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MONTREAL AREA, LAVAL AND LACHINE MAPS AREAS

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MONTREAL AREA
LAVAL AND LACHINE MAP-AREAS

by

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Aerial view of the central part of the city of Montreal looking northwestward from the waterfront across the business district toward Mount Royal — June, 1950.

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INTRODUCTION

Location and Extent of Area

Originally begun in 1938 as a study of Ile Jésus, the investigation here described was continued and extended through parts of 1939, 1940, and 1941 to include all the territory embraced by the Laval and Lachine map-sheets of the National Topographic series, published by the Department of National Defense. These areas comprise about 417 and 418 square miles, respectively, or a total of 835 square miles. Each is bounded by longitudes 73°30′ and 74°00′. The Lachine sheet extends from latitude 45°15′ to 45°30′, and the Laval sheet from latitude 45°30′ to 45°45′. The city of Montreal is in the east-central part of the region examined, straddling the boundary between the two map-areas. The central part of the area, Ile Jésus, and the Island of Montreal comprise the counties of Laval, Hochelaga, and Jacques Cartier. To the north lie parts of l'Assomption and Terrebonne counties, to the west part of Two Mountains county, to the east part of Chambly county, and to the south parts of Vaudreuil, Beauharnois, Chateauguay, Laprairie, and Napierville counties.

A Preliminary Report (P.R. No. 147) on the work done in 1938 and 1939 was published in 1940, and a further Preliminary Report (P.R. No. 158), published in 1941, included the results of the work of the 1940 field season.

Purpose of the Survey

Three major purposes contributed to make this survey of great importance. First, there is impending the complete outlawing of quarrying on the Island of Montreal. Whether or not this will, in practice, be applicable to the northern and western ends of the island, it is certain that, in the central part at least, the continued growth of the city will necessitate the discontinuance of heavy blasting. Quarrying activity will eventually migrate elsewhere. Ile Jésus offers the most likely field for limestone exploitation, for this is the only place close to the city where there is an abundance of limestone suitable for commercial purposes. It was considered that a geological survey of the area would serve to delimit the areas of satisfactory stone from those of formations which would serve little if any useful purpose. In this connection it might be stated that no geological map of Ile Jésus hitherto published is trustworthy, and any industry basing its development upon earlier publications would be sadly misled.

Secondly, questions are constantly arising with regard to the possibility of the occurrence of oil and gas in the Saint-Lawrence Lowland. Oil seeps, gas in wells, and stories of successful exploitation elsewhere, serve to stimulate local hopes. During the winter of 1937-38, a hole was drilled near Sainte-Thérèse to a depth of 3,036 feet in a fruitless search for oil. It was considered advisable to re-examine the geological structure of the neighbouring territory to determine whether or not local search for oil or gas held promise of success.

Lastly, the region around Montreal affords exceptional opportunities for the observation and study of geological structures and stratigraphy and thus is an excellent theatre for the instruction of students in geological methods; but for this it is necessary for the structure to have been worked out and mapped accurately beforehand. Such a piece of field work as this, therefore, may have considerable value in the training of young geologists of the future, upon whom the development of Quebec's resources will in so large a measure rest. Moreover, in a region such as this, where a large proportion of the Province's, and a sizeable portion of the Dominion's, population resides, a map showing where bed-rock actually outcrops, and the nature of the rock, should be of use in a wide sphere of activities.

Previous Work

In 1863, Sir William Logan, Director of the Geological Survey of Canada, published his *Geology of Canada,* in which he brought together the results of his earlier work, unified them, and presented a clear picture of the general and economic geology of 'Upper' and 'Lower' Canada as at that time known. He embodied the results of his field work in a map, and, so far as the Montreal area is concerned, the boundaries of formations as shown on that map remained the standard up to the present survey. Few refinements, and none of importance, had been suggested before the start of the present work. Logan's boundary lines between the various formations were accepted by Ells (1896), Adams and LeRoy (1904), Goudge (1935), and others. Difficulties in understanding Logan's interpretations may have been recognized, but no attempts were made to improve upon them. Except for the reports by Logan (1863) and by Ells (1896), and the *Guide Book No. 3* published by the Geological Survey of Canada in 1913, little of general importance has been written on that part of the Laval and Lachine map-areas covered by this report. Stansfield, who constructed the map accompanying the *Guide Book* (1913), was the first to show, in any detail, the distribution of the igneous rock varieties on Mount Royal.

Specialized papers such as those by Howard (1922), Stansfield (1923), Finley (1930), Bancroft and Howard (1923), Osborne and Grimes-Graeme (1936), Okulitch (1935, 1936), among a long list, have contributed greatly to our present knowledge. In addition to the published works there are, in the Redpath Library at McGill University, a number of unpublished theses by students in the Department of Geological Sciences. These are listed at the end of the *Bibliography*. They are for the most part detailed studies of restricted areas or subjects and have been drawn on freely by the present writer.

Acknowledgments

During the prosecution of the field work upon which this report is based, I had the welcome co-operation of Rev. Father Léo Morin, C.S.C., then professor of geology at the University of Montreal. I am indebted to Mr. R. de Roumefort for permission to use parts of his report on the drilling of the well at Sainte-Thérèse and for other incidental information. To scores of quarry owners and foremen my thanks are due for permission to examine their properties, and I am indebted to Dr. F. Fitz Osborne, for critical comments and constructive suggestions in connection with that part of this report concerned with the igneous rocks.

Method of Work

Copies of the Laval and Lachine map-sheets issued by the Department of National Defence, Ottawa, enlarged to a scale of two inches to one mile, were used as a base upon which to record the field data. Every visible exposure has been visited and plotted, approximately to correct scale, directly upon these maps. Outside of Mount Royal, most of the country is sufficiently open so that many of the exposures can be seen from the roads. In addition, practically all streams have been traversed, and, in wooded regions and in sections where the roads are far apart, traverses have been run sufficiently close together so that no important exposures could escape observation. Traverses across country were carried out by pace-and-compass methods. Transportation was provided by automobile.

DESCRIPTION OF THE AREA

Regional Development

The Laval and Lachine map-areas straddle the Saint-Lawrence river which, at Montreal harbour, is 58 feet above sea-level, and above the Lachine rapids where it widens into what is known as lake Saint-Louis, 69 feet above sea-level. From the shores of the river the land rises, both to the southeast and to the northwest, to heights of nearly 250 feet, forming a nearly featureless plain broken by such interruptions as Mount Royal (759 feet above sea-level) and La Prairie, Mille Isles, Mascouche, and Châteauguay rivers. The first two mentioned rivers, really branches of the Ottawa, enclose Ile Jésus between them, and between rivière La Prairie, the main Ottawa river, and the Saint-Lawrence lies the Island of Montreal.

The two map-areas lie wholly within the larger physiographic feature known as the Saint-Lawrence lowland. This, a wedge-shaped area, is hemmed in on the north by the Laurentian upland, and on the southeast by the Appalachian upland. The two uplands converge to within a few miles of each other in the vicinity of Quebec city, but at Montreal the lowland is 65 miles wide from the northwest to the southeast. There is little doubt that the lowland, and hence the general position of the Saint-Lawrence river, is due to the inferior resistance of its rocks to weathering and erosion, whereas the bordering upland belts consist of harder, more resistant rocks.

Dotted across the lowland is a group of eight hills known collectively as the Monteregian hills. These are, from west to east, Mount Royal, Saint-Bruno, Saint-Hilaire, Rougemont, Yamaska, Johnson, Shefford, and Brome. According to popular fancy Mount Royal, the one around which the city of Montreal has grown, is an extinct volcano. No good evidence exists for such a view. It is true that these hills are all composed of what was once molten rock but the evidence points to an exclusively sub-surface emplacement of their material. If this is correct, none could have shown at the surface at the time of their origin and, hence, none could have been volcanoes. Traditions and fancies die hard, and Mount Royal will probably long continue to be thought of as a volcano.

Both the hard rock of Mount Royal and the soft rock of the surrounding lowland are largely masked by a widespread deposit of clay, sand, boulders, etc. This has served partly to level up the country over which it has been spread, and partly to distribute, for good or ill, a variety of soils which make for a considerable diversity of agricultural interest and development. Hence, even the daily food supply of present-day Montreal is dependent upon its geological history, for the latter determined what kinds of soils were to be developed in the various parts of this area. Mixed farming is practised over the cultivated parts of these two map-areas. Low black-earth valleys, as at Sainte-Dorothée and Abord-à-Plouffe, make excellent truck-gardens. Elsewhere, clay areas yield splendid crops of wheat and oats, though careful rotation is necessary to prevent depletion of the mineral reserves of the soil. Some parts are fit only for pasturage.

Little by little, land is being withdrawn from productive uses as the city itself grows and the suburban population spreads out more and more widely. Twenty-five years ago what is now the Town of Mount Royal, at present largely built over, was a collection of prosperous farms such as today are to be found in the country immediately to the north. The past two years have seen the northern slope of Mount Royal on both sides of Côte des Neiges opened up as residential quarters, where before and during the 1939-1945 war, this area was being developed agriculturally. Though there seems to be plenty of land in the outlying districts, ease of travel furthers the withdrawal of land from farming and its transformation into country estates. There will be no let-up in this process as long as Montreal continues to grow.

Urban Development

Montreal owes its pre-eminence among Canadian cities to a combination of factors, the most important of which is its physiographic setting controlled by its geological background. Its uniqueness as the Metropolis of Canada stems directly from its position at the head of navigation on the Saint-Lawrence. The Lachine rapids, up which no shipping has been able to pass, are developed over a series of igneous intrusions.

Montreal has been called the place where great rivers meet. It is, therefore, a place where early and primitive transportation routes came together. To the early settlers it proved to be extremely significant that, near the limit of navigation, *i.e.*, the Lachine rapids, four major river routes radiated: one, the lower Saint-Lawrence, toward the sea: two, the upper Saint-Lawrence, toward the Great Lakes: three, the Ottawa river, toward the west: and four, the Richelieu river, pointing toward the Hudson and the English and Dutch settlements of the Atlantic coast. To be sure, it was the Lachine rapids that determined the site of Montreal, but the Ottawa and Richelieu routes enter the Saint-Lawrence at distances not great enough to make the site of the city inconvenient (Blanchard, 1947).

In prehistoric days, the Saint-Lawrence was a highway for Indian parties bent either upon warfare or upon seasonal travel to the fishing waters of the Gulf. These routes, whether by canoe or on land, provided the early European settlers with a network of communication ways which needed little further development. Not until settlements became sufficiently thickly populated were wagon roads necessary.

Once established, the settlement at Montreal grew and thrived upon the trade convergent upon it by land and water routes. There was little in the original physiography to prevent an almost unlimited expansion of the city. While, up to 1700, the settlement occupied only a few of the present city blocks, from that time on expansion to the north, west, and south was rapid. Only a few minor surface features close to the original settlement need be mentioned. Two small streams, Saint-Martin and Saint-Pierre, flowing respectively from the north and south, entered the Saint-Lawrence at Pointe-à-Callières after joining forces a few hundred yards above their common mouth. For a primitive settlement, these small streams served, first, as a boundary, and second, as a minor natural line of defence. As the city developed along what are now Bleury, Saint-Lawrence, and Saint-Denis streets, these streams became of no importance in defence and a positive drawback to settlement and hygiene. They are today non-existent as surface flows, though all Montreal engineering works near the waterfront must take note of their underground course. The low stretch upon which Craig street lies today is the site of Saint-Martin river.

Beyond these two streams expansion of the city met, but was not held up by, the numerous east and southeast facing terraces upon which the level streets, such as Dorchester, Sainte-Catherine, and Sherbrooke, were opened at a very early date. Actually, these terraces provided an incentive for the westward spread of the city, giving to dwellings and institutions a broader outlook and in all ways a more desirable site. The terraces have a definite geological cause. Each represents a beach made at times of stand-still of the receding sea subsequent to the almost complete inundation of this region in immediate post-glacial times. Expansion in a northwesterly direction, however, was brought to an abrupt halt early in the 19th century by the steep front of Mount Royal. From then on, the stream of population divided and swept around the mountain, the settlement on the northern side becoming what has been named, appropriately, Outremont. No other physical drawback to the expansion of the city within the Island of Montreal has prevented the growth of the city in any direction.

Remotely related to the geological controls is the racial development. Primarily French, other stocks have entered more or less largely into the make-up of the metropolis. With the advent of the British régime in 1759, a flood of businessmen, traders, artisans, etc., from Britain entered the city, and they have been followed to the present time by a steady stream of settlers from those islands. Thus it came about that from 1830 until 1860 the English-speaking section of the population outnumbered the French. However, the situation was subsequently reversed by a constant influx of French Canadians from the surrounding agricultural areas, so that, in spite of immigration of other nationals, the French proportion of the population since 1865 has been predominant. As intimated above, even this can be said to have had a geological control. For the first hundred years, Montreal and its surrounding plain were settled exclusively by emigrants from France and their descendants. The natural growth of the main city would come partly by means of domestic increase and partly by easy infiltration along level land. All outsiders (in this case largely English-speaking settlers from elsewhere) had mountainous barriers (Notre Dame, White, Green, and Adirondack mountains) to cross before reaching its site.

Montreal's position as Canada's chief commercial centre has never been seriously challenged by any other city. From modest beginnings when all the surrounding country contributed its furs to be shipped to Europe in exchange for food, machinery, and all but the coarsest clothing, the products to be exported have grown in variety and amount until today Montreal is North America's second largest port.

STRATIGRAPHY

General Statement

The stratigraphic succession, as worked out in the Laval-Lachine area, is set forth in the following table:

Stratigraphic Succession in the Laval-Lachine Map-Areas

Quaternary	Post-glacial sands and clays Later non-marine deposits Saxicava sands Leda clay Glacial deposits
Tertiary	Igneous series, consisting of essexite, nepheline syenite, dykes, and breccia Probably Early Tertiary, possibly Cretaceous
Devonian	Oriskany limestone (In Sainte-Hélène Island breccia) Helderberg limestone
Ordovician	Lorraine group Utica group Lachine formation Trenton group Terrebonne formation Tetreauville formation Montreal formation Rosemount member Saint-Michel member Mile End formation Black River group Leray formation Lowville formation Pamelia formation Chazy group Laval formation, including: Saint-Martin member Sainte-Thérèse member Beekmantown group Beauharnois formation Theresa formation
Cambrian	Upper Cambrian series Potsdam formation
Precambrian	Grenville and later Precambrian series

Precambrian rock occurs just within the western limits of the area, at Saint-Joseph-du-Lac, in both the Laval and the Lachine map-areas. The Potsdam sandstone is not known in that vicinity, but does outcrop at Sainte-Anne-de-Bellevue, on Ile Perrot, and on the mainland to the west and south of that island. The Beekmantown is the most widespread of all of the formations, and this is not surprising when one considers that it is the thickest of all. The Chazy rocks, instead of occurring in a continuous belt, are now shown to be in four areas separated by faults. In *Geology of Canada,* Logan distinguished the Black River group by name, but on his map the formation is nearly everywhere included in the Trenton. In this report and on the accompanying maps it is treated as a separate unit. The Trenton group is here subdivided for the first time into component formations. Utica shale occurs along the southeast shore of the island of Montreal. It is found also on the opposite shore of the Saint-Lawrence at Saint-Lambert and Longueuil, and on the mainland south of the Saint-Lawrence in the vicinity of Delson. A band of Lorraine outcropping on Ile à Boquet has been recognized for the first time. Devonian rocks occur only as fragments in the breccia of Sainte-Hélène island. No detailed study of the glacial or post-glacial deposits was made. The igneous rocks are bodies of gabbro, nepheline syenite, and related rock types. together with their associated sills, dykes, and igneous breccias, all of which were found to be younger than any of the consolidated sediments.

Of great interest and importance in the understanding of the stratigraphic succession is the log of a deep well put down near Sainte-Thérèse. This well, drilled in an unsuccessful search for oil, passed through the Chazy and Beekmantown formations and penetrated 1,696 feet into the Potsdam sandstone without reaching its base. The details of this log will be found under the description of the formations through which it passed. The influence of the information gained from this log upon the general concept of the possibility of oil being found near Montreal is discussed under the heading *Economic Geology.*

Of very great importance in the study of the local igneous rocks is the log of the Canadian National railway tunnel bored through the mountain from what is now the Central Station terminal to the Town of Mount Royal. This tunnel, more than three miles long, started and ended in the sedimentary rocks that flank the mountain and passed completely through its igneous core. Much of the geological information gained during the drilling of this tunnel is to be found in published papers *e.g.,* Bancroft and Howard, 1933; Finley, (1930) and in unpublished theses in the Department of Geological Sciences, McGill University.

PRECAMBRIAN

The Oka Outcrops

The only outcrops of indubitable Precambrian rocks in the entire Laval area are in the southwest corner of the Laval sheet. From the Saint-Eustache-Oka highway (No. 29), at a point about a mile east of the western margin of the Laval sheet, a side road branches off in a northwesterly direction to (and beyond) Saint-Joseph-du-Lac, a village half a mile beyond the boundary of the map-sheet. Just before reaching that village the road ascends a sharp rise, which is in large part due to the presence of Precambrian rock (see Plate I-A). Abundant exposures can be seen on both sides of the road for a mile or more, although only one or two of these are within the Laval sheet. About two miles south of Saint-Joseph there is a small area of outcrop of granite and syenite just within the Lachine sheet. These rocks have, in places, been shattered and re-cemented, and in the resulting breccia there are a few pieces of crystalline limestone, presumably belonging to the Grenville series. Similar brecciation can be seen north of highway No. 29, just within the Lachute map-area. It is assumed that this brecciation is connected with earth movements accompanying the intrusion of the igneous rocks of Mount Royal. It is discussed further in the section dealing with the Monteregian hills (p. 100). These occurrences are part of a fairly extensive area of Precambrian in the vicinity of Oka and La Trappe (see Figure 1). The rocks exposed include a great variety of so-called Grenville meta-sediments, mostly recrystallized limestones, with which are associated paragneisses and quartzites, together with a number of igneous types, among which granites, syenites, and quartz diorites predominate. In the extremely limited areas occupied by Precambrian rocks in the Laval-Lachine map-areas all of these types of rocks save the limestone are exposed. So meagre are the exposures, however, that little more than their actual presence can be noted here. No age relationship can be seen in the few outcrops. The space relationship between these outcrops and the large exposures to which they belong is shown in Figure 1.

There are two features of considerable interest in connection with this outcrop of Precambrian rock. First, the straightness of its eastern margin, which suggests a fault, and second, the absence of exposures of a marginal deposit of Potsdam sandstone. Both of these features may, however, be merely the result of the covering of the extension of the rock outcrops by the thick deposit of sand which is so widespread in the southwest corner of the Laval map-area. Potsdam sandstone has not been seen in place on the mainland within the limits of the Laval area, though at several places just beyond its boundary, along the eastern margin of the Lachute map-area, prominent outcrops of this formation are known.

The Cartierville Outcrops

There are at Cartierville, on the north side of the island of Montreal (Laval map-area), two exposures of anorthosite, petrographically similar to the Precambrian Morin anorthosite, about whose relationship to the local sedimentary rocks there is still some doubt. The exposures can be seen along the track of the Montreal Tramways line to Cartierville. One of them is in the immediate vicinity of Val Royal station on the Canadian National railway and occupies an area more than thirty feet by ten feet; the second is a quarter of a mile to the northwest, and consists of a series of small exposures spanning and extending westward from the railway

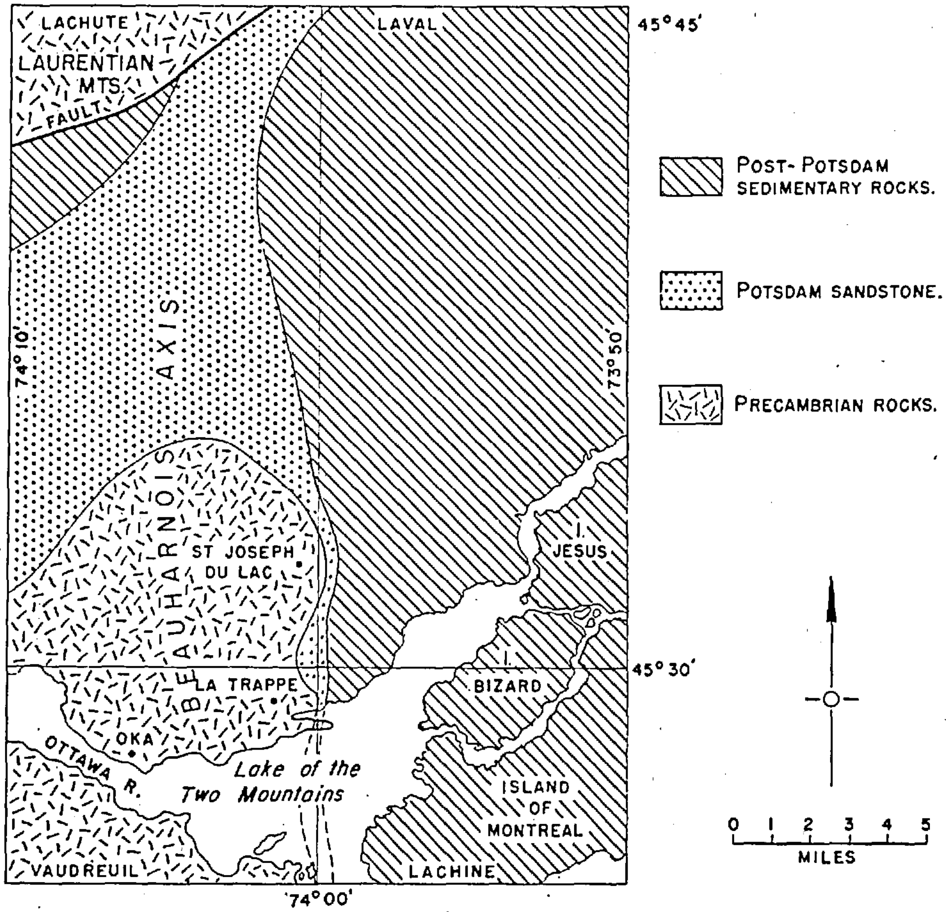

Figure-1 Sketch of parts of the Laval, Lachine, Lachute and Vaudreuil N.T.S. map-sheets.

To show relation of the small outcrops of Precambrian rock in the Laval and Lachine sheets to the larger outcrop of which they are parts and to the Precambrian of the Laurentian mountains. Lachute and Vaudreuil areas modified from A.E. Wilson, Ottawa-Cornwall map, 1946, and F.F. Osborne and H.W. McGerrigle, Lachute map, 1938.

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track for two hundred feet. On the basis of size alone, each of these exposures deserves to be considered an outcrop, and, though the possibility that each is a glacial boulder must be entertained until disproved, the number of exposures renders the latter hypothesis all the more unlikely. A bore-hole, starting in the anorthosite, and continuing therein or passing downward into the Chazy, would decide between the two hypotheses, or the spatial relationship between the anorthosite and the Chazy, the local sedimentary rock, could probably be demonstrated by geophysical means. Pending the possible future demonstration by some such means of the true relationship of the anorthosite to the limestone, the following comment is offered.

Should these exposures turn out to be glacial boulders, no further discussion is necessary. Should, however, they prove to be true outcrops, then they must be considered as hilltops not completely covered by sediment until toward the close of Chazy time. Allowing 250 feet for that part of the Chazy formation lying below their summits, and 1,060 feet for the Beekmantown, the hill must have been 1,310 feet above the top of the Potsdam sandstone. Even if it is assumed that, in the vicinity of Cartierville, the Potsdam is either missing or so thin that it can be neglected, there is still the thickness of 1,696 feet of Potsdam at the Mallet well at Sainte-Thérèse to be taken into account. The Precambrian surface at the location of the well is at least 1,696 feet below the base of the Beekmantown. At Cartierville it is 1,310 feet above the base of the Beekmantown, and this indicates a relief in the area considered of 3,006 feet at least. The clean sediments of the Potsdam indicate a general absence of soil, and the diminishing amounts of wind-blown sand—which is abundant in the lower Beekmantown, common through the rest of that formation, present but rare in the Chazy, and absent (as far as is known) from later formations—may show that the old hilly land was a desert, and consequently not vegetated, and yielded wind-blown sands as long as any essential area of land remained uncovered. The relatively great size, up to 3 mm., of some of the quartz grains in the limestones of the upper part of the Chazy formation is good evidence that they were not obtained by a re-working of the Beekmantown or of other parts of the Chazy, in which the sand grains are almost exclusively small (1 mm. or less).

Cambrian — Potsdam Sandstone

The lowest member of the Palaeozoic beds of the Saint-Lawrence lowland is the Potsdam sandstone, a formation named by E. Emmons in 1838. It consists of quartz sandstone, with a range in thickness from 0 to 1,696 feet, followed upward by the friable sandstone with dolomitic cement of the Theresa formation and, finally, by the dolomite beds of the Beauharnois formation, both Ordovician.

Throughout its extent it is predominantly a white, cross-bedded, quartz sandstone, rarely buff, yellow, or pink. In grain it ranges from a conglomerate with pebbles up to one inch in diameter to a fine siliceous shale, though all but an insignificant amount of the formation is a normal sandstone in which quartz predominates. In the sandstone, grains of feldspar are rare. Microscopic grains of 'heavy residue' minerals occur in some layers. It is therefore a typical orthoquartzite.

Distribution

Remarkably enough, no Potsdam sandstone was found flanking the outcrop of Precambrian in the southwest corner of the Laval area, near Saint-Joseph-du-Lac. As indicated above, this lack may possibly be due to a fault, but it is much more likely a vagary of exposure consequent upon the thick blanket of post-glacial sands spread over that part of the Laval area south of du-Chêne river. Just west of the limits of the Laval map-area, excavations to deepen the bed of this river have uncovered a considerable amount of Potsdam sandstone, which can also be seen in nearby fields. None occurs in place within the Laval sheet, either along du Chêne river or in the extreme northwest corner, two miles beyond which Precambrian rocks outcrop on the outskirts of Saint-Jérôme.

In the Lachine map-area, this sandstone is widespread. On the island of Montreal it occurs at the extreme southwestern end, within the village of Sainte-Anne-de-Bellevue, and it is also widespread on Ile Perrot, adjacent to that village, and on the mainland to the south, between Melocheville and Beauharnois.

At Sainte-Anne-de-Bellevue, the exposures are low and small but in most cases stratification is well shown and, in spite of cross-bedding, the general southerly inclination of the beds can be easily made out. The chief importance of this small group of outcrops is that wherever a dip can be discerned, it is, on the average, 5°S. although the outcrops immediately to the north are Beekmantown dolomite. Hence a fault undoubtedly intervenes between the two formations.

Ile Perrot and Lynch island (see Plate I-B) are entirely underlain by Potsdam sandstone. This is everywhere predominantly white, and composed almost exclusively of quartz. Along the north shore of Ile Perrot there is a considerable development of cross-bedded sandstone, whereas along the southeast shore and on Lynch island the bedding is in general very even. Most of the outcrops near the railway bridge that joins Sainte-Anne-de-Bellevue and Ile Perrot are coloured buff or reddish and are apt to be conglomeratic. The abundant exposures at Cascades point and on Cascades island, northwest of Melocheville, consist almost wholly of white quartz. On the mainland to the south, from Buisson point eastward to Beauharnois, exposures are abundant along the shore. Here the stratification is remarkably uniform, and although the sandstone is made up almost completely of quartz grains there is a considerable variation in sedimentary expression, cross-bedded, ripple-marked, *Scolithus*-bearing, dolomitic, and dense types succeeding one another, with few beds more than a foot thick. Some of the beds exposed at Melocheville are pure enough to be used in glass-making, and are currently used in the ferro-silicon alloy process. Inland, to the south, practically no outcrops of Potsdam sandstone have been found.

One mile west of Melocheville, a thickness of somewhat more than fifty feet of the Potsdam sandstone is exposed along the south shore of the Saint-Lawrence (Plate II). Though this is only a fraction of the whole section it is given in detail below because it is more or less typical of the Potsdam sandstone elsewhere. The section, in descending order, follows.

POTSDAM SANDSTONE — SECTION ONE MILE WEST OF MELOCHEVILLE

	ft.	in.
Quartzitic cross-bedded sandstone. Top of section	1	0
Quartzitic massive sandstone	1	0
Thin-bedded sandstone, some quartzitic, some broadly cross-bedded	3	0
Sandstone bed with horizontal *Scolithus* burrows	0	3
Dolomitic sandstone. (At about this horizon there occurs an area of breccia elongated parallel to shore. Contains nothing but Potsdam fragments)	1	0
Quartzitic, broadly cross-bedded sandstone, thin layers dolomitic. Fine and coarse ripple-mark at top	4	0
Dolomitic sandstone	0	6
Sandstone with horizontal *Scolithus* burrows	0	6
Quartzitic sandstone, cross-bedded and ripple-marked at top	3	0
Quartzitic sandstone, single bed	0	8
Quartzitic sandstone, single bed	1	0
Sandstone with vertical *Scolithus* burrows, coarse ripple-mark at top	1	0
Thin-bedded sandstone, somewhat cross-bedded	1	6
Scolithus sandstone with horizontal burrows. Dense sandstone, ripple-mark, mud crack at top	0	9
Scolithus sandstone with horizontal burrows	0	8
Dolomitic sandstone	0	9
Quartzitic thin-bedded sandstone, ripple-mark and mud crack at top	1	3
White, broadly cross-bedded, sandstone	1	8
Cross-bedded sandstone	1	0
Quartzitic sandstone, thin bedded	1	6
Dolomitic sandstone, massive	0	8
Thin- and cross-bedded sandstone. Horizontal *Scolithus* burrows	1	0
Dolomitic sandstone	1	0
Thin-bedded sandstone	2	0
Dolomitic sandstone, massive	1	0
Single bed of sandstone	0	6
Single bed of sandstone	0	4
Finely-laminated sandstone	0	8
Somewhat dolomitic sandstone, massive	1	0
Thin-bedded sandstone, various types	2	0
Not exposed	1	0
Dense sandstone	1	0
Dense sandstone, little bedding shown	2	0
Dense, cross-bedded sandstone	1	0
Not exposed	2	0
Cross-bedded sandstone	1	0
Dolomitic sandstone	0	6
Thin-bedded, dense sandstone, mud cracks at top	3	0
Dense sandstone	1	6
Dense, flinty sandstone	1	0
Cross-bedded sandstone, single layer, slightly dolomitic	0	8
Thin-bedded, dense sandstone. Base of section	3	0
TOTAL THICKNESS	53 ft.	10 in.

At several places, the Potsdam sandstone is brecciated over areas up to a few hundred square yards. The most noteworthy localities are, first, the quarry at Cascades point, second, the north shore of Split Rock rapids, and third, the south shore of Haystack rapids (see section given above). As with the brecciation of the Precambrian near Saint-Joseph-du-Lac, these occurrences are believed to be related to the Monteregian intrusives, and treatment of them is deferred for the present.

In nearly every exposure, rounded and frosted (presumably wind-blown) sand grains are common, in spite of the fact that the stratification, cross-bedding, ripple mark, mud flakes, and fossils all indicate a marine origin. It may well be that an essential part of the sands supplied to the sea came by the air route, which would not only explain the shape and appearance of the grains, but also the virtual exclusion of all else but quartz. In size, the sand grains range from an average of half a millimeter in diameter upwards. On Ile Perrot there are several beds of conglomerate in which the pebbles, exclusively of quartz, range up to one inch in diameter.

Ninety-nine per cent or more of the rock is made up of quartz grains. In many outcrops, nothing else can be seen. Here and there a few grains of feldspar appear, and more rarely a flake of mica. In the core of the Mallet well, at Sainte-Thérèse, there are several layers with heavy-residue minerals, among which garnet and magnetite predominate. Other minerals commonly present in minute amount are kaolin and limonite. The latter is probably the result of the weathering of secondary pyrite crystals, which are common in a few outcrops. Besides these minerals, small flakes of shale are occasionally seen.

In thin sections, the Potsdam sandstone is likewise seen to be composed almost exclusively of quartz. Of the four thin sections examined, all from the middle or upper parts of the formation, not more than three or four heavy-residue mineral grains of garnet, magnetite, etc., were seen in each. In two of the sections the grains are predominantly rounded, with the interstices filled with finely comminuted quartz. In the others, both rounded and angular grains are present. This, together with field evidence, indicates that wind-blown sand grains may be found practically throughout the formation; but form the bulk of the rock only toward the top.

There seems to be no doubt that, antedating Potsdam time, a vast mantle or 'regolith' of weathered material spread far over the southeastern part of the Canadian Shield. In the formation of this regolith, decomposition must have been active, removing the ferruginous minerals, feldspar, muscovite, and other less common minerals, all of which are relatively rare in the Potsdam sandstone. An invasion of the region by the sea provided the waves with enormous quantities of detrital quartz, to which the winds added their quota, and which was spread out on the beaches and the floors of shallow waters, as nearly barren of life as the shifting sands of much of the North Sea today.

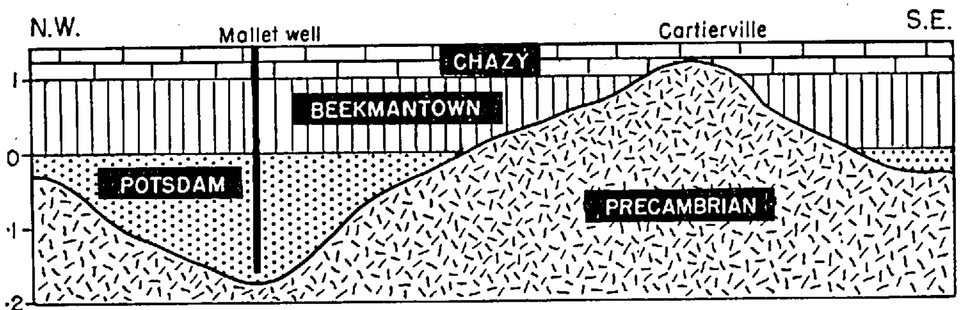
Structure

Throughout most of its exposed area, the Potsdam sandstone is approximately horizontal. Dips up to 5° are common; higher dips are rare. The northern limit of the formation is the Sainte-Anne-de-Bellevue fault, which has brought Beekmantown dolomite down to its level. East and west of the main area of Potsdam, the boundaries appear to be normal stratigraphic limits, and, because the Beekmantown dolomite is found on both sides, it is obvious that the Potsdam is anticlinal. Actually, the anticlinal axis can be identified by a change in dip about two miles west of the Beauharnois canal power house. The continuation of this anticlinal axis northward cannot be plotted with any degree of confidence. Because the eastern boundary is mostly under the waters of lake Saint-Louis, its course must remain uncertain. Farther northwest, the Oka Precambrian mass protrudes above the Potsdam which there assumes an anticlinal similitude, and still farther north it is again anticlinal with the Beekmantown dolomite exposed on both sides (see Figure 1). Elsewhere within the Lachine map-area, the dips, though noticeable, do not lend themselves to the elucidation of any general structure within the formation.

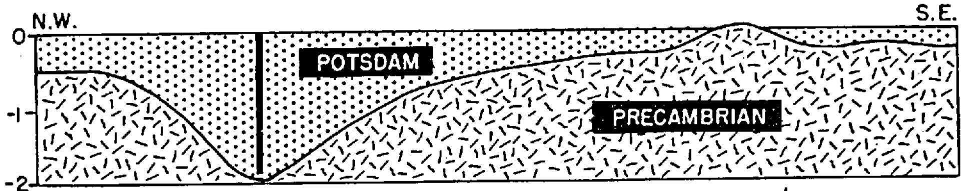
It must be admitted that the exposures of Potsdam sandstone described above are unsatisfactory in giving a complete picture of the development of the formation. Nowhere is there a continuous section of the sandstone exposed. The beds most likely to be close to the base of the formation occur in the vicinity of Sainte-Anne-de-Bellevue, and for three miles west of Saint-Louis river there is a fairly continuous series of exposures of what are probably the upper beds. Beyond this, little can be said of the distribution of the various parts of the formation.

Thickness

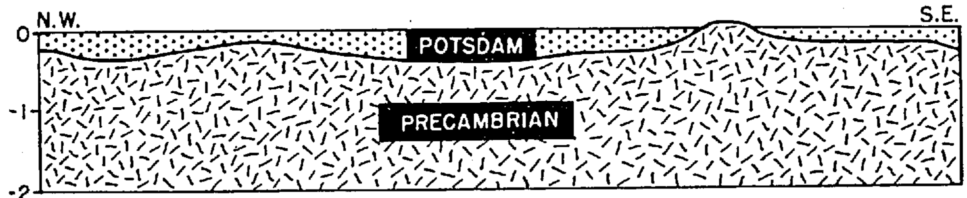
It seems reasonable to assume that the thickness of 1,696 feet of Potsdam sandstone logged in the Mallet well at Sainte-Thérèse was developed locally and over a restricted and specialized topography. It is likely that in most of the area the thickness of the formation ranges from zero to only a few hundreds of feet. Actually, the beds have been seen only in few and scattered outcrops. It has, therefore, been virtually impossible to find and to study a complete section anywhere. Nevertheless, other considerations have established that, within several scores of miles of Montreal, the sandstone is rarely more than two hundred feet thick, and nowhere more than six hundred. The greatest measured thickness is 540 feet on Covey hill, near Hemmingford, Huntingdon county, 33 miles south-southwest of Montreal. That the well at Sainte-Thérèse should have passed through more than treble this thickness without reaching the base of the formation is, to say the least, remarkable. The previously observed variation in the thickness of the Potsdam led to the belief that the old Precambrian land surface must have been worn down to a nearly level plain, with relief of the order of a few hundred feet. Consequently, the inundation of such a region would allow a basal sandstone to accumulate until the hilltops were covered and the source of supply of the sand was eliminated. In spite of this obvious though low relief, the Precambrian surface has usually been referred to as a peneplain. These relationships are shown on Figure 2.



C- Relationships as in B, but modified to include the hill of anorthosite at Cartierville, which was surrounded not only by the Potsdam sandstone, but by 1100' of Beekmantown dolomite and by about 250' of Chazy limestone.



B- Relationships as in A, but modified to include the 1696' of Potsdam sandstone logged in the Mallet well at Ste-Thérèse.



A- Relationship between pre-Potsdam topography developed upon Precambrian rocks, and Potsdam sandstone, as hitherto conceived, unmodified by information gained from the Mallet well, and disregarding the possibility of the existence of any important hill remaining uncovered at the end of Potsdam time.

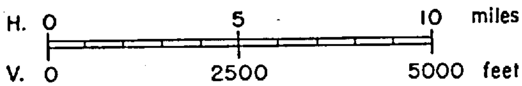


Figure-2 Three hypothetical cross-sections in the northwest part of the Laval map-area, to show the presumed relationships between the pre-Potsdam topography and the Potsdam, Beekmantown, and Chazy deposits. These sections are drawn as if the sedimentary beds were horizontal, with the top of the Potsdam being used as datum, 0 feet. D.M.Q. 1951 NO. 788

The unexpectedly great thickness of the sandstone in the Sainte-Thérèse well can best be explained as the result of the filling of a channel or gorge which had been dug in the old 'peneplain', or of a structural depression antedating the deposition of the Potsdam sandstone. Because, in many places where they might be expected, the beds are missing, the bottom of this gorge must have been at least 1,696 feet below the tops of some of the nearby hills. Nor is that all, for at Cartierville, as already mentioned, there is an exposure of anorthosite surrounded by the upper part of the Chazy formation. Ruling out, for the present, the possibility of this 'outcrop' being a glacial boulder, the implication is that a hilltop of Precambrian rock survived inundation until all of the Potsdam, all of the Beekmantown, and most of the Chazy, formations had been deposited. Because the Sainte-Thérèse well starts high up in the Chazy formation, its depth is a measure of the greatest known relief hereabouts on the old Precambrian basement, that is, the difference in elevation between the top of the Cartierville "hill" and the bottom of the Sainte-Thérèse well. We may never know how much farther the drill might have had to penetrate before reaching the Precambrian. We are safe in saying that there was a relief of at least 3,000 feet on the old surface inundated by the sea at the end of Cambrian time. Thus locally at least, all thought of this surface having been a peneplain must be abandoned. It was a surface with a relief comparable to that of our present Laurentians, and, as long as the topmost hills remained unsubmerged, a greater or lesser supply of detritus found its way into the sea to be incorporated into the accumulating sediment: first pure sandstone, later shaly dolomite and limestone, both with an abundance of wind-blown sand grains, and finally a deposit of nearly pure Chazy limestone. The succeeding Black River and Trenton formations carry almost no quartz sand, for the reason that they represent relatively deep water deposits which accumulated far distant from the shores whence such sand could be blown.

Fossils

On the whole, the Potsdam sandstone is a barren formation. Locally, the worm burrow *Scolithus* and the giant trails *Protichnites* and *Climactichnites* are the only fossils so far recorded, save for a poorly preserved fragment of a trilobite in the Mallet well core. *Climactichnites* and several species of *Protichnites* were described from the exposures of Henault's farm, Beauharnois, a locality now under the waters of the Beauharnois canal (Logan, 1863, p. 104; Owen, 1852), and can be seen in abundance on the floor of the Monpetit quarry, Melocheville (Clark and Usher, 1948). *Protichnites* can be seen on Lynch island. *Scolithus* occurs in about one-quarter of the outcrops. On the basis of the occurrence elsewhere in this formation of *Lingulella acuminata,* which has not been seen in any of the local exposures, the age of the Potsdam is generally accepted as Upper Cambrian, though there is a possibility that it might, in part at least, be lowermost Ordovician. With regard to the Nepean sandstone, which is probably of the same age as our Potsdam, A.E. Wilson (1946, p. 16) wrote: "There is no definite evidence that it is of Upper Cambrian age . . . The probability is that the sandstone was deposited in earliest Ordovician time as the basal phase of an advancing sea".

Uses

Locally, the Potsdam sandstone has been used as a building stone (Plate III). The quarries on Ile Perrot were opened for that purpose. The piers of the highway bridge over the Ottawa river at Sainte-Anne-de-Bellevue are composed of this rock, as are several dwellings in that village and on Ile Perrot. The Nepean sandstone, probably of the same age as the Potsdam, is quarried near Ottawa, and is currently being used in buildings in Montreal.

The only quarry actively engaged in producing Potsdam sandstone today is that of the St. Lawrence Alloys Company, at Melocheville. In earlier days, the Monpetit quarry (Carrière Silica) produced a crushed sandstone pure enough for glass-making. Importations of sand from Belgium, I was informed, put an end to that. Later, because of the high purity of its stone, the latter quarry became a source of silica used by the St. Lawrence Alloys Company in the production of ferro-silicon. As a consequence of this production, the quarry was much enlarged and at one time employed about twenty men. In recent years, the St. Lawrence Alloys Company has opened its own quarry about half a mile to the west of the Monpetit quarry, which is now disused.

A large quarry at Cascades point provided rock for the construction of the Soulanges canal, but it is now idle. A dozen pits and small quarries in Melocheville and Beauharnois attest the exploitation of this rock unit for building or other purposes, but, as mentioned above, there is but one quarry producing today. The extreme purity of certain layers of the sandstone should make it suitable for use as glass sand (See under *Economic Geology,* pp. 494-497).

Beekmantown Group

General Statement

Overlying the Potsdam sandstone in southern Quebec there is a thick series of beds consisting of dolomite and dolomitic limestone with minor amounts of pure limestone, shale, and sandstone, included within what has been called the Beekmantown group. At its base there is, locally, a development of a few tens of feet of dolomitic sandstone which, by many authors, have been called the 'passage beds' and by Cushing, in 1908, the Theresa formation. The whole group is for the most part unfossiliferous, hence its correlation with standard Lower Ordovician strata elsewhere is a matter of difficulty. Nowhere is there even an approximately complete section exposed. Its thickness in the vicinity of Montreal has hitherto been estimated to be between 100 and 1,000 feet. The boring at Sainte-Thérèse shows the latter figure to be more nearly correct.

Historical

Logan, in 1863, described this formation as the Calciferous formation, or Calciferous sand-rock. He wrote (p. 110): "The typical Calciferous sand-rock, which succeeds to the Potsdam in New York and the adjacent parts of Canada, consists in the lower part of a dark bluish-grey, crystalline, strongly coherent dolomite or magnesian limestone, weathering yellowish-brown, and very often holding small geodes, generally filled with calcareous spar, but sometimes containing quartz crystals, sulphate of barytes, sulphate of strontian, and sulphate of lime or gypsum. The fossils have in most cases disappeared, leaving only their moulds in the rock. The upper part of the formation is in some places a bluish-grey calcareous argillite, weathering yellow or brown, and often having a bituminous odour. The total thickness of the formation is supposed to be about 300 feet".

The only description Logan gave of its development in this area is as follows (1863, p. 114): "... the formation passes across the upper end of the island of Montreal, where the lower beds are characterized by *Leperditia Anna* and *Murchisonia Anna*. It then crosses the upper end of Isle Bizard, and the summit of the formation, turning more eastward, comes in upon the northwest side of the upper part of Isle Jésus, leaving, through the effect of gentle undulations, a broad expanse of the rock between the island and the Rivière du Nord, marked near the village of St. Eustache by *Lingula Mantelli*. North-eastward of this, the breadth rapidly diminishes, and north of St. Lin is reduced to about two miles". Ells (1896, p. 44-50j) was somewhat more specific in giving localities where exposures in the Calciferous formation may be seen, but, save for that, added very little. On the map accompanying Ells' memoir, Logan's boundary lines are followed without an exception.

Clarke and Schuchert (1899) were the first to use the present term Beekmantown, and stated that it replaced the older term Calciferous sand-rock, then in general use.

Ami (1900) described the distribution of the Calciferous formation hereabouts, noting its absolute conformability with the underlying Potsdam sandstone.

