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ST-JEAN - BELOEIL AREA, IBERVILLE, ST-JEAN, NAPIERVILLE - LAPRAIRIE, ROUVILLE, CHAMBLY,
ST-HYACINTHE AND VERCHERES COUNTIES

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PROVINCE OF QUEBEC, CANADA

Department of Mines

Honourable W.M. COTTINGHAM, Minister

A.-O. DUFRESNE, Deputy Minister

GEOLOGICAL SURVEYS BRANCH

I. W. JONES, Chief

GEOLOGICAL REPORT 66

ST. JEAN-BELOEIL AREA

IBERVILLE, ST. JEAN, NAPIERVILLE-LAPRAIRIE, ROUVILLE,
CHAMBLY, ST. HYACINTHE and VERCHÈRES COUNTIES

by

T. H. CLARK



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1955

The first part of the document
 discusses the importance of
 maintaining accurate records
 and the role of the
 committee in this regard.

It is noted that the
 committee has been
 working on this matter
 for some time.

The committee has
 received several
 reports from the
 various departments.

It is
 recommended that
 the committee
 should continue
 to monitor the
 situation.

The
 committee
 will
 report
 back to the
 board.

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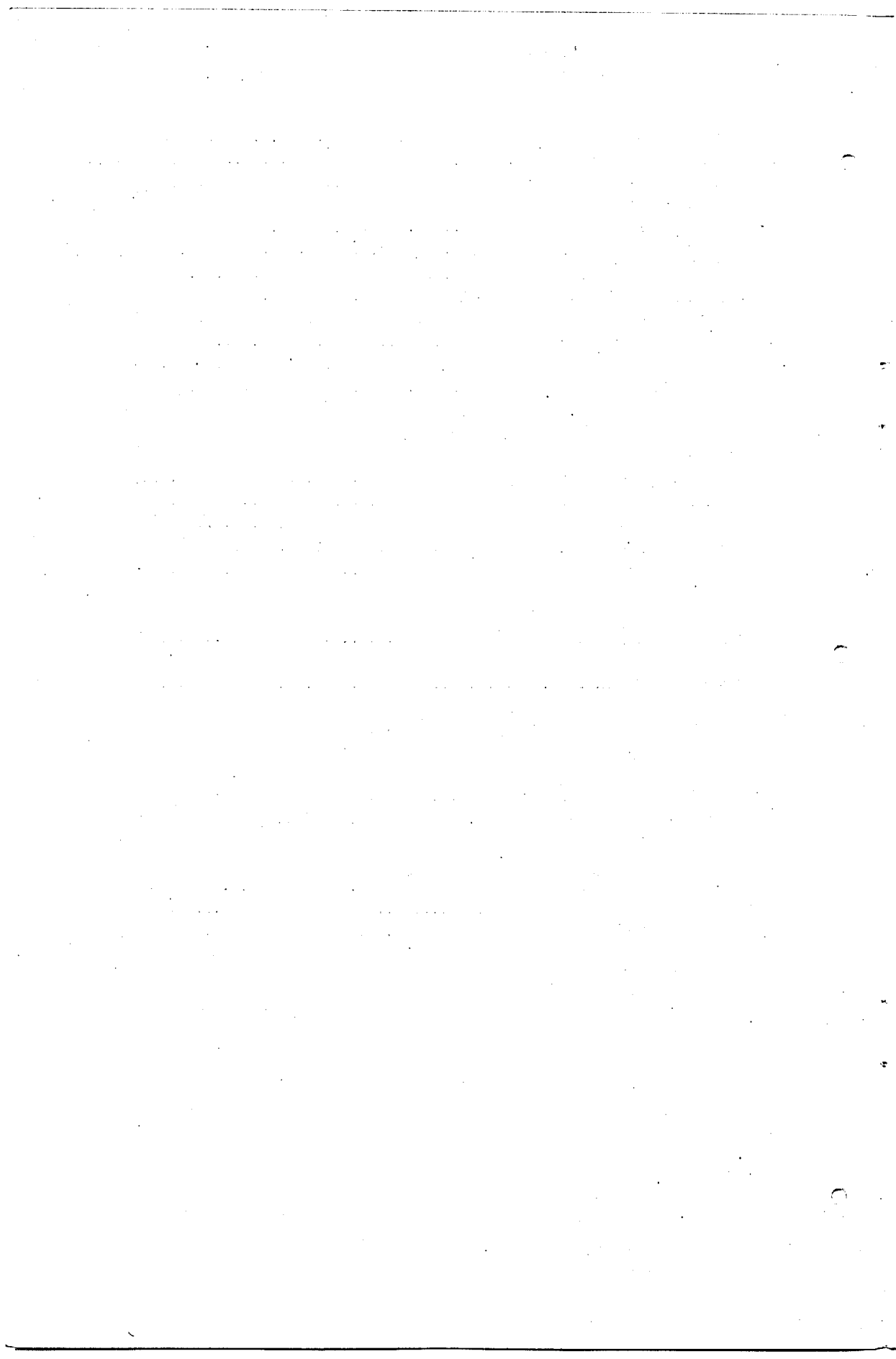
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ST. JEAN-BELOEIL AREA

Iberville, St. Jean, Napierville-Laprairie, Rouville,

Chambly, St. Hyacinthe, and Verchères Counties

By T.H. Clark

INTRODUCTION

Location and General Features

The area described in this report lies immediately east of the city of Montreal, extending eastward for twenty-five miles from St. Lawrence river between longitudes 73°30' and 73°00'W. It comprises two map-sheets: the St. Jean sheet, bounded by latitudes 45°15' and 45°30'N., and, adjoining this on the north, the Beloeil sheet, whose northern limit is latitude 45°45'N. Included wholly or partly within this area of some 835 square miles are the counties of Iberville, St. Jean, Napierville-Laprairie, Rouville, Chambly, St. Hyacinthe, and Verchères.

The area has very little relief. Only that part bordering the St. Lawrence lies less than 50 feet above sea-level, and, except in the immediate vicinity of St. Bruno, St. Hilaire, Rougemont, and Johnson mountains, no part is higher than 200 feet above sea-level. These four mountains rise to heights of 715, 1,350, 1,260, and 875 feet above sea-level, respectively. Richelieu river, which flows northward into the St. Lawrence, bisects the area in a north-south direction, and in places the St. Lawrence and Yamaska rivers form its western and eastern boundaries respectively. These rivers and a number of smaller streams drain the region.

The area lies within that physiographic division of North America known as the St. Lawrence Lowlands. It once probably formed part of the flood-plain of a more extended St. Lawrence river. In later geological times the region was glaciated, and still later most remaining irregularities were eliminated by widespread deposits of sediments from the post-glacial Champlain sea.

Geologically, the area is part of that often similarly designated the St. Lawrence Lowlands, though more properly it should

be considered to be a part of the great Interior Basin Province of North America. The rocks of the area are essentially flat-lying sedimentary rocks of Ordovician age, which were later intruded by alkaline magmas, the latter giving rise to the Monteregian hills.

The area lies within an important agricultural region. Mixed farming is the main support of the population. So much of the land is under cultivation that wood-cutting suffices for but little more than local needs except on the mountains and in the Verchères woods. Industries are confined to a few centres. Along the shore of the St. Lawrence between Longueuil and Boucherville several munitions and aircraft factories flourished during World War II. McMasterville, on Richelieu river, is one of Canada's largest explosives manufacturing centres. Within the St. Jean sheet most of the manufacturing is concentrated in St. Jean, a city of 22,000 population on Richelieu river, where a great variety of enterprises is carried on. Brick-making at Laprairie on the St. Lawrence, stone-quarrying at mount Johnson, and stone-cutting at Iberville, across the river from St. Jean, are other noteworthy industries.

Because of the network of good roads and several railways all parts of the area are readily accessible from Montreal. Three first-class highways traverse the region. Highway No. 3 parallels the St. Lawrence, passing through Longueuil, Boucherville, and Varennes, and thence reaching Sorel. Highway No. 9, from Montreal to St. Hyacinthe, passes through or close to St. Hubert, St. Bruno, St. Basile, McMasterville, Beloeil, St. Hilaire, and Ste. Madeleine. Highway No. 1 connects Longueuil, St. Hubert, Chambly, Marieville, Rougemont, and St. Césaire, thence passing east toward Sherbrooke. In addition, highway No. 9B connects Laprairie and St. Jean, and continues south to points in the United States. A network of secondary roads makes all parts of the area accessible from these and other centres.

The Canadian Pacific and Canadian National Railways serve the region well. The main line of the Canadian National from Montreal to Lévis and Halifax traverses the southern part of the Beloeil sheet. A branch line follows closely St. Lawrence river northward to Sorel. On the St. Jean sheet, a line of the Canadian National Railways runs from Montreal to St. Jean, and thence to St. Albans, Vermont. The Canadian Pacific also runs between Montreal and St. Jean, and thence continues to Sherbrooke, and Newport, Vermont. Both companies have in recent years abandoned a few rural lines. In addition, the Montreal and Southern Counties Railway (electric) traverses the St. Jean sheet

roughly parallel to highway No. 1, on its way from Montreal to Granby.

Richelieu river provides a short water route for traffic between the St. Lawrence water-way and New York. Rapids at, and between, St. Jean and Chambly are by-passed by the Chambly canal, 12 miles long, which follows the left (west) bank of the river. It can accommodate vessels up to 112 feet long, 22 1/2 feet wide, and with draft not exceeding 6 1/2 feet. Nine locks overcome a total differential of water-level of 80 feet.

The ease in travelling to and from Montreal has influenced the selection of St. Hilaire, Beloeil, and Chambly as summer residential centres, and points the way to an increasing utilization of Richelieu river in this respect.

Purpose of the Investigation

During the summers of 1938 to 1941, inclusive, the writer was engaged by the Quebec Department of Mines to map the Laval and Lachine map-areas (Clark, 1940, 1941, 1952)^x immediately to the west of the Beloeil and St. Jean map-sheets, and astride whose common boundary lies the city of Montreal. The Lacolle quadrangle, immediately south of the St. Jean sheet, had previously been mapped by Clark and McGerrigle for the Geological Survey of Canada. A start had thus been made toward the detailed outcrop mapping of the St. Lawrence Lowlands and it seemed advisable to continue this programme. The intervention of the war, however, would probably have temporarily halted such a project had it not been for the known occurrence of natural gas in the central part of the Lowlands.

The especial and immediate goal in view is the interpretation of the stratigraphy and structure in terms of favourable gas or oil reservoirs. Such an end, with its promise of great economic importance, would naturally involve close attention to the sedimentary rocks which, for the most part, lie nearly horizontal or are only gently folded. It is known that where the Lowlands abut against the Appalachian Province to the east, the sedimentary rocks are thrown into a series of more or less tight folds, and are, moreover, broken by numerous faults. In addition, the sedimentary rocks of the Lowlands are pierced by four intrusive 'plugs' which are not only in themselves barren so far as oil or natural gas possibilities are concerned but which have metamorphosed the surrounding sediments so as to render them barren also. Hence, it seemed advisable to carry

^xNames and years refer to the bibliography, p. 64.

on as thorough an areal survey of the sedimentary rocks - the potential oil or gas containers - as possible, paying but cursory attention to the igneous rocks.

Previous Work

Very little attention seems to have been paid, hitherto, to that part of southern Quebec included in this map-area, save for various reports on the Monteregian hills. Logan (1863, pp. 140, 206, 208, 209) in 1863, and in earlier reports too, gave a brief résumé of the distribution of the rock groups, and listed (1863, pp. 208-9) some of the fossils found in the Utica and Lorraine formations. Ells (1896) added very little. In 1916, Foerste (1916) published an extensive report on the Upper Ordovician formations of Ontario and Quebec, followed later (1924) by a companion volume on Upper Ordovician faunas. He collected fossils from a few scattered localities in the region with which we are presently concerned, but, though his palaeontological results are of much value, his work has very little areal import. In 1931 the Quebec Bureau of Mines published a report by Parks (1931) on Natural Gas in the St. Lawrence Valley, in which a great deal of detailed information regarding the occurrence of natural gas was brought together. Parks, however, was unable from the data at hand to elucidate the geological structure, and hence the search for oil and gas rested, more or less, upon an empirical basis. The following year, Hume (1932) published a Canadian Geological Survey report on Oil and Gas in Eastern Canada which included a summary of Parks' observations. Shortly thereafter, Snider and Farish (1935) wrote a short summary of their conclusions regarding natural gas in Quebec. A short article by Clark (1939) on the Lowlands, in Geologie der Erde, was merely a condensation of the information available at that time, as was also his contribution on the Lowlands to Geology of Quebec (1944b). Three other papers by Clark (1943, 1944a, 1947) may be considered to be reports of progress. A study of the fossils of the Lower Lorraine beds, largely from the Beloeil area, by S.R.L. Harding (1943) has proved very useful. H.R. Belyea (1952) listed and discussed the logs of many deep wells in the St. Lawrence Lowlands.

As regards the treatment of the igneous rocks, Logan (1863) and Ells (1896) gave general pictures of the occurrences. Later, Adams (1903), in his comprehensive paper entitled The Monteregian Hills - A Canadian Petrographical Province, gave a good account of the geology of mount Johnson, which he discussed in greater detail in a later paper (Adams, 1913). Dresser (1910) published a short memoir on mount St. Bruno, and later, O'Neill (1914) discussed mounts St. Hilaire and Rougemont. Thus, each of the four hills has received short monographic treatment.

In addition, Parks (1914), Keele (1915), Burton (1932), Osborne and Wilson (1934), and Goudge (1935) have published specialized reports on certain features.

The previous geological investigations and reports on this area, and the results obtained during the present work, make it incumbent upon the writer to stress very strongly how much any proper understanding of a region must depend on the construction of a reasonably accurate outcrop-map. None had been made before the start of the present work, and, as a consequence, conclusions have in the past been drawn upon insufficient evidence. Moreover, the most conspicuous outcrops are not always the most important ones. Only from a complete synthesis of all the information from all the exposures can a writer hope to be reasonably sure of his interpretations (Clark, 1944a, p.32). The accompanying outcrop-maps may have defects, but the author believes that all essential exposures are recorded.

Method of Work and Acknowledgments

The field work on which this report is based was carried out mainly during 1942, although some details are a result of work in subsequent years. During the course of this investigation every recognizable exposure was visited and examined. Travel around the country was accomplished by automobile, and all exposure surveying was done by the pace-and-compass method from known points. Good rural boarding-houses and hotels are sufficiently numerous so that all parts of the field are easily accessible. All the main rivers were followed on foot, so that it is the writer's hope that practically no exposure was missed.

During the field season of 1942 Mr. Jules Arcand, of Laval University, acted as assistant. To Mr. S.R.L. Harding, who in 1943 submitted an M.Sc. thesis at McGill University on the Lower Lorraine formations around Montreal, the writer is indebted for the identification of certain fossils, particularly graptolites.

STRATIGRAPHY

General Statement

Two classes of rocks, igneous and sedimentary, are exposed in the St. Jean-Beloeil area. Disregarding the overburden, almost all the surface of the region consists of sedimentary rocks of Ordovician age belonging to the Chazy, Black River, Trenton, Utica, Lorraine, and Richmond groups. These sedimentary rocks are for the most part flat-lying, with dips rarely exceeding five degrees. Evidence from deep wells (see Appendix A) indicates that Beekmantown and Potsdam beds underlie the Chazy. In addition, four igneous intrusions of alkaline rocks form erosion remnants ranging from less than a mile to four miles across. The sedimentary rocks are treated directly below. The igneous rocks are described in a later chapter.

The formations exposed in, or believed to underlie, the St. Jean-Beloeil area are set forth in the table on page 7.

Potsdam Sandstone Formation

No Potsdam sandstone is exposed within the St. Jean-Beloeil area. Because it outcrops so extensively in the Laval and Lachine areas it is reasonable to expect it to underlie the rest of the sedimentary sequence in the present area. Only one deep well, St. Johns Petroleum well No. 1 (Appendix A, p. 69), has penetrated through the overlying rocks to reach the Potsdam sandstone. This well, drilled just north of the village of St. Hubert, and adjacent to and west of the St. Hubert airport, reached Potsdam sandstone 3,965 feet below the surface and continued therein to a depth of 3,970 feet, where the drilling stopped. In all probability Potsdam sandstone occurs resting directly upon the Precambrian basement over the western half of, and possibly the whole of, the St. Jean-Beloeil area.

Beekmantown Group

As with the Potsdam sandstone, no beds of Beekmantown age outcrop in this area. However, data concerning the presence of this group can be found in the logs of two wells, as follows:

Cartier St. Hubert well No. 1 (Appendix A, p. 70).— The log of this well shows that the top of the Beekmantown beds was reached 2,625 feet below the surface, and the well remained in these beds to the bottom of the hole at 3,490 feet. Thus a minimum of 865 feet may be assigned to the thickness of the Beekmantown rocks.

Stratigraphic Succession in the St. Jean-Beloeil Area

QUATERNARY	Post-glacial sands and clays Glacial deposits
TERTIARY	Monteregian intrusives
ORDOVICIAN	<p>CINCINNATIAN SERIES</p> <p><u>Richmond Group</u> Bécancour River (Queenston) formation Carmel River member Pontgravé River (Waynesville) formation</p> <p><u>Lorraine Group</u> Nicolet River formation St. Hilaire member (<u>Pholadomorpha</u> zone) Chambly member (<u>Proetus-Leptaena</u> zone) Breault member (<u>Cryptolithus</u> zone)</p> <p>CHAMPLAINIAN SERIES</p> <p><u>Utica Group</u> Lachine formation</p> <p><u>Trenton Group</u> Terrebonne formation Tétreauville formation Montreal formation Rosemount member Lacolle member St. Michel member Mile End formation</p> <p><u>Black River Group</u> Leray formation Lowville formation Pamelia formation</p> <p><u>Chazy Group</u> Laval formation St. Martin member Ste. Thérèse member Beldens formation</p> <p>CANADIAN SERIES</p> <p><u>Beekmantown Group</u> Beauharnois formation Theresa formation</p>
CAMBRIAN	<p>UPPER CAMBRIAN SERIES</p> <p>Potsdam formation</p>
PRECAMBRIAN	Presumed basement rock of entire district

St. Johns Petroleum well No. 1 (Appendix A, p. 69).— This was drilled within one hundred feet of the preceding well. The Beekmantown was first struck at 2,640 feet below the surface, and the log shows that it persisted down to 3,965 feet. Thus here a total thickness of 1,325 feet is recorded for the rocks of this group.

These logs indicate a thickness of more than 1,300 feet of Beekmantown dolomites, etc., lying between the Potsdam sandstone and the overlying Chazy rocks. The thickness measured in the Mallet well in the Laval area is 1,060 feet (Clark, 1952, p. 32). In all probability the Beekmantown beds underlie the whole of the St. Jean-Beloeil area. No other well of which we have a record has penetrated to the Beekmantown rocks.

Chazy Group

The historical development of thought regarding the rocks of the Chazy group in southern Quebec has already been discussed in detail in the writer's report on the Montreal area (Clark, 1952). In that report the beds of Chazy age were called the Laval formation, and the term 'St. Martin limestone member' was adopted for the limestones of the upper part of the formation which, because of their superior resistance to weathering, usually show as prominent outcrops. Inasmuch as only the St. Martin member is exposed in the present area, either St. Martin or Chazy is an appropriate local term. Further information has been obtained from the logs of deep wells.

St. Martin Limestone Member

Distribution

This sedimentary unit, of Upper Chazy age, is sparingly exposed in the southwestern part of the St. Jean map-area. About four miles south-southwest of St. Jean there is an exposure in a pasture just beyond the southern boundary of the area. A few small exposures along the first stream east of St. André creek and those in a quarry at St. Jacques-le-Mineur complete the list. Wide areas close to the southwestern corner of the map-sheet are strewn with large blocks of Chazy limestone in such profusion as to suggest strongly the presence close beneath the surface of bed-rock of that type.

