these lenses appear as bands which are very narrow where squeezed by the garnets against the foliae of the rock, but widen into almost circular lobes between the foliae where the latter are free of garnets. Extinctions in the quartz bands are almost parallel to their long dimensions and suggest a preferred orientation of the c-axes within the plane of foliation. Some of the quartz occurs as small sutured grains. Perthitic untwinned microcline is practically the only feldspar in these rocks. It occurs as elongated, serrated grains that have a pinkish tinge in thin sections. Oligoclase (An_{25}) has been identified in one specimen. The other minerals noted are red biotite, graphite, magnetite and small zircons.

The proportions of these constituents vary considerably from place to place. A Rosiwal analysis of a medium-grained specimen gave the following proportions (by weight):

Garnet	15.3%
Quartz	36.8%
Microcline-perthite	24.6%
Sillimanite	22.1%
Opaques and accessories	1.2%

Some of the more graphitic specimens contain up to 5 per cent opaques.

The manner in which these rocks were deformed is easily understood from their texture and structure. In many the gneissic structure is planar and is manifested, even within a single thin section, by a distinct layering. Garnet-rich laminae are separated from sillimanitic or biotitic laminae by feldspathic layers. Such foliation is consistent with a compression normal to the plane of the laminae. Tension cracks in the garnets and sillimanite, and the parallel alignments of elongated crystals, indicate flowage and stretching in the plane of the foliation. After the garnets had reached a certain development, they resisted the compression and acted as pillars between the laminae. The quartz, squeezed out from the top of those pillars, has recrystallized in the pressure shadows, along the unstressed faces of the garnets. The gneissic structure also has a linear element; the alignment of the sillimanite crystals and the parallelism of tension cracks indicate that flowage in the plane of the foliation took place mostly in one direction. In many of these gneisses, the linear structure is the only one to be seen; there is no layering, the garnets forming large ovoid porphyroblasts which are uniformly distributed through the rock. The other minerals are wrapped around the ovoids with their long axes generally parallel to those of the garnets.

The fine-grained sillimanite gneisses show a regular layering. Very quartzose layers alternate with feldspathic layers containing much sillimanite. This layering may be a relic of an original bedding. A Rosiwal analysis gave the following composition (by weight):

Garnet	10.2%
Quartz	60.5%
Microcline-perthite	19.4%
Sillimanite	7.1%
Rutile and opaques	2.8%

Textures are similar to those of the coarse-grained gneisses, and also show many features seen in the quartzites. The fine-grained sillimanite gneisses represent a transition from the quartzites to the augen paragneisses. Other gneisses that appear granitic but are very garnetiferous have been mapped as Grenville rocks and are thought to belong to this transition facies because they occur as intercalations within the other paragneisses. One specimen of a transition gneiss contains myriads of acicular rutile crystals, some of them geniculated, measuring from one to two millimetres in length.

Bands of rusty-weathering, very graphitic gneisses outcrop among the Grenville rocks. Some of these bands are quite wide and form large exposures. The best of these are located east of Pierre lake, and at Manchester falls just below the railway bridge at Rawdon. Where freshly broken, the rock is light grey and appears banded. Thin quartz-feldspar layers alternate with grey laminae stuffed with shiny graphite flakes and strings of pink garnets. Some exposures show large augen of feldspars, up to one inch in diameter, the cleavages of which are bent and deformed. These augen stand conspicuously out of a rather fine-grained groundmass. Where exposed to the weather for any lenght of time, the rock acquires a crumbly, rusty crust, the thickness of which is proportional to the pyrite content of the rock.

Thin sections of fresh specimens show bands of quartz, much serrated perthites, graphite, opaque ores, pyrite, scattered sillimanite crystals some included in garnets, and poikilitic garnets.

Crystalline Limestone

A layer of crystalline limestone from 10 to 30 feet thick is exposed continuously along the Rouge river valley. At Rawdon the limestone disappears under the sands, but a fifty-foot-wide exposure of limestone at Darwin falls in the Ouareau belongs to the same band. Other bands of limestone, of similar widths but of less well-known extensions, have been mapped in the northern part of the area and near Rocher lake. Though representing layers less than 20 feet thick, these bands have been drawn on the map because they indicate that the bedding is essentially parallel to the foliation in the Grenville paragneisses.

The limestone layers are not pure limestone. They contain much paragneiss in the form of continuous layers, shreds, and angular fragments. As remarked by Adams, the outcrops of limestone mark calcareous horizons in which limestone is not everywhere the dominant rock. The crystalline limestone is coarse, white or pinkish, made up of large twinned calcite rhombohedra, brown biotite, and spherical granules of pale green serpentine. Some exposures show much diopside and an unidentified dark green amphibole. In places, graphite flakes and tiny apatite crystals are noticeable.

Amphibolite

As mentioned above, many exposures mapped as Grenville rocks consist of shreds and lenses of quartzites and paragneisses included in orthogneisses. The para-rocks ordinarily stand in relief and give to the exposures a washboard-like surface. Such is the mode of occurrence of black, coarse-grained amphibolites, in which large crystals of hornblende, up to 1/2 inch in length, mask the other constituents. All of these amphibolites contain garnets, in various proportions. The Rosiwal analysis of a typical specimen gave:

Brown hornblende	50.5%
Hypersthene	12.4%
Augite	7.5%
Andesine (An_{43})	26.1%
Magnetite and apatite	1.5%
Garnet	3.0%

The hypersthene and augite are partly resorbed by the hornblende which is in the form of large idioblastic crystals. Andesine occurs as granoblastic masses between the brown hornblende porphyroblasts. These rocks differ in composition from the amphibolites described by Osborne (1936A) as representing volcanic rocks that would constitute the lower part of the Grenville series. Furthermore, by the nature of their plagioclase, and their content of hypersthene, the amphibolites of Rawdon area seem to be related to the hypersthene-bearing orthogneisses described below. They could represent calcareous para-rocks which became silicated in contact with the hypersthenic orthogneisses.

Scapolite and Diopside-bearing Rocks

Two other kinds of silicated limestones were found in the limestone bands, particularly near the north end of Rocher lake, and near the bridge that crosses Assomption river east of Sainte-Béatrix. One of these rocks is grey and medium-grained, has a granoblastic texture, and contains much scapolite. The other, coarser-grained and pale green, is composed mostly of diopside, with large blades of phlogopite. These rocks clearly represent silicated zones along contacts of limestones with orthogneisses. An inclusion of the diopside-phlogopite rock was found in a band of norite-anorthosite near the east end of Deschênes lake.

