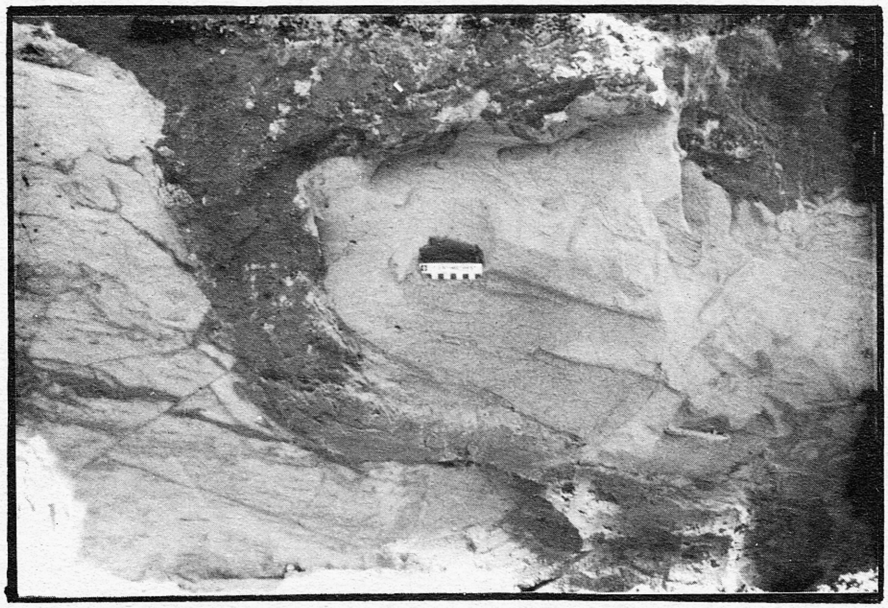
FRIENDS OF THE PLEISTOCENE

45th Annual Meeting

Drummondville–St-Hyacinthe, Québec, Canada

May 28-29-30, 1982



GUIDEBOOK

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Cover photograph: Till wedge, St-Césaire, Québec (P. LaSalle, 1981)

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INTRODUCTION

The authors of this field guide have planned for approximately one and a half day of excursion. Because of the scarcity of meaningful exposures in the central Champlain Sea plain, distances are often large between them and you may feel that you are being taken for a ride(!). However, there is not much that can be done about that, except to go along with it.

Some of the material that will be discussed during the meeting may seem familiar to you since the excursion will unavoidably lead to formerly visited sites and because the discussion of prevailing controversial subjects entails the repetition of already published geological data.

BEDROCK GEOLOGY

The area traversed by this field trip is located, from a geomorphological point of view, partly in the St. Lawrence Lowlands and partly on the northwest flank of the Appalachian Mountains (Fig. 1; Bostock, 1970).

The sedimentary rocks of the St. Lawrence Lowlands between Québec City and Montréal are of Ordovician age and consist mostly of limestones and shales which have been deformed very little and are almost flat-lying (Fig. 2). These rocks were intruded in Cretaceous time, circa 110 million years ago, by an alkaline magma which emplaced rock masses probably in the form of laccoliths along a line of weakness running east-southeast and shown by the present alignement of the Monteregian Hills (Fig. 2). There is no evidence that the pipes or feeders ever erupted to the surface. The erosional remnants of these intrusions, the various Monteregian Hills, stand out above the plain today. During the post-glacial marine transgression, these hills formed islands in the sea for most of its duration.

The rocks that occur on the northwestern flank of the Appalachian Mountains are quite varied; four lithologic units have been recognized by Harron (1967) which, from northwest to southeast, are described below.

1. A flyschoid belt which is approximately 30 km wide and is bordered on its northwest side the Logan's line. The rocks in this belt belong to the miogeosynclinal and eugeosynclinal suites of Hadrynian to lower Paleozoic age.

2. Southeast of the flyschoid belt, the first of two serpentine belts occur. Its width is very irregular with an average value of 15 km. The lithosequence includes Hadrynian metasedimentary and metavolcanic rocks presumably resting unconformably on a Grenville basement, followed by a clastic geosynclinal suite which forms the greater part of the rest of the sequence with minor miogeosynclinal quartzites and carbonates. These rocks

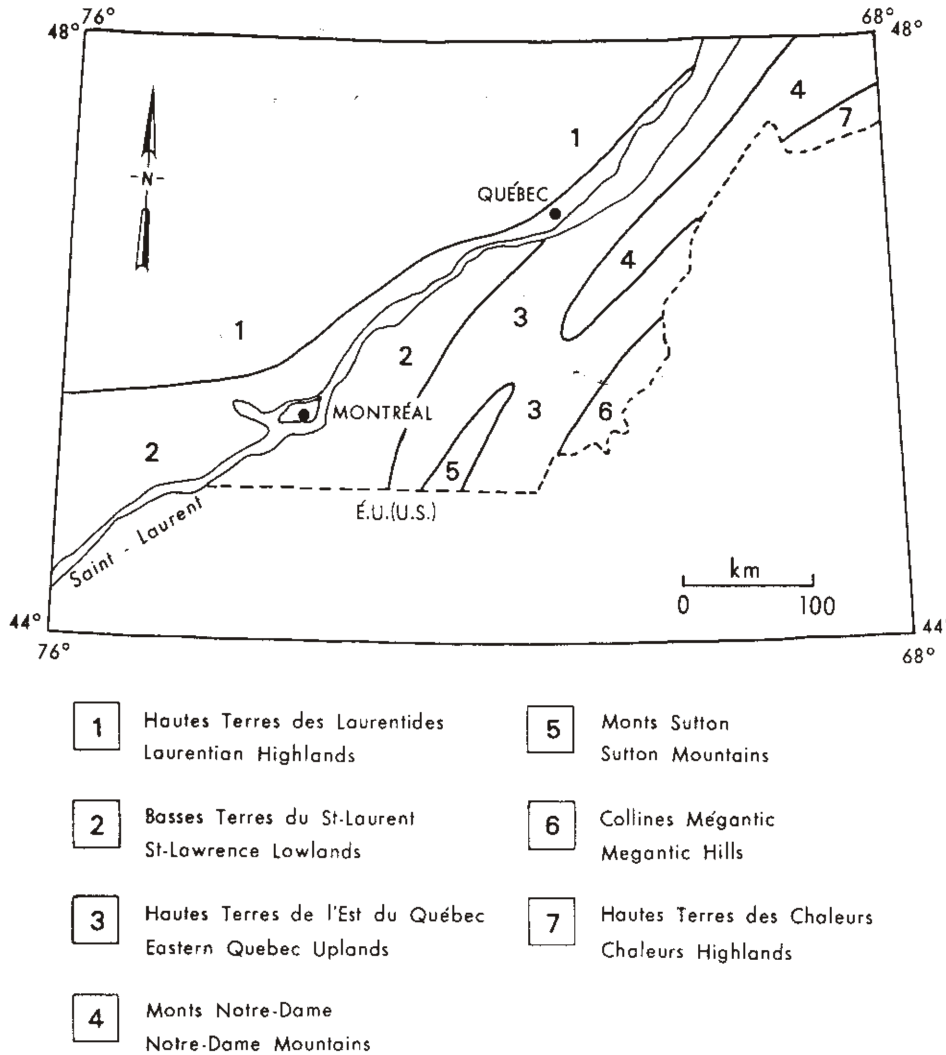


Figure 1. Physiographic units of southeastern Québec. From Bostock 1970.

range in age probably from Hadrynian to Ordovician.

3. The second serpentine belt lies southeast of the preceding one and it forms, with the associated sediments, the so-called "ophiolitic complex" of the Appalachian Mountains. There is controversy as to the origin of this complex. For most of its length, the most common rocks are peridotite and dunite associated with ultramafic to felsic vocanics. For some, this association meets the definition of an ophiolitic complex to which submarine volcanics are obviously associated. However, in other areas, besides peridotite, dunite and volcanics, there are black slates and limestones together with wildflysch rocks capping the sequence. Furthermore, it has not been demonstrated clearly whether the latter are essentially autochtonous or allochtonous.

4. The next geological unit is formed by the St.Victor synclinorium which lies southeast of the ophiolitic complex and runs for a distance of 250 km from Lake Memphremagog to the Québec - Maine border. It is essentially a flysch sequence. The rocks range from middle to upper Ordovician in age.

As mentioned above, the Appalachian geological province is separated from the St. Lawrence Lowlands by Logan's line which runs from the Gulf of St. Lawrence, through Québec City, then curving inland to reach the Québec - Vermont border in the Lake Champlain area. That line marks the location of complex thrust faulting involving in places blocks and nappes pushed from the southeast to the northwest.

EROSION AND EARLY DRAINAGE OF THE ST. LAWRENCE LOWLANDS AND NORTHWESTERN APPALACHIANS

Erosion became active in the Appalachians at the same time as those mountains were raised through deformation at the end of the Paleozoic. It suffices to mention here that debate has centered around two possible models of erosion to explain the evolution of the present landscape; these are the peneplain model and the dynamic equilibrium model (Stearn et al., 1979). However it may have happened, the relief of the Appalachians had been considerably reduced by Triassic time when renewed mountain building increased it again. Continued erosion, however, reduced it once again by Cretaceous time.

Further evidence from the area occupied by the St. Lawrence Lowlands today suggests that erosion of the Appalachian Mountains lasted all through the Cenozoic right to the onset of glaciations. The lines of evidence supporting this conclusion are as follows:

a- The absence of deposits of Cenozoic age. If such deposits had been emplaced, they could have hardly been all eroded away (Moore, 1958).

b- Provenance studies of the Atlantic Costal Plain sediments suggest that they were derived from the interior of the continent (Moore, 1958).

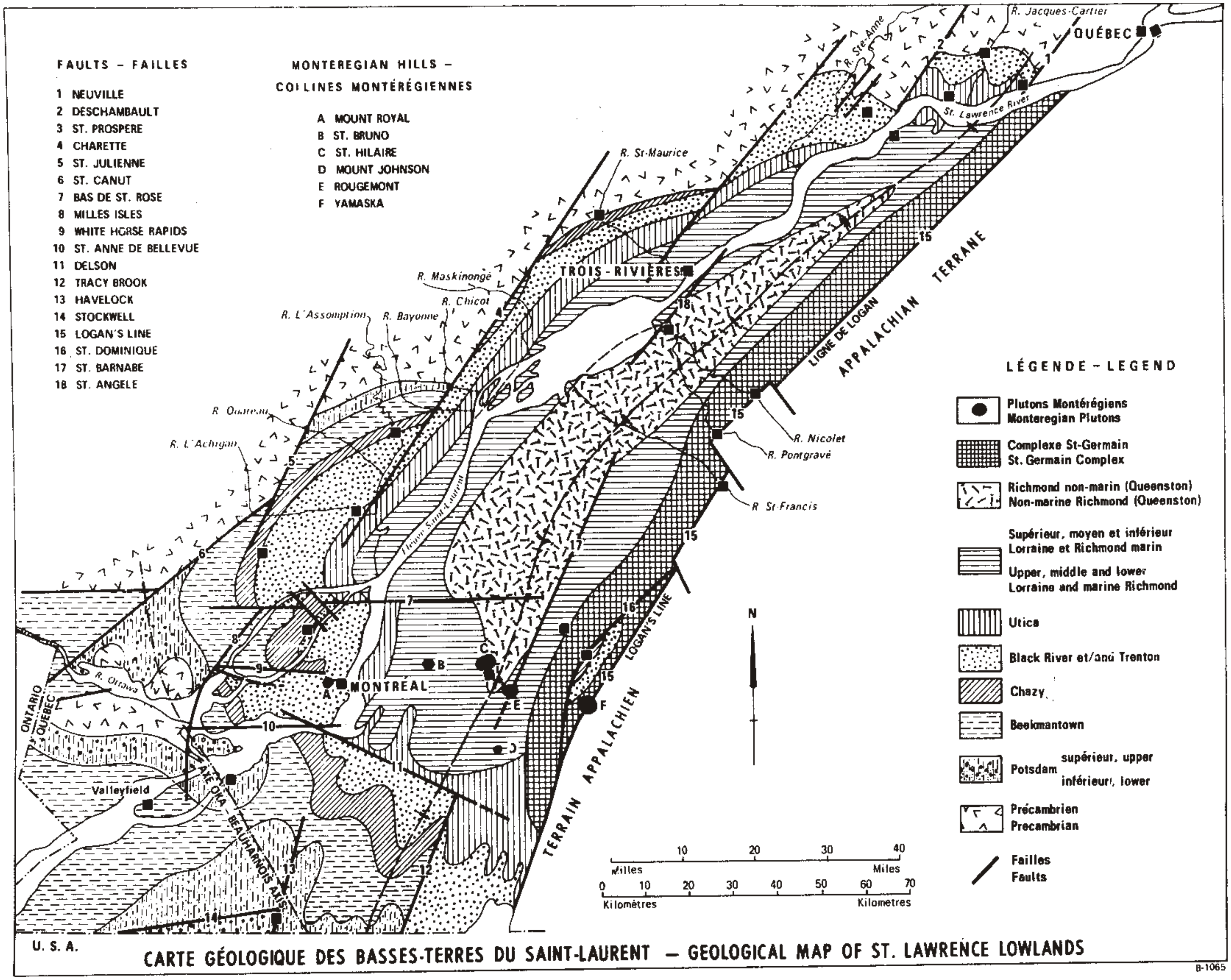


Figure 2. Geological map of St-Lawrence Lowlands. From Clarke et al. 1972

c- The reported occurrences of deep weathering profiles (saprolith) throughout the western and northern Atlantic regions (Dejou et al., 1982).

The St. Lawrence Lowlands were eroded out a miogeosynclinal rocks in post-Paleozoic time. There were at least 700 m of Paleozoic rocks left in the Montréal area when the Monteregian intrusions occurred in upper Cretaceous time.

The drainage in the Québec Appalachians and in the St. Lawrence Lowlands was thus possibly initiated as consequent streams flowing toward the Atlantic Ocean. As erosion of the softer rocks in the headwater regions within the St. Lawrence Lowlands progressed, a series of stream captures resulted that diverted drainage from the Atlantic Coastal Plain to the St. Lawrence River system and possibly to the Hudson Bay drainage system.

QUATERNARY STRATIGRAPHY AND GLACIATIONS

There is evidence for several episodes of Wisconsinan glaciation in the St. Lawrence Lowlands and in the Québec Appalachians, at least, within the area traversed by this excursion.

Concerning the glacial events in the lowlands proper situated northeast of Montréal, there is evidence for two Wisconsinan glacial episodes represented by the Bécancour and Gentilly tills and separated by the sediments of the St-Pierre interstadial (Gadd, 1971). Varved sediments are found associated with these glacial events. The St-Pierre Formation has been dated recently at about 75,000 BP (QL-198, 74,700 +2,700/-2,000 BP, Stuiver et al., 1978). Palynological studies by Terasmae (1958) suggest that climate during that episode was slightly cooler than now. No marine sediments have ever been found associated with the St-Pierre interval. The depositional environment was fluvial and estuarine with numerous peat bogs (Terasmae, 1958).

In the Appalachians of southern Québec, McDonald and Shilts (1971) and Shilts (1981) recognized three glacial episodes. The oldest one is represented by the Johnville Till which is correlative with the Bécancour Till. It is overlain by the interstadial Massawipi Formation which is correlative with the St-Pierre sediments. The Vallé-Jonction deposit (LaSalle et al., 1979) is probably correlative with them. The Gentilly stage of the St. Lawrence Lowlands is represented in the Appalachians by two glacial phases the sediments of which are the older Chaudière Till and the younger Lennoxville Till, separated by the glaciolacustrine Gayhurst Formation.

At certain locations, the Lennoxville Till can be divided into two members (Shilts, 1978, 1981; Chauvin, 1979). In the north, the upper member is oxydized, sandy and has only a weak fabric (Chauvin, 1979) while further south its fabric is well developed and indicates deposition by ice flowing to the southeast (Shilts, 1978). The lower member is gray, more clayey and shows everywhere a strong fabric indicating deposition also to the southeast (Shilts, 1978; Chauvin, 1979). Presumably, the emplacement of the upper sandy member is related in part to the stagnation of a residual Appalachian ice mass in late-glacial time (Chauvin, 1979; Shilts, 1981).