Lithology

The rock is a medium grey, crystalline limestone with irregular shaly seams which control and aid in its quarrying. At the exposure south of St. Jean there is a good deal of irregularly-distributed, brown-weathering magnesian material. This is also commonly found

in some of the Montreal exposures, particularly those of the reef type. In the stream exposures about two miles northwest of St. Jacques-le-Mineur, dark oolitic limestone is interbedded with the crystalline rock.

Thickness

From the few exposures themselves no reliable estimate of the thickness of this member in the region where it is exposed is possible. From an examination of the Mallet core (Clark, 1952, p. 43), one would be likely to conclude that no more than 64 feet of the St. Martin limestones would occur, and that below this crystalline type there should be as much as 154 feet of shaly limestones and shales, as is the case in the vicinity of Montreal. This is elaborated below.

Chazy Rocks in Deep Wells

Further information regarding Chazy beds comes from the two deep wells at St. Hubert, the logs of which are given in Appendix A (pp. 70 - 71). As can be seen in Figure 1, the lithology of these beds allows a correlation to be made with the rocks of the Montreal area on the one hand and with those of the St. Dominique (St. Hyacinthe map-area) area on the other. In all three cases there is a basal sandstone - the Ste. Thérèse sandstone member of the Laval formation, 42 feet thick, found in the Mallet well at Ste. Thérèse; the St. Dominique sandstone member of the St. Dominique formation, about 110 feet thick at St. Pie; and a basal sandstone, 241 feet thick, at St. Hubert. Whereas the St. Dominique sandstone is remarkably uniform in composition, being shaly only at its very top, the two other basal sandstones are both marked by common intercalated shaly beds and even thin limestone horizons. For this, and because of greater propinquity, it is deemed advisable to designate the sandstone in the St. Hubert well the Ste. Thérèse member, and to correlate it with the St. Dominique sandstone member. The latter term may, in fact, ultimately be replaced by Ste. Thérèse.

Similarly, the St. Dominique limestone is singularly free from shale except at its very base, whereas the limestone from the St. Hubert well core has several horizons of shale, especially in its lower third; and from the Montreal area that part of the Laval formation above the Ste. Thérèse sandstone member is very largely shaly. In this case, too, both lithology and propinquity suggest that the Chazy limestone of the St. Hubert wells, or at least its upper part, is the correlative of the St. Martin member of the Laval formation. The more shaly parts of the Laval formation as developed around Montreal do not appear in the cores of the St. Hubert wells. The St. Dominique limestone may ultimately be shown to be identifiable with the St. Martin member of the Laval formation.

A reasonable hypothesis concerning the regional development of the supra-Beldens Chazy beds over these three areas is that, as supposed in the Montreal Area report (Clark, 1952, p.126), the Chazy sea invaded this part of Quebec from the east, building up a basal sandstone as it progressed. The depressing of the Appalachian geosyncline (miogeosyncline, see Kay, 1951, p. 4), though located farther east than any of the areas here considered, so influenced these areas as to allow a greater thickness of beds to be accumulated in the more easterly St. Hubert and St. Dominique areas than in the western and more stable Montreal area. In the latter place, and to a lesser extent in the St. Hubert area, an abundance of mud, presumably from the Laurentians or an upland area that existed where the present Laurentians now stand, gave a shaly character to the resulting Chazy rock column, and prevented such an extensive development of nearly pure (St. Dominique) limestone as occurs in the eastern locality.

Beldens Formation

In the St. Hubert wells, core from immediately below the sandy beds of the Laval formation shows cuttings of an alabaster-like dolomitic limestone, identical in lithology and stratigraphic position with the Beldens formation of the St. Dominique area (Clark, Que. Dept. Mines, Ms. report on the West Half of St. Hyacinthe map-area). There the Beldens formation has been estimated to be somewhere around 275 feet thick. A maximum of 17 feet occurs in the St. Hubert wells, and it is unknown in the Montreal area (Figure 1). Hence, we have here corroborative evidence of the westward thinning of this formation. Because it occurs within the geosynclinal belt of central Vermont (Cady, 1945, p. 550), it was probably a deposit characteristic of the Appalachian geosyncline, and its non-extension far beyond the western margin of that geosyncline is not to be wondered at.

Fossils

The only species of fossils identified from exposures of the Chazy rocks is Camarotoechia plena. From the Montreal area (Clark, 1952, p. 45) and the St. Hyacinthe area (Clark, Que. Dept. Mines, Ms. report), abundant faunas have been recorded. However, Camarotoechia plena is sufficiently diagnostic of an Upper Chazy age that no corroborative evidence is needed.

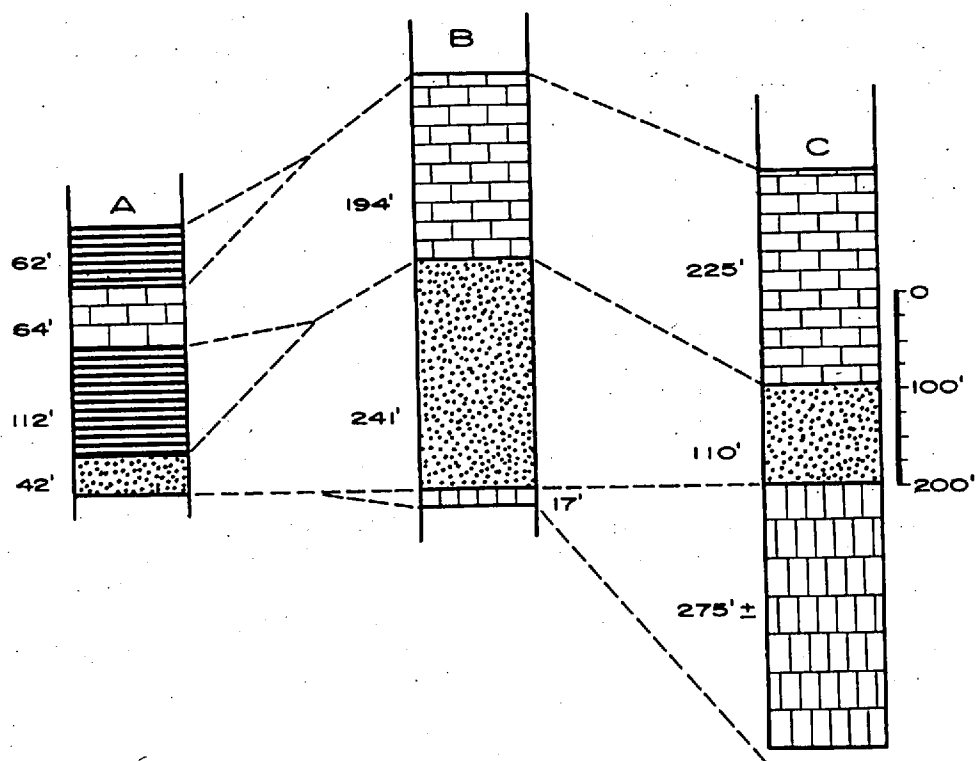


Figure 1.- Columnar sections of Chazy rocks from:
 A- Mallet well, St. Thérèse, Laval map area (NTS)
 B- St. Johns Petroleum well No. 1, St. Hubert,
 Beloeil map area (NTS)
 C- Sections as exposed on St. Pie hill, about two miles
 north of St. Pie, St. Hyacinthe map area (NTS)

The sections illustrate the general thinning out of the entire section toward the west, and in particular the rapid wedging-out of the Beldens formation.

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Black River Group

Distribution and Lithology

Only one exposure that can be referred to this group occurs in this area. About two miles northeast of St. Jacques-le-Mineur, in the bed of Noyers creek, there is a low outcrop of heavy-bedded, dark, finely-crystalline limestone. Lithologically, it resembles the heavy-bedded limestones of the Leray formation, and it is in the appropriate geographical position, but there are no fossils to make the stratigraphic identification positive.

Evidence from Deep Wells

At the St. Johns Petroleum Company well No. 1 at St. Hubert, 72 feet of Black River beds were recorded. While this estimate of the thickness cannot be accepted as strictly accurate -- since this was a cable-rig well -- it is doubtless approximately correct. The three divisions of the Black River seen in the excellent outcrops around Montreal -- the Leray, the Lowville, and the Pamela formations -- are all recognizable, and are 24, 36, and 12 feet thick, respectively. Inasmuch as the Black River sea is supposed to have spread into this region from the west, the thinness of the lowest (Pamelia) formation is not to be wondered at, nor is the excessive thickness of the Lowville formation, compared with its maximum thickness around Montreal of 17 feet, remarkable considering the nearness of St. Hubert to the sinking belt of the Appalachian geosyncline.

Trenton Group

Distribution

Rocks of the Trenton group are exposed chiefly from one to three miles west of the city of St. Jean, where beds of the Rosemount member of the Montreal formation (Clark, 1952, p. 67) of Middle Trenton age are now being quarried.

The westernmost exposure of Trenton rock is to be seen in the bed of L'Acadie river, about half a mile south of the bridge at L'Acadie. This exposure contains Cryptolithus, hence its age is that of the St. Michel member of the Montreal formation (Clark, 1952, p. 65). No shales comparable to the Stony Point formation, so widespread over the eastern part of the Lacolle map-sheet, can be identified here. Instead, the overlying formation, the Iberville shale of Utica age, probably occurs east of the Tracy Brook fault. No part of the Trenton limestone other than beds equivalent to the Montreal formation were seen as exposures.

Lithology

The exposed Trenton beds are in every way comparable to their equivalents of the Montreal area (Clark, 1952, pp. 65-71). Thin-bedded, dark bluish-black limestones predominate, the beds ranging from one to three inches in thickness separated by shaly partings which in only a few places are thick enough to be called interbeds. None of the limestone is well suited for use as a building-stone, though it is admirably adapted for use as road-material and for making concrete. Parks (1914, p. 72) records that the rock was used for foundation work in many of the buildings in St. Jean, and also that one or two buildings themselves were constructed of this stone. Two active quarries exploit this rock today (1953).

Thickness

In the logs of Cartier St. Hubert well No. 1 and St. Johns Petroleum well No. 1, both at St. Hubert, the Trenton limestone is recorded as being 860 and 868 feet thick, respectively, with 45 and 28 feet, respectively, of black shale covering the limestone. The total thicknesses, 905 and 896 feet, accord well with the thickness (800 ± feet) of the Trenton limestones at Montreal (Clark, 1952, p. 76). As in the latter locality, the lower part is largely limestone, probably the equivalent of the Mile End and Montreal formations. The upper part is composed of limestone and shale interbedded and is probably the equivalent of the Tetreauville formation. The overlying shale has no counterpart in the Montreal area. It is not possible in the well-cuttings from the upper part of the Trenton limestones to identify any material not referable to the Tetreauville formation, and hence the Terrebonne formation is presumably absent. In her log of the Longueuil Barracks well, which is west of Longueuil Annex and just without the area, Belyea (1952) assigned the lowest 990 feet to the Trenton. Though this figure seems high, there is no possibility of lowering the upper limit of the Trenton, as will appear from a scrutiny of the log. It is possible that some of the lower part assigned to the Trenton may belong to the Black River group.

Structure

The northward-plunging syncline indicated in the Lacolle sheet (Clark, 1934, p. 4) appears to continue into the St. Jean area. The exposures of Trenton limestone at Menard Corner lie close to the axis of the fold. The beds on L'Acadie river dip eastward and are somewhat lower stratigraphically than those in the vicinity of Menard Corner, which dip toward the north and northwest. This indicates that the axis is close to Menard Corner. The presence of Chazy rocks southeast,

southwest, and west of Menard Corner supports this conclusion. No Trenton rocks are known to be exposed north of Menard Corner. At the disused quarry of the Standard Clay Products Company, numerous joints and faults indicate the presence of a fault zone trending approximately N.65°W., with the downdrop to the northeast. Such conditions are almost precisely met by a southeastward prolongation of the Delson fault of the Lachine map-area (Clark, 1952, p. 119).

Fossils

The list of fossils collected from the exposures near Menard Corner is not a long one. It is, however, indicative of the Rosemount age of the beds. The list, compiled from the exposures of all the localities examined, follows:

Prasopora orientalis C
Platystrophia biforata C
Dalmanella roqata C
Rafinesquina alternata
Sowerbyella sericea
Zygospira recurvirostris
Pterygometopus callicephalus R
Isotelus gigas
Calymene senaria

Farther west, from the exposure on L'Acadie river, fewer species were identified, but the presence there of Cryptolithus tessellatus is indicative of a horizon in the basal part of the Montreal formation. The collected fauna consists of the following species:

Trematis terminalis
Platystrophia biforata
Dalmanella roqata
Rafinesquina alternata
Zygospira recurvirostris
Cryptolithus tessellatus

Lacolle Conglomerate

Although no exposures were seen, the belt of outcrop of the Lacolle conglomerate (Clark and McGerrigle, 1936) has been brought up onto the St. Jean map-sheet from the Lacolle area, as shown on the accompanying geological map. On the Lacolle sheet to the south, the Lacolle conglomerate, of late St. Michel or of early Rosemount (Middle Trenton) age, truncates, successively from south to north, the Potsdam

sandstone, Beekmantown dolomite, and probably the Chazy limestone. It is shown on the St. Jean sheet as successively truncating beds of Lower Middle Trenton (St. Michel member) and Lower Trenton (Mile End formation) and would, prior to the formation of the Delson and Tracy Brook faults, have probably truncated the Black River and Chazy beds also, on the east of the syncline. It is shown as dying out within the map limits. Such a distribution is an entirely logical interpretation of stratigraphic structure between the known exposures of Chazy, Black River, and Trenton rocks on the Lacolle sheet and on the St. Jean and Beloeil sheets.

Utica Group

Distribution

Although Utica shale underlies a considerable area covered by drift in the southeastern part of the St. Jean sheet, only one exposure (half a mile southwest of St. Gregoire Station) was seen. North of the Delson fault in the western part of the same sheet, there should be Utica shale beneath the drift, but here there are no exposures. Just to the west of the map limit, at Delson, it is exposed abundantly in the brickyard quarries and in the bed of Tortue river. In the extreme northwestern corner of the St. Jean map-area it outcrops at a few places, and in the Beloeil map-area there are a number of exposures, along or close to the St. Lawrence. In addition, there are several exposures which can be doubtfully assigned to either the Utica or the Lower Lorraine. In spite of the scarcity of exposures it would seem that the Utica shale should be found along a belt immediately south of the known belt of outcrop of the Lorraine shale in the St. Jean area, and west of the Lorraine in the Beloeil area. The indefiniteness of the lithologic evidence relied upon to differentiate between the Utica and the Lorraine shales makes the position of the boundary between the two somewhat uncertain.

Lithology

The typical Utica is a black, fissile shale, usually containing an abundance of extremely small but visible mica flakes, and showing (by its superior hardness) a considerable content of quartz. In fact, examination of thin sections of some of the typical Utica shales from the Lachine map-area showed that they were, in effect, extremely fine-grained quartz sandstones with a mixture of a few other ingredients. Such a composition renders them relatively resistant compared with the kaolin-rich Lorraine shales, and allows whole slabs to be extracted from an exposure in searching for fossils, whereas rarely can more than a few square inches of Lorraine shale be split off evenly from an outcrop.

There are only a very few, very thin layers which, from megascopic examination, could be termed sandstone, and no limestone beds were seen. The huge flattened concretions up to 8 feet in diameter and 30 inches in thickness, characteristic of a few exposures in the Lachine map-area, are unknown in the St. Jean-Beloeil area.

Thickness

On the basis of the exposures in this area no accurate estimate of the thickness of the Utica formation can be made. By comparing breadths of outcrop, the Utica shale should not be more than half the thickness of the Trenton limestone, and a third or so of that of the Lower Lorraine. On the first count, the figure should be a little more than 400 feet, on the second a little less. The method used in obtaining this estimate is not to be considered as more than a means to an approximation of the true figure. The writer has often used this method elsewhere, and it is gratifying to find that, in the light of the measurements obtained from deep wells, the results seem reasonably accurate.

According to the log of the St. Johns Petroleum Company well No. 1 (see Appendix A, p. 69), the Utica shale measures 380 feet in thickness. That this is more than its estimated minimum thickness in the Montreal area (Clark, 1952, pp. 78, 79) is quite consistent with the concept that the Utica shale is a formation thicker in the east and thinning out westwards. The log of the Cartier St. Hubert well No. 1 (Appendix A, p. 70) errs in not claiming enough for the Utica; probably a couple of hundred feet of the "Lorraine and Utica" should have been placed in the Utica.

Fossils

None of the exposures classed as Utica in the St. Jean area contains fossils. At the western margin of the Beloeil map-area, excavations for war-time factory foundations exposed rock in which a few fossils were found. This locality, one mile northwest of Longueuil Annex, is listed hereunder as locality Beloeil 1E-2. About one mile north of the latter place, just west of the Fairchild aeroplane factory, and adjacent to the highway, another excavation was made earlier in Utica shale (Beloeil 1E-3) from which a single graptolite was taken. A mile and a half southeast of Boucherville, outcrops along a deepened stream show a fissile shale which, lithologically, is Utica, but which contains several Lorraine species. This is locality Beloeil 2D-1, which is shown on the map as of Lorraine age. Also, about one and a half miles south of Varennes, the same kind of shale is exposed along a small creek on both sides of the main highway, but here it is

unfossiliferous. A few other exposures of Utica shale occur within a three-mile radius of Boucherville.

The list of fossils is not a large one. It is, however, distinctly Utica, and contains many species found also in the Utica of the Montreal area (Clark, 1952, p. 80). The following tabulation contains the faunas of the exposures noted above, and also, for comparison, those species occurring in the Laval and Lachine map-areas to the west. A further column indicates which of the species are known to persist into the Lorraine formation.

Tabulation of Occurrence of Fossils (by Localities) Found in Exposures of Utica Shale in the St. Jean-Beloeil Area

	Species known from the Montreal Area	Beloeil 1E-2	Beloeil 1E-3	Beloeil 2D-1	Species persisting into Lorraine beds
<u>Mastigograptus tenuiramosus</u>	x			x	x
<u>Leptograptus annectans</u>	x				
<u>Climacograptus</u> sp., cf. <u>C. typicalis</u> ..	x				
<u>C.</u> sp., cf. <u>C. typicalis</u> , var. <u>posterus</u>	x				x
<u>Diplograptus recurrentis</u>	x	x		x	
<u>Glossograptus quadrimucronatus</u>			x		x
<u>G. quadrimucronatus</u> var. <u>timidus</u>	x				
<u>G. quadrimucronatus</u> var.	x				
<u>G.</u> sp.				x	
<u>Leptobolus insignis</u>	x	x		x	x
<u>L. insignis</u> var. <u>latus</u>	x			x	
<u>Schizocrania filosa</u>	x			x	x
<u>Lingula</u> sp. indet.		x			
<u>Cyrtolites ornatus</u>				x	x
<u>Ctenodonta</u> sp.				x	x
<u>Byssonychia vera</u>				x	x
<u>Geisonoceras</u> sp.	x	x		x	x
<u>Triarthrus</u> sp., cf. <u>T. huquesensis</u>		x		x	x

Of these fossils, Triarthrus huquesensis is the only one which can be said to have definite Lorraine affinities. There is a small variety of Cyrtolites ornatus in the Trenton, and Byssonychia vera occurs there also. Nevertheless, the large number of species found in both Utica and Lorraine rocks is an indication that, save for the graptolites of the Utica and the pelecypods of the Lorraine, there may not be much difference between the two faunas. The chief difference comes in the facies development. Most of the Utica fossils are those of pelagic forms, whereas the Lorraine fauna was a bottom-dwelling group. The mixing of the two types of assemblages, apparent in the list of species for locality Beloeil 2D-1, is one of the best arguments for supposing that there was no break between the deposition of the two groups of rocks, but that, instead, there was a gradual change in conditions of sedimentation which resulted in a somewhat different kind of sediment, and parallel with that change there took place a modification of the fauna, giving rise to the Lorraine assemblage. There is much in the Lorraine that is reminiscent of the Trenton, and it is quite correct to consider the Lorraine fauna as a recurrent Trenton fauna, temporarily driven out while Utica conditions prevailed, and returning, modified of course, when clear seas allowed the benthonic animals to migrate back freely across the sea-floor.