Adams and LeRoy (1904, p. 20), describing it as the Calciferous Sand Rock, noted the variability of the petrographic nature of this formation and concluded: "From surface measurements, the thickness of the formation seems to vary from 300 feet to 450 feet". On page 73 they wrote that "the Calciferous would have a thickness of over 1,000 feet", basing this conclusion upon the correlation of the logs of two wells ten and a half miles apart, from neither of which a suitable suite of samples had been taken. Though this conclusion is in accord with modern knowledge, it rested upon evidence so hazy as to give it a standing little better than a guess. The map accompanying their report was taken almost directly from Ells (1896).

Raymond (1913, pp. 139-140) was the first to subdivide the original Beekmantown into what, today, we would designate 'formations'. To the development around Montreal he gave the name 'Beauharnois formation'. This, elsewhere, he stated, overlies the Theresa formation, not known to be exposed hereabouts. The Beauharnois, he wrote "is probably a composite formation, and a great deal remains to be done on its stratigraphy and fauna". He made no estimate of it's thickness.

Parks (1931) followed Raymond in dividing the group into the Theresa and Beauharnois formations, but arrived at the conclusion that strata of the Beekmantown group were probably not more than 100 feet thick.

Goudge (1935, pp. 14, 15) gave a short description of the Beekmantown limestone. His map showed no variation from that published by Ells as far as the Beekmantown was concerned. Goudge gave the thickness as 100 feet, probably following Parks (1931).

Clark (1939), in a brief review of the local stratigraphy, stated nothing new.

Areal Distribution

The rocks of the Beekmantown group are spread over the western third of Ile Jésus (save for the south shore, which is occupied by Trenton limestone), and northward and westward on the mainland from Sainte-Thérèse and Saint-Eustache to the western limit of the Laval map-area. In the Lachine map-area, the western third of Ile Bizard and almost all of the western four or five miles of the island of Montreal are occupied by the Beekmantown rocks. South of the Saint-Lawrence, they are exposed close to the shore between Maple Grove and Chateauguay and at a few places along Chateauguay river. The belt of these Beekmantown rocks, about six miles wide along the Saint-Lawrence shore between the two towns mentioned, widens southward. Its western boundary trends southward, while the eastern boundary is believed to have at first a south-southeast trend and then southeast to the southern boundary of the Lachine map-area, where the belt probably has a width of about twelve miles. Within a triangle made by joining Saint-Remi and Primeauville, (both close to the southern margin of the map), and Chateauguay, however, hardly an exposure occurs. The position of the boundary which passes to the east of Saint-Remi is governed to some extent by the known distribution of the Beekmantown and Chazy groups in the Lacolle quadrangle to the southeast. Beekmantown beds occur also in the southwest corner of the sheet, where their exposures are separated from those along Chateauguay river by the anticlinal band of Potsdam sandstone which passes through Melocheville.

Outcrops of the Beekmantown group are abundant only at Saint-Eustache-sur-le-Lac and Plage Laval in the Laval map-area, and between De Lery and Chateauguay in the Lachine map-area. Nowhere within these two areas does the contact of this group with the overlying Chazy show at the surface, so that the boundary lines between these two formations are all approximate. The limit between the Beekmantown dolomite and the Trenton limestone (the White Horse Rapids fault) from Sainte-Dorothée to Abord-à-Plouffe, on the south side of Ile Jésus (Laval area), is likewise not seen, but its position is controlled fairly closely by the exposures. This distribution is in marked contrast to that first given by Logan, in which the Beekmantown dolomite was limited to the northern part of the western end of the island.

Structure

The attitude of the beds is one of near horizontality, from which, in general, the departure is toward the east with a dip of one or two degrees.

Stratification is rarely seen in a hand specimen but is usually apparent in a weathered cliff or quarry face (Plate IV), where one can see the result of an almost constant change in depositional conditions. Some parts consist of a series of fine laminæ. Others are massive or coarsely stratified. In much of the middle part of the formation, the bedding is shown by a development of irregular partings resembling stylolites but which are not improbably organic. Thin beds of intraformational conglomerate are common and minor unconformities abound in the stratified parts. Mud cracks and cross-bedding also occur, but are uncommon. In all parts of the formation one is likely to find the dense dolomite relieved by a series of cavities, rarely more than one or two inches across, partially or completely filled with calcite or dolomite.

Petrographic Description

Theresa Dolomitic Sandstone

Because of the gradation of this formation downward to the Potsdam sandstone and upward to the Beauharnois dolomite, it is difficult in the field to be sure whether some exposures belong to the Potsdam, the Theresa, or the Beauharnois formation. The Theresa beds consist mostly of rounded sand grains held together by a dolomitic cement. Because the carbonate cement renders them usually liable to decomposition they rarely show at

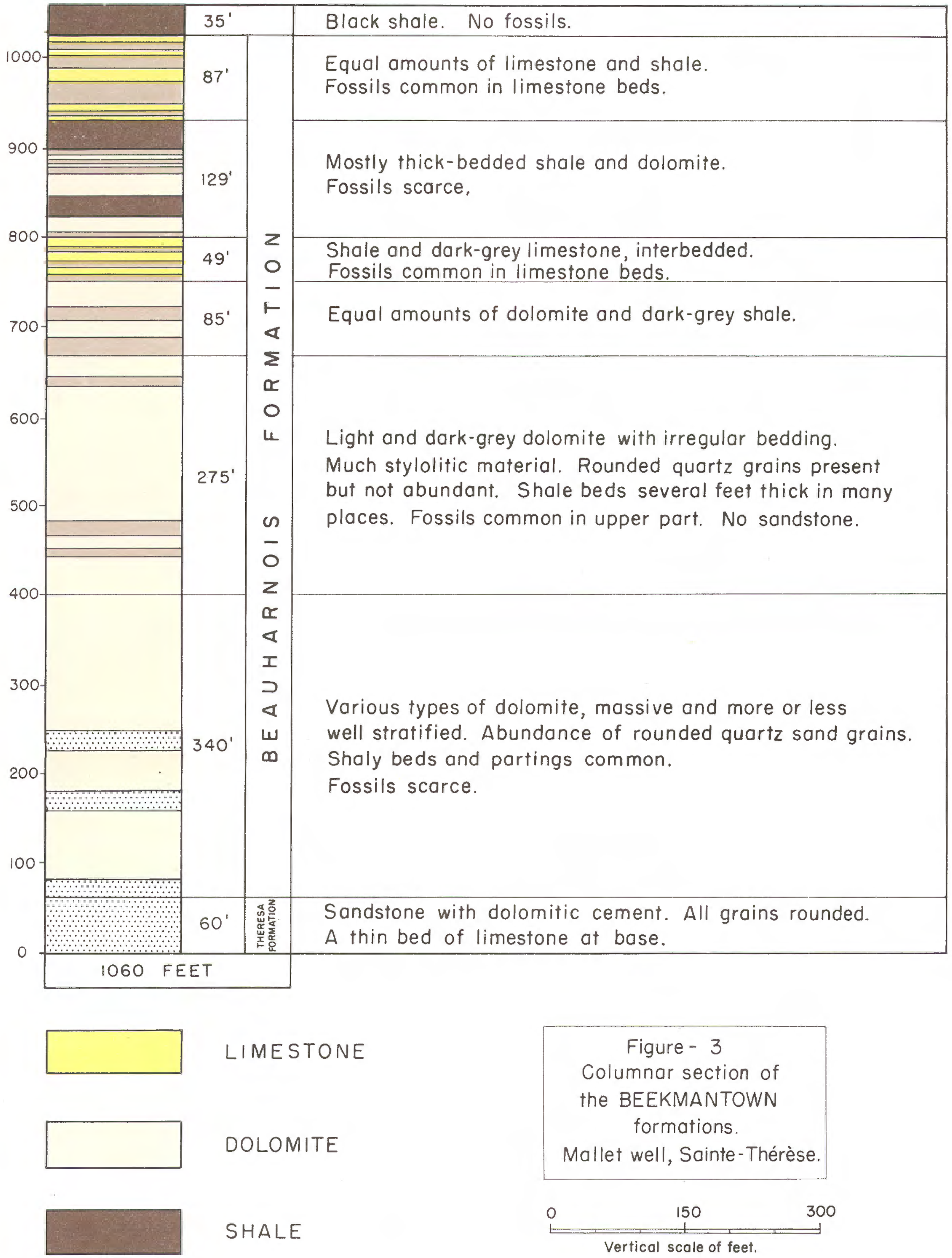


Figure - 3
Columnar section of the BEEKMANTOWN formations.
Mallet well, Sainte-Thérèse.

D.M.Q. 1951 No. 789

the surface. They are probably covered throughout most of their extent by their own weathering products or by glacial débris. Exposures which suggest this formation may be seen at the southwestern end of the island of Montreal in Morgan's quarry, three-quarters of a mile south of Senneville. Parts of the exposure along Chateauguay river in the neighbourhood of Laberge suggest, by the alternation of dolomitic and practically pure sandstone beds, that they may belong to these passage beds. Because of the uncertainties in their identification, the Theresa and Beauharnois formations are not mapped separately. It would appear from the Mallet well at Sainte-Thérèse that the Theresa occupies the basal 60 feet of the Beekmantown group.

Dolomite (Beauharnois formation)

Although, in general, this formation consists of a light, medium, or dark grey dolomite, and although it is petrographically distinct from all other formations, it is impossible to list all the inherent variations within the dolomitic parts. Exposure after exposure consists of one variety of dolomite or another, mostly medium to dark grey when fresh, cream to pale buff when weathered, and all with a fine-grained or medium-grained crystalline texture. Quarries, of which there are several, all small, show the same general type of rock. The crowded exposures in the neighbourhood of Saint-Eustache-sur-le-Lac are practically all of this dolomite. The exposures uncovered during 1939 in the laying out of the new road east and west of Beaurepaire (on the south side of the western end of Montreal island) are, too, all of the same types of dolomite. Actually, from an examination of exposures alone, one would be justified in considering this formation to be composed dominantly of dolomite. Because of the lack of a continuous section, no stratigraphic sequence could be deduced from an examination of the exposed rocks.

Fortunately, we have the complete log of the Mallet well to reply upon, and the descriptions given below are based largely upon that log. The succession of Beckmantown rock types in the test hole is shown in Figure 3.

From an examination of the core of the Mallet well it appears that, in the lower part of the formation, above a basal development of 60 feet of sandstone, there are 340 feet of massive or fairly well stratified dolomite of many manifestations, all types being rich in rounded quartz grains, especially in the lower part, where, in fact, such grains are so numerous as to warrant some beds being called sandstones. For a thickness of 275 feet near the middle of the section, the beds are light and dark dolomite with irregular bedding, the irregularity being due either to stylolitic development or to organisms. Then follows a thickness of 85 feet in which dolomite and shale are equally developed. In the uppermost 300 feet, dolomite plays a subordinate part, though there is a great variety of types—in colour light, medium, or dark grey, some almost black; in structure massive, stratified or conglomeratic; in composition some beds pure dolomite, others intermediate between limestone and dolomite. Throughout the section, most of the dolomite is finely crystalline; in very few beds are the crystals more than two or three millimeters in diameter.

Six thin sections of the Beckmantown dolomite were examined. Four are of rocks from the lower part of the formation, in all of which quartz occurs as extremely fine angular particles making up from 10 to 50 per cent of the volume of the rock. In one of these four sections, almost certainly from the Theresa beds, larger rounded quartz grains occur. The remaining two sections of rock, from the upper part, contain practically no quartz. This is in accordance with the evidence of the quartz content from the log of the Mallet well. Fossils are scarce. They were seen in two slides only and in both their preservation is such that no identification is reliable. In one slide, what is presumably a *Stromatocerium* shows no structure whatever, such obliteration doubtless being due to dolomitization.

Shale

In the Mallet well core there is a total of about 195 feet of shale, almost all of which occurs above the middle of the Beckmantown section here. Most of this is dark grey to black, with minor amounts of a light grey, greenish-grey, and greyish-brown colour. It is all fairly well stratified, showing abundant mica flakes but no other minerals. Fossils are virtually absent. The shale is practically never seen in exposures, save in beds a few inches thick. For instance, in the quarry opposite Butternut Lodge, Sainte-Rose, (northwest side of Ile Jésus, Laval map-area), there is a section of 9 feet 3 inches of dolomite in which two beds of shale, one three inches and one four inches thick, occur, as well as half a dozen shaly partings each less than an inch thick. In one of the cuts at Beaurepaire, made during the construction of the new trans-island highway, shale beds resting unconformably upon dolomite can be plainly seen (Plate V-A).

Limestone

In all, about 50 feet of limestone, in part magnesian, occur in the Mallet well core. Not all of the limestone layers contain fossils, though most of the fossils observed were in, or from, limestone. Limestone was rarely seen in exposures, but in the few places where it actually outcrops it is dark grey to black, massive, poorly stratified, and nowhere crystalline. One place where it can be seen is in a small abandoned quarry just within the margin of the woods, three-quarters of a mile northwest of Sainte-Dorothée church. However, the best locality is along the northwest shore of Ile Bizard, partly in the Laval and partly in the Lachine map-area, where there is an exposure of Beckmantown limestone which must be very close to the top of the formation, for Chazy limestone outcrops to the northeast and is exposed less than half a mile across the strike of the beds, and this interval must accommodate the lower and shaly part of the

Chazy formation. Here the Beekmantown beds are particularly rich in gastropod fossils, mostly *Pleurotomaria,* together with one or more species of *Hormotoma* and trilobite fragments; one layer consists almost entirely of large and small heads of *Cryptozoön ?steeli* (Plate V-B). Much oölitic and intraformational conglomeratic matter is to be found in the twenty feet which make up this section. The stone walls for a mile or so to the south consist in places of blocks and boulders of Beekmantown limestone and dolomite abounding in fragmentary fossils, and they have not, in all probability, travelled as much as a mile. Other exposures of limestone can be seen on Chateauguay river, both above and below the village of Chateauguay.

Sandstone

Of the lower 60 feet of the Mallet well core, 40 feet consists of pure sandstone belonging to the Theresa formation and composed almost exclusively of well rounded and frosted quartz grains. None of this sandstone was seen in exposures, though the sandy dolomitic rock of the exposures a mile and a half north of Fresnière (or about six miles north of the southwest corner of the Laval map-area), and the rock of the quarry in Morgan's Woods, Senneville, and to a less extent of Burnett's quarry at De Lery, almost deserve to be termed sandstone.

Weathering

Without exception, all varieties of the dolomite and limestone weather to a light to medium buff colour, or, more rarely, to a pale grey. The colour of the original rock does not seem to influence the colour of the weathered surface, so that in every case an examination of the fresh rock is essential. In most cases, weathering serves to emphasize such features as stratification, conglomeratic structure, and the presence of quartz sand grains, which features are in most cases scarcely recognizable on a fresh surface. Very rarely does weathering obscure any of the original features except fossils. These, save for some of the larger gastropods and some Cryptozoa, are seldom seen on weathered surfaces, but they do show up well enough on a freshly broken face. The shales show a much greater variation in weathering, though some of the darker ones are scarcely changed at all. No exposures of pure sandstone were seen so that a generalization about its weathering cannot be made. However, dolomite with a high percentage of sand grains, as seen in some stone walls at Senneville, is peculiarly susceptible to weathering and is only known in two natural exposures, one north of Fresnière, and another in the quarry in Morgan's Woods, Senneville.

As a major feature probably due to weathering, one may mention that although 53 per cent of the Beekmantown group consists of nearly pure dolomite, as measured from the Mallet well core, probably 90 per cent of all of the exposures are of dolomite. The softer or more easily disintegrated shales, sandstones, and limestones now occur for the most part below the present cover of glacial drift.

Thickness

As has already been stated, estimates of the thickness of this group, based on field evidence, have ranged from 100 feet by Parks (1931) to 450 feet by Adams and LeRoy (1904). The latter two authors, to be sure, published an estimate, quite unjustified from the data presented, of over 1,000 feet. The log of the Mallet well at Sainte-Thérèse (see Figure 3) shows the group to be 1,060 feet thick, with no indication of folding or of faulting which might influence that figure.

On the basis of the available field evidence from the Laval area, the breadth of outcrop of the Beekmantown formations in an east-west line is at least seven and a half miles, and may even reach twelve miles. Confining ourselves to the breadth between the most distant exposures within our area, seven and a half miles, the thickness, based on one- and two-degree dips, would be 691 and 1,283 feet, respectively. The actual breadth of outcrop is more likely to approach twelve miles and the average dip one degree, which assumptions would give a thickness of 1,276 feet. Hence the measured section of 1,060 feet in the Mallet core need occasion no surprise.

In the Lachine map-area, the width of outcrop is at least four miles on the island of Montreal, though the variations in direction and amount of dip make any calculations of the thickness unreliable. In Chateauguay county, the width of the band as mapped is at least five and a half miles, measured from Maple Grove to Chateauguay. The barren ground between Maple Grove and Beauharnois may possibly be occupied by Beekmantown beds, which, especially near their contact with the Potsdam, are everywhere more susceptible to erosion than is the Potsdam. This possibility would increase the width of outcrop to from six to seven miles. Because of the great amount of sandstone, presumably belonging to the Theresa formation, in the flat country northeast of De Lery and southeast of Woodlands, it is likely that an anticlinal axis, or a dome, occurs in these parts. In this case, the section from, say, Woodlands to Chateauguay contains the whole, or nearly the whole, of the Beekmantown section, unless some parts have been removed by faulting. Here, however, the paucity of exposures with reliable dips makes the estimating of the thickness concerned too uncertain. In this part of the Lachine map-area, therefore, the evidence does not allow us to estimate the thickness of the Beekmantown upon the basis of areal distribution. Hence it is desirable to accept the thickness as measured in the Mallet well as the standard for the whole Laval-Lachine area.

Fossils

Few exposures of the Beekmantown rocks have yielded fossils. Near the northwest corner of the Laval map-area, a mile northwest of Saint-Janvier, a new cut on highway No. 11 has exposed a dolomite which contains numerous specimens of a new species of *Lingula.* At Saint-Eustache-sur-le-Lac, small *Cryptozoön* remains abound, and Logan mentioned finding *Lingula mantelli* there. At Laval-sur-le-Lac there are layers with *Hormotoma anna* in abundance, together with rare and poor specimens of *Lecanospira.* On Ile Bizard, an outcrop, midway along the northwest shore, carries an abundance of large *Cryptozoön,* gastropods, and a few other fossils (Plate V-B). In the Lachine map-area, still another fossiliferous outcrop is to be found in Morgan's Woods where an abandoned quarry, 250 feet by 200 feet, originally opened to provide road material, occurs about a mile east-southeast of the Senneville Golf Club. There, the Beekmantown dolomite is very sandy, in places almost a sandstone, and hence is probably low down in the formation. The fossils, restricted to an arenaceous layer two feet above the base, are almost all gastropods, *Lecanospira* being the largest, with which are associated one or more species of *Hormotoma.* In earlier times, a limited but rich zone of fossils was located in a quarry, now no longer available, a short distance from the Canadian Pacific Railway station at Sainte-Anne-de-Bellevue. Gastropods, ostracods, and trilobites were found here; in fact this was the type locality for *Hormotoma anna* (Billings) and *Leperditia anna* Billings. On the mainland south of the Saint-Lawrence certain layers in the upper part of Burnett's quarry at De Lery are exceptionally rich in *Lecanospira compacta.* Elsewhere this species can be identified in many outcrops in fragmentary or poorly preserved form. Two miles above Chateauguay, on the east bank of Chateauguay river, there is an exposure with highly fossiliferous layers but, unfortunately, none of the forms, save possibly some ostracods, can be broken out of the rock for identification. A quarter of a mile below the bridge at Chateauguay, on the same side of the river, there is another very fossiliferous exposure from which, however, it is not possible to secure any specimens.

It is obvious that fossiliferous exposures of Beekmantown rocks are very few in number, and in none are the fossils well preserved. Partly because of the difficulty in the study of poorly preserved fossils, and partly because of the inherent difficulty in studying Beekmantown fossils, most lists of such fossils should be regarded very critically. In the list given below, compiled from many sources, I have omitted all those species which have been included in lists published by various authors but for which, so far as the present locality is concerned, no adequate authority has been cited. The occurrence of all species hereunder listed can be verified in the older reports, or they are species that may be seen in the collections in the Redpath Museum, McGill University, or in the collections made during the course of the present work. It is hoped that later elaboration of this list, and the close palæontological study of the collections made during the course of this work, when a method of developing the fossils from their refractory matrix becomes available, will throw a great deal of light upon the precise correlation of the Beekmantown beds of this area with standard sections elsewhere.

A complete list of all fossils known from the Beekmantown rocks of Quebec, with illustrations of a few common forms, is given in *Geology of Quebec,* Vol. II, p. 257, Pl. XXVI.

PLANTAE
- Algæ, branching forms
- *Cryptozoön lachutense* Dawson [from Lachute]
- *C.* cf. *steeli* Seely

BRACHIOPODA
- *Lingula mantelli* Billings

GASTROPODA
- *Hormotoma anna* (Billings)
- *Pleurotomaria gregaria* Billings
- *P. calcifera* Billings
- *Lecanospira compacta* (Salter)
- *L. sigmoidea* Ulrich and Bridge
- *L. salteri* Ulrich and Bridge

CEPHALOPODA
- *Piloceras amplum* Dawson
- *Endoceras montrealense* (Billings)

TRILOBITA
- *Bathyurus conicus* Billings
- *B. angelini* Billings
- *Holasaphus moorei* Raymond
- *Isoteloides whitfieldi* Raymond

OSTRACODA
- *Leperditia anna* Jones
- *L. canadensis* Jones

Raymond, in 1913 (p. 140), suggested that the fossils of the Beauharnois formation indicated a position low in the Champlain section. Later, Bridge (1930, pp. 204-206) described the fauna of the Roubidoux formation of Missouri, which contains the same assemblage of species of *Lecanospira* as does the Beauharnois formation. The Roubidoux dolomite and sandstone are placed by Bridge fairly late in the Beekmantown. Beyond these two views, not necessarily disharmonious, we have as yet little to depend upon for a better understanding of the stratigraphic position of the Beekmantown formations.

CHAZY GROUP

Above the Beekmantown in southern Quebec and neighbouring parts of North America there lies a group of formations which are mostly limestone and which are named collectively the Chazy group, a term first used by E. Emmons in 1842. These reach their greatest nearby development in the Champlain Valley region where, on Valcour island, they attain a thickness of 890 feet and are divisible into three formations. In the vicinity of Montreal only the uppermost of the three formations is represented. Its thickness in all probability nowhere exceeds 300 feet, and this decreases northward and westward. The formation is generally described as a grey crystalline limestone though, as will appear from the description below, scarcely one-half of it is limestone.

Historical

The name Chazy was first applied by E. Emmons in 1842 to a series of limestone beds lying between the Beekmantown and the Black River groups. Logan (1863, pp. 125-126) described the rocks of this formation in the Montreal area as follows: "The upper part of the formation is largely developed in the neighbourhood of Montreal. and is associated with beds almost filled by *Rhynchonella plena,* which appears to be most abundant at the top. Others are made up of comminuted organic remains, in which fragments of cystideans and crinoids largely prevail, giving to the rock a granular or crystalline character, from the usual peculiar crystallization of these fossils..."

"...The thickness of this part of the deposit is estimated to be about sixty or seventy feet, and the total volume of the formation is supposed not to exceed 150 feet".

Ells (1896, p. 45*j*) added little to Logan's description. "The limestones have, however, a very considerable extent on Isle Jésus and a number of fine quarries have been opened in the beds in the vicinity of St. Martin Junction, where the strata lie nearly flat".

Ami (1900), in an interesting summary of the knowledge of the geology of the vicinity of Montreal, briefly described the distribution of the Chazy formation, but mentioned nothing new.

Adams and LeRoy (1904, p. 20) wrote as follows: "In the Chazy time, with a farther deepening of the sea, the conditions became more truly oceanic, and there was consequently a great development of marine life, particularly of the Brachiopoda. These, through the accumulation of their shells, built up extensive beds of limestone, many of the latter consisting almost wholly of the shells of a single species, Rhynconella plena.

"The formation is represented by granular, semi-crystalline light and dark grey limestones, made up in great part of shells and their comminuted fragments. Interstratified with the limestone beds are occasional shaly layers which indicate the influx of muddy waters into the prevailingly clear waters".

Raymond (1913, p. 140) described the exposures under the name 'Aylmer formation', which he had proposed in 1905 for beds of Chazy age of the Ottawa valley. In that earlier paper he discussed the distribution of the Chazy sandstone and limestone in considerable detail, particularly with regard to the distribution of fossils.

Parks (1931) added nothing to what was already known.

Goudge (1935, pp. 15, 17) gives excellent detailed descriptions of the stone of some of the quarries. He sums up the most important features as follows: "The lower part of the Chazy formation as exposed north of Ottawa river and in some places in the Montreal area consists of sandy shale and sandstone, but over much of the Montreal area, and south and northeast thereof, the shaly and sandy strata are either poorly represented or are entirely absent and the Chazy limestone rests directly on the Beekmantown dolomite. The estimated thickness of the Chazy formation is 100 feet.

"The limestone varies from very fine to coarse in grain, and the prevailing colours are blue-grey and brownish-grey, the coarse-grained stone being always lighter in colour than the fine-grained and occurring mostly in zones at and near the top of the formation. Individual beds range from a few inches to an observed maximum of 4 feet. Thin, irregular seams of shale are present in many of the beds, and in some these seams are sufficiently numerous to impart a nodular appearance to the stone, but other beds are nearly free from this feature. On exposure, the stone assumes a light grey colour. Fossils, both well preserved and fragmentary, are very numerous, some strata being composed almost entirely of fossil shells and of oölites".

Clark (1939), in a brief summary, added nothing that was new.

Areal Distribution

The rocks of the Chazy group, in a belt about 1¼ miles wide, presumably enter the Laval area in the neighbourhood of Petite Mascouche, whence they continue directly southward to their first exposure two miles north of Sainte-Thérèse. They are then deflected to the east as shown by exposures three miles east-northeast of Sainte-Thérèse, and are cut off by the Bas-de-Sainte-Rose fault. On the south side of this dislocation, the band of Chazy is shifted about six miles to the east, where, with several minor dislocations shown on the map, it turns around the nose of the Ile Jésus anticline two miles south of Saint-François-de-Sales, and trends southwesterly and southerly, in a band four miles wide, through the central part of Ile Jésus, skirts Saint-Vincent-de-Paul, and includes Saint-Elzéar, Cap Saint-Martin, Village Bélanger, Laval des Rapides, and Saint-Martin, in each of which villages it has been extensively quarried. Thence it crosses rivière des Prairies and, swinging eastward and northeastward around the nose of the Ahuntsic syncline, is seen in several exposures in Cartierville, Bordeaux, the Town of Mount Royal, and Villeray, a suburb of Montreal, where it again turns, this time to the south, around the Villeray anticline. Its southernmost exposure on the east limb of the Villeray anticline can be seen in Outremont at the intersection of Van Horne and Stuart avenues. Instead of being continuous to the south, the Chazy is replaced by Trenton limestone, of which there are numerous exposures along Van Horne avenue, Rockland avenue, etc., in Outremont and the part of Montreal just southwest of there. Hence a fault must intervene here between the Chazy and the Trenton. This fault is in all probability the eastern prolongation of the White Horse Rapids fault, and it is so mapped. It is unfortunate that there are no exposures or records of exposures in the southern parts of Saint-Laurent or the Town of Mount Royal; as a consequence, the location of this fault can be only approximated. Along the north side of the fault, the Chazy probably extends for a distance of seven and a half miles westward from the exposure at Van Horne and Stuart avenues.

It may occur again, on the south side of the fault, some seven and a half miles farther west in a small triangular area — in which, however, there are no outcrops — on the northwestern side of Lake of the Two Mountains. The first outcrops of Chazy one finds, as one goes westward on the south side of the fault, are on Ile Bizard, along or near whose northwest shore this formation has a distribution of less than a mile and a half. At the southern limit of these exposures, Beekmantown dolomite occurs in its normal stratigraphic position (where the line of junction of the Laval and Lachine map-areas intersects the western shore of the island), whereas to the northeast, Middle Trenton beds outcrop within an eighth of a mile of the Chazy limestone, thereby implying the presence between the two formations of a fault (the Ile Bizard fault), which is made all the more probable by the peculiar distribution of the Black River rocks farther east and the dislocation in the most northerly Chazy rocks along the western shore of the island, at Pointe-aux-Carrières.

From the northwest shore of Ile Bizard the band of Chazy rocks, entering the Lachine area, traverses the island in a southeasterly direction, with some outcrops showing on the highest part of the island, northwest of the village of Ile Bizard. It crosses rivière des Prairies to the island of Montreal at Sainte-Geneviève, where it is exposed in a few small quarries. Thence the belt of outcrop continues southward until, with at least one slight dislocation, it sweeps around toward the east through Beaconsfield and attains the shore of lake Saint-Louis at Pointe Claire, where it is probably about a mile and a quarter wide.

On the south shore of the Saint-Lawrence, exposures of Chazy are found in the neighbourhood of Caughnawaga, eight miles east of the exposures in Beaconsfield and Pointe Claire. Because the outcrops at Pointe Claire and Caughnawaga are not in alignment and because there are no structural indications that they form part of one continuous band, it is necessary to assume the presence of a fault between the shores of this part of the Saint-Lawrence. In all probability, the Sainte-Anne-de-Bellevue fault is responsible for this offset, and it is so recorded on the map.

Because the mantle of drift is so persistent south of the Saint-Lawrence, outcrops of the Chazy formation are restricted for the most part to the vicinity of the village of Caughnawaga. The limestone is abundantly exposed along the shore at several places south of highway No. 3 and particularly at some points where it has been extensively quarried about a mile southwest of the village, adjacent to highways Nos. 3 and 4, which here follow a common route. Two miles south-southwest of these quarries, along the same highway, there is a shallow disused quarry in shaly limestone, and a mile and a half farther southwest, or about 1,800 feet northwest of where highway No. 3 leaves No. 4 to turn sharply to the west, one finds the most westerly exposure of this belt of Chazy. This is a shaly rock, easily distinguished from the nearly pure limestone of the upper part of the formation. Elsewhere, Chazy rocks can be seen in an old quarry a mile east of Saint-Isidore Junction, and in the bed of La Tortue river three miles south of Delson. All these outcrops south of the Saint-Lawrence lie in a belt of Chazy formation believed to be from four to seven miles wide and extending southeastward from the vicinity of Caughnawaga to the southeast corner of the Lachine map-area.

Petrographic Description

Without exception, all writers who have had occasion to describe the Chazy formation as it exists hereabouts have stressed its calcareous nature, mentioning sandstone and shale as being present in only minor amounts and in only its lower part. This conclusion is a justifiable one when based upon observed exposures, for with hardly an exception the exposures of the Chazy formation are of limestone, and every one of the quarries in the formation has been excavated in the relatively pure limestone beds. Shaly beds occur in some of the quarries, but in minor amounts only. That this apparent exclusion of all types of beds other than limestone from the exposures must be due to peculiar results of weathering and erosion is evident from the examination of the core of the Mallet well, in which the calcareous part of the formation barely exceeds one-half of the total. To be sure, Goudge (1933, p. 55) stated that, in the Chazy formation, the stone suitable for quarrying is restricted to the uppermost 25 feet. This does not presuppose a critical examination of the whole section, but merely implies a belief by Goudge that, whatever the rest may be, the uppermost 25 feet in some places consists of good quarryable rock. Without being specific, Goudge goes on to say "Below this zone the limestone is thinner bedded and in general is unsuitable for the production of cut stone".

An examination of the log of the Chazy formation from the Mallet well (see Figure 4) shows some interesting features. Although the section there displayed is not complete, it is probably nearly so. In the Montreal Crushed Stone Company's quarry at Saint-Vincent-de-Paul, it is known that a thickness of 5 ft. 9 in. of interbedded shales, sandstones, and limestones lies at the top of the Chazy limestone (Okulitch, 1936, p. 126). In the Mallet log there is, near the top, a thickness of about 34 feet of practically pure crystalline limestone, above which lie 38 feet of impure limestone and shale, with, however, about 14 feet of pure limestones at the top of the core. Above that the drill passed through 10 feet of drift. It is likely, from a consideration of the nearby Chazy and Black River outcrops, that the top of the 14-foot thickness of pure limestone is not more than 10 feet below the top of the Chazy formation. It is most probable that that part of the section represented by the 10 feet of drift would be of much the same kind as the uppermost strata at Saint-Vincent-de-Paul, *i.e.,* interbedded impure limestone and shales. Thus the uppermost 60 feet, more or less, would be largely shale or thin-bedded limestone, and hence not so likely to be preserved as the heavy-bedded crystalline

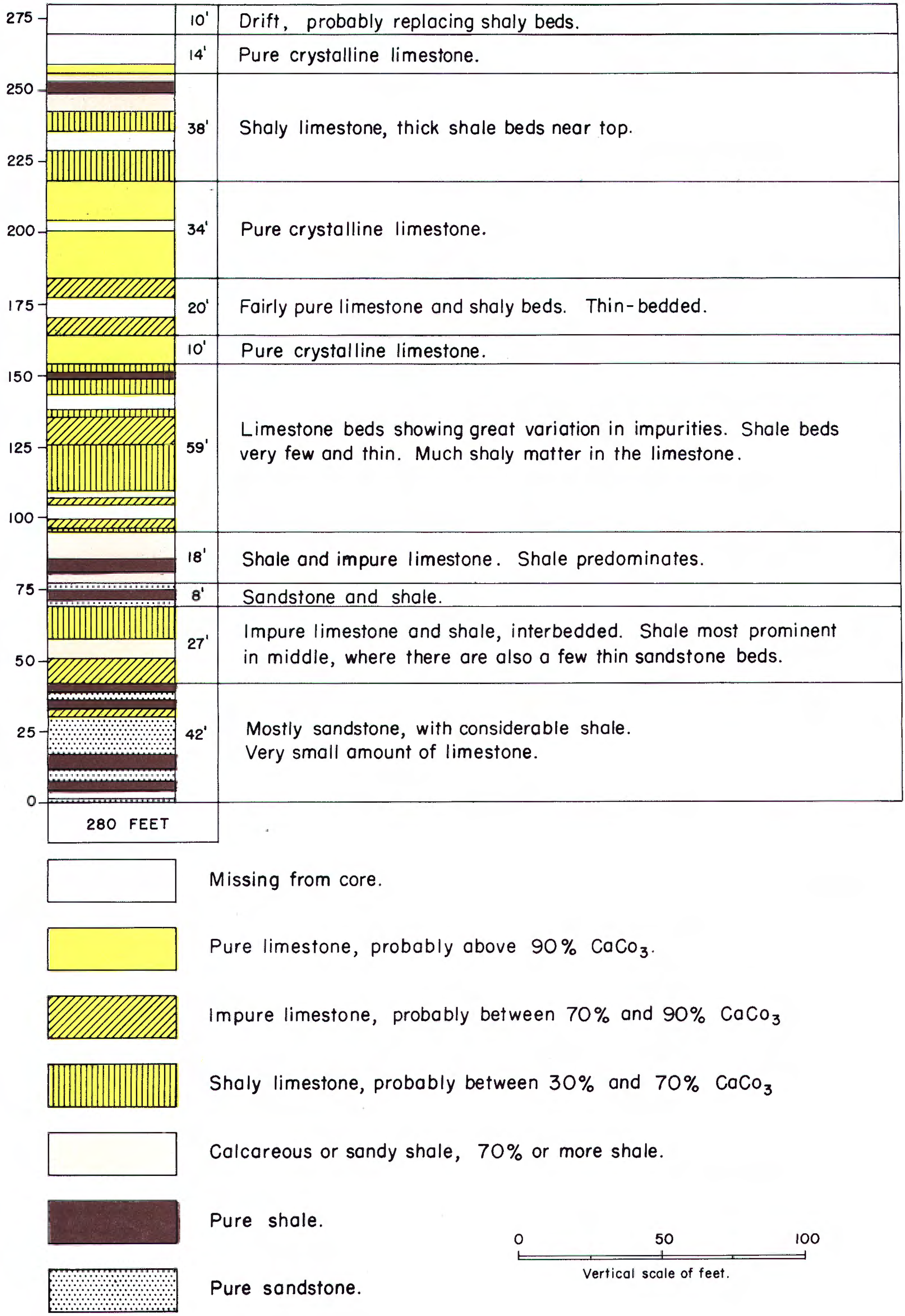


Figure 4 - Columnar section of Chazy formations, Mallet well, Sainte-Thérèse.

beds immediately below. For precisely the same reason, the lowest 154 feet of the Chazy formation, as shown in the Mallet core, would not stand up against weathering and hence would not yield exposures. To be sure, there is a bed of about 10 feet (126-136 feet above the base of the formation) which might, over limited areas, be resistant enough to form outcrops, but nearly all of the known exposures are of limestone 15 to 50 feet thick. It should also be recognized that there are several stretches marked 'missing' on the core log; none however, save those at the top, could carry sufficient limestone to form extensive outcrops. Therefore it seems obvious that Goudge's conclusion that the quarryable part of the Chazy is confined to the upper 25-feet of the formation should be broadened to include at least the upper 100 feet.

The two outcrops of the Chazy group near Chateauguay basin (Lachine map-area) offer corroborative evidence of this stratigraphic development. The westernmost, and therefore, presumably, the lowest of all of the exposed Chazy, a mile east of Chateauguay, is a fossiliferous shaly limestone, rich in bryozoa, but quite unsuitable as a building stone or as a source of lime. In the quarry two miles east of Chateauguay basin, though there is a good development of some pure limestone beds, there is also a great deal of shaly and sandy material, to an extent unknown in the quarries in the vicinity of Caughnawaga.

The log of the Mallet well shows that the sandstone is characteristic of, and practically confined to, the lowest 42 feet of the Chazy, although a few thin layers of a foot or less occur higher up and there is a three-foot stretch from 73 to 76 feet above the base. Nearly pure limestone, that is, limestone free from any abundance of shaly seams or disseminated shaly matter, occurs in two beds of two feet each (113-115, 119-121), a thicker bed of 10 feet (154-164), a considerable thickness of 34 feet (184-218), and again in a group of beds totalling 14 feet at the top of the core (256-270). All of the rest of the core is made up of interbedded limestones of various degrees of impurity and of shales. So important did the shale appear to be, and so relatively unimportant the limestone — contrary to the generally accepted opinion — that I re-surveyed the Chazy core, beginning 10 feet below the top of the hole, classifying it inch by inch as pure limestone, impure limestone, shale, sandy shale, and sandstone. By visual examination, aided by reaction of the rock to hydrochloric acid, I assigned the impure limestone to nine categories, beginning with practically pure limestone (*i.e.,* 10 per cent or less shale), and so on down to rock with 90 per cent shale and 10 per cent limestone; and a similar method was adopted for the types intermediate between shale and sandstone. By suitable calculations it could therefore be determined what part of the whole consists of limestone, what part of shale, and what part of sandstone. Naturally, errors would occur in such a rough and ready method, but it is my opinion that they would tend to balance each other. On the other hand, the missing portions are in all probability shaly beds, and so the complete figures should show a higher percentage of shale and smaller percentage of limestone and of sandstone. The results of this survey of the available data from the log of the well are as follows:

	Measurement in Feet	Percentage of Whole
Limestone	113.5 feet	42 per cent
Shale	85.9 "	32 "
Sandstone	22.0 "	8 "
Missing	48.6 "	18 "
	270.0 feet	100 per cent

If, however, the survey is started at the top of the hole, and the missing 10 feet (drift) is included, the percentages for limestone, shale, sandstone, and 'missing' become 40, 31, 8, and 21, respectively.

These figures must be considered merely as records, but they do indicate that this formation, always considered to be dominantly calcareous, is in all probability not even half calcium carbonate.

Limestones

The 'pure' limestones are all of one general type—grey, crystalline rocks. They range from light to dark grey, usually with a bluish tinge, weathering lighter. The grain may be fine (1 mm. or less) to coarse (5 mm. or more), though a medium grain (2 or 3 mm.) is by far the commonest. There is little uniformity in the bedding. Rarely can a bed of more than 30 inches be found (Goudge, 1935, p. 17, mentions 4 feet as the maximum), even though it may be separated from the rock above and below by nothing more than a shaly parting. Often the beds are less than a foot thick. Cross-bedding is very common, almost universal, and affects beds 2 inches thick as well as some 30 inches thick (Plate VI-A). Neither ripple mark nor mud cracks are to be found. Whole fossils, mostly brachiopods, with bryozoa a close second, are abundant in a few of the limestone beds. Practically all the crystallized limestone seems to be composed of fragmentary echinoderm fossils, cystids and crinoids, in which one always sees the result of the well known tendency of echinoderm skeletons to crystallize. What would otherwise be a clastic coquina (*i.e.,* a limestone composed of shells and shell fragments) is here a crystalline limestone. About 210 feet above the base of the formation in the Mallet core there is a layer, ranging from 5 to 10 feet in thickness, and easily recognizable in several quarries, of limestone in which some of the crystallized fossil fragments are pink. In addition, in one or two places uncrystallized bryozoa are coloured a deep pink. This colour seems to have developed through the action of circulating solutions after the formation of the rock. Pyrite is not common, nor does it often occur in crystals more than two or three millimeters across, but few beds are free of this mineral. Only a few beds here and there are oölitic. Dolomitic patches and streaks occur occasionally, particularly associated with reef developments. There is no regularity to their occurrence. They usually show as fawn or brown colorations and are far more marked on weathered than on fresh surfaces. Goudge (1933, p. 56) writes: "The magnesian matter rarely occurs intimately intermixed with the calcium carbonate but rather as streaks, patches, and occasional beds of finely granular, dark grey material erratically distributed through the high-calcium matrix. It usually contains a much higher content of impurities such as silica, iron, sulphur, and compounds of sodium and potassium than does the stone in which it occurs. On exposure to the weather it rapidly assumes a drab olive-green or rusty-yellow tint and eventually tends to disintegrate and scale badly". Quartz grains abound, and are largely responsible for the high percentage of silica shown in most analyses of the Chazy limestones. These grains are of all sizes up to 5 mm. across and are almost invariably rounded and frosted, features indicative of wind-blown sand. Doubtless high off-shore winds carried the fine sand over the sea in which the limestones were originally deposited as calcareous mud.

From this 'pure' limestone there are all gradations to nearly pure shale. One of the most abundant of the impure limestones is that in which shaly matter makes up 20 to 50 per cent of the rock and occurs as black seams which form an approximately horizontal network across a vertical face of the stone. They may be in part a kind of stylolite development. In another type, the shaly matter occurs as definite beds up to half an inch thick and separates beds of limestone of equivalent thickness. In both of these types, the limestone may be crystalline, though in general the grain is exceedingly fine. Fossils are common.

In thin section, some of the Chazy limestones show both coquina and oölitic structures. The coquinas are rich in remains of brachiopods and bryozoa, with many other types of fossils represented. The interstitial calcite is finely crystalline. There are some brownish streaks and patches in which dolomite (?) rhombohedra have grown. Oölitic structure was seen in only one slide. Some of the oölites are concentrically banded, some appear to be mere shells filled with crystals of calcite, and one or two fragments have an arrangement of exceedingly fine dots and may be foraminifera.

Two thin sections of sandy limestone were examined. One of these is from the limestone beds at Cap Saint-Martin (Laval map-area), the other from the exposure in the abandoned quarry, three miles southwest of Caughnawaga (Lachine area). In both, small angular quartz grains make up more than half the slide; the interstices and irregular areas are occupied by finely crystallized calcite.

Shale

In the measured log of the Mallet well there are altogether 32 feet of what might be called pure shale. If we designate as shale those impure limestones and impure sandstones in which shaly matter makes up 60 per cent or more of the whole (and they would certainly be so designated if found in the field), we should have a further 34 feet, making in all somewhat more than 66 feet of shales of all kinds. Pure shale can be seen in the quarry of the Montreal Crushed Stone Company at Saint-Vincent-de-Paul, in thin black bands in the quarry one and a half miles northwest of the penitentiary at the same place, and here and there in the quarries elsewhere. It is, as exposed in quarries, a rare type. In colour it varies from pure black (Penitentiary quarry) through all shades of dark grey to olive-buff (Montreal Crushed Stone Company quarry). It is for the most part lacking in fossils. *Camarotoechia plena* and a *Lingula* occur in shales belonging to the upper part of the Chazy, and bryozoa and *Camarotoechia plena* in the shales of the rest of the formation. Flakes of mica are usually discernible, though they are very small.

Sandstone

So far as is known, sandstone does not outcrop anywhere within this area, though at an extended exposure in fields one mile southeast of Saint-Martin village (Laval area) there are many beds of a highly sandy limestone. The lower 42 feet of the Chazy in the Mallet core includes a number of layers from 2 to 27 inches thick of a light grey or white quartz sandstone, speckled with small flakes of a nearly black shale. Although this rock is more than 90 per cent quartz it is nowhere exposed, probably because the soluble nature of its calcareous cement renders it peculiarly liable to disintegration. This sandstone is always sharply separated from the shale. Nowhere in the core does one find it grading into the latter although there are variations in the amount of included shale flakes. The sandstone higher in the core, from 69 to 77 feet above the base of the Chazy, is fine-grained, grey or buff in colour, and everywhere intimately interstratified with shale. Although the sandstone fails as one goes southeastward into New York and Vermont, it is probably continuous westward toward Ottawa.