In the Montréal area, Prest and Hode-Keyser (1961, 1977) studied the Quaternary stratigraphy. In their reports on the Island of Montréal, they adopted the stratigraphic nomenclature used by MacClintok (1958) and MacClintok and Stewart (1965). Hence, they named the lower till resting directly on bedrock, the Malone Till, while they named the upper till the Fort-Covington Till. They called the inter-till sediments the Middle Till Complex (Prest and Hode-Keyser, 1961, 1977) and correlated it with the Gayhurst Formation (Shilts, 1970; McDonald and Shilts, 1971). These inter-till sediments comprise a mixture of varved and proximal ice-contact deposits. The nature of these sediments suggests that the ice front retreated to some distance north of the present Montréal area at the time of emplacement of the sediments. In the vicinity of Montréal (east and south), the stratigraphic succession (Stop 1, St-Césaire) is similar to that described by Prest and Hode-Keyser (1977), though the picture is far from clear (LaSalle, 1981) this field trip will demonstrate it.

Controversy still persists concerning the stratigraphy and succession of events in the Covey-Hill area in Québec and in the adjacent New England states (Fullerton, 1981). The limit of the Fort-Covington readvance as suggested by MacClintok (1958), MacClintok and Stewart (1965), and MacClintok and Terasmae (1960), seems to be very much in question. According to our interpretation, the glacier which deposited the Fort-Covington till and which is apparently equivalent to the glacier that formed the Lennoxville till, spread over the New England states as fas as Long Island, N. Y. This matter will certainly be raised and discussed during the present excursion.

DEGLACIATION

Deglaciation in the region began following the deposition of the Lennoxville and Gentilly tills. Because of the controversy generated by the problem of late-glacial northward ice flow, a brief historical background is in order.

Ells (1887, 1889) was supposedly the first to report evidence for northward flowing ice in southeastern Québec. Chalmers (1898) also cited field observations supporting the concept of northward flow of ice in the same region. However, his definition of the features, as well as Ell's (1887), which he used to arrive at such conclusions, is not clear. The concept of a system of late-glacial Appalachian glaciers was not retained in the years that followed the publication of Chalmer's studies. The only idea that was given consideration was the existence of local residual ice masses the flow of which was supposedly governed by the regional slope.

Mackay (1921) suggested that local glaciers might have formed in the Appalachians before the continental ice cap overrode them at the inception of a glaciation. At the end of the glaciation the reverse process took place. For a number of years, the field evidence for northward movement was ignored, except for the work of Cooke (1937) in the Thetford-Mines area, and of Clark (1937) in the Bedford region, immediately southeast of Montréal.

It was only after the more recent discoveries of striations, made by Lamarche (1971, 1974), that the concept of a residual Appalachian ice mass became fashionable again. Lamarche, based on numerous azimuth recordings of miniature crag-and-tail features, demonstrated the existence of a late-glacial movement towards the north in the Thetford-Mines region and towards the north and west near Asbestos.

Prest (1970) also suggested the existence of local glaciers in late-glacial time in the first modern synthesis on the subject. Gadd et al. (1972) in their synthesis showed the glacial retreat with an active ice front regressing toward the north and northwest and being responsible for the deposition of a series of discontinuous moraines. According to them, active ice persisted in the Thetford-Mines area after the separation of the Laurentide ice from the Appalachian ice. The information available at that time to those authors, however, did not allow them to set the precise limits of this late-glacial ice mass. Nevertheless, they outlined the area of influence of a hypothetical ice mass extending from East Angus in the southwest to east of Beauceville in the northeast.

The studies of Gauthier (1975) and Lortie (1977) show evidence of late-glacial northward ice flow in the areas east and west of the Chaudière River valley and in the area north of Asbestos. Based on the assumption that the Appalachian and Laurentide ice masses separated from one another along the axis of the St. Lawrence channel all the way to the Québec City area, these two authors had to introduce into their model a hypothetical readvance across the St. Lawrence channel to explain the emplacement of the Highland Front Moraine by the Laurentide ice. However, no field evidence has ever been found yet to support this readvance. Furthermore, new field data indicate that separation between the Laurentide and Appalachian ice masses occurred on land between Rivière-du-Loup and Québec City (LaSalle et al., 1976, 1977), thus providing the necessary Laurentide ice front for the Highland Front Moraine without any readvance, in the Québec City area.

More recently, LaSalle et al. (1976, 1977) and Martineau (1977) extended the limit of northward flow of ice still further northeast as far as the Rivière-du-Loup area, Locat (1976) still further east, and Lebuis and David (1977) all the way into the Gaspé Peninsula. (To do justice to those who have preceded us, it must be mentioned that evidence for northward moving ice in most of the areas mentioned above is more of the nature of a rediscovery, as the subject is amply discussed in older literature which, unfortunately, had been neglected).

Current ideas then suggest that calving in the St. Lawrence Estuary caused drawdown of the ice surface upstream in the St. Lawrence channel, and the consequent reversal of ice flow on the south side of the channel. Paleocurrent directions observed in morainic deposits suggest also that the latter were emplaced, in part, from residual ice masses located south of the St. Lawrence channel, at least in the area situated east of Québec City.

Deglaciation of the Québec City area occurred approximately 12,500 to 13,000 years ago (see dates in Fig. 3; LaSalle et al., 1977). Marine waters, however, apparently reached the Ottawa area by around 12,800 years BP (Richard, 1978), or, approximately at the same time as the St. Lawrence channel became free of ice near Québec City.

There was a recurrence of glacial activity north of the St. Lawrence channel around 11,000 years BP (LaSalle et Elson, 1975; LaSalle et al., 1977) when the St-Narcisse moraine system was formed. There is controversy as to the climatic significance of the St-Narcisse moraine system. Its formation has been variously attributed to such causes as changes in the regime of the ice sheet (LaSalle and Elson, 1975), or as the reestablishment of the glacier's equilibrium (Hilaire-Marcel et al., 1981). The latter however applies to glaciers with a marine margin which is obviously not the case for the greater part of the St-Narcisse moraine system which extends for over 320 km in length. Whatever is the case, at the time of the emplacement of the moraine system north of the channel, arctic vegetation was present south of the present St. Lawrence River east of Québec City (Mott et al., 1981).

The Champlain Sea lasted until 9,500 years ago when waters gradually became less and less brackish as shoaling progressed. A series of fresh water lakes (Lampsilis) existed in the lowlands before the present erosional conditions became dominant (Elson, 1962; Richard, 1978).

SHORELINES IN THE MONTREAL AREA

Isostatic rebound in the Montréal area has been discussed at various lengths by a number of authors (McDonald, 1967; MacPherson, 1967; Elson, 1969; Walcott, 1972). No detailed work has been done in recent years to re-appraise the newly available data. In the earlier works, the curve published by Walcott (1972) is possibly the most empirical one. MacPherson (1967) discusses the position of the various shorelines (the Montréal and the Rigaud shorelines) as the shoaling of the Champlain Sea progressed and as the drainage of the present St. Lawrence River gradually developed. Elson (1982) discusses these same problems based on the pollen record obtained from Beaver Lake, a small pond located on Mount Royal in the City of Montréal. He concludes (Elson, 1982) that the St. Lawrence River has occupied its present channel in the Montréal area since about 6,700 years BP.

Lab. no.	Locality	Matérial	14C BP
GSC - 1803 GSC - 1344	Lac des Bouleaux, Mont St-Bruno (Lowdon and Blake 1975)	deepest levels of gyttja, silty, compact.	12,400 ± 170 (263-267cm) 13,000 ± 290 (267-271cm)
GSC - 419	Mont St-Hilaire (Lowdon and Blake 1968) (LaSalle, 1966; Gadd et al, 1972)	deepest levels of gyttja, from a filled lake bassin.	12,570 ± 220
GSC - 1533	Charlesbourg (Québec) (Gadd et al, 1972)	Shells of <u>Portlandia Artica</u>, in fine shate fied sand, overlain by fill.	12,400 ± 160
GSC- 312	Lac Crève-la-faim (Buckland) (Gadd et al 1972)	deepest levels of gyttja.	12,640 ± 190
GSC - 2151	Ottawa (Richard 1978)	Shells of <u>Hiatella artica</u>	internal fraction: 12,700 ± 100 external fraction: 12,800 ± 100

Figure 3. List of selected dates pertinent to the deglaciation of the Montréal area and to the inception of the Champlain Sea in the St-Lawrence Lowlands.

ACKNOWLEDGMENTS

This excursion and meeting could not have been organized without the collaboration of many colleague-friends, and we would like to acknowledge their contributions. Special thanks are due to Michel Bouchard who looked after all the material arrangements; to Kristine Crossen and Bernise Grandchamp who contributed to the preparation of this manuscript; to the field assistants of Pierre LaSalle who, hopefully, will have cleaned the exposures by the time this excursion takes place. We have also benefited from the comments of Nelson Gadd, Bill Shilts, Michel Bouchard and Michel Valade during the field preparation of the excursion.

We also express our gratitude to the Ministère de l'Energie et des Ressources du Québec, and to the Département de Géologie de l'Université de Montréal for helping in one way or another in the organisation of this field conference.

FIELD EXCURSION

The main features to be exam ned and passionately discussed during this one day and a half excursion are new elements of the Quaternary stratigraphy of the Champlain Sea basin east of Montréal (Stop 1) as well as the well known classical stratigraphy of the north-central lowlands (Stop 5). In addition, several sites will be visited, where data pertain to problems of the regional surface till near Montréal (Stop 2), the Champlain Sea levels (Stop 3), and the Highland Front Moraine (Stop 6). One stop (Stop 4) will be about soils in the St-Hyacinthe region.

Day 1 - May 29, 1982 (See Map 1)

The first day, travel will be by bus. The bus will take route 231 from St-Hyacinthe to Rougemont, then route 112 to St-Césaire and, finally, route 233, toward Farnham, to Stop 1.

The whole trip of this day will be across the marine plain area underlain by Champlain Sea clays which are locally covered by sand. The isolated hills that you see after leaving St-Hyacinthe are the Monteregian Hills. You can spot on your left Mont Yamaska, straight ahead Mont Rougemont and to you right Mont St-Hilaire (Stop 3) with Mont St-Bruno (Stop 2) behind it. You may also see in the far distance ahead, the cone-shaped outline of Mont St-Grégoire (Mt. Johnson). While these hills are well known for their geology, they have renown for their wide-spread apple orchards and, in fact, they form the principal apple production centre of Québec.

Leaving St-Césaire on route 233, you will know that we are approaching Stop 1 when you see on your right indications for the "Far West Village". Unfortunately, we will not visit this "interesting" attraction. Who wants to see a tourist attraction anyway, when we can visit the "Sablière Larocque" (Stop 1) in a short distance. Why look at cowboys when you can search for fossils? We will probably spend the whole morning in this gravel pit, looking at various aspects of the local Quaternary stratigraphy.

Upon leaving the pit, the bus will head west, toward Montréal, on the Eastern Townships Autoroute (Route 10). You may relax as the drive may take about 30 minutes. Soon after crossing over the Richelieu River, the bus will exit for the recently completed autoroute 30 toward St-Bruno-de-Montarville, and then to Stop 2 across the town. At Stop 2, we will discuss the petrography and the mode of emplacement of the surface till (St-Jacques till ?)

A WORD OF CAUTION!!! Since the exposures are at the top of an active quarry, near the rim of the excavation, please take exceptional care while at this stop!!!

From Mont St-Bruno, the bus will take us back to route 116 and east to Mont St-Hilaire (Stop 3). We will head for the gravel pit on the southeast side of the mountain. The discussion will focus on the chronology and on the various water levels of the Champlain Sea. You are warned that the noise which will most likely surround us is not from giant mosquitoes but from motocross motorcycles expertly driven by another species of gravel pit fans.

From Mont St-Hilaire, we will pass by St-Jean-Baptiste-de-Rouville north to Ste-Madeleine and to the Transcanadian Autoroute (20) east. We will leave the autoroute at exit 130 and head north along route 235 to St-Thomas-d'Aquin and St-Barnabé (Stop 4). There, in trenches, we will observe profiles of the St-Hyacinthe soil series. The parent material of these soils is varved clays and silty clays which possibly represent deposits of the low-saline or fresh water (Lampsilis) phase of the Champlain Sea episode. The origin of this material as well as its regional extent will also be discussed.

MAP 1. Day 1 - May 29. Location of stops and route followed.

Stop 1 - St-Césaire gravel pit (P. LaSalle)

This gravel pit is located in a ridge situated approximately in the middle of the Champlain Sea basin. The location of the ridge is apparently due to the "shadow effect" of Mont Rougemont relative to the direction of ice flow. It formed as the ice retreated and readvanced across the southern part of Québec and extended all the way across the New England states. As shown in Figure 4, one can observe south of Montréal a series of similar ridges generally located down-glacier from either one of the Monteregian Hills or from a bedrock high.

The granular sediments of the St-Césaire ridge form an important aquifer for the area. Its zone of recharge presumably extends all the way to the base of the mountain.

Points of interest in the gravel pit are indicated on the airphoto shown in Figure 5.

Location 1 - This location shows best the stratigraphy in the gravel pit (Fig. 6). At the base of the sequence, below the floor of the pit, one finds a unit of coarse-grained, sandy gravel. The thickness of this unit has been well documented by borings and excavations in the pit, and reaches about 15 m. This gravel overlies a till that is observed only by drilling. The gravel is overlain by well sorted fine- to medium-grained sands, 3 to 4 m thick, containing layers of silty and clayey sand and showing a fair degree of compaction. Thrust faults and load structures are common in the unit. Cross stratification in the sand unit suggest current directions in a general southwesterly direction.

Varved sediments, absent in this gravel pit, overlie the former sand unit as seen in other gravel pits developed in similarly located ridges and showing the same general sequence of sediments as here (Fig. 7, the St-Jacques section)** At this location, the varved sediments are present only as inclusions in the till (St-Jacques Till) overlying the sand, as will be seen at Location 2. The St-Jacques Till here contains a fair amount of clay-sized fraction and, in some of the other ridges, it is composed almost entirely of clay- and silt-sized material. The fabric of the till at this location (1 to 3 in Figs 8 and 9) suggest ice flow to the southeast. The significance of these fabrics when compared with the others shown in Figures 8 and 9, is debatable at this time and requires further study.

Above the till, there is a thin sequence of reddish-coloured varved sediments (Chambly) with abundant clasts of silt and other ice-rafted material. No marine fossils have been found anywhere in these sediments suggesting that they possibly belong to a water body that formed the extension of Lake Vermont into the St. Lawrence Lowlands (Chapman, 1937; Denny, 1974) prior to the arrival of the marine waters of the Champlain Sea. This matter is also debatable as there is no agreement either on the

** A similar sequence of sediments is also described by Prichonnet (1982) from a gravel pit near L'Ange Gardien.

upper marine limit south of Montréal, or on the significance of the small unfossiliferous deltas occurring above the marine limit(?) in the same area.

The varved sediments (Chambly) are in turn overlain by fossiliferous Champlain Sea clays and sands. Foraminifera are quite abundant in these sediments. Dates obtained on shells of Hiatella arctica are 10,500 ± 140 BP (QU-1059) and 10,500 ± 90 BP (GSC-2861, Lowdon and Blake, 1979).

Food for thought: the sedimentary sequence under the St-Jacques Till, described above, shows a definite fining upwards from coarse-grained gravel to sand and to varved fine-grained sediments. They suggest a deglaciation sequence with the obvious absence of the sea. We also know that the sea was not present either when the St-Pierre or when the Gayhurst sediments formed. Therefore, one may ask whether we are looking at the equivalent of the St-Pierre sediments or of the Gayhurst deposits. Our interpretation is shown on Figures 10 and 11, in any case.

Location 2 - Tethya logani (sponge spicules) has been found at this location. They appeared abundantly in fairly continuous layers. It is not certain that they can be seen again as excavation at this location is advancing at a high rate.

Location 3 - In this part of the gravel pit the exposed till contains a lower gray unit and an upper brown unit. The contact between the two units appears to be a thrust fault. The upper brown unit contains large blocks of varved sediments which have been deformed and sheared to some degree. Fabric measurements in both units of the till gave similar results. The till overlies a sand unit which shows some thrust faults and load structures. At the contact of the sand and till there are several till wedges (see front cover) penetrating into the sand unit. These wedges appear to indicate ice flow direction to the west-southwest.

Location 3a (J.P.Guilbault) - Exposure in marine sediments situated just north of former location. The marine sediments exposed in the pit have been sampled at two locations but only this location is described here. The lithological sequence at this exposure is shown in Figure 12, along with a description of the lithologic units, the biostratigraphic zonation, and the paleoecologic interpretations of the different zones based on the foraminifer and ostracod fauna.

The sequence of biofacies observed here is similar to that reported from the Drummondville area (Guilbault, 1980). Lower brackish (or freshwater ?)

deposits are overlain by sediments deposited in full marine conditions, followed by deposits which record a decrease in salinity. Most of the deposits studied by Guilbault (1980) in the St.Lawrence Lowlands above 60 m altitude, show similar sequences. Localities situated at altitudes below 60 m generally show a sequence which grades upward into freshwater clays. The fact that the sequence at St-Césaire (altitude ca. 50 m) terminates at its top in marine shore facies, is somewhat anomalous considering the age of the deposits (see at Location 1). A similarly anomalous sequence was observed in a section near Ste-Philomène (Elson, 1969; Guilbault, 1980) where the relative sea level of ca. 43 m has been dated at not less than about 10,200 years BP. If other similar sections are discovered, it will become necessary to assume very low sea levels on the south side of the St. Lawrence River for the period from 10,500 to 10,000 years BP.