Correlation

In the Mohawk valley of New York State there is no limestone of Trenton age above the lower part of the Sherman Fall (Middle Trenton, equivalent to Montreal formation) beds. Instead, the section is made up of the Canajoharie shale, equivalent to the late Sherman Fall, and that is followed by the Utica, divided into three parts - the Nowadaga below, then the Loyal Creek, and the Holland Patent above (Ruedemann, 1947, pp.120-121). No fossil species occur in this part of Quebec to suggest equivalence of the containing rocks to the Nowadaga or the Loyal Creek. On the other hand, several species, e.g., Leptograptus annectans and Glossograptus quadrimucronatus var. timidus, suggest close relationship to the Holland Patent beds. Moreover, in northwestern New York the development equivalent to the Holland Patent is that of the Deer River and Atwater Creek beds. Many of the Utica fossils from the present area have affinities with species characteristic of these latter stratigraphic divisions. And, in addition, some of our species pass on up into the next succeeding division in northwestern New York State, the Whetstone Gulf formation, which is part of the New York Lorraine. Hence it is apparent that the local Utica is approximately equivalent to the upper part of the New York Utica, and in some features bridges the gap between it and the Lorraine.

Lithologically, our beds are closely related to the Lotbinière shales (Clark, 1947, p. 7) of the Quebec-Trois-Rivières region, though the buff-weathering dolomitic beds, so characteristic of the lower part of the Lotbinière development, do not appear in this area. It may be that the large, buff, dolomitic concretions of the Delson quarries are the southern equivalent of similar occurrences in the Lotbinière shales.

Lorraine Group

Distribution

A large part of the St. Jean-Beloeil map-area is underlain by rocks of the Lorraine group. Although exposures are not common, they are in a few places sufficiently abundant to allow an almost complete section of the rocks of the group to be worked out. Exposures in the St. Jean sheet at the brickyards at Laprairie, along both shores of Richelieu river for four miles south of Chambly basin, and discontinuous exposures along Huron river near its mouth in Chambly basin, give the most information. Good exposures can be seen in places around mounts Rougemont and Johnson in the eastern part of the St. Jean area, and around mounts St. Hilaire and St. Bruno in the southern part of the Beloeil area, but partial metamorphism has obscured much of the diagnostic value of the fossils. No exposures of Lorraine were seen in the northern half of the Beloeil area.

Subdivision

Any study of the Lorraine group in Quebec must be based upon Foerste's analysis (1916, pp. 18-39) of the section exposed along Nicolet river near Ste. Monique. A recent re-study of this section by Clark (Aston Map-Area, unpubl. Ms., Que. Dept. Mines; 1947, pp.9-14) has allowed some modifications in terminology which are adopted in this report. Revisions in thickness, not yet published elsewhere, are also given in the following table.

In each classification, the section is carried up to, but does not include, the red shales and sandstones of the Queenston or Bécancour River formation. Throughout this report both Clark's formational and member terms and also Foerste's zone terms are used. Save for the merging together of the Proetus and Leptaena zones into the Chambly member there is no difference in the actual stratigraphic subdivision.

Classification of Lorraine and Richmond Rocks of
the Nicolet River Section

Foerste, 1916			Clark, 1947
<u>Richmond Formation</u>			<u>Richmond Group</u>
Queenston member - bluish grey shales	<u>Feet</u> 52+	<u>Feet</u> 53	Bécancour River formation Carmel River member
Waynesville beds	<u>156</u>	<u>164</u>	Pontgravé River formation
<u>Total Richmond</u>	208	217	
<u>Lorraine Formation</u>			<u>Lorraine Group</u>
<u>Pholadomorpha</u> zone	538	591	Nicolet River Formation St. Hilaire member
<u>Proetus</u> zone	287)	880	Chambly member
<u>Leptaena</u> zone	569)		
<u>Cryptolithus</u> zone	963+	1,020+	Breault member
<u>Total Lorraine</u>	2,357	2,491	

Four of the five deep wells drilled in this area started in Lorraine beds. There are reasonably accurate logs of three of these four wells (Appendix A) and from them the minimum thickness of the Lorraine can be given as follows:

Cartier St. Hubert well No. 1	820 feet (see p. 16)
St. Johns Petroleum well No. 1	840 "
Hamilton Powder Co. well	610 "

In addition to these three, however, there was the deep well drilled to 2,330 feet in search for oil on the Laprairie Brick Company premises. This is said to have penetrated 1,500 feet of shales and 800 feet of limestone. The rock at the top of the well, as exposed throughout the brickyard, belongs to the Cryptolithus zone, though to what part thereof the fossils do not tell us. If it be the uppermost part, and we allow 400 feet for the Utica formation, the Cryptolithus zone must be at least 1,100 feet thick. This accords well enough with the minimum thickness of the equivalent beds in the Nicolet gorge, where 1,020 feet were measured, the base being the centre of an anticline with no information as to how far below that horizon the top of the Utica might lie.

The figure of 1,100 feet would have to be increased if the Utica were found to be less than 400 feet thick, or if the rock exposed in the brickyard were found to lie below the top of the Cryptolithus zone. Thus all possibilities converge in influence to make us consider that 1,100 feet is a minimum thickness for the beds of the Cryptolithus zone.

From an examination of the exposures in the St. Jean-Beloeil map-area, the subdivisions of the Lorraine, from top to bottom, may be described as follows:

St. Hilaire Member, or Pholadomorpha Zone.- Thin-bedded, dark grey shales, some surfaces covered with pelecypods; brachiopods rare. Exposed only west of St. Hilaire mountain, whence came the name given this member.

Chambly Member, or Proetus and Leptaena Zones Combined.- Light and dark grey shales interstratified with thin bands of limestone up to six inches thick, often veritable coquinoids of Catazyga, and sandstone lenses up to two inches thick, the latter rarely fossiliferous. Pelecypods abound in the shales and occur sparingly in the sandstones. Brachiopods are common in the limestone beds and in the shales adjacent thereto. Because of the virtual absence of Leptaena from this area, and the presence of Proetus throughout the exposed section between the Cryptolithus zone and the Pholadomorpha zone, it is not possible to identify the Leptaena zone. The name of this member was suggested by Foerste (1916, p. 30) as a possible future name for his Proetus zone. The chief exposures are: along Richelieu river at Chambly Canton and Chambly Basin; along Huron river near its mouth; hornfels outcrops around mount Rougemont.

Breault Member, or Cryptolithus Zone.- Thin-bedded, dark grey shale with a few thin sandstone layers, and still fewer limestone beds. Fauna not abundant, but pelecypods predominate. Trilobites and brachiopods are fairly common in the sandy beds. Dalmanella is very common in the shale and fine sandy beds. The name is taken from the excellent exposures on Bécancour river near the village of Breault. Among the best exposures are: those at Laprairie brickyards; L'Acadie river for about a mile north of highway No. 9B; Richelieu river at, and for one mile below, Fryers rapids; a mile and a half southeast of Boucherville (Utica-Lorraine transition); hornfels around mount St. Bruno, mount Johnson, and the southeast side of mount Rougemont.

Breault Member, or Cryptolithus Zone

Descriptions of some of the most important exposures of this member are given below, followed by lists of fossils so far identified from these beds, which outcrop over a far greater area than do those of any other member of the Lorraine. This is but natural, for not only is it the thickest member, but the presence of a couple of undulations in the section between Laprairie and Chambly has resulted in an undue broadening of the belt of outcrop.

Petite Caroline

The quarry mentioned by Foerste (1916, p. 48) is situated two and a half miles northeast of Rougemont Station on the road that skirts the base of Rougemont mountain. The quarry is now almost completely obscured by refuse and brush, so that no new collection of fossils could be obtained. It might also be added that the Canadian National Railway's line referred to by Foerste has been abandoned. The list of species, combined from Foerste's own collection and from O'Neill's (1914, p. 13), the latter identified by Schuchert, is as follows:

Glyptocrinus columnals
Heterocrinus columnals
Cornulites flexuosus
Dalmanella roqata
Sowerbyella sericea
Rafinesquina alternata
Leptaena sp., cf. L. rhomboidalis
Catazyga headi
C. sp., cf. C. erratica
Eotomaria sp.
Clidophorus sp.
Calymene callicephala (prob. C. meeki)
Cryptolithus tesselatus

On the basis of the presence of the last listed species and the occurrence of Leptaena cf. rhomboidalis, Foerste (1916, p. 49) placed this horizon provisionally near the top of the Cryptolithus zone.

Laprairie Brickyard Exposures

The Laprairie Company, Incorporated, and the St. Lawrence Brick Company, Limited, are actively engaged in brickmaking at the present time (March 1954). Among the raw materials used is shale obtained from wide exposures, the area of exposures for each Company being somewhat less than a

mile by half a mile. The rock is a dark grey, clay shale, essentially the same in both pits, though there seems to be a belief that there is sufficient difference between the rocks of the two exposures to warrant different treatment. The readiness with which the shale disintegrates upon exposure reduces the work of crushing the rock for treatment. Interstratified with the shale are numerous thin beds of sandstone and a few of limestone. Fossils are equally common in all three lithologic types, but can rarely be preserved for study within the easily disintegrating shale. The complete list collected from this locality during the progress of the present work follows:

Crinoidal columnals
Cornulites sp., cf. C. progressus
Lingula sp., cf. L. westonensis
Dalmanella roqata
Sowerbyella sericea
Leptaena moniquensis
Catazyga sp. prob. C. erratica
Ctenodonta pectunculoides
C. sp., cf. C. filistriata
Clidophorus planulatus
C. brevis
C. sp., cf. C. neglectus
Colpomya faba var. intermedia
Cymatonota pholadis
Hormotoma gracilis var. sublaxa
Geisonoceras sp.
Cryptolithus bellulus
Isotelus sp.
Calymene sp.
Lepidocoleus jamesi

The presence of Cryptolithus in considerable numbers is sufficient indication that the beds belong to the Cryptolithus zone. Leptaena moniquensis is reported by Foerste from both Cryptolithus and Leptaena zones, though its presence in the former may be taken as favouring a horizon high up therein. Several other species, such as Ctenodonta filistriata, Clidophorus brevis, and Colpomya faba intermedia are unknown outside the Cryptolithus zone in Quebec, or the Lower Lorraine elsewhere. The conclusion that these beds are high up in the Cryptolithus zone, and hence more or less equivalent in horizon to the exposures at Petite Caroline, is in accord with the analysis of the Laprairie brickyard well given above.

Richelieu River Exposures

Two and a half miles south of the Montreal and Southern Counties Railway bridge across Richelieu river at Chambly there are, on the west side of Richelieu river, low exposures of a banded, dark grey shale, some layers of which are richly fossiliferous. The identified fauna includes the following species:

Crinoidal columnals
Cornulites progressus
Lingula hyacinthensis
Dalmanella sp.
Cuneamya scapha, cf. var. brevior
Ctenodonta sp., cf. C. filistriata
Clidophorus planulatus
C. brevis
C. sp., cf. C. neglectus
Cymatonota pholadis
Rhytimya radiata
Archinacella pulaskiensis
Cyrtolites ornatus
Liospira sp.
Geisonoceras sp.
Cryptolithus bellulus
Triarthrus sp., prob. T. huguesensis

The great similarity between this fauna and that from the Laprairie brickyards is sufficient evidence that the two localities represent essentially the same horizon.

Between Lonqueuil and St. Hubert

In the southwestern corner of the Beloeil sheet, about a mile and a half west of St. Hubert, on highway No. 9 in the angle made by the Montreal and Southern Counties Railway track and the Canadian National main line, several acres of dark grey, soft, slightly calcareous shale were exposed in 1942 by steam-shovel excavation when obtaining fill for the building of the highway. No limestone beds were seen, but an inconsiderable amount of sandstone, in beds an inch or two thick, was exposed. Since their excavation, the remaining blocks of shale have disintegrated so thoroughly that no shale fragment showing more than one square inch of bedding surface can be found. The sandstone beds have withstood the atmospheric attack well, and now contain the only collectible fossils. Some layers are extraordinarily rich in fossils, both in numbers of individuals and in variety, as the following list shows:

Glossograptus quadrimucronatus
Heterocrinus sp.
Serpulites lorrainensis
Cornulites progressus
Lingula sp., cf. L. westonensis
Pholidops cincinnatiensis
Dalmanella multisepta
Rafinesquina mucronata
Zygospira modesta
Cuneamya scapha, prob. var. brevior
Ctenodonta sp., cf. C. filistriata
Clidophorus planulatus
C. scitulus
C. obliquus
C. sp., cf. C. neglectus
Whitella huquesensis
W. sp., cf. W. impressata
Pterinea parva
Byssonychia radiata
B. sp., cf. B. vera
Colpomya faba var. intermedia
Cymatonota pholadis
Rhytimya radiata
R. cancellata
R. sp., cf. R. producta
Sinuities cancellatus
Cyrtolites ornatus
Liospira sp., cf. L. micula
Geisonoceras sp.
Triarthrus glaber
Homotelus stegops
Isotelus sp.
Calymene sp.
Ceraurinus sp.
Lepidocoleus jamesi

Of this assemblage, not a single species is known to occur in the local Utica rocks, although one or two, such as Sinuities cancellatus, do occur elsewhere in Utica beds. The abundance of Glossograptus quadrimucronatus, Pterinea parva, and Triarthrus glaber, all of which are characteristic of the Gloucester or of the Atwater Creek beds of immediately pre-Lorraine time, indicates that these exposures belong low down in the Lorraine. This is borne out by the presence of known Utica beds a short distance northwest, west, and southwest of this locality.

St. Bruno Mountain

On the northwest slope of St. Bruno mountain, close to the igneous contact, hornfels rock is exposed in a large quarry - the so-called Mt. St. Bruno quarry - at present (March 1954) being actively used as a source of crushed stone. The hornfels for the most part ranges in colour from black to dark and even medium grey, though there are beds which have a decided reddish tinge. This colour characteristic was noticed in otherwise dark grey hornfels in the neighbourhood of St. Hilaire and Rougemont mountains. It should not be the cause of assigning the so-coloured rock to the Queenston red shale formation. The rock splits quite easily along some bedding-planes, and exposes an abundant fauna in point of numbers of individuals, if not of species. Dalmanella multisecta is the dominant species. The entire fauna follows:

Mastigograptus tenuiramosus
Diplograptus? sp.
Cornulites sp.
Lingula sp., cf. L. hyacinthensis
Pholidops cincinnatiensis
Dalmanella multisecta
Sowerbyella sericea
Clidophorus scitulus
Geisonoceras sp.
Isotelus sp.
Triarthrus sp.

Because of the abundance of Dalmanella multisecta it is supposed that this locality belongs low down in the Lorraine, but there is nothing that suggests a Utica age for these beds. One remarkable feature of this exposure is the abundance of fossils, especially Dalmanella, replaced by pyrite. The quarry is located less than 250 feet from the igneous contact.

About a mile due south of this large hornfels quarry, a small quarry in fairly soft shale has been opened on the grounds of St. Gabriel College. Very minor amounts of sandstone and limestone are present. Fossils are abundant in certain layers. Graptolites and inarticulate brachiopods occur in the darker shales, pelecypods and articulate brachiopods in the more calcareous beds. The list of fossils identified follows:

Mastigograptus tenuiramosus
Climacograptus typicalis var. posterus
Leptobolus insignis
Lingula ?hyacinthensis

Schizocrania filosa
Pholidops cincinnatiensis
Dalmanella multisecta
Sowerbyella sericea
Catazyga sp., prob. C. erratica
Ctenodonta pectunculoides
Clidophorus planulatus
C. scitulus
Whitella? sp.
Pterinea parva
Rhytimya ?cancellata
Cyrtolites ?carinatus
Geisonoceras sp.
Cryptolithus bellulus
Lepidocoleus jamesi

The presence of Cryptolithus bellulus and the comparative scarcity of Dalmanella multisecta make a position for this locality somewhat higher than that of the hornfels quarry last described very probable. It is, however, definitely a part of the Cryptolithus zone of the Lower Lorraine.

Two Miles Southwest of St. Bruno Station

The only other exposure of any importance of rocks of the Cryptolithus zone was to be seen along a drainage ditch crossing highway No. 1 and proceeding northeastward to and across highway No. 20. No specimens can be collected today, for in the few years that have elapsed since the digging of the ditch the shale has disintegrated to a sand-like consistency. A large collection made by the writer when the ditch was newly opened contains the following species:

Cornulites sp.
Dalmanella multisecta
Sowerbyella sericea
Catazyga ?erratica
Ctenodonta pectunculoides
C. sp., cf. C. filistriata
Clidophorus planulatus
Colpomya faba var. intermedia
Hormotoma gracilis, cf. var. sublaxa
Liospira sp.
Geisonoceras sp.
Cryptolithus bellulus
Primitia ?rudis
Lepidocoleus jamesi

A mile and a third northeast of the village of Varennes and east of the railway, Shawinigan Chemicals, Limited, recently (1951) drilled two wells to depths of 99 and 150 feet in an unsuccessful search for an abundant supply of water. Abridged logs of these wells are given below.

<u>Hole No. 1</u>	<u>Hole No. 2</u>
64' 0" Overburden	76' 0" Overburden
25' 10" Dark igneous rock	74' 0" Dark grey shale, with
2' 0" Hard flinty hornfels	thin, 1-in., beds of
2' 2" Semi-hornfels	sandstone and limestone.
2' 0" Slightly baked shale	No trace of the igneous
3' 6" Normal shale, fossils	rock of hole No. 1.
sparingly present	Fossils abundant, all
	of the <u>Cryptolithus</u>
	zone

These logs show the Cryptolithus zone of the Lorraine to occur below the drift at this locality, and the boundary between that member and the overlying Chambly member is drawn on the map accordingly.

Chambly Member, or Proetus and Leptaena Zones

The place where beds of this member can best be seen in this area is along the west bank of Richelieu river in the vicinity of Chambly, and up Huron river for half a mile. In fact, Foerste (1916, p.30) suggested that if the beds there exposed should later be given a geographic name they should be called the Chambly member of the Lorraine. Elsewhere, the only exposures of importance referable with reasonable assurance to this zone are to be found around Rougemont mountain, but these are for the most part unfossiliferous, or, because of their metamorphism into hornfels, do not yield their fossils readily. The lowest beds of this zone are to be found along Richelieu river about two miles south of Chambly. These latter beds are sparsely fossiliferous, and are not included in the tabulation given below. The section may be followed upward by progressing downstream until the mouth of Huron river is reached, then by proceeding up the latter stream for about half a mile. Exposures are discontinuous, but some are richly fossiliferous, particularly in the upper part of the section at Chambly and along Huron river. In the tabulation given below, the columns are arranged from left to right as nearly as possible in their stratigraphically ascending order.