Stratigraphic Subdivisions

Cushing (1905) named the three divisions of the Chazy rocks exposed in the Champlain valley as follows:

CHAZY GROUP	Valcour limestone Crown Point limestone Day Point limestone

Of these, the two lower divisions are not represented in the Ottawa-Saint-Lawrence region, where the Chazy rocks are shown by their fauna to belong to the Valcour formation. However, rocks of this group occurring in the vicinity of Montreal have, in the past, usually been classed together under the general designation 'Chazy limestone'. As with the terms Beekmantown and Trenton, it is now apparent that Chazy can only be used as a group term, thus allowing for appropriate and various subdivisions in different places. Raymond (1905) recognized several differences, both stratigraphic and faunal, between the Lake Champlain and Ottawa sections, and proposed the term *Aylmer* for the Chazy beds of the Ottawa valley in the vicinity of Ottawa. In 1937, A. E. Wilson proposed the term *Rockcliffe* formation for the shale and sandstone in the lower part of the Chazy in the Ottawa region and *St. Martin* formation for the limestone in the upper part. These formations are described in Dr. Wilson's memoir (1946) on the region and their distribution was shown on the map accompanying her report. Because the development around Montreal is different from that of Ottawa there appears to be no justification for using the term Rockcliffe in this vicinity. The rocks of the St. Martin formation, however, are recognizable here, though it seems more appropriate to reduce them to the status of a member within the Laval formation.

A glance at the log of the Mallet well shows that the Chazy hereabouts can be divided into four parts:

(*d*)	62 feet................	Mostly shaly limestone with some pure limestone (including uppermost 10 feet missing from core)
(*c*)	64 feet................	Pure or nearly pure limestone
(*b*)	112 feet................	Shale and impure limestone
(*a*)	42 feet................	Sandstone with considerable shale and a little impure limestone
	280 feet................	Total thickness

It is also apparent that there is an almost perfect gradation from one part to another. Hence, it does not seem appropriate to refer to any of the subdivisions as formations. The entire development is best considered as a formation characterized chiefly by calcareous shales and argillaceous limestones. Because of the many differences between this development and that of the Valcour formation in the Champlain valley, I propose the name *Laval formation* for these rocks hereabouts. The name is taken from the county of Laval, which covers Ile Jésus, one half or more of whose area is underlain by these rocks. At the base of the Laval formation is a development of sandstone which I propose to call the *Sainte-Thérèse* member. Because it is known only from the log of the well at Sainte-Thérèse, its extension laterally cannot be told. It may be continuous with the sandy beds named the Aylmer formation by Raymond. The second member which can be differentiated from the generally impure limestones of this formation is a thickness of 64 feet of relatively pure limestone. This is the so-called 'Chazy limestone' which has been quarried so extensively around Montreal and which regardless of the elaboration of the stratigraphic classification, will probably long continue to be called 'Chazy limestone'. It is this part of the Chazy rocks which most closely corresponds to Wilson's Saint-Martin 'formation', and that name is here employed, as the Saint-Martin 'member', for the heavy beds of reasonably pure limestone. It can be seen at Saint-Martin and, still better, at Saint-Martin Junction and Saint-Elzéar and Village Bélanger (all in the Laval map-area).

Though this limestone is splendidly exposed, the overlying shales are very poorly exposed at any of those places. At Saint-Vincent-de-Paul there is an excellent section of the top of the Chazy in which the pure limestone is capped by 6 feet of shales, some calcareous. It can also be seen along the shore at Caughnawaga (Lachine map-area) from the site of the old ferry-landing eastward to the Mercier bridge, and it is also excellently exposed in the quarries one mile southwest of the village. The classification of the Chazy rocks is shown diagrammatically in the accompanying table.

CLASSIFICATION OF CHAZY ROCKS

	Champlain Valley	Ottawa Valley		Montreal Area	
	Cushing 1905	Raymond 1905	Wilson 1937-40	Authors in general	Clark (Present report)
Chazy Group	Valcour formation	Aylmer formation	St. Martin formation Rockcliffe formation	'Chazy limestone'	Laval formation including the Saint-Martin and Sainte-Thérèse members
	Crown Point formation	Not exposed			
	Day Point formation				

Thickness

The Mallet well passed through 10 feet of drift before striking the Chazy formation, in which it stayed for 270 feet. The Chazy formation is therefore, in that vicinity, at least 270 feet thick. Because of the distribution of the overlying Black River it seems likely that, at the ground level, the Chazy-Black River boundary should lie within a few feet of the site of the well and I have assumed that this boundary passed almost immediately over the well site. We are therefore justified in assigning an additional 10 feet to the log, to make the estimated thickness of the Chazy 280 feet.

Fossils

Almost any exposure of Chazy rock will yield a good number of fossils. The more weathered parts of abandoned quarries, particularly the shaly beds, are the best localities for finding whole or nearly whole fossils. The following list includes all which have so far been identified from the beds of Chazy age in the area under consideration. As noted in the lists, neither the bryozoa nor the ostracods were studied critically. Both require microscopic examination, and the former, in addition, the preparation of numerous thin sections. Inasmuch as there are no stratigraphic conclusions dependent upon the identification of fossils of these groups, it was thought best to allow their elaboration to await more favourable opportunity. A complete list of all Chazy fossils identified from Quebec before 1936, together with illustrations of the commonest species, is given in *Geology of Quebec,* Vol. II, p. 259, Pl. 27, 1944.

Chazy Fossils from the Vicinity of Montreal

ALGAE
- *Girvanella* sp.

COELENTERATA
- *Fletcheria incerta* (Billings)
- *F. sinclairi* Okulitch
- *Billingsaria parva* (Billings)
- *Stromatoporella* sp.

CYSTOIDEA
- *Canadocystites barrandei* (Billings)
- *C. emmonsi* (Hudson)
- *Malocystites murchisoni* Billings
- *Paleocystites dawsoni* Billings
- *P. tenuiradiatus* (Hall)
- *Cheirocrinus forbesi* (Billings)
- *Bolboporites canadensis* Billings

BLASTOIDEA
- *Blastoidocrinus carchariaedens* Billings

CRINOIDEA
- *Deocrinus asperatus* (Billings)
- *Hybocrinus pristinus* (Billings)
- *Palaeocrinus striatus* Billings
- *Pachyocrinus crassibasalis* Billings

BRYOZOA
- *Chasmatopora aspera* (Hall)
- *Stictopora glomerata* Hall

NOTE: Our collection contains at least a dozen other species of bryozoa, at present unidentified.

BRACHIOPODA
- *Lingula belli* Billings
- *Schizambon duplicimuratus* Hudson
- *Hebertella borealis* (Billings)
- *H. imperator* (Billings)
- *H. vulgaris* Raymond
- *H. bellarugosa* (Conrad)
- *Orthis? acuminatus* Billings
- *Hesperorthis ignicula* (Raymond)
- *Dinorthis* (*Plæsiomys*) *platys* (Billings)
- *Leptæna incrassata* Hall
- *Rafinesquina champlainensis* Raymond
- *Valcourea strophomenoides* Raymond
- *Clitambonites porcia* (Billings)
- *Camarotœchia plena* (Hall)
- *C. orientalis* (Billings)
- *Rhynchocamera varians* (Billings)
- *Zygospira acutirostrata* Hall

PELECYPODA
- *Vanuxemia montrealensis* Billings
- *Modiolopsis parviuscula* Billings

GASTROPDA
- *Scenella montrealensis* (Billings)
- *Maclurites magnus* Lesueur
- *Bucania sulcatina* (Emmons)
- *Raphistoma immaturum* (Billings)
- *R. stamineum* Hall
- *Climacoconus rallus* Sinclair
- *Conularina triangulata* (Raymond)
- *C. irrasa* Sinclair
- *C. raymondi* Sinclair
- *C. undosa* Sinclair

CEPHALOPDA
- *Cameroceras velox* (Billings)
- *Loxoceras moniliforme* (Hall)

ANNELIDA
- *Serpulites splendens* Billings

TRILOBITA
- *Eoharpes antiquatus* (Billings)
- *Remopleurides? canadensis* Billings
- *Bumastus globosus* (Billings)
- *Thaleops arcturus* (Hall)
- *Amphilichas minganensis* (Billings)
- *Nieszkowskia satyrus* (Billings)
- *Sphærexochus parvus* Billings
- *Pseudosphærexochus vulcanus* (Billings)
- *Pterygometopus annulatus* Raymond

OSTRACODA
- *Leperditia canadensis*, var. *labrosa* Jones

NOTE: Our collection contains several other species, at present unidentified.

The list of fossils shows most conclusively that the local development is the equivalent of the Upper Chazy of the Lake Champlain region. *Camarotoechia plena* occurs throughout the calcareous portions of the local formation. Only three or four local species are found in the Lower or Middle Chazy of the Lake Champlain region. Thus, as pointed out by Wilson (1937), the absence of the Lower and Middle Chazy indicates a local disconformity, though there is no evidence of anything but weak erosion affecting the underlying Beekmantown beds.

Black River Group

No general map of the region around Montreal so far published has shown the outcrops or distribution of strata of Black River age. Because it has always been considered that these beds are far more closely allied to the Trenton than to the underlying Chazy, they have invariably been mapped with the Trenton, though they are lithologically so distinct as to merit a separate description. Thus Logan (1863, p. 136) discussed the "Birdseye and Black River formation, and the Trenton formation" together in one chapter (though a boundary line between the two formations can be found upon his map, subsequently used by Ells), explaining this treatment in the following words: "In their extension into Canada it has been found that the distinctions between these divisions of this group are less definite than in New York, and the whole series of strata is therefore described together". There is actually little reason for such grouping, but no one since Logan's time has actually mapped the Black River beds separately from the Trenton.

Historical

In 1842, Vanuxem, in describing the rocks of New York State, grouped together as 'Black River limestone' all the beds between the Beekmantown and the Trenton. This included, besides some of the present Trenton, (1) grey limestone, (2) Birdseye limestone, and (3) Chazy limestone. Hall, in 1847, re-defined these groups, naming the grey limestone the Black River limestone. In this he was followed by Logan and by subsequent Canadian writers. It was not until 1910 that Ruedemann introduced the term 'Black River group' to embrace all beds lying between the Chazy and the Trenton. His, and later, subdivisions of these beds are shown in the accompanying table.

	New York				Montreal
	Hall, 1847	Ruedemann, 1910		Kay, 1929	Clark (present report)
BLACK		Amsterdam			
RIVER	Black River	Watertown			
GROUP				Chaumont {Watertown, Glenburnie, Leray}	
					Leray
	Birdseye	Lowville	{Leray, Lowville}	Lowville	Lowville
				Pamelia	Pamelia

Subdivisions of the Black River Group

In the exposures of this group in the Montreal area, a magnesian development called the Pamelia formation is recognized at the base. This is followed by the Lowville limestone, and the topmost formation is the Leray limestone. This is the classification adopted by Okulitch (1936) in his study of the Black River rocks of the area. As indicated in the table, New York sections of the group include other formations overlying the Leray — the Glenburnie and Watertown limestones of Kay's (1933) 'Chaumont' beds, and, above these, Ruedemann's (1910) Amsterdam. These do not occur in the Montreal area.

Areal Distribution

Starting from the north, in the Laval map-area, the first exposure of rocks of the Black River group, consisting of the Lowville and Leray limestones, is found less than half a mile south of Ravins station, or about three-quarters of a mile north-northeast of the Mallet well so frequently mentioned in the preceding pages. A profusion of large blocks of Leray limestone immediately to the east of the site of this well and a similar occurrence two and a half miles east-northeast of Sainte-Thérèse indicate a north-south and then an easterly direction for the band of outcrops, which, however, seems to be cut off a short distance farther on by the Bas-de-Sainte-Rose fault where it crosses rivière des-Mille-Iles. It reappears on the south side of the fault about four miles to the east, where it is exposed in several places south of the east end of Côte des Perrons, whence, with several dislocations, it is presumed to follow around the northeast end of the Ile Jésus anticline, though it is nowhere seen until the southeast limb of this fold is attained. Good exposures can be seen on the west side of highway No. 18 two miles north of Saint-Vincent-de-Paul. A dislocation (Saint-Vincent-de-Paul fault) shifts the belt of outcrop about a mile southeastward where it can be picked up along the northwest shore of rivière des Prairies near the junction of highways Nos. 18 and 38 (on the grounds of the Penitentiary) and thence it continues southwestward near the southeast side of Ile Jésus, through the village of Saint-Vincent-de-Paul and, by numerous well exposed outcrops and the splendid exposures in the quarry of the Montreal Crushed Stone Company, as far as Pont Viau, whence the belt undoubtedly turns southward to cross the river on to the island of Montreal. Thence, the exposures at Côte Saint-Michel are sufficient indication that these rocks bend around the Ahuntsic syncline and the Villeray anticline in harmony with the adjacent formations. A minor series of exposures on both sides of rivière des Prairies at Saint-Vincent-de-Paul is due to the southeastward dip of the rocks bringing both the Black River and the Trenton to view in the river-cut cliffs.

No exposures of Black River rocks are known in Montreal south of Côte Saint-Michel, save in the lowest parts of the Mile End quarries (two miles due north of the summit of Mount Royal). The belt of Black River is believed to continue southward from the exposures at Côte Saint-Michel until it is cut off by the White Horse Rapids fault. Although the movement on this fault was probably nearly vertical, the Black River rocks, together with the Chazy, were apparently moved westward along the south side of this fault, the first outcrops on that side being some twelve miles distant, in the northeastern part of Ile Bizard. That section of the north shore of this island, however, where the expected strike-wise continuation of the exposures would bring the Black River, is occupied by Trenton limestone. This anomaly gives rise to the assumption of a fault here — the Ile Bizard fault — as indicated near the southeast corner of the Laval map-sheet. As also shown on that map, there may be a small area of Black River rocks underlying Lake of the Two Mountains between the Ile Bizard and White Horse Rapids faults.

From the exposures on Ile Bizard, the belt of Black River beds continues southerly across this island, into the Lachine map-area. It crosses rivière des Prairies and, on the island of Montreal, the beds are exposed on and near the Saint-Jean road at points respectively one mile and a mile and a half from the river. The belt then swings to the southwest to an exposure, at the junction of Sainte-Marie and Saint-Charles roads, which is at present being actively quarried. Resuming a southerly course for about a mile, it reaches exposures in the northern part of Pointe Claire, a village on the southern side of the western part of Montreal island. These exposures are on the south side of a minor fault, and the belt here trends eastward. It probably swings back to a southward course at Charlebois point and, as no exposures of Black River rocks are to be found south of the Saint-Lawrence, the belt is probably cut off by the Sainte-Anne-de-Bellevue fault somewhere under the channel of the river; and farther south and east, where it should appear again, it is cut out by the Delson fault (see Lachine map).

The width of the belt, or belts, of Black River as mapped in the Montreal region (Laval and Lachine map-areas) varies from place to place, with limits between about 2,000 and 3,000 feet.

Petrographic Description

Wherever a reasonably complete section of the Black River rocks can be seen hereabouts they can be easily divided into three formations, the Pamelia, Lowville, and Leray. All of these are known elsewhere. The Pamelia is predominantly a dolomite with lesser amounts of shale, the Lowville consists of thin-bedded limestone, and the Leray of thick-bedded limestone. In two localities, complete sections occur — the Montreal quarry (between de Normanville and de Lanaudière streets, northwest of de Fleurimont street), and the Montreal Crushed Stone Company's quarry at Saint-Vincent-de-Paul (half a mile northwest of Pie IX Boulevard bridge). In addition, an almost complete section can be compiled at Pointe Claire. Except for minor differences in petrographic expression and in thickness, the sections are essentially similar. Brief descriptions of the most important follow.

Local Development

Of the splendid exposures in the quarry of the Montreal Crushed Stone Company, Saint-Vincent-de-Paul, Okulitch (1936, pp. 124-127) gives a detailed stratigraphic description, which need not be repeated here. The section is as follows:

6 ft. 6 in.	Trenton	
23 ft. 6 in.	Leray	Black River group 46 ft. 3 in.
13 ft. 4 in.	Lowville	
9 ft. 5 in.	Pamelia	
35 ft. 9 in.	Chazy	

The Pamelia consists of orange-weathering dolomite and shale. The Lowville, which rests upon the Pamelia with no observable unconformity, but with a very sharp lithologic break, is thin-bedded limestone throughout, whereas the Leray is characteristically thick-bedded limestone with large cephalopods and chert.

The section in the Montreal quarry, Montreal (Plate VI-B), has not been published, hence it is given herewith. Save for the fact that it is somewhat thinner than the sections elsewhere, it seems to be quite typical. This quarry has recently been filled in.

Mile End formation of Trenton group		23 ft. 4 in.
Top of Leray		
Dark grey, dense limestone, unfossiliferous. This may possibly be the equivalent of the Watertown member of New York (Ruedemann, 1910), but is here included with the Leray	10 ft. 3 in.	
Black, light-weathering limestone with chert	2 3	
Granular crystalline limestone	0 3	
Black, light-weathering limestone, rich in *Rafinesquina*	1 3	
Granular limestone. Nearly black, light-weathering	1 6	
Dense, black, light-weathering limestone with worm tubes	4 0	
Granular limestone, dark, but light-weathering, small fossils abundant, stratification obscure	1 8	
Dense, dark-weathering limestone with brown-weathering streaks	3 0	
Total thickness of Leray		24 ft. 2 in.
Top of Lowville		
Tetradium-rich limestone, practically no shale	0 ft. 3 in.	
Impure limestone, light-brown-weathering, grading upward into shale. Upper 3 in. rich in gastropods. *Stromatocerium* and *Tetradium*	1 3	
Limestone, shaly at base, grading upward into pure, white-weathering limestone at top	1 6	
Massive limestone in three beds with *Tetradium*	1 6	
Shale	0 1	
White-weathering, pure limestone, very finely stratified	0 9	
Light buff massive limestone	1 3	
Well stratified unfossiliferous limestone, white-weathering, with shaly beds	1 0	
Highly fossiliferous white-weathering limestone. Stratification poor	1 0	
Interstratified well stratified unfossiliferous limestone, white-weathering, with shaly beds and light buff massive limestone	0 3	
Total thickness of Lowville		8 ft. 10 in.
Top of Pamelia		
Buff-weathering, greenish-grey dolomite, indistinctly banded but top 6 in. well stratified and conglomeratic	3 ft. 9 in.	
Black shale	0 9	
Light-brown-weathering dolomite	0 3	
Black shale	0 6	
Light-brown-weathering dolomite	0 3	
Black shale. Fossils common, fragments only, at base	2 6	
Total thickness of Pamelia		8 ft. 0 in.
Chazy limestone and shales		8 ft. 6 in.
Total thickness of section		72 ft. 10 in.

The section at Pointe Claire (Lachine map-sheet) is very much as it was when described by Okulitch in 1936 (pp. 119-123). A row of quarries and exposures extends for more than half a mile in an east-west line from Cedar avenue westward to the Pointe Claire Golf Club on Cartier avenue, and a small exposure can be seen a quarter of a mile farther west. All three formations comprising the Black River group outcrop there, though the limestones of the Leray formation are the most noticeable, and the shales and dolomites of the Pamelia formation are to be seen in only one quarry. Okulitch states (p. 119) that "about half a mile due north of Pointe Claire, situated about 250 yards to the west of Cartier street, is a disused quarry. The maximum height of the vertical wall is 38 feet. The upper 21 feet is definitely a part of the Leray formation; the lower 17 feet belongs to the Lowville, and again he states (p. 122) of the Devito quarry (later owned by the Lakeshore Construction Company, and abandoned in 1949) that "this quarry is situated on the east side of Cartier street nearly opposite the golf course escarpment. A thickness of 31 feet 7 inches of strata is exposed. The lower beds, totalling 11 feet, are members of the Pamelia formation, followed by the Lowville (16 feet 11 inches). The topmost strata exposed (3 feet 9 inches) is the basal bed of the Leray". Work done in this quarry since Okulitch's paper shows 22 feet of Pamelia dolomites and dolomitic shales lying with no apparent unconformity upon 5 feet of Chazy limestone and shales. Just to the east of the old Devito quarry is the Fuger and Smith quarry, developed mostly in the Lowville limestone and now being worked for high-grade building stone and for general crushed stone. To the east of this quarry, between Walnut avenue and Cedar avenue there is a wide, flat exposure of Leray limestone, and at the head of Pointe Claire avenue Leray limestone is exposed at the top of the north-facing bluff. No other outcrops are known east or west of this line of exposures. Two miles northwest of Pointe Claire village, at the junction of Sainte-Marie and Saint-Charles roads, a quarry, operated for crushed stone, has been opened in the Leray and Lowville limestones, though neither the top of the former nor the base of the latter is exposed. The observations made here tally with those made at Pointe Claire, and the section measured in the quarry, which was not published by Okulitch, is given here:

Top of quarry		
Cross-bedded, fragmental crystalline limestone, three beds of conglomerate each 1/4 inch thick	6 ft. 0 in.	
Dark blue, finely crystalline, well and evenly bedded limestone, grading downward into next stratum	2 0	
Similar to above but very irregularly bedded. Cross-bedded	2 0	
Dark blue limestone, fairly thin but irregularly bedded. Abundance of brown-weathering streaks. Algal layers. Some zones rich in *Rafinesquina*	4 0	
Black limestone. Fossils scarce, save for algae	1 3	
Black limestone with fossils abundant at top. *Columnaria*, large flat heads of *Tetradium*, crinoids, algae, *Streptelasma*, *Rafinesquina*, etc.	1 0	
Massive black limestone, weathering dirty yellow. No fossils seen save worm tubes	3 6	
Total thickness of the Leray formation as exposed		19 ft. 9 in.
Top of Lowville		
Thin-bedded typical Lowville	1 ft. 6 in.	
As above. *Tetradium* especially abundant	2 0	
Thick-bedded black limestone	1 0	
Total thickness of the Lowville formation as exposed		4 ft. 6 in.
Total thickness of quarry section		24 ft. 3 in.

Save for one or two small exposures along the Saint-Jean road, no Black River rocks are known elsewhere in the western part of the island of Montreal, but low, flat exposures, abundantly supplied with *Columnaria* heads, can be seen on Ile Bizard (Laval sheet) in a position that would make it impossible for the band of outcrop of the whole group to pass between the Chazy limestones at Pointe-aux-Carrières, and the nearby Middle Trenton exposure along the shore to the east of the point. Hence a fault (the Ile Bizard fault) is indicated passing to the north of the Black River outcrop. No Black River exposure is known on the southwest end of Ile Jésus or on the mainland immediately to the north.

In the vicinity of Côte Saint-Michel, just north of Montreal (Laval sheet), Black River rocks occur between Lower Trenton and Chazy exposures in such a manner as to suggest their position on the nose of an anticline. These exposures, in both of which only Leray limestone shows, present no characteristic unknown elsewhere.

From an assimilation of the foregoing sections, it is a simple matter to adduce the chief characteristics of the three formations of the Black River group.

Pamelia Formation

This consists of buff-weathering, pale bluish-grey, magnesian limestone, mostly heavy-bedded, and devoid of fossils. Toward the base there are shale beds, at one place grey, elsewhere black. These shales carry fragmentary fossils. Mud cracks are abundant, and ripple mark also occurs in some of the sandy interbeds. Intraformational conglomerates are common.

Lowville Limestone

This consists for the most part of thin-bedded limestone, in layers from two to ten inches thick, separated in places by seams of shale. Only a few beds of shale are thick enough to be measurable. The limestone is in part oölitic, in part of the 'Birdseye' type, *i.e.,* lithographic, with small crystals of calcite filling tubes presumed to be burrows (named *Phytopsis*), the cross-section of the tubes fancifully resembling the eyes of birds. Most of the limestone is dove-coloured, weathering nearly white. Fossils abound in most layers, various species of *Tetradium* being the most characteristic element, except in some very nearly pure beds of the Birdseye type in which the tubes of *Phytopsis tubulosum* are the only organic remains. Thin beds of dark grey to black shale are equally fossiliferous.

Leray Limestone

This is composed of dark grey, white-weathering, thick-bedded limestone, mostly in beds two feet thick. Above its middle part it is characterized by an abundance of plates of chert. Some of the lower beds are exceedingly fossiliferous. *Columnaria halli, Streptelasma profundum,* and *Hormotoma gracilis* are characteristic and common species. There is a development of from 8 to 10 feet of unfossiliferous limestone at the top which may possibly be the equivalent of the Watertown member (see p. 47).

Thickness

The thickness of the Black River formation in the several localities around Montreal (as given by Okulitch, 1936, with additions by the writer) is tabulated below, together with the thickness of these same formations at Ottawa.

	Ottawa	Pointe Claire	Saint-Vincent-de-Paul	Montreal Quarry
Leray	40 ft. 0 in.	21 ft. 4 in.	23 ft. 6 in.	24 ft. 2 in.
Lowville	30 0	16 9	13 4	8 10
Pamelia	65 0	22 0	9 5	8 0
Total	135 ft. 0 in.	60 ft. 1 in.	46 ft. 3 in.	41 ft. 0 in.

As can be seen, there is a somewhat greater thickness at Pointe Claire than is measurable at Saint-Vincent-de-Paul or at Montreal, and the difference might well be more if the contacts of the Leray with the Trenton and the Pamelia with the Chazy were exposed at Pointe Claire. It is not possible to achieve a bed-by-bed correlation between the three localities, so that no explanation, save that of normal sedimentary inequalities, can be invoked.

Fossils

To the thorough work of Okulitch (1935) on the fauna of the Black River beds we have little to add and his lists are appended hereunder practically unchanged. For the Pamelia formation, however, there are two fossils to be recorded, both from the black shales of the basal part of the formation. From the Devito (later Lakeshore Construction Company, now abandoned) quarry at Pointe Claire, we have a species of *Modiolopsis,* and from the Montreal quarry, a species of *Lingula.* In both places, the black shales of the Pamelia formation abound in fragments of what were probably shells of *Lingula.* Illustrations of some of the commoner fossils in this list are given in *Geology of Quebec,* Vol. II, Pl. 28, 1944.

PAMELIA FORMATION

BRACHIOPODA
Lingula sp.

PELECYPODA
Modiolopsis sp.

LOWVILLE FORMATION

ANTHOZOA
Streptelasma corniculum Hall
S. profundum (Conrad)
Columnaria alveolata Goldfuss
C. halli Nicholson
Tetradium cellulosum (Hall)
T. clarki Okulitch
T. cylindricum? Wilson
T. fibratum Safford
T. racemosum Raymond

HYDROZOA
Stromatocerium canadense cf. var. *minimum* Parks
S. rugosum Hall

"WORMS"
Phytopsis tubulosum Hall

BRYOZOA
Stenopora fibrosa Billings
Pachydictya acuta Hall

BRACHIOPODA
Rafinesquina alternata (Emmons)
R. transitionalis Okulitch
R. grandis Okulitch
R. minnesotensis (Winchell)
Strophomena incurvata (Shepard)
Rhynchotrema increbescens (Hall)
Zygospira recurvirostris (Hall)

PELECYPODA
Cyrtodonta huronensis Billings
C. subcarinata Billings

GASTROPODA
Hormotoma gracilis (Hall)
Liospira peneplana Okulitch
Lophospira bicincta (Hall)
L. perangulata (Hall)
Trochonemella montrealensis Okulitch
Holopea similis Ulrich & Scofield
Trochonema umbilicata (Hall)

CEPHALOPODA
Cameroceras(?) multicameratum (Emmons)
Cycloceras decrescens (Billings)
Spyroceras cylindratum Foerste
Sactoceras josephianum Foerste
S. pictolineatum Foerste
Actinoceras billingsi Foerste

TRILOBITA
Bathyurus extans (Hall)
Isotelus gigas DeKay
Encrinurus vigilans (Hall)
Ceraurus pleurexanthemus Green
Pterygometopus harrisi Okulitch

LERAY FORMATION

ANTHOZOA
Streptelasma corniculum Hall
S. profundum (Conrad)
Columnaria alveolata Goldfuss
C. halli Nicholson
Tetradium minus Safford

HYDROZOA
Stromatocerium canadense Nicholson and Murie
S. rugosum Hall

BRACHIOPODA
Hebertella sp. ind.
Hesperorthis cf. *tricenaria* (Conrad)
Dinorthis sp. ind.
Pionodema sinuata Okulitch
P. subaequata gibbosa (Billings)
Leptaena radialis Okulitch
Rafinesquina alternata (Emmons)
R. clara Okulitch
R. transitionalis Okulitch
R. grandis Okulitch
R. minnesotensis (Winchell)
R. wagneri Okulitch
R. williamsi Okulitch
Strophomena corrugata Okulitch
S. emaciata Winchell and Schuchert
S. incurvata (Shepard)
S. irregularis Wilson
Rhynchotrema increbescens (Hall)
Zygospira recurvirostris (Hall)

PELECYPODA
Ctenodonta abrupta(?) Billings

GASTROPODA
Phragmolites triangularis Ulrich and Scofield
Hormotoma gracilis (Hall)
H. wilsoni Okulitch
H. subangulata Ulrich and Scofield
Liospira larvata (Salter)
L. cf. *micula* (Hall)
L. peneplana Okulitch
L. cf. *vitruvia* (Billings)
Lophospira bicincta (Hall)
L. cf. *oweni* Ulrich and Scofield
L. perangulata (Hall)
Maclurites logani (Salter)

CEPHALOPODA
Cycloceras decrescens (Billings)
Spyroceras cf. *paquettense* Foerste
S. cylindratum Foerste
Zitteloceras sp.
Sactoceras josephianum Foerste
Actinoceras billingsi Foerste
Gonioceras anceps Hall
Ormoceras sp.
Richardsonoceras (?) sp. ind.

TRILOBITA
Isotelus gigas DeKay
Bumastus bellevillensis Raymond and Narraway
Illaenus martineauensis Okulitch
Encrinurus vigilans (Hall)
Ceraurus pleurexanthemus Green

In addition, Okulitch lists the following, not from his own collections but from lists given by Logan, Billings, Ami, and Raymond, in which no distinction was made between Lowville and Leray.

PLANTAE
Fucoids
Licrophycus cf. *L. ottawaense* Billings
Solenopora compacta Billings

ANTHOZOA
Fletcheria incerta (Billings)

BRACHIOPODA
Trematis montrealensis Billings

PELECYPODA
Ctenodonta contracta Salter
C. nasuta (Hall)

GASTROPODA
Lophospira ventricosa (Hall)
Helicotoma planulata Salter
Raphistoma aperta Salter
R. rotuloides (Hall)
Raphistomina lapicida (Salter)

CEPHALOPODA
Endoceras sp.
Orthoceras recticameratum Hall
Actinoceras bigsbyi Bronn
Cyrtoceras sp. ind.

TRILOBITA
Bumastus milleri (Billings)

OSTRACODA
Leperditia canadense Jones
Primitia logani leperditoides (Jones)

Examination of these lists fails to show a single species surviving from the Chazy. In spite of this condition, which is duplicated in the Ottawa region, Wilson (1937, p. 57) concluded that the time which elapsed between the deposition of these two rock groups "was of short duration". No angular unconformity can be seen between the Chazy and the overlying Black River beds at any of the places where that contact is or was visible. It is likely that a very gentle regional tilt of this part of the continent drained the Chazy sea off toward the east, and, by an equally gentle reverse tilting soon thereafter, allowed Black River waters to invade these parts from the south and west, and to cover the Chazy deposits before there had been much chance for the latter to suffer erosion. The general muddiness of the early Pamelia beds is the only evidence that near-shore deposition of clastic materials occurred before the dominantly clear-water limestone formation of the rest of the Black River group began.

Trenton Group

The Trenton limestone is one of the best known of all of the Ordovician rock divisions in the Saint-Lawrence lowlands. In most places it is a well-bedded black or dark bluish-grey limestone, abundantly fossiliferous, and characterized by shaly partings between the successive beds, which are from one inch to a foot thick. As the top of the formation is approached the shaly content of the beds becomes more important, so much so that the uppermost beds are quarried as a natural source-rock from which cement is made. Of less importance are beds of crystalline limestone, usually devoid of shaly partings, up to ten feet thick and for the most part restricted to the lower part of the group.

Historical

The earliest account of the Trenton limestone of Montreal is contained in an article published by J. J. Bigsby in 1825. In this description there was no attempt to separate any of the local limestones; the Beekmantown, Chazy, Black River, and Trenton were all grouped together as limestones of the Secondary class. Save for some details of the distribution of the limestone in parts of the city now completely built over, this report is of historical interest only.

No further information was forthcoming until Logan published his *Report of Progress* for 1847-48. In this report he gave a good deal of general information regarding the 'Montreal limestone', following Bigsby in grouping all the limestones together. That this was but the result of his preliminary examination is shown by the detailed exposition in 1863 of the characteristics and distribution of the Trenton limestone — then mentioned by name — and by his attempts to arrive at its thickness.

In the meantime, in 1842, Vanuxem, in his report on *The Geology and Natural History of New York,* Part 3. had defined the Trenton limestone as the 300 feet of beds lying between the Black River limestone and the overlying Utica shale. With a few exceptions, subsequent authors have held to that definition, and it is the one in current use in Eastern Canada today. There has been considerable elaboration of the description and subdivision of the formation, so that it now is generally ranked as a group composed of half-a-dozen formations. Its thickness in the Saint-Lawrence lowland is nearly everywhere considerably above the New York figure.

Logan, in 1863, included the limestones of the Black River group with the Trenton, but this was more for convenience than anything else, for his treatment clearly shows that he kept the two elements separate in his mind. Ells (1896, pp. 44-50) treated the Black River and the Trenton as two divisions of a greater 'Trenton formation', but added little to the clarification of the classification of Trenton rocks, and it remained for Raymond (1914, 1921) to initiate the attempt to subdivide the Trenton limestone assemblage into its component formations. Several references to the limestones of this group occur in the literature of this century, but, apart from Raymond's contributions, none need be mentioned as having any direct bearing upon the development of our understanding of the geology of Montreal. Wilson (1932) and Kay (1937), however, have done a good deal of work on the fauna and the distribution of the Trenton limestone in general. The present account depends in part upon all of the preceding work and is an attempt to harmonize it with the most detailed and, it is hoped, accurate plotting of the local outcrops of the Trenton limestone.

The tendency today is to consider the Black River group and the Trenton group as quite separate, though it is rarely easy to point to the dividing line between them, and to define the Trenton group as consisting of those formations which lie between the Black River group and the Cincinnatian series (of which the Utica formation is usually considered to be the lowest). The chief problem regarding the upward limits of the Trenton limestone is concerned with its relationship to the 'Utica' shale. Everywhere in Quebec the Trenton limestone is succeeded by a black or dark brown shale, which has customarily been termed the Utica formation, and this in turn is overlain by the beds of the Lorraine group. It has long been recognized that the Utica black shales originated as a contribution from Appalachia (a highland of sub-continental proportions which occupied the region east of the present Appalachian mountains during most of the Palaeozoic era) and that they are thickest in the east, and thin westward. It has also been recognized that the 'Utica' has not everywhere the same thickness, nor does it everywhere represent the same time lapse.

If we think of the Trenton limestone as a reasonably pure calcareous deposit, forming in the more open waters of the epicontinental sea which occupied North America during most of the Ordovician period, and if we consider the Utica shale the result of mud being washed into the Appalachian geosyncline flanking that epicontinental sea on the east, it is apparent that both Trenton limestone and Utica shale could have been formed, in part at least, at the same time. Toward the close of Middle Trenton time, mud began to be deposited in the sea in such quantities as to mask, and later to prevent, the accumulation of limestone. Hence in Middle Trenton time it is suggested that mud (Utica shale) and calcareous (Trenton limestone) deposits were contemporaneously formed in northeastern North America.

By the beginning of Upper Trenton time the accumulation of mud had become so great that the whole of the Appalachian geosyncline became the locus of mud (Utica shale) deposition. However, in the vicinity of Montreal, forty to fifty miles west of the border of the geosyncline, limestone continued to be deposited, albeit with a recognizable percentage of mud. Either during Upper Trenton time, or possibly in post-Trenton time, mud deposits spread far west of the geosynclinal zone, and extended as far as Buffalo, N.Y. In general, then, the Utica shale can be thought of as a widespread mud-delta deposit progressively being built out into the Ordovician sea, replacing the Trenton limestone more and more as time went on. Hence, except probably for the lowest part of the Trenton and the upper part of the Utica, the two formations are essentially contemporaneous.

In a restricted region such as the Laval-Lachine areas, these considerations are not of much importance, and it may be assumed that the Trenton and Utica are two separate formations. In the interest of convenience, the two rock units are so treated here.

Areal Distribution

Beginning at the northern boundary of the Laval map-area, the Trenton limestone enters as a belt, about nine miles wide, between Mascouche on the east and Lepage station on the west. The belt continues southward as far as the Bas-de-Sainte-Rose fault, close to which the lower (westernmost) parts of the group have been so affected by the movement along the fault as to trend southeasterly and, in the vicinity of Bois de Filion, even easterly. Between the Bas-de-Sainte-Rose fault and the White Horse Rapids fault, the belt of Trenton rocks is shifted eastward so as to coincide very roughly with the northern part of the island of Montreal. Exposures of Trenton rocks are known on Ile Jésus only in three localities; first, along Côte des Perrons, two and a quarter to three and a quarter miles east of Bas-de-Sainte-Rose, where small exposures owe their position to having been caught in the complex faulting that has dislocated the Bas-de-Sainte-Rose fault in that vicinity; second, a narrow belt, nowhere more than half a mile wide, occupying the shore of rivière des Prairies from Saint-Vincent-de-Paul upstream for about four miles; and third, exposures a mile and a half north of the Penitentiary at Saint-Vincent-de-Paul, on both sides of highway No. 18 where, though dislocated by cross faults, the Trenton is a continuation of the exposures along the river banks at Saint-Vincent-de-Paul. Moreover, the distribution of the Black River and Chazy rocks makes it certain that the northern part of Ile Jésus south of the Bas-de-Sainte-Rose fault is occupied by Trenton rocks.

Crossing over to the island of Montreal, Trenton limestones occupy the entire region between the Bas-de-Sainte-Rose and the White Horse Rapids faults, save for the areas of Black River and Chazy already described, and a narrow, discontinuous belt of Utica shale along the Saint-Lawrence river. South of and adjacent to the Bas-de-Sainte-Rose fault, the Trenton rocks have a width of outcrop of five miles, as compared to a width of nine miles north of the fault. Trending southwestward, the various subdivisions can be seen to fold over the axis of the Ahuntsic syncline and then trend northeastward until the axis of the Villeray anticline is attained, around which they swing and pursue a southerly course as far as the White Horse Rapids fault. Duplication of the beds on the flanks of these folds results in an increase in the width of the Trenton belt to a maximum of seven miles, and immediately north of the White Horse Rapids fault the belt is narrowed to three miles in width.

Between the White Horse Rapids fault and the Ile Bizard fault, Trenton limestone is exposed in many places, particularly along both shores of Dutchman rapids, at the northeast corner of Ile Bigras, and along the south shore of White Horse rapids. The easternmost exposure is in a cut of the Canadian National railway a mile and a half southwest of Cartierville.

Elsewhere in the Laval map-area, Trenton rocks occur only around Mount Royal and to the southwest (in the Lachine map-area) in Westmount. Although disturbed considerably by the igneous intrusion, the beds indicate a southerly or southwesterly trend. In the Lachine map-area, that part of the island of Montreal lying between the belt of Black River rocks in the vicinity of Pointe Claire and the area occupied by the Utica shale roughly southeast of the Lachine canal is mapped as being occupied by rocks of the Trenton group. There are few exposures, chiefly in the vicinity of the Canadian National and Canadian Pacific railways from Dorval to Ville Saint-Pierre. Unless it could be demonstrated that the shallow folding has allowed the overlying Utica shale, or the underlying Black River, to come to the surface, it is best to leave the southern part of the island of Montreal as Trenton.

South of the Saint-Lawrence, no exposures of Trenton were known in the Lachine map-area until the building of the new boulevard (No. 9c) from the south end of the Mercier (Saint-Louis) bridge, just east of Caughnawaga, eastward until it joins highway No. 9 one mile east of Delson village. From a mile and a half to three miles and a half east of Mercier bridge, low gutter exposures of Upper Trenton limestone were made available by the construction of the road. Some of these have since been covered by mud and grass. In attitude, these exposures are not structurally harmonious with either the nearby Lorraine of Ile à Boquet and adjacent parts of the mainland, or the Utica shale of the island of Montreal or of the Saint-Régis and La Tortue rivers north and northwest of Delson or at Delson itself. Nor can they be brought into harmony structurally with the broad belt of Chazy which occupies much of Laprairie country within the Lachine map-area. They are indicated on the map as a sliver caught between two branches of the Delson fault.

Subdivisions of Trenton Group

Several subdivisions of the Trenton had become recognized before the end of the last century. Raymond (1914) was the first to apply geographic names to faunally distinct limestone subdivisions in the vicinity of Ottawa.

SUBDIVISIONS OF THE TRENTON GROUP

Ottawa Area		Montreal Area
Early Faunal Designation	Raymond (1914)	Clark (present report)
Rafinesquina deltoidea beds	Cobourg formation	Terrebonne formation
———	———	Tetreauville formation
Prasopora beds	Trenton (restricted) formation; later (Kay 1929) called Sherman Fall formation	Montreal formation { Rosemount member; Saint-Michel member }
Crinoid beds	Hull formation	Mile End formation
Dalmanella beds	Rockland formation	———

The development around Montreal does not allow the identification of the *Dalmanella* and *Crinoid* beds, although the *Prasopora* and *Rafinesquina deltoidea* zones can be readily recognized. In her recently published Ottawa-Cornwall map, A. E. Wilson retains Raymond's subdivisions without change. For the Montreal area, because the local development differs from that at Ottawa and elsewhere, I propose to use the designations shown in the table. All of these terms are new.

Although there is a general homogeneity to all the faunas of the local Trenton subdivisions, there are but few species which have been recognized in all the subdivisions. These, which are all common species, follow:

Rafinesquina alternata
Sowerbyella sericea
Dalmanella rogata
Isotelus gigas
Calymene senaria
Ceraurus pleurexanthemus

In addition to these there are a few other fairly common species whose occurrence is so nearly general throughout the Trenton that we may well consider them of almost as much value as those of the above list: These are:

Lingula cobourgensis
Trematis terminalis
Platystrophia amoena
Strophomena filitexta
Parastrophia hemiplicata
Rhynchotrema increbescens
Zygospira orientalis

Rockland Formation

Save for the possibility that the Rockland formation is represented by the basal ten feet of unfossiliferous limestone resting upon the recognized Leray limestone in the quarries at Mile End (see p. 54), it is not developed in this area. Nowhere have we found beds characterized by *Columnaria halli, Calapoecia huronensis, Doleroides ottawaensis, Triplecia cuspidata, Hesperorthis tricenaria, Maclurites logani,* or *Bathyurus spiniger,* all of which are listed by Kay (1929, p. 225) as characteristic of this formation. Indeed, of this list *Hesperorthis tricenaria* is the only form so far identified from the Montreal area. Nor do we know of any occurrence farther to the northeast toward the Saint-Maurice river where this fauna has been identified.

Mile End Formation

Practically everywhere, the lowest beds of the Trenton are well stratified, thin- and thick-bedded limestones of a great variety of petrologic types, but with a reasonable community of fossil forms.

The section given below was recorded in 1940 from the old Martineau quarry at Mile End (between Garnier and Marquette streets, southeast of de Fleurimont street). Since then this quarry has been completely filled in by the city. In the photograph (Plate VII-A) the man is standing upon the top of the Leray. The lowest ten feet in the cliff may possibly be the equivalent of the Rockland formation but it is unfossiliferous, or it may be uppermost Black River. The Mile End formation extends for 25 feet up to the base of the heavy bed near the top of the photograph. This heavy bed is the base of the Saint-Michel member of the Montreal formation.

Montreal formation, Saint-Michel member:		
Medium-bedded limestone, inaccessible; top of quarry section	12 ft.	0 in.
Medium-bedded limestone with *Cryptolithus*	9	0
Thin-bedded limestone with *Cryptolithus*	18	0
Crystalline limestone; practically no fossils	0	9
Rubbly limestone; *Cryptolithus*	4	0
Mile End formation:		
Crystalline bed; fossils scarce	2 ft.	6 in.
Thin-bedded limestone	0	9
Thick-bedded crystalline limestone with 2 in. thin-bedded (like 9 in. immediately above) at top	1	9
Thin-bedded crystalline limestone	3	0
Thick-bedded crystalline limestone in four beds	4	6
Thin-bedded nodular limestone, crystalline near top	12	6
Leray formation:		
Thick- and thin-bedded unfossiliferous limestone; included with the Leray, but may possibly belong to the Watertown	7 ft.	11 in.
Chert-bearing dark limestone, light-weathering; lower half has what look like mega-ripples; no fossils; finely stratified	4	0
Dark limestone in irregular 6-in. beds	8	0

In the adjacent Montreal quarry (between de Normanville and de Lanaudière streets, northwest of de Fleurimont), now completely filled in, the section as seen in the eastern corner was as follows:

Top of quarry wall

Mile End formation	23 ft. 4 in.	
Leray limestone with chert; the upper 10 ft. 3 in of dark grey, dense, unfossiliferous limestone may possibly be Watertown	24 2	
Lowville limestone	8 10	
Pamelia dolomite and shale	8 0	
Chazy (exposed above the water level)	8 6	
		72 ft. 10 in.
Two sills	2 ft. 6 in.	
		75 ft. 4 in.

Elsewhere, the Mile End formation may be seen in a few outcrops of thin-bedded limestone along Côte des Perrons (Ile Jésus). Along the banks of rivière des Prairies below the Visitation Island dam there are exposures of this rock, which can also be seen to good advantage in the Montreal Crushed Stone Company's quarry at Saint-Vincent-de-Paul. It is present in all of the quarries of the Saint-Michel group (northwest of Côte Saint-Michel, between three and four miles north of Mount Royal), particularly well in the Canadian quarry, where it is 28 feet 6 inches thick.