Location 4 - At this location, the direction of cross lamination in the sand underlying the till suggests paleocurrent directions to the southwest.

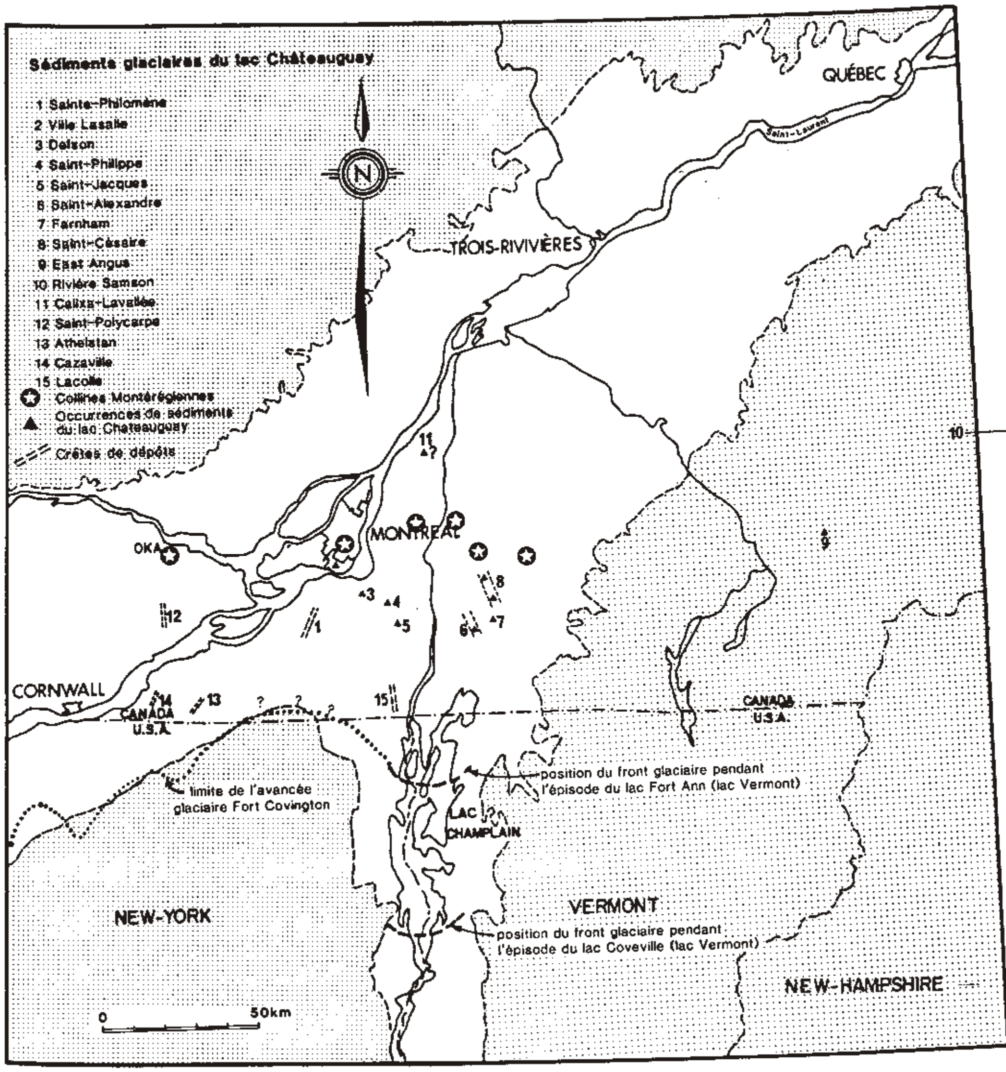


Figure 4. Map showing amongst other features the occurence of ridges comparable to the one in which the St-Césaire (location 8) gravel pit was excavated.

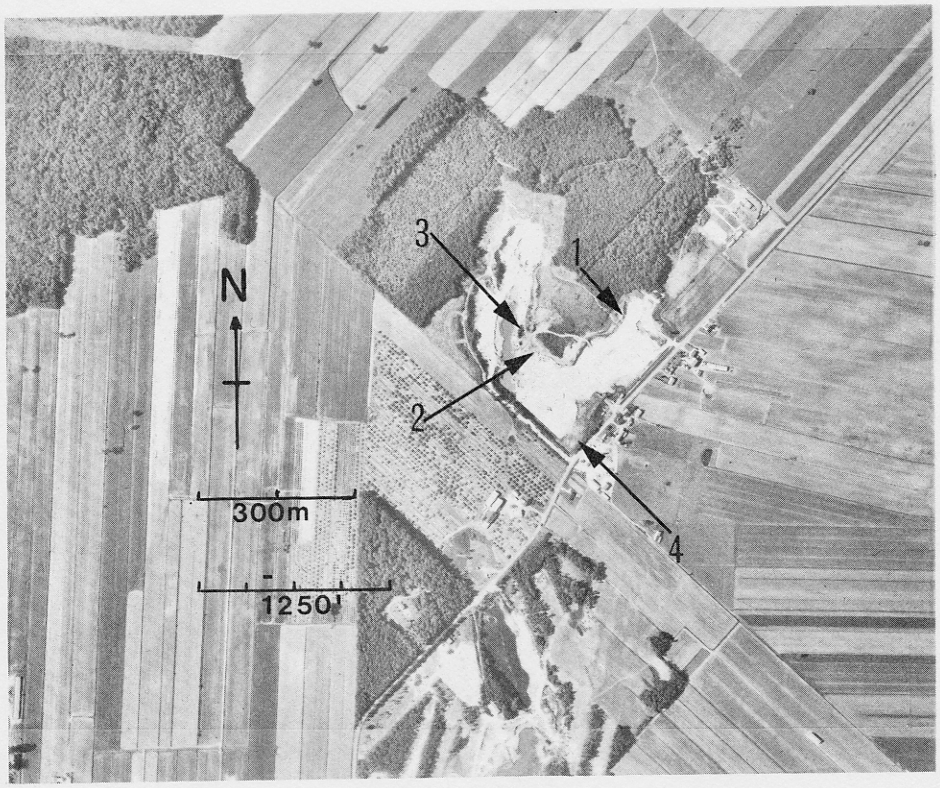


Figure 5. Points of interests. STOP 1. St-Césaire gravel pit.

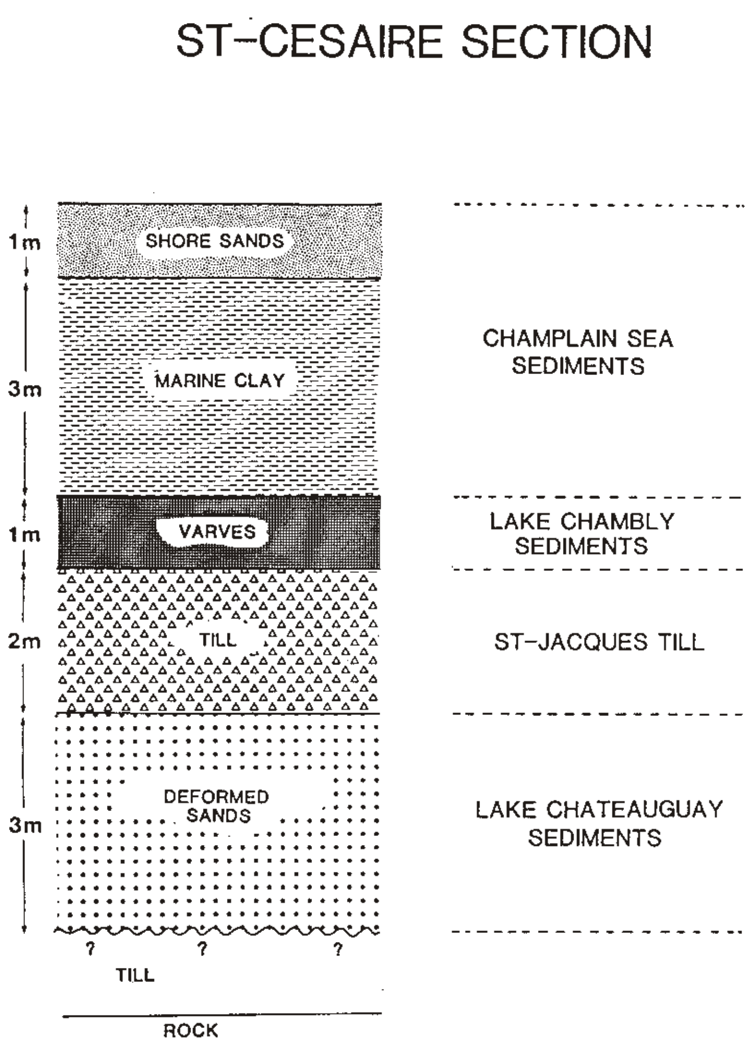


Figure 6. Schematic stratigraphic sequence, St-Césaire gravel pit.

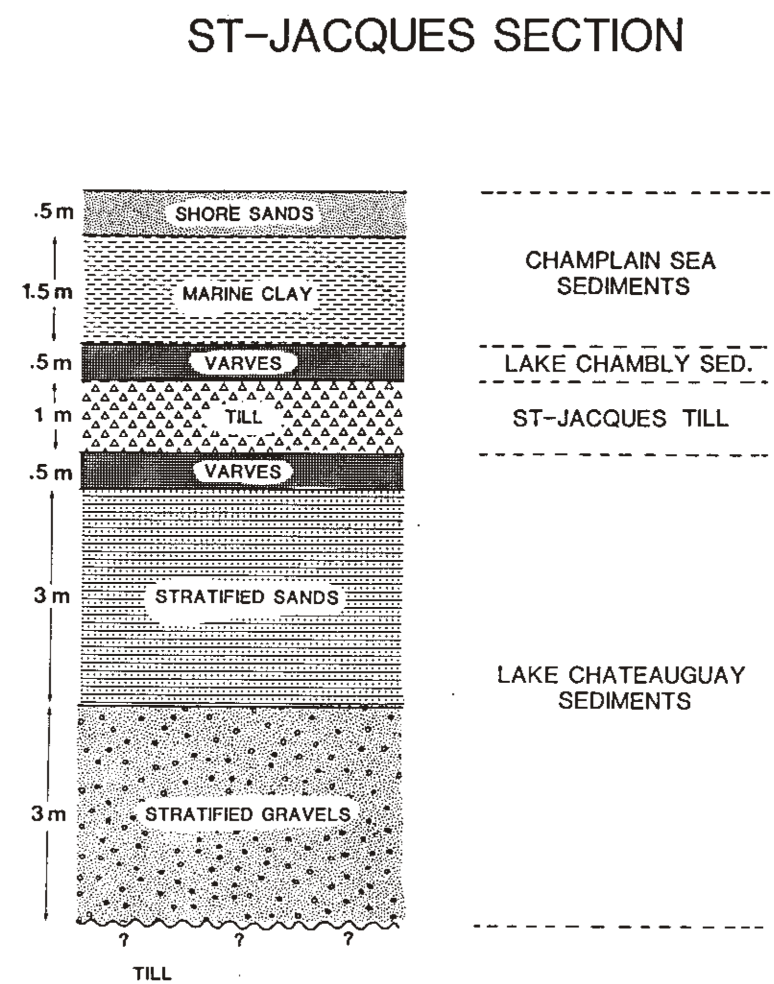


Figure 7. Schematic stratigraphic sequence, St-Jacques-le-Mineur gravel pit.

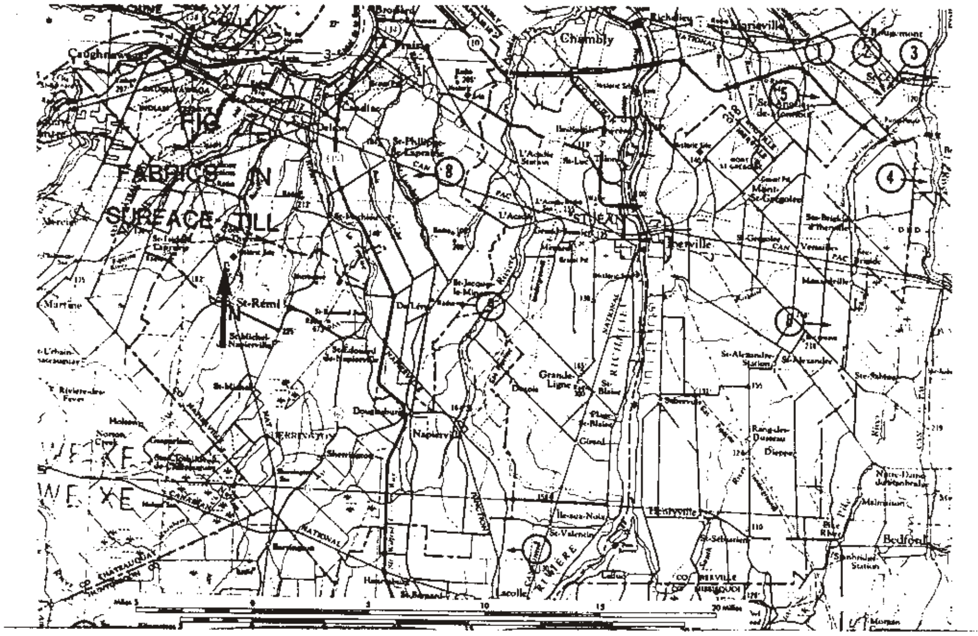


Figure 8. Fabrics in surface till.