Occurrence of Fossils of Chambly Member of Lorraine Formation
in Vicinity of Chambly, St. Jean Map-Area

- 6B-3, 4, 5 West shore of Richelieu river at Chambly
 6B-2 Mouth of Huron river, south bank
 6A-1 Huron river at bridge one-quarter mile upstream from mouth
 6A-2 Exposures for one-quarter mile above bridge, to end of
 outcrop
- x signifies present in Quebec Department of Mines collection
 F signifies reported present by Foerste, and not in Quebec
 Department of Mines collection

6B- 3,4,5	6B- 2	6A- 1	6A- 2	SPECIES
	x			<u>Cornulites sp.</u>
F				<u>Glossograptus quadrimucronatus approximatus</u>
x	x	x	x	<u>Pholidops subtruncatus</u>
x				<u>Hebertella occidentalis</u>
	x			<u>Rafinesquina alternata</u>
x				<u>R. mucronata</u>
	x			<u>Strophomena planumbona</u>
x	x		x	<u>Sowerbyella sericea</u>
x	x			<u>Dalmanella sp.</u>
x	x		x	<u>Catazyga erratica (C. headi per Foerste)</u>
	x	x	x	<u>Zyqospira modesta</u>
	x			<u>Ctenodonta lorrainensis</u>
	x			<u>C. borealis</u>
x				<u>C. chamblensis</u>
F				<u>C. sp., cf. C. simulatrix</u>
F				<u>C. sp., cf. C. filistriata</u>
	x			<u>Clidophorus praevolutus</u>
	x		x	<u>C. poststriatum</u>
	x			<u>C. brevis</u>
x				<u>Whitella complanata</u>
	x			<u>W. sp.</u>
x	x	x		<u>Pterinea demissa</u>
	x			<u>Clionychia curta</u>
x	x		x	<u>Byssonychia radiata</u>
	x		x	<u>B. hyacinthensis</u>
		x		<u>B. sp., cf. B. richmondensis</u>
F	x	x	x	<u>Lyrodesma poststriatum</u>
x				<u>L. major</u>
	x		x	<u>Colpomya faba</u>
x				<u>Colpomya faba pusilla</u>
x				<u>Cymatonota sp.</u>

Occurrence of Fossils of Chambly Member of Lorraine Formation
in Vicinity of Chambly, St. Jean Map-Area (Cont'd)

6B- 3,4,5	6B- 2	6A- 1	6A- 2	SPECIES
	x			<u>C. pholadis</u>
x				<u>C. recta</u>
x	x			<u>Modiolopsis borealis</u>
F		x	x	<u>M. sp., cf. M. concentrica</u>
	x			<u>Orthodesma pulaskiensis</u>
		x		<u>O. postplicata</u>
x				<u>Psilococoncha sp.</u>
	x		x	<u>P. sinuata borealis</u>
		x		<u>P. subovalis</u>
x	x	x		<u>Pholadomorpha pholadiformis</u>
		x		<u>P. divaricata</u>
	x			<u>Rhytimya granulosa</u>
F	x			<u>R. oehana</u>
		x		<u>R. colemani</u>
F				<u>R. sp., cf. R. compressa</u>
F				<u>Archinacella pulaskiensis</u>
		x		<u>Cyrtolites sp.</u>
x	x			<u>Sinuities cancellatus</u>
F				<u>Eotomaria sp. cf. E. canalifera</u>
		x		<u>Cyclomena bilix</u>
	x			<u>Hormotoma gracilis var.</u>
	x			<u>Pterotheca sp.</u>
	F			<u>P. pentaqona</u>
x				<u>Geisonoceras tenuifilum</u>
F				<u>Spyroceras sp., cf. S. bilineatum</u>
	x		x	<u>Isotelus sp.</u>
F	x			<u>Proetus chamblensis</u>
	x			<u>Calymene granulosa</u>
	x	x	x	<u>Technophorus quincuncialis</u>
F	x		x	<u>Bythocypris sp., cf. B. cylindricum</u>
	x		x	<u>Lepidocoleus jamesi</u>
	x			<u>Eusarcus sp.</u>

Foerste's contention that the Proetus zone should be correlated with the Southgate member of the Eden formation (Foerste, 1916, p. 33) is open to revision. Now that the re-study of the section along Nicolet river (Clark, Aston Map-Area, unpub. Ms., Que. Dept. Mines) is complete, it is possible to correlate the Chambly member pretty definitely with the Pulaski beds of Maysville age.

St. Hilaire Member, or Pholadomorpha Zone

It is questionable whether this part of the section belongs properly in the Lorraine or in the overlying Richmond. Because of the gradual introduction of Richmond species into the Lorraine beds it is virtually impossible to be sure just where the boundary line should be drawn between Lorraine and Richmond. This was more clearly indicated to Foerste in the Nicolet River section than to the writer in the examination of the Chambly-Huron River exposures, but the difficulty is present in the latter locality nevertheless. For the present, Foerste's Pholadomorpha zone, or the writer's St. Hilaire member, will be retained as a designation for those beds at the top of the Lorraine formation, though they contain faunal elements which link them closely to the overlying Richmond.

St. Hilaire Mountain

Along Huron river there are no beds exposed whose stratigraphic position is in much doubt. For four miles upstream from the easternmost exposures of the Proetus beds there are no outcrops. Then, dark shales appear, and these bear a fauna characterized by Catazyga headi and other Richmondian elements, and are referred to as the Pont-gravé River formation (Clark, 1947, p. 13) of the Richmond group. On the west side of St. Hilaire mountain, however, there are many exposures of shale between the mountain and Richelieu river. These contain, in places, an abundant fauna. Some of these occurrences can be definitely correlated with the Richmond, but the faunas of several of the westernmost exposures do not include Catazyga headi, and, although they have Richmondian affinities, they are predominantly Lorraine. Because of the mixture of species it is considered best, at present, to assign these westernmost exposures to that subdivision just described, that is, the Pholadomorpha zone. These beds at St. Hilaire correspond, then, to the gap in the sequence of exposures along Huron river. Because of the excellence of the few, though small, exposures on the flank of St. Hilaire mountain, the name St. Hilaire has been proposed (Clark, T.H. 1947, p.9) for the member which they constitute.

Fossils

The fauna of these beds consists of the following species:

Cornulites sp.

Cyrtolites ornatus

Lophospira sp.

L. tropidophora

Cuneamya scapha brevior
Ctenodonta borealis
Clidophorus praevolutus
C. poststriatum
Ischyrodonta sp.
Whitella sp.
W. huquesensis
Pterinea sp.
Byssonychia radiata
B. sp., cf. B. richmondensis
Cymatonota pholadis
Modiolopsis concentrica chambliensis
Psilococoncha sinuata borealis
Pholadomorpha divaricata
Eusarcus sp.

Richmond Group

Historical Review

The Richmond group consists of two parts. The lower, and fossiliferous, portion, correlated by Foerste (1916, pp.141-150) with the Waynesville, is a series of shales essentially similar to the Lorraine shales, and succeeding the latter with no observable break. Above these Lorraine-like beds is a thick development of unfossiliferous red shale known as the Queenston formation. This is the highest formation exposed in the St. Jean-Beloeil map-area. The difficulties involved in drawing a boundary line between the Lorraine and the Richmond groups have already been outlined, and will be referred to again below.

Richmond fossils had not been reported from southern Quebec before O'Neill's (1914, pp.10-15) publication on St. Hilaire and Rougemont mountains. In that report he quoted both Ulrich and Schuchert as favouring a Richmond rather than a Lorraine grouping for certain shales occurring near St. Hilaire station. Later, Foerste (1916, pp. 150-155) showed conclusively that in several places undoubted Richmond strata occurred in southern Quebec, and in particular along Huron river and at St. Hilaire. Still later, Foerste (1924) published the results of his palaeontological investigations on the Lorraine and Richmond of Ontario and Quebec. No subsequent research had been conducted on this subject until this present undertaking began.

Pontgravé River Formation, or Waynesville Member

Distribution

Beds of the Proetus zone are well exposed on Huron river for half a mile upstream from its mouth. There follows a stretch of four miles with no exposures, doubtless occupied in part by the upper beds of the Proetus zone, and also by the Pholadomorpha zone. Then exposures begin again, and are continuous for about a mile eastward. The westernmost of these exposures consists of dark grey shales which, except for being slightly harder, are lithologically indistinguishable from the shales of the Proetus zone, but their fauna includes certain distinctly Richmondian species. These shales are overlain by somewhat lighter coloured shales, barren of fossils and abundantly ripple-marked, which, together with the following and overlying red and green shales, are referred to the Queenston formation and within that formation have been designated the Carmel River member (Clark, 1947, p. 14). The base of the Richmond beds in the St. Jean-Beloeil area is, therefore, not known. Their top is at the uppermost fossiliferous horizon.

The lowermost beds exposed are dark grey shales. Toward the top, limestone beds occur but they are never a dominant feature of the section. At St. Hilaire, all those exposures west of St. Hilaire mountain, except the westernmost ones already described as being a transition from the Lorraine to the Richmond, fall, as far as their limited fossiliferous content indicates, clearly into the Richmond. There, dark shales predominate. Sandstone beds also occur, but no limestone was seen. It appears that these minor irregularities and departures from the normal shale are of insignificant importance.

Thickness

On Nicolet river Foerste measured 156 feet of beds referable to the Waynesville (1916, p. 147), and later Clark expanded this figure to 164 feet (Clark, Aston Map-Area, unpubl. Ms., Quebec Dept. Mines). On Huron river the section is discontinuous, but the calculated thickness of the beds exposed is only 75 feet. In all probability much more of the Pontgravé River formation is hidden along the stretch of Huron river where there are no outcrops.

Fossils

In the lists which follow there are two localities recorded from the Huron River exposures. Locality St. Jean 8A-2 is the lowest in the sequence, and St. Jean 8A-3 the highest. The latter is not more

than 20 feet below the top of the Waynesville beds. From the Beloeil map-sheet, two localities are recorded. Beloeil 8E-2 is just over a mile southeast of St. Hilaire Station, where excavation for a drain alongside of the road to Mont St. Hilaire village exposed fossiliferous rock. Beloeil 8E-3 is 500 feet southeast of Beloeil 8E-2 in a quarry belonging to Alfred Noiseux. This was formerly used for supplying road-material, but has long been inactive. In the following tabulation, a species known to occur elsewhere in either the Lorraine or the Richmond is indicated by the letter L or R, respectively. Also recorded, by the letter F, are Foerste's species (1916, p. 153) from Huron river and from a locality that cannot at present be identified, but which is in all probability practically identical with locality Beloeil 8E-2.

Occurrence of Richmond Fossils, St. Jean-Beloeil Map-Area

St. Jean		Beloeil		L or R	SPECIES
8A-2	8A-3	8E-2	8E-3		
		F		R	<u>Streptelasma rusticum</u>
x	x	x			<u>Cornulites</u> sp.
F					<u>Rafinesquina alternata</u>
x	x			L? R	<u>Hebertella occidentalis</u>
F		F		R	<u>Strophomena hecuba</u>
F		F		R	<u>S. planumbona</u>
x					<u>S. sp.</u>
		F		R	<u>Platystrophia clarksvillensis</u>
F				L? R	<u>Catazyga headi</u>
x				L	<u>C. erratica</u>
			x		<u>Zygospira</u> sp.
x	x	F		L	<u>Cuneamya scapha brevior</u>
x				L	<u>Ctenodonta borealis</u>
x				L	<u>C. lorrainensis</u>
x				L	<u>C. chamblensis</u>
	x			R	<u>C. sp., cf. C. albertina</u>
		F		L R?	<u>Clidophorus planulatus</u>
x	x	x		L	<u>C. praevolutus</u>
x				L	<u>C. postvolutus</u>
x				L	<u>Whitella huguesensis</u>
		F		L? R	<u>W. complanata</u>
	x			R	<u>W. securiformis</u>
x				R	<u>W. sp., cf. W. goniumbonata</u>
x					<u>W. sp.</u>
	x	x		L R	<u>Pterinea demissa</u>
x	x	x		L R	<u>Byssonychia radiata</u>
			x	R	<u>B. sp., cf. B. richmondensis</u>

Occurrence of Richmond Fossils, St. Jean-Beloeil Map-Area (Cont'd)

St. Jean		Beloeil		L or R	SPECIES
8A-2	8A-3	8E-2	8E-3		
x				L	<u>Colpomya faba pusilla</u>
	x			L	<u>Cymatonota recta</u>
x	x			L	<u>C. pholadis</u>
		x		R	<u>C. semistriata</u>
		F			<u>C. sp., cf. C. recta</u>
x				L	<u>C. sp., cf. C. pholadis</u>
F				R	<u>Modiolopsis concentrica</u>
x					<u>M. sp.</u>
x				R	<u>Orthodesma postplicatum</u>
	x		x	L R	<u>Psiloconcha subovalis</u>
x					<u>P. sp., cf. P. subovalis</u>
	?			R	<u>P. borealis</u>
	x	F		R	<u>Pholadomorpha pholadiformis</u>
x				R	<u>P. divaricata</u>
x				L	<u>P. subtruncata</u>
x				L	<u>Rhytimya colemani</u>
			x		<u>R. sp.</u>
	x				<u>Hormotoma gracilis var.</u>
x	x			R	<u>Lophospira beatrice</u>
			x		<u>L. sp.</u>
		F		L	<u>Eotomaria remotistriata</u>
x					<u>E. sp.</u>
x				L	<u>Pterotheca harviei</u>
x				L	<u>Calymene granulosa</u>
x				L	<u>Proetus sp., cf. P. chamblensis</u>
			x	R	<u>Drepanella sp., cf. D. richardsoni</u>
x	x		x		<u>Eusarcus sp.</u>

On statistical evidence there is little to influence one in deciding whether the above fauna is more closely related to the Lorraine than to the Richmond. However, because most of the Lorraine species are long-ranging forms, it is to be expected that many of them may have persisted beyond their Lorraine time-horizon. The presence of sixteen species elsewhere restricted to the Richmond is sufficient evidence for correlating these beds with the Richmond, and heavily outweighs the evidence of the almost equally numerous Lorraine hang-overs. Foerste (1916, p. 20) identified equivalent beds along the gorge of Nicolet river as belonging to the Waynesville phase of the Richmond.

Bécancour River (Queenston) Formation

The uppermost formation exposed in this part of Quebec is a shale, grey or greyish-green at its base, but becoming red throughout most of its thickness. This shale has been correlated, largely upon lithologic grounds, with the Queenston shale of Ontario. Its stratigraphic position is in accord with such an assumed relationship. No fossils occur in these rocks in Quebec, although a few ostracods have been found in the Queenston shales of Ontario (Foerste, 1916, p. 162).

Distribution

The southernmost exposures are to be found along Huron river about five miles above its mouth, and about 2,000 feet below the cement bridge at that locality. Just below this point 17 feet of fossiliferous shales of the Waynesville member are well exposed. These are succeeded by the lowest part of the Queenston, a medium-grey shale, abundantly ripple-marked, which has an estimated thickness of about 90 feet. Elsewhere, Clark (1947, p. 14) has termed these grey shales the Carmel River member of the Bécancour formation. They are succeeded by red shales with which some red sandstone beds are interstratified. The red shales as exposed in this locality are about 50 feet thick. Elsewhere, as in the St. Barnabé district of the St. Hyacinthe map-area (Maddox, 1931b, p. 92D), drill-holes have penetrated about 1,620 feet of red shale and sandstone, all of which doubtless belongs to the Queenston formation. The top of this formation is unknown. At the base there is everywhere a grey or greenish-grey shale a few scores of feet thick (the Carmel River member) grading upward through interstratified red and green shales into a uniformly red coloured shale.

On land belonging to Leon Moreau, to the south of St. Hilaire mountain, quarrying has exposed red and green 'semi-hornfels'. No exposures of any kind of red rock are known north of the immediate vicinity of St. Hilaire mountain. That Queenston beds underlie the northeastern corner of the Beloeil map-area, and a north-northeast trending belt immediately east of St. Hilaire mountain, is indicated by a score or more occurrences of red rock encountered during the drilling of water wells. These localities, although not plotted on the accompanying geological map, serve to show to what extent information gained from proprietors concerning their wells can be of service in approximating certain geological boundaries. In this case, even the trace of the Bas de Ste. Rose fault can be carried east of Richelieu river in the vicinity of St. Charles.

IGNEOUS ROCKS

General Statement

The igneous rocks of the St. Jean-Beloeil map-area occur as large 'plug-like' masses (mounts St. Bruno, St. Hilaire, Rougemont, and Johnson), and as numerous scattered dykes and sills. The latter are presumably genetically related with the so-called plugs. The 'mountains' named above, and other similar nearby hills (mounts Royal, Yamaska, Shefford, and Brome), collectively make up the 'Monteregian hills' (Adams, 1903), a group of prominences characterized by the relatively rare alkaline suite of intrusive rock-types. According to age determinations (Urry, 1936, p. 38) based on the 'helium ratio' of rocks from the neighbourhood of Montreal, the Monteregian intrusives originated in early Tertiary time.

Mount Johnson

This mountain, in the east-central part of the St. Jean sheet, is the smallest and in some ways the most interesting of the Monteregian hills. Every part of it is readily accessible from the surrounding roads, and exposures are reasonably abundant.

The earliest reference to the rocks of this mountain was made by T. Sterry Hunt (1859, p. 180), and was subsequently quoted by Logan in his Geology of Canada (1863, p. 664). Hunt briefly noted a few varieties of 'diorite'. Logan came to no structural conclusion save that the rocks "break up through the unaltered strata, and are clearly intrusive" (1863, p. 663). He devoted half the following page to a brief description of the rock types found on the mountain. Ellis (1896, p. 73J) remarked that nepheline syenite also occurs on mount Johnson.

No further information became available until Adams (1903) published a fairly detailed description of the mountain. He emphasized the concentric arrangement of the several rock types, and also their peculiar succession, the most acidic ones lying around the periphery, and the most basic in the central part. He accounted for this by assuming deep-seated differentiation and successive intrusions along the axial portion, crowding the earlier, and more acidic, portions out toward the walls of the pipe, the last and most basic differentiate occupying the central core. Later, Adams (1913) expanded parts of his earlier description, but did not modify his conclusions essentially. A more recent study of the rocks of the mountain was made in 1933 by N.L. Wilson, whose conclusions may be seen in an unpublished thesis in the Redpath Library at McGill University, Montreal. In the following years,

Osborne and Wilson (1934) published a short paper on some dyke rocks from Mount Johnson, and Osborne (1935) some data regarding the essexite of the mountain. The use of the rock as building-stone has been described by Parks (1914, pp.175-180) and by Burton (1932, pp. 107-116). Graham (1944, pp.471-474), in a review of the Monteregian hills, contributed to the Geology of Quebec, gave a brief statement of what was known up to that date.

Mount Johnson rises nearly 700 feet above the surrounding plain, and 876 feet above sea-level. Its nearly perfect conical form is marred by a steep cliff on the south side, whereas on all the other Monteregian hills the northern slopes are the steepest. It consists of intrusive igneous rocks which are surrounded by a collar of hornfels. Adams stated that this hornfels could be seen in a number of places around the mountain, but today it appears only on the northwest and west sides, where it dips gently away from the mountain. The essential horizontality of the hornfels shows, according to Adams, that the sedimentary beds were not much disturbed by the process of intrusion. Fossils in the hornfels indicate that the latter occupies a position in the lower part of the Lorraine (Breault member, or Cryptolithus zone).