Thirty-four species, exclusive of bryozoa and ostracods, the latter occurring in profusion, have been identified. Fourteen of these are restricted to the Mile End beds, as follow:

Actinoceras imperator
Ambonychia orbicularia
Bucania punctifrons
Bumastus bellevillensis
Climacoconus clarki
Clionychia undata
Cyclonema hageri
C. montrealensis
Eoharpes ottawaensis
Phragmolites compressus
Receptaculites occidentalis
Schizambon canadensis
Spyroceras bilineatum
Whitella ventricosa

The remaining twenty-two species, which range upward into other subdivisions of the Trenton group, are as follows:

Calymene senaria
Ceraurus pleurexanthemus
Clitambonites americanus
Dalmanella rogata
Dinorthis pectinella
Isotelus gigas
Lingula cobourgensis
Liospira americana
Parastrophia hemiplicata
Pionodema cf. *perveta*
Platystrophia amoena
Plectorthis plicatella trentonensis
Prasopora orientalis
Rafinesquina alternata
R. robusta
Rhynchotrema increbescens
Sowerbyella sericea
Strophomena filitexta
S. irregularis
Trematis terminalis
Zygospira recurvirostris
Z. exigua

Montreal Formation

The middle part of the Trenton group is by far the most fossiliferous in the vicinity of Montreal. This is the equivalent of the Sherman Fall formation elsewhere, and is here named the Montreal formation. It can be readily divided on faunal grounds into two parts which are here designated the Saint-Michel and Rosemount members. The Saint-Michel member, not more than 120 feet thick, is petrographically varied, but contains, besides a great abundance of bryozoa, *Cryptolithus tesselatus,* and *Parastrophia hemiplicata,* together with *Prasopora orientalis,* though this last is rarely in abundance and is usually an exceptionally large form. The Rosemount member, 250 feet thick, is also petrographically varied, but contains *Prasopora orientalis* and *Zygospira recurvirostris* in abundance, together with a few other diagnostic forms. This is the most richly fossiliferous part of the whole Trenton group.

Saint-Michel Member

These beds can be best seen in the walls of the National Quarries Company's quarry, Côte Saint-Michel (4 miles north of Mount Royal). They dip toward the northwest, allowing 14 feet of the underlying Mile End limestones to be seen near the grade going down to the quarry. Thence, along the northeast wall, there are 101 feet of limestone fully exposed (Plate VII-B) abundantly fossiliferous, as will appear in the following section:

Top of quarry section		
Yellow- and brown-weathering beds with large *Prasopora* heads (4 in. across) *Parastrophia* locally in great abundance	3 ft.	0 in.
Irregularly-bedded limestone and shale, the former in beds one to four inches thick, the latter rarely exceeding one inch in thickness; the shales are unusually rich in bryozoa	25	0
Even-bedded, finely-banded limestone, in part finely crystalline; *Phytopsis*-like tubes common in places	1	6
Sill of basic rock .... 2 ft. 9 in.		
As above	1	9
Limestone and shale, the limestone becoming more abundant and regularly-bedded above, approaching the overlying even-bedded limestone; *Prasopora* common in one or two beds	2	0
Dense blue limestone, splinters vertically, fossils scarce	1	0
Medium grey crystalline limestone with very little shale; bryozoa abundant, especially in shale seams; other fossils rare	4	9
Dense crystalline limestone in beds from two to eight inches thick with shale partings up to six inches; bryozoa common throughout	5	6
Sill of basic rock .... 1 ft. 3 in.		
Light grey, medium-grained crystalline foetid limestone; fossils scarce. To the west of the fault which occurs about midway along the quarry wall this bed is split by the sill which, to the east of the fault, lies above it	1	0
Fine-grained crystalline limestone and shale, the former in beds up to twelve inches thick, the latter up to six inches; bryozoa abundant throughout	15	3
Fine-grained crystalline limestone in beds from four to six inches thick with very irregular shaly partings up to three inches thick; no bryozoa	8	6
Dense, well stratified limestone, in part finely crystalline; bryozoa abundant	1	6
Black shale, rich in bryozoa	0	3
Sill of basic rock .... 0 ft. 3 in.		
Irregularly-bedded, rubbly-weathering limestone in beds from two to six inches thick with shale partings up to two inches; one *Prasopora* specimen	12	0
Sill of basic rock .... 3 ft. 9 in.		
As above	6	9
Medium- to fine-grained crystalline limestone; fossils rare	0	9
Irregularly-bedded, rubbly-weathering limestone in beds from two to six inches thick with shale partings up to two inches; *Cryptolithus* common	3	0
Alternating limestone and shale; well stratified and cross-bedded; the limestone in beds up to six inches thick, the shale up to two inches	3	3
Fine-grained dark limestone	0	6
Medium-grey crystalline limestone with thin shale seams	2	0
Medium grey, medium-grained, crystalline limestone in one bed, fossils rare	1	3
Black shale and limestone in equal amounts; very fossiliferous. This is the lowest bryozoa-rich horizon	0	9
Base of Saint-Michel member		
Total thickness of Saint-Michel member, exclusive of sills	101 ft.	3 in.

It will be seen that over 100 feet of Saint-Michel beds occur in this quarry. How much thicker the member is cannot be told with exactness, but the presence in the uppermost beds of fair numbers of *Prasopora* may betoken a close approach to the base of the Rosemount member which is characterized, above all, by an abundance of *Prasopora*. In my opinion, 120 feet would be a fair estimate of the thickness of this member.

The same beds may be seen in the other quarries at Côte Saint-Michel. They occur also along the south bank of rivière des Prairies at

Montreal Nord, opposite the dam at the lower end of Visitation island, where they are rich in *Cryptolithus tesselatus*. Elsewhere these beds may be seen on both sides of rivière des Mille Iles at Pont David, and at a few other places.

List of fossils which are confined to the Saint-Michel member:

Cryptolithus tesselatus	*Pseudosphaerexochus trentonensis*
Eccyliomphalus trentonensis	*Rafinesquina robusta*
Hebertella frankfortensis	*Rhynchotrema dentata*
Lingula modesta	*Strophomena trentonensis*
Maelonoceras neleus	*Trematis ottawaensis*
Modiolopsis maia	*Triplecia nucleus*

Species occurring in the Saint-Michel member which also occur in the underlying Mile End formation:

Calymene senaria	*Plectorthis plicatella trentonensis*
Ceraurus pleurexanthemus	*Prasopora orientalis*
Clitambonites americanus	*Rafinesquina alternata*
Dalmanella rogata	*Rhynchotrema increbescens*
Isotelus gigas	*Sowerbyella sericea*
Lingula cobourgensis	*Strophomena filitexta*
Parastrophia hemiplicata	*Trematis terminalis*
Pionodema cf. *pervetus*	*Zygospira recurvirostris*
Platystrophia amoena	*Z. exigua*

Species occurring in the Saint-Michel member which pass up into the overlying beds:

Calymene senaria	*Plectorthis plicatella trentonensis*
Ceraurus pleurexanthemus	*Prasopora orientalis*
Conularia trentonensis	*Pterygometopus callicephalus*
Dalmanella rogata	*Rafinesquina alternata*
Hormotoma gracilis	*Rhynchotrema increbescens*
Isotelus gigas	*Serpulites* sp.
Lingula cobourgensis	*Sinuites cancellatus*
L. iowensis	*Sowerbyella sericea*
Platystrophia amoena	*Strophomena filitexta*
Parastrophia hemiplicata	*Trematis terminalis*
	Zygospira recurvirostris

Rosemount Member

The name Rosemount is proposed for the upper member of the Montreal formation because of its typical exposures in Rosemount ward of the City of Montreal. It consists largely of limestone of many types — pure, dense, crystalline, argillaceous, etc. Minor amounts of shale occur at some points. Nowhere have its contacts with the underlying Saint-Michel member or with the overyling Tetreauville formation been seen. The figure given for its thickness (p. 65) is therefore provisional, but is probably correct within 25 feet.

It has not been possible to correlate the all too few outcrops of this member with any degree of satisfaction. Its thin-beddedness (Plate VIII-A) and its general argillaceous nature have operated to render it peculiarly liable to weathering. Hence, save where these beds have been protected by igneous rocks, as in the quarry on the grounds of the Montreal Botanical Gardens, (Plate VIII-B) near the intersection of Rosemount and Pie IX boulevards, or exposed by streams as at rivière des Eboulis (Island of Montreal, entering rivière des Mille Iles a mile and three-quarters northeast of Montreal North) and at D'Argenson (north shore of Ile Jésus, four miles west of Terrebonne), they are almost completely drift covered. In many places, such as at D'Argenson, these beds are very shaly. The section at the latter locality, with remarkably regular alternations of petrographic types, follows:

Thin-bedded fossiliferous limestone with shaly partings	2 ft.	0 in.
Grey calcareous shale	1	3
Thin-bedded fossiliferous limestone with shaly partings	1	0
Grey calcareous shale	0	6
Thin-bedded fossiliferous limestone with shaly partings	1	6
	6 ft.	3 in.

Elsewhere, shale rarely amounts to as much as ten per cent of the total, though most of the limestone beds are to some extent argillaceous.

There is nowhere a continuous section of this member showing as much as forty feet of beds. The type locality is the large quarry on the grounds of the Montreal Botanical Gardens, near the corner of Rosemount and Pie IX boulevards (Plate VIII-B). Formerly used for the production of crushed stone, this quarry now belongs to the Botanical Gardens, and it was at one time the intention to transform it into a sunken garden, for which purpose it is admirably suited.

The section seen in this quarry, compounded from measurements made at three different points, is as follows:

Top of quarry		
A succession of beds of the same types as in the underlying 8 ft. 11 in. Examined mostly from fallen blocks	8 ft.	0 in.
Alternation of crystalline limestone and shale in beds one inch thick. *Dalmanella rogata, Prasopora orientalis, Sowerbyella sericea*	3	3
Alternation of crystalline limestone and shale in beds two to three inches thick. Fossils as above	4	6
Shale and argillaceous limestone. *Prasopora* very abundant	0	8
Crystalline limestone with common Trenton fossils abundant	0	6
Alternating argillaceous crystalline limestone. *Zygospira recurvirostris* very abundant	2	3
Baked limestone, considerably whitened in places, breaking with splintery fracture. Fossils obscured	1	0
Sill of basic rock .... 2 ft. 3 in.		
Fine-grained crystalline limestone alternating with dense limestone. The uppermost 1 ft. baked and whitened by the adjacent sill. Fresh surfaces show an abundance of gastropods and pelecypods which, however, are almost impossible to free from the rock	5	6
Thin-bedded limestone, crystalline, dense, and argillaceous types alternating. Shaly partings common. The more argillaceous layers are extremely rich in *Prasopora orientalis*, the crystalline limestone in *Zygospira recurvirostris*. Most of the common Middle Trenton fossils occur here in abundance	11	0
Total thickness of limestone exposed	36 ft.	8 in.

Although this section is rich in number of individuals, particularly of *Prasopora* and of *Zygospira,* the fauna is indeed a sparse one. The forms collected and identified are as follows:

Dalmanella rogata	*Rafinesquina alternata*
Isotelus gigas	*Rhynchotrema increbescens*
Lingula cobourgensis	*Sowerbyella sericea*
Prasopora orientalis	*Zygospira recurvirostris*

A much larger fauna has been listed from a collection made from an abandoned cellar-hole a quarter of a mile to the northwest, on the north side of Pie IX boulevard. Here, in addition to the species mentioned, were found the following forms:

Archinacella cf. *deleta*	*Platystrophia amoena*
Calymene senaria	*Plectorthis plicatella trentonensis*
Ceraurus pleurexanthemus	*Pterygometopus callicephalus*
Hormotoma ?trentonensis	*Rafinesquina praecursor*

In addition to the abundant *Prasopora orientalis* there is little that is distinctive in this fauna. *Rafinesquina praecursor* is not known below this member. Large Hormotomas, provisionally identified as *H. trentonensis* are more common in the upper beds. In addition, it may be noted that it is in this member alone that we find in abundance *Prasopora orientalis* and *Zygospira recurvirostris* although both species range practically throughout the whole Trenton group.

There are a few small, isolated exposures in the flat region below Côte Saint-Léonard and Montreal North (such as the limestone out of which the Trou-de-Fée * has been eroded, but, save for their significance in aiding to elucidate the regional structure, these are of little importance. About two and a half miles northward from Côte Saint-Michel, along Côte Saint-Léonard, one comes to a group of outcrops, including an old quarry belonging to Mr. Roy on the west side of the road and an old excavation, said to have been made by the Canadian National Railway, on the east side. From this group of outcrops the following list of fossils can be made up:

Dalmanella rogata	*Platystrophia amoena*
D. whittakeri	*Prasopora orientalis*
Isotelus gigas	*Rafinesquina alternata*
Lingula iowensis	*R. praecursor*
Orthoceras sp.	*Sowerbyella sericea*
Parastrophia hemiplicata	*Zygospira recurvirostris*

Here again, amid a number of forms which persist through the entire

* This is one of the several small underground solution channels and cavities known in this area. Access underground is gained by a gently inclined slope, and the cavern does not extend more than 75 feet. On the land of Mr. Garth at Rosemere (Laval map), a stream flows for 1,000 feet intermittently underground, and one can walk for 200 feet along the subterranean channel. A second Trou-de-Fée has been reported near Saint-Vincent-de-Paul but is unknown to me. See Gibb, C.D., and Vennor, H.G., in Bibliography for the only known references to these caverns. A scientific compilation of all information concerning them would furnish much of local interest.

Trenton group, we may pick out *Dalmanella whittakeri, Prasopora orientalis,* and *Zygospira recurvirostris,* the two last in abundance, which mark these outcrops as belonging to the Rosemount member.

The most northerly exposures of the Rosemount member on the island of Montreal are in Rivière des Prairies, in the Parent and Dufresne quarries, but there these beds are poorly fossiliferous, and probably lie close to the top of the member. Farther south, a splendid series of disconnected exposures may be found by following up the small stream known as rivière des Eboulis just north of the boundary line separating the parishes of Sault-au-Recollet and Rivière des Prairies. From the exposures along its natural channel where it descends the steep slope toward rivière des Prairies, and from the débris cast aside by the excavator where the south fork of this stream runs across the nearly level surface on which the Island boulevard and the new Canadian National railway line have been built, a large and varied fauna can be assembled. The complete list from all of these outcrops is as follows:

Ambonychia amygdalina	*Platystrophia amoena*
Calymene senaria	*Plectorthis plicatella trentonensis*
Ceraurus pleurexanthemus	*Prasopora orientalis*
Conularia trentonensis	*Rafinesquina alternata*
Dalmanella rogata	*R. praecursor*
D. whittakeri	*Rhynchotrema increbescens*
Endoceras proteiforme	*Serpulites* sp.
Hindia sp.	*Sinuites cancellatus*
Hormotoma gracilis	*Sowerbyella sericea*
H. ?trentonensis	*Strophomena filitexta*
Isotelus gigas	*Trematis terminalis*
Lingula cobourgensis	*T. millipuncta*
Parastrophia hemiplicata	*Zygospira recurvirostris*

Only one other exposure in this part of the island deserves mention. On the north side of the Island boulevard, about three-quarters of a mile southwest of the cross-road between Rivière des Prairies and Montreal East, there is a long but low cut made for the purpose of obtaining fill for the building of the newly constructed boulevard. Fossils from this outcrop include:

Calymene senaria	*Prasopora orientalis*
Ceraurus pleurexanthemus	*Rafinesquina alternata*
Dalmanella rogata	*Receptaculites* sp.
Lingula iowensis	*Rhynchotrema increbescens*
Orthoceras sp.	*Sinuites cancellatus*
Parastrophia hemiplicata	*Sowerbyella sericea*
Platystrophia amoena	*Zygospira recurvirostris*

This is definitely a Rosemount fauna, and the lithology corroborates this conclusion. The beds are argillaceous, rubbly-weathering, thin-bedded. Almost immediately both to the north and the south are outcrops which just as definitely belong to the next higher formation. Hence, because no evidence from the dips and strikes will allow us to interpolate a fold so that the outcrops can be brought up on the crest of an anticline, its position may well be due to one or more faults. This structure is probably of very little consequence in shaping the major features of the region, but it is an example of how much structural geology depends on palaeontology.

On the western slopes of Mount Royal, Rosemount beds may be seen on Rockland avenue, Outremont, just southeast of the Canadian Pacific railway, and also a mile more or less to the south in numerous exposures near Van Horne avenue and Côte Sainte-Catherine road. Some of the limestone exposed on both banks of rivière des Prairies at White Horse rapids belongs to this formation.

In the Lachine map-area, Rosemount beds are exposed along the north shore of lake Saint-Louis, from a quarter to a half mile west of Lachine wharf, where thin-bedded limestones are exposed at times of low water, and are rich in *Prasopora* and *Platystrophia*.

List of fossils confined to the Rosemount member:

Ambonychia amygdalina
Archinacella cf. *deleta*
Dalmanella whittakeri
Hindia sp.
Pleurocystites elegans
Rafinesquina praecursor
Schizocrania filosa

List of fossils which pass up from underlying members into the Rosemount:

Calymene senaria
Ceraurus pleurexanthemus
Conularia trentonensis
Dalmanella rogata
Dinorthis pectinella
Hormotoma gracilis
Isotelus gigas
Lingula cobourgensis
L. quadrata
Orthoceras sp.
Parastrophia hemiplicata
Platystrophia amoena
Plectorthis plicatella trentonensis
Prasopora orientalis
Pterygometopus callicephalus
Rafinesquina alternata
Rhynchotrema increbescens
Serpulites sp.
Sinuites cancellatus
Sowerbyella sericea
Strophomena filitexta
Trematis terminalis
Zygospira recurvirostris

List of fossils which pass from the Rosemount up into higher formations:

Calymene senaria
Ceraurus pleurexanthemus
Cheirocrinus logani
Conularia trentonensis
Dalmanella rogata
Endoceras proteiforme
Hormotoma gracilis
Isotelus gigas
Lingula cobourgensis
Orthoceras sp.
Platystrophia amoena
Prasopora orientalis
Rafinesquina alternata
Rhynchotrema increbescens
Serpulites sp.
Sowerbyella sericea
Sinuites cancellatus
Strophomena filitexta
Trematis terminalis
T. millipunctata
Zygospira recurvirostris

Tetreauville Formation

The northern end of the island of Montreal, south of the Bas-de-Sainte-Rose fault, and most of its eastern shore at least as far south as

Longue Pointe, are underlain by limestones of what I propose to call the Tetreauville formation. This formation is, in general, uniform in its petrographic expression. It consists of beds of dense bluish-black limestone up to 6 inches in thickness, separated by shaly partings. The limestone weathers a yellowish-buff upon exposure, and the colour gives it one of its most distinctive features. The dense limestone has here and there small crystals of calcite, but on the whole it has the appearance of a lithographic stone. Lenses of crystalline limestone up to a foot thick, and up to several tens of feet wide, consisting of fossils and fossil fragments are present, though rare. In many of the outcrops, the beds are characterized by a strong petroliferous odour, and in a few places, notably west of Terrebonne, small droplets of oil may appear on freshly broken surfaces of this rock. Its regularity of bedding, general lack of crystallinity and of fossils, and its yellow colour upon weathering, serve to distinguish this formation from those above and below.

There are possibly more outcrops of this member than of all of the rest of the Trenton group combined, due in large measure to the superior resistance to erosion offered by these dense limestones. Unfortunately, this same characteristic has prevented the fossils in these beds from weathering out in any of the recent quarry exposures. Even in the old abandoned quarries, fossils can be obtained only with difficulty.

In two places north of Montreal there are deep quarries where good sections of the rocks of this formation can be seen. The Durocher quarry, two blocks northeast of the corner of Broadway and Sherbrooke streets, Pointe aux Trembles, shows nearly vertical and unbroken walls on three sides, with a maximum thickness of 63 feet of remarkably even-bedded, argillaceous limestone with practically no crystalline beds, and very few fossils (Plate IX-A). Only one prominent band of black shale, a few inches thick, ten feet above the quarry base, mars the perfection of the stratigraphic uniformity. As is typical with rocks of this member, the few beds at the top show the characteristic yellow-weathering, and most of the stone yields a strong smell of petroleum.

A mile and a half to the south-southwest, and on the west side of Sherbrooke street, is the quarry of the Canada Cement Company, where, in the southern corner, about 56 feet of limestone is exposed. This is fairly evenly bedded, but shows more crystalline material than the Durocher quarry, although the bulk of the limestone is argillaceous. This quarry is by far the largest in the vicinity of Montreal, but even in those parts which have not been worked for ten to twenty years, weathering has not been able to do much in freeing fossils from their matrix. It is interesting to note that Goudge (1935, p. 112) gives analyses of each ten feet of limestones "made from a core obtained from a drill hole located 400 feet north of the present quarry". Save for a decided increase in SiO_2, Al_2O_3, and Fe_2O_3, and a corresponding decrease in $CaCO_3$, at about the 30-foot level, which could easily be explained by the inclusion of a small amount of igneous matter, and also for a minor diminution in the amount of SiO_2 in the lowest beds, the analyses are remarkably uniform, which is corroborative evidence of the observation that the Tetreauville formation is lithologically homogeneous. The core was taken from a hole 142½ feet deep and, because of the presence of the belt of the Montreal formation a third of a mile to the west and dipping eastward, the bottom of the hole must have been near the base of the Tetreauville formation.

At Saint-François-de-Sales, on the north shore of Ile Jésus, a few hundred feet northwest of the northernmost quarries in the Chazy limestone, there is a small quarry cut out of the Tetreauville beds. The close proximity of Chazy and Terrebonne formations demands a fault; in fact, before the quarry was investigated, the Bas-de-Sainte-Rose fault was actually projected so as to lie between the Chazy quarries and this subsequently discovered one. The rock is of the normal Tetreauville type, evenly bedded and yellow-weathering. Fossils are scarce, but *Conularia* and cystids are characteristic. Elsewhere, the rocks of this formation are well shown along the shores of rivière des Mille Iles at Ile aux Vaches, on the eastern side of Mount Royal and, in the Lachine map-area, on Westmount mountain, and along the new boulevard (No. 9c) from the south end of the Mercier bridge eastward. To this formation also belong the exposures at Dorval.

Species found in the Tetreauville formation:

Calymene senaria
Ceraurus pleurexanthemus
Cheirocrinus logani
Climacoconus quadratus
Conotreta rusti
Conularia trentonensis
Cyclospira bisulcata
Dalmanella rogata
Ectenocrinus canadensis
Endoceras proteiforme
Heterocrinus tenuis
Hormotoma gracilis
Hyolithes sp.
Isotelus gigas
Lasiograptus cf. *eucharis*
Leptaena rhomboidalis
Lingula cobourgensis
Liospira americanus
Orbiculoidea lamellosa
Orthoceras sp.
Paterula sp.
Prasopora orientalis
Pseudosphaerexochus trentonensis
Rafinesquina alternata
R. camerata
R. praecursor
Schizotreta pelopea
Serpulites sp.
Sinuites cancellatus
Sowerbyella sericea
Strophomena filitexta
Trematis millipunctata

Although the above list contains many long-ranging species, the following are confined to the Tetreauville formation:

Conotreta rusti
Heterocrinus tenuis
Hyolithes sp.
Lasiograptus cf. *eucharis*
Leptaena rhomboidalis
Orbiculoidea lamellosa
Paterula sp.
Rafinesquina camerata

None in this list can be called common, and of some there is but a single specimen. The most obvious characteristic of the Tetreauville fauna is the presence in almost every outcrop of both *Cheirocrinus logani,* sometimes whole, and *Conularia trentonensis*. Both occur in the underlying and overlying members, but are common only in the Tetreauville limestone.

Terrebonne Formation

This, the uppermost of the Trenton limestone divisions, consists of thin-bedded dark limestones yielding a fair abundance of fossils. Crystalline beds, though not abundant, are present. There is nowhere the regularity of bedding that characterizes the underlying Tetreauville limestone. Its lesser resistance to weathering is probably responsible for its paucity of outcrop.

Nowhere can its contact with the underlying or overlying beds be seen. Its thickness is therefore a matter of conjecture but, judging from the distribution of the formation as seen on the map, it is of the same order of magnitude as that of the Tetreauville formation.

Exposures of Terrebonne beds can be seen from half a mile to a mile west of the village of Terrebonne on both sides of rivière des Mille Iles (Plate IX-B), also along both shores of Dutchman rapids (rivière des Prairies), and at a few localities on the south shore of White Horse rapids from A Ma Baie (three-quarters of a mile northeast of Sainte-Geneviève station) to Ile Bigras. The structure as seen near Terrebonne is very simple. The beds lie at the top of the whole Trenton development, which is there slightly tilted to the east. At the Dutchman and White Horse rapids localities, the structures are not easy to understand, for major faults bound the exposures on both their north and south sides.

List of species confined to the Terrebonne formation:

Holopea paludiniformis	*Rafinesquina deltoidea*
Oxyplecia sp.	*R. normalis*

List of species which pass up from underlying formations into the Terrebonne formation:

Calymene senaria	*Leptaena rhomboidalis*
Ceraurus pleurexanthemus	*Platystrophia amoena*
Climacoconus quadratus	*Rafinesquina alternata*
Conularia trentonensis	*Rhynchotrema increbescens*
Dalmanella rogata	*Sinuites cancellatus*
Endoceras proteiforme	*Sowerbyella sericea*
Hormotoma gracilis	*Trematis terminalis*
Isotelus gigas	*Zygospira recurvirostris*

Thickness

On the island of Montreal, Logan (1863, p. 139) measured 530 feet of Trenton beds and estimated that the formation as a whole would reach at least 600 feet. Others have copied this figure, which, as a minimum, is substantiated by the boring mentioned by Ells (1896, p. 46J), in which

2,000 feet is attributed to the limestones of the Beekmantown, Chazy, Black River, and Trenton formations. Allowing 1,060 feet for the first, 280 feet for the second, 50 feet for the third (the thickness in the Mallet well), a balance of 610 feet is left for the Trenton.

In the absence of a reliably logged drill core, the problem of arriving at a reasonable estimate of the thickness of the rocks of the whole Trenton group is not easily solved. It can be approached, however, on the basis of measurements from quarries, etc., and computations from the exposures as plotted on maps.

Mile End Formation.—As stated earlier, this formation, as measured in the Martineau quarry, is 25 feet thick.

Saint-Michel Member.—As measured in the quarry of the National Quarries Company, Saint-Michel, this formation is 101 feet 3 inches thick. It is probable that its maximum thickness is little, if any, more than that. I have assigned 100 feet and 120 feet as the minimum and maximum thicknesses of this member.

Rosemount Member.—No measurements of any value have been made of the thickness of this formation. On the island of Montreal its breadth of outcrop is generally two and a half to three times that of the Saint-Michel member, which would give it 250 feet and 360 feet as minimum and maximum calculated thicknesses.

Tetreauville Formation.—From the boring put down by the Canada Cement Company, probably about in the middle of the supposed belt of outcrop of these rocks, a thickness of 142½ feet was measured. Its total thickness, therefore, might be 285 feet. From calculations based on breadths of outcrop on the island of Montreal, this member should have about three-quarters the thickness of the Rosemount—or from 190 to 270 feet.

Terrebonne Formation.—Save for assuming, from insufficient map data, that the Terrebonne is probably as thick as the Tetreauville, there is little more that we can say of this formation.

Summary.—The measured and estimated thicknesses of the Trenton limestones are shown in the following table.

	MINIMUM	MAXIMUM
Terrebonne	190 feet	285 feet
Tetreauville	190 "	285 "
Rosemount	250 "	360 "
Saint-Michel	100 "	120 "
Mile End	25 "	25 "
	755 feet	1,075 feet

As a check upon the above figures there is still to be considered the wide expanse of Trenton rocks north of rivière des Mille Iles between Bois de Filion and Terrebonne. Measuring across the strike, this section is 9 miles long, but there is reason to suppose that this is a minimum measurement. Wherever dips can be obtained they are approximately 1°. According to these data, the thickness works out to be 830 feet as a minimum measurement.

As a result of these observations we can say that the Trenton limestones hereabouts are certainly as much as 755 feet thick, with a possibility of even a hundred feet more than this. In my opinion, the minimum calculated thickness of 755 feet is closer to the true thickness than the maximum of 1,075 feet given above. With the present data, 800 feet is a reasonable compromise.

Fossils

Enough has been said to indicate some of the outstanding and diagnostic fossils in the formations and members of the Trenton group; enough, it is hoped, to permit ready separation of these units on the basis of their fossil content. This has been a comparatively simple though lengthy undertaking because of the abundance of fossils in the greater part of the rocks of this group and the large collections made during the course of this work. For stratigraphic purposes, the field has been more than adequately covered. Much more needs to be done along purely palæontological lines. For instance, there are fossils which we customarily identify as *Isotelus gigas, Calymene senaria, Platystrophia amoena, Dalmanella rogata, Sowerbyella sericea.* There is no doubt that in this area these so-called species include several varieties and not improbably several species. To establish the truth of this would require far more time than it is possible to bestow, and it is questionable whether the elaboration would be stratigraphically valuable. All of the species so far identified in the collections made during the present field work, or reported in recent publications, are included in the subjoined list. Several new and undescribed species, which are of no stratigraphic value, are not included. A complete list of Trenton fossils, as recognized up to 1936, is given, with illustrations of the commonest species, in *Geology of Quebec*, Vol. II, 1944, pp. 264-266, Pl. 29-31.

List of fossils collected from the rocks of the Trenton group during the progress of the present work:

PORIFERA
Hindia sp.
Receptaculites occidentalis Salter
ANTHOZOA
Streptelasma sp.
GRAPTOZOA
Diplogratus sp.
Lasiograptus eucharis (Hall)
ANNELIDA
Serpulites sp.
CYSTOIDEA
Cheirocrinus logani (Billings)
Pleurocystites elegans Billings
CRINOIDEA
Heterocrinus tenuis Billings
Ectenocrinus canadensis (Billings)
BRYOZOA
Prasopora orientalis Ulrich
Note: at least a dozen other species
BRACHIOPODA
Paterula sp.
Lingula trentonensis (Conrad)
L. cobourgensis Billings
L. iowensis Owen
L. modesta Ulrich
L. riciniformis (Hall)
L. cf. *rectilateralis* Emmons
Schizambon canadensis (Ami)
Conotreta rusti Walcott
Schizocrania filosa Hall
Trematis terminalis (Emmons)
T. ottawaensis Billings
T. millipunctata Hall
Orbiculoidea lamellosa (Hall)
Schizotreta pelopea (Billings)
Dalmanella rogata Sardeson
D. whittakeri Raymond
Hebertella frankfortensis Foerste
Platystrophia amœna McEwan
Hesperorthis tricenaria (Conrad)
Plectorthis plicatella (Hall)
Dinorthis pectinella (Emmons)
Pionodema cf. *perveta* (Conrad)
Leptæna rhomboidalis (Wilckens)
Sowerbyella sericea (Sowerby)
Rafinesquina alternata (Emmons)
R. deltoidea (Conrad)
R. camerata (Conrad)
R. præcursor Raymond
R. normalis Wilson
R. robusta Wilson
Strophomena filitexta Hall
S. cf. *thalia* Billings
S. trentonensis Winchell and Schuchert
S. irregularis Wilson
Triplecia nucleus Hall
Oxyplecia sp.
Clitambonites diversus (Shaler)
Parastrophia hemiplicata Hall
Rhynchotrema increbescens (Hall)
R. dentatum Hall
Zygospira exigua (Hall)
Z. recurvirostris (Hall)
Cyclospira bisulcata (Emmons)
PELECYPODA
Ctenodonta levata (Hall)
C. nasuta (Hall)
Whitella ventricosa (Hall)
Ambonychia amygdalina Hall
A. orbicularis (Emmons)
Clionychia undata (Emmons)
Colpomya faba (Emmons)
Modiolopsis mytiloides (Hall)
M. maia Billings
GASTROPODA
Archinacella cf. *deleta* Sardeson
Sinuites cancellatus (Hall)
Bucania punctifrons Emmons
Phragmolites compressus Conrad
Hormotoma gracilis (Hall)
H. trentonensis Ulrich and Schofield
Liospira americana Billings
Eccycliomphalus trentonensis (Conrad)
Cyclonema hageri Billings
Cyclonema montrealensis Billings
Holopea paludiniformis Hall
Hyolithes, sp.
Climacoconus quadratus (Walcott)
C. clarki Sinclair
Conularia trentonensis. Hall
TRILOBITA
Cryptolithus tesselatus (Green)
Eoharpes ottawaensis (Billings)
Isotelus gigas DeKay
Bumastus billingsi Raymond and Narraway
B. bellevillensis Raymond and Narraway
Calymene senaria Conrad
Ceraurus pleurexanthemus Green
Pseudosphærexochus trentonensis Clarke
Pterygometopus callicephalus (Hall)
CEPHALOPODA
Endoceras proteiforme Hall
Orthoceras sp.
Spyroceras bilineatum (Hall)
Actinoceras imperator Clark
OSTRACODA
Isochilina gracilis (Jones)

Numerous unidentified species

UTICA GROUP

Lachine Formation

A mile and a half east of the north end of the railway bridge from Ile Bigras to the southwest end of Ile Jésus there is an inconspicuous outcrop of black shale of the shore of the river, exposed only at low water. Obscure cephalopods, possibly a species of *Geisonoceras,* make it likely that the shale belongs to the Utica group, but no graptolites or trilobites occur to confirm this. Owing doubtless to the present higher level of the river this outcrop is not as extensive as it once was. Logan (1854, p. 8) wrote "...at the White Horse rapids, on the river des Prairies, a patch of black bituminous shales of the Utica formation, about a mile long and not half that in width, occupies a position not far below Isle-Bizard, showing a narrow strip on each side of the stream, which cuts it in two lengthwise. This is the deepest part of a shallow trough;...". In his report for the previous year (1852, p. 17) he reported finding *Triarthrus becki* and *Diplograptus bicornis.*

Elsewhere this black shale formation has a fair development. The eastern shore of the island of Montreal from Longue Pointe southward toward Lachine is occupied by these rocks in a wedge-shaped outcrop widening toward the south, including the whole length of the Lachine canal. Good exposures can be seen at Bronx Park (near the southeast corner of Montreal island) and on the adjacent island immediately downstream from the power house. Heron and Goat islands are composed of this rock, plus a complex of basic sills. It also occurs on the eastern shore of the Saint-Lawrence at Longueuil, Montreal South and Saint-Lambert. The southern part of Sainte-Hélène island is also of this shale. South of the Saint-Lawrence it outcrops only at Delson and in a few small exposures between Delson and Ile au Diable, though it is certainly distributed over a wide expanse of barren country. There are some outcrops of a grey shale along La Tortue road, two miles west of Baurette, which belong to the next higher formation, the Lorraine. The black shale is in one or two localities abundantly supplied with fossils, so that its stratigraphic position is assured.

At several places on Mount Royal, the Utica shale has been changed by contact metamorphism to a typical hornfels. This can best be seen in the cliff immediately below the Lookout, and along the Montreal Tramways track ascending the north slope of the mountain, just below the point where it enters a tunnel.

There arises here the problem of the broad expanse of barren ground northeast of Terrebonne on the Laval sheet. If we are right in our assumption of the thickness of the Terrebonne limestone, then the boundary between the Trenton and the Utica should pass about a mile to the east of Terrebonne, leaving a stretch of country to the east, five and a half to six miles wide, devoid of outcrops. With an average dip of 1°, which is correct for the Trenton to the west, the minimum estimate of 300 feet given below for the Utica should mean a width of outcrop of 17,145 feet, or about 3½ miles. The remainder to the east would necessarily be the Lorraine. In confirmation of this it may be noted that large blocks of Lorraine sandy limestone occur in the drift at the quarries near de la

Réparation Shrine, two miles east-northeast of Rivière des Prairies. Both of these formations are thin-bedded, low in resistance to weathering, and hence nowhere stand up in escarpments.

As exposed along the Saint-Lawrence river and in the vicinity of the Lachine canal, the shale has a breadth of outcrop of from two to four miles. The former figure, with a dip of 2°—not too low for these parts—gives us a thickness of 369 feet, whereas twice that distance, with a similar dip, would give 738 feet. The dips are not apt to be constant, however, and rarely exceed two degrees, and moreover, in many places, the shales are bulged upward by outcrops of breccia (Sainte-Hélène island) or by sills (Bronx Park) so that their apparent thickness may be much greater than their actual thickness. Because there are no borings upon which we may rely, it would seem expedient to assume 300 feet as a minimum thickness for this formation, recognizing that it may possibly be as much as twice that.

Although they cannot be called widespread within these map-areas, elsewhere the black shales have a very extensive development, extending from Toronto through Ottawa, east to Richelieu river, and northward to Quebec city, where they can be seen at Montmorency falls. They have a considerable range in thickness. It is quite likely that on the Laval and Lachine sheets they are no more than a few hundred feet thick, but farther east, in the Lacolle map-area, they are almost certainly more than 1,000 feet thick. And at Laprairie, only a few miles east of this area, a drill hole penetrated 1,500 feet of shale—all once supposed to be Utica, though much of it is probably Lower Lorraine—before reaching the Trenton limestone below.

Through the courtesy of Mr. J. F. Brett, of the Montreal Water Works, I have been able to examine cores of Utica shale taken in several places in the neighbourhood of the Lachine canal. Three cores from test holes put down at the site of the new pumping station at the intake of the aqueduct show no more than 50 feet of black shale each. Inasmuch as these were taken from positions separated by a few tens of feet, there is probably nearly complete duplication in each pair; hence these borings do not help in gaining an insight into the actual thickness of the Utica shale. They are very valuable, however, in providing us with a great number of graptolite fossils which serve to establish definitely the stratigraphic position of the shale.

In the Montreal area, it is almost everywhere a fine disintegration shale. At Bronx Park there are frequently seen thin irregular lenses of fine, white, quartz sandstone. Elsewhere, for example at Delson, there is a greater proportion of the kaolin minerals. No visible trace of carbonate has been recognized in this rock, except in the huge flattened concretions, up to 6 feet across and 2 feet thick, common in certain layers, especially at Delson.

The problem of the separation of the Utica and Trenton group is one which cannot be settled in any one locality alone. As explained on page 58, for a limited area it seems best to consider the two formations to be separate. Whatever their stratigraphic relations may be a hundred miles north, west, or south, hereabouts the Utica shale definitely overlies, and is everywhere younger than, the Trenton. No contact or intergradation is known. On Mount Royal, just below the Lookout, less than 3 feet of beds are hidden between the topmost Trenton (Tetreauville) and the overlying hornfels (Utica). No sign of a gradation from one to the other can be seen.

Fossils are common in a few places, elsewhere they are practically absent. Graptolites make up the greater part of the fauna for the entire Province of Quebec, which, except for the Portneuf region, numbers only fifteen species. The following forms were collected by the writer in the course of the present work:

GRAPTOLITES
Climacograptus bicornis (Hall)
C. typicalis (Hall)
Glossograptus eucharis Ruedemann
G. quadrimucronatus (Hall)

BRACHIOPODS
Leptobolus insignis Hall

CEPHALOPODS
Geisonoceras (?) tenuistriatum (Hall)

This is a small but characteristically pelagic fauna. Its similarity with other Utica faunas of Quebec and New York indicates not only a continuity of the marine waters over those localities during Utica time, but a similarity of environment. Nowhere did the sea floor support indigenous life. All of the fossils, without exception, are those which swam or floated at the ocean surface. The fuller significance of this is given later in the chapter on *Historical Geology*.

LORRAINE GROUP

Above the Utica shale in Quebec there lies the Lorraine formation. This consists of a thick series of sandy shales and shaly sandstones with subordinate amounts of more or less pure limestone and pure sandstone. Along Nicolet river (a hundred miles to the northeast) the section is 2,500 feet thick. In the Laval-Lachine map-areas, Lorraine beds outcrop in only two places: first, in a small drainage ditch nearly two miles west of the mouth of La Tortue river (parallel to and two miles west of the eastern margin of the Lachine map), on the south side of the road; and second, in a more extensive outcrop on the north and northeast sides of Ile à Boquet, at the lower end of the Lachine rapids, where they are closely associated with an overlying sill. In all probability the outcrops visible on Ile au Diable, around which the roughest waters of the rapids swirl, belong to this same combination.

The shale is grey to fawn in colour, in marked contrast to the black Utica shale. Only one specimen of a graptolite has been collected, too poor to identify. Instead, the shale is replete with pelecypods of a few varieties, brachiopods of a Trenton aspect, etc. Abundant mica flakes occur throughout, but stratification, though visible in the cliff face, is marked in a hand specimen only by the alternation of sandy and shaly beds.

Because the Utica occurs both to the west and to the east of these Lorraine exposures, it is obvious that the distribution is controlled either by a slight fold or by a fault. There is no corroborative evidence of the latter, for which reason the Lorraine beds are shown as a shallow synclinal fold, with its axis parallel to the regional strike.

The fossils show a very close affinity with the fauna described by Foerste from the Lorraine beds at Chambly, Saint-Hyacinthe, etc. The most interesting fact is that all of the species, with the exception of the one poor graptolite, are of benthonic forms. Hence, after Utica time, the sea floor had become sweet again, allowing a bottom fauna to develop and to persist. The list of fossils so far identified from these beds follows:

BRACHIOPODA
Leptæna rhomboidalis (Wilckens)
Dalmanella rogata Sardeson
Sowerbyella sericea (Sowerby)

PELECYPODA
Ctenodonta chambliensis Foerste
Clidophorus brevis Foerste
C. planulatus (Conrad)
C. prævolutus Foerste
Lyrodesma poststriatum (Emmons)
Rhytimya oehana Ulrich

GASTROPODA
Archinacella puliaskiensis Foerste

CEPHALOPODA
?Geisonoceras sp.

TRILOBITA
Cryptolithus cf. *bellulus* (Ulrich)
Calymene sp.
Proetus cf. *chambliensis* Foerste

The combination of *Cryptolithus* with *Proetus* is good evidence that these beds belong to the top of Foerste's *Cryptolithus* zone. There are no higher Ordovician strata within the limits of the Laval-Lachine sheets.

DEVONIAN FORMATIONS

Sainte-Hélène island consists largely of a breccia (see p. 14) presumed to be associated in origin with the intrusion of the Monteregian igneous rocks. Its low, flat, southern end, however, is underlain by horizontal Utica shale, bearing graptolites. Dark and light dykes and sills abound in the shale, but are found but rarely in the breccia. The latter, because of its superior hardness compared with the adjacent shale, rises to a height of 125 feet above the Saint-Lawrence. It contains fragments of Precambrian rocks and of all of the known formations in this vicinity, and also blocks of Devonian rock of two ages, Helderberg and Oriskany. The origin of this breccia will be discussed later under Igneous and Associated Rocks (see pp. 98, 103); it will suffice to say here that it was probably formed as a diatreme, and that the shattered and ejected blocks fell back into the pipe in confusion. Hence, on any horizontal surface one would be likely to meet representatives of every geological formation through which the hole passed. Of these fragments, the most inherently interesting are those of Devonian ages (Plate X-A). In the case of all other formations we are enabled to study not only the thickness but also the areal extent, the succession of faunas, and the structural relationship with the under- and over-lying formations. Such approaches are denied us in the case of the Devonian rocks and we must be content with a tantalizingly small amount of information gleaned from a few adventitious blocks.

Although the breccia was noted by Bigsby in 1825, the first critical observations on these rocks were made by Logan in *Geology of Canada* (1863), in which he gave a list of seven Helderberg fossils and concluded that "a considerable area in the Champlain and St. Lawrence valleys was once continuously covered with rocks of the Lower Helderberg group" (p. 358). In 1880, J. T. Donald, one of Sir William Dawson's students, drew up a list of 36 Devonian species which he recognized from these rocks. Among these he noted not only Helderberg fossils but also examples of an Oriskany fauna. In 1890, Deeks swelled the list of species to 44. In a paper published in 1901, Schuchert, after giving a detailed account of the then recent developments and publications, presented a revision of the species thus far collected and, with it, conclusive evidence of two distinct faunas, one of Helderberg, the other of Oriskany, age.

In 1910, Williams presented a thorough palaeontological description and criticism of these Devonian faunas, as a basis for which he had at his disposal not only all the material hitherto collected, but also a considerable amount of newly blasted material as well. After an exhaustive treatment he confirmed the earlier reports of the presence of two separate faunas, of Helderberg and Oriskany ages. Williams' discussion of the relation of these faunas to each other, to the Lower and Middle Devonian faunas of New York, and to the Coblenzian fauna of Europe, may be studied in his extended report.

Williams' faunal lists, which have not been expanded since their publication, follow:

LIST OF FOSSILS FROM THE LOWER HELDERBERG
(*Gypidula pseudo-galeata* Zone)

COELENTERATA
Favosites helderbergiae Hall
BRYOZOA
Cf. *Lichenalia distans* Hall
Lichenalia cf. *torta* Hall
BRACHIOPODA
Orthis (Schizophoria) multistriata Hall
Dalmanella cf. *subcarinata* Hall
D. concinna Hall
Schizophoria multistriata Hall
Rhipidomella oblata Hall
Orthostrophia strophomenoides Hall
Leptaena rhomboidalis (Wilckens)
Stropheodonta arata Hall
S. cavumbona Hall
S. (Amphistrophia) continens Clarke
S. leavenworthana Hall
Orthotetes cf. *deformis* Hall
O. cf *woolworthana* Hall
Gypidula pseudo-galeata Hall
Uncinulus planoconvexa Hall
Camarotoechia ventricosa Hall
Rhynchonella formosum Hall
Spirifer concinnus Hall
S. concinnus var. *helenae* Williams
Cyrtina dalmani Hall
Atrypa reticularis (Linnaeus)
Meristella princeps Hall

S. planulata Hall
S. blainvillei Billings
S. perplana Hall
S. beckii Hall
Strophonella punctulifera Conrad
Merista laevis (Vanuxem)
Rensselaeria cf. *mutabilis* Hall

PELECYPODA
Platyceras cf. *clavatum* Hall

LIST OF FOSSILS FROM THE ORISKANY
(*Spirifer arenosus* Zone)

BRYOZOA
Chaetetes sphaericus Hall

BRACHIOPODA
Orthis (Rhipidomella) cf. *oblata* Hall
O. (Dalmanella) subcarinata Hall
O. (Dalmanella) cf. *quadrans* Hall
Leptaena rhomboidalis (Wilckens)
Orthothetes cf. *woolworthana* Hall
Chonetes hudsonicus gaspensis Clarke
C. striatissimus W. & B.
?*Camarotoechia* sp. indet.
Uncinulus cf. *mutabilis* Hall
Rhynchonella eminens Hall
Eatonia peculiaris Hall
E. cf. *whitfieldi* Hall
Spirifer arenosus Conrad
S. montrealensis Williams
S. pennatus var. *helenae* Williams
S. gaspensis Billings
S. cumberlandiae Hall
S. cyclopterus Billings
Cyrtina rostrata Hall
Metaplasia pyxidata Hall

PELECYPODA
Modiomorpha helena Williams
Palaeoneilo ("cf. *maxima* Clarke") *helena* Williams

GASTROPODA
Tentaculites schlotheimi Koken

GLACIAL AND POST-GLACIAL DEPOSITS

By far the greater part of this area is covered by deposits of Pleistocene and Recent age. These are in part directly of glacial origin, in part deposits made in the sea of the Champlain submergence, and in part deposits of these two categories re-worked by rivers and waves. A detailed account of these deposits on the island of Montreal was presented by Stansfield (1915).