The scapolite rocks are dark grey, with a slight greenish tinge. Grain sizes are from 3 to 4 mm. Vitreous quartz and grains of pyrrhotite or pyrite are easily discernible. The scapolite occurs in crystals large enough to show their cleavages clearly; nevertheless, the mineral is easily mistaken for feldspar. Careful examination with a hand lens reveals green diopside and dark violet crystals of sphene. In thin section the quartz, which constitutes nearly 40 per cent of the rock, is seen to form elongated and ramified groups. It has a wavy extinction which, as in the paragneisses, appears related to a linear structure. Scapolite is about as abundant as quartz. Its birefringence, measured by means of a Berek compensator, indicates a composition near theoretical mizzonite. The scapolite grains are rounded and grouped in elongated masses parallel to the quartz. Because of this arrangement, the scapolite rock appears strongly gneissic in thin section. On the exposures, however, this foliation is not noticeable. Diopside has also been identified in the thin sections. It occurs as much-indented irregular grains. Some have their cleavages parallel to the foliation of the rock and are cut by tension cracks. Others have their cleavages normal to the foliation and are not fractured. The latter are also much smaller than the former and are less elongated along their c-axis. All specimens of scapolite rocks contain from 10 to 25 per cent calcite mostly as relics in the scapolite or as interstitial filling between the other minerals. This calcite explains the development of a porous crumbly crust at the surface of many exposures. Other minerals recognized, besides opaque grains of pyrite and pyrrhotite, include sphene, small flakes of biotite, apatite, and small garnets.

The diopside rocks are recognized by their thin blades of phlogopite, up to one inch in diameter, which become dull and greenish in weathering. Weathered surfaces take a typical sugary appearance owing to the coarseness of the diopside aggregates. Only one thin section of this rock has been examined. It shows only diallagic diopside in decussate, granoblastic arrangement showing no alignment of either cleavages or partings.

Morin Series

Nature and Distribution

The Morin series, as defined by Adams, is a sequence of intrusive rocks varying in composition from anorthosite to granite. Osborne has published a variation diagram showing compositional relationships within rocks of the series in the Sainte-Agathe - Sainte-Jovite area (see Bibliography). All rocks of the series are plagioclase-rich - the two main rock types being anorthosite and mangerite - and contain hypersthene as their chief mafic mineral. Osborne has also included in the series some hornblende-biotite granites rich in orthoclase. In the Rawdon area, most of the igneous or meta-igneous rocks recognized are anorthosites, norites, and hypersthene-bearing plagioclase gneisses belonging to the Morin series. The few small masses of granitic microcline-biotite gneisses encountered have been shown as distinct from the Morin series on the map because their relationship to the series is unknown. The Morin rocks may be divided into two main categories: one including the homogeneous masses of coarse-grained anorthosites and norites; the other consisting of hypersthene gneisses, quartz mangerites, and fine-grained quartzose granulites (1), which are intermixed with the Grenville paragneisses.

Norite-anorthosite

The western limit of the Rawdon sheet crosses an appendage, compared by F.F. Osborne to the trunk of an elephant, of the Morin massif of anorthosite. The rock of the appendage was called by F.D. Adams the Chertsey facies of the Morin anorthosite, and has been described by P.-E. Coté in a geological report on the Chertsey area, and in an unpublished doctorate dissertation presented at McGill University. The Chertsey anorthosite is light coloured and strongly

(1) In this report, granulite designates an equigranular rock composed of feldspars and pyroxenes.

Plate I

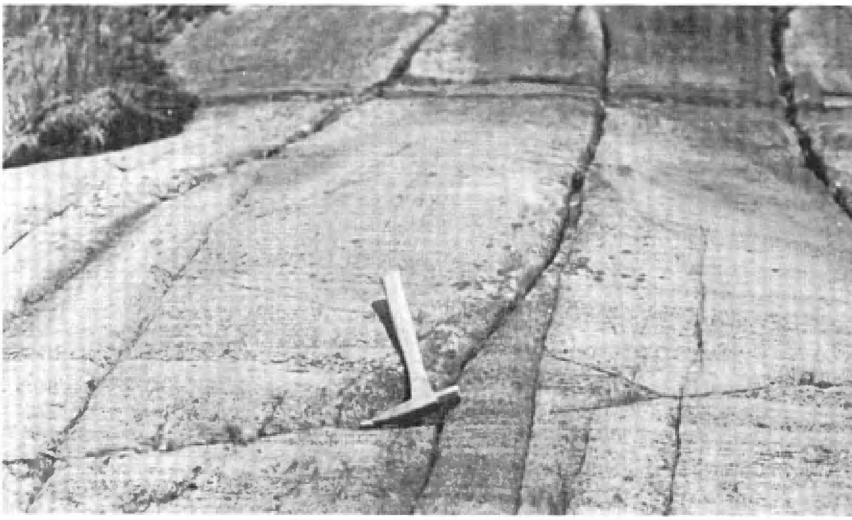
A — General view of Rawdon area, from the northern limit.

B — Valley of L'Assomption river, northwest of Sainte-Béatrix.

A — Mound of fine sand, northwest of Sainte-Béatrix.

B — Layered white quartzite, half way between Français and Cloutier lakes.

Plate III



A — Banded norite-anorthosite. The joints are normal to the lineation.

B — Spotted norite-anorthosite, east of Cloutier lake. The spots are coarser-grained than the matrix.

Plate IV

A — Norite-anorthosite in bands of different grain-sizes, east of Cloutier lake.

B — Giant hypersthene crystals in anorthosite.

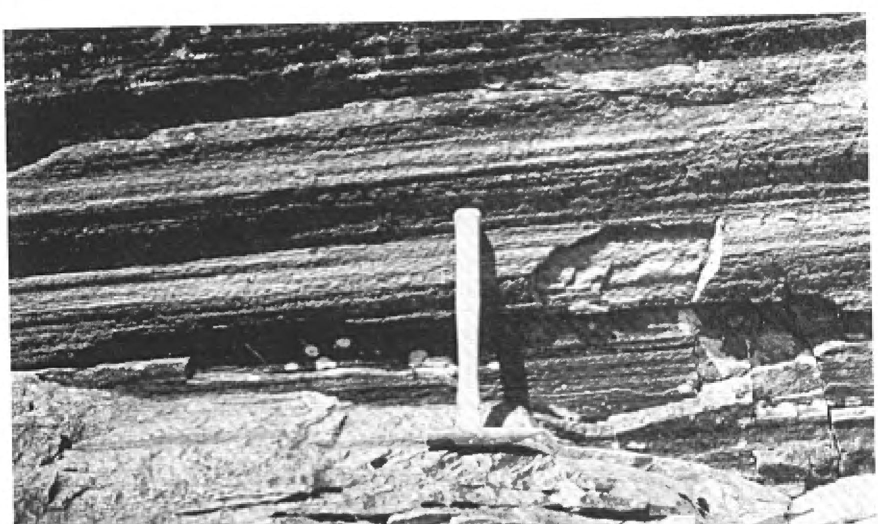
Plate V

A — Paleozoic sandstone, Saint-Liguori bridge.