The igneous rocks of the mountain are of five kinds, arranged in concentric bands. The most concise statement concerning the rock types and their arrangement is to be found in Osborne's 1935 paper. It is as follows: "... five facies of plutonic rocks arranged as vertical, hollow, coaxial cylinders may be recognized. The core is of olivine essexite, surrounded by a fine-grained essexite known in the monument-stone trade as Ebony. The next facies is also an essexite which, on account of the pellucid character of its feldspars, resembles the stone from Quincy and is known commercially as Canadian Quincy. These are surrounded by a porphyritic rock for which N.L. Wilson and the writer have coined the term monnoirite. The outer annulus is a pulaskite porphyry grading to a pulaskite near the hornfels collar that surrounds the mountain. The rock of the core is the finest grained but the granularity does not increase uniformly outward. The coarsest appears near the contact of monnoirite and pulaskite porphyry" (Osborne, 1935, p. 670).

"The olivine essexite and the pulaskite both show a marked alignment of the inequidimensional minerals in a vertical direction. The rocks of the other three bands show a banding parallel to the outcrop of the annuli as well as the vertical alignment" (Osborne and Wilson, 1934, p. 181).

The annular arrangement is significant. It led Adams to postulate successive intrusions filling a diatreme from the outside inwards, though such an order would not be that of decreasing basicity, as is the case with Mount Royal, and probably with most of the other Monteregian hills. On the hypothesis that the more basic types are the oldest it would appear that the central part was first emplaced, and was surrounded, in ring-dyke fashion, by rocks of progressively increasing acidity. Such ring-dyking should, however, have deformed the surrounding sediments. On most of the other Monteregian hills some trace of brecciation, accompanying or related to the intrusion of the syenitic rocks, can be seen, but none has been observed on mount Johnson.

The outermost ring of intrusive rock is a buff-coloured, coarse-grained, porphyritic rock known as pulaskite, a variety of sodasyenite. It consists of large crystals, up to an inch in length, of white or light grey feldspars, probably mostly oligoclase, with relatively little orthoclase, set in a groundmass of smaller, buff-coloured feldspars, with a small amount of biotite, hornblende, sphene, and very subordinate nepheline. This grades more or less insensibly into what Adams called the 'transition rock', intervening between the pulaskite and the essexite. Osborne and Wilson named the transition rock monnoirite (1934, p. 181), thus perpetuating the earlier name of the mountain, Monnoir. This is a very coarse-grained rock consisting of phenocrysts of feldspar up to two inches in length set in a groundmass of feldspar, hornblende, augite, biotite, etc. Mineralogically, it is closely similar to the pulaskite, but the greater proportion of ferromagnesian minerals gives it a darker aspect, so that it more closely approaches the essexite in appearance. Because of the tendency of the abundant feldspars of these two rocks to weather readily they have not been used as building-stones.

Within the monnoirite ring there are three varieties of essexite, concentrically arranged. The two outer rings consist of normal essexite, divided into two varieties for which there are at present no other designations than 'Canadian Quincy' and 'Ebony', both of which are terms used by local quarrymen. The central core of the mountain consists of olivine essexite. All of these essexites contain plagioclase, hornblende, biotite, pyroxene, nepheline, etc. Hornblende is the commonest mineral in the normal essexite, pyroxene in the olivine essexite. Olivine is found only in the innermost part. In order, the 'Canadian Quincy', the 'Ebony', and the olivine essexite are arranged according to colour, granularity, and composition, the olivine type being the darkest, the finest in grain, and the richest in basic constituents. The olivine essexite has not been quarried for building-stone.

All these five varieties show, in some measure, an alignment of the coarser, lath-shaped crystals of plagioclase and hornblende,

more or less parallel with the margin of the rock body concerned. This alignment is most pronounced in the 'Canadian Quincy' variety.

Rougemont Mountain

Rougemont mountain is situated in the northeast corner of the St. Jean map-area. Its summit is 1,260 feet above sea-level and about 1,150 feet above the surrounding plain. Steep, in some places precipitous, slopes border the mountain on its west, north, and east sides. The south side, nowhere precipitous, affords fairly easy access to the higher parts. Rougemont provides no exception to O'Neill's observation regarding the Monteregian hills that "most of them present in plan the form of a horseshoe-shaped ridge, opening southward, surrounding an interior basin" (O'Neill, 1914, p. 17).

Logan, in 1863 (p. 667), briefly described the rocks of Rougemont as dolerites, and gave some details of their composition. In this he closely followed the earlier report of T. Sterry Hunt (1859, p. 184). Little else is recorded in the literature until O'Neill's memoir (1914) on both this mountain and St. Hilaire mountain. Since then no further descriptions have been published. Graham (1944, pp. 470-471) provided a brief summary of the petrology of the mountain.

According to O'Neill there are three main types of rock on Rougemont, all of which are characterized by a high content of lime and magnesia. The greater part, four-fifths at least, of the area of the mountain is occupied by yamaskite, with which minor amounts of normal essexite are peripherally associated, and into which there appears to be every gradation. The yamaskite is a dark-coloured rock, ranging in grain-size from very fine to very coarse, but is in general coarse-grained. It consists mostly of augite, with which minor amounts of colourless olivine, hornblende, anorthite, and minor accessories occur. The essexite, usually medium- to fine-grained, differs from the yamaskite chiefly in its greater abundance of anorthite. The third type of rock, rougemontite, occupies the western fifth or so of the mountain, and consists predominantly of anorthite, with minor amounts of augite, reddish-brown olivine, etc. It is usually fine- to medium-grained, and medium grey in colour. O'Neill maintained that though there was but one main intrusion forming the mass of the mountain, the yamaskite slightly preceded the more feldspathic rougemontite. He further concluded (O'Neill, 1914, p. 90) that "there was a differentiation before the intrusion took place, and a segregation contemporaneous with the intrusion served to accentuate the contrast between the two main products of differentiation (yamaskite and rougemontite) and to produce a third type (essexite) intermediate to the extremes".

St. Hilaire Mountain

St. Hilaire mountain, or, as it is sometimes called, Beloeil or Rouville mountain, is situated in the southeastern part of the Beloeil sheet. It is rudely circular in form and, like most of the Monteregian hills, its slopes are precipitous on all sides but the south. Its highest point is about 1,350 feet above sea-level and 1,230 feet above the surrounding plain. The history of its investigation closely parallels that of Rougemont. Practically all that has been published concerning this mountain is contained in O'Neill's memoir (1914).

The western half, more or less, of St. Hilaire mountain consists of essexite, the eastern part of nepheline syenite. The essexite varies considerably in colour and in granularity but is, in most places, a dark, medium-grained rock consisting chiefly of plagioclase (labradorite), which makes up about one-half of its bulk, and augite, with lesser amounts of hornblende, biotite, iron oxides, nepheline, apatite, etc. Olivine also is present, but in very small amount. In one part of the mountain, the rock consists almost entirely of labradorite and nepheline, with less than 15 per cent ferromagnesian minerals. To this variety O'Neill (1914, p. 28) gave the name rouvillite, from Rouville county, in which the mountain is situated.

The nepheline syenite is a greyish-green rock, generally somewhat porphyritic in texture. Nepheline, sodalite, and albite, in about equal amounts, together make up three-quarters of the bulk of the rock, the balance being chiefly orthoclase and aegirite. Inclusions of essexite in the nepheline syenite show that it was intruded after the essexite. The syenite is usually bordered by a brecciated zone. It is rare that brecciation of the adjacent rocks accompanies the essexite, either on this mountain or on any of the other Monteregian hills.

All of the St. Hilaire rocks are characterized by a high content of soda, which in one variety of the syenite, known as tawite, amounts to nearly 20 per cent. Sodalite makes up about 17 per cent by volume of the normal nepheline syenite, whereas it comprises 70 per cent of the tawite. In three places around the margin of the nepheline syenite there are small patches of a feldspathic tawite which O'Neill (1914, p. 46) describes as having "the appearance of a mosaic of well-bounded crystals of feldspathoid, in a matrix of white feldspar together with a few small crystals of pyroxene and a little black iron ore". On page 49 he gives the composition, by volume, as follows: sodalite, 70 per cent; orthoclase, 12 per cent; nepheline, 8 per cent; albite and aegirite, 5 per cent each. Although O'Neill used the descriptive name 'feldspathic tawite' for this exceptional rock type, he suggested that the varietal name in the quantitative classification should be beloeil-

ose. Later, Johannsen (1938, p. 282) proposed the name beloelite for this rock.

Included within the nepheline syenite are three large blocks of Trenton limestone, up to 500 feet in length. Though largely crystallized, fossils occur in some parts. These have been reported upon by Schuchert (O'Neill, 1914, p. 24), but the only species identified is Cyclospira bisulcata. This indicates an upper horizon in the Trenton group, not a lower one as stated by Schuchert. According to Ells (cited by O'Neill 1914, p. 24), Devonian fossils had earlier been found in xenolithic blocks in the mass of this mountain, but although careful search was made by O'Neill, and later by the present writer, in the locality indicated, no Devonian fossils were found.

The problem of the form of intrusion of the Montereian hills has not yet been solved. O'Neill's (1914, p. 25) conclusion regarding this mountain is important. "In summary then, the evidence of undisturbed country rock; the coarse texture of the igneous mass close to the outer contact; the vertical conduit through which the magma passed; the striking development of flow structure in the essexite; and finally, the churning action shown in the syenite, all point to the conclusion that St. Hilaire mountain represents an eroded volcanic neck".

St. Bruno Mountain

This mountain is near the southwest corner of the Beloeil sheet. Other names which have been applied to it are Boucherville mountain and Montarville. Its highest point is about 715 feet above sea-level, and 620 feet above the surrounding plain. The igneous rocks occupy about one and three-quarter square miles. Among the Montereian hills only mounts Royal and Johnson are smaller. As with the more easterly hills, some early descriptive work was published by Hunt (1859, p. 181) and Logan (1863, pp. 464, 468, 479, 665, 666). Ells mentioned the mountain, but added no new information. It remained for Dresser (1910) to present the first, and only, detailed report upon this intrusion.

Petrographically, this is the simplest of all the Montereian hills. There is, according to Graham (1944, p. 468), but one main type of rock, essexite, which, because of its abundance of olivine, might in places well be called peridotite. In its normal development it consists of augite, hornblende, and biotite in nearly equal amounts, with lesser amounts of olivine and labradorite. Dresser describes a small patch of umptekite, a light grey rock consisting, megascopically, of almost nothing but feldspar. The writer's examination of the contact

between the igneous mass and the surrounding hornfels indicates that syenite-like rocks are reasonably abundant as peripheral developments.

Dresser mentions (1910, p. 20) flow-structure as being frequently observed, though it is nowhere as prominent a textural feature as on mount Johnson. The shales in contact with the intrusive have been changed into a hard, flinty, ringed hornfels in which many of the fossils have been replaced by pyrite. Dresser stated that the age of the hornfels was Utica, but close to the Lorraine. Large collections made during the present investigation change this slightly, for the fossils indicate a lower Lorraine age.

Dykes and Sills

Within, and in the close vicinity of, each of the Montere-gian hills dykes and sills are fairly common. Several occur in the so-called Duquette quarry on the northwest flank of mount St. Bruno. Graham (1944, p. 468) generalizes concerning these and other dykes associated with this mountain by stating that they have the composition of camptonite. Many of them are coarsely porphyritic, with large phenocrysts, up to an inch in length, making up a large part of the rock.

Mount Johnson is poorly provided with dykes. Adams mentioned only five. Osborne and Wilson (1934) described some peculiar types of dyke rocks: "one is a camptonite glass, another is a tinguaitite porphyry, the third is composed principally of the iron-ore minerals, and the fourth has a large amount of alkaline amphibole".

Dykes and sills of each of the main types of intrusive rocks that form mounts St. Hilaire and Rougemont were noted by O'Neill (1914, pp. 50-62, 78-85, 91). These occur both in the intrusive mass itself and in the hornfels collar.

A complex of basic sills and a few dykes forms a natural dam across Huron river, less than a mile above its mouth (Figure 3C). The sill is composite, and probably more than 24 feet thick.

Elsewhere, with the exceptions described below, dykes and sills are scarce, and occur as single, narrow or thin, bodies (Figure 3A). Two acidic sills deserve especial attention: first, the St. Amable sill in the western part of the Beloeil map-area, exposed mostly in the Verchères woods, though its southwesterly extension may be recognized; and second, the St. Luc sill which can be seen in the central part of the St. Jean area.

St. Amable Sill

Two miles west and west-northwest of the village of St. Amable abundant and widespread exposures of an acidic sill can be found. In places, the exposures are flush with the ground; in others, they form 40-foot cliffs. Two miles due west of St. Amable church there is a hill whose summit is at least 50 feet above the surrounding plateau, but which is not shown on the topographic map. Bold exposures of a feldspathic sill, probably a tinguaite, flank the hill along its western margin. The sill body, which is up to 40 feet thick, is composite, for it is made up of a number of individual injections, two to four feet thick, each with an approach to a chill zone and one of them actually vesicular at the base. Throughout most of the rock an extremely fine-grained equigranular texture prevails, though marked coarser textures are common in the mid-portions of the individual sills. In all of them, feldspar makes up the bulk of the rock, with thin laths of hornblende as a minor constituent. No other minerals are megascopically visible. Several irregular and lenticular 'inclusions' of deeply rusted, almost black shale occur between sill units (Figure 2A). In the southwestern part of the exposure there is a gravel pit owned by Mr. X. Dalpé, northeast of which is a cliff, 25 feet high, composed of the sill rock (Figure 2B). A deeply weathered brownish shale containing Triarthrus, and therefore either of Utica or Lower Lorraine age, outcrops on the edge of the pit. Northward for more than a mile, low exposures of the same sill body are widespread through the woods, rarely making escarpments of more than a foot or two.

Better exposures of the same sill complex can be seen on land belonging to Lucien Lapointe close to a road corner one and three-quarter miles northwest of St. Amable church. There is no high cliff here, but the outcrop rises ten to twenty feet above the level of the meadow to the southeast. The rock here is somewhat more coarsely crystalline, and the texture, which approaches ophitic, is well displayed on weathered surfaces. Feldspar predominates. Internal contacts cannot be recognized. One very strange dark body of much the same kind of rock, with a sinuous course, occurs on a vertical face at the southernmost part of the exposure (Figure 2C). The surface of the rock is peppered with cavities half an inch to an inch deep and from two to four inches across. No reason for their formation could be found.

No further exposures are known to the northeast. Several miles southwestward, the same kind of rock, with sill-like relationships, outcrops at several points, though this gives no assurance that the following occurrences were ever in continuity with the St. Amable body.

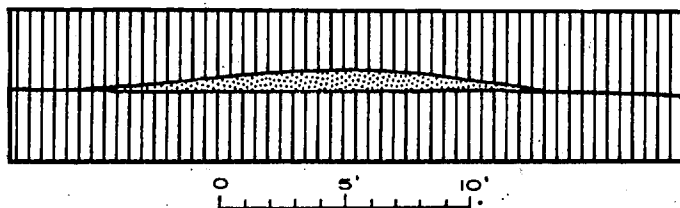


Figure 2A.- St. Amable sill, two miles west of St. Amable. Inclusion of dark Lorraine shale between two sill units

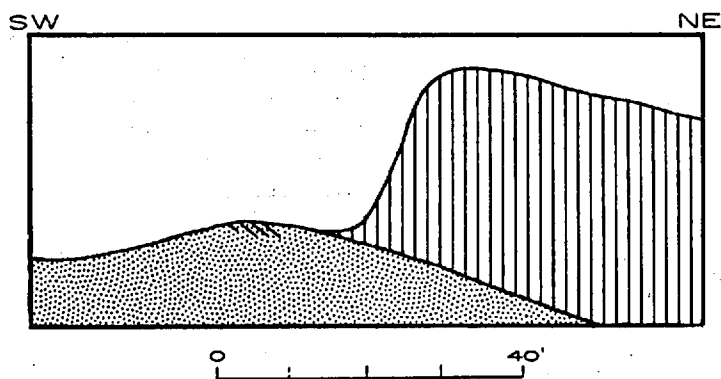


Figure 2B.- St. Amable sill. Vertical section at Dalpé's gravel pit, two miles west of St. Amable. Lorraine shale (stipple); sill (lines)

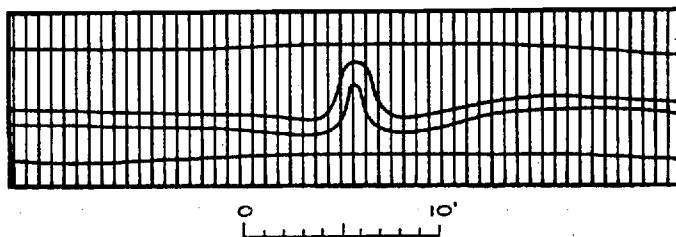


Figure 2C.- St. Amable sill, 1 3/4 miles northwest of St. Amable. Peculiar sinuous structure within sill unit. Perhaps several sill injections here.

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(1) On the east bank of the St. Lawrence, three-quarters of a mile south of the Verchères-Chambly county-line and just north of the tip of Boucherville islands, a six-foot sill intrusive into Utica shale is exposed (Figure 3B). There are probably two injections concerned here, each amygdaloidal at the top. The rock is medium buff-coloured, very fine-grained, and consists almost wholly of feldspar, which also largely fills the amygdules.

(2) A slightly more basic sill, five feet thick, outcrops along the shore of the St. Lawrence forming a small point half a mile downstream from the western margin of the Beloeil map-area. Brecciated Utica shale below and baked Utica shale above contain it. The rock is dark grey, finely crystalline, and is composed partly of feldspar and partly of glass, with a few hornblende phenocrysts. A very few crystals of pale amber sphene can also be seen in some specimens.

(3) A mile and a half northeast of the last-described exposure, and just within the margin of the woods some two-thirds of a mile from the shore of the St. Lawrence, there is an abandoned quarry, opened into essentially similar rock, which extends for several hundred feet to the northeast and to the southwest. In 1951, draining of the water-filled quarry by the new owner, Mr. Polis, exposed twenty-five feet of sill rock together with the underlying shale. The rock is very fine-grained, consisting mostly of laths of feldspar together with a much lesser amount of hornblende, in fine needles. Within it are abundant vugs lined with a variety of minerals. These vugs are presumably flattened amygdules.

St. Luc Sill

Two miles north of St. Jean, highway No. 9B turns sharply to the west, and after three-quarters of a mile turns off to the northwest. At this latter turn, and on the outside of the bend, there is an abandoned quarry (P. Baillargeon quarry) in a fine-grained nepheline syenite porphyry. Two other smaller quarries on the northeast side of the road expose the same rock, and for 1,500 feet northwestward along the highway there are scattered exposures of this rock. A few outcrops show up in the woods to the north. Burton (1932, p. 116) was inclined to consider this rock a sill. Parks (1914, p. 180) referred to it as volcanic. There seems little doubt that it is a sill genetically connected with the Monteregean intrusion. Though the quarry at present (1954) is water-filled, Burton gives its depth as 20 feet, and it is probable that this is at least the minimum thickness of the sill.