Unmodified glacial deposits are not as abundant as one might expect. There is a prominent belt of morainal material on the south side of rivière des Mille Iles between Plage Laval and Sainte-Rose. Traces of this can be seen on the north shore below Rosemere. No other area of unmodified glacial deposit was recognized at the surface, although excavations frequently penetrate the thin veneer of covering drift and expose the till beneath.

Save for these exceptional occurrences of undisturbed glacial till, nearly all of the surficial material of the area consists, first, of glacial deposits of the ground moraine type much modified, presumably by wave erosion, and second, of a thick mantle of sands and muds deposited in part under the Champlain sea and in part by the swollen rivers immediately after the withdrawal of that sea. The former type is well shown south of rivière aux Chiens below Sainte-Thérèse, and in a considerably modified condition on the southwest part of Ile Jésus; the latter by the extensive plain north of rivière aux Chiens, and the highland north of Bois de Filion and Terrebonne. River-deposited and river-modified deposits occur also in a wide area around the northeast end of Ile Jésus and the island of Montreal. The wide area south and west of the city of Montreal is covered with sands of the same types. A final elucidation of the unconsolidated deposits would depend upon the accumulation of innumerable soil profiles and analyses.

Although the Champlain sea inundated this whole area (save perhaps for the summit of Mount Royal) very few recognizable traces of its occupancy can be seen. In the cut made in 1939 in putting through the new road (highway No. 11) on the mainland near Saint-Lin Junction (one mile north of Sainte-Thérèse), marine shells occur in abundance in the clays. At this place, the section as given by the engineer in charge of highway construction is as follows:

Top of section .... 218 feet above sea level	
Black sand	4 feet
Stratified blue clay, marine fossils	45 "
Stratified red clay, no fossils	12 "
Fine-grained compact sand	1 "
Gravel	2 "
Base of section .... 154 feet above sea level	

Marine shells occur in the coarse gravel of the gravel pit a quarter of a mile northwest of Saint-Lin Junction but none were found two miles north, in the pits in the vicinity of Ravins Station (3 miles due north of Sainte-Thérèse).

One very prominent gravel ridge, of unknown origin, extends from within a mile of the southern boundary of the Lachine map-area, near Sainte-Philomène Station (5½ miles south of Chateauguay), north-northeasterly for seven miles in a nearly straight line. Eskers are usually sinuous, but this ridge is remarkably straight. Its sides are so steep as to appear wave worn. The gravel ridge, much worked for railway and road material, deserves further study as a valuable resource of road and structural material. Elsewhere on the mainland to the south, the surface is a nearly featureless plain with wave-washed glacial drift occupying most of the region, but here and there low swells of the original till showing up above the general level.

Three miles south of Saint-Janvier (northwest corner of Laval map-area), there is an area of several hundred acres of wind-blown sand. It is not unlikely that other dune areas could be found. Before this region was settled such sand areas were thinly grassed or bush-covered, but since the removal of the weak topsoil by grazing or farming there has been nothing to stop the wind from denuding the surrounding area and laying bare acres of sand. Adequate agricultural supervision would have prevented anything but highly specialized cultivation of such an otherwise unproductive area.

IGNEOUS AND ASSOCIATED ROCKS

Introduction

Mount Royal is one of a series of eight essentially similar hills which, spaced at intervals over a distance of about fifty miles along a somewhat curved line extending easterly from Montreal, rise abruptly from the lowland plain. Adams (1904) named these the *Monteregian Hills,* taking the name from Mount Royal, the one best known geologically and topographically. Mount Royal, with an area of slightly more than 3 square miles, is one of the smaller of these hills, only two of the others —Johnston and Saint-Bruno—having a lesser area, and, next to Saint-Bruno, it has the lowest elevation, its summit being 759 feet above sea level. Its 'mountainous' appearance arises by contrast with the surrounding plain, which hereabouts lies from 100 to 150 feet above sea level. It is in reality a double mountain, with the Côte des Neiges depression separating the two parts, known respectively as Mount Royal and Westmount mountain. The latter is composed almost exclusively of sedimentary rock, and hence, save for its northern edge adjacent to Côte des Neiges, it lies beyond the scope of this chapter. Mount Royal is composed almost wholly of igneous rocks (see Figure 5 in pocket), which are described below.

The igneous rocks of this area are concentrated chiefly in the resistant core of Mount Royal and consist of two principal plutonic rock types. The more abundant and the older is a medium- to coarse-grained rock of dark colour and of diverse composition. The second type, a medium-grained and light-coloured rock found in some force in some localities, may be observed to cut the darker rock and is therefore younger than it. From an examination of hand specimens in the field, the darker and the lighter rocks would be named gabbro and syenite, respectively. Although these rocks are of a suite that makes them unlike some of the more common gabbros or syenites, these terms afford an accurate means of designating them. Besides these two main intrusive bodies there are, on and around the mountain, numerous sills and dykes of satellitic rocks which, as is evident from their distribution and composition, are genetically related to the plutonic rocks that form the core of the mountain.

Each of the Monteregian hills is surrounded by an irregular halo of such satellitic rocks. In the case of Mount Royal, the numerous road cuts, quarries, and openings for foundations for buildings that have been made in and near the metropolis have given abundant data on the dyke rocks (Plates X-B to XIII). Furthermore, the Canadian National railway tunnel through the mountain has furnished a continuous exposure through the mountain core and the dykes associated with it. Partly because of the abundance of exposures, and partly because of their ready accessibility, the dykes on and around Mount Royal have been studied in much greater detail than those associated with any other of the Monteregian hills. They are present in such variety that even the naming of them involves many problems. In modern petrology, the assigning of a multiplicity of varietal names to rocks serves no useful purpose, and this practice has fallen into disrepute. Such was not the case at the beginning of this century when, in the scramble to name as many rock varieties as possible, minor and insignificant features were given an importance they in no way deserve.

Thus we find that the varieties of satellitic rocks exposed on Mount Royal have been assigned names with recklessness. Not only is there overlap in characteristics of many of the rock varieties to which distinctive names have been given, but for many of them the definitions themselves are not clear. For these reasons, many of the names are unserviceable for the Mount Royal area and only general names are used in this report. A simple subdivision of the satellitic rocks is given below. The dyke and sill rocks are divided into the light-coloured varieties and the dark-coloured varieties (Plates XI-A, XI-B). In general, these correspond, respectively, to the syenite and gabbro of the core of the mountain. The light-coloured rocks may be further divided into the even- and fine-grained types, and the porphyritic varieties with a fine-grained matrix. The phenocrysts in the latter are in most cases feldspar, but nepheline phenocrysts occur in some types. The dark varieties, too, include an even-grained group and a porphyritic group. The phenocrysts in most of the dark dykes are of the dark (ferromagnesian) minerals. Most of the dark dykes belong to the enigmatic division of satellitic rocks known as 'lamprophyres', the name of one variety of which, camptonite, has appeared so frequently in the literature that it may be used to designate the bulk of the lamprophyres of Mount Royal. Some of the light- and dark-coloured dykes are in reality only chilled parts of the gabbro and syenite, characterized as a rule by plagioclase phenocrysts set in a dark matrix, and these micro-syenites and micro-gabbros are difficult to distinguish from the normal varieties of the satellitic rocks. It was mentioned at the beginning of this section that the gabbro is older than the syenite. Among plutonic rocks of any intrusive cycle, this order, dark rocks preceding light, is universal, but the satellitic rocks are bound by no such rule. The lamprophyres especially tend to show a remarkable diversity in age. Near Mount Royal this has led to the drawing up of complicated sequences of intrusions. These sequences, however, are difficult to correlate from place to place, and it is doubtful whether they are of importance, even locally (see Figures 6, 7 and 8).

Minerals of the Monteregian Rocks

Petrologically, the outstanding feature of the Monteregian rocks is that certain of the minerals they contain differ from the corresponding minerals found in most igneous rocks in being, chemically, of alkaline type. The significant minerals are the pyroxenes and amphiboles. The amphiboles, particularly, contribute much to the 'alkaline' character of the rocks of this petrographical province. Also, some of the rocks contain nepheline.

Olivine is found in the most basic, that is the darker-coloured, rocks. Most commonly, it would seem, it is an optically negative (high-iron) variety, such as occurs in force in the ultra-basic rock called 'montrealite' and in certain of the dark dyke rocks. The alnoite dyke at Sainte-Anne-de-Bellevue is distinctive by virtue of the red alteration of large olivine crystals. A similar alteration is found in some of the olivine gabbro on Mount Royal. The light-coloured rocks of the area contain no olivine.

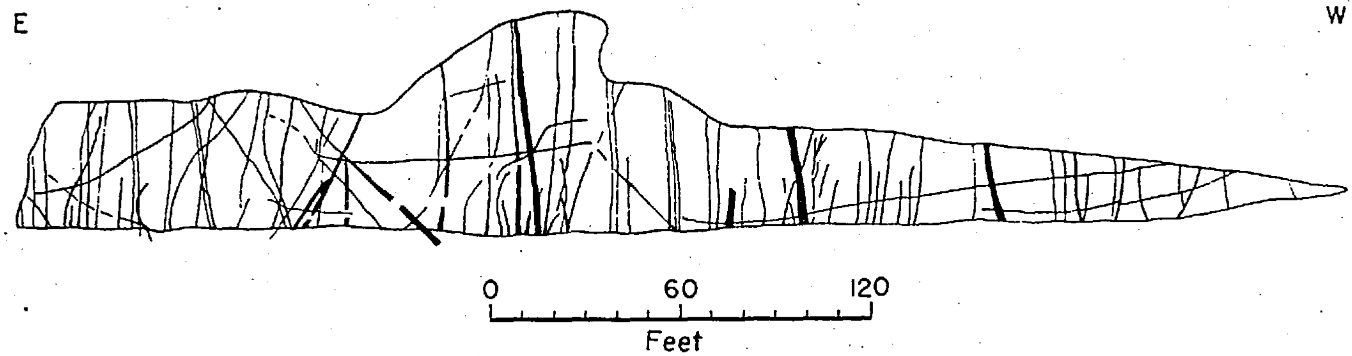


Figure - 6 Sketch of quarry wall behind Côte des Neiges reservoir, showing ninety dykes and sills in a cliff about 400 feet long. The country rock is Trenton limestone, approximately horizontal. (After Davis, unpublished manuscript, 1937).

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Pyroxene is much more abundant than olivine, and several varieties can be recognized. In the gabbro, the cores of the pyroxene crystals are slightly mauve in tint in thin section; this is indicative of titanium. The next enveloping shell is colourless augite, and this may be surrounded by a rim of greenish ægirine-augite. Aegirine-augite is more abundant in the syenite than in the gabbroic rocks and is commonly surrounded by ægirine itself. In the more basic dyke rocks, the pyroxene may form short prismatic phenocrysts. In the more acidic rocks, the phenocrysts of pyroxene (ægirine) tend to be needle-like.

The amphiboles belong, in part at least, to the hastingsite group. Adams and Harrington (1896) first recognized a peculiar green amphibole in a thin section of syenite from Hastings county, Ontario. Analysis showed that the mineral has much less silica in its composition than most amphiboles. In the Mount Royal rocks, the green (hastingsite) amphibole can be seen in many thin sections to form a rim on seal-brown amphibole, which also is of the hastingsite type. The low silica content of the hastingsite is responsible for the nepheline that certain computations, based on the chemical composition of the rocks, suggest should be present. In most amphiboles, the ratio of the oxygen of the silica to the oxygen of the bases is only slightly less than two to one. In hastingsite, on the other hand, it is near one to one and it is slightly lower than this in the seal-brown amphiboles. If, therefore, in the computation of the mineralogical make-up of a gabbro from the chemical analysis, the full amount of silica is assigned to the bases forming the amphibole, not enough is left to form feldspar, and the feldspathoid, nepheline, appears in the resulting 'norm' of the rock. In most of the gabbros of the Montreal area, no nepheline is present, but computations from analyses show 'normative' nepheline. So it has come about that some of the basic rocks of Mount Royal have been called 'essexite' or 'theralite' because of their chemical similarity to—and despite their lack of mineralogical identity with—these rocks which, by definition, are rocks of gabbroic composition which contain nepheline as an essential constituent. Since the Mount Royal rocks do not conform to this definition, the more general term 'gabbro' is preferable. The seal-brown amphiboles form phenocrysts in some of the dark satellitic rocks, and the green varieties are found in the syenite and the light-coloured satellitic rocks.

Biotite, or black mica, is found in many varieties of the Mount Royal rocks. The large phenocrysts of biotite in the satellitic rock alnoite are noteworthy. In other rocks, biotite is generally less conspicuous but may be seen in most thin sections.

The most abundant light constituent of the rocks is feldspar, and it is commonly plagioclase. This plagioclase generally shows a difference in composition from core to rim and the difference may be extreme, *e.g.*, from Ab_9An_{91} to $Ab_{92}An_8$ in one thin section examined. In general, however, the range is much less than this. Zoning is nevertheless conspicuous, and makes the estimation of average composition difficult. In the gabbro, labradorite or andesine is the average; in the syenitic types, albite-oligoclase is the rule. Microcline or orthoclase is not common. Most of the potash shown in analyses of the feldspars is in solid solution in plagioclase. Potash-bearing albite (probably cryptoperthite) rims the plagioclase crystals in some syenites. Plagioclase does not form phenocrysts in the lamprophyres, but in some of the light-coloured satellitic rocks phenocrysts of albite-oligoclase are found. Generally, the phenocrysts are tabular.

Nepheline is rare in the gabbros but is present in such abundance in some of the syenitic rocks that nepheline-syenite is an appropriate name for them. This mineral is not easily identified megascopically, but may be seen as irregular grains in thin sections of the syenites. It appears as phenocrysts in some of the light-coloured rocks. Nosean, blue sodalite, and hauynite also occur in the syenites. Sodalite has been noted in gabbro, but it may have been introduced. Analcite is widely distributed. It forms part of the paste in monchiquites and is abundant in some of the light-coloured dykes. Quartz is found in only a few of the Mount Royal rocks. A few pegmatitic rocks show druses with quartz crystals, and this is true also of some of the lamprophyres. Melilite is present in some of the basic dykes, notably alnoite. Accessory minerals include titanite, apatite, pyrite, pyrrhotite, perovskite, melanite, and zircon. Minerals of the lavenite, astrophyllite, eucolite, and eudyalite types have been reported from Mount Royal; if they are anywhere present they are not conspicuous.

Rock Types

"The Monteregian Hills form an exceptionally distinct and well marked petrographical province, being composed of consanguineous rocks of very interesting and rather unusual type. These are characterized by a high content of alkali and in the main intrusion of almost every mountain two distinct types are found associated with one another, representing the products of the differentiation of the original magma" (Adams, 1913, p. 33). These two types are described below as gabbro and nepheline syenite.

Gabbro

The dark-coloured plutonic rock which occupies nine-tenths of the area of the igneous rock of Mount Royal has for decades been called 'essexite', a name given to a somewhat similar rock found in Essex county, Massachusetts. There is, however, an insuperable obstacle to the correct usage of this name for the local dark rock. Essexite, by definition, must contain modal nepheline. In the Massachusetts rock, the excess of alkalies has combined with alumina and silica to form nepheline, whereas in the local rock the excess of the alkalies has been absorbed in the making of an alkaline amphibole, hastingsite, leaving no alkalies free for the production of nepheline. If a reconstruction of the mineralogy of the local gabbro be attempted from its known chemical composition, and if we assume that no unusual minerals would be produced during the crystallization, then there would be some hypothetical, or 'normative', nepheline left over.

Both mineralogically and texturally this rock shows a very wide range of characteristics. Mineralogically it consists very largely of pyroxene and amphibole, with a lesser amount of plagioclase. Of the plagioclase, far more is labradorite than andesine, so that on the basis of the feldspar as a criterion for classification, the rock would be definitely a gabbro. In a few exposures, plagioclase makes up nearly one-half of the material of the rock, which is then light-coloured (leucocratic). Almost everywhere, however, plagioclase is so subordinate that the hornblende-augite (or amphibole-pyroxene) combination results in a very dark grey to almost black (melanocratic) rock. The only accessory minerals commonly seen in hand specimens are olivine and biotite, but most thin sections of the rocks are found to contain also sodalite, apatite, magnetite, pyrite, and titanite. Nepheline is rarely seen in the rock itself and has been reported in very few thin sections. Some varieties of this nearly black 'gabbro' appear to be made up almost entirely of amphibole, others of pyroxene.

In texture and structure there is great diversity. The normal rock has a coarse-grained granitic texture with the crystals from one-eighth to one-quarter of an inch long. Fine-grained types are relatively rare. Pegmatitic varieties in which, for example, the rock is made up of crystals of pyroxene up to 2 inches in length, can be found in several places. An example of this can be seen within the hair-pin turn on Belvedere road (running south from Côte des Neiges, close to its summit) where seams of a hornblende-rich facies traverse the main gabbro mass, with crystals of hornblende several inches long aligned at right angles to the direction of the seam. For the most part, the texture is even granular. Very rarely is it porphyritic, but in several localities, as the vicinity of the Cross and in the northwest corner of the Côte des Neiges cemetery, a very marked flow or alignment structure is apparent. Although in all cases the layering of the minerals is vertical, the strike of this structure is irregular. Another variation, which can be seen in almost every exposure, is the tendency for dykelets of a light-coloured gabbro to traverse the darker and normal rock in all directions, reducing it to a breccia. These dykelets are so numerous that Stansfield (unpublished manuscript) mapped the brecciated 'essexite' as a separate unit; however, it is not considered advisable to make such a separation in this report.

As a result of the diversities mentioned above, it is rare to find an exposure presenting uniform characteristics. Hence it was deemed sufficient here to include all of the variations together under the name gabbro and to leave further elaboration to detailed field studies. Such studies have been in progress for many years at McGill University, where restricted areas of Mount Royal have been worked over in detail by graduate students. The results of these studies are to be found in the theses presented for the M.Sc. or Ph.D. degrees at McGill. I am indebted to many of these for petrographic and other details (see Bibliography). Bancroft and Howard (1923) gave, in their paper on the essexites of Mount Royal, a detailed description of the mineralogical and petrographical characteristics of this rock.

Distribution

Gabbro is the predominant rock over the entire area of Mount Royal save in the northwest portion, where, in the grounds of the University of Montreal, parts of the Côte des Neiges and Mount Royal cemeteries, and adjacent areas, it occurs in roughly equal amount with nepheline syenite. Although, in some parts of the mountain, exposures are so abundant that there is little uncertainty as to the position of the geological boundaries, elsewhere, as in the Côte des Neiges cemetery and the parts around Beaver lake, exposures are so sparse that it is difficult to fix the boundaries. The best localities where one may see and study the gabbro are: first, at and near the summit of Mount Royal, particularly between the Lookout and the Cross, and on both sides of the cut leading to the south portal of the Montreal Tramways tunnel; second, at the hair-pin turn on Belvedere road near the Côte des Neiges reservoir, and also opposite the entrance to the Côte des Neiges cemetery; third, the exposures along the northwest boundary of the Côte des Neiges cemetery. Practically all varieties of the gabbro may be seen in these localities.

Nepheline Syenite

Besides the gabbro, only one other rock type occurs in any great mass in Mount Royal. This is a light grey syenite in some parts of which nepheline is so abundant as to be visible in the hand specimen. In some outcrops it appears in grains 2 mm. in diameter. Although dykes of this rock are common everywhere, it is only on the northwest side of the mountain that large and irregular masses occur.

The nepheline syenite is remarkably uniform in most respects. It is nearly everywhere a light to medium grey rock, with medium, even grain. In but few places is it porphyritic. Flow structure is not marked. Mineralogically, the rock consists principally of plagioclase (which may be rimmed with potash feldspar) amphibole, pyroxene, and nepheline. Additional minerals megascopically visible in many exposures are biotite, sodalite, nosean, garnet, titanite, and perovskite. Apatite, zircon, and fluorite are to be found in most thin sections.

Finley, in his paper on the nepheline syenites of Mount Royal (1930), gave a good general review of the subject, together with a great deal of new information gained during the drilling of the Canadian National Railways tunnel.

The nepheline syenite occurs as irregular masses in the grounds of the University of Montreal, in the Corporation quarry, Montreal, and in a few nearby places. Elsewhere, as in the vicinity of Côte des Neiges from the reservoir to Queen Mary road, and also in the Côte des Neiges and Mount Royal cemeteries, it occurs in dyke-like bodies, up to ten feet across. Where the relationship can be determined, the nepheline syenite is seen to be a later intrusive than the gabbro.

One detail of occurrence worth mentioning is that in almost all outcrops of the syenite there may be found dyke-like bodies of a coarser, in places pegmatitic, variety of the same rock. Usually, the boundaries between the pegmatite and the syenite are not sharp. The grain is so coarse that minerals which, in the normal syenite, can be seen only under magnification are plainly visible in the hand specimen. Such coarsely crystalline syenite in, for instance, the Corporation quarry, Montreal, has proved a rich hunting ground for minerals, and Harrington has given analyses of many of these. Among others, the following may be found: blue sodalite, greenish nepheline, black ægerine, violet fluorite, and white feldspar.

Satellitic Rock Bodies

On Ile Jésus and on the mainland to the north and south of the island of Montreal, dykes and sills are great rarities. They are infrequent also at the western and northern end of the island of Montreal. There are more of these satellitic bodies at Saint-Vincent-de-Paul than in the surrounding countryside, and the same may be said of Montreal East, where they are particularly numerous in the old and new quarries of the Canada Cement Company. In the central part of the Island, dykes and sills are common, both in the igneous rocks of the mountain and in the surrounding sedimentary rock.

Near Caughnawaga (Lachine map-area), a thick sill cuts the limestone half a mile above the bridge on the outskirts of the village. It is possible that this sill crosses the Saint-Lawrence and is to be seen along the shore at Highlands and at the Lachine Locks. Six miles south-southeast, in the quarry near Saint-Isidore, owned by Mrs. Charron, there is a basic dyke. The shale quarries and nearby outcrops at Delson show a few dykes and sills. A basic sill occurs in the eastern section of the map-area south of the Saint-Lawrence at the mouth of La Tortue river, possibly part of a ten-foot sill to be seen on Ile à Boquet and on the neighbouring mainland. This sill probably passes through Ile au Diable and then across the river, making the Lachine rapids, and it is seen again within the Utica shale at Bronx Park, on the other side of the river.

As already noted, dykes and sills are rare in the western end of the island of Montreal. There are two dykes in the Fuger and Smith quarry, Pointe Claire, one on the south bank of rivière des Prairies immediately below the bridge to Ile Bizard, a sill on the northeast shore of Ile Bizard, a dyke in the Paiement quarry at Sainte-Geneviève, two in fields just east of Sainte-Geneviève station, and no more until one approaches within 5 miles of Mount Royal. In the Town of Mount Royal, and in Cartierville and Bordeaux, dykes and sills are more common. In the immediate vicinity of the igneous core of Mount Royal there is a veritable network of these satellitic bodies (Plates X-B to XIII). Nearly every exposure shows a dyke or a sill. This condition continues northward as far as the Canada Cement Company's quarry at Montreal East, beyond which locality igneous rocks are relatively rare.

Dykes

The igneous rocks of Mount Royal and the immediately surrounding sedimentary rocks are criss-crossed by a host of dykes and sills of an apparently endless variety. For every dyke or sill known and plotted, probably ten lie beneath the drift. In some places, they occur in such profusion that they can be recorded only on a large scale map (see Figures 6, 7, and 8). As one goes outward from the mountain, they become less and less common. At first sight there appears to be no possibility of reducing these thousands, probably tens of thousands, of dykes and sills to order with respect to their attitude, their composition, or their age relationships. As far as their attitude is concerned we can say little more than that, in general, the majority of the dykes radiate from the periphery of the intrusives. Rarely are they exposed for more than a few tens, or one or two hundreds, of feet. The greatest length observed is that of a light-coloured dyke on Fletcher's Field, which can be followed more or less interruptedly for about half a mile. Most of the dykes are from one to two feet wide, from which they range downward to paper thinness and upward to a maximum of twelve feet (Plates X-B to XIII).

Composition of Dykes

In 1863, long before the microscopical examination of thin sections of rocks was relied upon for their identification, Logan, depending largely upon the chemical investigations of T. Sterry Hunt, divided the dyke rocks of the vicinity of Mount Royal into trachytes and dolerites, a classification roughly corresponding to the light- and the dark-coloured rocks — the syenites and gabbros of this report. The earliest investigation of the satellitic rocks around Montreal was reported in 1878 by B.J. Harrington, who described the results of his examination of some of the local 'diorite' dykes after they had been "sliced and examined with the microscope" (p. 43G). In 1896, F.D. Adams was appointed to the McGill staff. His accomplishments in the field of petrography gave an impetus to the study of these rocks that is still a part of the McGill tradition.

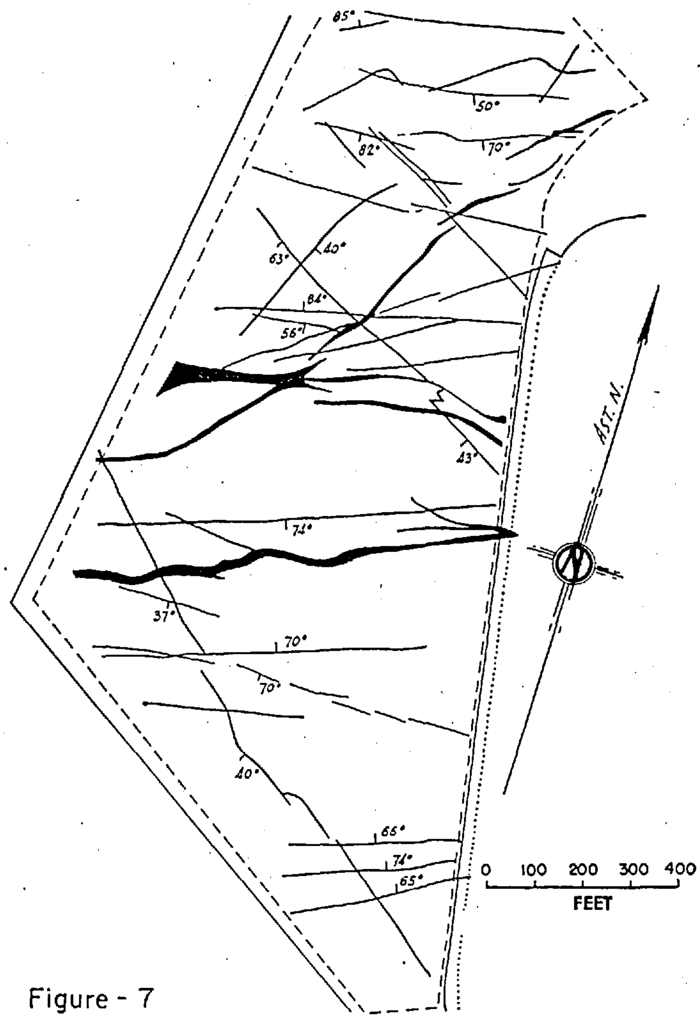

Figure - 7

Plan of the excavation of part of the municipal reservoir, McTavish street and Pine Avenue, Montreal, showing a number of nearly parallel dykes cutting Trenton limestone and striking approximately at right angles to the margin of the Mount Royal intrusive.

(After Allan, unpublished manuscript, 1908).

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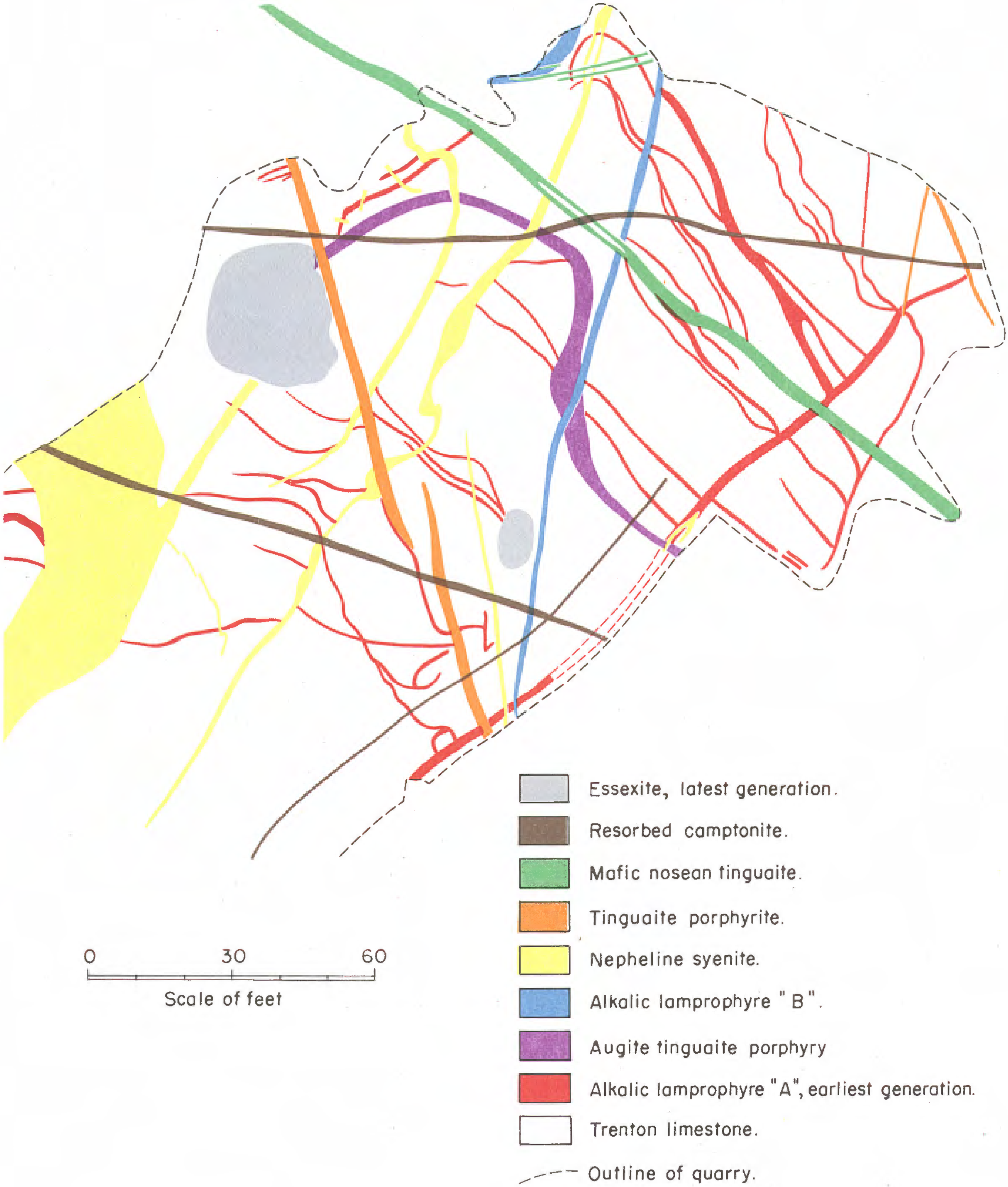


Figure-8 Plan of northeastern end of Corporation quarry, MONTREAL (near Bellingham Road and Maplewood Avenue), to show the great number of dykes and dyke generations. (After Halet, unpublished manuscript, 1932).

One of the basic dykes near Montreal has received particular attention because of the rarity of its rock type. This was first found near Alño island, Sweden, and thence received its name 'alnoite'. It is a striking-looking rock in a hand specimen. Large brown or black crystals of biotite, commonly with bleached edges, are set in a matrix that may contain pyroxene and olivine. In the dyke at Sainte-Anne-de-Bellevue, the olivine is red. Melilite, one of the diagnostic minerals of an alnoite, occurs in the matrix. This rock forms part of the matrix of the breccias of Sainte-Dorothée, Ile Bizard, and Beaconsfield. The first exposure of alnoite recorded from the Montreal area was a dyke, 18 inches wide, cutting the Potsdam sandstone in the bed of the Ottawa river at Sainte-Anne-de-Bellevue. A second dyke has been recorded from the bed of the Saint-Lawrence river at Pointe Saint-Charles (Montreal, just south of the west-end of the Victoria bridge), at a time of extremely low water. The basic sill at Sainte-Monique shows some similarities to alnoite in composition. Four other occurrences of alnoite have come to light during the present work. First, there is an irregular dyke, ranging from six to fifteen inches in width, which traverses the Robillard quarry in the Potsdam sandstone on Ile Perrot, with a strike that makes it probable that it is the continuation of the first alnoite dyke described by Adams. Second, a thin, irregular dyke of alnoite, nowhere more than 6 inches wide, with large biotite crystals, occurs in the Fuger and Smith quarry, Pointe Claire. Third, a dyke ranging from one to two feet in width cuts the Potsdam sandstone of the Monpetit quarry at Melocheville, near Beauharnois. Fourth, there is a six-inch dyke of this rock cutting the Potsdam sandstone of Bruneau's quarry, Cascades Point.

Sills

Sills are nowhere as numerous as dykes, though they may be found in many places intruding the limestone and shale in the immediate vicinity of Mount Royal (Plates VIII-A, VIII-B, XIII). Strangely enough, the thickest sills lie farthest from the mountain. Around the periphery of the igneous body there are dozens of sills not more than two feet thick, and probably hundreds a foot or less thick. Elsewhere some very thick sills are known. Three of these deserve especial mention and are described below.

Masson Street Sill

One of the most extensive sills in the immediate vicinity of Montreal is a body of a light-coloured satellitic rock (tinguaite) which extends northward by discontinuous exposures from Saint-Joseph boulevard at Papineau avenue, passing to the west of the Angus Shops, as far as the grounds of the Botanical Gardens at Pie IX and Rosemount boulevards (Plates VIII-A, VIII-B). It is thus to be seen over a distance of about two miles. Its best exposures today are in a series of quarries southeast of Masson street. It is nowhere being quarried at the present time, and the quarries developed in it are due, in the normal course of events, to be filled in, and the other exposures will, with the growth of the city, be built over. Unless the Botanical Gardens' quarry is preserved, there will soon cease to be any exposures of this extensive body.

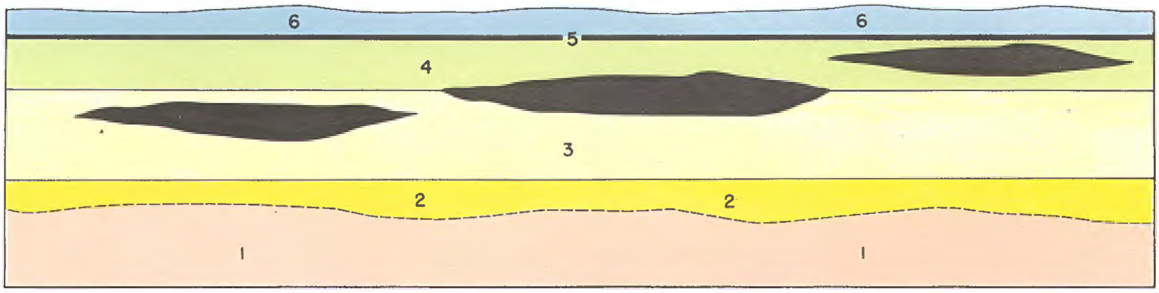
In a hand specimen, the rock can be seen to consist of a fine-grained ground mass, through which are distributed phenocrysts of pyroxene, nepheline, haüyne, and orthoclase. Logan (1863, p. 144) noted this "intercalated mass of trap" and said that it could be traced for five miles northward. Either the northerly outcrops have been built over or otherwise covered up in the meantime, or possibly some of the petrographically similar dykes in the vicinity of Sherbrooke and Dickson streets were taken to be parts of the same body. Both upper and lower contacts of the sill can be seen in many places.

Basic Sill at Sainte-Monique

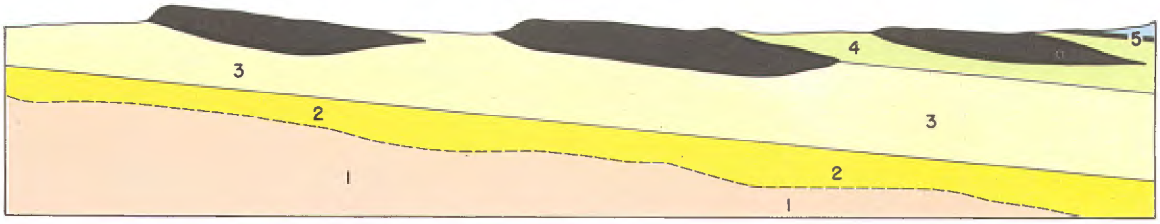
For a mile or more north and south of the village of Sainte-Monique (western margin of Laval map-sheet), outcrops of a basic sill occur upon the summits of pratically every hillock. It is impossible, on account of the lack of exposure of upper and lower contacts, to give any measurements of the thickness of this sill. My impression is that it is between ten and twenty feet thick. The igneous rock concerned has been described in detail by Howard (1922, pp. 61-68), who finds two textural variants, one fine-grained, the other and principal type coarse-grained and porphyritic. Howard noted the horizontal distribution of these two types and came to the obvious conclusion that "as all these exposures cover a comparatively small area, it is believed that they represent portions of a sheet which originally covered the area within whose limits the present outcrops appear".

Sainte-Dorothée Sill

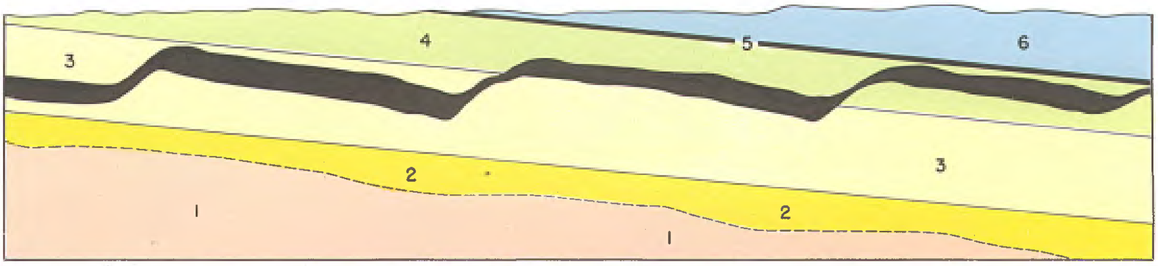
At several localities, basic sills occur of such thickness and other characteristics as to warrant the supposition that they form parts of a once continuous sill body. The westernmost of these can be seen about two miles due west of Saint-Eustache (eastern end of lake of Two Mountains, Laval map-area) where it is underlain by Beekmantown dolomite. The most extensive exposure is one mile north and east of Sainte-Dorothée (3½ miles east of Saint-Eustache) whence the sill derives its name (Plate XIII). This rock is also underlain by Beekmantown dolomite. A third exposure of the same sort of rock occurs somewhat more than a mile northeast of Petite Côte Sainte-Rose (1½ miles southeast of Sainte-Rose), and a mile east of Sainte-Rose a railway cut exposes basic rock, which can also be seen in the fields half a mile to the south. No associated sedimentary rock is exposed in the two last-named localities. Two miles northeast of Saint-Vincent-de-Paul, wide areas of the same type of rock occur intercalated between beds of the Leray formation, and about half a mile to the west of there the same kind of rock is to be found



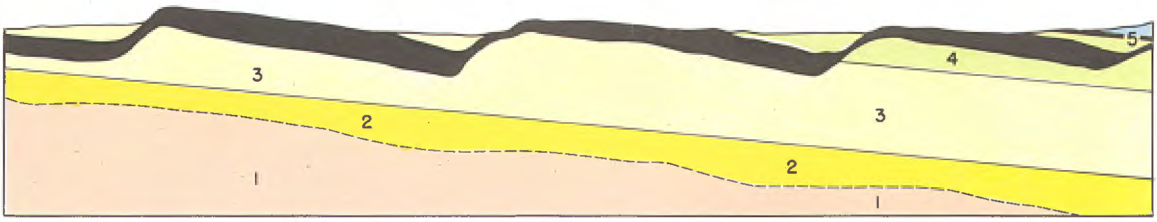
(A) Intrusion of separate sills at different horizons.



(A') Tilting of region subsequent to (A) results in the exposure, on the present erosion surface, of sill rocks in different horizons.



(B) Intrusion of igneous rocks after tilting had taken place, the sills being intruded at approximately the same depth below the surface at the time of intrusion.



(B') Subsequent erosion would result in a series of exposures not essentially different from those of (A').

- Igneous rocks intrusions
- 6 Trenton limestone
- 5 Black River Group
- 4 Chazy limestone
- 3 Beekmantown dolomite
- 2 Potsdam sandstone
- 1 Precambrian

Figure-9 Diagrams illustrating two possible modes of origin of the outcrops of basic rocks on and near Ile Jesus. All sections are represented as if cut parallel to, and close to, the plane of the feeder dyke.

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in sill relation to Chazy limestone above and below. Lastly, opposite Rivière des Prairies at the ruins of the old mill, a sill of similar rock is responsible for the rapids at that point. Of the exposures here correlated, those at Sainte-Dorothée, Sainte-Rose, and Rivière des Prairies were mapped by Howard (1922), who, however, described only the Sainte-Dorothée outcrop.

The general similarity of appearance and habit of the intrusive rock in these several exposures suggests that all may be part of one rock body. Such a correlation receives further support from the fact that the rock exposed at a number of the localities mentioned is vesicular or amygdaloidal, structures which are quite uncommon in the dark-coloured intrusive rocks elsewhere in the area. At the best exposure, Laurin's quarry, half a mile east of Sainte-Dorothée (Plate XIII), the following section was measured about in the middle of the quarry wall. It is presented only as an illustration of the variation in petrographic expression from top to bottom of the sill. Sections taken elsewhere would show differences in thickness and in rock types. Howard (1922) gave a petrographic description of the rock. None of these rocks have been examined in thin section during the course of this work.

Aphanitic to very fine crystalline rock, almost a glass in upper part	1 foot
Highly vesicular, the vesicles round, tubular, and irregular shapes, now filled with a mixture of hornblende, plagioclase, and other minerals	4 feet
Dark, finely crystalline rock, hornblende phenocrysts common	6 "
Similar to above but with an abundance of large pyroxene phenocrysts up to half an inch across	2 "
Finely crystalline rock, few phenocrysts of hornblende and augite	4 "
Very fine-grained rock with ill-defined crystals half an inch long and about two inches apart seen only on weathered surface	2 "
Baked Beekmantown dolomite	Base

The thickness, wherever it could be measured in the several localities mentioned, does not exceed nineteen feet. Prominent vertical joints can be seen in nearly all exposures. With the exception of the railway cut near Sainte-Rose, the present exposures are bounded on one side at least by cliffs ranging up to twenty feet in height. Nowhere is there any positive corroborative indication that these cliffs are the result either of the weathering back of a sill of more extensive distribution at the present level, or of faulting, though, as shown below, the systematic variation in age of the host rock from west to east favours the former view.

If we are justified in our assumption that these exposures are parts of a once continuous sill, several interesting conclusions follow. First, the succession, as one goes from west to east, of a higher and higher horizon for the host rock is far too regular a progression to be a mere coincidence. This relationship is what would follow were an intrusive sheet to transect beds which are stratigraphically younger from west to east. Such occurrences are not uncommon, one of the best known examples being the body known as the Whin sill, in northern England. In the case of the local rock, however, when we try to reconstruct the original sill we are first constrained to decide whether the stratification was horizontal at the time of intrusion or whether the igneous rock was emplaced after tilting had deformed the beds (see Figure 9). Unfortunately, there is nothing in the outcrops themselves to help one decide between these two alternatives. It is, however, reasonably certain that the deformation of the sediments long antedated the intrusion of the igneous rocks of the Monteregian hills. Hence the second alternative is the preferred one.

One of the most puzzling problems that this presumably once continuous sill presents is that, despite its great linear extent, it is not known north or south of the line of exposures discussed above. It is not found in the core of the Mallet test hole at Sainte-Thérèse, nor can it be correlated with the Saint-Vincent-de-Paul or Masson Street sills.

Igneous and Associated Breccias

At several places within the Laval-Lachine map-areas there are outcrops of breccias associated, or presumably associated, in origin with the Monteregian igneous activity (see Figure 10). Several varieties of breccias may be recognized. Some of them outcrop over a considerable area, as for example, at Sainte-Hélène island, where breccia occupies an area of one-eighth of a square mile; in others, more limited in extent, the sedimentary rocks, or earlier igneous rocks, have been freely cut by intrusions. The latter, or 'shatter-zone' type of breccia exhibits all gradations from xenolith-crowded intrusives to masses of sedimentary rock fragments with little or no igneous rock. Even thin dykes and sills may be margined by a brecciated border zone. This type of breccia is invariably composed of angular fragments of the rock adjacent to the intrusive at the present surface; very rarely is there a mixture of rock types. One of the best localities where this kind of breccia can be seen is at Mount Royal Heights, where shatter breccias associated with several dykes of different ages can be seen.