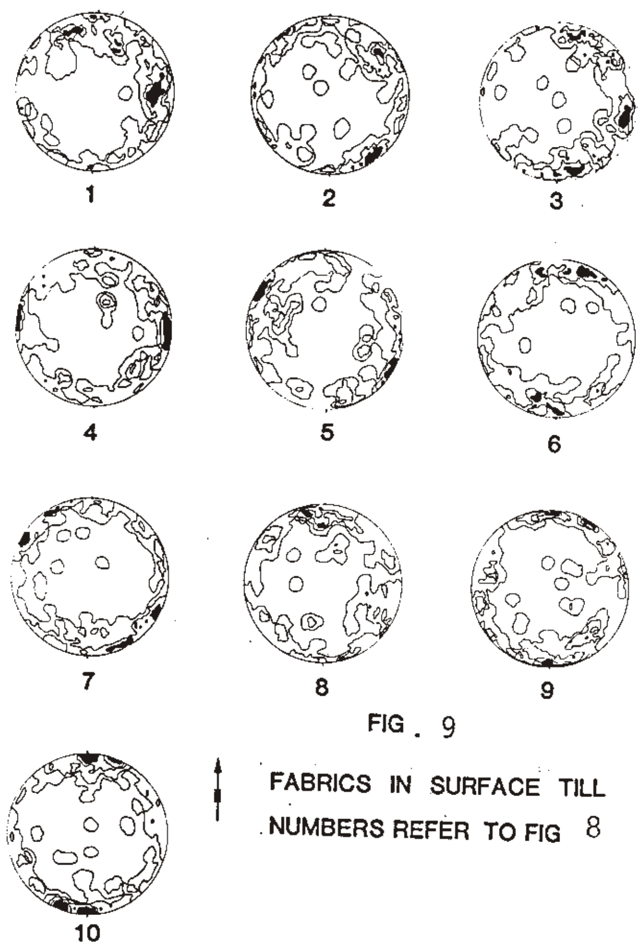


FIG. 9

FABRICS IN SURFACE TILL

NUMBERS REFER TO FIG 8

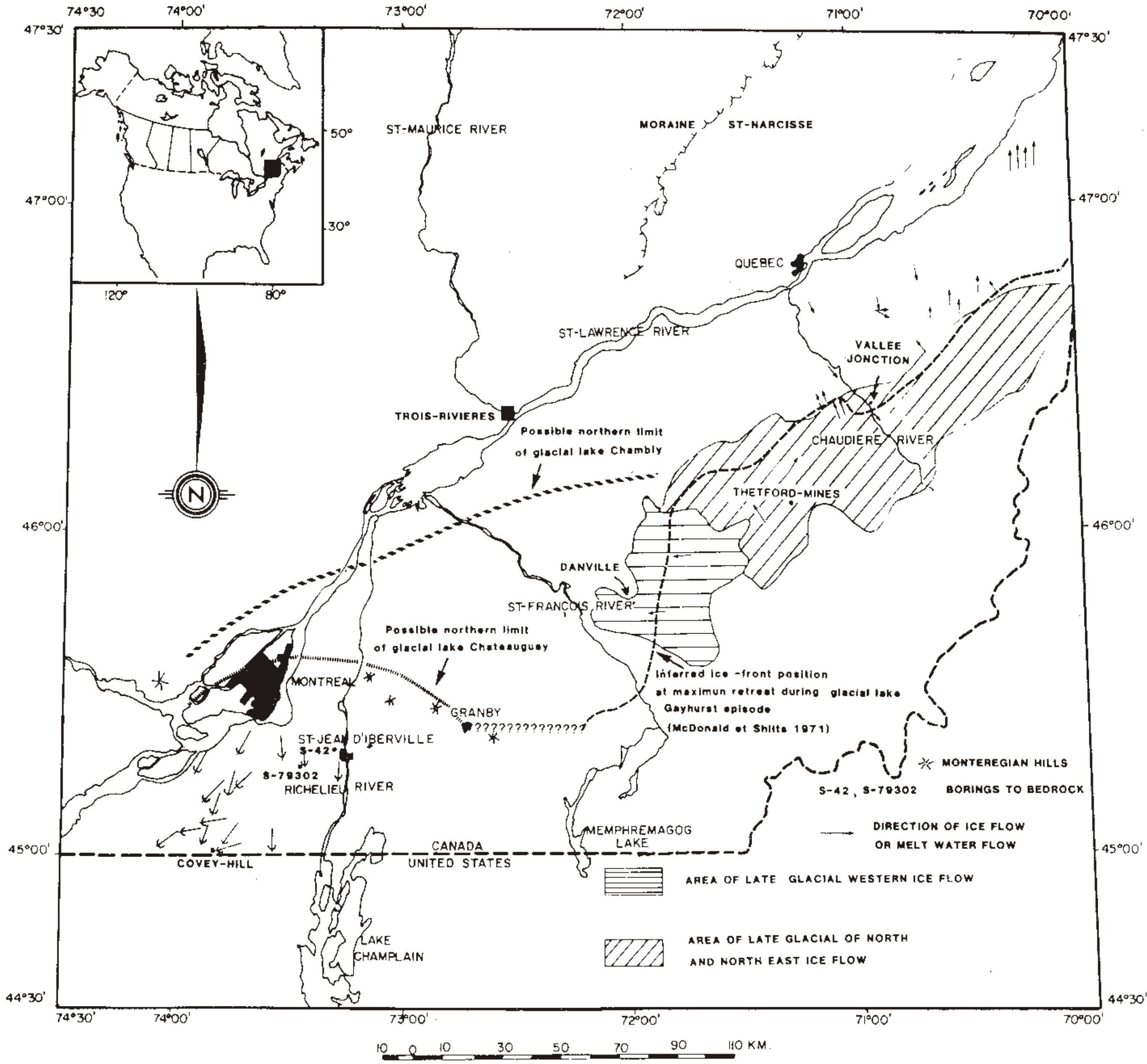


Figure 10. Summary of glacial geological interpretations of some of the deposits observed in the St-Césaire gravel pit.

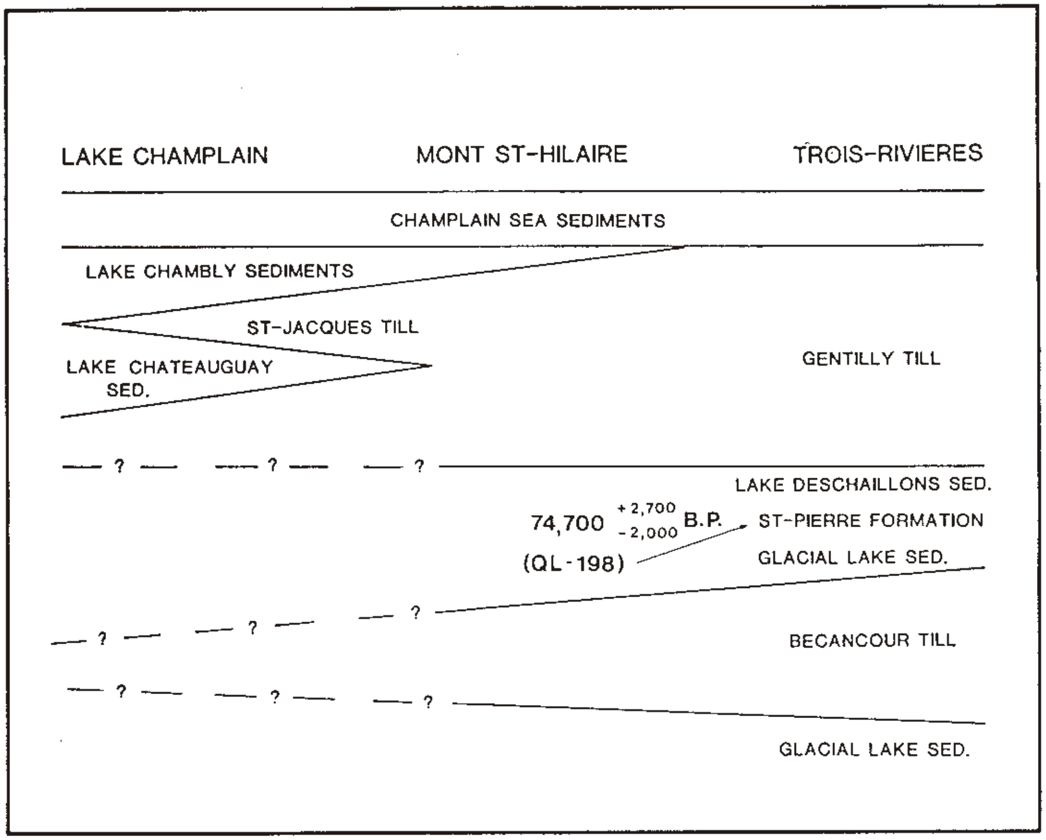
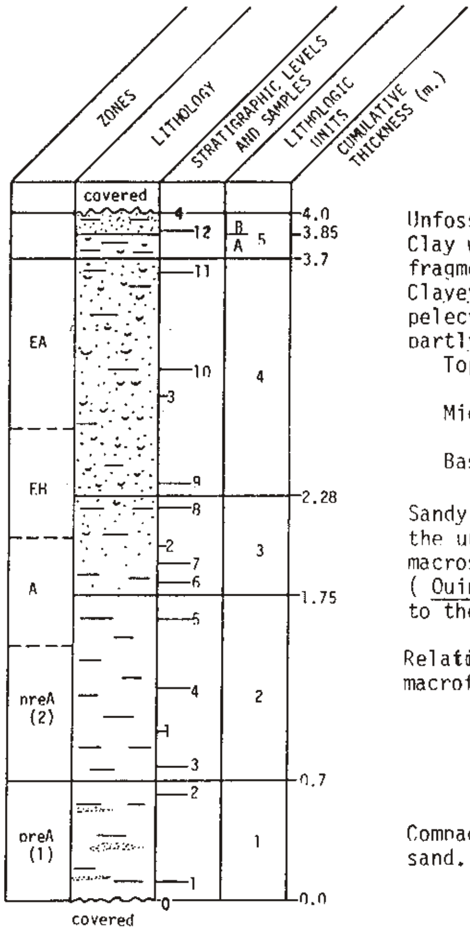


Figure 11. Tentative regional correlations of the sequence of sediments observed at St-Césaire.



DESCRIPTION		PALEOECOLOGIC INTERPRETATION (zoning of Guilbault 1980) based on foraminifer and osttracod fauna.
Unfossiliferous clayey sand Clay with few indeterminate macrofossils fragments Clayey sand packed with disarticulated pelecypod valves. The sediment is at least partly shell-supported. Macrofossils : Top : Macoma balthica, Mytilus edulis scattered Hiatella arctica Middle: Hiatella arctica, scattered Mytilus edulis Base : Hiatella arctica, Mya truncata	EA	Paleosalinity variable but probably not more than 10% at the top of the unit. Water depth very shallow, possibly no more than a few meters but as the material appears reworked, the actual depth might have been greater. THere is evidence for a water temperature increase in this zone compared to the underlying zones, but this might be only a consequence of reduced depth.
Sandy clay to clayey sand, more sandy in the upper part. Few small indeterminate macrofossils. Scattered large foraminifers (Quinqueloculina seminulum) are visible to the naked eye.	EH	Paleosalinity highly variable with a maximum probably lower than zone A. Water depth maximum 20 m. The abrupt lithological change in the middle of the zone correlates with a faunal change suggesting a decrease in the water depth. This can be explained if the shell bed is assumed to be formed of material washed down from shallower water by wave or tidal action.
Relatively soft clay. Few small indeterminate macrofossils inthe upper part of the unit.	A	Paleosalinity in the range of 25 to 30 %. Water depth 20 to 30 m. or more. This is the main deep water facies of the Champlain Sae with near to normal marine conditions.
	pre A (2)	Freshwater to oligohaline (maximum salinity 2 to 3 %). Water depth unknown.
Compact clay with irregular bands of fine sand.	pre A (1)	No reliable evidence available. Probably freshwater to oligohaline. Water depth unknown.

Figure 12. Description, zonation, and paleoecologic interpretation of the Champlain Sea sediments at St-Césaire.

Stop 2 - St-Bruno (P.P. David)

Stop at exposure in unconsolidated glacial sediments overlying glacially abraded bedrock surface at the northwest end of a quarry (Carrière Saint-Bruno Lté.) located on the north side of Saint-Bruno-de-Montarville (David, 1972).

The bed rock underlying the region comprises the black, Lower Paleozoic Lorraine shales which are flat-lying and are criss-crossed by numerous dykes and sills of igneous rocks associated with the Mount St. Bruno intrusion.

The site is situated on the southwest side of the mountain, a short distance from the base of the steeply inclined slopes. The exposure shows two distinctly coloured tills overlying one another: an upper RED TILL and a lower GRAY TILL. At the exposure, the lower till rest directly on the bedrock surface. However, a little further south, as in the whole region around (LaSalle and Elson, 1962), the upper red till directly overlies the bedrock surface. The two tills are described in Table 1.

The bedrock surface. The bedrock surface is uneven at the exposure. Under the section to be examined, it has an extensive but shallow depression on it, not more than one meter deep and limited to the south by a sudden rise of the bedrock surface. The lower till appears to be restricted to this depression. The surface of the bed rock is striated. Within the depression, one set of striations is visible, while on the higher surface above the rise, there are two sets.

One of the sets of striations on the higher ground is oriented at around 5^{o} Azimuth, in the same direction as the single set in the depression. The other set is oriented at about 55^{o} Azimuth. The sense of ice flow related to both sets is southerly, as determined on the basis of minute crag-and-tail features formed by small, more resistant inclusions in the bedrock shale, and by the igneous dykes themselves which come to the surface.

The relative age of the two sets has been identified on the basis of their fineness and their relative frequency on the outcrops. Since the 5^{o} striations are coarser and less frequent, they are considered to be the older set and the 55^{o} ones the younger set.

Pebble-orientation measurements have been made in the two tills on the occasion of yearly field excursions to the exposure. Because of continued excavation in the quarry through the years, the yearly measurements were almost always taken in different sections of the tills. The preferred orientation of the long axis of pebbles varied from one place to another in both tills, more so in the red till than in the gray till. In the red till it varied from a northerly one at one place to a northeasterly one elsewhere, the most frequent direction was at an average of 45^{o} Azimuth for statistically selected rod-shaped particles. In the gray till the results varied less and gave a preferential orientation of 10^{o} Azimuth.

Interpretation. On the basis of the above data it is suggested that the two tills were deposited by one and the same glacier but that they represent two different sedimentary facies and glacial environments. Accordingly, the lower GRAY TILL was deposited as a lodgement till at the base of a glacier which, at one time, flowed almost due south across the region and, by flowing along the west side of the mountain before arriving to the site of observation, it was only slightly deflected from its predominantly southerly direction. This glacier brought with it from distant sources some Shield lithologies, while the local Paleozoic bed rock dominates its till.

At a later time, this same glacier changed direction from a mostly southerly one to a mostly southwesterly one. On its way to this location, it passed over the red-couloured bedrock shales and associated fine-grained lithologies of the Richmound Group which outcrop northeast of the area (see LaSalle, 1981). It acquired from those rocks a predominantly red-couloured basal dêbris which became basal englacial dêbris by the time it reached the area on the downglacier side of the mountain. This glacier was eroding its base everywhere and removed most of the already deposited gray till except in the 'flow shadow' of the mountain. At the same time, it imprinted its new flow direction on the formerly eroded and now unprotected portions of the bedrock surface, it compacted the gray till that remained at its base, it caused the fracturing of the closely packed sand-sized particles in the gray till, unprotected by a fine-grained matrix, and, finally, it deposited its new, red-coloured load. This load which originated from some distance upglacier and was carried into the area as a near-base englacial dêbris, became deposited as a loose, strongly fissile, basal melt-out till containing several thin laminae of sand. At the same time, the red till became squeezed into fissures in the gray till to form till wedges.

TABLE 1. DESCRIPTION OF THE TWO TILLS

Properties	RED TILL	GRAY TILL
Colour	5YR 6/2 (pinkish gray) to 10YR 6/2 (gray)	5Y 5/1 (gray)
Grain-size of matrix	Sand: 33 % Fines: 67 % Evenly distributed sand-sized fraction	Sand: 45 % Fines: 55 % High proportion of fine-grained sand-sized fraction
Pebble-shape	Fewer blade-shaped particles	More blade-shaped particles
Structure	Strong fissility; Not compact, loose	Weak fissility; Very compact, dense
Oxidation	Unoxidized	Unoxidized
Carbonate in matrix	2 - 3 % (total)	4 - 6 % (total)
Lithology	Many particles of red siltstone and shale in fractions $<$1 cm diam. Frequent gray sansdstone (fine-grained) and limestone particles; Some igneous particles	No red siltstone or shale particles; Few sanstone (fine-grained) and limestone partilces; Many small black shale particles; Numerous igneous and metamorphic rock particles; Large quantities of fractured quartz grains in sand fraction
Inclusions	Thin laminae of sand ($<$1 cm); Small fragments of lower gray till near base including thin laminae of it	Very thin laminae of sand (1-5 mm) near top; Wedge of red till (40-60 cm long, 15-20 cm wide) extending into gray till from above (not visible any more)

Contact between the two tills:

Very sharp both megascopically and microscopically.
Even megascopically; irregular microscopically

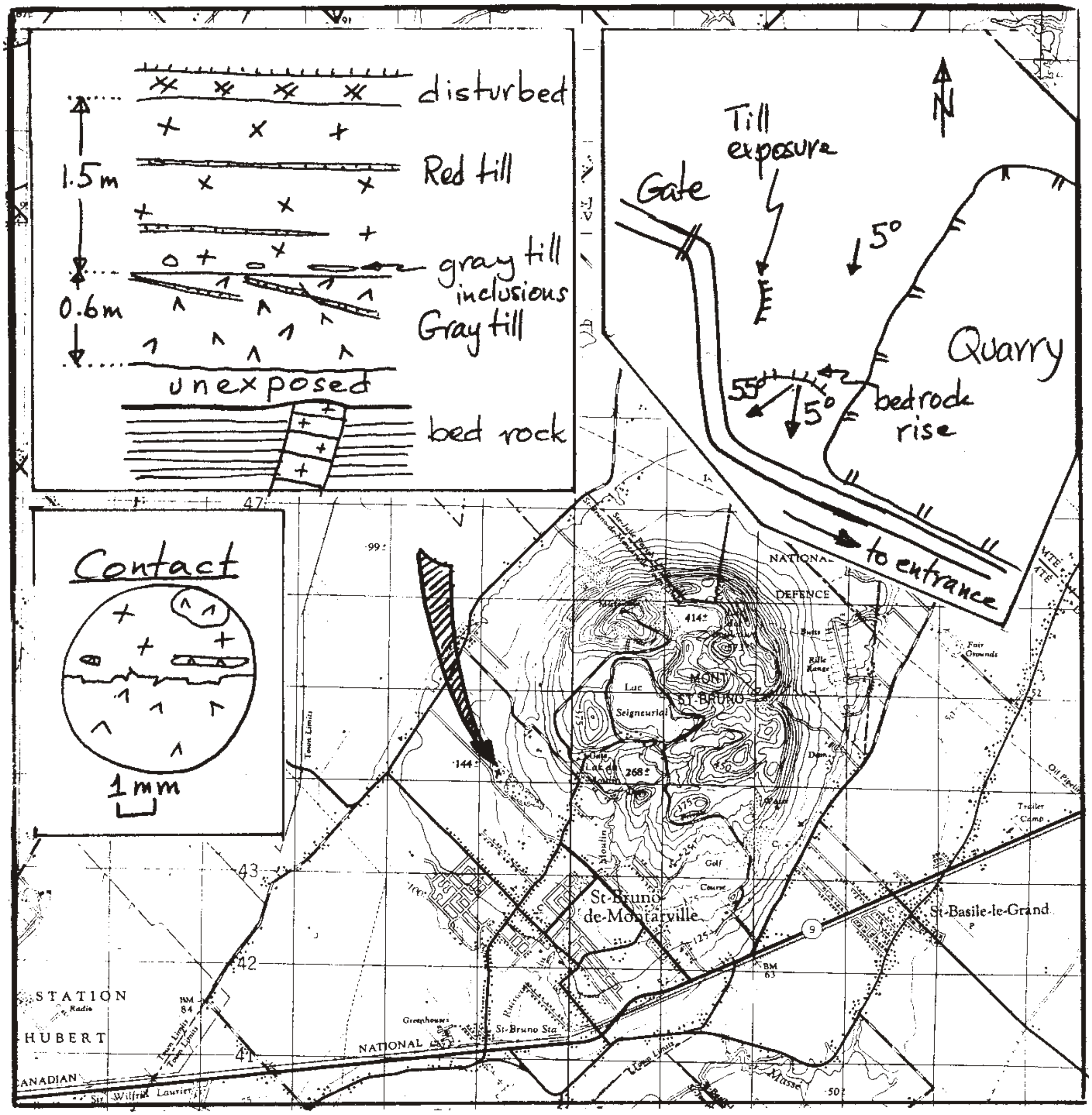


Figure 13 Location of STOP 2 at Mount St. Bruno. Stratigraphy and ice flow directions at the site. Details of the contact between the upper red till and the lower gray till.