On an island close to the west bank of Richelieu river at Fryers rapids, six miles north of St. Jean, there is an old, long-

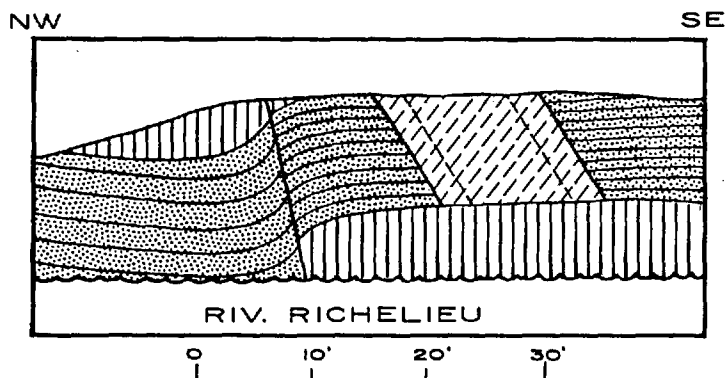


Figure 3A.- Vertical section along south bank of Richelieu river just below dam at Chambly. Lorraine shales (stipple) intruded by acidic sill (lines) and basic dyke (hatched lines); porphyritic in central part

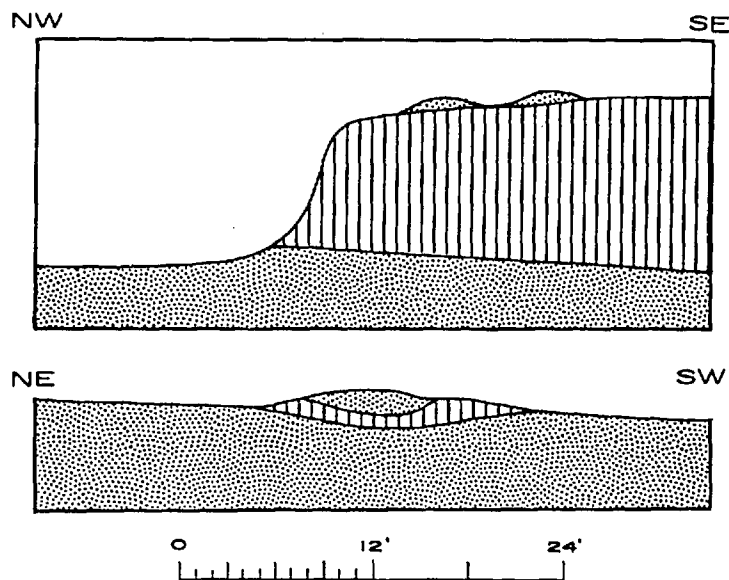


Figure 3B.- Two vertical sections of acidic sill (lines) between beds of Utica shale (stipple). Small point on east bank of St. Lawrence river, three miles below Boucherville

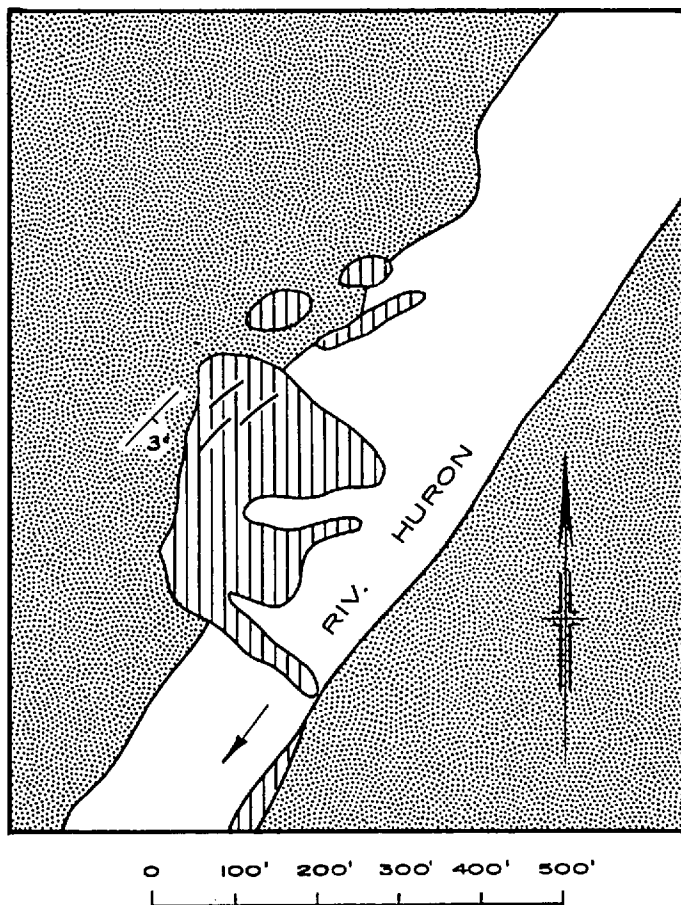


Figure 3C.- Plan of basic sill (lines) cutting Lorraine shale (stipple) and damming Huron river three quarters of a mile above its mouth
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abandoned quarry in Lower Lorraine shale which is here cut by a five-foot acidic sill of rock which is light grey when fresh but weathers yellowish. Half a mile downstream, and on the opposite side of the river, a ten-foot acidic sill, similar to the preceding, is responsible for conspicuous rapids, and is exposed in the cliff face from the water's edge to the top. Again, two miles west of Marieville, and less than a mile south of the Montreal and Southern Counties Railway line, there are two abandoned and water-filled quarries, both in an acidic sill-rock similar to the above, but only one or two feet of rock show in either quarry.

At all the three last-mentioned places the rock is essentially like the finer-grained facies of the St. Luc sill, and it is possible that the three occurrences may once have been parts of a single sill body, subsequently separated by the erosion of the erstwhile intervening connecting stretches. It is also possible that an acidic sill (Figure 3A) at Chambly, just below the dam, and a similar sill to be seen on the left bank of Richelieu river half a mile or so below the highway bridge at Chambly, are both segments of this St. Luc sill.

Other Sills

One important sill, apparently unrelated to any of the igneous bodies known within either this map-area or the Montreal area, is that penetrated by hole No. 1 drilled by Shawinigan Chemicals, Limited, just northeast of Varennes. The log of this well (see p. 28) shows, below 64 feet of overburden, a thickness of 25 feet 10 inches of a dark igneous sill-rock apparently allied to the Essexites of the Montereian suite. Detailed study may later show that it is a composite body. The heat from this thick sill transformed the underlying shale of the Cryptolithus zone to hornfels for a depth of six feet or more. Below that depth the shale contains recognizable fossils of the Cryptolithus zone.

STRUCTURAL GEOLOGY

General Statement

In general terms, the gross geological structure of this region is that of a wide open syncline traversing the map-area diagonally from southwest to northeast, and pitching very gently to the northeast. This large fold is complicated in the Laprairie region by secondary wrinkles, and in the vicinity of St. Hilaire mountain by irregularities in pitch. It is cut by at least three major faults. Finally, the complex has been intruded by the igneous masses of four of the Montereian hills.

Folds

Chambly-Fortierville Syncline

The dominating structural feature of this area is the syncline whose axis passes approximately along the line of Huron river and also through Chambly. A hundred miles farther to the northeast it passes through Fortierville, and the writer has suggested (1947, p. 15) that it be called the Chambly-Fortierville syncline. Because of the general near-flatness of the dips, the synclinal disposition of the beds cannot be seen directly in the field. There is, however, abundant evidence for this fold on both structural and stratigraphic grounds. Structurally, the exposures of the Lorraine rocks along Richelieu river near Chambly dip inward toward the vicinity of the dam across the river just south of Chambly Basin. At Simard's quarry, a mile to the southwest, the dip is toward the north-northwest, hence the axis of the fold should pass to the north of that locality. The beds at the mouth of Huron river dip southeastward, thus indicating that their position is north of the axis. Farther to the northeast along Huron river, the Richmond marine shales and the Queenston green and red shales dip somewhat irregularly, but consistently eastward or southeastward. It would seem, therefore, that the axis should pass very close to these outcrops and somewhat to the south of them. On Rougemont mountain, the dips, with one exception, are all toward the northwest. Hence, that mountain can be said to be definitely on the southeast limb of the fold.

The stratigraphic evidence is in complete harmony with the above structural synthesis. The Queenston shale is followed southwestward, that is, downstream along Huron river, by the next underlying formation, the Richmond marine shales (Pontgravé River formation). Still farther downstream, and in the same compass direction, the beds of the Proetus zone of the Lorraine group outcrop. The latter are well developed on the west side of Richelieu river at Chambly. Thence, passing along the axis, Cryptolithus zone beds, approximately horizontal, occur plentifully along L'Acadie river. Passing up Richelieu river from Chambly, the Cryptolithus zone of the Lower Lorraine is seen from three to four miles south of the dam at Chambly. Beyond Fryers rapids in a southerly direction there are no exposures. Hence, an incomplete section of the Richmond and Lorraine beds may be seen along Huron and Richelieu rivers, with the highest beds to the northeast, and the lower beds to the south.

Around Rougemont mountain, the hornfels on the southeast side is part of the Cryptolithus zone of the Lower Lorraine. Other hornfels exposures around the mountain are devoid of diagnostic fossils, but their arenaceous and calcareous nature makes their allocation to the

Chambly member probably correct. In the neighbourhood of St. Hilaire mountain, an abundance of red rock in water wells along Huron river betrays the presence of Queenston shale in that vicinity. Though there appears to have been some dislocation of the hornfels in the immediate vicinity of the igneous body (vide Queenston rock of Moreau quarry, p.36), such evidence as there is from the fossils in the hornfels and the neighbouring shales north and south of the mountain indicates a Richmond age for the beds there exposed. West and northwest of the mountain the hornfels and shale contain fossils of the upper part of the Lorraine (Pholadomorpha zone). Though there are no exposures of the middle part of the Lorraine near St. Hilaire mountain, still farther west the exposures around St. Bruno mountain are all of the lowest subdivision of the Lorraine. Hence, whereas the beds along Huron and Richelieu rivers show a progressive section of the Richmond and Lorraine, the section transverse to that line, through Rougemont, St. Hilaire, and St. Bruno mountains, shows a symmetrical disposition with Lower Lorraine at each end and Queenston in the middle.

The Chambly-Fortierville syncline is a canoe-shaped fold. The plunge at the Chambly end is toward the northeast, and beds higher and higher in the sequence are met with as one travels northeastward along the axis as far as the junction of St. Louis brook with Huron river. Between this point and St. Hilaire mountain, where an extension of the red Queenston beds might be expected, water-well records show grey rock under the soil. This might, of course, be the grey Queenston (Carmel River member). A small area of indubitable red rock (hornfels) occurs directly south of St. Hilaire mountain, but it is likely that the reddish hornfelsic beds southeast and east of the mountain are Richmond (Pontgravé River formation), and may have received their faint colour during the baking process attendant upon the intrusion of the igneous rock of the mountain. The same may be said of the hornfels on the northeast and northern flanks of the mountain. Thus, the small exposure of Queenston south of the mountain seems to be an isolated occurrence, and does not lie near the axis of the Chambly-Fortierville syncline. Northward from St. Hilaire mountain, the prevalence for three or four miles of grey rock in water-wells strongly indicates, but does not positively prove, the absence of the Queenston red shale formation. North of Ste. Madeleine, only red rocks are recorded from water-wells, and from the data concerned it is possible to draw the Queenston-Pontgravé River boundary with reasonable accuracy. The presence of red Queenston shale and sandstone in the Ste. Madeleine well (Appendix A, p. 73) is discussed later.

That the axis of this fold, drawn along the base of the Queenston, is undulatory is shown by the isolation along Huron river,

south of St. Hilaire mountain, of a small area of red shale and sandstone. Between the mouth of St. Louis brook and the latitude of mount St. Hilaire only grey rock is recorded from water-wells, and it is therefore likely that no red Queenston occurs there. Hence the southernmost Queenston occupies a basin about a mile wide and two miles long.

Minor Folds

On the west flank of the Chambly syncline the belt of lower Lorraine beds (Breault member) is abnormally wide, stretching as it does from a mile east of St. Bruno mountain to within three miles of St. Lawrence river, a distance of some seven miles. In all probability its western border comes even closer to the river than that. In accordance with what structural data we possess it seems to be correct to explain such a great width of outcrop by means of two minor anticlinal wrinkles, of undetermined extent northeastward. The first of these, the St. Bruno anticline, is drawn with its axis passing through mount St. Bruno, thus explaining the prevalent westward dip of the hornfels on the western side of the mountain and the easterly dips on the east side. The second, the St. Hubert anticline, is placed passing close to St. Hubert, so as to accommodate the exposure of Utica shale two miles west of Ste. Julie de Verchères, which occurs within the belt of outcrop of the Lorraine shales, and leaving the map-area in the southwest, close to the mouth of St. Lambert river. Accordingly, the La Prairie brickyards would lie in a syncline, which is in agreement with the stratigraphic determination (see p. 23) that their rocks lie high up in the Cryptolithus zone. Still farther west, a short canoe-shaped syncline - the Boucherville syncline - is introduced to take care of an exposure of Utica-Lorraine transition beds (mapped as Lorraine) a mile and a half southeast of Boucherville (see p. 16). Regardless whether these should properly be called Utica or Lorraine they certainly belong close to the boundary, and hence a synclinal setting is indicated. No evidence for an extension of this fold in either direction is indicated anywhere.

Napierville Syncline

In the southwestern part of the St. Jean sheet, rocks of Chazy, Black River, and Trenton ages are disposed in a syncline whose axis trends more or less northeast-southwest. Farther to the south, in the Lacolle sheet, this axis passes close to the village of Napierville (four miles south of the St. Jean map border), which name has been chosen by the writer to designate this fold. To the west of the axis of this fold the beds are all essentially horizontal, but the beds near Menard Corner, of Rosemount age, together with the exposure, of St. Michel age, on L'Acadie river, indicate a syncline plunging to the northeast. The

Black River limestone seen on Noyers creek is also found in the village of Napierville in the Lacolle sheet, and the Chazy beds occur west, southwest, and southeast of Menard Corner, both in the Lacolle and the St. Jean sheet. It may eventually be shown that this Napierville syncline is the southern extension of the Chambly-Fortierville syncline, in which case the latter name should be used for the whole structure. The reason for doubt as to whether these two synclines are parts of the same structure is the presence of the Delson fault which separates them. A horizontal shift of the belt of outcrop of a particular zone can usually be explained in terms of vertical movement, but in this case the axes of the two synclines are separated by several miles. Inasmuch as there is no evidence that the axial planes deviate essentially from the vertical position, this would involve an actual horizontal movement in which the mass north of the Delson fault was shifted approximately six miles westward. No evidence elsewhere in these map-areas, or in the Montreal area, is known to corroborate, or even to indicate, such a horizontal movement. It is assumed, at present, therefore, that the folds are separate structural features, although it is impossible with the data at hand to show their respective prolongations beyond the Delson fault.

Faults

Four prominent faults occur in this area. They are the Tracy Brook, Delson, Bas de Ste. Rose and St. Barnabé faults, all of which have been recognized in neighbouring map-areas and have been previously named (Clark, 1934; Clark, 1944a; Clark, 1947).

Tracy Brook Fault

The Tracy Brook fault, as mapped in the St. Jean area, is merely a prolongation of the structure so definitely established in the Lacolle map-sheet to the south (Clark, 1934; Clark and McGerrigle, 1936). It is shown on the St. Jean sheet as terminating against the Delson fault, though there is, it must be said, no visible evidence of its presence within the St. Jean area.

Delson Fault

The Delson fault, as it occurs in the St. Jean sheet, is a prolongation of its extent in the Lachine map-area to the west. The succession, going west from St. Jean, of Trenton, Black River, and Chazy in the St. Jean area, is continued into the Lachine sheet, where Chazy limestone is found on Tortue river. Two miles or so north of this occurrence there are the exposures of Utica shale at Delson. It was because of this

relationship that the Delson fault was proposed. In the St. Jean sheet there are no outcrops on the north side close to the fault as projected southeastward, but the exposures at the Laprairie brickyards and the hornfels at mount Johnson, together with the outcrops along Richelieu river south of Chambly, all conspire to make the sweep of the Lower Lorraine and the Utica beds as mapped the most reasonable disposition possible with our present knowledge. This sweep is out of harmony with the disposition of the beds of the Napierville syncline, so that it appears necessary to assume a dislocation. Because the Delson fault will serve, it has been extended across most of the St. Jean sheet. It has been prolonged east of Richelieu river mainly to allow it to truncate the Tracy Brook fault, an arrangement of convenience, for there is less reason for producing the Tracy Brook fault north of St. Jean city than there is for producing the Delson fault east of the same place.

The vertical displacement in the vicinity of Menard Corner, where the Rosemount member of the Montreal formation is brought against the upper part of the Utica, is of the order of 800 feet.

Bas de Ste. Rose Fault

There is no visible evidence in the Beloeil sheet for the existence of the Bas de Ste. Rose fault. This fault is projected from its known position in the Laval area eastward into the Beloeil area, first, because the dislocation involved along this fault in the Laval area was so great as to demand some such extension, and second, because evidence from water-wells concerning the distribution of the red Queenston beds indicates a disruption of the western margin of the Queenston, such as would occur were the fault to be continued into the area of Queenston rocks. Hence, though the Bas de Ste. Rose fault must be considered as crossing most of the Beloeil area, and certainly crossing Richelieu river, it may possibly die out before reaching the eastern margin of the map. Thus the easterly prolongation of this fault shown by Clark (1944a, p. 27) is possibly exaggerated.

St. Barnabé Fault

Four and a half miles east of Ste. Madeleine (Beloeil map-area) and south of the road, a well was drilled in 1917, the log of which (Appendix A, p. 73) shows what is apparently nothing but a sequence of red and grey Queenston (Bécancour River) sandstones and shales. According to the normal synclinal structure, the rocks thereabouts should be Lorraine. There is no justifiable way of bending the Queenston-Pont-gravé River boundary southward to include this well-site within the Queenston area. This locality lies approximately along the strike of

the St. Barnabé fault (Clark, 1947, p. 16, map), one of the major faults affecting the lowland south of the St. Lawrence. Striking about north-northeast it passes west of St. Hyacinthe and east of St. Barnabé, presumably dying out within the Beloeil map-area on the south and the Upton area to the north. In the vicinity of St. Barnabé, the displacement, with the downdrop on the west, is of the order of about 1,100 feet. Drag along this fault cannot be invoked, for this should cause the curvatures of the stratigraphic boundaries east of Ste. Madeleine to deviate more toward a northward direction. Hence, the writer has assumed that a sliver of rock, with Queenston at the present topographic level, was loosened between the two sides of the fault and dropped somewhat farther than the relatively stable mass to the west.

Intrusions

The structural features introduced by the intrusion of the rocks of the Montereian hills are, first, the obvious fact of intrusion which has already been discussed (see p. 37), and second, the relatively minor complications imposed upon the sedimentary rocks in the immediate vicinity of the igneous masses.

Form of Intrusion

First, as to the form of the intrusions, all evidence save that of size has, in the past, been taken to point to the intrusions being eroded volcanic necks. This presupposes volcanic action, of which we have no other evidence, direct or indirect. Daly (1933, p. 150) cites one mile, more or less, as the maximum known diameter of volcanic necks. By the application of that limiting criterion, mount Johnson would not be ruled out, but the other three mountains within the area are far too large to qualify. All of the characteristics seen in the exposures could equally well be attributed to stocks, and that these are the topmost projections of an underground magma chamber is an alternative thesis. Against the latter view is the verticality of the magma chamber walls wherever the contact can be seen to advantage. There is no evidence that any of these four bodies was a laccolith. The intrusions have no relation to, nor were they influenced by, the limbs of the Chambly-Fortierville synclinal structure.

Deformation Within the Hornfels Collars

In the cases of mounts Johnson and Rougemont, no essential deformation of the hornfels is apparent. Little evidence can be found around mount Johnson, but what is known shows the hornfels attitude to be in harmony with the overall structure. Some brecciation accompanied

the hornfelsization of the shale there. Around mount Rougemont, abundant exposures of hornfels show, with one exception, the expected regional attitude, though many of the dips are steeper than usual. Mounts St. Hilaire and St. Bruno are somewhat different. From the evidence at hand the hornfels around mount St. Hilaire dips in toward the igneous rock. These adcentral dips cannot be considered to be connected with the elongate synclinal basin paralleling Huron river, and are best thought of as consequences of the deformation in the immediate vicinity of the intrusion. So many high dips and disharmonious strikes occur as to make it entirely possible that the whole collar is an annular complex of faults. The Queenston exposure south of the mountain is shown in faulted contact with the remainder of the collar. The dips on the east and west sides of mount St. Bruno are easterly and westerly, respectively, that is, away from the mountain. They are taken to be a reflection of an anticlinal axis passing through the mountain. On the north side, the dips are southerly, a circumstance for which there is at present no satisfactory explanation. They possibly reflect the southerly plunge of the northern end of the concerned anticline, though they are far too great to be explained thus. A better thesis is that they represent some local defect in the hornfels developed by the force of the intrusion.