The other group of breccias, typified by the exposures on Sainte-Hélène and Round islands, consists of many angular or rounded fragments of a variety of rock formations, both the rounding and the variety suggesting that considerable movement was involved in bringing the fragments to their present position. This group appears to be the result of gas explosions progressing upward from a magmatic chamber and shattering and loosening the rock formations through which their passageways were drilled. It is supposed that those breccias with a great variety of rock types, and in which the rock fragments are well rounded, were formed in a diatreme which reached or nearly reached the surface, whereas those with a limited variety of rock fragments and those mostly angular, as in the breccia near Cascades point, are close to the top of abortive diatremes which progressed no farther upward than their present horizon. Hence they would show little movement or rounding of the fragments.

If a classification of these breccias could be satisfactorily completed it would seem that a separation should be made between those breccias belonging to the shatter-zone type, including breccias due to stoping, and those due to diatreme formation. The occurrences to be described may be grouped as follows:

A.—Shatter-zone Breccias:
- 1.—Mount Royal Heights—both camptonite and syenite varieties
- 2.—Abord à Plouffe West
- 3.—Westmount Mountain

B.—Diatreme Breccias:
- 4.—Breccias in the Precambrian near Saint-Joseph-du-Lac
- 5.—Breccias in the Potsdam near Cascades point
- 6.—Ile Bizard
- 7.—Sainte-Dorothée
- 8.—Sainte-Hélène Island

C.—Breccias of Uncertain Relationships
- 9.—Beaconsfield
- 10.—Utica breccia of Mount Royal
- 11.—Breccias in the Corporation quarry, Montreal

A.—Shatter-zone Breccias

1.—Mount Royal Heights. Situated to the west of Mount Royal, partly in Outremont, partly in Mount Royal ward, Montreal, there is an irregular area of hummocky ground, approximately half a mile across once replete with outcrops but at present being rapidly built over. Part of this area is occupied by Trenton limestone, and part by a variety of breccias of which the most important is one with a camptonitic matrix. The contrast between the black matrix and the light grey limestone inclusions results in a rock striking in appearance. This is the so-called 'Outremont breccia'.

Grimes-Graeme (unpublished manuscript) described the formation of the 'Outremont breccia' as follows: "Following the essexite, after the latter had consolidated, a very fluid camptonitic magma was irrupted into the rocks of the area to form the widespread, striking-looking breccia which underlies so much of this suburb. In places, the injection of this magma shattered the limestone and disrupted the bedding with the result that blocks of varying size and orientation are to be found held in the dark camptonite matrix". The chief characteristics of this breccia are the initial complete fragmentation of the limestone, and the extreme fluidity of the magma, allowing it to penetrate every available crevice in the limestone. Probably the breccia so widely distributed over Mount Royal Heights belongs to this same period, although there is no igneous matrix to much of it.

The syenitic breccia is far less widespread than the camptonite type, but here and there in some outcrops of nepheline syenite xenoliths are sufficiently numerous to make the term breccia not altogether out of place. Thus on Bates road, 500 feet southwest of Rockland avenue, there is an old quarry in which pink nepheline syenite bearing a large number of pebble-like masses of quartzite, presumably from the Potsdam formation, is exposed. Elsewhere in this locality the syenite is medium grey in colour and contains xenoliths not only of quartzite but also of limestone, presumably Trenton. In the Canadian National railway tunnel, which passes directly beneath this area, Pelletier (unpublished manuscript) noted that the breccia contains a greater number of the quartzite, and a smaller number of the limestone, xenoliths than are to be seen in outcrops at the surface, exactly what one would expect in the case of an ascending magma stoping off blocks of the formations through which it passed.

2.—Abord-à-Plouffe West. A somewhat different type of breccia can be seen on the property of Jos. Berthiaume, Abord-à-Plouffe Ouest. There the breccia contains a minimum of fragments of other rocks and the matrix is a camptonite replete with large hornblende phenocrysts.

3.—Westmount Mountain. On the east end of Westmount mountain, between the junctions of Sunnyside avenue and Belvedere road, and of Belvedere road and Summit avenue, there are exposures of a breccia with a syenitic matrix. Harvie (1910, p. 268) mentioned other than nepheline syenite dykes which have caused brecciation here. The exposure is well seen in the west part of Littles' quarry, and along the north side of Sunnyside avenue, to the west of the quarry.

Farther to the north and beyond the declivity which bounds Westmount mountain on the north, there is, just behind the Côte des Neiges reservoir, an excavation known as the Westmount quarry. Here, within a mass of hornfels let down by faulting into the Trenton limestone, there is an intrusion of a dark nepheline syenite which in places contains fragments of granite, quartzite, limestone, and gabbro to an amount in excess of the matrix. Hence one may conclude that at the time of the intrusion of nepheline syenite a north-south zone of weakness developed from Littles' quarry southwestward to Viewmount avenue, and that this weak zone was repeatedly shattered as successive intrusives forced their way upward.

B.—Diatreme Breccias

4.—Breccias in the Precambrian near Saint-Joseph-du-Lac. Just within the limits of the Lachine sheet, and in its northwest corner, there is a small outcrop of granite. In one or two places this granite is brecciated, but no definite boundaries to the brecciated zones could be made out. Except for a few fragments of crystalline limestones, nothing but igneous rocks of various acidic types are found among the fragments. Farther north, just west of the boundary of the Laval sheet and on the north side of highway No. 29, there are other breccias associated with the Oka intrusives (Harvie, 1910; Grimes-Graeme, unpublished manuscript). In the case of the exposure close to the Laval sheet boundary, the breccia is essentially like that of Sainte-Hélène island, though the fragments appear to be exclusively of Precambrian and Potsdam rocks.

5.—*Breccias in the Potsdam Sandstone near Cascades point.* At three localities in the western part of the Lachine sheet there are breccias within the Potsdam sandstone formation composed exclusively of fragments of that formation. The most important of these is in the quarry at Cascades point. In the southeast corner of the quarry, there lies within the nearly horizontal Potsdam sandstone a rudely cylindrical mass of breccia composed of fragments of Potsdam sandstone jumbled together with no semblance of order. The blocks range in size up to six feet across, and show no sign of having been rounded. The quarry wall has cut clear through the middle of this breccia mass, so that one semi-circular half of it is now exposed on the quarry floor and the other half on the flat above. The breccia boundaries on the quarry wall are obscured by fallen blocks, but in all probability they are nearly vertical. The mass has a diameter of 60 feet.

Three other such breccias occur within about two miles. One, along the shore about a mile west of Melocheville, a second in the Monpetit quarry at Melocheville, and a third on the north shore of Split Rock rapids. In the first mentioned locality, the breccia, composed of nothing but blocks of Potsdam sandstone, occupies an area 25 feet long and 6 feet wide, on all sides of which the Potsdam sandstone is undisturbed. At the Split Rock locality, the relationships are obscure, but breccia occurs along the shore for 150 feet, with blocks, all of Potsdam sandstone, up to 3 feet in diameter. In the Monpetit quarry, the conditions are essentially those seen at the Cascades Point quarry. Unfortunately, however, the floor of the quarry is now covered with fallen blocks.

There is no trace of igneous rocks in these breccias, although an alnoite dyke occurs, apparently independently, in the quarry at Cascades Point, and also in the Monpetit quarry. Nevertheless, comparing them with the other known breccias, it seems probable that they are due to gas explosions consequent upon abortive attempts of some intrusive, presumably Monteregian, to burst its way through to the surface. The close proximity of these four occurrences is weakly corroborative evidence supporting this hypothesis.

6.—*Ile Bizard.* There are three outcrops of breccia on Ile Bizard, as shown in figure 10. The first of these is near the northwestern shore of the island where it forms a steep-sided hill (Plate XIV-A) between sixty and seventy feet in height, close to the road and less than half a mile southwest of the only road crossing that part of the island. Practically all of the hill consists of breccia, but on the southwest side there is a considerable mass of Chazy limestone which is probably in place though no doubt somewhat disturbed by the violence of the emplacement of the breccia. In this outcrop, the matrix, which has the composition of alnoite,

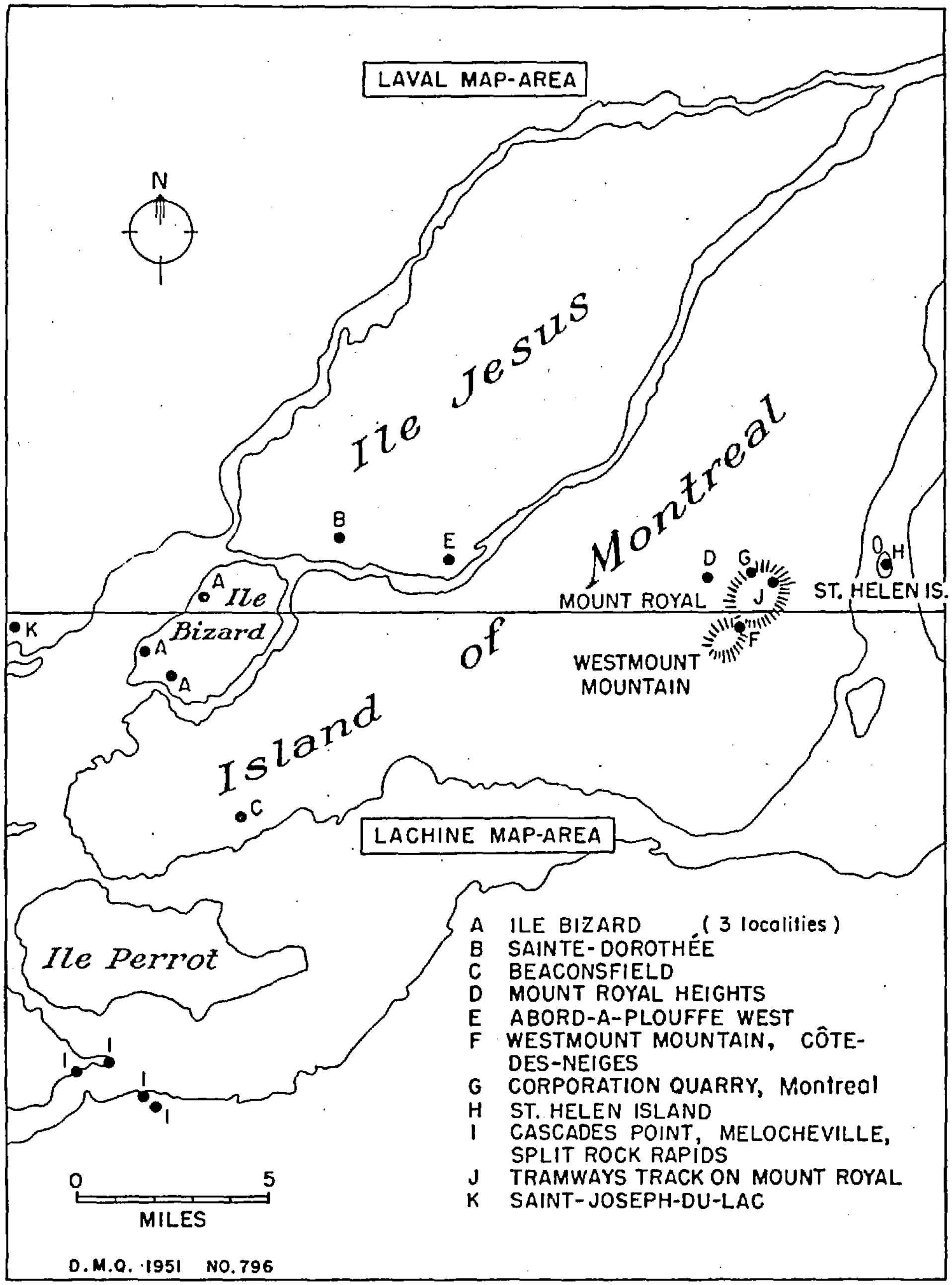

Figure 10 - Map showing outcrops of breccia, Laval-Lachine map-areas.

is not difficult to identify because of its tendency to weather brown. The greater part of the rock is made up of included angular fragments which are in many places almost exclusively sandstone, presumably belonging to the Potsdam formation. Most of them are surrounded by a thin discoloured zone, but it does not appear that this can be ascribed to baking. The fragments average, perhaps, one to two inches across, with the largest observed nearly two feet in one dimension. In addition to the prevalent quartzites there are fragments of the younger shales and limestones, and, to a very limited extent, of Precambrian rock. In his examination of thin sections, Grimes-Graeme (unpublished manuscript) found that limestone fragments are common in the matrix.

The second occurrence of breccia on Ile Bizard can be seen one-eighth of a mile due west of the sharp right-angle turn in the road. There are dozens of large blocks of breccia, similar to that described above, scattered about the surface of a pasture in the close vicinity of the fence which bounds the road that runs beside the summer cottages here. There is no definite exposure, and the possibility must be admitted that these field masses may be glacial boulders; yet the breccia is so consistently uniform as to warrant the belief that there is an outcrop below the soil.

The third of the Ile Bizard breccias occurs about midway along the road which passes in a northwest direction along the western shore of the island, just where the road rises sharply over a small hill. Cuts on both sides of the road have exposed fresh rock, and weathered exposures may be seen in the pastures to the west for five hundred feet. Two kinds of rock occur here. That in the southern two-thirds of both cuts is a breccia made up mostly of large blocks of limestone and dolomite with, here and there, small patches of a crystalline igneous matrix showing a fair abundance of pyroxene and biotite crystals. Careful search of the present exposures failed to show any Precambrian rock or any Potsdam sandstone, though Grimes-Graeme reported having seen both.

7.—*Sainte-Dorothée breccias.* Just north of Sainte-Dorothée, three small conical hills stand up in strong relief above the surrounding flat field. These hills contain outcrops of a tough, orange-weathering breccia. The fragments are all small, rarely over a foot in any dimension, and many can be recognized as belonging to the Precambrian, Potsdam, or Beekmantown formations. Dark shale fragments, which occur in great abundance, need not be interpreted as Utica or Lorraine, for both the Beekmantown and Chazy formations are well provided with black shale beds. Moreover, no limestone fragments identifiable as Chazy or Trenton were seen. Igneous matrix (alnoite) is present in which there are a great many large crystals of biotite.

8.—*Sainte-Hélène Island.* The largest and the best known of all of the local breccias is that which occupies all of Sainte-Hélène island, save for a small part of the southern end, and the adjacent ile Ronde. The breccia consists of a compact mass of predominantly angular fragments of Precambrian rock and of all of the sedimentary formations known hereabouts, together with pieces of two Devonian formations (see p. 82 and Plate X-A). The breccia body on Sainte-Hélène island is rudely elliptical in surface outcrop. Practically nothing is known of its vertical extent save that it ranges from the river level to the highest point on the island, a difference of 125 feet. It is presumed that its contact with Utica shale on the south end is essentially vertical. If so, the breccia would occupy a vertical pipe, starting somewhere in the Precambrian rocks below, and passing upward through all of the Palaeozoic beds in the local section. The fragments are usually fresh, but the matrix weathers orange-brown, resembling the colour of the weathered surface of some of the breccias of Ile Bizard and Sainte-Dorothée. Upon examination, however, the matrix fails to reveal any igneous material whatever. Microscopically, it consists of finely comminuted particles of the same kinds of rocks which make up the visible fragments. This breccia, and the problems connected with its origin, have recently been treated by Osborne and Grimes-Graeme (1936, p. 47), who wrote: "No matrix of the composition of camptonite or alnoite, such as form the mesostases of the other Monteregian breccias, can be found. Undoubtedly, some carbonates (ankerite), apatite, perovskite, analcite, and possibly some quartz, may be considered a part of the matrix, but there is no evidence to suspect they have originated by alteration of igneous material, and, indeed, the absence of metamorphism comparable to that exerted by the matrices of the other breccias is fairly conclusive evidence that they are not so derived". These authors ascribe the formation of the breccia pipe to the action of gas liberated explosively from a magma source below. "Such explosions would tend to comminute the rocks of the crust, and the zone of broken rock would continue to advance toward the surface. The emanations would act as a lubricant and the mass would be relatively 'quick', so that great mixing of fragments from different horizons would be possible, and the mutual interference of the fragments would result in some of them becoming rounded". The same writers conclude (1935, p. 48) that "as the breccia came closer to the surface, the pipe probably was able to widen because of the lower rock pressure and, at the same time, larger blocks of the surrounding rock were broken off. These were able to sink into the breccia to lower levels so that, at the present island level, one finds that the largest blocks are of the younger formations, and the nearby limestones, although represented, have not left large blocks at this level". Because the breccia is cut by basic dykes, it must antedate those dykes, but no direct correlation with the intrusives of Mount Royal is possible from observed data. All that can be said is that it was, in all probability, formed as a consequence of explosive activity connected with an intrusion of basic magma. Although the latter failed to reach the surface, the explosions were on such a scale that a diatreme was eventually punctured through to the surface.

C.—Breccias of Uncertain Relationships

9.—*Beaconsfield.* Logan (1863, p. 357) mentioned an exposure of conglomerate between Pointe Claire and Sainte-Anne-de-Bellevue. This has recently been uncovered in one of the cuts in the Beekmantown dolomite along the new road between Montreal and Sainte-Anne. It is a deeply weathered dyke with an alnoitic matrix, crowded in places with angular fragments of limestone and dolomite, presumably belonging to the Beekmantown formation.

10.—Utica Breccia of Mount Royal. A few hundred feet within the edge of the woods, on the east side of the Montreal Tramways track on Mount Royal, there is an exposure of brecciated Utica shale. Its only contact visible is with the Trenton limestone, which flanks it on the west side. The contact is one which is too irregular to be a fault, and there is no sign of intrusion. The breccia consists of jumbled blocks, ranging up to two feet across, exclusively of the Utica shale, which is here not metamorphosed to hornfels. The matrix is apparently finely comminuted Utica shale. There is little here to indicate that this breccia owes its origin to the same kind of intrusion which has apparently produced those previously described, save for a small patch of breccia of the Sainte-Hélène Island type that occurs in a 10-foot cliff of the Trenton limestone just at the edge of the woods, on the east side of the track.

11.—Breccias in the Corporation Quarry, Montreal. At least two generations of breccia can be seen in this quarry, situated on the north-western slope of Mount Royal near the intersection of Bellingham road and Mount Royal boulevard. A breccia containing fragments of gabbro, sandstone, shale, limestone, and dark dyke rocks set in what is probably a syenite matrix is exposed on the floor of the quarry. It is cut by a swarm of nepheline syenite dykes, thus indicating that the brecciation was due to disruption caused early in the nepheline syenite intrusion. Other breccias along the gabbro-syenite contact can be seen on the wall of the quarry.

The occurrences at White Horse rapids, Medical building of McGill University, Côte Saint-Paul, and Saint-Paul street, Montreal, listed by Harvie, are not here included, for no exposures of these are to be seen today.

Derivation of Rock Types

There is no opportunity here to enter with detail into the complex subject of the differentiation of the igneous rocks of the Monteregian Province, but some observations and deductions may be permitted. What are the facts involved? A major intrusion of basic rock (gabbro) was followed by a minor intrusion of less basic rock (nepheline syenite), and, if the minor episodes of dyking be disregarded, such a sequence agrees with that which is found in almost all regions of diverse intrusions. Hence, although the rock types are unusual, there is nothing unusual about their development.

The character of the ultimate magma from which all of the Monteregian intrusives have been derived is uncertain. Nevertheless, examination of the segregations of the intrusion forming Mount Royal (and this applies to the other Monteregian hills also) makes it reasonable to suggest that all the differentiates could be derived from a rock of the composition of the alkaline gabbro. The origin of the camptonites, which are directly dependent in composition on the plutonic rock with which they are associated, is still an unsolved problem of petrogenesis. Much the same uncertainty applies to the origin of the light-coloured satellitic rocks near Mount Royal. The examination of thin sections of these rocks with the petrographic microscope reveals that such satellitic rocks may not be greatly different from the completely plutonic rocks, except for the large content of H_2O and CO_2 and other fugitive constituents in their magmas. The prevailing unfresh appearance of the dykes, which contrasts with that of the plutonics, might be considered the principal corroborative evidence for such a view.

Form of Intrusion

Mount Royal has been described at various times as a stock, a plug, a volcanic neck, and a laccolith. The area of igneous rock of the mountain is irregularly elliptical in cross-section. Its long diameter (roughly northeast and southwest) is 1.88 miles; at right angles to this diameter, the maximum width is just short of a mile. The total area is 1.27 square miles. Those exposures in which the igneous rock and surrounding country rock can be seen together suggest a vertical contact, and the steeply rising slope inward from this contact corroborates this. The best evidence that the intrusion is pipe-like in form comes from the position of the two contacts as intersected by the Canadian National railway tunnel. These contacts were found to be almost exactly vertically beneath the corresponding contacts on the surface of the mountain (Bancroft and Howard, 1933, p. 13), showing that, at those two places at least, the contact surfaces are practically vertical for depth of a few hundred feet. It is interesting to note that, at an early date, it was held that Mount Royal was a laccolith, a view based upon the presence of a mass of recrystallized Trenton limestone near the summit. This 'evidence' vanished when it was shown that the limestone (Montreal Tramways station near end of Remembrance road) is part of a vertical screen, and is intersected by the Canadian National railway tunnel vertically beneath (Bancroft, 1923, p. 13).

Any consideration of the form of the intrusion must take account also of the rock through which it made its way. A reference to the table on p. 13 shows that it has penetrated the Potsdam, Beekmantown, Chazy, Black River, and Trenton groups to reach the level of the present summit. If we allow 300 feet for the Potsdam, this stratigraphic series to the top of the Trenton is 2,500 feet thick. Above the level of the summit there once lay the Utica, Lorraine, Richmond, and Queenston formations, whose thicknesses, either in this vicinity or in nearby parts of Quebec, have been recorded as 300, 2,357, 156, and 1,500 feet, respectively, a total of at least 6,813 feet (Clark, 1947). To this must be added the thickness of any Silurian beds that may have been present and also the thickness of the Helderberg and Oriskany limestones whose remnants are preserved on Sainte-Hélène island. It seems well within the bounds of probability that the latter alone were at least 500 feet thick, so that, eliminating for the present consideration of possible Silurian beds, the sedimentary sequence overlying the Precambrian must have amounted to more than 7,300 feet. Although Twenhofel (1928, p. 15) reports 1,233 feet of Silurian beds on Anticosti island, and 2,579 feet have been recorded from the Ontario peninsula (Geol. Surv. Can., 1947 p. 167), the two regions had little in common and there is scant justification for assuming that there were any Silurian deposits in the intervening region. Hence the thickness of 7,300 feet, arrived at above, should stand. This is somewhat less than a mile and a half, or about half way between the longitudinal and transverse diameters of the igneous rock of Mount Royal, and therefore not excessive in relation to the size of the pipe.

There still remains the question of the upward extension of the pipe. It may have ended bluntly, or it may have fed a laccolith above, or it may have burst through to the surface to form a volcano. The coarse grain of the gabbro, even, in some places, within a fraction of an inch of its contact with the surrounding sedimentary rocks, may be considered an evidence of slow cooling, and for this it would seem that the rock intruded must have been so throughly heated that the loss of heat by the magma during the crystallization was comparatively slow. Such a high temperature could scarcely have been engendered in the country rock without either a long-continued circulation of the magma or its renewal consequent upon the drawing off of magma to build either a laccolith or a volcano. The large number of differentiates indicates the passage through the pipe of a considerable volume of magma. That the upper terminus of the pipe was a dead end, has, therefore, no support in theory or fact. What little evidence we have tends to show that either the Mount Royal pipe proceeded upward to spread out laterally to form a laccolith where the rock pressure was considerably less than it would have been at the present physiographic level, or that the magma rose through the pipe to support a volcano a mile and a half, more or less, above the present summit of Mount Royal. Many years ago, Daly, (1914, p. 282) noted that "the average diameter of the pipes recorded in geological literature is well under 300 meters". Later, the same author (1933, p. 150) tabulated the diameters of several hundred volcanic necks in Africa, Europe, and North America, and showed 1,600 meters as the greatest diameter measured. If Mount Royal could be proved to be a volcanic neck, it would take its place as one of the largest in the world.

Effect upon Surrounding Sediments

The effects of an intrusion upon the surrounding country rocks are, in general, twofold: first, a degree of metamorphism and, second, deformative changes (tilting, crumpling, brecciation) consequent upon pressures developed during the intrusion.

Metamorphism

Some degree of metamorphism of the surrounding limestone can be noticed over a distance of a few hundred feet from the margin of the igneous rock. Megascopically, this usually shows itself as a bleaching of the limestone and, in a few places, as in increase in the size of its constituent calcite crystals. In the Corporation quarry, Montreal, the metamorphism of the Trenton limestone has resulted not only in recrystallization but in the whitening of the limestone as a consequence of the volatilizing of the hydrocarbon colouring matter (Plate XIV-B). In addition, it has induced the formation along the contact zone of numerous minerals, of which the most common are garnet, vesuvianite, diopside, wollastonite, and scapolite. Dolan (1923, p. 131) gives a list of twenty-nine minerals detected in the limestone close to the igneous contact. In some localities, the rock has a pale olive-green colour due to the large amount of diopside it contains. Such a rock, if abundant enough — which is nowhere the case in present exposures — would make a handsome interior decorative stone.

Other minerals, among which may be mentioned galena, sphalerite, native arsenic, and dawsonite, are found in various situations close to the periphery of the igneous mass of Mount Royal. None of these is strictly a contact mineral. Their emplacement close to the contact between igneous and sedimentary rock is probably fortuitous. Dawsonite, first described from Montreal (Harrington, 1874; Graham, 1908), may be the result of hydrothermal changes more nearly akin to weathering than to metamorphism.

Hornfels. Along the northern and northeastern margins of the intrusive there are exposures of the Utica shale metamorphosed to a tough and flinty hornfels. On a fresh surface it is dark grey to black, but because it contains a fair abundance of pyrite its weathered surfaces are almost always slightly tinged with brown. Usually, the rock shows some trace of stratification and, in fact, where this is not seen, it has all the appearance, megascopically, of a fine-grained intrusive rock. Microscopically, it is seen to consist, essentially, of biotite and feldspar, with, in some specimens, cordierite. The hornfels can best be seen on the bluff immediately below the Lookout, and can be followed thence for a thousand feet southwestward through the woods. To the north, its outcrop is obscured on the cliff face by talus, but its presence can be inferred at several points and it continues as far as the southern end of the tunnel on the Montreal Tramways line up Mount Royal.

Crumpling and Fragmentation

Physical deformations include brecciation (Plate X-A), already discussed, local tilting, and local crumpling of the rock. On the east side of the mountain, the normal dip to the southeast is maintained or in places possibly steepened somewhat. In many places on the north and west sides, where one would expect the limestone to dip in toward the mountain, the reverse is the fact and the beds dip fairly steeply outward. That this is only of local significance is seen from the near horizontality of the beds a few hundred feet from the contact. Also, in some places, as in the Corporation quarry, Montreal, and on the north side of Summit Circle, Westmount, the limestone, highly crystalline, has been subjected to intense local crumpling, which must have been preceded by the development of a thorough plasticity of the rock (Plates XII-B, XIV-B). Thus heat and pressure combined in this case to deform the rock.

Time of Intrusion

The dating of the formation of the Monteregian hills has ranged from the Silurian (Deeks, 1890, p. 109), through the Devonian or Carboniferous (Adams, 1903, and others). Inasmuch as the Sainte-Hélène Island breccia contains fragments of Lower and Middle Devonian fossiliferous rocks, the formation of that breccia, and therefore presumably of the whole Monteregian complex, could not have antedated the Middle Devonian. No younger consolidated rocks occur in this region. From Middle Devonian to latest Tertiary is, then, the gap which the gross geological relations provide for the dating of the intrusions. With nothing else to guide speculation, it was but natural than an early, rather than a late, date should have been chosen. Those of the Monteregian hills which are said to lie within the sphere of the Acadian orogeny, that is, Shefford and Brome mountains, show no deformation comparable to that which that orogeny must have occasioned. Hence a Middle Devonian age can be abandoned, thus narrowing the gap to a slight extent. The Appalachian revolution did not affect any part of Canada occupied by the Monteregian hills, so we cannot further limit the date by reference to that event. No rate of erosion is known which would allow us a measure of the time for the stripping off of the superincumbent cover. Osborne, who has examined numerous thin sections of rocks from all of the Monteregian hills, states that only in one section did he find biotite crystals showing pleochroic haloes, which they should do if the rocks are as old as late Palaeozoic (personal communication). Moreover, Eve and

McIntosh (1907) showed that the Masson Street sill (tinguaite) is four times as radioactive as the average igneous rock, which could be possible only if the sill were of fairly recent geological age. These lines of evidence pointing to a relatively late age receive strong support from Urry's more recent (1936) determinations, by the helium method, of the radioactivity of the local intrusive rocks, which give the age as $57 \pm 1\frac{1}{2}$ million years, dating the intrusion at about the beginning of the Tertiary period. Because of the recognized inability of most rocks to retain their helium, or at least the whole of it, ages based upon the helium content must be looked upon as minimum ages. Hence it is quite possible the Monteregian rocks were intruded as early as the Cretaceous.

STRUCTURE

Throughout the whole area, the rocks are predominantly sedimentary, nearly flat-lying, but with a regional dip of a few degrees toward the east. The sedimentary series rests upon a basement of Precambrian rocks, and these basement rocks appear at the surface in the extreme southwestern corner of the Laval map-area, in the northeastern corner of the Lachine map-area, and in the presumed exposure of anorthosite at Cartierville. The sediments have been warped into a few low folds, recognizable for the most part only by the distribution of outcrops as plotted on a map. And, in addition, numerous east-west normal faults throughout the area complicate the distribution pattern considerably. Here and there, igneous rocks have intruded the sediments as dykes and sills. The main intrusion of Mount Royal pierced both the Precambrian basement and its superincumbent sedimentary veneer and now appears as the filling of a vertical pipe.

Character of the Precambrian Basement

It has already been suggested (p. 24) that a relief of at least 3,000 feet was in existence at the beginning of Potsdam time. Because of the lack of outcrops of Precambrian rocks, except as noted above, there is nothing to add to that statement. Where Precambrian rocks outcrop in the western parts of the map-areas, a very considerable relief is indicated, unless the relatively straight and steep north-south boundary of the Precambrian exposures indicates a fault.

Structure of the Sedimentary Rocks

General Attitude

In general, the sedimentary rocks of these map-areas are disposed in an essentially horizontal attitude (Plates IV, VIII-A, VIII-B, IX-B, XVI-A), and few outcrops can be found in which the departure from the horizontal is more than 2°. On the eastern part of the island of Montreal, however, steeper dips are the rule, in many places being 5°, and even reaching or exceeding 10°.

Moreover, on a palaeogeological map portraying their distribution, prior to folding and faulting, the structure of the pre-Monteregian rocks is revealed as a shallow basin, scarcely deserving the term syncline, plunging gently toward the east (Figure 11). Both the northern and southern parts of this shallow structure can be seen in these map-areas. The mainland north of Ile Jésus consists of a north-south striking series of beds from the Beekmantown through to the Upper Trenton. The mainland south of the Saint-Lawrence consists of much the same series striking approximately northwest-southeast. This is the succession which can be seen in general from Ottawa to Quebec city, between which localities the strike of the beds parallels the Precambrian-Palaeozoic contact. In the vicinity of Montreal, the Oka axis has prevented the beds from continuing in this manner and has caused, on both sides of the axis, a local deflection southward of the strikes of most of the formations. Hence, the original simple structure arose as a result of the presence of the Oka axis and, had that been the only complication, the distribution of beds would have been as shown in Figure 11, where the chief distributional effects of the Oka 'anticline' are the exposures of Precambrian rocks in the vicinity of Oka, and the anticlinal relationship of the Potsdam and Beekmantown in the southwest corner of the Lachine area. However, major faults and minor folds have interfered with this orderly concept of the continuity of the beds, as is indicated on the geological map. There are doubtless other faults involving mappable separations but which, because of the paucity of outcrops over much of the area, have not been recognized.

Disregarding the complications introduced by the Delson fault, the beds south of the Saint-Lawrence are disposed in part as an orderly series dipping to the east and northeast, thus continuing the general southerly sweep of the sedimentary series as indicated in the northern part of the Laval sheet. In the Beauharnois-Melocheville region, an anticlinal disposition of the rocks allows the Beekmantown to occur to the west of the Potsdam as well as to the east of it. This anticline is the southern representation of the Oka axis farther north, which has not only allowed the Precambrian to be exposed but has actually been the cause of the general southerly trend of the beds.

The interruptions and complications of this simple structure, first considering folds, and later faults, will be dealt with below.

Ile Jésus Anticline

The northeastern half of Ile Jésus is featured by a prominent ridge or backbone which, upon examination, proves to be the physiographic expression of the resistant Upper Chazy limestone (See Figure 12). From

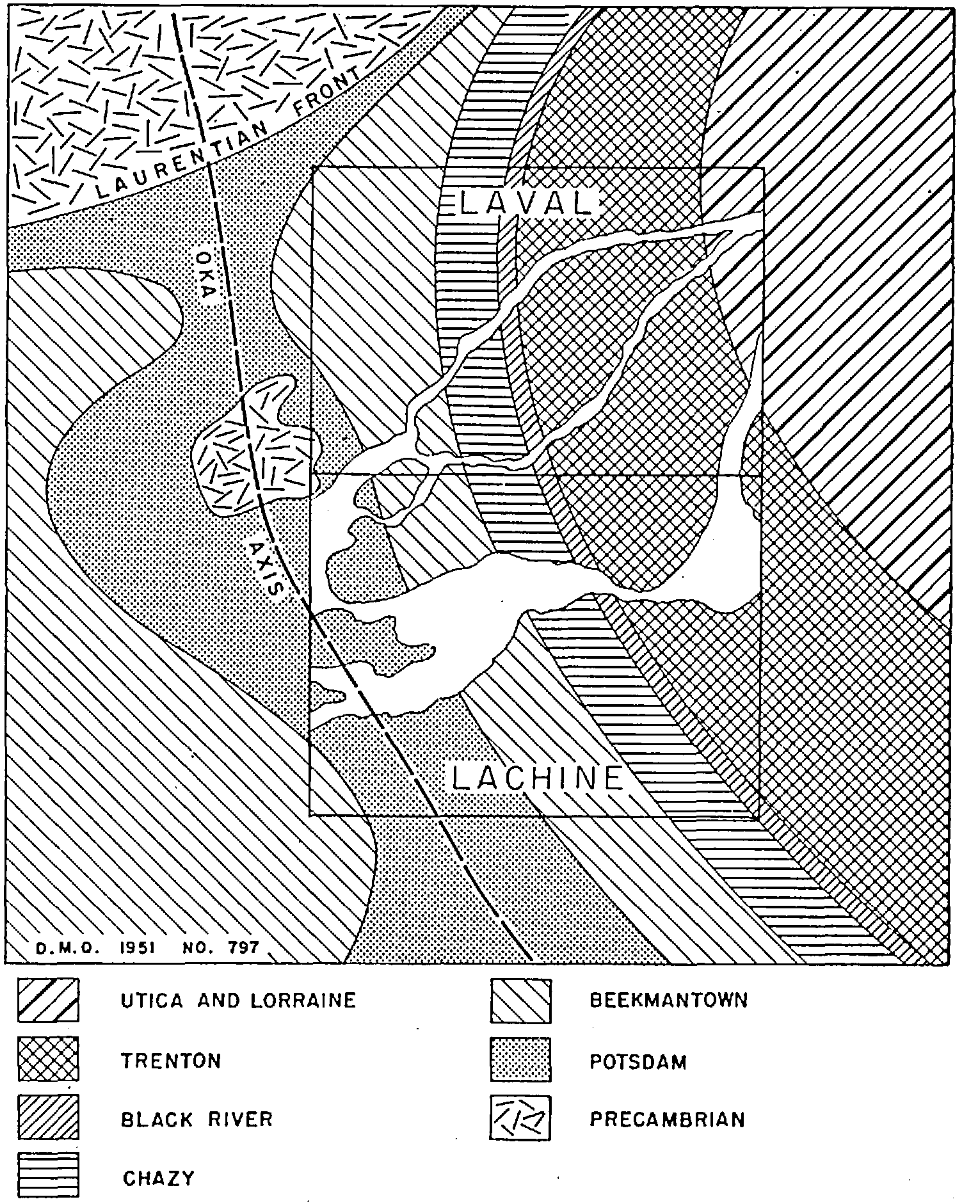

Figure 11 - Palæogeological map of the Laval-Lachine areas and surrounding territory showing probable distribution of rocks at about present-day sea-level and prior to folding and faulting.

a quarry two and a half miles north of Sainte-Thérèse, where the Chazy beds strike almost due north and south, these beds sweep around to an outcrop on rivière aux Chiens where they strike about east and west, dipping beneath the Leray and Trenton to the north. Thence outcrops are missing along the strike to the east up to the vicinity of Côte des Perrons (6 miles east of Sainte-Thérèse) where the same beds are seen again, and thence, with some interruptions, they can be followed toward but not reaching Saint-François-de-Sales (across rivière des Mille Iles from Terrebonne), their boundary bending around to the southwest, skirting Saint-Vincent-de-Paul, and crossing to the island of Montreal in the vicinity of Pont Viau. In all of this stretch, the majority of dips and strikes show the outcrops to be arranged around an anticline plunging to the northeast at a very low angle, probably not more than one or two degrees. Outcrops are abundant in the central part of this fold, rare on the flanks. This is due partly to the non-resistant nature of the beds on the flanks, and partly to the heavy blanket of sands and silts spread over the lowlands adjacent to the river, effectively blotting out all outcrops save where they have been exposed by river work. Erosion has not yet been able to cut through the heavy-bedded crystalline limestones of the upper part of the Chazy formation (save, possibly, in the low ground between Saint-François road—3 miles and more north of Pont Viau—and Saint-Vincent-de-Paul); hence they maintain their integrity as an unbroken arch, sustaining the central ridge of the northeastern part of Ile Jésus. Farther to the southwest, where these resistant beds have been cut through, the less resistant and lower beds, in part Beekmantown, lie at the surface and have been unable to maintain a high physiographic expression. The southwestern part of the island is therefore, relatively, monotonously flat.

The implication of this concept of the structure is that the area of the quarryable upper beds of the Chazy formation can be fairly well mapped out. This is done on the accompanying map (Figure 12). Everywhere within the area of the upper part of the Chazy limestones one may confidently expect to find good building stone of the Chazy type. Only testing will show whether the thickness of the beds is one foot or fifty feet. In the direction of the plunge, no outcrops occur beyond the Chazy quarries at Saint-François-de-Sales. In the opposite direction, the Chazy beds give way to dolomites of the Beekmantown formation which continue through Plage Laval and other localities to the limits of this area.

Ahuntsic Syncline and Villeray Anticline

The broad band of Chazy limestone which traverses Ile Jésus sweeps around the nose of a syncline in the vicinity of Cartierville and the Town of Mount Royal, only to turn again southward, indicating a corresponding anticline, toward Hampstead and Notre Dame de Grace (all west and northwest of Montreal). These folds are here called the Ahuntsic syncline and the Villeray anticline, respectively, both plunging very gently toward the north-northeast. The course of these folds is adequately shown by the distribution of the Chazy, Black River, Mile End, and Saint-Michel beds. The boundary line between the Rosemount and Tetreauville beds is not closely indicated by the juxtaposition of outcrops of the two members, but it has been drawn to conform with the two folds mentioned above. Very rarely do dips occur as high as ten degrees, and, because of the regional dip toward the east, it is the east limbs of the anticlines which show the steepest dips.

At the western end of the island of Montreal and on Ile Bizard, the distribution of the various beds is not one to warrant the use of the terms anticline or syncline. The band of rocks of the Black River group, which may be taken as a horizon marker, sweeps southeastward from Ile Bizard to Pointe Claire, where, complicated by a fault, it goes below the waters of lake Saint-Louis.

Between the White Horse Rapids and Ile Bizard faults there is a complicated pattern of limestones and shales of the Trenton group. Although it does not seem at present possible to assign a simple structure to the whole of this complex, it is certain that it is in part basin-like, with the shales of the Utica formation exposed in the middle.

Bas-de-Sainte-Rose Fault

On the map, the north flank of the Ile Jésus anticline is shown as complicated by a dip slip or an oblique slip fault which has succeeded in partly or entirely eliminating the Chazy limestone from the region between Sainte-Thérèse and Côte des Perrons. The fault surface is nowhere observed, but its existence is postulated for the following reasons: in the stone walls, beaches, and glacial drift to the southwest along rivière des Mille Iles from Plage Laval (opposite Saint-Eustache) northeastward, there is an abundance of Beekmantown and Trenton boulders but exceedingly few of the Chazy formation. Beyond the railway bridge at Rosemere (2 miles east of Sainte-Thérèse), the boulders are practically all Trenton, both Beekmantown and Chazy being virtually absent. Along the shores of the river, where one would expect to find outcrops of the rock which elsewhere is resistant enough to hold up the backbone of Ile Jésus, no outcrops occur. At the quarry a mile and a half north of Rosemere, the Chazy beds have an abnormally high dip, measurements up to 11° being recorded, though 7° is more usual. Eastward, at the end of Côte des Perrons road, obvious dislocations occur. Lastly, the relationship between the horizontal Chazy limestone of the quarry area south of Saint-François-de-Sales and the eastward dipping Upper Trenton of the outcrops on both sides of the river above Terrebonne requires a structural adjustment. The horizontality of the Chazy would carry them, if unrelieved, above Terrebonne, for there is a difference of more than twenty-five feet in elevation between the two outcrop areas. Instead of this, the Trenton beds dip to the east, and properly belong at least 700 feet above the Chazy horizon. Such a stratigraphic condition could be explained by a constant northward dip of about 6° of all the beds between the Chazy and the Upper Trenton. Nowhere is such a dip observed — instead, the beds along rivière des Mille Iles have an eastward dip of one or two degrees. The validity of the above arguments is shown by an outcrop of Upper Trenton limestone within 500 feet of the Chazy beds at Saint-François-de-Sales. The high dip of the Trenton limestone indicates a drag along a fault.

All of these anomalous conditions can be satisfactorily explained by the assumption of an east-west dislocation along the north side of the Ile Jésus anticline, with the down-drop on the north, thus eliminating at least the western part of the east-west expression of the Chazy band on the surface. The strong curvature of the bands of Black River and Chazy beds as they turn to the eastward in the neighbourhood of Sainte-Thérèse may in part be due to drag along this fault. The nearly flat but generally eastward dipping Trenton limestone exposed between Pont David and Terrebonne are the undisturbed upper members of the same series preserving their pre-faulting attitude. It is quite possible, if not probable, that the Bas-de-Sainte-Rose fracture and the Ile Jésus anticline were the result of the same deformative process.

The continuation of this fault eastward across the island of Montreal cannot be plotted with certainty. Two observations make such a continuation likely. First, the Trenton outcrops are cut off quite abruptly in an east-west direction just about where this fault is postulated. The Dufresne quarry in Rivière des Prairies and the outcrops in the vicinity of the Reparation Shrine in Pointe-aux-Trembles are two of the most northerly outcrops. North of this line, the level of the land falls considerably, which may be due to erosion of glacial and post-glacial débris, but even so might depend upon bed-rock control. These outcrops all belong fairly high in the Trenton, and any down-dropping of a block immediately to their north should bring the soft Utica shales into juxtaposition with these relatively harder limestones. Thus, the topographic break would be easily explained. Actually, boulders of Lorraine shale can be found in the drift near the Reparation quarry. And secondly, both of the outcrops mentioned show evidences of dislocation. The Dufresne quarry is traversed by a fault striking 85° with, as shown by the drag, a down-drop on the north; and the Reparation outcrops can be seen, where they have been quarried, to be considerably disturbed. Hence there is abundant justification for carrying the Bas-de-Sainte-Rose fault completely across to the eastern margin of the Laval sheet.

White Horse Rapids Fault

Outcrops of Beekmantown dolomite in the vicinity of Sainte-Dorothée and Laval-sur-le-Lac (near southwestern end of Ile Jésus), all with near horizontality, occur in close proximity to exposures of essentially horizontal Middle, and possibly Upper Trenton limestone at Dutchman rapids, White Horse rapids, and Abord-à-Plouffe Ouest. There is no possibility of the occurrence of the Lower Trenton, Black River, and Chazy beds in between these rock masses. The Beekmantown and Trenton rocks are therefore separated by a fault whose course must pass along the southern part of the island north of, and more or less parallel to, rivière des Prairies.

This fault appears to cross rivière des Prairies a mile or less below Paton island and to continue on through the town of Saint-Laurent. Somewhere near here it probably merges with the Ile Bizard fault, though the two may be independent. The chief determining factors in the locating of the eastern part of this fault have been the outcrop of Trenton limestone along the railway track near the Montreal Polo Club and the exposures of Chazy limestone in the Town of Mount Royal. As corroborative evidence of its presence, Trenton outcrops along Dutchman rapids and White Horse rapids, especially on the south shore, contain in many places east-west shear zones with gouge, veins, and minor dislocations, all reflections of a larger controlling movement. It is probable that the easterly course of rivière des Prairies is controlled by this fault zone.

It is interesting in this connection to note that Logan, in his *Report of Progress* for 1852-53, considered the possibility of a fault here. In the more generally accessible *Geology of Canada,* 1863 (p. 131), after noting the close proximity of the Beekmantown and Trenton formations at Laval-sur-le-Lac, he wrote: "The Chazy, unless it is let down and buried by a fault, must enter on the island at the very extremity in a very narrow band".