Stop 3 - Mont St. Hilaire, southeast gravel pit. (J.A. Elson)

Mont St. Hilaire is the erosional remnant of a Cretaceous intrusion projecting through Ordivician shale. The west half is essexite (Fig.14) and the east half syenite and igneous breccia. A hornfels collar surrounds the intrusion which stands as high 410 m above sea level, about 370 m above the surrounding plain. The mountain is a circle of hills, largest in the W and N, enclosing a basin containing Lac Hertel (altitude 174 m). A valley bisects the mountain from N to S, roughly following the boundary between essexite and breccia. The NW outer slopes are precipitous cliffs with an apron of coarse talus.

The surficial geology was mapped by LaSalle and Elson (1962); the NE bog was studied by LaSalle (1966) and the sediments in Lac Hertel by Terasmae and LaSalle (1968). Brackish water diatoms in the basal sediments suggest that marine water was nearby but not within the basin.

A large body of sand and gravel extends 1.2 km SE from Mont St. Hilaire but has been mostly consumed by gravel pit operations; these have ended and most exposures have collapsed. There are (were) three or four principal levels of multiple terraces (Fig.14, hachures). The highest level has the form of a fan sloping uniformly SW from the apex, at 162 m (530 ft), to 116 m (380 ft) at the top of a steep distal scrap, now destroyed. Several beaches and low scarps cross the fan from W to E. The NW side of the fan is against the mountain but the SE side drops off in an abrupt scarp. The fan is gravel with numerous foreset beds of cobble and boulder gravel dipping SW. The clasts are rounded and some are as long as 2 m. Fragments of marine shells occur in at least one lens of coarse sand beneath bouldery foresets. The majority of the large clasts are from the immediate vicinity as a count of about 95 stones larger than 0.6 m shows:

Syenite	38.2 %	73.3 %	(occur adjacent to the fan)
Breccia	15.5		
Hornfels	19.6		
Essexite	15.5		
Precambrian gneiss		11.3	(distant)

The structure, grain size, and provenance of the gravel in the fan suggest deposition between the mountain and an ice margin to the SE probably when the inner basin was still filled with ice. This assemblage of rocks could have been gathered by a meltwater stream flowing from the north col SE to the east col which is almost at the apex of the fan. The shell fragments indicate that this must have occurred after the inception of the Champlain Sea

(12 800 B.P.?) when the northern part of the St. Lawrence Lowlands was still occupied by glacier ice. The ice must have retreated before 12,600 B.P. when the NE bog began to accumulate (LaSalle, 1966).

The highest water levels are recorded as deltaic terraces along streams inside the rim of hills, N and W of Lac Hertel, and must represent levels outside because the wide valley S of Lac Hertel gives no closure at these levels. Evidence for freshwater (glacial lake) or marine origin is lacking; steep slopes (average 14°) vitiated the preservation of any higher water planes.

The lower parts of the sand and gravel mass were formed by shore processes repeatedly reworking the material from the fan, and sand and pebble gravel dominate. Many shoreline scarps, terraces, and beach ridges are present (Fig.15 (a)). Some weak strandlines on the lower slopes S of the mountain (Fig.14) are recognizable on air photographs taken when there was no foliage, but their altitudes have not been measured.

An interpretation of relative sea level from 13,000 to 10,000 B.P. at Mont St. Hilaire is offered in Figure 15 (b). Several dates have been projected along sloping water planes to provide more control. The data indicate an early time of accelerating uplift (restrained uplift ?) followed by very rapid uplift from about 11,000 to 10,500 B.P. This supports the hypothesis that an ice margin stood at Mont St. Hilaire when the Champlain Sea first invaded the St. Lawrence Lowlands.

Acknowledgments: P. David first suggested that the fan was of glaciofluvial origin. The lower strandlines were surveyed by P. LaSalle and J.A. Elson in 1961, others by me in 1981-2. The lowest radiocarbon samples were collected by F. Mayr (G.S.C. Radiocarbon Dates XIX, 1979), and the others by P. LaSalle.

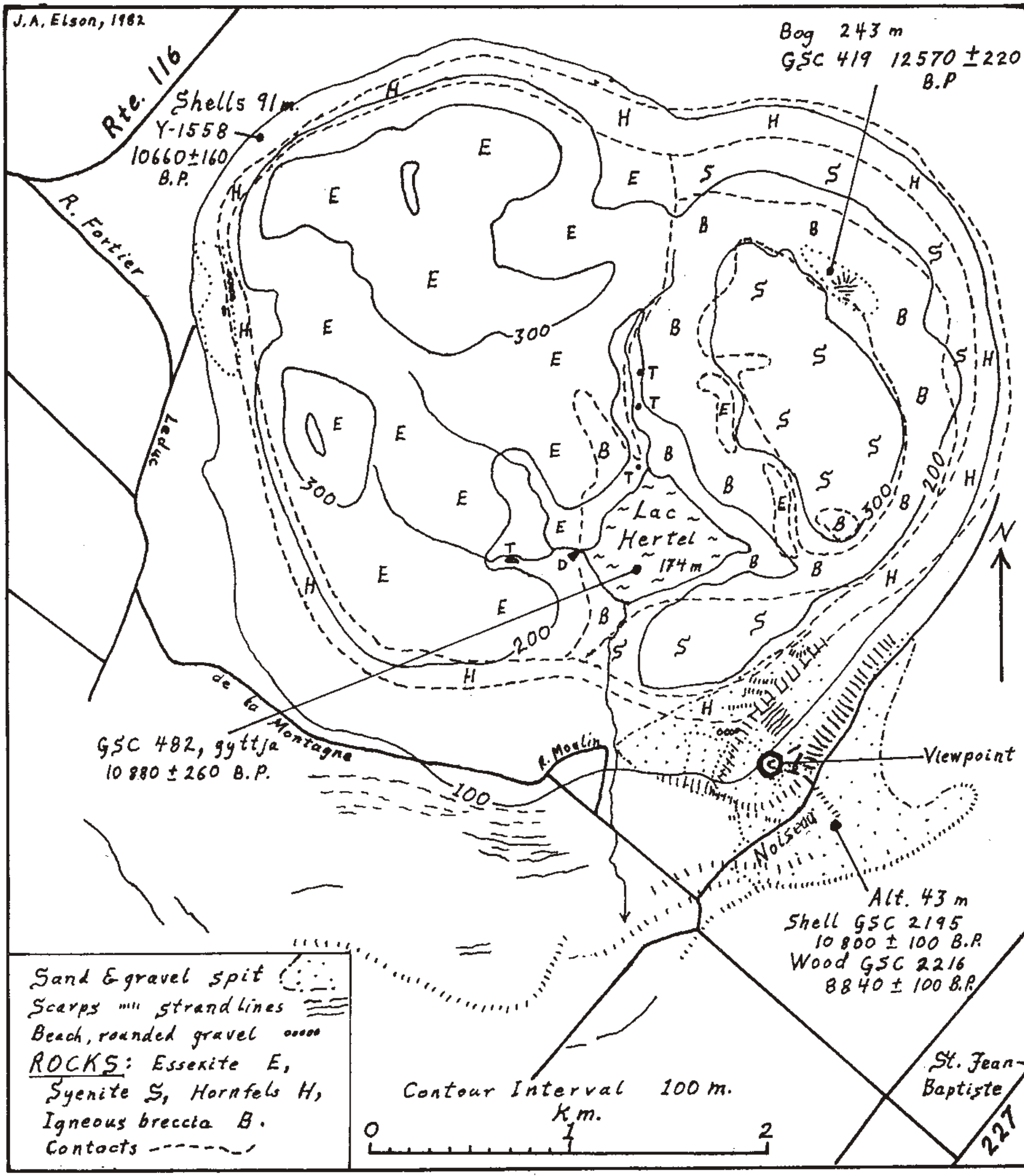


Figure 14. Sketch-map of Mont St. Hilaire showing relief (100 m interval), bedrock geology, strandlines of the Champlain Sea, form of the SE gravel body (reconstructed from air photographs), and locations of radiocarbon samples. The observation viewpoint is circled. Prepared from maps by D.F. Gold and P. LaSalle, and unpublished work of Elson.

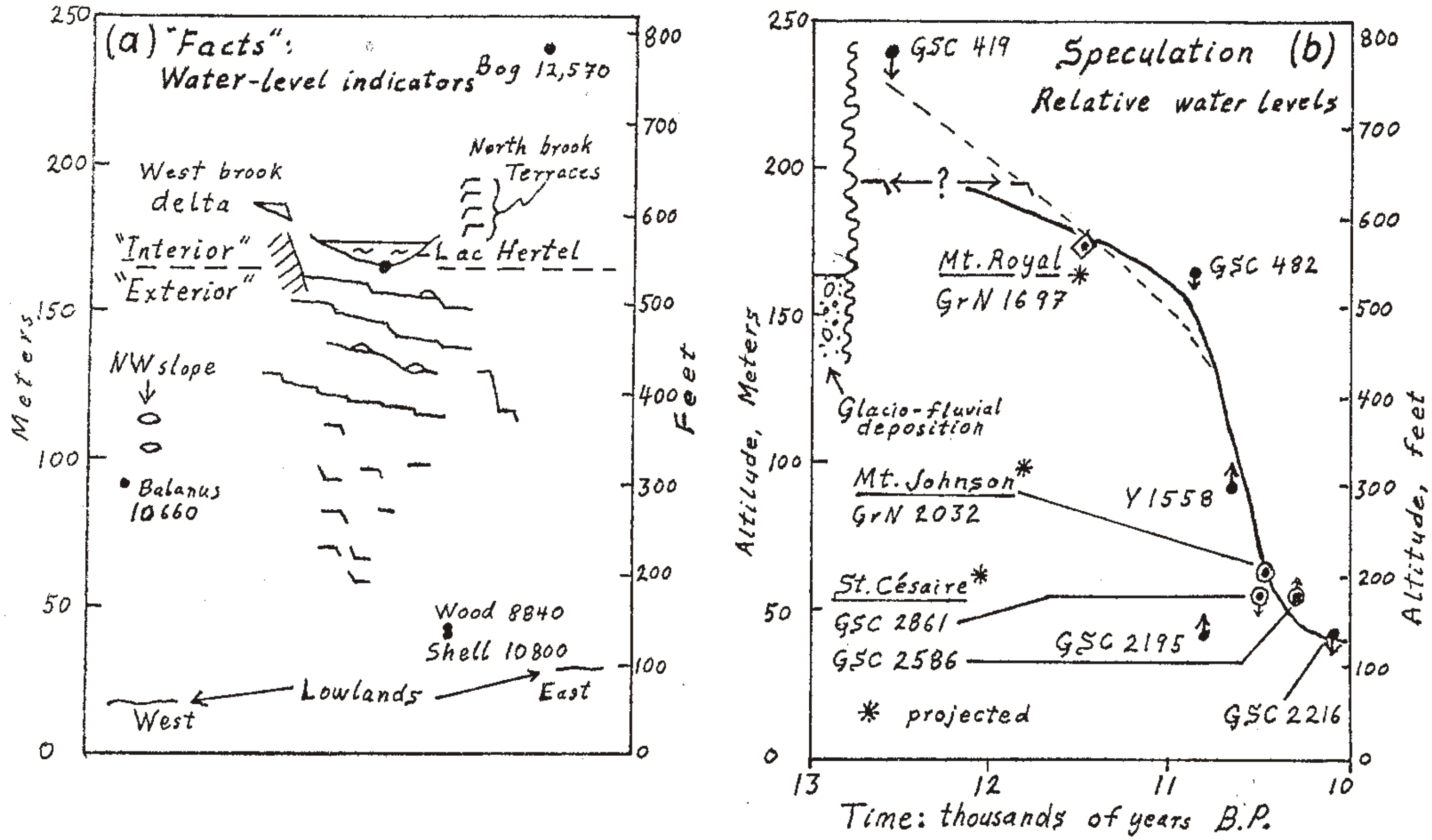


Figure 15. (a) Chart showing altitudes of terraces, scarps, and beaches (lenticular symbols) and the positions of radiocarbon dates. (b) An interpretation of the relative land-water levels at Mont St. Hilaire between 13,000 and 10,000 B.P., based on (a) with additional dates projected to Mont St. Hilaire from nearby localities along presumed water planes sloping S at 0.375 m/km.

STOP 4 Soils developed on stratified and varve-like materials
(De Kimpe, Cossette, Laverdière)

Saint-Hyacinthe and Richelieu counties occupy about 120,000 hectares in the Saint-Lawrence lowlands. They are located between the Yamaska and Richelieu rivers.

Richelieu county extends northwards to the Saint-Lawrence river. Topography of this marine plain is flat, with slopes ranging from 0 to 2%. Elevation decreases from about 35 meters AMSL in the Saint-Hyacinthe area to about 30 meters AMSL at Saint-Robert, 40 kilometers north of Saint-Hyacinthe. Intensive agriculture is the main land use and the area supplies Montreal, about 60 km to the west, with horticultural products.

Surficial materials

"The fine textures marine sediments were widely deposited over the deep water sections of the sea in layers up to 61 m thick (Antev's 1925). These deposits have been separated into two layers on the basis of modifications of the original clay deposits in the upper 5 meters. The two clays have been described in detail, first by Gadd (1961) and later by Crawford and Eden (1965). The upper layer appears to have been affected by redistribution and modification of the original marine clays by estuarine or fluvial conditions".* This type of material has also been found in the Ottawa area; clays formed in these deposits have been mapped as either North Gower or Dalhousie Association. In Saint-Hyacinthe and Richelieu counties, three soil series have been identified on the basis of texture and organic matter content. The series are Saint-Aimé, Saint-Hyacinthe and Kierkoski. The Saint-Aimé soils are stratified with coarse loamy and clay layers which indicate fluvial reworking. The Saint-Hyacinthe adn Kierkoski series have varve-like parent materials with silt layers interbedded with silty clay. The distribution of these soils is schematized on the map. However, no separation is given for the Saint-Hyacinthe and Kierkoski soils, which are differentiated only by the organic matter content in the surface horizon. This aspect will be discussed later. Morphologically, the varve-like material shows alternate layers of silt (a few millimeters thick) and clay (a few centimeters thick). This succession is more evident in the deposits of the southern part of the area as the varve-like aspect gradually disappears northwards. But the average particle-size distribution in the B and C horizons remains closely similar throughout the area. The absence of the varve-like morphology in the northern part of the area can be possibly explained by a greater turbulence of the waters.

* Marshall, I.B., Dumanski, J. et al (1979). Soils, capability and land use in the Ottawa Urban Fringe. Soil survey report #47, Ontario Soil Survey, Ottawa.

Mineralogical properties

X-ray diffraction analysis was performed on the total clay fraction, separated after organic matter oxidation and free sesquioxides removal.

Primary minerals, feldspar, hornblende, quartz and a well-crystallized chlorite are abundant in all samples, while illite is present in lower amounts. Chlorite and illite are probably present as primary and secondary clay minerals. The abundance of feldspar and hornblende indicates a low degree of weathering, which is also supported by the low values found for Fe and Al in the DCB extracts. On the basis of X-ray diffraction peak intensities, the hornblende/quartz and feldspar/quartz ratios are slightly increasing with depth. The hornblende/feldspar ratio does not show any useful trend to evaluate the weathering. Vermiculite is present in all the profiles as the first stage in the evolution towards swelling minerals.