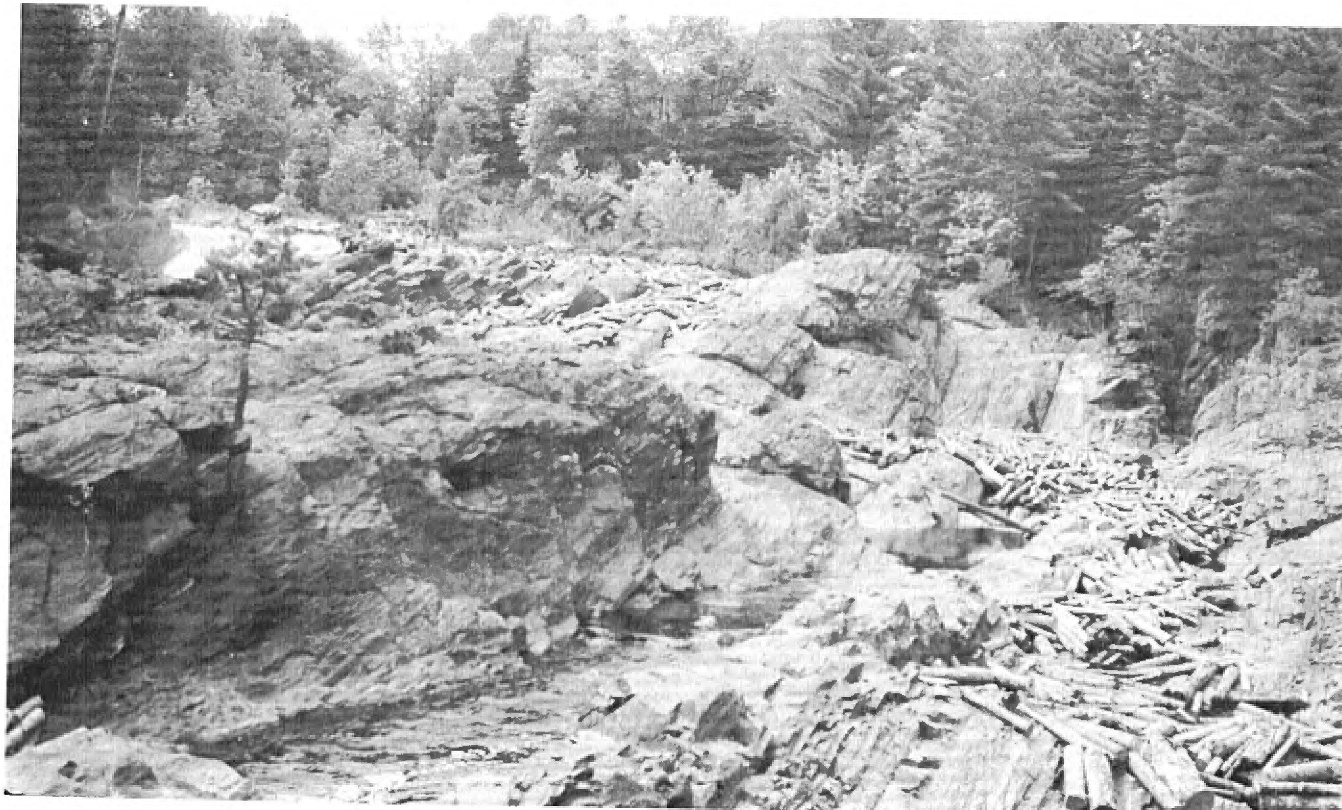
B — Ripple marks in Paleozoic sandstones.

Plate VI

A — Layered quartzite, with flat, easterly dip.



B — Lineation parallel to fold axes, Manchester falls.



Folds plunging south, Manchester falls.
Joints normal to the lineation.

Plate VII

Pit exploited by Brouillette Sand & Gravel, at Hamilton, near Rawdon.

Plate VIII

gneissic. The mafic minerals are segregated into narrow bands, and the feldspars are extremely granulated, in contrast with the main facies of the Morin anorthosite which is dark violet in colour, massive, and very coarse grained. In places the Chertsey facies has a more varied composition than the main part of the Morin anorthosite. In the Rawdon area, much of the Chertsey norites and anorthosites occur in satellitic bands without visible connection with the Morin massif. The widest and best defined band extends from a point two miles east of Rawdon to Pierre lake. Another one follows Cloutier lake, crosses under Français lake, and is well exposed in the escarpment that marks the edge of the Shield. A third band has been traced from Deschênes lake to Sainte-Marcelline, where it disappears under the unconsolidated sediments of the Lowlands. Another band is exposed east of Deschênes lake and at Dalles bridge, which crosses Assomption river at Sainte-Béatrix. Large outcrops of norite-anorthosite have been mapped near the junction of Noire river with Assomption river, and northeast of Rocher lake. A biotitic norite, different from the others, is exposed in three rocky knobs in the northwest corner of the area. All of these outcrops of norite-anorthosite represent homogeneous masses, which stand in high relief. They constitute the topographic framework of the area.

The rocks of the anorthosite-norite formation present two petrographic types: a white, almost pure feldspar anorthosite, and a hypersthene-rich rock which is called a norite.

The white Chertsey anorthosite described by Adams is fine grained, sugary, buff or greenish white. In the Rawdon area, rock conforming to his description is restricted to the western boundary where it is exposed in large areas of roches moutonnées. In freshly broken surfaces, the rock appears glassy and is easily mistaken for a quartzite. Careful examination of hand specimens reveals the bright cleavage faces of the feldspars. Weathered surfaces show a telltale earthy, yellowish crust, from 1/8 to 1/4 inch thick, in which the altered feldspars are somewhat loosened from one another and form a saccharoid aggregate. This type of anorthosite is believed to have been derived from the coarse anorthosite by processes involving shearing and granulation followed by recrystallization and annealing.