It would appear, therefore, that, with the exception of mount St. Hilaire, the hornfels collars around these hills derive their structures primarily from the prevailing regional pattern. Here and there, e.g., north side of St. Bruno, east side of Rougemont, and west side of Johnson, the hornfels is either brecciated or has abnormal dips, in amount or in direction. These abnormalities can be ascribed to the mechanics of the intrusion, and it appears, though detailed corroboration is wanting, that such deformations attended the intrusion of the syenitic rocks rather than that of the more basic types.

HISTORICAL GEOLOGY

There are but two main rock-forming epochs in the history of this region. First, during the Ordovician period, the sea more or less continuously covered this area, with the consequent formation of marine sedimentary rocks. Later, probably during the early part of the Tertiary period, igneous intrusions resulted in the formation of the Monteregian hills. During the interval between these two periods of rock-formation, and also subsequent to the second, erosive forces were at work wearing down the exposed rocks. The events recorded below are shown on the accompanying tabulation.

Resumé of the Geological History of the St. Jean-Beloeil Area

<u>ERA</u>	<u>PERIOD</u>	<u>MILLIONS OF YEARS AGO</u>	<u>EVENTS</u>
CENOZOIC	QUATERNARY	1	The area as it is today Glaciation, and Champlain sub- mergence
	TERTIARY	60	Erosion Igneous activity, Montereian hills
MESOZOIC	CRETACEOUS	140	E r o s i o n
	JURASSIC	175	
	TRIASSIC	200	
PALAEOZOIC	PERMIAN	240	
	CARBONIFEROUS	310	
	DEVONIAN	350	
	SILURIAN	380	? Emergence and erosion
	ORDOVICIAN	450	Taconic mountain building Marine submergence continued. Deposition of Beekmantown, Chazy, Black River, Trenton, Utica, Lorraine and Rich- mond rocks
	CAMBRIAN	540	Marine inundation. Deposition of Potsdam sandstone
	PRECAMBRIAN		Long continued erosion Formation of granites, gneisses, etc., of the Laurentians, and of the basement rock underlying this area

Ordovician Sedimentation

From what is known in nearby regions, and from the evidence from local deep wells, it is certain that below the lowest exposed formation, the Chazy limestone, there occur both the Beekmantown dolomite and the Potsdam sandstone, the latter resting upon the Precambrian basement. This basement had been exposed to erosion during the last few hundred million years of late Precambrian time. An invasion of the sea during the Upper Cambrian (or possibly not until the beginning of the Ordovician) allowed a deposit of sand, washed from the regolith, to be spread out as a basal layer resting upon the Precambrian rock surface. This is what is at present called the Potsdam sandstone, and it doubtless tended to fill any low areas in the pre-Potsdam erosion surface. Subsequent enlarging of the sea allowed limestone to accumulate, later to be modified into the Beekmantown dolomite. Although no Precambrian, Potsdam, or Beekmantown, rocks are exposed within the limits of the St. Jean-Beloeil map-area, all three types are exposed in the Montreal area to the west, and the Potsdam and Beekmantown are recognized in deep wells in the St. Jean-Beloeil area.

The earliest events recorded by the exposed rocks in the St. Jean-Beloeil area are those of Chazy, Black River, and Trenton times. The evidence is so meagre that about all that can be said is that at certain times during those epochs the sea occupied these parts, allowing limestone to accumulate on the sea-floor. This is entirely in harmony with what is known of the sequence of events in the neighbouring areas. Following Trenton time, mud was being carried from the nearby highlands on the east in such quantity as to obliterate all calcium carbonate deposits and to cause the accumulation of the Utica shale. Conditions on the sea-floor where the mud, later to become the Utica shale, was accumulating were such as to forbid the existence of life, for all the fossils are of pelagic forms, mostly graptolites, whose skeletons and shells sank from the sea-surface and settled on the muddy bottom. Eventually, however, this lethal condition on the sea-floor disappeared, and animals and plants again began to populate the bottom of the sea. At that time mud with a greater proportion of kaolin than had been the case with the makings of the Utica shale began to be delivered to the sea, later to become a shale which would disintegrate very easily upon exposure to the atmosphere. These changes ushered in what is called Lorraine time. Mud continued to be delivered to the sea and to be swept around by marine currents in such quantities that only those animals that could tolerate a muddy habitat could persist. Hence we find that more than one-half of the species of Lorraine fossils are pelecypods, characteristically mud-lovers. Occasional lapses in the

delivery of mud to the sea by rivers resulted in the deposition of sufficient amounts of calcium carbonate to form limestone layers. Now and again the rivers would send down to the sea more sand than mud, so that layers of sand were spread far and wide on the sea-floor to make beds of sandstone interspersed among the beds of shale. Although little difference can be detected in the shales, a gradual change in the fossils tells us that the muds continued to be deposited after the Lorraine epoch, into Richmond time. It was during the latter time, in fact soon after its inception, that the sea withdrew, but mud continued to be delivered to this area by rivers pouring out from the Appalachian hilly or mountainous region. This mud was spread out as a sub-aerial delta, drying and oxidizing without coming into contact with the sea. This is the so-called red Queenston shale of today. From that time on there is no evidence of the existence of the sea here until post-glacial time, although it is probable that a Devonian sea, in which were deposited the limestones of the breccia of St. Helen island (Laval sheet, Clark, 1952, pp. 81, 129) covered both the Beloeil and the St. Jean map-areas.

Taconic Disturbance

At the close of the Ordovician period, that is, shortly after the formation of the Queenston shale, the Appalachian region to the east was disturbed during the formation of the first edition of the Appalachian folded range. It is possible, though not probable, that some of the eastern parts of this region may have been overridden at that time by the most advanced thrust-sheets pushing their way out over the flat plains to the west of the advancing mountain front. Whether this was so or not, the close proximity of a newly-formed and large mountain mass was sufficient to disturb the original nearly horizontal position of the beds, resulting in the aberrations from the horizontal seen today in the low folds. In addition, possibly due to the compression by the westward advancing mountains, or to relief therefrom as erosion later wore them down, faults sliced the earth's crust into blocks which adjusted themselves in harmony with the stresses involved. Thus the Chambly-Fortierville syncline and the main faults postulated for this region date from this time.

Subsequent Pre-Tertiary Events

Between the end of the Ordovician period and the beginning of the Tertiary we have no direct evidence of rock formation. Instead, in all probability, during the greater part of that stretch of time, nearly 300 million years, the country lay open to erosion, sometimes active, sometimes weak. The fact that erosion might have had an opportunity to wear away parts of the local rock development over a period of a few hundred million years makes one suspicious that there may have

been other rock formations which took the brunt of the erosion, protecting those which remain today. For instance, the Devonian limestone, known in the St. Lawrence lowland only from blocks in the St. Helen island breccia, is good evidence that this whole region was occupied, at least during Lower Devonian time, by a sea in which limestone accumulated, probably to a thickness of several hundred feet. It is likewise by no means improbable that Carboniferous sediments also once covered this area, possibly with rich coal deposits, although no evidence direct or indirect remains save for the occurrence of such deposits both to the southwest (Pennsylvania) and northeast (Cape Breton and Nova Scotia).

Monteregian Intrusions

According to researches carried out on their helium content, the igneous rocks of the Monteregian hills were formed about 57 million years ago, or near the beginning of the Tertiary period. Probably a vast underground reservoir of magma succeeded in working its way upward until it had come so close to the surface that here and there in favourable locations off-shoots managed to force their way toward the surface and perhaps actually to reach it. There is no direct, and little indirect, evidence that any of the Monteregian hills ever supported volcanic action. Some, like mount Royal and mount Johnson, are cylindrical, pipe-like masses which formerly led upward, through rocks since destroyed by erosion, either to volcanoes or to laccolithic bodies. Mounts St. Bruno, St. Hilaire, and Rougemont may be the enlarged parts of such pipes immediately below the laccolithic expansion. There is nothing to show that they might be laccoliths themselves. A simpler explanation for these larger bodies is that they are stocks, that is, the smaller apical portions of more or less irregular, upward-working masses of igneous rock. Such speculative discussion is at present unprofitable. Only one thing is certain: when the Monteregian intrusives were being emplaced, the upper parts of the hills as now exposed must have been a few thousand feet below what was at that time the physiographic surface. Hence, at St. Hilaire mountain, an additional two thousand feet at least of sedimentary material overlay the Queenston shale as it is there exposed, and one would say that at least a like amount had been destroyed by pre-Tertiary erosion. In all probability, five, or even ten, thousand feet of sedimentary beds once covered the Queenston shales.

Following the emplacement of the Monteregian intrusive rocks, which need not have disturbed the surface at all, erosion continued its work of cutting into the Ordovician and any overlying rocks, and exposing the igneous rocks beneath. The latter, because of their superior resistance to erosion, everywhere remain as hills, whereas the less

resistant shales and limestones were worn down closer to sea-level. Because of this, Dresser (1910, p. 10) was justified in calling the Montereian hills a series of igneous buttes.

Glacial and Post-Glacial Events

A million years ago glaciation affected nearly all of Canada, and this region was covered with glacial ice a mile or possibly two miles thick. Compared with the previous long-continued sub-aerial erosion, the glaciation achieved little rock destruction. It did, however, succeed in bestrewing the countryside with boulder-clay and glacial sands and gravels which help to obscure much of the solid rock beneath. The Champlain marine submergence, consequent upon the withdrawal of the ice and the inability of the crust to spring back immediately to its earlier and normal position, allowed the St. Lawrence Lowlands to be flooded by an arctic sea. On the floor of this sea there accumulated deposits of clay and sand, which, with the disappearance of the sea, remained to conceal still further the bed-rock beneath. The retreat of that sea left the countryside much as it is today.

ECONOMIC GEOLOGY

Brick-Making

Both the Laprairie Company, Inc., and the St. Lawrence Brick Company, Ltd., employ the Lower Lorraine shales as a prominent constituent of their brick products. In the Laprairie operation, advantage is taken of the well-known tendency of this rock to crumble upon exposure to the weather, as follows: during the season when the shale is free from snow, a tractor traverses the whole yard of some 250 acres, ploughing up or tearing up the topmost six to eight inches of rock, which is then left for several weeks or months to weather. The shale is readily torn up by the tractor and no steam-shovelling and no blasting are necessary. Though the rock does not disintegrate to a powder, the mill work of grinding is very much decreased. In the St. Lawrence Company's yard, the shale is obtained partly from surface stripping and partly from quarrying. In both yards the shale is mixed with local glacial clays, both of the boulder-clay type and the Leda clay type. Boulders in the clay sometimes cause trouble, especially if they are of limestone and are not sufficiently finely ground. Slaking of the quick-lime formed from their burning has disastrous effects on the brick. At the time of writing (March, 1954) both brickyards are operating at full capacity. Many interesting technical details not directly concerned with the geological situation are given by Keele (1915, pp.13-15).

Sand and Gravel

Abundant deposits of sand and gravel are to be found surrounding each of the Monteregian hills, and are thickest along their southwest, south, and southeast flanks. Elsewhere, sand is common in the vicinity of the Verchères Woods (Beloeil map-area), where a remnant of the earlier surface has escaped destruction by erosion. Around this remnant, the earlier cover of sand has largely been removed, laying bare the underlying clay. The distribution and economic possibilities of the sand and gravel deposits of the St. Jean-Beloeil area have been adequately treated by McGerrigle (1937).

Building-Stone

The Donneau quarry, near the southwestern corner of the St. Jean sheet, two miles north-northwest of St. Jacques-le-Mineur, once produced dimensional stone of the Chazy limestone for one of the local churches. It has been abandoned for decades. As far as the writer knows, no other limestone, with the exception (noted below) of the Trenton limestone near Menard Corner, a few miles west of St. Jean (Parks, 1914, p. 72), has been quarried in this area.

Mount Johnson. Building-stone of excellent quality has been quarried on the north and east flanks of mount Johnson for more than half a century. Parks (1914, pp.175-180) and Burton (1932, pp.107-116) give valuable technical information concerning the quarryable rock, past production, and future possibilities. At present, the only producing quarry is operated by Brodie's Limited, of Montreal, with a cutting plant at Iberville. Production is obtained solely from the essexite, the outer part of which is coarse-grained and known as 'Canadian Quincy' and the inner part finer-grained and called 'Ebony'. "Both are dark grey in colour ... Both take an excellent polish and the contrast between hammered and polished work is strong, so that carving and lettering stand out well" (Burton, 1932, pp. 110).

Road-Material and Concrete-Mix

A dozen or so quarries in various rock exposures have provided road material for local requirements. There are two sources of active production today: the Trenton limestone quarries at Menard Corner (St. Jean sheet) and the hornfels quarry on the west flank of mount St. Bruno (Beloeil sheet).

In the Beloeil area, the so-called Mount St. Bruno quarry (formerly Duquette quarry), situated on the northwest side of mount St. Bruno and currently (March, 1954) owned by J.R. Polis, is being actively

worked to yield a superior grade of hard crushed stone from the hornfels.

Two limestone quarries are in operation near Menard Corner, in the St. Jean area, from which locality there has been production for several decades. For information concerning earlier operations see Parks (1914, pp. 70-72) and Goudge (1935, p. 229). The Bernier quarry, owned by Philodore Ouimet, has been excavated in a thin-bedded, dark, splintery limestone in beds mostly two inches thick, but ranging up to six inches. Both dense and crystalline types occur, the former making up about 80 per cent of the stone. Shaly partings are common, and may be as much as one inch thick, making it virtually impossible to utilize the stone for building purposes. Road material, concrete aggregate, and agricultural lime are produced. The quarry, which is about 300 feet square and 85 feet deep, is closed during the winter, but employs 30 men during the operating months.

The Baillargeon quarry, operated by Philippe Baillargeon of St. Jean, was opened in the fall of 1950, and has already been excavated to a depth of about 40 feet over an area of 400 ft. by 1,000 ft. Operation is suspended during the winter months, but during the rest of the year 40 men are employed. Part of the product goes to an associated asphalt-mix plant. The rock is essentially like that of the Bernier quarry.

The quarry of the Standard Clay Products Company (Goudge, 1935, p. 229) is now abandoned.

Oil and Natural Gas

The St. Lawrence Lowlands has long been considered a region where the possibilities of finding oil or natural gas should be carefully investigated. For scores of years, in certain places, seeps of oil have been reported, and gas has been encountered in wells drilled for water. Parks (1930, 1931) conducted an investigation into the possibilities of finding oil or gas in the Lowlands, and his reports were published by the Quebec Bureau of Mines. They contain a vast amount of information concerning the actual occurrences of gas, including data that today would be difficult, if not impossible, to assemble. Other reports or papers by Hume (1932), De Mille (1930), and Jones (1941) have made special or general contributions to the subject. A paper by Snider and Farish (1935), illustrated with a map showing certain features of the geology as related to oil and gas and based in part upon their own field explorations, summarizes the information available. None of these researchers had complete outcrop maps to depend upon, and consequently their reports lack the conviction that comes from areal evidence.

The occurrence of oil or gas depends upon three factors:

(1) a parent rock in which oil or gas is being or was once generated by the decomposition of organic matter; (2) a reservoir rock into which oil or gas has migrated or is being held because of its superior porosity — it may be that no migration of the oil or gas takes place, in which case the parent rock is also the reservoir rock; and (3) a suitable geological structure, by which is meant a suitable arrangement of the bedding or other structural features such as to induce the oil or gas to remain where it is or to migrate to a more suitable spot, where it may be stabilized and from which it may be extracted. The most obvious situation is a porous sandstone layer in an anticline, with a limestone rich in organic material directly below, and an impervious shale layer above.

In this region, the Trenton limestone is generally considered to be a reasonably good source rock for oil and gas. It is abundantly fossiliferous, which means that life teemed on the sea-floor where the sediment was accumulating, later to be compressed into limestone (Jones 1947, p. 5). In many places, the limestone gives off a strongly petroliferous odour when freshly broken, and can sometimes be seen to contain small cavities filled with petroleum, which spreads over the freshly broken surface. There are stories of doubtful authenticity of oil having been found in quantity at places to the north of St. Lawrence river. None of these, as far as the writer is aware, has ever been authenticated.

The Trenton limestone in the vicinity of Montreal is the chief artesian water-bearing horizon, according to Adams and Leroy (1904, pp. 26-29), though Cumming (1915, p. 26) was of the opinion that "the underground circulation at Montreal is not confined to any water-bearing porous rock at any definite horizon but occurs in fissures and cracks in the limestone and at no particular horizon". Since, with its fissures and cavities, the rock can serve as a reservoir for water, it should, theoretically, be able to serve as a reservoir for oil. Neither the Utica shale nor the Lorraine shale appears to be well suited to act as a reservoir rock, although the abundance of sandy lenses in the Proetus zone of the Lorraine might provide storage space for either oil or gas.

Geological Structures

The favourableness of a geological structure as regards oil or gas storage is predicated upon the tendency of both substances to rise by capillary action or to rise so as to settle on top of an underlying body of water. In absolutely dry rock regions, gas will, of course, rise as far as possible and will probably be lost to the air, whereas oil

will tend to saturate a porous rock and to stay as low as possible. Other conditions may obtain at great depths, say, ten to fifteen thousand feet below the surface, but in the St. Lawrence Lowlands we are dealing, as far as possible oil and gas horizons are concerned, with depths of no more than four or five thousand feet, and also with wet rocks. We should therefore consider the geological setting to ascertain where there may be suitable structures.

The structures most likely to be present in the local terrane are the anticline, terrace, special cases of fault zones, unconformities, and sedimentary traps. Inasmuch as the gross structure of the St. Jean-Beloeil area is a syncline, much of it would appear to be devoid of possibilities on that account. Close to the St. Lawrence, however, the author has mapped two minor anticlines, either of which would fulfil all of the requirements. The Trenton limestone, as both source and reservoir rock, would lie beneath an arch of impervious Utica shale, the latter presumably having acted as a seal preventing any escape of oil or gas contained in the Trenton limestone below. Of terraces — minor flexures in a series of beds which possess a general inclination in one direction — there is no indication. These may be thought of as a sort of parasitic anticlinal structure developed upon a series of beds already tilted. Without such minor flexures there would be nothing to prevent oil and gas from migrating upward and being lost to the air or penetrating and permeating the overlying glacial drift. Exposures in the Lowlands are much too far apart for the determination of such structures, but their presence could be readily determined by a campaign of geophysical prospecting. No unconformity of importance above the base of the Black River group is known. The Trenton, Utica, Lorraine, and Richmond beds form a series of strata indicating practically continuous sedimentation. However, the impervious Utica shale cover to the Trenton limestone must have acted as a deterrent to the upward migration of any oil or gas generated in the Trenton beds. Special cases of faulting occur wherever faults act as a seal rather than as a leak, thus preventing, rather than facilitating, the escape of oil or gas. Nothing is known regarding the conditions attending the known normal faults which might allow us to consider them either favourable or unfavourable to oil or gas migration. Low-angle thrust faults, because of the great amount of rubbing and scraping of the overriding mass on the overridden rocks, are more apt to be featured by gouge, a fine, generally impervious, rock flour resulting from the intense trituration of the rocks on both sides of the fault. Along the eastern margin of the Lowlands, low-angle thrust faults are common features, although none is known in the St. Jean-Beloeil area. Elsewhere, however, such structures should be investigated very thoroughly.