Ile Bizard Fault

The above described anomalies of the structure cannot be resolved by the White Horse Rapids fault alone. On Ile Bizard, the band of Black River rocks, trending northwesterly with a width of outcrop of half a mile, fails, within the distance of one mile, to attain the northern shore of the island. Instead, the Chazy limestones of pointe aux Carrières are succeeded, within one-eighth of a mile, by limestones of the Rosemount member. Hence, all of the Black River group, the Mile End formation, and the Saint-Michel member, are eliminated. To explain this peculiar situation a second fault, which I propose to call the Ile Bizard fault, is necessary, passing between the Chazy of pointe aux Carrières and the adjacent Trenton, north of the Black River outcrops, and thence eastward, though its extension in that direction is doubtful because of the lack of outcrops to the south of its presumed extension. Its presence is further indicated by the prominence of east-west joints and minor slips in the Chazy limestone of pointe aux Carrières, though the less crystalline

Trenton and Black River beds have apparently received little if any impression of the movement.

It is probable that, of the east-west faults in this vicinity, the White Horse Rapids fault was the first to develop. By an appropriate down-dropping of the block to the south, the Trenton limestone was brought into juxtaposition with the Beekmantown dolomite of Sainte-Dorothée and Saint-Eustache. A later and minor movement along the Ile Bizard fault, equivalent to an elevation of the territory to the south, brought the Chazy limestone into contact with the Trenton on the north, and eliminated the Black River from the present land surface. According to this explanation, the Black River beds should be sought for between the two faults beneath the waters of the lake of the Two Mountains.

Whether these faults extend as far as the Precambrian on the western border of the Laval map-area is not known, nor what effect, if any, they may have had upon the regional distribution of the Precambrian rocks. They are represented as dying out before reaching the margin of the map.

The movement, assumed to be entirely vertical, was considerable. Along the White Horse Rapids fault, at Sainte-Dorothée itself, there are brought together the Beekmantown dolomite (say, 300 feet from the top) and the uppermost Trenton limestone or possibly the Utica shale. That part of the whole section eliminated consists of the following:

Trenton	800 feet
Black River	60 "
Chazy	280 "
Beekmantown	300 "
	1,440 feet

At pointe aux Carrières, we may assume that the top of the Chazy is exposed. Hence, to bring the Rosemount member into contact with the top of the Chazy, we must allow for the elimination of the following along the Ile Bizard fault:

Saint-Michel	100 feet
Mile End	25 "
Black River	60 "
	185 feet

This change in displacement may indicate a rapid dying out of the faults westward, and this may well be the reason for the lack of a noticeable shift in the Precambrian boundary, at least within the Laval map-area.

Sainte-Anne-de-Bellevue Fault

Two more east-west faults remain to be noted. First, there is one which traverses the village of Sainte-Anne-de-Bellevue, whose name may be applied thereto. South of this fault are southward dipping beds of Potsdam sandstone. North of it are Beekmantown dolomites, essentially horizontal, though in one place, where an underpass at Macdonald College below the new boulevard exposes the Beekmantown beds, they have an irregular dip of 6° to 8° west, as if due to drag. Logan mentioned the Potsdam sandstone as occurring for two miles eastward along the shore. Possibly because of consistently higher water, the visible distribution is now restricted to the village of Sainte-Anne, but the earlier observations indicate an east-west direction for this fault. Although the Delson fault is responsible for the distributional discordance in the vicinity of the Lachine rapids, the eastward extension of the Sainte-Anne fault no doubt passes between Lachine and Caughnawaga and so helps in explaining the anomalous distribution of the beds on both sides of the Saint-Lawrence river at the eastern end of lake Saint-Louis.

Pointe Claire Fault

Again, there is an anomalous condition at Pointe Claire. A series of outcrops of the complete Black River section stretches in an east-west direction for more than a mile along a slight elevation south of the railway track. The strike of these beds is east-west, the dip 2° south. Therefore the underlying Chazy should be looked for in the vicinity of, or north of, the railway track, and the Trenton along the shore. Actually, it is the Chazy which occurs at the shore, on the west side of the point, and, though no outcrops are known north of those in question, the attitude of the Black River and Chazy to the northwest shows that only the Trenton could occur where the Chazy was expected. Not only is there no repetition of the Black River beds, but we do not find any evidence of reversal of dip, and we are therefore forced to conclude that a fault bounds the east-west outcrop on its north side. This conclusion is corroborated by the straightness of the northern margin of the outcrops and by its steepness, which features, though they might have arisen in other ways, are exactly what we should expect if this northern margin were a fault with a down-drop on the north. It is likely that the vertical movement is of the order of a few tens of feet at the most.

Because of the possibility that, between the outcrops and the shore, there may be a reversal of dip, allowing the Chazy limestone to occur in its normal position, no fault has been placed to the south of the outcrops, although, in the absence of such a reversal of dip, a fault, again a few tens of feet at the most, must, as Raymond pointed out (1913, p. 148), be postulated.

That the Pointe Claire fault is of more than local significance is indicated by the distribution of the Trenton outcrops in Lachine and Dorval. At Lachine Locks and at several places along the canal, Utica shale occurs. Between Lachine wharf and Stony Point there are shore outcrops of the Rosemount member of the Montreal formation. At Ville Saint-Pierre and at several localities along the Canadian Pacific railway in the vicinity of Dixie (2 miles west of Lachine) there are numerous outcrops of the Tetreauville member. The dip of the Rosemount beds is to the east-southeast, which would carry them northwestward to a position above the Tetreauville beds, an anomalous condition. Secondly, the Rosemount outcrop intervenes between the Tetreauville and the Utica, again an anomalous condition unless a fold, unusually sharp for this region, has brought the Rosemount to the surface at Lachine wharf. Of this there is no corroborative evidence. The Tetreauville outcrops are either approximately horizontal or are disposed with a north-south strike, and the Utica dips to the northeast. There is no way by which the attitude of these beds can be reconciled save by postulating a fault between the Rosemount and the Utica. An easterly continuation of the Pointe Claire fault satisfies the former demand, and the Delson fault, to be described below, the latter.

Delson Fault

South of the Saint-Lawrence there is but one fault of any magnitude. This passes between Caughnawaga and Delson and has a southeast trend. It is necessary to postulate this fault because, although the strata at the two localities mentioned are approximately horizontal, those at Caughnawaga belong to the Chazy group, whereas the outcrops at Delson are of Utica age. In Logan's map, later used by Ells, the Trenton and Black River are shown as passing in orderly succession between these two places. The attitude of the Chazy and the Utica would make this improbable, and actually it is rendered impossible by the presence, along the south shore of the Lachine rapids, about half-way between Delson and Caughnawaga, of outcrops of both Utica and Lorraine beds, the latter almost certainly disposed in a syncline. Moreover, south of the postulated fault, Chazy beds outcrop at Saint-Isidore (8 miles due south of Caughnawaga), a locality which should lie near the middle of a belt of Trenton if the full thickness of this group were present between the Chazy and the Utica. Chazy beds are to be seen also along La Tortue river at a locality which, if the Delson fault were non-existent, would be within a continuous band of Utica. Hence an orderly succession is impossible, and all of the difficulties are simply and easily resolved by the recognition of the Delson fault. Its direction can be fairly well established. It passes between the Utica outcrops at Delson and the Chazy outcrops in the river bed two miles to the south. It also passes under the Mercier (or Saint-Louis) bridge, for the outcrops at the south end are Chazy whereas those at the north end are Utica.

The displacement along this fault at the Mercier bridge is approximately the thickness of the Black River and the Trenton groups; possibly a little more, depending upon how high in the Utica the outcrops at Ville Lasalle and Lachine rapids are. It might possibly be shown to be a little less by outcrops (if there be such) on the floor of the Saint-

Lawrence, which is at this place from three-quarters of a mile to a mile and a quarter wide. A reasonable estimate would be a down-throw on the northeast side of 900 feet. Farther southeast, although there is no evidence within these map-areas, it is possible that the fault dies out, allowing the Trenton and Black River to come back into their normal position at Saint-Johns.

Its continuation northwestward is opposed by a number of outcrops of Tetreauville limestone distributed widely across its path. No reasonable offset of the Delson fault can be deduced from the known distribution. There is, moreover, no valid reason why it should not abut against the Sainte-Anne-de-Bellevue fault.

That the Delson fault is not a simple dislocation is indicated by the occurrence of Trenton limestone, probably Tetreauville, in roadside cuts (by 1949 largely covered up) along the new highway No. 9c, beginning a mile and a half east of the south end of the Mercier bridge, and continuing for another mile and a half eastward. In the only exposure where attitudes can be accurately measured, the dips range in amount from 4° to 8°, and in direction from northeast, through east, to southeast, indicating the possibility of some local deformative process. Because these beds are obviously Upper Trenton, and probably Tetreauville, in age, there is insufficient room between them and the Chazy exposures at the south end of the Mercier bridge for the intervening Black River beds (60 feet) and the lower parts of the Trenton (400+ feet). Nor do these beds accord in attitude or distributional pattern with the Utica and Lorraine in the vicinity of the Lachine rapids and of Delson. It is entirely reasonable that they should be considered to be a faulted mass caught between the main Delson fault and a nearly parallel subsidiary fault, as indicated on the map.

Saint-Vincent-de-Paul Fault

The northeastern end of the outcrops on the Ile Jésus anticline is broken by a fault trending approximatly northwest, along which the rock on the northeast has apparently moved a mile or less to the northwest. No confirmation of this fault on the mainland or on the island of Montreal is known at present. A second fault, a mile northeast of this one, has apparently shifted the end of the anticline a quarter of a mile back toward its original position.

These two cross-faults cutting the Ile Jésus anticline on Ile Jésus are not shown on the map as continuing southeastward across the island of Montreal because of lack of critical outcrops. To be sure, there are many outcrops in Tetreauville and Notre-Dame-des-Victoires which are not in accord with their general structural setting, but more problems are raised than settled by attempting to explain such minor irregularities by through-going faults. It should be added that the boundary line between the Rosemount and Tetreauville members, as drawn, in Notre-Dame-des-Victoires and Maisonneuve is not strictly parallel to the strike of the strata concerned.

Minor Faults

In most of the large quarries in the Trenton limestone in the northern end of the island of Montreal, faults may be seen, with movements ranging from a foot or two to possibly tens of feet. In the quarry operated by National Quarries Limited, Côte Saint-Michel (Plates VII-B, XV-A), and in the Canada Cement Company and Durocher quarries in Montreal East, the dislocations are all strike faults and may, conceivably, be related to the mild folding. In the Dufresne quarry, a mile east of Rivière-des-Prairies, the strike of the fault is 85°, much more nearly parallel with the Bas-de-Sainte-Rose fault. In fact, it might well be considered as a branch of that fault. It is significant that minor faulting seems to be practically confined to the Trenton and Black River formations. No fault within the Chazy or Beekmantown has been observed.

Less than three miles north-northeast of Saint-Vincent-de-Paul, a small outcrop of Leray and Lowville is entirely surrounded by Chazy in such a way as to preclude its being a basin. All the rocks are essentially horizontal. Along the southwestern margin of the Black River beds, the latter and the Chazy beds, both horizontal, outcrop within ten feet of each other in a flat pasture. The exposures toward the east end of the Côte-des-Perrons road show complications which are somewhat more difficult to unravel. Relatively high dips, up to five degrees, are indications of faulting and the distribution of the outcrops demands it. I have interpreted the long, narrow outcrop of Leray limestone which crosses the road three miles northwest of Saint-Vincent-de-Paul as being in its normal position on the north flank of the anticline above the Chazy and as being succeeded by the Trenton limestone. Its continuation to the west is offset by a small fault and this offset probably is separated from the Chazy by a fault. Both of the latter faults are probably parallel to the Saint-Vincent-de-Paul fault. The Chazy outcrops immediately to the north must be brought into their present position by faulting. I have shown them as having been caught, as a sliver, in between the main Bas-de-Sainte-Rose fault and a branch fault two miles long.

Of the many other minor faults — which are too numerous to mention — one in particular is of interest because it is so clearly exposed. This is a nearly vertical normal fault to be seen on the rock wall behind the reservoir on Côte-des-Neiges, Westmount (Plate XV-B). There the much dyked Trenton limestone (Plate X-B and Figure 6), essentially horizontal, is dragged downward steeply against its contact with the Utica hornfels. The Trenton limestone is practically unfossiliferous and doubtless belongs to the Tetreauville member. The displacement, therefore, might be anywhere from one hundred to three or four hundred feet. The relatively steep dip to the south of the prominently banded Trenton limestones forming the cliff along the north side of Côte des Neiges just east of the top of the hill may also reflect the drag along the same fault continued a quarter of a mile to the east.

HISTORICAL GEOLOGY

The understanding of geological processes and results, together with the successful exploration for and the practical exploitation of valuable natural resources, depends not only upon our understanding of the geological materials themselves — such as limestone, coal, granite, etc. — but upon their age relationship to one another. All geological investigations are based explicitly or implicitly upon those two factors, material and time. To sum up the age relationships existing between the many rock groups in the Laval-Lachine area is the purpose of this chapter. We shall therefore start with the earliest recorded events and progress period by period to the present time. A resumé of the geological history is given in the accompanying table, reference to which will allow each local event to be placed in its correct place, with regard to the complete span of geological time.

Resumé of the Geological History of the Region around Montreal

Eras	Periods	Millions of Years Ago	Events
Cenozoic	Quaternary	1	Montreal as it is today Glaciation, and Champlain submergence
	Tertiary	60	Erosion Igneous activity. Monteregian hills
Mesozoic	Cretaceous	140	Erosion
	Jurassic	175	
	Triassic	200	
Palaeozoic	Permian	240	
	Carboniferous	310	
	Devonian	350	Short submergence
	Silurian	380	? Emergence and erosion
	Ordovician	450	Taconic mountain building in Eastern Townships. Marine submergence continued. Deposition of Beekmantown, Chazy, Black River, Trenton, Utica, and Lorraine rocks.
	Cambrian	540	Marine inundation. Potsdam sandstone.
Precambrian Time	Late	1,000	Long continued erosion
	Early	2,000 +	Formation of granites, gneisses, etc., of the Laurentians, and of the basement underlying Montreal

Precambrian Eras

We have no clear picture of what was happening in Precambrian time. The only rocks of these eras now exposed in this area are to be found in the vicinity of Saint-Joseph-du-Lac and at Cartierville. Not far to the northwest, an abundance of Precambrian rocks outcrop and it is fair to assume that similar rocks underlie the present area. If so, then the records of a very complex past lie buried beneath our feet. For hundreds of millions of years, geological processes were in operation resulting in the formation of sedimentary rocks, their folding and metamorphism, and eventually intrusion by various igneous rocks such as the granite of Saint-Joseph, and the anorthosite of Cartierville. Our information is so meagre that we cannot tell from the evidence at hand much more than that these things happened, and that there probably was a mountainous terrane over most of southern Quebec composed of the rocks above mentioned. Erosion reduced this terrane to a lowland of moderate relief by the beginning of Palaeozoic time. Thus, by reference to the table of geological history, three-quarters of geological time passed by with little more than a few outcrops of indecisive rock to show for it today. To be sure, in the 'Laurentians', which bound the Saint-Lawrence lowland immediately north of the present area, the story of those early days is a more connected one, and we unconsciously borrow from it in our work upon less well known areas.

Cambrian and Ordovician Periods

There is no record in this area of any event of Lower or Middle Cambrian time save the implication, seen in the quartz-rich Potsdam sandstone, that the vast area of Precambrian rocks of the Canadian Shield had been undergoing subaerial weathering long enough to allow the almost complete decomposition of all minerals but the quartz. Late in the Cambrian, probably late in the Upper Cambrian, the spreading waters of the expanding Appalachian geosyncline began to bathe the shores of the Precambrian uplands which spread across the present Laval-Lachine area. Irregularities in the land surface were evened up as rapidly as possible by the deposition of all detritus too large for currents to carry away. As explained earlier, these irregularities presented a relief of 3,000 feet at least, though as to what the quality of that relief was we have nothing to say. Although it is hardly pertinent, the great amount of quartz in the Potsdam sandstone bespeaks at least an equally great amount of muddy sediment which must have been carried outside of the present area of sedimentation, presumably to the east. The sands of the Potsdam formation were the playthings of the waves and currents of the Upper Cambrian sea. The ever present cross-bedding indicates not only the mobility of the sand grains but the vacillation of the waters. Possibly the tides ebbed and flowed over a wide off-shore platform where one day's deposit of sand could be shifted from its resting place to another on the following day. Exceptionally high tides would build up bars behind which orderly sedimentation could go on unimpeded by tidal fluctuations. And, too, in such sheltered lagoons, the organisms responsible for *Climactichnites, Protichnites,* and *Scolithus* could pursue their lives and leave behind them a permanent record of their existence. At the close of Cambrian time there had been spread out over these parts a blanket of sand, filling up all hollows, river channels, etc., leaving bare those parts which were still high enough to remain as yet uncovered by the waters of this Upper Cambrian sea.

At the close of the Cambrian period, the sea was drained off, as is indicated by the 'passage beds' which lie at the base of the Ordovician. These, locally known as the Theresa formation, are invariably composed of rounded and frosted sand grains, whereas the Potsdam itself is predominantly composed of angular, bright, water-borne grains. It would appear that portions of the Potsdam sandstone exposed by the retreat of the Upper Cambrian sea were whipped around by the wind, rounded, and left as a desert accumulation topping the Potsdam sands beneath, later to become the Theresa sandstone of today. A rise of the sea during the early Ordovician allowed some rearrangement of these sands, but for the most part they seem not to have been much disturbed. Probably the incoming sea completed its invasion with great rapidity, for otherwise these sands would have been swept away. And, moreover, the general lack of basal detrital matter in the succeeding Beekmantown formation is a good indication of rapid covering of the invaded sea-floor so that calcareous deposits could form almost at once. Descending solutions from those earliest Beekmantown limestones and dolomites doubtless furnished the carbonate cement that characterizes the 'passage beds' and to some extent the uppermost layers of the Potsdam sandstone.

In southern Quebec, the Beekmantown dolomite, or that part above the Theresa passage beds now known as the Beauharnois formation, was the result of precipitation of calcium carbonate on the floor of a shallow and fluctuating sea. This deposition kept pace with the submergence of the land so that, throughout the entire thickness of 1,060 feet (Theresa and Beauharnois), there is no evidence of other than very shallow water. Many layers are mud cracked, others consist of pebbles which are probably shifted mud-crack spalls. Most of the Beauharnois formation was originally deposited on the sea-floor as calcium carbonate, but while still wet on the sea-floor it was subjected to a base-exchange so that magnesium in the sea was substituted for calcium on the sea-floor. This resulted in a residue of calcium-magnesium carbonate, or dolomite remaining on the sea-floor. All gradations exist in the Beauharnois formation from unchanged calcium limestone to completely dolomitized limestone. Minor unconformities, even subaerial erosion surfaces, all attest the instability and the shallowness of the sea. We cannot say much about the life of that sea for, though there may well have been an abundant fauna, most traces of it were probably destroyed by the dolomitization process. Some of the larger gastropods are still preserved as molds. In the upper part of the formation, where limestone beds are preserved unchanged, fossils are fairly common.

That the Beekmantown submergence was of far more widespread importance than that which permitted the Potsdam to accumulate is shown by the finding, in many places in Quebec, of the Beekmantown beds resting directly upon the Precambrian. No such exposures are known in the Montreal area.

At the close of Beekmantown time, the sea withdrew completely, a conclusion which is borne in upon us not because of any angular unconformity between the Beekmantown and the overlying Chazy beds, for the contact is nowhere to be seen, but because of the totally different types of sediment characteristic of each, and because of the appearance of a completely new fauna. These features have been analysed exhaustively by Wilson (1937, p. 48). Moreover, were these indications lacking, we know that there is in this region no representative of the Lower or of the Middle Chazy. This new sea came in from the south or possibly east, probably along an embayment of a more widespread Chazy sea in the eastern part of the Appalachian trough, where the complete section of the Lower, Middle, and Upper Chazy was accumulated, as we see it at Chazy, N.Y. The embayment spread northeastward and northward and westward far beyond Montreal. As with most invading seas, there seems to have been plenty of detritus to be spread around and we find sandstones and shales common in the lowest beds. When the sea had spread enough to leave the Montreal area far out in clear waters, limestones could accumulate, and, in fact, the bulk of the formation is impure limestone. The invading sea brought with it its own quota of organic life, prominent among which were cystids and crinoids. These probably thrived in droves on the Chazy sea-floor and, when they died, their skeletons, disarticulated into the hundred or so separate calcareous plates characterizing each, were gathered up and swept around by the currents in the Chazy sea, making submarine bars and shoals of pure limy materials. All echinoderm skeletons show a marked tendency to crystallize upon burial, so that these piles of shell fragments soon took on a granular crystalline appearance, as we find them today. Here and there on such heaps of débris on the Chazy sea-floor and coral-like organisms built up reefs, later to be submerged by a fresh influx of current-borne cystid remains. The Chazy period was ended by a complete withdrawal of the sea in southern Quebec, probably in the same direction as that from which it came. Wilson (1937, p. 54) demonstrated that the unconformity between the Chazy and the Black River is not of great significance, and that the time interval concerned was of comparatively short duration, not comparable to that which separated the Beekmantown and Chazy.

Beginning with Black River time, another invasion by the sea began, this time, judging by the thickness and other features of the sediments deposited, coming from the west where, around Ottawa, the lower part of the Black River formation is very much better developed and more nearly complete than in the Montreal area. Locally, the lowest deposit of the early Pamelia sea was a thin-bedded black shale in which only a single species of a pelecypod, too poorly preserved for identification, and a *Lingula,* have been found. Both of these are mud-loving forms, and *Lingula* especially can live under almost any conditions on a shallow, muddy sea-floor. No free-swimming animals, no bottom-cruising animals, left a trace behind. It was, apparently, a fairly unhealthy place for organic life. Such mud as was swept in by streams draining the neighbouring lands, by that time probably reduced to old age so that nothing but fine mud was available, contributed to the present shales. It would appear, also, that the eastern end of this advancing sea was a cul-de-sac, devoid of open circulation and in which none but the least susceptible of organisms could survive. As the basin widened, the muds and their highly tolerant fauna probably hugged the shore line, whereas, in the central part, limestone was probably precipitated chemically, and was diagenetically altered to make the Pamelia dolomite as we see it today. It is not impossible that the waters were more than normally saline, for not a single fossil is known to occur in this dolomite. This is not attributable to the crystallization of the dolomite, for such characteristic is barely noticeable. Eventually, however, the land sank enough to allow the free circulation of sweet sea water. As that was accomplished, Pamelia deposits gave way to Lowville sediments. The abundance of oölitic beds in the Lowville formation betrays the tendency of this water to become saturated with $CaCO_3$, though the abundance of fossils shows that this was no debarment to an abundant fauna. The thin-bedded nature of the stratification and the abundance of local unconformities show that the sea level or the sea currents, or both, were fluctuating rapidly. By Leray time, such fluctuations had ceased, possibly because of a deepening of the waters, for we find thick, even-bedded limestones containing an abundance of corals, indicative of clear water, in which chemically precipitated $CaCO_3$ could form and remain undisturbed by currents.

Between Leray and Trenton times there seems to have been little if any break. One can find an erosion surface between the uppermost Leray and the basal Trenton, but the lithology of the adjacent formations is much the same and there was no greater break than those we see within both the Leray and Trenton rocks themselves. During Trenton time, Quebec, as with the rest of North America, suffered one of the greatest submergences of all time, and the Montreal area was below sea level for all but insignificant intervals.

The lack of outcrops of Black River formations south of the Saint-Lawrence might of itself be significant of nothing more than a vagary of exposure, complicated to some extent by faulting. But, in addition, nowhere south of Montreal do we find Lower Trenton beds. Beyond the Laval-Lachine areas, evidence from Lacolle allows us to conclude that the Black River beds and the Lower and lowest-Middle Trenton were actually deposited throughout southern Quebec but were destroyed in the minor and local uplift which followed soon after their formation, and which resulted in the formation of the Lacolle conglomerate (Clark and McGerrigle, 1936).

The long continued submergence of this part of the Province resulted in the accumulation of 800 feet, more or less, of limestones. That these were deposited in a shallow, well-lighted, food-filled sea is proved by the abundance of fossils and of hydrocarbons throughout the formation. In general, the Trenton limestones are purer at the base and more shaly at the top. The shaliness is made apparent by more consistent and thicker shaly partings between limestone layers in the Upper Trenton, and also by a greater diffused argillaceous content throughout the limestone. This argillaceous increase eventually reached its logical goal in the deposition of pure shale of the so-called 'Utica formation'. Because the Utica shales are, on the whole, thicker in the east than in the west of Quebec, Ontario, and New York, the source of the muds has been considered to be Appalachia, which at that time must have been rising unduly to shed an enormous amount of mud into the Appalachian geosyncline. This mud progressively smothered more and more of the Trenton limestone until, by what we call 'Utica' time, it formed a widespread blanket over the entire area in northeastern North America where previously the Trenton limestone had been accumulating.

This mud obliterated almost all life in the Trenton seas, and allowed little to come in from outside, for we find that with few exceptions the fossils in these beds are pelagic types, which lived and died on the surface of the sea, allowing their shells or skeletons to fall to the sea-floor and to be entombed there. The abundance of life is indicated by the general blackness of the shale, which, in its turn, is due to an abnormally high carbon content. The absence of benthonic elements in the faunas indicates a foul sea-floor, upon which no living thing could persist, but on which the constant decomposition of fallen pelagic bodies would generate, among other products, abundant H_2S which would not only militate against any indigenous bottom life but, in combination with any iron in the rocks, would make for the production of FeS_2, iron pyrite. It is a fact that, in many places, the Utica shale fossils are found replaced by pyrite. Graptolites, free-floating pelagic forms, make up the bulk of the Utica fauna, which otherwise includes only a small number of swimming or attached animals which were associated with the graptolites in much the same way as crabs, etc., are associated with the Sargasso seaweed today.

The change from the Utica to the Lorraine formation is marked by a change in rock type and in fossils. The Lorraine consists very largely of light to medium grey shale with interstratified beds of limestone and sandstone, and is apt to be abundantly provided with fossils of indigenous benthonic types. Thus there was a change from the conditions obtaining in Utica time of a sea-floor barren because of the abundance of putrid, decomposing surface-living forms, to a well aërated expanse teeming with life in Lorraine time. No doubt Appalachia continued its upward rise during this latter epoch so as to provide the enormous amount of sediment recorded elsewhere (2,357 feet on Nicolet river), although in the Lachine area only a few tens of feet are exposed.

The Lorraine strata are the last of the superimposed sedimentary rock bodies to be found hereabouts.

Following the Ordovician, there occurred in northeastern North America the Taconic disturbance, during which the first generation of Appalachian mountains was raised. Although no mountain making was experienced around Montreal, this region was sufficiently close to the scene of intense folding that its horizontal strata received gentle flexures. It is possible that some of these folds were induced, or perhaps exaggerated, during the Acadian disturbance in the Devonian, but there is no corroborative evidence, nor is there the slightest evidence that the final orogeny during the Carboniferous and Permian periods affected this region in any way now visible. The synclines and anticlines, then, date from the close of the Ordovician. It is more than likely, also, that the regional tilting of the beds to the southeast dates from this time.

Although there is little factual basis for the conclusion, it is quite possible that the major faulting was the result of the reaction of the crust to the overloading on the east by the piling up of the thrust sheets of the Taconic mountains. This applies to the named faults, such as the Bas-de-Sainte-Rose fault and the Sainte-Anne-de-Bellevue fault. Of the others, too small to map and too numerous to mention, some are probably to be ascribed to the continuous adjustment that takes place within the earth's crust consequent upon unloading by erosion, and some were doubtless caused by the Mount Royal intrusions.

Of the events of Silurian time we have no record. We know that a Lower Devonian sea was spread over southern Quebec during Helderberg and Oriskany time and that limestone formations of unknown thickness were accumulated, later to be brecciated during the formation of the Sainte-Hélène Island diatreme. A few such fragments, some fortunately abundantly fossiliferous, remained in the breccia at the present physiographic level.

Late Palæozoic Time

Later Palæozoic history is not vouchsafed us. Whether this region was once covered by Carboniferous forests later to be formed into coal we do not know; it is a possibility well worth considering academically, though no practical importance can be attached to it. We are just as much in ignorance regarding Mesozoic events, though there is almost a certainty that this region, in common (as it believed) with the rest of this part of Canada, was above sea level and exposed to erosion, although it does not appear that the removal of rock material was either rapid or great in amount.

Tertiary Period

Following prolonged erosion, plutonic activity manifested itself in the formation of the Monteregian hills at about the beginning of the Tertiary period. This is not the place to discuss the nature of the intrusion or intrusions as a whole: we must confine our remarks to the happenings in the vicinity of Mount Royal. As in the case of each of the other Monteregian hills, the first and most important intrusion was of a basic nature, locally resulting in the formation of a gabbro, usually known as essexite. After one or two episodes of dyking, a second intrusion, much more restricted, of nepheline syenite took place. Dykes or sills of several types continued to be injected before the force of the controlling magma chamber below was spent. It is possible that, at least as far as the gabbro is concerned, the magma actually reached the surface to issue as lava flows, or, more probably, it may have domed up the cover of sedimentary rocks to become emplaced as a laccolith. Minor manifestations of activity probably followed, with such events as the driving through to the surface of the Sainte-Hélène Island diatreme, forming a pit comparable to the maaren of the Eifel. The metamorphism and crumpling of the limestones surrounding Mount Royal, and the brecciation attendant upon the successive injections, have already been described.

The remainder of the Tertiary period, about 50,000,000 years, was occupied by ceaseless wearing away of the volcano or laccolith, if any existed, and also of the Devonian and any superincumbent strata, and by the planing-off of the tilted Ordovician beds, whose bevelled edges today expose the successive formations and permit determination of the stratigraphic succession. It is too highly speculative to discuss the rôle of the Laurentian river (the ancestral, pre-glacial Saint-Lawrence) in reducing this terrane to its present low estate, but it is perhaps permissible to hazard a guess that the Quebec lowland was in reality the wide flood-plain of a river in old age, bordered on the northwest edge by the Laurentians and on the southeast by the Appalachians.

Quaternary Period

This period ushered in the glacial episode, which still further reduced, by glacial abrasion, the surface of the rock floor hereabouts, and stripped from the rocks of the mountain and elsewhere all trace of pre-existing soil. (For a description of the effects of glaciation upon the Montreal area, see Stansfield, 1915). In immediately post-glacial time this region was low enough to suffer the Champlain marine submergence during which the lowland was partly filled with marine clays and sands. The final disappearance of the sea left the countryside much as it is today.

ECONOMIC GEOLOGY

The economic resources of the Montreal area that are now utilized are the solid rocks, gravel, sand and clay, and ground water. The possibility of the presence, in some places, of underground stores of oil and natural gas should not be ruled out, despite the fact that drilling for these resources in the Montreal and adjacent areas has, up to the present, met with no success.

Each of the main types of sedimentary rocks of the area is used as a source material for a manufactured product of some kind or other, and, save for the Lorraine shales, every age group is represented in the list of valuable source materials. Sandstone is used in the manufacture of ferro-silicon, shale for brick-making, dolomite for building-stone, and limestone for building-stone, road-material, and cement. The igneous rocks are used to a slight extent — less so today than formerly — as road-material.

Sandstone

In former years, the Potsdam sandstone was quarried extensively on Ile Perrot for the building of the bridges and abutments at Sainte-Anne-de-Bellevue. Elsewhere, at Cascades point, a large quarry provided rock for the work along the Soulanges canal. At Melocheville, numerous small quarries were formerly operated to yield building-stone for the works along the old Beauharnois canal and for local buildings. One quarry in Melocheville once provided crushed sandstone for glass-making, until the importation of Belgian sand made this unprofitable. In earlier years, also, this quarry, now known as the Monpetit quarry, furnished practically pure crushed silica to St. Lawrence Alloys, Limited, for use in the manufacture of ferro-silicon. That Company now operates its own quarry, half-a-mile farther southwest.

In many places, the sandstone is pure enough and in sufficient thickness for exploitation as a source of practically pure crushed silica. Keele and Cole (1922, p. 100) give the following analysis of crushed and screened rock from Melocheville ready to be shipped to Montreal for glass-making:

SiO_2	98.25	per cent
Fe_2O_3	0.16	"
Al_2O_3	0.17	"
CaO	0.70	"
MgO	—	
Loss on ignition	0.35	"
Total	99.63	per cent

Demand for this stone for the making of ferro-silicon is not likely to increase materially, but for glass-making, for abrasives, and for local construction, the Potsdam sandstone deserves further consideration.

Shale

The shale beds of the Chazy limestone are nowhere adequately exposed, nor, from an examination of them in the core of the Sainte-Thérèse well, would one be justified in expecting them to be of commercial value. The Lorraine shales, intermixed as they are with sandy and calcareous beds, are nowhere, within the limits of the present area, used for any purpose whatsoever, as far as the writer knows. The Utica shale, on the other hand, is a suitable raw material for brick-making where it contains a fair amount of kaolin. It is quarried by steam shovel at the Laprairie Brick Company's plant at Delson, left to disintegrate under the weather for a few days or weeks, and then mixed with varying proportion of glacial clay before final crushing and levigation. The National Brick Company formerly operated a huge pit at Delson, but the plant is now dismantled and the pit abandoned.

Limestone and Dolomite

Beekmantown Dolomite

It is remarkable that the Beekmantown dolomite has not been more widely utilized as a building-stone. Although from outcrop to outcrop it is a very variable stone, such buildings as have been constructed of it, e.g., the churches at Sainte-Thérèse and Saint-Eustache, are fully as pleasing in appearance as any made of the Chazy limestone. To be sure, it weathers readily to a greyish-buff, which is not so 'clean' looking as the Chazy limestone, but even so, its colour is anything but displeasing. As road-material, the stone is satisfactory provided it is not coarsely crystalline, when it tends to crumble. A dozen or so small quarries attest its use as a source of road-material, some opened solely for the purpose of providing crushed stone for a few miles of highway. Only three or four have been developed to the extent of being capable of providing building-stone. The most important of these is a mile south of Sainte-Thérèse, whence came part of the stone for the Roman Catholic church at that village. The lower, more sandy beds should never be used for structural purposes because of the ease with which they lose the magnesian cement from between their sand grains and in consequence crumble.

At De Lery, a series of small quarries have been opened which at various times have produced stone for local use. One, owned and operated by Alphonse Faubert, produced and shipped stone to Montreal for building purposes. Saint-Paul's school, Westmount, and Saint-Peter's church, Town of Mount Royal, are constructed of stone from this quarry, in which it occurs in several beds, ranging in thickness from 6 inches to 1 foot, which are nearly pure dolomite, and hence are free from the objectionable pitting due to weathering which soon disfigures a dolomite with an abundance of sand grains.

Farther to the northeast, a mile west of Chateauguay, a quarry operated by Laberge and Marchand has been providing crushed dolomite for road-material and for the manufacture, at the quarry, of cement sewer pipes. The rock is a dense dolomite and dolomitic limestone, with not many beds thick enough to yield a good supply of building-stone.

Chazy Limestone

This was once the most important source of building-stone and crushed stone in this area. For the past few decades production of dimension-stone has been at a low level, partly on account of depressed levels of business, and partly on account of the decline in the use of stone for building construction, particularly so far as private residences are concerned. One must also appreciate the ease with which stone may be imported from other centres today compared with the difficulty and expense of such a procedure fifty to a hundred years ago. In 1939, of the group of more than half-a-dozen quarries at Saint-François-de-Sales, some huge by any standard, only one was producing, and that to a very limited extent. At Village Bélanger, two quarries were active, four or more inactive. At Cap Saint-Martin, two were active, six were quiet. At Saint-Martin, one was active, one quiet. Inactive quarries could be seen north of Sainte-Thérèse, eastnortheast of Sainte-Thérèse, at Côte-des-Perrons, Rue Saint-Elzéar, and Saint-Vincent-de-Paul. At Cartierville, one quarry alone was producing stone and only in insignificant amount. At Bordeaux there was no production. Two large quarries at Saint-Laurent were active, supplying crushed stone for building and highway purposes. The Villeray quarries were unused and water-filled. No production was to be noted from the Chazy quarries on Ile Bizard or at the western end of the island of Montreal. Numerous openings not worthy of the name quarry can be seen wherever the Chazy rock occur at the surface. In 1949, conditions had improved a great deal, and though the number of active quarries remained much the same (two at Saint-François-de-Sales, four at Cap Saint-Martin) the quantity of stone produced had more than doubled as compared with the output in 1939.

South of the Saint-Lawrence there are a dozen quarries in and to the south of the village of Caughnawaga. One only, the most extensive of these, a mile southwest of the village, is at this time active. Excellent building-stone is available here, and these quarries could provide crushed rock far in excess of local needs. Six miles southeast, and a mile east of Saint-Isidore Junction, there is a small disused quarry, on the farm of Domina Charron, once used for the production of stone for the Saint-Constant church. It has since remained idle and is now filled with water.

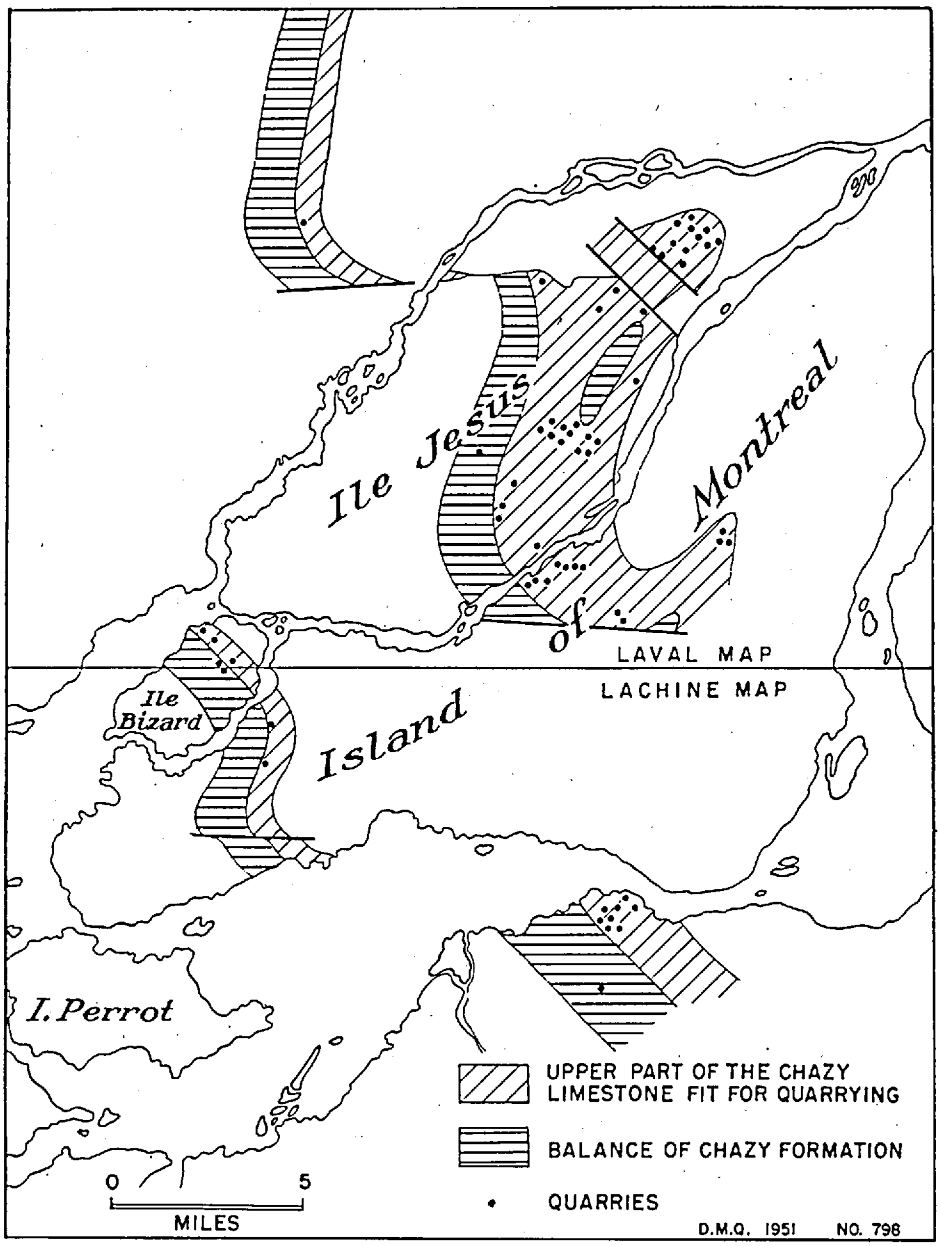

Figure 12 - Map showing quarryable deposits of Chazy limestone, Laval-Lachine map-areas.

These quarries are, without exception, opened in the heavy-bedded, crystalline strata of the upper seventy-five to one hundred feet of the formation. This, as noted earlier in this report, has an area of outcrop disproportionately great considering that it is one-third or less of the thickness of the entire formation. The fact remains that, on Ile Jésus alone, over an area of at least 15 square miles, crystalline limestone of the Chazy formation will be found at the surface or below the drift (see Figure 12). There is no lack of this important resource. The present quarrying operations have merely scratched the surface. While it is not to be supposed that, in future years, the consumption of limestone for building purposes will approach, much less surpass, the high level of fifty years ago, it is important to bear in mind that this limestone, or certain beds of it, are remarkably high in calcium carbonate, high enough to support certain chemical industries which do not demand a stone containing more than 96 per cent $CaCO_3$. Also, a revival of road building would stimulate the production of crushed stone, and the building up of more settled areas would increase the consumption of curb stones. The Chazy limestone suffers at the present form a reputation to develop seams upon weathering. If this were avoided by a judicious choice of suitable beds, there seems no reason why this stone should not return to favour as a building-stone, though its production will always be dependent upon labour costs.

At the Legacé quarry, Saint-Martin, about sixty men were employed in 1938 taking out dimension and crushed stone for the building of the Charlemagne bridge. The Andorno quarry at Cap Saint-Martin, the Charbonneau quarry at Saint-François-de-Sales, the Charron quarry at Village Bélanger, and the Martineau quarry at Pont Viau, produce a small amount of cut stone, and in recent years the last-named quarry has supplied cut stone for several large buildings in Montreal, *e.g.*, the Neurological Institute, McGill University. The Soula and Polis quarries, at Saint-Laurent, are both active in the production of crushed stone. They are now operated by, respectively, St. Francis Rock Products and Equipment, Limited, and St-Laurent Stone Products and Supplies, Limited.

For a full description of the technicalities of this resource, the reader is refered to works by Parks and by Goudge listed at the end of this report.

Black River Limestone

Two miles north of Saint-Vincent-de-Paul, two or three exploratory pits, and a small quarry, have been opened in the Black River limestones, all probably in the search for road-material. The only extensive use in this area to which these rocks have been put was in connection with the building of the dam below Visitation island. For the purpose of providing suitable stone, the huge quarry of the Montreal Crushed Stone Company was opened a mile west of Saint-Vincent-de-Paul. There the entire thickness of the Black River group was cut through and, though the heavy-bedded Leray limestone is admirably exposed, no information could be obtained as to whether or not advantage was taken of its special qualifications. It would yield an abundance of blocks, about 24 to 36 inches thick, in almost any desired size. It is far more durable than the Chazy limestone and, even if considerably less abundant, constitutes a potential resource of large-dimension blocks with which builders should acquaint themselves.

The Lowville limestone, though for the most part fairly pure, is too thin-bedded to be of much use as a building-stone. For crushed stone it is admirable, and its thin-bedded structure reduces considerably the expense of crushing.

It is at Pointe Claire that the rocks of the Black River group have received most attention. Along an east-west ridge which extends for two miles between the shore of lake Saint-Louis and the railway tracks, quarries have been opened in three places and have yielded building-stone of very high quality. On the west side of Cartier avenue is an escarpment which was at one time the back wall of an earlier quarry whence, it is said, came some of the stone for the piers of the Victoria bridge. Across the road to the east, is a quarry, now abandoned, known earlier as the Davito quarry and laterly as the Lakeshore Construction Company Quarry, which produced only crushed stone; and, still farther east, the Fuger and Smith quarry specializes in the production of a small amount of high-grade building-stone. Because it is all pried out by crowbar, there is no blasting to weaken the rock, and, although the product is expensive, it is well worth the extra cost.

Trenton Limestone

By far the most valuable rock unit, as far as its products are concerned, is the Trenton formation. However, save for its exposures on the northern part of the island of Montreal, Trenton limestone has not been successfully used for anything but crushed stone for road-material, and only at Saint-Vincent-de-Paul have there been any large-scale operations. One small quarry at Lepage produced rock for lime-burning up to 1944.

On the northern part of the Island, there is a different story to tell. All divisions of the Trenton group have been quarried. The Mile End and Saint-Michel beds originally provided Montreal with much of its building-stone, and even now the Mile End member contains a 13-foot tier of remarkably pure limestone which is sometimes burned for lime. Quarries at Rosemount (all now inactive), Mile End (all now filled-in), and Saint-Michel were all opened in these lower members of the formation. Miron et Frères, Canadian Quarries, Montreal Quarry, and National Quarries all operate quarries in the lower Trenton beds exposed along the northwest side of Côte Saint-Michel. Of considerable importance is the limestone of the Tetreauville member, abundantly exposed from Notre-

Dame-des-Victoires northward. It is this member that provided the rock for three great cement quarries, of which but one (Canada Cement Company quarry) is operating today. Its value as a source rock for cement rests partly upon its argillaceous content, but also upon the constancy of its composition. Moreover, it happens that that part of the island of Montreal is supplied with dykes and sills which give the requisite proportions of silica and iron in the resulting cement.

Until 1931, two companies were quarrying limestone here for the manufacture of cement. The National Cement Company was working a quarry in the northwest corner of Sherbrooke street and Broadway, and the Canada Cement Company's quarry was two miles to the south. The latter Company had already abandoned an old quarry at Longue Pointe. In 1931, the Canada Cement Company acquired control of the National Cement Company, since which time the latter Company's quarry has been disused and the plant gradually dismantled. There is, therefore, one quarry only actively engaged in the production of the raw materials for the manufacture of cement. This is without doubt the largest quarry in this area, possibly the largest in Canada, nearly half a mile square and in one or two places nearly one hundred feet deep. The stone for a depth of 142½ feet from the surface is remarkably uniform in composition (see page 72, and Goudge, 1935, p. 112).