At the edge of the Morin massif and in its satellitic bands, the anorthosite contains much pyroxene. It is also disposed in alternating anorthositic and noritic layers. In the southwest corner of the area, at the extreme limit of the Morin massif, one of the layers is a pyroxenite with veinlets of magnetite. All these layered rocks are gneissic, and the foliation parallels the layering. The pyroxenes, especially in the noritic layers, are ordered into parallel lines within the planes of foliation (Plates III A and IVA). Some norite layers, in which the pyroxenes are uniformly distributed, have a linear rather than planar gneissic structure; the pyroxenes line up in regular rows. The petrologists who have studied this type of anorthosite give much importance to the layering. They believe that it has developed during the crystallization of the magma, prior to any deformation of the rock. It is true that many examples are known of undeformed gabbroic complexes in which anorthosite layers alternate with gabbroic layers. The exposures photographed in plates IIIA and IVA, however, suggest that the layering, in some cases, may result from the deformation of a peculiar type of anorthosite described by Adams. These photographs were taken at points half a mile apart along the band of gabbroic anorthosite that lies on the east shore of Cloutier lake. Plate IIIA shows the structure described by Adams. Large blobs of coarse anorthosite are distributed evenly in a matrix finer-grained but of identical composition. Plate IVA shows the same coarse- and fine-grained anorthosites disposed in bands, as if the blobs had been squeezed and stretched into regular bands.

In these rocks the feldspars, buff or grey in colour, are generally granulated and small. The largest cleavage faces measure less than one-quarter of an inch. The pyroxenes are usually better developed; in some noritic bands they occur as clusters (Plate IVB) of crystals measuring 3 or 4 inches, cemented together by magnetite, feldspars, and even quartz. These clusters may represent clots formed in the original magma, but they certainly have been reshaped and re-crystallized. The most abundant pyroxene is hypersthene easily recognized by the bronzy lustre of its cleavage and parting planes. Augite, though less abundant, is also present as dull, black crystals. Most of the pyroxenes are fresh and all are but little altered.

A few thin sections of gabbroic anorthosite and norite have been studied. Because of the coarseness of the pyroxene, the sections had to be cut from specimens that were finer grained than the typical rock. One such specimen was of a blue-grey anorthosite in which the dark minerals formed thin plates in the plane of foliation. Even to the unaided eye, the dark minerals of this rock appear more deformed and altered than in the average anorthosite. The thin section was cut normal to the foliation. The rock is composed of 75 per cent labradorite (An_{52}), 15 per cent much serpentinized hypersthene and fresh augite. At least 5 per cent of the rock consists of pinkish interstitial scales of a mineral that has the refringence, birefringence and cleavages of potassic feldspar. Small grains of green-brown hornblende, flakes of biotite, minute grains of opaque ores, some with leucoxene coatings, and tiny prisms of apatite are enmeshed with the pyroxenes. The plagioclase crystals measure from 0.02 to 1.5 mm. They are intricately sutured with one another. The larger ones show bent twinning lamellae and wavy extinctions. They are also fractured, and their borders are granulated, the whole producing a typical mortar texture. This anorthosite is, therefore clearly cataclastic. The dark minerals are grouped into discontinuous chains along which the feldspars are much granulated. The pyroxene crystals, all small and less than 0.5 mm. in diameter, show no pronounced deformation. But most of them are altered, and all are smaller than the crystals of the same minerals occurring in the typical anorthosite of the area. Perhaps these small pyroxenes resulted from the comminution of larger ones. The hypersthene is serpentinized and occurs as clear islands, showing pink to green pleochroism, in felty greenish masses rendered semi-opaque by the accumulation of secondary magnetite.

Other specimens of norite or noritic anorthosite contain the same minerals in similar textural arrangements but in different proportions. In some, the pyroxenes are very fresh, without any serpentinization. The plagioclase (labradorite An_{50-52}) crystals show typical mortar textures; the granulated borders of the larger crystals coalesce into a fine-grained cement which binds together ovoid cores of plagioclase. The noritic anorthosites, richer in pyroxene, are proportionately poorer in feldspar. In all these rocks the quantity of pink interstitial potassic feldspar seems to bear a fixed ratio to the quantity of plagioclase, from which it may be inferred that the potassic feldspar has been exuded from the plagioclase during deformation. Pyroxenes, mostly bronzy hypersthene, make up about 50 per cent of the norite. The hypersthene has the usual low birefringence, parallel or symmetrical extinction in sections normal to the principal optical directions, and marked pleochroism (green to pink) in sections normal to Z. Some crystals show also a well-developed Schiller structure. The other pyroxene is greenish augite, very weakly pleochroic. Extinction angles indicate compositions varying from magnesian diopside to ferroan augite. The crystals of the two pyroxenes generally occur side by side, grouped with flakes of reddish brown biotite and heteromorphic grains of brown hornblende. Magnetite and apatite are the main accessory minerals.

The occurrence of undeformed pyroxenes in rocks in which the feldspars are much granulated suggests that the pyroxenes are porphyroblastic and developed after the rock had been deformed. It is probable, however, that the original primary mafic constituent was also hypersthene because the undeformed ungranulated Morin anorthosite also contains hypersthene. Moreover, in some of the cataclastic anorthosite, the hypersthene is deformed, albeit less than the feldspars. Such deformation and cases of serpentinization as described above are consistent with a primary crystallization of the hypersthene. Perhaps the combined effects of shearing and recrystallization vary from place to place within the masses of anorthosite. In some localities the primary pyroxenes have been preserved, though deformed and degraded; elsewhere they have been completely made over into undeformed neoblasts.

The biotitic norites that outcrop in the northwest corner of the area differ from the other norites only in their biotite content, which is about 15 per cent. Biotite is an essential rather than accessory constituent in them. The other minerals are proportionately less abundant but bear the same ratios to one another as in the other norites. The plagioclase has the same composition: labradorite An_{51-53}. The mortar texture is also developed, but the fine mortar is less abundant. There is no interstitial pink potassic feldspar; its place is taken by biotite flakes more or less chloritized. The absence of potassic feldspar is perhaps due to a less severe granulation of the plagioclase. Or it might be supposed that the potassium exuded from the plagioclase has taken the form of biotite instead of feldspar. The pyroxenes are the same as in the other norites. In some specimens, hypersthene cleavages that lie across the foliation are bent. The biotite clings to the pyroxenes, penetrates and seems to have replaced them. There are also tentacular masses of brown hornblende which replace the pyroxenes and are in turn corroded by biotite. All the mafic minerals are in part replaced along their edges, cleavages and fractures by gangrenous growths of chlorite and finely fibrous amphiboles.