Further transformation into smectite is limited to profiles 2 and 3 only. In profile 2, low amounts can be detected in the Bg and Cg horizons. In profile 3, larger amounts are detected in the Bg than in the Ckg horizon.

Soil evolution

A number of factors may explain the fact that the Saint-Hyacinthe, Kierkoski and Saint-Aimé soils present only the characteristics of a slow evolution. These soils were deposited by the Champlain sea, some 10,000 years ago and for most of the time, were maintained under high water table conditions. In Quebec, mean annual soil temperature is low, and the various weathering factors were thus not very efficient. In recent history, drainage was implemented to initiate cultivation and leaching processes may now become active.

In comparable soils found at higher elevations, and thus subjected to better drainage conditions, $CaCO_3$ may be found at greater depth, the content of feldspar is much reduced, while primary chlorite desappears to give rise of swelling minerals, vermiculite and chlorite.

When subjected to internal drainage, some of these soils, especially the Saint-Hyacinthe soils can develop and maintain a good soil structure. Under these conditions, the saturated hydraulic conductivity may be high. This is not uncommon in many of the clay-rich soils of Quebec lowlands.

Differences are often found between the properties of the Ap and the underlying horizons. They could result from cultivation processes or addition of different texture material by late estuarine waters. This generates problems for soil mapping.

TYPICAL PROFILE DESCRIPTION

Saint-Hyacinthe Series

Location: Saint-Barnabé, Saint-Hyacinthe county: Lat. 45 43'37'' N, Long. 72 56'32''W

Classification: Orthic Gleysol, Fine clayey, mixed, neutral, mild subaquic

Drainage: Poor.

Horizon	Depth (cm)	Description
Ap	0-35	Very dark grayish brown (2.5Y 3/2 m) silty clay; medium to coarse granular structure; friable, slightly hard and plastic; abrupt, smooth boundary.
Bg	35-50	Brown (10YR 5/3 m) silty clay loam (Stratified layers of silty clay and silt 1 to 7 cm thick); moderate fine and medium subangular blocky structure; strong brown (7.5YR 4/6) frequent mottles; thin clay films, exped; clear wavy boundary.
Cg	50-100	Gray (2.5YR 5/1 m) silty clay loam: same description as above except for less mottles and clay films are absent.

Saint-Aimé Series

Location: Saint-Barnabé, Saint-Hyacinthe county: Lat. 45 47'08'' N, Long. 72 55'40'' W

Classification: Orthic Gleysol, fine loamy, mixed, weakly calcareous, mild, subhumid.

Drainage: Poor.

Horizon	Depth (cm)	Description
Ap	0-25	Very dark gray (2.5Y 3/1 m) loam; weak coarse subangular blocky structure; friable; abrupt, smooth boundary.
Bg	25-53	Dark grayish brown (2.5Y 4/2 m), silt loam and sandy loam in alternate layers 10 to 15 cm thick; many medium and coarse prominent mottles (7YR 4/8); weak medium subangular blocky structure; very friable; clear, undulating boundary.
BCkg	53-64	Same as above; no mottles.
Ckg	65-100	Gray (2.5Y 5/1 m) silt loam; weak fine subangular blocky structure; very friable; moderate effervescence.

Physical properties

The profile contain low amounts of very coarse and coarse sand. In profiles 2, 3 and 4, texture of the Ap horizon is coarser than that of the underlying horizons, but there is not evidence of clay illuviation: no clay film is observed on the peds of the Bg horizons and the fine clay / total clay ratio does not show an increase that could support the fine material translocation. The maximum of the FC/TC ratio is found in the Ap or the BCg horizons for these profiles. The situation could be different in profile 2, because of the lithologic discontinuity, but in that profile, the FC/TC ratio is higher in the II Cg_2 than in the II Cg_1 horizon.

Profile 1 is somewhat different. Thin clay films can be found on the surface of the peds in the Bg horizon and at that level, the FC/TC ratio is also greater with respect to those in the Ap and Cg horizons.

Plastic limit varies in a narrow range, from 16 to 25% H_2O, while the liquid limit varies from 13 to 43% H_2O. Plasticity index is generally low and exceeds 10 in four horizons only.

Chemical properties

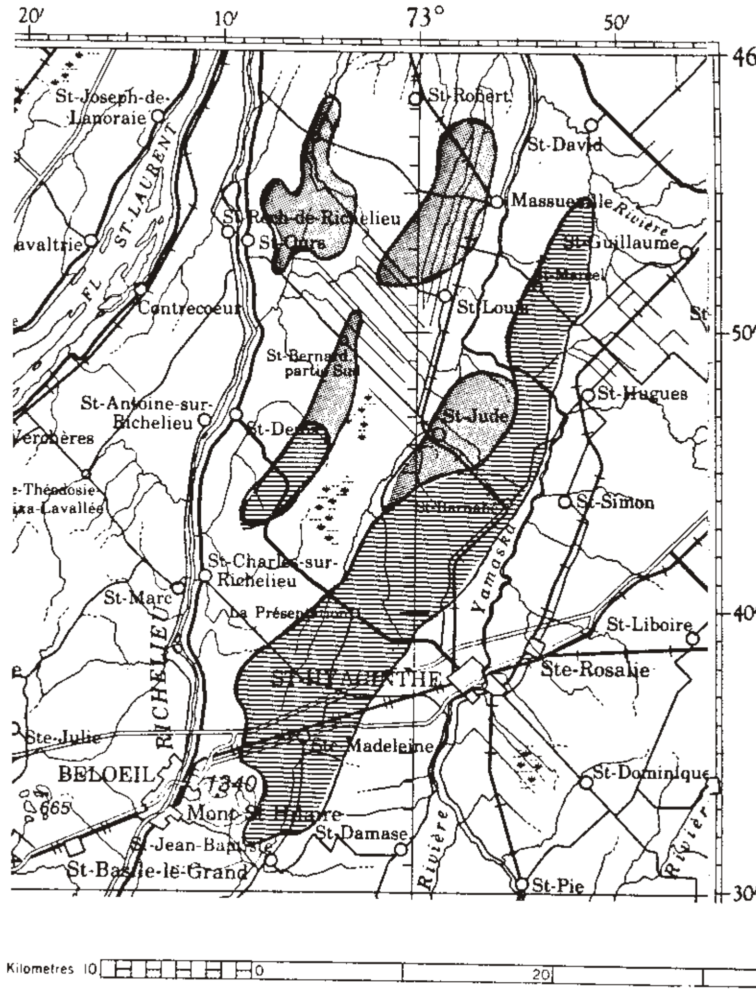
Soil reaction is neutral to mildly alkaline in the four profiles and pH generally increases with depth as carbonates are found in the BCkg and Ckg horizons. The opposite trend is found in profile 1, most likely because of liming. It can be assumed that calcareous material would be found at depth greater than one meter.

Organic matter content is moderate in the Ap horizon and decreases abruptly in the Bg horizon where the content is less than 1%. The difference in the organic matter content in the Ap horizon of profiles 1 and 2 was the only justification to separate the Saint-Hyacinthe and Kierkoski soil series. In the Canadian system of soil classification, the limit between the Humic and Orthic Gleysol is presently set at 2% organic carbon, or 3.4% organic matter.

Cation exchange capacity of the soil (NaCl extraction) is less than 20 meq/ 100 g of soil, in spite of a clay-size particle content that ranges from 51 to 16%. An excess of Ca^{2+} ions is commonly found in the soil extract, because of the carbonates. Exchange capacity has thus been also measured at pH 8.2 and in this case, the average cation exchange capacity was 2.8 meq / 100 g greater than the value measured at pH 7. The soil exchange capacity is adequately explained by the contribution of the clay fraction, except in the Ap horizons, where the organic matter has also a contribution.

The CEC of the clay, after removal of organic matter and free sesquioxides, varies from 33.0 to 56 meq / 100 g of clay. These values indicate a low degree of transformation of the primary minerals into high charge swelling minerals.

Except for the Bg and Cg horizons of profile 1, less than 1% extractable Fe and 0.1% extractable Al are found in the DCB (dithionite-citrate-bicarbonate) solution. The oxalate solution contains less than 1% extractable (Fe + Al). The Fe_0/Fe_D ratio varies from 0.17 to 1.0 but it does not present any regular trend with depth.



St-Hyacinthe Soils (clay + silt)

St-Aimé Soils (clay loam + sand)

Figure 16. Distribution of the soils described at STOP 4.

PHYSICAL ANALYSES OF SOIL PROFILES

	Particle-size distribution												Atterberg limits	
	2-0.5 mm	0.5-0.25 mm	0.25-0.1 mm	100-50 µm	Σ sand 2 mm-50 µm	50-20 µm	20-5 µm	5-2 µm	Σ silt	2-0.2 µm	< 0.2 µm	Σ clay < 2 µm	Plastic Limits	Liquid Limits
Profile 1	Saint-Hyacinthe													
Ap	0.8	2.9	3.3	2.6	9.6	4.7	21.3	13.6	39.6	30.0	20.8	50.8	25	42
Bg	0.8	3.0	3.9	3.1	10.8	18.5	28.6	9.9	57.0	13.2	19.0	32.2	22	34
Cg	0.4	1.5	2.1	1.7	5.7	14.5	27.8	13.4	55.7	18.5	20.1	38.6	23	38
Profile 2	Kierkoski													
Ap	4.8	13.2	24.8	5.3	48.1	8.8	10.9	5.6	25.3	9.4	17.2	26.6	22	29
II Cg_1	0.9	1.4	2.0	2.3	6.6	22.1	22.3	10.1	54.5	20.6	18.3	38.9	22	27
II Cg_2	0.7	1.1	1.2	2.9	5.9	27.8	23.3	8.4	59.5	16.2	18.4	34.6	18	24
Profile 3	Saint-Aimé													
Ap	3.0	11.7	22.0	15.0	51.7	15.7	10.1	4.0	29.8	5.7	12.8	18.5	22	24
Bg_1	3.1	9.8	15.1	18.9	46.9	12.2	11.9	4.7	28.8	8.6	15.7	24.3	16	19
Bg_2	1.6	4.7	6.4	16.1	28.8	21.7	16.0	5.6	43.3	11.0	16.9	27.9	17	26
BCg	3.3	8.0	9.9	20.7	41.9	26.9	13.0	2.4	42.3	3.5	12.3	15.8	16	13
BCkg	3.6	7.4	6.7	8.4	26.1	36.5	10.3	3.7	50.5	9.1	14.3	23.4	17	21
Profile 4	Saint-Aimé													
Ap	4.3	18.6	36.3	4.7	63.9	8.1	8.5	2.9	19.5	4.4	12.2	16.6	17	19
Bg	5.4	12.7	16.1	8.5	42.7	21.4	12.0	3.5	36.9	6.3	14.1	20.4	17	21
Cg	1.4	4.8	6.3	4.8	17.3	33.5	22.0	5.1	60.6	8.8	13.3	22.1	20	26
Ckg	0.6	2.4	2.4	0.6	6.0	6.7	25.9	16.0	48.6	29.9	15.5	45.4	22	43

CHEMICAL ANALYSES OF SOIL PROFILES

	pH		$CaCO_3$	Org. Mat.	CEC (soil)		CEC		Fe_D	Fe_O	Al_D	Al_O	Fe_O/Fe_D
	H_2O	$CaCl_2$	%	%	NaCl pH 7	NaOAc pH 8.2	clay	silt	%	%	%	%	
					meq/ 100 g		meq/100 g						
Profile 1	Saint-Hyacinthe												
Ap	7.55	7.37	2.5	2.6	18.3	22.2	35.5	1.5	0.7	0.5	0.1	0.1	0.71
Bg	7.43	6.98	0.1	0.6	17.9	22.9	56.0	3.0	1.4	0.6	0.1	0.1	0.43
Cg	7.36	6.87	0.0	0.5	19.0	22.1	53.5	4.0	1.5	0.7	0.2	0.1	0.47
Profile 2	Kierkoski												
Ap	6.53	6.20	n.d.	4.3	11.2	19.7	38.0	2.5	0.2	0.2	0.1	0.1	1.00
II Ckg_1	7.71	7.12	2.3	0.7	12.6	15.8	35.5	2.5	0.5	0.4	0.1	0.2	0.80
II Ckg_2	7.91	7.38	5.5	0.5	10.3	12.4	33.0	2.0	0.6	0.3	0.1	0.1	0.50
Profile 3	Saint-Aimé												
Ap	6.70	6.26	n.d.	3.3	9.2	14.3	41.5	2.0	0.3	0.1	0.1	0.1	0.33
Bg_1	7.36	6.72	n.d.	0.4	9.8	11.3	46.0	2.5	0.7	0.2	0.1	0.1	0.29
Bg_2	7.75	7.05	0.9	0.4	11.4	11.9	43.0	3.5	0.9	0.2	0.1	0.1	0.22
BCkg	7.98	7.41	3.8	0.2	6.3	5.5	39.5	2.0	0.6	0.1	0.1	tr	0.17
Ckg	8.12	7.50	4.8	0.3	7.5	8.0	35.5	2.0	0.3	0.2	0.1	0.1	0.67
Profile 4	Saint-Aimé												
Ap	7.06	6.96	0.5	1.9	8.4	11.7	44.0	3.0	0.4	0.1	0.1	0.1	0.25
Bg	7.16	6.79	tr	0.4	9.4	11.0	52.0	5.5	0.9	0.2	0.1	0.1	0.22
Cg	7.66	7.13	0.9	0.2	9.7	12.3	41.0	1.0	0.7	0.2	0.1	0.1	0.29
Ckg	7.84	7.44	5.1	0.4	16.2	19.8	37.5	3.5	0.7	0.3	0.1	0.2	0.43

n.d. not determined

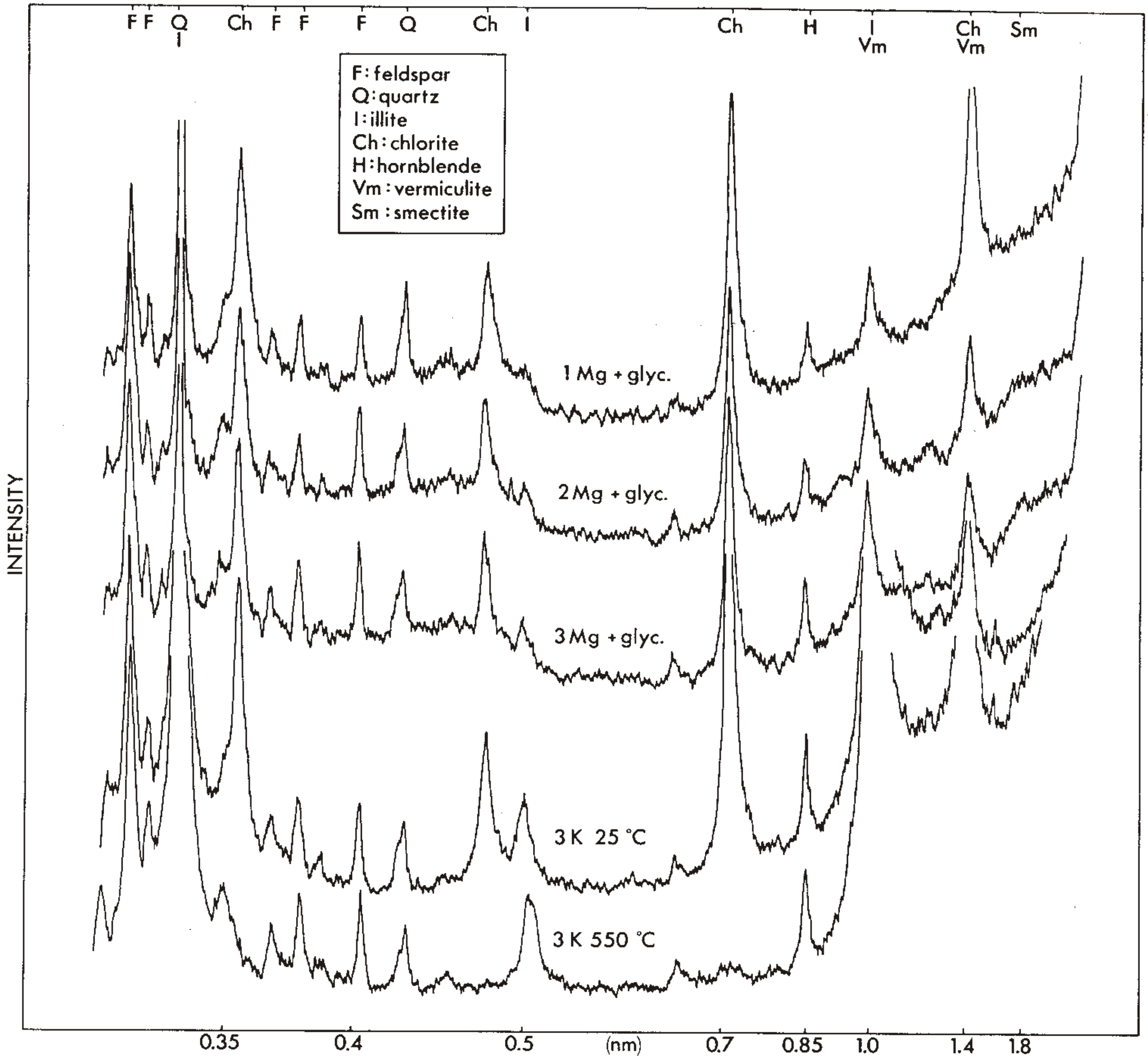


Figure 17.Profile 2: Kierkoski series

1: Ap horizon, Mg-saturated and glycerol-solvated
2: II Cg_1 horizon, Mg-saturated and glycerol-solvated
3: II Cg_2 horizon, Mg-saturated and glycerol-solvated
K-saturated
K-saturated and heated at 550°C