One mile east of the old National Cement Company's quarry is the Durocher quarry (Plate IX-A) actively engaged in producing crushed stone. This quarry, about 500 feet by 600 feet and 65 feet deep, exposes evenly stratified limestone of remarkable regularity, complicated by but one dyke.

Igneous Rocks

Before the general use of asphalt-mix and concrete for roads, the igneous rocks hereabouts were to some extent used for road-metal. Their superior hardness made them durable, but their poor accessibility prevented their general use. Today, as far as is known, no igneous rock is quarried for any purpose, save as an adulterant in the making of cement. Nevertheless the Corporation (or Forsyth) quarry, several smaller nearby quarries, and the Westmount quarry, all utilized, as part of their product, the igneous rocks of Mount Royal. The Trenton and Chazy limestones, infinitely more abundant, and easier to quarry, have been ever-present substitutes for the more durable igneous rock.

At several places in this area there are exposures of tough sill rock capable of producing stone for both roads and buildings. One of the best known of these is the Sainte-Dorothée sill. Although this rock is difficult to crush it makes the very finest type of road-material for unsurfaced roads. Basaltic jointing renders the rock peculiarly easy to quarry; in fact, when the quarry belonging to Camille Laurin (Plate XIII) was being worked twenty-five years ago, the practice was to dynamite the base of a column which would tumble *en masse,* effecting a satisfactory amount of self-fracturing as it fell. The rock weathers very little, and is, in particular, nearly free from iron-rust stains. The dykes and sills of the Montreal Crushed Stone Company's quarry and along the north shore of rivière des Prairies nearby decompose and rust too rapidly to be of much value as either building-stone or road-material.

The tough, resistant Masson Street tinguaite sill (Plates VIII-A, VIII-B) was quarried for years, although all production has now ceased. In 1939-40, the exposure in the Rosemount quarry, now the property of the Botanical Gardens, was worked to a limited extent to provide stone for some of the developments in connection with the Gardens. The tinguaite of these quarries, termed by the quarrymen 'banc rouge', was crushed and sold separately from the limestone, and, because of its superior hardness, brought a higher price.

The pleasing appearance of the breccia quarried on Sainte-Hélène island, and incorporated into several buildings there, indicates that breccias elsewhere might be similarly utilized.

SAND AND GRAVEL

The escarpment one mile north of Terrebonne is a potential source of sand of many different qualities. Much of it carries considerable admixed mica and thus would not be satisfactory as a raw material for cement making. Sand and gravel, wherever found and needed, are utilized for roads. It is impossible to give any figure indicating the tonnage or value of production. The chief output is from the western part of the area. East of Plage Laval there are sand pits covering several acres whence sand has been extracted to a depth of twenty feet, much of it being shipped to Montreal to be used in concrete making. In the southwestern corner of the Laval area there is a widespread blanket of sand which, if it could be shown to be economically important, would constitute a valuable resource. To the northwest of the mainland lie, virtually untapped, resources of sand which should be sufficient for the needs of the metropolis for centuries to come.

The gravel ridge traversing the southern half of the Lachine map-area has already been described. The material has been used extensively for railway embankments and is actively quarried today for use in road making. For both purposes, there is a practically unlimited reserve.

ARTESIAN WATER

Practically the entire rural population of the area depends upon artesian water or well water. Because of the importance of the proved occurrence of ground water in deep wells and of the demand for more artesian water for special purposes, the Geological Survey of Canada published a report by Adams and LeRoy in 1904 on *The Artesian and Other Deep Wells on the Island of Montreal.* Within ten years of the publication of that report the number of deep wells on the Island had doubled, doubtless in part as a consequence of the information contained in that report. To satisfy the demand for additional data, the Survey in 1915 published a memoir by Cumming on *The Artesian Wells of Montreal,* from which the following paragraph (p. iv) is reproduced:

"In the main, the deductions drawn in the first report have been fairly well substantiated. The chances of striking water are, however, considerably more favourable than appeared from the data then available. Only one well in ten yields less than 5,000 gallons per diem. Also, with regard to the depth to which it is advisable to bore, the conclusions there deduced have been well verified.

In general, artesian supplies of water are found in the Trenton formation; more rarely, they are encountered in other rock bodies. They appear to depend largely upon the existence of small cavities in the limestone. However, because there are no data concerning such cavities, all predictions as to the success or failure of a projected well are based upon an evaluation of the evidence given by the 'average' success of previous wells in the proposed area and the depth to which they were sunk. Cumming (p. 3) states that "the most favourable depths for obtaining good supplies of water are between 300 and 1,000 feet", and he adds that "below 1,000 feet, the chances of striking substantial supplies of water become very small".

Cumming was able to delimit areas where 'soft' sodium waters could confidently be expected. This is of great importance to concerns needing water for steam boilers, for tanning purposes, or for breweries. A good deal of the artesian water contains so much calcium carbonate as to unfit it for use in boilers. Most of the water actually withdrawn from artesian wells today is used for cooling purposes.

In the surrounding country, practically the whole water supply for houses beyond the confines of the larger villages comes from shallow wells dug in the glacial drift. The supply of such water is dependent almost wholly upon the contemporaneous rainfall, whereas the flow from an artesian well, although ultimately dependent upon rainfall, is probably independent at any given time of the current years precipitation and is hence more reliable.

Oil and Gas

In many places the Trenton limestone, when freshly broken, shows a few small cavities, each containing not more than a droplet of oil. This oil can rarely be collected, but instead spreads over the fractured surface and yields the characteristic petroleum odour. Quite naturally, this phenomenon has aroused in many minds the possibility of finding oil or natural gas in commercial quantities. To date, no exploration for either of these commodities has been successful.

There are three essential elements in the natural formation of a reservoir of petroleum. First there must be, or must have been, a source rock; second, there must be a suitable reservoir rock; and third, the geological structure must be suitable for oil storage. Of these, the first, though an essential original factor, need not be a lasting one. Oil, generated in a source rock, may migrate elsewhere, after which it is not affected by the fate of its parent formation, which may be totally destroyed. In the local situation, the Trenton limestone is the only rock known to bear indigenous oil, and it therefore ranks as the only competent source rock. Gas in small quantities has been found in other formations, but, as far as is known, no indigenous oil has been discovered outside of the Trenton limestone.

Oil and gas once generated may remain in the source rock, which thereby becomes, in addition, the reservoir rock, or it may migrate, in almost all cases upward, until it reaches a rock sufficiently porous to retain it. Of all of the local formations, only the Potsdam sandstone and the Trenton limestone seem to be capable of acting as reservoir rocks. The Potsdam sandstone, on account of its high porosity, would act as a competent reservoir rock though its relatively great depth below the Trenton limestone (source rock) reduces the chances of its having received any oil from that source. There is always the possibility that organic remains within the Potsdam sandstone itself might have yielded oil, though this seems, in quantity at least, to be very remote. The only available analyses of the hydrocarbon content of this formation were made during the drilling of the Mallet well, and, coming from samples from the horizons whence came the greatest flow of gas, 973 feet below the top of the formation, showed 0.504 and 0.450 per cent free hydrocarbons, neglible amounts in terms of the requirements for commercial production. The Trenton limestone might serve as both source and reservoir rock, for not only does it actually contain a small quantity of oil but it is known elsewhere to be a competent reservoir rock for artesian water. However, no wells so far drilled into or through the Trenton limestone hereabouts have discovered oil.

The third factor, a suitable geological structure, controls the ability of the rock formations to stop the migration of oil and gas and to hold them more or less intact so that they may be found in later exploration. The structure of the local rocks in general consists of a series of easterly dipping strata complicated by folds and faults. A simple series of evenly dipping strata is not a favourable structure in which to find oil, for any migration would carry the oil upward, in this case to the west, into parts of the formation since removed by erosion. *A priori,* then, one would consider most favourable some complication of this simple structure which has resulted in a monocline, a dome, or a fault which would have acted as a dam to migrating oil. Of folds, we have on Ile Jésus but one of any interest—the Ile Jésus anticline. Although the structure is satisfactory, it contains—except in the northeastern extension, as noted below—nothing which could be considered a source rock, and hence, in the absence of known oil deposits, it should be considered potentially barren. No trace of oil or gas has, to my knowledge, been discovered within the area covered by this fold on Ile Jésus.

The Villeray anticline, on the island of Montreal, is not a favourable structure because erosion has truncated it, as a consequence of which any oil or gas migrating up the dip would escape. No local expressions of any importance lead one to suspect the presence of oil or gas save where the limestone of the Tetreauville member outcrops, with its strong petroliferous odour.

The Ahuntsic syncline would not be considered a favourable structure for prospecting. Synclines, except in the very rare condition where the rocks are dry, are practically never oil bearing.

The Bas-de-Sainte-Rose fault might have acted as a dam to oil migrating toward it from the northward, but such oil would have been offered no barrier to its migration due westward. Not enough is known yet regarding the structure of the Trenton limestone south of the White Horse Rapids fault to draw conclusions as to its probable influence upon oil accumulations, but the complete lack of oil seep and oil pockets in the rocks themselves, or of gas in water wells, is negative evidence that cannot be neglected.

There is therefore nothing in the local structure which could be considered favourable to the successful exploration for gas or oil hereabouts. What of the actual findings? For a few miles west of Terrebonne, the limestone is petroliferous, as it is also at the outcrops one mile east of Lepage, on Mascouche river. The cavities in the rock are seldom larger than a common pin head and never more than a quarter of an inch across. They could not, in themselves, be considered a source of petroleum, though one might adopt the view that they are all that is left after the more mobile oil has left. The Tetreauville limestone is in many places petroliferous. Gas has been encountered in drift wells at Saint-François-de-Sales. No other actual occurrence is known.

Under these circumstances, the search for oil in the drilling of the Mallet well at Sainte-Thérèse during the winter of 1937-38 was an undertaking which could be justified only by success. The reasons for the selection of the actual spot where drilling was undertaken are not such as would be of interest to geologists. The drill penetrated ten feet of drift, 270 feet of Chazy limestone, 1,060 feet of Beekmantown dolomite, and had gone through 1,696 feet of Potsdam sandstone when operations were suspended because of the imminent failure of the drilling machine. At the conclusion of the work, the drill had penetrated 3,036 feet below the surface, and had yielded a nearly continuous 1⅛-inch core of the solid rocks traversed. This core, which Mr. R. de Roumefort presented to the Quebec Department of Mines, has been examined by the writer and is the basis for much of the information, and many of the conclusions, given in the foregoing pages. The thickness and characteristics of the Chazy and Beekmantown beds penetrated have already been detailed. The relatively enormous thickness 1,696 feet, of Potsdam sandstone, with no base reached, is astounding. Elsewhere, the thickness of the Potsdam sandstone ranges as a rule up to a mere two or three hundred feet. It is obvious that the surface of Precambrian rocks upon which the Potsdam sandstone was deposited must have had a relief hereabouts at least equal to the thickness of the sandstone in the well, 1,696 feet, plus the thickness that remained undrilled when the hole was abandoned in 1938. The hole was found to be dry, and all the water used for drilling was pumped from a nearby shallow well.

Practical results achieved in the course of drilling were not encouraging. No oil was found anywhere. Puffs of gas occurred at several horizons within the Beekmantown and the Potsdam formations, being more numerous in the latter. With the permission of Mr. de Roumefort, I am able to quote directly from the report of the engineer in charge concerning the occurrences of gas, as follows:

> "*Natural gas:* The following is a resumé of the natural gas seepages encountered in the test hole. The first gas occurrence was met on the 329-foot level in the Beekmantown, where a strong flow of gas lasted for a period of two hours under fairly high pressures.
>
> "Eleven other gas occurrences of minor importance were encountered above the 1,000-foot level, with pressures only strong enough to clear the hole of its water content.
>
> "On the 1,000-foot level, a strong flow occurred raising the water some twenty feet above the derrick. In this case, the drill was held up for a period of two hours.
>
> "Six other gas occurrences, all of high pressure, were encountered in the Beekmantown formation, the flow lasting from one to three hours.
>
> "The next flows were recorded on the 1,457- and 1,630-foot levels in the Potsdam, but they were of minor importance. On the 1,644-foot level, the gas flowed steadily for a matter of three hours.
>
> "The strongest flow in the hole was encountered on the 2,313-foot level, lasting six hours under very high pressures and forcing the water some 100 feet over the top of the derrick.
>
> "In all instances where gas was encountered, the residue gathered from the water in the hole contained particles of black carbonaceous shale matter.

"Owing to the absence of meters for registering the flow of gas, tests were made by piping the flow outside of the drill shaft and burning same.

"A strong odour of petroleum emanated from this gas, which I would judge to be fairly pure methane gas with a substantial hydrocarbon content...

"*Presence of Petroleum:* On the 2,313-foot level, where the strongest flow of gas under high pressure was obtained, carbonaceous shale and core were found and samples of these shales were sent to McGill University for analyses. Two determinations were made, samples Nos. 1 and 2, containing 0.450 per cent and 0.506 per cent hydrocarbons, respectively".

It may not be amiss to quote from W. A. Parks (1930, p. 81) as follows: "In the first place, it must be emphasized that the occurrence of small quantities of gas in holes drilled into stratified rocks is the rule rather than the exception. Little or no significance should be attached to occurrences of this kind".

It had been the intention of the sponsor of the Mallet well to continue drilling farther, but the *B* machine used had been extended to the limit. Installation of an *N* machine was contemplated, but, because continuation of the same hole would have required, first, its reaming out from the surface downward, the question arose as to whether or not it would be advisable to drill elsewhere. In April, 1938, operations ceased, the rig was dismantled, and the hole sealed.

From the geological point of view there is nothing to recommend the site of this well as a potential oil-producing location. The surface rocks are below the accepted source rocks, no actual indication of oil occurs nearby, and there was no known or suspected geological structure to arouse reasonable expectation of the presence of an oil pool.

Nor does there seem to be any *a priori* reason for expending anything but trivial sums upon exploration anywhere in the area here considered, except possibly in the extreme northeastern corner. There one finds the local source rock, the Trenton limestone, covered by an impervious layer of Utica shale, and, given a normal amount of irregularity of dips, there is at least the possibility that oil might have been trapped beneath the shale. It cannot be said what effect the Bas-de-Sainte-Rose fault may have had upon oil possibilities there, without a considerable amount of geophysical prospecting. I do not mean to say that I would recommend drilling there, but I do mean that in the vicinity of Saint-François-de-Sales, Terrebonne, and Lachenaie, the cards are at least not stacked against the prospector. Even so, geophysical work should be carried out to determine the minutiae of the underground structure, and this would probably not be undertaken by a responsible company until the region had been proved productive by an exploratory well.

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The following theses, presented in partial fulfilment of the requirements for the degrees of M.Sc. and Ph.D. in the Department of Geological Sciences at McGill University, and kept on file in the Redpath Library, have been consulted freely. Acknowledgments in the text of this report are given thus: (Allan, unpublished manuscript).

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APPENDIX

(Based on information submitted in 1950)

SHALE, LIMESTONE, AND SANDSTONE QUARRIES

SHALE

LAPRAIRIE BRICK COMPANY, Delson, Laprairie County

Approximate dimensions: 477,200 square feet, 20 feet deep
Men employed (in quarry): 5
Equipment: 2 steam shovels, 1 truck
Production: Shales for 20,000 M brick equivalent per year
Analysis of stone:

SiO_2	55.80	per cent
Al_2O_3	20.02	"
Fe_2O_3	8.88	"
CaO	1.60	"
MgO	3.70	"
Loss on ignition	6.45	"
Alkalies by diff.	3.55	"

LIMESTONE

CANADA CEMENT COMPANY, LTD., Montreal East

Operated by present owners since 1909
Approximate dimensions: 1,950 ft. by 2,400 ft. by 85 ft. deep
Men employed (in quarry): 59
Equipment: 3 well drills (1 9-in., 2 6-in.), 3 electric shovels (1 5-yd., 2 3-yd.), 9 15-ton trucks, 1 54-in. gyratory crusher, 2 *SXT* No. 14 hammer mills
Production: Raw cement rock, 5,500 tons per day
Analysis of Stone:

SiO_2	12.10	per cent
Al_2O_3	3.96	"
Fe_2O_3	1.58	"
CaO	42.30	"
MgO	2.50	"
Loss on ignition	36.07	"

Stone is hauled from electric shovels up a ramp of 7 per cent grade by trucks which dump directly into the gyratory crusher. After passing through the hammer mills, the product is conveyed on dual belt conveyors to storage.

LASALLE QUARRY, LTD., 8413 Blvd. Saint-Michel, Montreal

Quarry opened in 1945. Previus owners: *Lasalle Builders Products Company,* Stinson Reeb Supply Company
Men employed: 30
Equipment: 5 trucks, 5 drills, 2 crushers, 9 vibrators, 1 pulverizer
Production: Up to 2,000 tons crushed stone per day, and could produce up to 200 tons of agricultural lime per day

MIRON & FRÈRES, LTD., 2201 Côte Saint-Michel, Montreal

Quarry opened 1949
Approximate dimensions: 1,200 ft. by 300 ft. by 30 ft. deep (direction of principal axis northwest)
Men employed: 41
Equipment: 4 crushers, 4 25-ton trucks, 2 mechanical shovels, etc.
Production (per hour): 200 tons crushed stone, 100 tons rock sand, 90 tons agricultural stone, 30 tons limestone dust
Analysis of stone:

SiO_2, Fe_2O_3, Al_2O_3	7.75	per cent
$CaCO_3$	90.00	"
$MgCO_3$	0.40	"

ST. FRANCIS ROCK PRODUCTS & EQUIPMENT, LTD. Ville Saint-Laurent, Jacques Cartier County

Approximate dimensions: 400 ft. by 300 ft. by 75 ft. deep
Men employed: 10 to 12
Equipment: Crushers, screens, compressors, drills, power shovels, trucks, etc.
Production: Crushed stone only; 6,000 tons per month

ST. LAURENT STONE PRODUCTS AND SUPPLIES, LTD. Ville Saint-Laurent, Jacques Cartier County
Approximate dimensions: 800 ft. by 300 ft. by 75 ft. deep
Men employed: 2 to 3
Equipment: Crushers, power shovel, compressors, drills, etc.
Production: Rubble stone only; 2,000 tons per month

HARGATE QUARRIES, LTD., Cap Saint-Martin, Laval County
Present owners began operations in 1947. From 1935 to 1945 the quarry was operated by J. E. Andorno
Approximate dimensions: 325 ft. by 200 ft. by 50 ft. deep
Men employed: 7
Equipment: 2 crushers, 2 rotary screens, 2 trucks, 1 compressor, 3 electric motors, 1 bucket loader
Uses and production: 2,200 tons crushed stone per month, operating 9 months per year; 400 tons agricultural lime per year
Analysis of stone: 95 to 97 per cent $CaCO_3$

LA CARRIÈRE CAP ST. MARTIN, ENRG., Cap Saint-Martin, Laval County
Prior to 1935 known as the Laval Quarry Company, Ltd.
Men employed: about 15
Equipment: 3 crushers, 3 trucks
Production: Crushed stone only; 300 to 400 tons per day
Analysis of stone:

SiO_2 and insol	2.80 per cent
Fe_2O_3	3.07 "
Al_2O_3	1.53 "
CaO	51.12 "
MgO	0.57 "
Loss on ignition	40.91 "

Spur track connection with Canadian Pacific railway

MARTINEAU CUT STONE COMPANY, LTD. (LA CIE DE PIERRE DE TAILLE MARTINEAU, LTÉE.) Pont Viau, Laval County
Prior to 1946 operated by Martineau Fils, Ltée.
Approximate dimensions: 600 ft. by 360 ft. by 25 ft. deep
Men employed: 12
Equipment: Mechanical shovels, derrick with electric hoist, compressors, drills
Production: Building-stone only
Analysis of stone:

SiO_2	0.86 per cent
Fe_2O_3	0.69 "
Al_2O_3	0.50 "
$Ca_3(PO_4)_2$	0.07 "
$CaCO_3$	92.70 "
$MgCO_3$	4.64 "

FUGER & SMITH, LTD., Brunet Ave., Pointe Claire, Jacques Cartier County
Prior to 1923 operated by Charlesbois & Schetagne
Approximate dimensions: 300 ft. by 400 ft.
Men employed: 3
Equipment: 2 compressors
Production: Building-stone only; about 50 cu. ft. per week

CANADIAN QUARRIES COMPANY, Ville Saint-Michel, Laval County
Formerly worked by Varin & Barbin, Ltd.
Approximate dimensions: 2,000 ft. by 1,000 ft. by 50 ft. deep
Men employed: 40
Equipment: 3 crushers, 4 vibrators, 3 rolling screens, 6 trucks, 3 shovels
Production: Crushed stone; 50,000 tons per month

CHARRON ET FILS, Canton Bélanger, Laval County
Opened in 1946
Approximate dimensions: 75 ft. by 20 ft. by 7 ft. deep
Men employed: 4
Production: Building-stone only; 5 tons per day

PÉNITENCIER ST. VINCENT DE PAUL, Saint-Vincent-de-Paul, Laval County
Approximate dimensions: 300 ft. by 200 ft. by 15 ft. deep
Men employed: 1 instructor, 40 prisoners
Equipment: 1 crusher, 2 derricks, 1 compressor, 1 locomotive and wagons
Production: 30 tons crushed and construction stone per day

CARRIÈRE POINTE CLAIRE, Beaconsfield, Jacques Cartier County
Approximate dimensions: 3,000 ft. by 200 ft.
Men employed: 10
Equipment: 1 crusher, 1 mechanical shovel, trucks, drills, etc.
Production: 250 tons crushed stone and 100 tons of stone for lime, per day

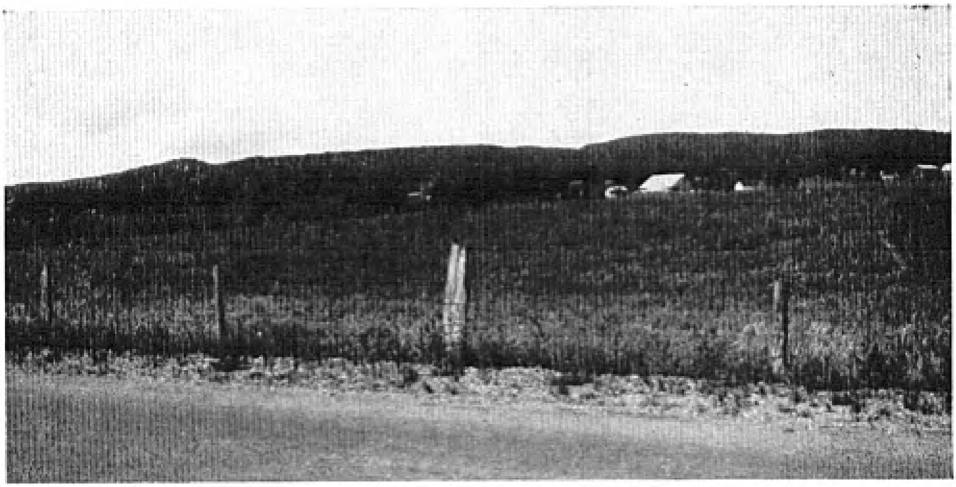
JEAN BÉDARD, LTD. Caughnawaga, Laprairie County
Quarry operated earlier by Co-operative Agricole de Ste-Martine
Men employed: 25
Equipment: 1 crusher, 4 trucks, 2 mechanical shovels, 2 drills (mechanical), 1 compressor
Uses and Production: Crushed stone, 600 tons per day; agricultural lime, 50 tons per day; asphalt-mix rock, 50 tons per day

Analysis of stone:	SiO_2 and insol	2.89	per cent
	Fe_2O_3, Al_2O_3	1.57	"
	$CaCO_3$	91.45	"
	$MgCO_3$	2.62	"
	Undet	1.47	"

SANDSTONE

ST. LAWRENCE ALLOYS AND METALS, LTD., Melocheville, Beauharnois County
Quarry opened 1945
Approximate dimensions: 350 ft. by 600 ft. by 40 ft. deep
Men employed: 43
Equipment: Drills, crushers, conveyors, screens, trucks
Production: Crushed stone exclusively, for use in manufacture of ferro-alloys
Analysis of stone: 99 per cent SiO_2

Plate I



1-A—View of Oka hills, looking northwest across Saint-Joseph-du-Lac (Lachute map-area), southwest corner of Laval map (p. 15).

The resistant, crystalline Precambrian rocks of the Oka hills allow the latter to stand up in sharp relief against the less resistant Palaeozoics of the plain.

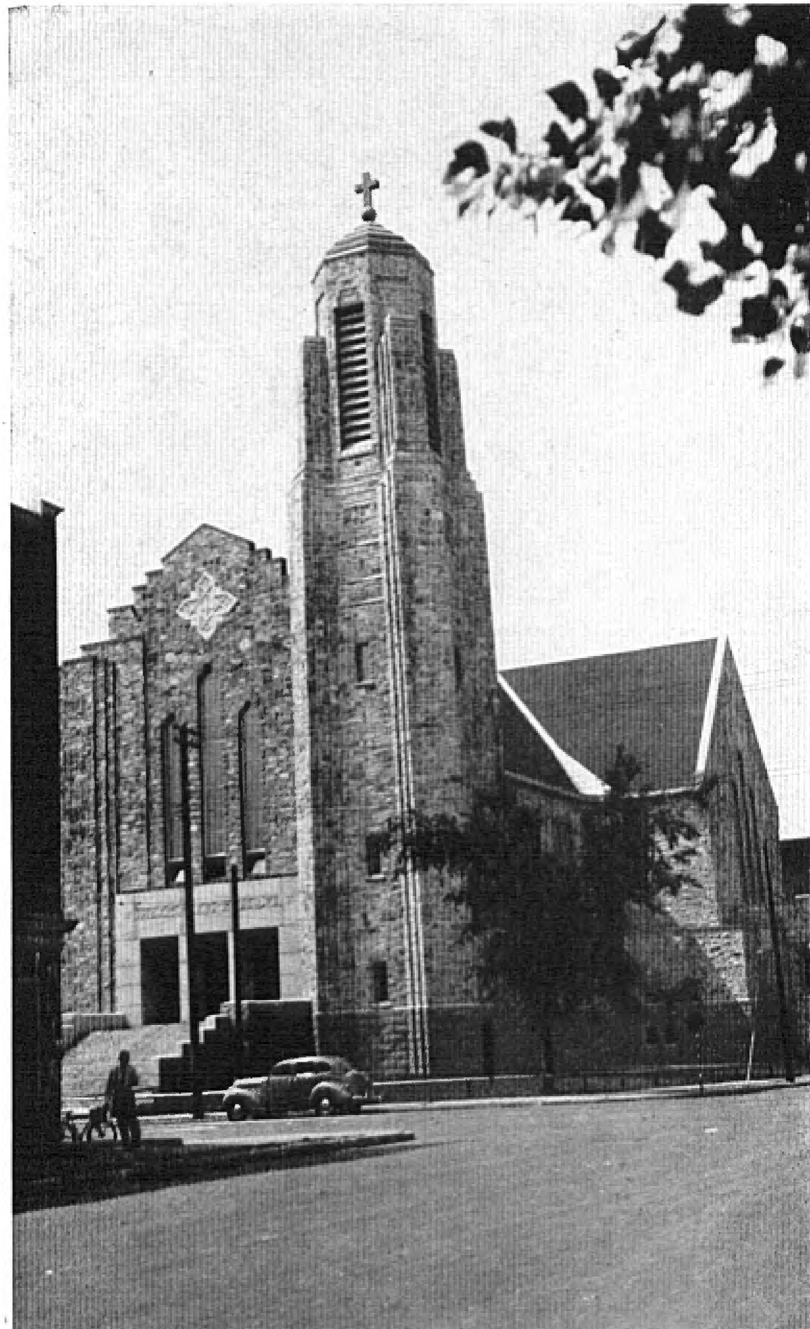
1-B—Potsdam sandstone, Dowker point, Lynch island, lake Saint-Louis (p. 18).

Zig-zag ripple mark such as this is very unusual.

II—Potsdam sandstone, south shore of Saint-Lawrence river, Melocheville (p. 19). The beds dip 10° to the east away from an anticlinal axis.

Plate II

Plate III



III—Saint-Jean-Berchmans church, Montreal, Built of Potsdam sandstone from Saint-Canut (p. 25).

Though the source of this stone is not within the Laval-Lachine map-areas, there is an abundance of similar stone at Beauharnois and Melocheville.

Plate IV

IV—Beekmantown dolomite, northwest wall of quarry belonging to Marchand Frères, half a mile southwest of Châteauguay, Lachine map-area (p. 28).

The rock here is a relatively pure dolomite, with some thin beds of limestone.

Plate V

V-A—Beekmantown dolomite and shale, road-cut on south side of highway No. 2, Beaurepaire, Lachine map-area (p. 30).

The shale lies on an eroded surface developed upon the underlying dolomite. This is one of the many indications of an unstable sea-floor during Beekmantown time.

V-B—" Cryptozoon " reef in Beekmantown dolomite, northwestern shore of Ile Bizard at junction of Laval and Lachine map-areas (pp. 31, 33).

The nearest ' head ' is about 24 inches across.

Plate VI

VI-A—Chazy limestone. Cross-bedding shown in wall of quarry operated by Jean Bédard, Ltd., southeast of highway No. 3, Caughnawaga, Lachine map-area (p. 40).

VI-B—Chazy, Black River, and Trenton limestone, Montreal quarry, Mile End, Montreal; now filled in (p. 50).
The light-coloured rock at the base is the St. Martin limestone of the Chazy group. The dark bed overlying it is the Pamelia formation of Black River age. This is succeeded by the Lowville limestone, also of Black River age, which completes the cliff in the foreground. The Leray limestone (Black River group) forms the base of the cliff in the background. The upper part of the cliff in the background is composed of the Mile End formation, of Lower Trenton age.

Plate VII

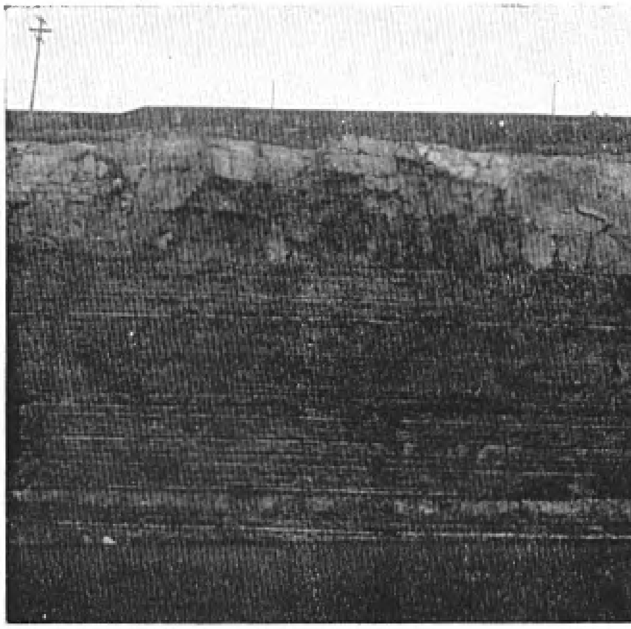
VII-A—Black River and Trenton limestones, Martineau quarry, Mile End, Montreal; now filled in (p. 63).

The man stands on the top of the Leray formation, with the Lowville just showing below it. The cliff in the background is made up of ten feet of dark-stained beds, at the base, which are unfossiliferous and may be either basal Trenton or uppermost Black River. Thence, up to the base of the single heavy bed, is the Mile End formation, Lower Trenton. Above that lies the Saint-Michel member of the Montreal formation, carrying " Cryptolithus tesselatus ". Note also the remarkable ' stagger ' dyke, in places cutting diagonally across the limestone beds, in others lying parallel to the bedding as does a sill.

VII-B—Saint-Michel limestone of Middle Trenton age. Wall of quarry operated by National Quarries, Ltd., Côte Saint-Michel, Montreal (p. 65).

The variability in bedding is well shown. Note also the fault with the down-drop on the left. A sill, or better a nearly horizontal dyke, post-dates the fault.

Plate VIII



VIII-A—Middle Trenton (Rosemount member) limestone overlain by the Masson Street Sill. Abandoned quarry of Martineau Fils, south of Masson Street at 13th street, Rosemount, Montreal (p. 67).

The light bands are pure limestone ; most of the dark bands are shale or shaly limestone. Note the narrow sill near the base of the cliff.

VIII-B—Trenton limestone (Rosemount member) and Masson Street sill, quarry of the Botanical Gardens, Pie IX and Rosemount boulevards, Montreal (p. 68).

At the time this picture was taken (1939), the sill was being quarried for buildings in the Gardens and for the curb around Beaver lake in Mount Royal Park. The overlying Trenton limestone on the right shows how rapidly the sill pinches out in that direction. The lower, dark sill has whitened the limestone along both upper and lower contacts.

Pate IX

IX-A—Upper Trenton limestone (Tetreauville formation) cut by wide vertical dyke; Durocher quarry, Pointe aux Trembles, Montreal (p. 72).

Regular bedding and uniform composition characterize this formation. For clearer detail, see Plate XVI-A.

IX-B—Upper Trenton limestone (Terrebonne formation), south shore of rivière des Mille Iles, opposite ile Saint-Jean, Saint-François-de-Sales, Laval map-area (p. 74).

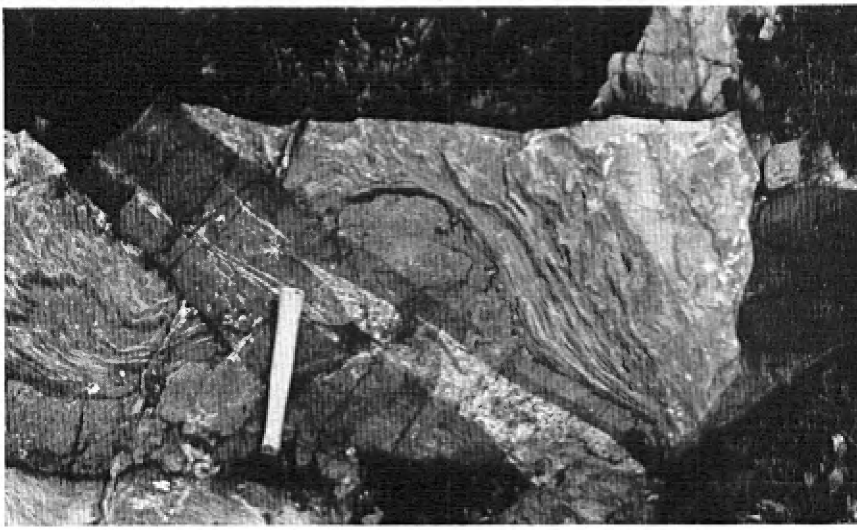
The heavy-beddedness and lack of shaly interbeds characterize this formation.

Plate X

X-A—Sainte-Hélène Island breccia, northeast shore of Sainte-Hélène island, Montreal (p. 82). The white mass in the right foreground is a large fragment of Devonian limestone. The man stands on another equally large Devonian fragment. The cliff at the left is normal breccia, containing fragments of Precambrian, Potsdam, and all Ordovician ages.

X-B—Network of dykes and sills cutting Upper Trenton limestone (Tetreauville formation). Northward-facing cliff behind reservoir at summit of Côte des Neiges, close to Belvedere road, (pp. 85, 121 and Figure 6).

Plate XI



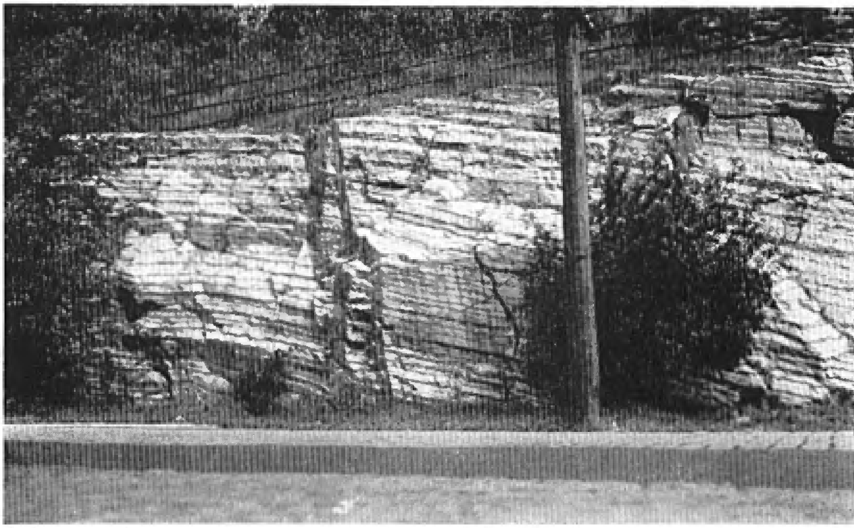
XI-A—Complex of dykes, sill, and marmorized Trenton limestone, Corporation quarry, on grounds of the University of Montreal, near Bellingham road and Mount Royal boulevard, Montreal (p. 86 and Figure 8).

The limestone, ordinarily dark and flat-bedded, was rendered plastic by the heat of the intrusive mass of Mount Royal, and in that condition was easily deformed. A sill, to the left of the hammer, probably pre-dates the deformation. The second igneous body is a thin dyke , nearly vertical, also to the left of the hammer. This cuts the sill, but is intersected by the dark dyke. The latter, the third igneous rock body recorded here, is itself invaded and split by a light (syenitic) dyke complex.

XI-B—Dykes and Trenton limestone, quarry on land of Les Soeurs de Jésus et de Marie, Mount Royal avenue, Outremont (p. 86).

The photograph was taken looking vertically downward. Note the whitening of the limestone on both sides of the dyke, the repeated cross-fracturing of the latter, and the intrusion of the dark dyke by a smaller, light-coloured one.

Plate XII



XII-A—Upper Trenton (Tetreauville formation) limestone cut by a pair of dark dykes, north side of Côte des Neiges, just east of Westmount boulevard (p. 93).

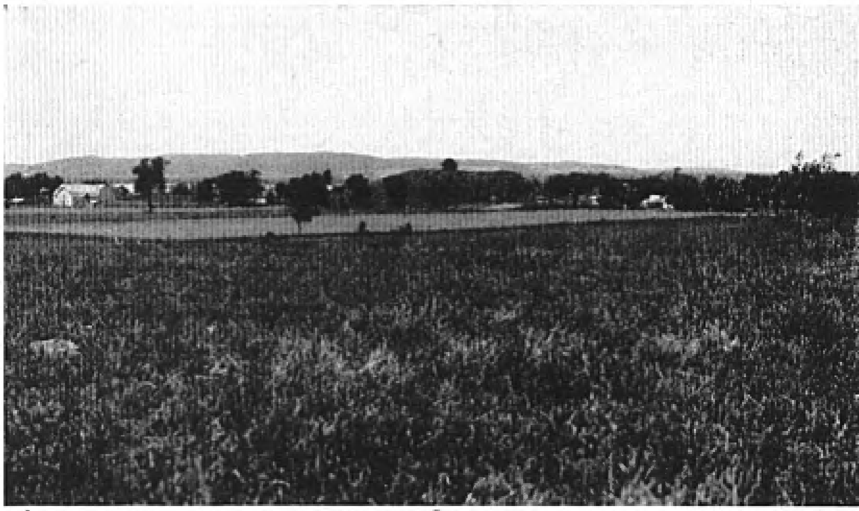
This prominently striped rock is a familiar sight to many Montrealers. The limestone dips at unusually steep angles, perhaps as a result of the fault behind the Côte des Neiges reservoir.

XII-B—Split dyke and Trenton limestone, Summit Circle, Westmount (p. 93).

Plate XIII

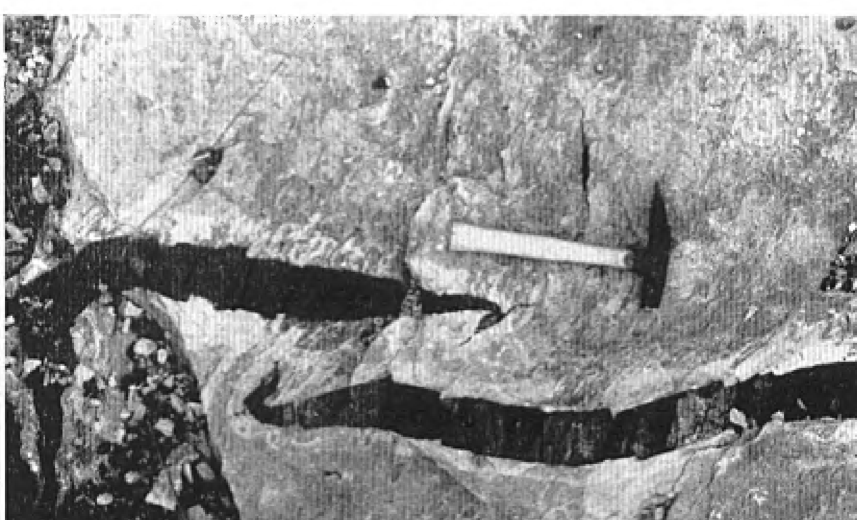
XIII—Sainte-Dorothée sill, Laurin's quarry, half a mile east of Sainte-Dorothée, île Jésus (pp. 96, 137).
This basic sill shows pronounced basaltic jointing, which was taken advantage of during the quarrying of this rock. The cliff is twenty feet high.

Plate XIV



XIV-A—The "Pain de Sucre", a hill composed of breccia near the north shore of Ile Bizard (p. 101).

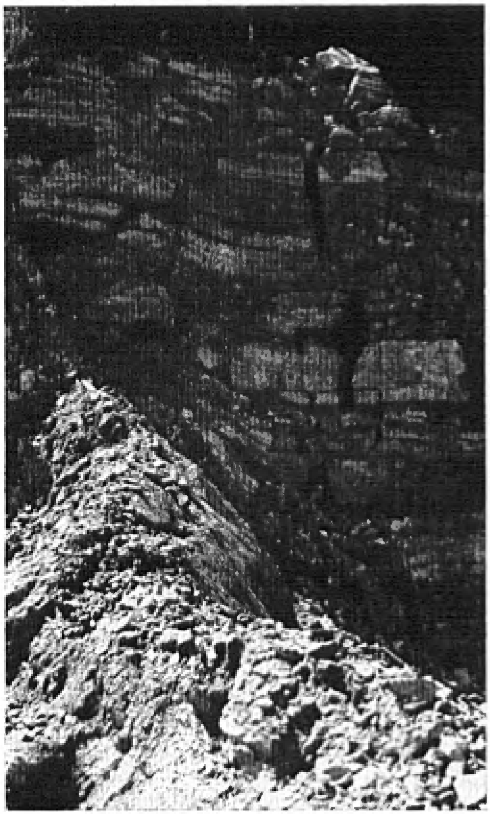
Most of the fragments are of Potsdam sandstone. Oka hills in the distance.



XIV-B—Ruptured dyke in Trenton limestone, Corporation quarry, on grounds of the University of Montreal, Montreal (p. 108).

The drag at both ends of the dyke, and the flowage of the limestone — not well shown in photograph — indicate that the break took place after the emplacement of the dyke.

Plate XV

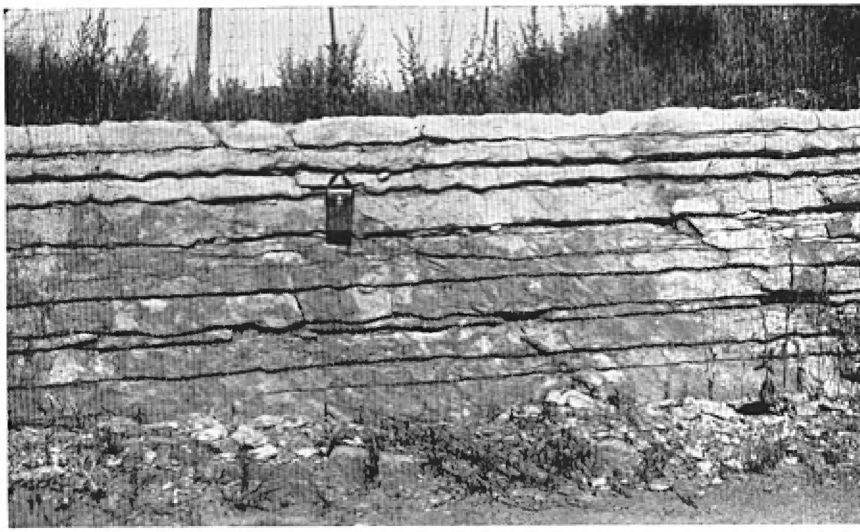


XV-A—Middle Trenton (Saint-Michel formation) limestone cut by normal fault, Lasalle quarry, Côte Saint-Michel, Montreal (p. 121).
The smooth face, not quite covered by rubble, is the fault face. Drag along the fault is plainly visible. Looking southwest.

XV-B—Faulted contact between Utica hornfels (left) and Trenton limestone (right). Cliff face south of Côte des Neiges reservoir, summit of Côte des Neiges road, Westmount. Looking southwest (p. 121).

Note how the Trenton limestone, nearly horizontal ten feet away, has been dragged down to a near-vertical attitude. The Utica hornfels actually occupies a graben-like structure, having faulted contacts with Trenton limestone on both sides. The southerly contact is a hundred feet or so beyond the limit of the photograph.

Plate XVI



XVI-A—Regularly bedded Tetreauville limestone (Upper Trenton). Fillion's quarry, Summerlea Avenue, Lachine.

XVI-B—Irregularly bedded Rosemount limestone (Middle Trenton). Masson Street quarry, Masson and 13th streets, Rosemount, Montreal.
Note contrast between regularity of Tetreauville (upper photo) and irregularity of Rosemount limestone (lower photo).

ALPHABETICAL INDEX