All the anorthosites and norites of the area contain a little quartz. According to Osborne (1949), chemically analyzed specimens all show some normative quartz, 3 per cent in average. The proportion of modal quartz, however, is difficult to estimate in thin section because of the near equality in refringence and birefringence of the quartz and feldspars.

The norites and anorthosites are everywhere fresh and free of hydrothermal alterations. Partly for this reason they are thought to be derived from dry charnockitic magmas. One exception has been found just east of Sainte-Marcelline, along the Rawdon - Pied-de-la-Montagne escarpment. A hypersthene norite passes within a short distance to an altered gabbro which resembles a greenstone. The feldspars appear as white, earthy veinlets which fade into a pale green mass dusted with pyrite. When examined in thin section, the alteration appears much less severe than might be thought from the external appearance of the rock. The plagioclases, fractured and sericitized though they be, have been determined optically to be labradorite (circa An_{50}). Masses of serpentine clearly show the outlines of pyroxene, perhaps hypersthene, crystals. Other pyroxenes have been transformed into fibrous masses of blue-green amphiboles of actinolite-tremolite compositions, as indicated by extinction angles. The feldspars are sliced into thin slivers which lie oblique to the foliation. The latter is marked by a parallel arrangement of the elongate serpentinized pyroxenes. These shear surfaces, as well as the alteration of the minerals, may be related to the fault that is believed to follow the escarpment at that point.

A thin section has been cut from a specimen of the pyroxenite found along the anorthosite contact in the southwestern corner of the area. The section shows a mosaic of hypersthene crystals from 3 to 4 mm. across, with scattered magnetite and interstitial feldspars which are too small for optical measurements.

The anorthosite is intrusive into the Grenville paragneisses. In one contact, tongues of anorthosite cut across banded paragneisses. Lenticular widenings in these tongues contain inclusions of paragneisses.

Pyroxene Gneisses, Quartz Mangerites, and Granulites

The other rocks of the Morin series are hypersthene-bearing orthogneisses; some quartzose, others without quartz. The former are leucocratic and contain potassic feldspars as well as calcosodic plagioclases. In the quartz-free gneisses, the plagioclases are rather calcic. For purposes of description, the Morin gneisses have been divided into three main classes according to their content of dark minerals and of potassic feldspar. The three classes are: hypersthene gneisses almost noritic in composition, quartz mangerites which are hypersthene granodiorites, and granulites which have the same feldspars as the mangerites but are less mafic and richer in quartz. None of these rocks form large homogeneous masses; they outcrop as intertwined discontinuous bands which cannot be shown individually on the map. Adams and all observers who have studied adjacent terrains have thought the Morin gneisses to be igneous rocks, comagmatic with the Morin anorthosite. The gneisses surround in a somewhat irregular but nonetheless striking fashion the Morin anorthosite massif. They have a similar charnockitic make up, with hypersthene as the chief mafic constituent. Their textures are protoclastic rather than cataclastic or mortar-type as in the Chertsey anorthosite-norite. This is interpreted to mean that the gneisses formed later than the anorthosite.

The pyroxene gneisses are dark grey, fine-grained rocks with a "pepper and salt" appearance. The pyroxenes have the shape of buckwheat seed and are uniformly distributed throughout the rock. The gneisses outcrop in bands of varied widths, from a few inches to hundreds of feet, more numerous and wider near masses of norite-anorthosite. Thin sections of these rocks reveal true gabbroic compositions: hypersthene plus augite from 35 to 50 per cent, plagioclase from 40 to 55 per cent, magnetite and apatite from 5 to 8 per cent, with some potassic feldspar as antiperthite lamellae or as interstitial splinters. The pyroxene gneisses differ from the norites by their fine grain - feldspars from 0.1 to 0.5 mm., pyroxene from 0.5 to 1.0 mm.- their mosaic texture (though occasional mortar structures have been observed), and a lower calcicity of the plagioclase, which is generally An_{40-42}, with some An_{30-35} and, very rarely, An_{50}. The pyroxene gneisses contain more hornblende - a dark variety with green-brown colours - than the norites. In one specimen, hornblende porphyroblasts constitute 20 per cent of the rock. The hornblende replaces the pyroxene and is rimmed with magnetite. Other specimens are strongly biotitic (18%); they also have the most sodic plagioclase (An_{33}). The most abundant pyroxene is hypersthene in rounded grains everywhere accompanied by augite. The pyroxenes are usually undeformed, but in one specimen in which the feldspars are much granulated some of the pyroxenes are likewise broken up and many have their cleavages bent.

The quartz mangerites are greenish, fine-grained gneisses in which the foliation is well marked by thin leaflets of mafic minerals. One variety has an augen texture; large ovoids of green feldspars (5-20mm.) are set in a dark mortar containing garnets. This augen gneiss outcrops as a continuous band, from 100 to 500 feet wide, enough perhaps to have been shown on the map. This band follows the west shore of Cloutier lake and is exposed at both the north and south ends of Stevens lake and at Corcoran near Français lake; from Corcoran, it may be traced southward to the middle of Range IX in Kildare township. Fine-grained mangerite without the augen texture is more common. It occurs along the borders of norite-anorthosite masses, mixed with pyroxene gneisses. Fine-grained mangerite is particularly abundant in the region between Sainte-Béatrix and Saint-Jean-de-Matha. In this part of the area the rock is more fissile than elsewhere, and its exposures have squamose surfaces. The main constituent of the quartz mangerites is plagioclase of composition between An_{30} and An_{40}. The facies richer in mafic minerals contain the more calcic plagioclase. Quartz, though inconspicuous to the naked eye, makes up nearly 25 per cent of the mangerites. It occurs in ragged lenses, 1 mm. long, or as small interstitial grains. Potassic feldspar is subordinate to the plagioclase in ratios between 6 to 1 and 1 to 1. It takes the form of antiperthitic lamellae, of vermicules, or of pinkish coatings up to 0.2 mm. thick around the plagioclase. Some of the worm-like antiperthitic growths sprout from these coatings into the plagioclase. In one specimen the potassic feldspar has been recognized as microcline by its wide optic angle and faint quadrille twinning. In other specimens the properties noted are those of orthoclase or anorthoclase. The mafic minerals are mainly hypersthene and augite, the former more abundant than the latter, and the two combined making up from 10 to 20 per cent of the rock. The pyroxene grains, from 0.2 to 1.0 mm. in diameter, are usually accompanied by swarms of biotite and magnetite. Apatite has been noted in all specimens.