Sedimentary traps, due to lateral facies changes or to lenticular pinch-outs, may well be present and may be potential reservoirs for oil or gas, but their recognition demands far more detailed and extensive information than is presently available from the meagre exposures and the few deep wells of which we possess the logs.

Known Occurrences of Natural Gas

Appendix B (p. 74) consists of brief notes on twenty-five occurrences of natural gas, most of which are indicated on the maps accompanying this report. Six gas occurrences, all inconsequential in themselves, occur in the eastern two-thirds of the Beloeil map-area. Another nineteen are concentrated within the western third of that area and immediately adjacent parts of the St. Jean map-area. It is interesting to note the striking correspondence between those sections of the map-area where gas records are most plentiful with the prevalence of undulatory structures. The conclusion that the St. Bruno and St. Hubert anticlines have been responsible for the localization of the gas occurrences is well nigh inescapable. Nowhere has the gas been found in commercial volume, although in places there is enough for cooking and heating purposes for a single dwelling. The appropriate structures seem not to have stored up gas in valuable quantities, despite the favourable correspondence between occurrence and structures. However, the fact remains that, elsewhere in the general region, the search for similarly appropriate structures may well uncover accumulations of gas, and possibly of oil, of sufficient volume to warrant commercial development.

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APPENDIX A

CONDENSED DATA ON DEEP WELLS

St. Johns Petroleum Company Well No. 1

Location: Beloeil map-sheet (1) - lot 26, St. Hubert parish, Chambly county (about 100 feet from Cartier St. Hubert well No. 1)

Elevation: 90 feet

Drilled: 1947-48, for gas

Total Depth: 3,970 feet

Rig: cable

<u>Depth in Feet</u>	<u>Lithology</u>
0-20	Overburden
	<u>Lower Lorraine:</u>
20-280	Medium grey siltstone, with faint brown streak
280-840	Same, but faintly calcareous, and with few sandy beds
	<u>Utica:</u>
840-1,220	Medium grey siltstone, with brown streak
	<u>Upper Trenton:</u>
1,220-1,248	Calcareous black shale
	<u>Trenton:</u>
1,248-1,656	Tétreauville Formation - crystalline, dark grey limestone, with much shale
	Montreal Formation
1,656-2,010	Rosemount member: coarsely crystalline limestone, in places a coquina; <u>Prasopora</u> and <u>Dalmanella</u> common
2,010-2,086	St. Michel member: dark grey shale and fine-grained limestone; fossils scarce
2,086-2,116	Mile End Formation - light grey, crystalline limestone
	<u>Black River:</u>
2,116-2,140	Leray Formation - medium grey limestone, very finely crystalline.
2,140-2,176	Lowville Formation - grey, lithographic, fine-grained, crystalline limestone
2,176-2,188	Pamelia Formation - fine-grained dolomitic limestone, with a little black shale

St. Johns Petroleum Company Well No. 1 (Cont'd)

<u>Depth in Feet</u>	<u>Lithology</u>
	<u>Chazy:</u>
	Laval Formation
2,188-2,382	St. Martin member: medium- to coarsely-crystal- line limestone; fossils common; shale rare
2,382-2,623	Ste. Thérèse member: light grey sandstone, with minor amounts of dark shale and of crystalline limestone
2,623-2,640	Beldens Formation - dark limestone, with alabaster- like dolomite
	<u>Beekmantown:</u>
2,640-3,530	Beauharnois Formation - fine-grained, crystalline dolomite, with minor amounts of shale and grey limestone; fossils very scarce
3,530-3,965	Theresa Formation - fine-grained, quartz sandstone, with interbedded, light grey, fine-grained dolomite
	<u>Potsdam:</u>
3,965-3,970	Medium-grained quartz sandstone, grains rounded and frosted
3,970	Bottom of hole

Cartier St. Hubert Well No. 1

Location: Beloeil map-sheet (2) - lot 26, St. Hubert parish, Chambly
county (about 100 feet from St. Johns Petroleum
Company well No. 1)

Elevation: 91 feet

Drilled: 1934-35, for gas

Total Depth: 3,490 feet

Rig: cable

<u>Depth in Feet</u>	<u>Lithology</u>
0-20	Overburden
	<u>Lorraine:</u>
20-140	Grey to dark grey dolomitic shales, with interbedded siltstones

Cartier St. Hubert Well No. 1 (Cont'd)

<u>Depth in Feet</u>	<u>Lithology</u>
	<u>Lorraine and Utica:</u>
140-1,020	Medium to dark grey, laminated to irregularly-bedded, silty shales, some with brown streak; siltstone common in upper 350 feet
	<u>Utica:</u>
1,020-1,195	Black shale with brownish streak, calcareous below
	<u>Upper Trenton:</u>
1,195-1,240	Dark grey calcareous shale
	<u>Trenton:</u>
1,240-1,650	Tetreauville Formation - shale and argillaceous limestone
1,650-2,070	Montreal Formation - very fossiliferous crystalline limestone
2,070-2,100	Mile End Formation - light grey crystalline limestone
	<u>Black River:</u>
2,100-2,140	Leray and Lowville Formations - mostly lithographic limestone
2,140-2,160	Pamelia Formation - dolomite
	<u>Chazy:</u>
	Laval Formation -
2,160-2,400	St. Martin member: dolomitic limestone, with much shaly matter
2,400-2,615	Ste. Thérèse member: calcareous sandstone
2,615-2,625	Beldens Formation - dark argillaceous limestone, with pale grey lithographic dolomite
	<u>Beekmantown:</u>
2,625-3,490	Beauharnois Formation - dolomite, shaly towards the top; sandy zones common; limestone zones rare; medium grey
3,490	Bottom of hole

Hamilton Powder Company Well

Location: Beloeil map-sheet (3) - lot 2, St. Mathieu de Beloeil parish, Verchères county (now the property of Canadian Industries, Ltd.)

Total Depth: 1,400 feet

Drilled: 1905, to provide cooling water for nitrate process

Note 1: The following data are condensed from a manuscript report by H.M. Ami to the Geological Survey of Canada. The report appears to be made up of notes referring to samples at selected horizons.

No record exists, as far as is known, of the findings below 610 feet.

<u>Depth in Feet</u>	<u>Lithology</u>
85	Fine-grained mudstone or shale, non-calcareous; no fossils
110	Dark grey or black, non-calcareous shale; fossils present - <u>Triarthrus</u> , <u>Leptobolus</u> , and <u>Leperditia</u> questionably identified (Just below the 'gas')
240	Dark grey, crystalline, igneous rock
270	Dark grey shale, mixed with light grey igneous rocks
370	Fine-grained dark or black shales; no fossils
405	Shale, similar to above, finely comminuted; decomposed readily with water
460	Black shale, very finely comminuted
500	Hard, finely crystalline igneous rock
520	Green and grey igneous rock
550	Fine-grained black shale, finely comminuted; similar to shales above
590	Black shale, mixed with green igneous rock fragments
610	Fine-grained crystalline igneous rock

Note 2: No additional information concerning the gas, other than a note describing it as inflammable, occurs in Ami's report.

The rocks, from the descriptions, might as well be Lorraine as Utica. The decomposition of the shale favours a Lorraine age rather than a Utica age, and this is in accord with the setting on the geological map.

It is said that the water encountered was free-flowing, very sulphurous, and too corrosive to be of industrial use, and that the well was closed almost at once.

Ste. Madeleine Well

Location: Beloeil map-sheet (4) - lot 93, Ste. Madeleine parish, St.
Hyacinthe county

Elevation: 100 feet Drilled: 1917

Total Depth: 525 feet Rig: cable

<u>Depth in Feet</u>	<u>Lithology</u>
0-185	Overburden
	<u>Richmond:</u>
	Becancour River Formation -
185-225	Green-grey sandy shale
225-235	Dark grey sandstone
235-305	Green-grey sandy shale
305-315	Reddish brown sandy shale
315-325	Green-grey sandstone
325-335	Sandy shale, mottled red
335-355	Green-grey sandstone
355-405	Medium grey sandstone, grey shale fragments present
405-515	Green-grey sandstone, red shale fragments present
515-525	Red shale
525	Bottom of hole

Laprairie Company, Inc., Well

Location: St. Jean map-sheet (1) brickyard of the Company, Laprairie,
Napierville-Laprairie county

Total Depth: 2,330 feet Drilled: For oil

Note: The following is quoted from Maddox (1931b, p. 870):

"A well drilled by the La Prairie Brick Company to a depth of
2,330 feet is reported as passing through 1,500 feet of shale
and 800 feet of limestone. No records of oil or gas being
found are on hand".

APPENDIX B

NOTES ON OCCURRENCES OF NATURAL GAS

Location: 916 King George Ave., Notre-Dame du Sacré-Coeur,
Napierville-Laprairie County

Occupant: Julien Claing

Date: Well driven by Réal Proulx in May, 1948. Twenty feet clay,
seven feet broken rock (Utica or Lorraine shale). Milky
water containing small amount of matter in suspension.
Violent outburst of gas when pump is emptied, with a four-
foot flame at water-tap when lighted. No attempt at control.

Date: January, 1950.

Location: 924 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Gérard Proulx

Date: Well driven in 1946. Thirty feet overburden, a foot and a
half of soft rock. Gas struck in rock, merely bubbles. Gas
issues from water-taps throughout house, ignites with four-
inch flame. No attempt at control.

Date: January, 1950

Location: 950 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Roland Hamel

Date: Well driven in 1947. Thirty-six feet overburden, one foot
grey to black rock. At times gas ignites at water-tap with
twelve-foot flame, at other times only small outbursts of
gas from tank when pump is emptied. No attempt at use or
control.

Date: January, 1950

Location: 992 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Leopold Richard

Date: Well driven in 1945. Good water, slightly gaseous. Gas
ignites at water-tap with twenty-inch flame when pump is
emptied.

Date: January, 1950

Location: 1016 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Pierre-Paul Pharand

Data: Well driven in 1948. Twenty-seven feet overburden before
rock. Milky, gaseous water. Very violent outburst of gas
when pump is emptied. Gas is under high pressure but in
small amount due to small capacity of pump. Gas ignites at
water-tap with two-foot flame.

Date: January, 1950

Location: 1035 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Cyrille Crevier

Data: Well driven in June, 1949. Thirty-four feet overburden, one
foot rock. Milky, gaseous water. Forty-gallon water-tank
allows greater accumulation of gas than in previous homes.
When tank is emptied gas ignites at water-tap with four-foot
flame, burning from three to five minutes. No attempt at use
or control.

Date: January, 1950

Location: 1060 King George Ave., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Philip Munroe

Data: Well driven in 1950. Thirty-eight feet overburden without
reaching bed-rock. When pump is emptied gas ignites with
two-foot flame. No attempt at use or control.

Date: January, 1950

Location: 909 Donneville St., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Roger Latour

Data: Well driven in 1948. Twenty feet clay, eight feet broken
rock and clay, approaching bed-rock. Water often milky and
gaseous, slight sulphur taste. When pump is stopped, strong
outburst of gas occurs at moment flow of water ceases. Gas
ignites with three-foot flame. Can be repeated about every
hour. No attempt at use or control.

Date: January, 1950

Location: 907 Donneville St., Notre-Dame du Sacré-Coeur, Napierville-
Laprairie County

Occupant: Réal Proulx

Data: Well driven in 1949. Twenty feet clay, fifteen feet broken rock (probably shale) to bed-rock. When pump is emptied, light outburst of gas which ignites with two-foot flame. No attempt at use or control, but plans to in spring, 1950.

Date: January, 1950

Location: Range II, St. Marc, Verchères County (a mile and a quarter west of St. Marc village)

Occupant: Alphérie Archambault

Data: According to neighbours, gas in well when first dug. Not used at all.

Date: Summer, 1942

Location: Lot 88, Nord de la Rivière Range, St. Jean-Baptiste, Rouville County (a mile and a half northeast of Mont St. Hilaire village)

Occupant: Eustache Brodeur

Data: Well drilled in 1927-28, inch and a quarter diameter. One hundred and eighty feet overburden before reaching bed-rock. Gas encountered between overburden and bed-rock. During drilling, strong flow for two days, but none since completion of hole. Well is about one mile from house, close to base of mountain. No attempt at use or control.

Date: Summer, 1942

Location: Lot 18, Range V, La Présentation, St. Hyacinthe County (about three miles northwest of La Présentation village)

Occupant: Cabana

Data: Occasional large bubbles of gas. Oily taste and film to water.

Date: Summer, 1942

Location: Lot 82, Range Au Pin, Verchères County (about three and a half miles northeast of Boucherville)

Occupant: Philippe Choquette

Data: Here, and in several neighbours' wells, there is a little gas,

nowhere enough to use. No precise information.

Date: Summer, 1941

Location: 974 Riverside, Longueuil (Ville Jacques-Cartier), Chambly County (about three miles northeast of Longueuil proper)

Occupant: Peter Colivas

Data: Well driven in 1949. Forty-five feet overburden, two feet bed-rock. Gas encountered between overburden and bed-rock. Easy flow at first, decreasing to infrequent bubbling. Gas ignited when well first drilled, not tested since. No attempt at use or control.

Date: 1949

Location: Lot 223, Amyot River Range, St. Charles Parish, St. Hyacinthe County (about two miles northeast of St. Charles-River-Richelieu village)

Occupant: Paul Emile Corbeau

Data: Gas bubbles from well in field. Burned for two days when first dug.

Date: Summer, 1942

Location: Pays Brûlé Range, Verchères County (about two miles southeast of Varennes village)

Occupant: Jean-Baptiste Langlois

Data: Original well driven about 1905 into ninety-two feet overburden. Merely bubbles of gas. Gas issues in small quantities, especially when wind is high and pump is working well. Water slightly salty. No attempt at control. Second well dug in 1940. Water slightly salty. A little gas.

Date: Summer, 1942

Location: About three miles east-southeast of Varennes village, Verchères County

Occupant: Louis Langlois

Data: Well driven in 1910 into forty feet overburden. Gas encountered at thirty-three feet. For ten years gas pressure pushed water up pipe, then no more water, though gas continued. Well

plugged after explosion (caused by someone entering barn where well is located with lighted lantern) that destroyed barn. No attempt at control.

Date: Summer, 1941

Location: Côte d'en Bas Range, Verchères County (about two and a half miles north-northeast of Varennes village)

Occupant: Raymond Langlois (house owned by his father-in-law, Jules Archambault)

Data: Well driven about 1939. One hundred and ten feet overburden, ten feet bed-rock. Gas encountered ten feet below top of rock. Flow violent at first, rock thrown forty feet into air. Salt water followed. No attempt at control. Well plugged and abandoned.

Date: Summer, 1941

Location: 869 Riverside, Longueuil, Chambly County (about three and a half miles northeast of Longueuil proper)

Occupant: J.A. Reilley

Data: Well driven in 1949. Seventy-eight feet overburden, twenty feet bed-rock. No gas issued when well was drilled. Inconsiderable amount seeped into water later. No harmful results. No attempt at use or control.

Date: 1949

Location: One mile south of St. Basile-le-Grand at road corner, Chambly County

Occupant: Ernest St-Jean

Data: Well driven about 1941. Eighty feet overburden, one foot bed-rock. Gas encountered one foot below top of rock. Easy flow. No attempt at control, considered too expensive.

Date: Summer, 1942

Location: Grande Côte Range, Verchères County (about one mile north-east of Varennes village, opposite abandoned brick-yard)

Occupant: Albéric Tremblay

Data: Two wells driven about 1941. Sixty feet overburden at house, forty feet at barn. Gas encountered between overburden and

rock. Flow easy and constant, 1/4 lb. pressure. Gas from both wells piped together to house and used to heat water; main supply is from well at barn. About 1945, Mr. Tremblay tried using gas to heat a steam boiler for house heating, but supply was insufficient.

Date: 1942, 1945

Location: Range VI, Boucherville Parish, Chambly County (about three miles northwest of St. Bruno village)

Occupant: Maurice Viau

Data: Well driven about 1895. Forty feet overburden, two feet bed-rock. Gas encountered two feet below top of rock. Owner lit pipe near well. Explosion followed, destroyed barn and left ten-foot flame at well. Flow ceased naturally during the fall of 1942.

Date: Summer, 1944

Location: Lots 372, 373, 374, St. Basile-le-Grand Parish, Chambly County (highway No. 20, just south of St. Basile village)

Occupant: Unknown

Data: Well driven in 1940 into fifty feet overburden. Gas encountered between overburden and rock. Flow explosive at first, too strong to be controlled by placing foot over hole. No attempt at control. Well plugged, as owner did not want to use gas. Second well nearby gave a little gas at fifty feet. Continued digging to sixty or seventy feet and obtained supply of good water.

Date: Summer, 1942

Location: Pays Brûlé Range, Verchères County (about two and a half miles southeast of Varennes village)

Occupant: Unknown

Data: Well, 1 1/2 inch, driven in 1928. Fifty feet overburden, ten feet bed-rock. Gas encountered ten feet below top of bed-rock. At first gas blew out three wagon loads of gravel. When lighted the flame was ten feet high. Well plugged but gas still leaks out. Well is in fields, about half a mile south of house.

Date: Summer, 1942

Location: Three and a half miles south-southeast of Varennes village,
Verchères County

Occupant: Dubois

Data: None

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St. Bruno mountain	42,58	Urry, W.D. -	
St. Bruno mountain exposures ..	26	Ref. to work by	37,68
St. Dominique limestone	9	Utica fossils	17,18
St. Dominique sandstone	9	Utica group	15
Ste. Madeleine well	73	Utica shale	16
St. Hilaire member	21,31		
St. Hilaire mountain	41,58	Waynesville member	33
St. Hilaire mountain exposures.	31	Wells, condensed data on	69
St. Hubert anticline	50	Wilson, A.E. -	
St. Johns Petroleum well ..	6,8,69	Ref. to work by	68
St. Lawrence Brick Co.	22,59	Wilson, N.L. -	
St. Luc sill	43,46	Ref. to work by 5,37,38,39,43,67	
St. Martin limestone member	8	Yamaskite	40

1. The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that proper record-keeping is essential for the integrity of the financial system and for the ability to detect and prevent fraud. The text notes that without reliable records, it would be difficult to track the flow of funds and identify any irregularities.

2. The second part of the document outlines the specific procedures for recording transactions. It details the steps involved in entering data into the system, from initial verification to final posting. The procedures stress the need for consistency and accuracy in all entries, as well as the importance of regular audits to ensure that the records are up-to-date and correct.

3. The third part of the document addresses the issue of data security. It discusses the various risks associated with storing sensitive financial information and provides recommendations for minimizing these risks. This includes implementing strong password policies, using secure communication channels, and ensuring that all data is properly backed up and protected from unauthorized access.

4. The fourth part of the document focuses on the training and development of staff. It recognizes that the success of the financial system depends on the skills and knowledge of the personnel who use it. Therefore, it outlines a comprehensive training program that covers all aspects of the system, from basic operations to advanced troubleshooting techniques. The program also includes ongoing education to keep staff up-to-date on the latest developments in the field.

5. The fifth part of the document discusses the importance of collaboration and communication. It notes that the financial system is a complex, multi-faceted operation that requires the input and cooperation of all stakeholders. Regular communication and collaboration are essential for identifying and resolving issues, as well as for ensuring that the system is used effectively and efficiently.

6. The sixth part of the document concludes with a summary of the key points discussed. It reiterates the importance of accurate record-keeping, proper procedures, data security, staff training, and collaboration. The text emphasizes that these elements are all critical to the success of the financial system and that they must be implemented and maintained consistently over time.