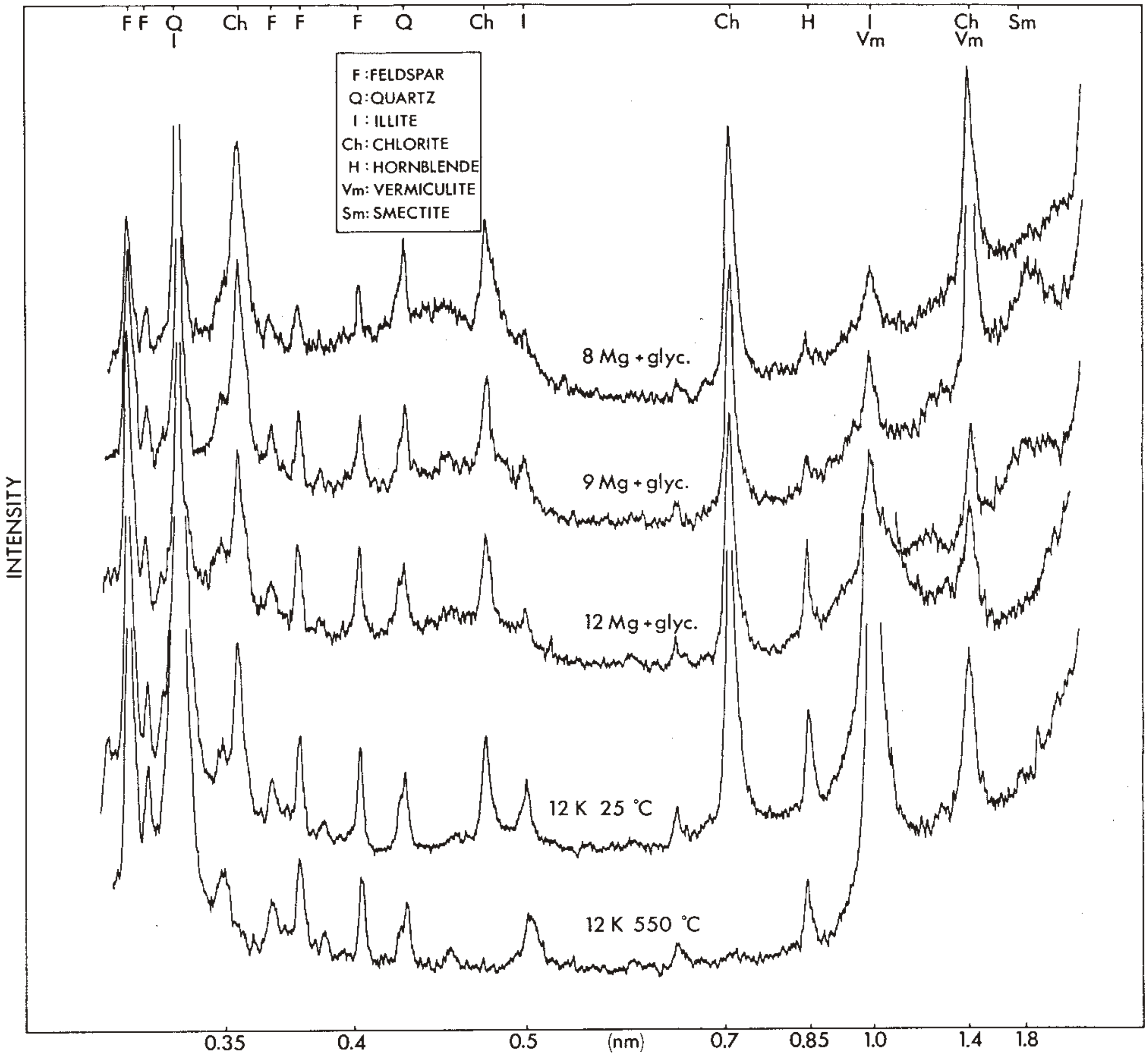


Figure 18. Profile 3: Saint-Aimé series

1: Ap horizon, Mg-saturated and glycerol-solvated
2: Bg_1 horizon, Mg-saturated and glycerol-solvated
3: Ckg horizon, Mg-saturated and glycerol-solvated
K-saturated
K-saturated and heated at 550°C

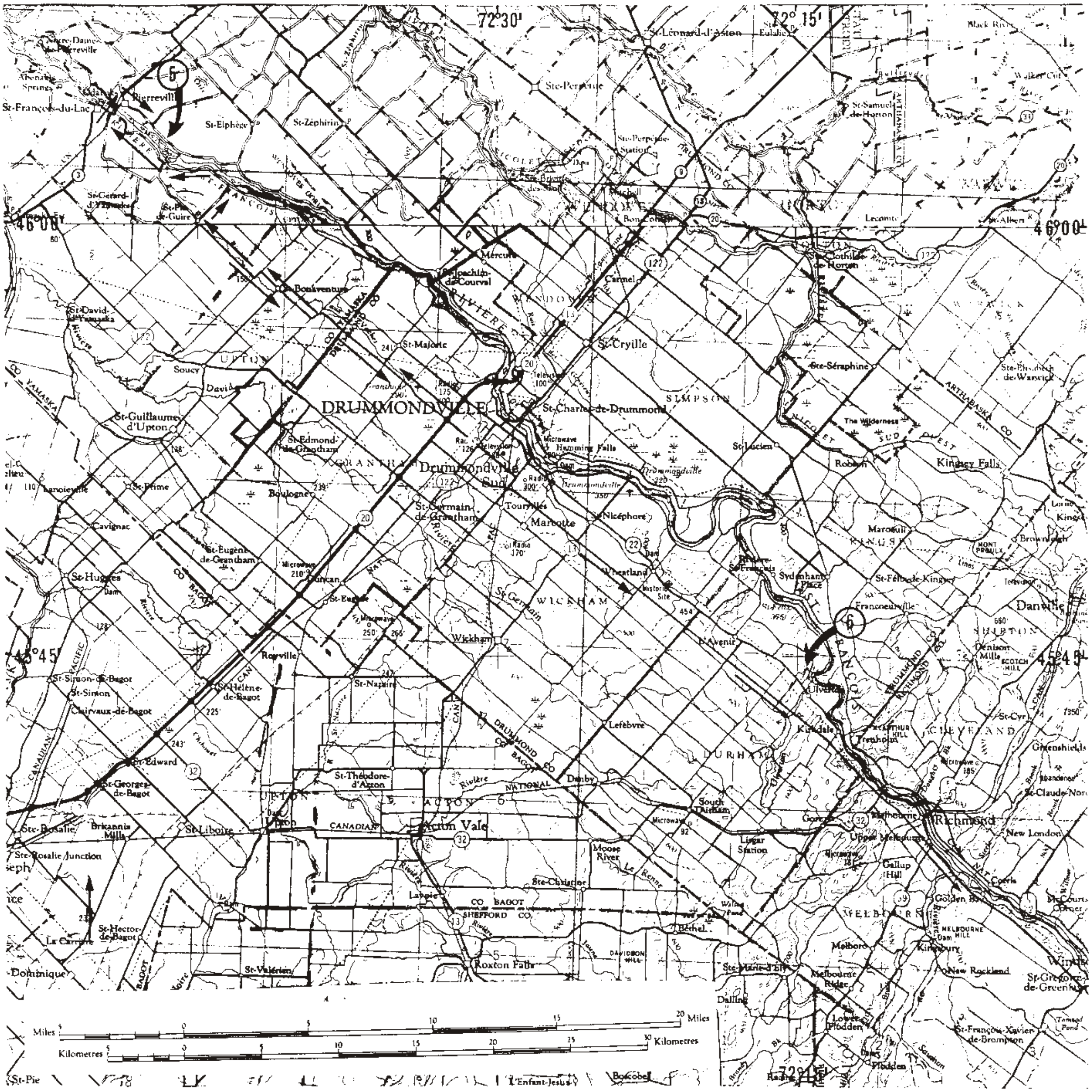
Day 2, May 30, 1982 , (See Map 2)

This part of the field trip will be run by private cars. Leaving from Drummondville, the first stop of the day (STOP 5) will be at Pierreville, a 35 minutes drive.We will follow route 143 north through St-Majorique, St-Bonaventure and Ste-Pie-de-Guire. At the junction with route 132, you turn right on the bridge across the St-François River, and then right again to follow the road along the north side of the river.

The section of Pierreville is a classical locality of the Quaternary stratigraphy of the St-Lawrence Lowlands where the sediments of the Saint-Pierre Formation are well exposed. We will spend about two hours at the section and this will be the opportunity to discuss the significance of new radiocarbon dates, recently published, which were obtained from concretions in sediments exposed at Pierreville.

Leaving Pierreville, we will drive back eastward to the Appalachian Front and to STOP 6.This is slightly less than an hour drive. Once you arrive at the junction of route 143 and the Transcanadian Autoroute (20), take the autoroute 20 west to exit 173, and from there follow autoroute 51 South in the direction of Sherbrooke. We will leave that autoroute at the Ulverton exit.

After leaving the main highway, and after many curves and turns that hopefully you will not miss, behind the lead car, we will stop first at a vantage point from where The Highland Front Moraine Complex topography can be observed. A short distance from that point, many gravel pits in the Highland Front Moraine can be visited and one of them will be STOP 6. It will likely be "another one of those" gravel pits. In fact, we hope that this stop will, above all, offer the opprtunity to discuss the yet unresolved problems associated with the reconstruction of the sequence of events that preceded and followed the emplacement of the Highland Front Moraine Complex.



Map 2, Day 2, May 30, 1982

Stop 5 - The Pierreville section (M.A. Bouchard, P.P. David, P. LaSalle).

This section was visited on the occasion of the Friend's meeting held in Drummondville in 1956 (Gadd). The composite section presented herein (Fig. 19) has been compiled from Gadd (1971) and Gadd et al. (1972). The description of this particular section is also included in Gadd 1971. The visit to the Pierreville section will be an excellent opportunity to examine one of the classical localities for the Wisconsinan stratigraphy of eastern North America where the St-Pierre sediments are exposed. In addition, this visit will also provide the opportunity to discuss some of the questions that have recently been raised about the chronology of the events recorded in the Pierreville section, and by way of implication, about the whole Wisconsinan glaciation in southern Quebec (Lamothe et al. 1982). N.R. Gadd and M. Lamothe will be available at the site for discussions on the stratigraphy of the region.

At the present state, the generally accepted interpretation for the sequence of events is that shown in Figure 19. The chronological control of the interpretation is from a series of radiocarbon dates on wood from the compressed peat unit of the St-Pierre sediments. As radiocarbon dating techniques improved since the introduction of the dating method,increasingly greater ages have been obtained on the St-Pierre wood, at the Pierreville section and elsewhere. From this particular site, the following dates have been reported:

Y-256	> 29,630 BP (Preston et al., 1955)
GRO-1711	67,000 ± 2000 BP (Dreimanis, 1960)
QL-198	74,700 + 2700/-2000 BP (Stuiver et al., 1978)

In addition, Terasmae (1958) concluded, based on studies of the pollen assemblage of the St-Pierre sediments, that the interval, as recorded by the organic sediments, lasted about 6,000 to 7,000 years, and indicated a climate slightly cooler than the present. Consequently, the St-Pierre sediments have been considered to represent an early Wisconsinan interstadial, and the subsequent Gentilly stadial, to have lasted for the better part of the last 60,000 years or so.

Lamothe et al. (1982) have recently proposed a preliminary interpretation of the Pierreville section which differs from that exposed above, based on new radiocarbon dates obtained on calcium carbonate concretions, at the Pierreville section and elsewhere, and from a radiocarbon date on wood from presumably St-Pierre correlative sediments near Quebec City. From this particular site, the following dates have been reported (Lamothe et al. 1982):

UQ-312	34,000 + 1800/-1470 BP striated concretion
UQ-130	28,030 ± 760 BP concretion, unknown stratigraphic position.

The striated concretion is from the base of the Gentilly till, and since it is included as a clast in the till, it is interpreted as providing a maximum age for the base of the Gentilly stade (Lamothe, pers. comm.). From radiocarbon dates, all in the finite range of 28,000 to 38,000 years BP, obtained on concretions at other sections in lacustrine sediments overlying and underlying the St-Pierre organic beds, it is concluded by these authors that the concretion

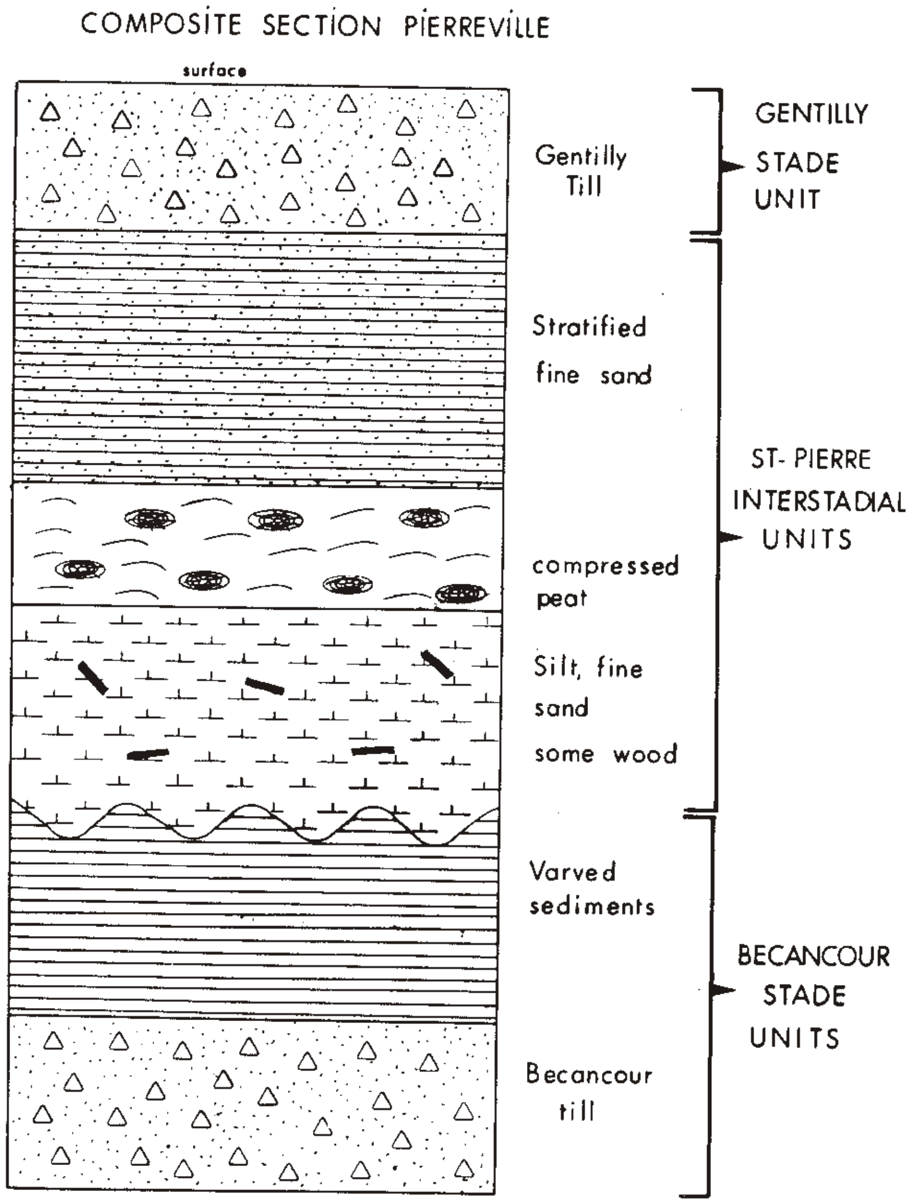


Figure 19

Location: 31½ St-François River, northeast bank, 1.6 miles upstream from bridge on highway 3; the Pierreville section. 46°03'N, 72°47'20"W, elev. 100 feet approx.