The fine-grained mangerites have granoblastic textures; the feldspars are generally undeformed, and show smooth contours and uniform extinction. Intricate sutures and wavy extinctions do occur, however. In the augen mangerites, the large feldspars are deformed and show bent twinning lamellae, fractures normal to the foliation of the rock, and granulated borders. In some cases these signs of deformation have been partly erased by recrystallization; clear porphyroblasts with uniform extinction and straight twinning lamellae have taken the place of the older phenocrysts or crystalloblasts, of which only occasional vestiges remain. The ground-mass of the augen mangerites, except for the mylonite-like mortar surrounding the feldspar augen, is granoblastic.

The granulites are very similar in texture to the fine-grained mangerites. They differ from the latter by their buff to chamois colour, their small, almost negligible, content of mafic minerals, and their high content of quartz. This granular quartz occurs as clear lenses, from 1 to 2 mm. thick and from 20 to 30 mm. in diameter, which stand in relief on exposed surfaces and reveal the attitude of the foliation. Many of the granulites are garnetiferous and resemble the finer-grained sillimanite paragneisses described above. In fact, some of the sillimanite paragneisses have been recognized as such only in thin sections, so that many exposures mapped as mangerite-granulites may actually be Grenville paragneisses. Even allowing for such mistakes, the buff granulites constitute more than one sixth of all the gneisses in the area. Practically all the orthogneisses outcropping between the two bands of Grenville paragneisses along Rouge river are buff granulites. They are also very abundant near Rocher lake and Camp Marcel. Mineral constituents identified in thin sections of the granulites are quartz in long lamellae 0.5 mm. wide, plagioclase, and potassic feldspars as tiny, pinkish grains similar in shapes and quantity to the ones noted in the mangerites. Quartz and plagioclase each make up 40 per cent of the granulite. The rest consists of disseminated small crystals of hypersthene, magnetite, and apatite. The quartz lenses have clean, smooth outlines which truncate the twinning lamellae of the plagioclases and contacts between feldspar grains. The quartz lenses consist of only one crystal or of a few crystals and swarm with rutile needles arranged in regular patterns and oriented at about 45° with the foliation. The rutile needles thus appear to lie in shear planes or particular crystallography planes within the quartz crystals. The feldspars form granoblastic aggregates between the quartz lenses. In brief, the granulites are like mangerites which would be low in pyroxene and rich in quartz.

The pyroxene gneisses, quartz mangerites and granulites are younger than the Grenville paragneisses that they have invaded. In contact zones, the orthogneisses become garnetiferous and are loaded with shreds of quartzite, amphibolites, and garnetiferous gneisses. They are also richer in potassic feldspar and biotite, and thus, through endomorphism and exomorphism, have been transformed into true migmatites. Half a mile north of Rouge lake a brecciated contact zone consists of rounded fragments of quartzite, sillimanite garnet gneiss, amphibolite, and graphitic rusty-weathering gneiss engulfed in buff granulite. A similar contact may be observed near Dalles bridge on Assomption river east of Sainte-Béatrix.

Relationships of the granulites and associated gneisses with the norite-anorthosite are less clear. Along the margin of the Morin massif, northwest of Rawdon, pyroxene gneisses and mangerites are so intertwined with the anorthosite that the limit of the anorthosite could not be established at the beginning of field work; on the field map this limit was first drawn about a quarter of a mile to the west of its position on the final map. In this contact zone the mangerite and pyroxene gneisses seem to penetrate the anorthosite. Elongated inclusions of anorthosite were found within the bands of pyroxene gneisses.

Age relationships between the pyroxene gneisses, mangerites, and granulites have not been indicated for lack of conclusive evidence. Most contacts between these rocks are sharp and concordant, even within a single thin section. Such a section was prepared from a specimen showing the contact between pyroxene gneiss and a buff granulite. The contact is a sharp line, and the plagioclases are the same on both sides of it. On the granulite side there is much quartz and potassic feldspar, and only three small grains of hypersthene. On the pyroxene gneiss side there are only two grains of quartz and numerous large crystals of hypersthene. One exposure, however, in the Rouen concession near Assomption river shows discordant relationships. Thin layers, plicated and bleached on the edges, of amphibolite and quartzite are included in a grey fine-grained mangerite. A tongue of augen mangerite cuts through the fine-grained mangerite and the layers of amphibolite along the axial plane of one of the small folds in a manner recalling diapiric intrusives. (1)

If all these gneisses containing hypersthene are truly igneous rocks and are all derived from the same Morin magma, they must have crystallized at approximately the same time since their feldspars all have the same compositions. On the other hand, if the present mineralogical assemblages result entirely from metamorphic changes, identity of mineral phases mean only a common isograd of metamorphism of which hypersthene, common to all these gneisses, is the index mineral.

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(1) Nicolesco C.P. (1929) - Anticlinaux diapirs sédimentaires, volcaniques et plutoniques: C.R. Jour. des séances, Soc. Géol. de France, pp. 21-24.

Pink Granitic Gneisses

Granitic gneisses unlike the granulites of the Morin series are exposed at the extreme edge of the Shield area, south and west of Rawdon, near the church at Saint-Ambroise-de-Kildare, and in several other places. The mafic minerals in these gneisses are greenish phyllosilicates arranged in thread-like groups. Quartz is abundant; it does not form flat lenses as in the granulites but occurs in irregular grains. All the feldspars are pink. Grain sizes vary markedly, but keep generally between 1 and 5 mm. Pegmatitic infiltrations are common, particularly near contacts with other rocks. A typical mineral composition may be given as:

Quartz	30%
Microcline-perthite	35-40%
Oligoclase (An_{17-22})	15-20%
Green chloritized biotite	10-15%
Apatite, zircon, magnetite	2%

The quartz grains are much indented, tend to stretch parallel to the foliation, and show undulating extinction. Tiny pink slivers of very fresh potassic feldspar border some of the quartz. This untwinned feldspar differs in appearance from the cloudy perthitic microcline that constitutes much of the rock. The oligoclase is somewhat altered, like the microcline, and its cleavages are lined with chlorite. The two feldspars, with the quartz, form granoblastic aggregates in which grain boundaries are somewhat sutured. The biotite flakes are oriented parallel to the foliation. All are green, and in some specimens they are completely changed to chlorite.

The quartz mangerites that are in contact with the pink granitic gneisses contain pegmatitic lenses; this suggests that the pink gneisses are younger than the hypersthene-bearing rocks of the Morin series. In the bed of Kildare brook, small exposures of garnetiferous quartzite contain injections of pink granitic rock almost free of biotite and composed entirely of microcline perthite and quartz. The grain is coarse, up to 2 cm. These injections are probably pegmatitic apophyses related to the Kildare granitic gneisses.

Diabase

Several small diabase dykes have been mapped within six miles of Rawdon, in the western part of the area. The largest one, 15 feet wide, is exposed in the banks of Ouareau river, at the foot of Manchester falls. Another dyke, 10 feet thick, appears in a railroad cut south of Rawdon. The others are very small, less than 3 feet thick. In most the diabase is black and fine-grained. One specimen from the railroad cut has been examined in thin section. In spite of its dark colour the rock is quite feldspathic. Rectangular laths of andesine (An_{40}), rendered almost opaque by dust-like inclusions, surround heteromorphic crystals of hypersthene, augite, magnetite, and especially myrmekitic aggregates of quartz and plagioclase. These aggregates constitute more than a quarter of the rock. A similar diabase containing hypersthene and graphic intergrowths of quartz and feldspar has been described by Adams from a locality about 1 mile northwest of Rawdon. The diabase at Manchester falls is greenish black and rather coarse grained. To the unaided eye the texture does not appear ophitic; the feldspars and pyroxenes appear distributed at random in all possible orientations. As seen in thin section, however, the rock is decidedly ophitic, with rectangular blades of plagioclase piercing through large crystals of augite. The plagioclase is zoned, and compositions in the zones in which extinction angles could be measured vary between An_{55} and An_{60}. There are some interstitial granophyric aggregates in which the indices of the feldspar are low enough to indicate potassic compositions. The pyroxene is mainly augite, but some grains are uniaxial and have the properties of pigeonite. Other minor constituents are biotite, hornblende, magnetite, and apatite.

These diabases are not in the least deformed or metamorphosed. They must be younger than the other crystalline rocks. They all strike east-west, and, though none of them has been traced for more than 50 feet, they are definitely parallel to the regional zones of fractures described above. The dykes occupy fractures which developed, perhaps earlier, but under the same stresses as those regional fractures.

Pegmatite

Small lenses of sheared pegmatite are intercalated in the Grenville paragneisses in various places. All are simple pegmatites, which are white weathering and are composed entirely of quartz and very pale feldspars. Their derivation is unknown.

Pink dykelets of similar rock, from one to three inches thick, cut across the foliation in the anorthosite. The dykelets are undeformed and fill fractures, some of which show displacements of their walls. The dykelets may represent a pegmatitic fraction of the anorthositic agma. However, since they are posterior to the cataclastic structure of the anorthosite and are undeformed, their genetic connection with the anorthosite is uncertain.

Paleozoic Rocks

Four large exposures of sedimentary Paleozoic rocks have been mapped along the banks of Ouareau river. For purposes of description they are designated as follows:- Exposure No. 1 is situated a short distance below the bridge in Ruisseau Vacher Concession. Exposure No. 2 is halfway between this bridge and the one at Saint-Liguori. Exposure No. 3 lies 1/4 of a mile above Saint-Liguori bridge, and exposure No. 4 is at the latter bridge. The rocks are mainly nonfossiliferous sandstones dipping gently to the southeast (Plate VA). In exposure No. 1 the rocks are white orthoquartzitic sandstones, typically Potsdam. The total thickness of the exposed layers is only 15 inches. More of the same rock is visible in exposure No. 2 where 18 feet of strata have been measured. The lowermost 21 inches of beds consist of grey, well crystallized limestone peppered with spherical frosted grains of quartz. The rest of the exposure consists of typical white Potsdam orthoquartzite, composed of well rounded spherical quartz grains from 0.2 to 0.5 mm. in diameter. The rock is porous, but does not effervesce with hydrochloric acid; its cement is, therefore, not calcareous. Beds of calcareous sandstone of "Fontainebleau" type are intercalated within the uppermost strata. The calcite cement in these beds forms large crystals in which the clastic quartz is imbedded. The appearance of the quartz is that of the nearly spherical clear inclusions so common in the andalusite of hornfels. Some of these calcite crystals stuffed with quartz have cleavage faces measuring 2 to 3 inches in breadth. One conglomeratic layer noted in these beds contains pebbles from 1/8 to 1/2 inch in diameter of vitreous quartz. A few interbed surfaces show ripple marks (Plate VB).

Exposure No. 4 at Saint-Liguori bridge shows 10 feet of the same sandstones. The lower beds are white orthoquartzites; the upper beds consist of calcareous sandstones, some of Fontainebleau type. Considering the average easterly dips of these strata, exposures Nos. 1, 2 and 4 probably belong to the same stratigraphic horizon. Exposure No. 3 contains 8 feet of strata which are not exposed continuously but in three sections with intervening gaps. The lowermost beds are of very calcareous sandstones like the beds of exposures Nos. 2 and 4. Fontainebleau-type sandstones overlie these calcareous beds. The upper beds are very calcareous and consist mostly of a pinkish grey limestone, crystalline in texture, which seems very pure; no clastic quartz could be found in it with a binocular microscope. At the very top of the section lies a 15-inch bed of buff pitted limestone, which looks dolomitic.

The white sandstones of exposures Nos. 1, 2 and 4 resemble in detail the Potsdam orthoquartzites that are exposed at Saint-Canut and elsewhere in the Saint-Lawrence Lowlands. They were, moreover, termed Potsdam by Logan. Exposure No. 3 may be an upper stage, that is, the beginning of a transition zone between the Potsdam sandstones and the Trenton limestones that are exposed lower down the Ouareau, 1 mile south of the area.