Thickness (feet)	Lithology	Cumulative thickness
GENTILLY STADE UNITS		
7.5	Brownish grey calcareous sandy till	7.5
ST. PIERRE INTERVAL UNITS		
17.5	Stratified, fine-grained buff to brown sand, becoming silty in lower 5 feet	25
1	Compressed peat with some wood	26
9	Stratified fine-grained sand and silty sand grading downward into subjacent silt	35
BECÂNCOUR STADE UNITS		
16.5	Grey to brownish grey varved silt (in lower part of section beds are repeated by slumping; some contacts apparently are fault contacts)	51.5
25.5	Section covered by slump debris	77
GENTILLY STADE UNITS		
3	Brownish grey calcareous sandy till	80
ST. PIERRE INTERVAL UNITS		
2	Stratified fine-grained buff sand	82
1	Compressed peat with some wood. (This peat bed was reported by Joseph Keele, 1916)	83
BECANCOUR STADE UNITS		
7	Grey and brownish grey varved silt	90

After Gadd, 1971.

dates give the time of post depositional calcium carbonate precipitation event (s?) in the Lowlands, providing minimum age estimates for the sediments containing them.

Consequently, the St-Pierre sediments together with the other units between the Bécancour and the Gentilly tills, in the Lowlands, including unknown intervals of time represented by hiatus in that particular sequence, are, in a preliminary way, considered to represent a long mid- and possibly early-Wisconsinan interstadial; the subsequent Gentilly Stade is then thought to be a late Wisconsinan event, younger than 34,000 years BP.

Be that as it may, the whole subject of the significance of the dates, and the correlation of the sediments is open for debate and discussion, which is precisely the purpose of the present meeting.

STOP 6. The Highland Front Moraine Complex (W.W. Shilts)

Development of Concepts

When the surficial geology of the St. François River valley was mapped by McDonald seventeen years ago, the work provided the first potential ties between similar contemporary studies in the New England Appalachians and the well-documented glacial events inferred from studies of the St. Lawrence-Great Lakes Lowlands. The model of retreat of the last ice sheet to cover the region was thought to be fairly straight forward – the edge of an active Laurentide Ice Sheet retreated more-or-less regularly from south to north, leaving behind local pockets of stagnant ice in high-relief areas. In the Appalachians, bands marked by major accumulations of ice-contact stratified drift were thought to mark either stillstands or minor readvances of the ice front, caused either by temporary climatic deterioration or by adjustment of the ice sheet's profile as its front retreated from areas of high relief to areas of low relief.

In 1964 Gadd published a description of a belt of ice-front deposits lying along the northwest flank of the Appalachians, which he named the Highland Front Moraine complex, and which he suggested formed as the ice sheet readjusted its profile on retreating from the Appalachians into the lower, more flat lying terrain of the St. Lawrence Lowlands. One of the major accumulations of drift in this belt of deposits lies across the St. François River (Fig.20).

A few years after Gadd published his reconnaissance maps of the Highland Front system, McDonald mapped the central portion of it in detail, and added new information on several older moraine complexes lying within the Appalachians. At this time he mapped the ice front deposits of the St. François valley and attempted to work out the relationships of these deposits to proglacial lakes ponded in the St. François and tributary valleys. McDonald also studied the relationship of the Highland Front System to deposits of the Champlain Sea, which flooded the area below about 540' a.s.l. some time after the moraine was formed. When McDonald finished his work in the St. François valley, he recognized two major moraine systems, the Cherry River Moraine, in the vicinity of Sherbrooke and the Highland Front Moraine, in the vicinity of Ulverton. Both of these moraines were built along a southeast-facing ice front into a major proglacial lake, Glacial Lake Orford, which filled the St. François and adjacent northward-sloping valleys. Between the Highland Front and Cherry River systems, major eskers with southward current structures were formed in and adjacent to the St. François valley. Thus, the last events to affect the valley formed water-laid ice-contact deposits at the edge of an ice mass standing to the north and presumably connected to the Laurentide Ice Sheet across the St. Lawrence Valley.

In the early 1970's, Robert Lamarche discovered that much of the bedrock between the lower St. François valley and the Chaudière valley, the next major northward sloping valley to the northeast, was striated by debris in ice that was clearly flowing northward toward the St. Lawrence at some time after the major regional (Lennoxville) southeastward movement of the Laurentide Ice Sheet. Further work by Lamarche, Lortie, and others showed that the latest flow over much of this terrain was westward toward the St. François River. These observations immediately posed a dilemma

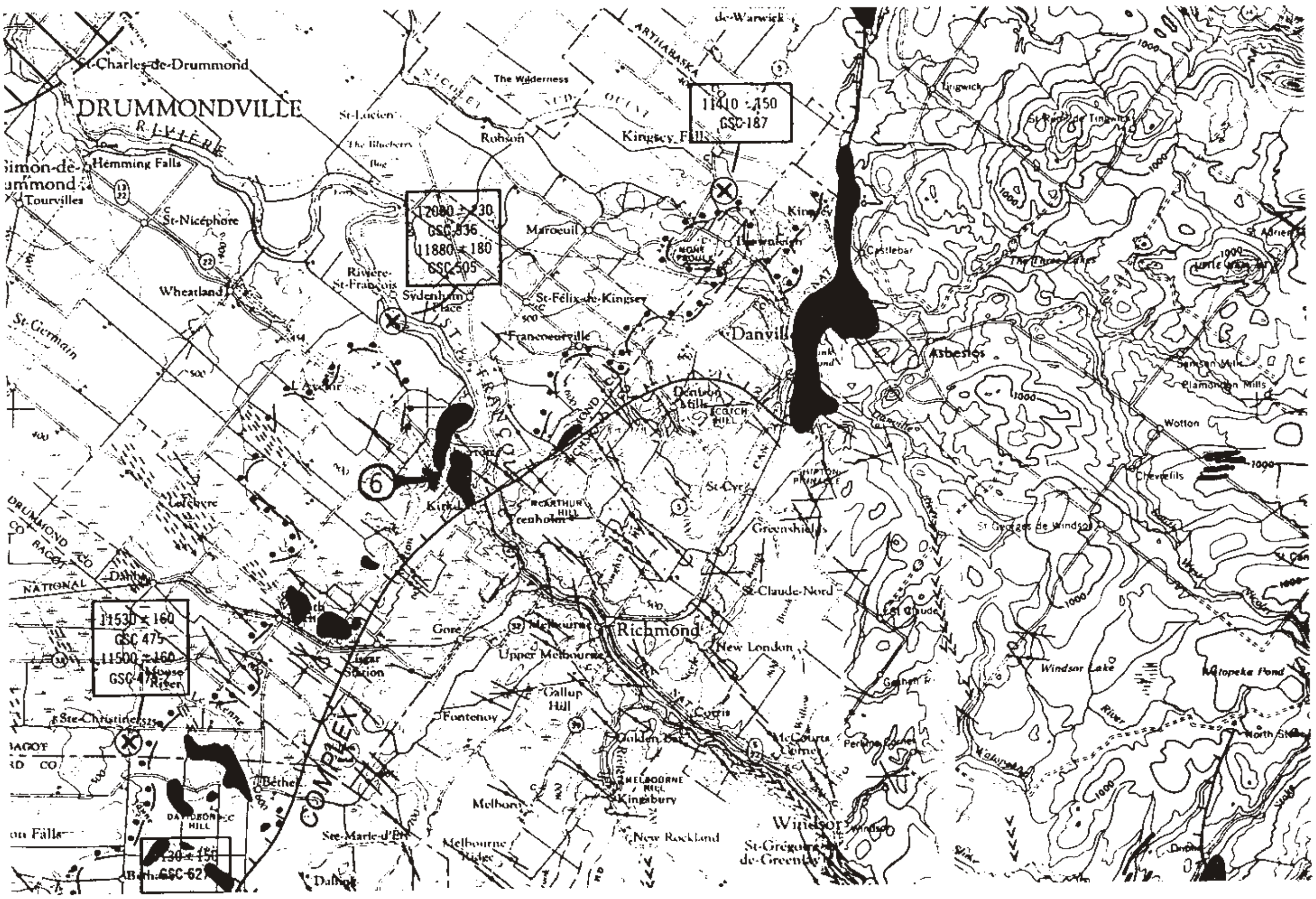


Figure 20. Map showing part of the Highland Front Moraine Complex in the vicinity of Stop 6. The dotted line represents the marine limit. The hachured line represents the Highland Front Moraine Complex (hachures are on the glacier side). From Gadd et al. 1972.

for those who had worked out ice retreat patterns based on the assumption that the edge of the Laurentide Ice Sheet had retreated regularly down the St. François valley toward the north: i.e. the last area known to have been affected by southward or southwestward flow (or northward retreat) cut deeply into the region where the last glacial event was clearly flow toward the north, and furthermore, the last major depositional event to affect valleys in much of the region characterized by reversal of flow was ponding of proglacial lakes by ice standing at or near the Highland Front position. Also, and most importantly, the area where evidence of reversed or northward ice flow was mapped extends into the St. Lawrence Lowlands, north of the Highland Front system which was clearly built by ice with a southerly flow component. Thus, southward flowing ice replaced northward flowing ice in a broad belt paralleling the Appalachian Front.

If the Laurentide glacier had readvanced to the Highland Front position after ice associated with the reversed flow had melted, the paradox might have been resolved, but other than a few stratigraphic sections indicating a few kilometres of readvance in the Rivière Noire valley west of the St. François, no such readvance has been documented. At present, although LaSalle et al. (1977) have offered some suggestions as to how the St. Lawrence Valley could have opened to accommodate the features of deglaciation that have been mapped, the problem is still largely unresolved.

The following scenario of late glacial events was conceived by Shilts in 1976 before LaSalle et al. (1977) proposed an alternate model. The main difference between the two models, as pointed out in the latter publication, is that the former (Shilts, 1976) requires a readvance to the Highland Front and possibly Cherry River positions, through sea water admitted to the St. Lawrence Valley at the narrows of Quebec City. The latter (LaSalle et al., 1977) requires no readvance, but prevents the sea from entering the upper St. Lawrence Valley by maintaining ice against the highlands that form the south side of the narrows south of Quebec City.

A Possible Scenario

Quebec Ice Divide

The southward and southeastward-flowing Lennoxville glacier retreated through New England and Quebec mostly by regular backwasting of active ice fronts in the valleys with separation of large blocks of ice in closed bedrock basins or in restricted valleys. At some point during this general retreat, sea level had risen enough to contact the glacier in the lower St. Lawrence Estuary along a significant portion of its front, causing rapid drawdown into a calving bay. Proglacial lakes in the Hudson-Champlain, St. François, and Chaudière River basins were probably producing a similar drawdown effect on the southern portion of the glacier at or about the same time. The result of the drawdown in the St. Lawrence estuary was to direct ice lying far up the valley toward the point of drawdown, creating a saddle in the ice sheet along a zone approximating the axis of the valley. This situation created the Quebec Ice Divide, a fairly well-defined line that marks the southern and eastern limits of a zone where ice flow reversed to flow northward to northeastward from near the height of land on the U.S.-Canadian Border toward the saddle in the St. Lawrence Valley. Ice in the St. Lawrence valley flowed northeastward toward the ice-sea interface in the lower St. Lawrence Estuary. The Quebec

Ice Divide is probably time-transgressive, the reversal of flow taking place progressively farther westward as the reentrant of marine water extended up the valley. The actual ice-sea interface may have been east of Quebec City for a considerable time while its effects (northeastward flow) extended far to the west up the valley, effectively cutting off Appalachian ice from its original Laurentide source. The splitting of the ice sheet may have been very rapid, leaving a considerable amount of ice, detached from the Laurentide source, stranded in New England and in extreme southern Quebec. Opening of the St. Lawrence Valley may have taken place 13,000 to 15,000 years B.P. because dates on lake bottoms from Monteregian hills near Montreal and dates on marine shells as far west as Ottawa are in the 12,500 to 13,000-year B.P. range. If these dates are valid, one could suppose that the ice remaining over New England was extensive; Borns has shown that active sedimentation was taking place at an ice front on the northeastern coast of Maine within or before this time range. The reversal-of-flow phase continued for a minimum of 400-800 years, based on geochemical and visual estimates of northward transport of erratics, assuming rates of flow of 30-60 m/year. A rate of 10 m/year would necessitate northward flow for over 2,000 years.

Remnant Ice Caps

The ice sheet remaining south of the St. Lawrence disintegrated into several independent ice masses that either were active, with ice flowing radially away from their centers, or stagnant, especially where trapped in restricted intermontane basins. The remnant masses shrank toward their centers, and ice-flow directions varied radically over short distances in response to topographic irregularities or to drawdown where ice was in contact with lakes or marine waters.

Deposition of the Highland Front Moraine

It is difficult to accommodate the Highland Front complex and its equivalents within the sequence of events observed in southern Quebec. For instance, sediments deposited in proglacial lakes that require extensive ice dams along the Appalachian Front occur in many places throughout the Quebec Appalachians within the zone of northward trending striations. Also, northward trending striations are found within and even north of the Highland Front complex while observations of paleocurrent directions in the ice-contact stratified sediments that comprise the moraine require a south or southeastward-facing ice front of a glacier lying in the St. Lawrence Lowlands. On the other hand, there are some gravels west of Chaudière River in the vicinity of Leeds, Quebec and well north of the lake sediment deposited in valleys blocked by ice in the Highland Front position, that appear to have been deposited by water flowing northward from an icecap standing to the south. Thus, it may be that the Highland Front Moraine complex is the terminal position of a surge-like readvance of ice through the Champlain Sea to the north-facing slopes of the Appalachian and Adirondack Mountains, with deep lobes extending up the major valleys (Champlain, St. François, Chaudière) through these mountains. If it occurred, evidence for or against such a readvance will be exceedingly difficult to find because of the heavy cover of marine sediments over the lowlands.

However the Highland Front system was formed, it was probably a relatively short event taking place a few hundred years prior to 12,000 years B.P., and ice probably did not cover the tops of the more southern Monteregian hills where dates of 12,500 to 13,000 years have been obtained from lakes above or near marine limit. By 12,000 years B.P., the narrows at Quebec City had opened and the sea had finally worked its way along the front of the ice as far west as Ottawa.

Summary

To summarize the problem, one can say that (1) between the St. François River and the Chaudière River to the northeast, there is a zone which parallels both the St. Lawrence River and the Appalachian Front where ice flow indicators suggest that regional southeastward flow of the Laurentide Ice Sheet was followed by (2) northward, westward and north-eastward flow of a local ice mass, detached by events associated with a calving bay in the lower estuary, and (3) that along the front of the Appalachians the reversed flow was followed by renewed south to south-eastward flow from the Laurentide Ice Sheet.

Although a great deal of work has been done in the region in the past 17 years, these questions remain to be resolved satisfactorily: Was the northward flowing ice replaced by southward flowing ice without the terrain becoming ice free? If the terrain did become ice free did marine water penetrate the lowlands through the narrows of Quebec? How far up the major valleys did the southward flowing ice that ultimately built the Highland Front (and Drummondville?) moraine extend? What is the age of the Highland Front Moraine — is it older than the ~12 800 year B.P. and 13 000 B.P. dates on marine shells and terrestrial lake bottom sediments from Ottawa and Mont St. Bruno, respectively? What is the origin of the proglacial lake sediments in the valleys of the terrain where reversal of flow occurred? Why are marine shells generally only found seaward of the Highland Front complex at altitudes well below marine limit in the St. François valley? Why are ice contact deposits well below marine limit in the St. François valley capped only by fresh water and not marine clay? Why are marine shell dates in Ottawa significantly older than those in lower St. François River valley where the oldest dates are ~11 800 years B.P.?

Although each of these individual questions may be answered, finding a late glacial model that answers them all has proven difficult.

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-ERRATA-

p. 3, par. 3, l. 7	alignement	should read	alignment
p. 7, par. 2, l. 1	a	should read	of
p. 7, par. 6, l. 4	Massawipi	should read	Massawippi
p. 11, Fig. 3, Matérial Column			
l. 4	bassin	should read	basin
l. 6	shate fied	should read	stratified
p. 13, par. 1, l. 1	exam ned	should read	examined
p. 42, par. 4, l. 7	opprtunity	should read	opportunity

p. 53, 12th reference should read

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