STRUCTURAL GEOLOGY

Folding and Foliation

Excepting the Paleozoic sandstones and limestones, and the few dykes mentioned above, all the crystalline rocks of the area are gneissic. In the norite-anorthosite the foliation is parallel to the layering, i.e. to the alternating layers of gabbro and of anorthosite that are believed to have developed during orthomagmatic crystallization in the Morin massif. In the Grenville paragneisses, the banding and the foliation are also parallel, and both are thought to follow an original stratification. This is clearly the case where layers of limestone are intercalated within the paragneisses. Similarly, the foliation follows the layering in those gneisses and quartzites (Plate VIA) in which this layering is so regular that sedimentary stratification seems the only way to account for it. The foliation in the orthogneisses is concordant with contacts and with the gneissic structures of the other rocks; there is no apparent discontinuity in the gneissic structure in passing from one rock to another. This pervasive foliation is folded, and its strike clearly follows the contour of the Morin massif. The gneisses strike north-south in the central and southern parts of the area but oblique towards the west in the northern and northeastern parts of the area. Dips are rather flat; the amplitudes of the folds, everywhere small, decrease toward the east. Near Saint-Jean-de-Matha and Rocher lake, the gneisses are horizontal over wide areas. The axial portion of one of the sharpest anticlines is well exposed in the bed of Rouge river at the point where the latter crosses the boundary between Juliette and Montcalm electoral districts.

When all these observations are pieced together, the outcrops of the Grenville paragneisses appear, not as discrete or disconnected shreds, but as the exposed edges of a single, folded, thick layer of metasedimentary rocks, locally thinned by injected Morin orthogneisses. The whole complex has been folded; erosion has planed off the anticlines and thus exposed the paragneisses as more or less parallel bands. The several bands of crystalline limestone may very well as Adams thought, belong to a single stratigraphic horizon, or at most to two or three such horizons. Similarly the bands of norite-anorthosite appear as synclinal segments of a single sill that thins out and splits into small tongues in its eastern part. The circular outcrop of anorthosite-norite east of Rocher lake belongs to such a tongue, more or less cylindrical in shape. The short band of the same rock that outcrops at the confluence of Assomption and Noire rivers is another branch of the main sill, more tabular in shape. If the Morin massif is a laccolith, than the whole sill and its various branches may be the thin edge of the laccolith itself.

In the Grenville paragneisses, the foliation, being parallel to the stratification, must have developed through mimetic recrystallization. In the orthogneisses and in the norite-anorthosite masses, the development of the foliation must have been influenced by schlieren types of fluidal structures and by early segregation of mineral constituents into stratiform layers.

The folding must be posterior to the intrusion of the norite-anorthosite because a large sill of these rocks, as well as the edge of the Morin massif itself, has been folded. The core of the massif, however, has seemingly resisted deformations; fold axes had to bend around this passive rigid block. The mangerites and granulites have protoclastic textures which suggest folding and deformation prior to complete crystallization, or at least at a time when recrystallization was easy.

In all of these rocks, folding was accompanied by much stretching. Adams has described, in some orthogneisses, inclusions of amphibolites stretched into separate fragments, the broken ends of which are seen to match perfectly. Many fragments of quartzites and paragneisses included in mangerites and granulites, though they cannot be pieced together as easily, show evidence of stretching. In the layers of crystalline limestone, blocks of paragneisses have been fractured and drawn out into fusiform masses, or brecciated. In some of the petrographic descriptions above, attention has been drawn to the linear element added to the foliation through stretching of the rocks. Wherever the comparison could be made, this lineation was found to be parallel to the axes of small folds and generally to the main fold axes. One of the best exposures where this relationship may be observed is situated at the discharge end of Rawdon lake (Plate VIB). According to the attitude of the lineation, fold axes at the latitude of Rawdon plunge southward at approximately 15^{o} (Plate VIIA). The lineation becomes horizontal a little farther north, and plunges to the north between Français lake and the northern limit of the map-area.

Fracturing

No faults have been observed in the crystalline rocks; a few small fissures filled with quartz or pegmatite veins show insignificant displacements of their walls. As remarked by Adams, any rupture developed in these rocks during folding would not have persisted because, in the physical environment in which metamorphism reaches the sillimanite isograd, deformations take place by flowage rather than by rupturing. The most conspicuous fractures that developed in the gneisses after recrystallization, when the rocks had become elastic again, are tension cracks that show no displacements of their walls. The existence of a fault along the Rawdon - Pied-de-la-Montagne escarpment has been surmised mostly from topographic features, as explained above. An additional argument for the presence of a fault at that place may be drawn from the attitude of the lineation in the rocks of the Kildare ridge. This lineation has a steep northward plunge, but, at the same latitude, near Rawdon, on top of the escarpment, lineations are horizontal or plunge at small angles southward. This abrupt change and reversal in the plunges of lineations across the escarpment may indicate tilting as well as down-faulting of the Kildare block.

Garnets and other minerals in the gneisses show parallel tension cracks that are normal to lineations. Because of these cracks, the rocks have a kind of cleavage that has made easier the development of tension joints normal to the lineation (Plates IIIA and VII). Many other types of joints occur in the rocks of the area, but have not been mapped.

ECONOMIC GEOLOGY

Sands and gravels are the only mineral resources now exploited in the area. Most of the pits are small and serve to supply local needs for road building and maintenance. At Hamilton, south of Rawdon, a large pit has been excavated in the Rawdon sands. About 100 tons of sand and gravel are extracted daily. The greater part of this material is sold to Canadian National Railways for ballast and concrete aggregate. Some of the sand is shipped to Montreal foundries as moulding sand.

Rawdon is situated near the edge of the Morin anorthosite. The existence within the area of ilmenite or titaniferous ore deposits, similar to those at Ivry, is possible.

Many pits and shafts were dug in the past by prospectors in search of gold. Two such excavations were visited. The first one, described by Adams, is located one mile south of Rouge lake and was dug in crystalline limestone. Adams reports that the samples that he collected and had assayed contained neither gold nor silver. The other excavation visited is so old that the local people do not know when it was dug. The rock is a peculiar breccia composed of small angular fragments of granulite cemented with calcite, some of it in large rhombohedra from 2 to 3 inches in diameter. The breccia contains some pyrite, and it is probably this sulfide that attracted the attention of the prospector. Near the pit is an exposure of paragneiss very rich in graphite; the local people use pieces of this rock to polish their stoves. The quantity and grade of this graphite ore are insufficient, however, to justify even a small-scale exploitation.

In the summer of 1948, somebody was diamond drilling the thick quartzite that is exposed in the escarpment north of Pied-de-la-Montagne. When the writer visited the locality, operations had ceased because of the lack of water. The object of this drilling is unknown.

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APPENDIX

Mining Developments from 1948 to 1959

by J.-E. Gilbert

A limited amount of systematic geological exploration work was carried cut in the Rawdon area between the years 1948 and 1959. A study of the clay deposits of the Ste-Julienne area was carried out in 1957 and it was found that the material had many desirable qualities. Some prospecting, geophysical work and a little diamond drilling were also done on occurrences of ilmenite and titaniferous magnetite.

November 13, 1959.

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