FRIENDS OF THE PLEISTOCENE

52^{nd} Annual Reunion

QUEBEC CITY, Quebec, Canada

May 19-20-21, 1989

Guidebook for field excursions

Field leaders and contributors:

A. Blais
D. Demers
M. Lamothe
W.W. Shilts
P. LaSalle

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Field leaders and contributors:

Andrée Blais, Dept. of Geology, Carleton University, Ottawa

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Cover: Varved sediments in the Beauport River Valley. Opposite Lyell section.

P. LaSalle, editor

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INTRODUCTION

We have prepared for approximately two days of field excursion. This is more than we can possibly do. However, in case of unfavorable weather, we can fall back on the more accessible sites and exposures. Some sections may be in such a poor state after the winter and spring run-off, that they will not be worth a visit. Also, two gravel pit operators have refused to let us enter their premises over the weekend.

HISTORICAL NOTES

The names and endeavors of a few past luminaries in the geology of this area should be recalled, especially C. Lyell, R. Chalmers, A.P. Coleman, J.W. Dawson and J.W. Goldthwaith.

Presumably, when Lyell visited the area prior to 1845 (Lyell, 1845) it was still densely forested. He described a section along the Beauport River (reproduced in Gadd et al., 1972). That section is covered by talus, trees and brushes today. It may have been exposed by slumping in Mr. Ryland's backyard at the time of Lyell's visit. Today, only the lowermost unit of varved sediments underlain by colluvium or alluvium is exposed on the west bank of the river. Mr. Ryland's house is classified as a historical building. Mr. Ryland was secretary of the executive council of Lower Canada and presumably an important public figure of the time.

Robert Chalmers (1899) mapped the superficial sediments of the Beauce area. He formulated hypothesis concerning the origin of gold in the area, and the inception of glaciation in the Appalachians of southeastern Quebec. He was also, presumably, the first to suggest a reversal of the ice flow at the end of glaciation(s).

J.W. Dawson (1872, 1893) certainly made many excursions along the shores of the St.Lawrence River. He described fossils of the Champlain and Goldthwait seas. He visited the fossiliferous site near St.Nicolas probably several times. Today, it is a fairly large gravel pit and a good site for collectors (see list of species further in this guidebook).

Coleman (1941) described a section at Donnacona. He reported the presence of several tills separated by non-glacial sediments including organics. He correlated those sediments with the midwest sequence. Karrow (1957, p. 94) described the same or an equivalent section along the Jacques-Cartier River.

Finally and not the least, J.W. Goldthwait, who did large amount of field work in this area. He wrote a report on the St.Lawrence Lowlands for the Geological Survey of Canada which has been published in Gadd (1971). In particular, he studied the Micmac terrace (Goldthwait, 1911) and the deposits associated with the marine limit.

Before closing this brief introduction, I would like to welcome everybody: The Friends of the Pleistocene and Les Amis du Pleistocène.

I hope that you will enjoy this excursion.

Pierre LaSalle

Acknowledgements:

I would like to thank Minze Stuiver of the University of Washington in Seattle for QL-1909 on organics sediments from Pointe St.Nicolas. I would like also to thank the Geological Survey of Canada and Weston Blake jr. for radiocarbon dates, done over the years, on organics and marine shells from this area. J.V. Matthews and R.J. Mott have examined and reported on many samples of organics. The author is very grateful for their contribution. Excursions and discussions with Andrée Blais, W.W. Shilts, Cyril G. Rodrigues and D. Demers have helped clarify a few ideas and given confidence in some of the interpretations presented here. Finally, Denis Demers, Jean Vézina and colleagues at Transports-Quebec have taken care of the material organization of this meeting and of the printing of the guidebook. Their contribution is gratefully acknowledged.

Pierre LaSalle

FIELD GUIDE - SAINT-JOSEPH-DE-BEAUCE REGION

W.W. Shilts and Andrée Blais

Introduction

The glacial stratigraphy of the Appalachians has evolved steadily since the first modern studies of St. Lawrence Lowlands and Appalachian stratigraphy by Gadd (1971) and by Stewart and MacClintock (1964), respectively. From the first recognition of two glaciations separated by organic beds in the Lowlands, the number of events thought to have affected adjacent Appalachian terrain has grown steadily in complexity as more detailed studies have been made. Figure 1 is an attempt to illustrate how the authors view this evolution of stratigraphic concepts. All of the glacial events were originally thought to be Wisconsinan in age, but there has been some consideration lately of the possibility that the Johnville/Bécancour Till may be Illinoian, despite the decidedly boreal nature of the organic components in overlying Massawippi-St-Pierre beds. The purpose of this part of the field trip is to show some relatively recently discovered sections and exposures which seem to validate the essential elements of the stratigraphic framework as traditionally understood in the region and to add new details to our understanding of both older and the latest glacial events.

Stop 1 – Rivière des Plante

A series of sections along Rivière des Plante and its tributary, Rivière Fraser were shown to the authors by Professor Jacques Locat and his colleagues from Université Laval in 1983 (Figure 2). Fairly intensive study of the sections was carried out in 1986 in conjunction with a Geological Survey project designed to clarify the stratigraphic position and genesis of buried preglacial gold placer deposits of the middle Chaudière Valley (Figure 3). Major flooding in summers of 1987 and 1988 created good exposures at the bases of these already well-exposed sections. The sections include virtually all of the major Quaternary stratigraphic units, including

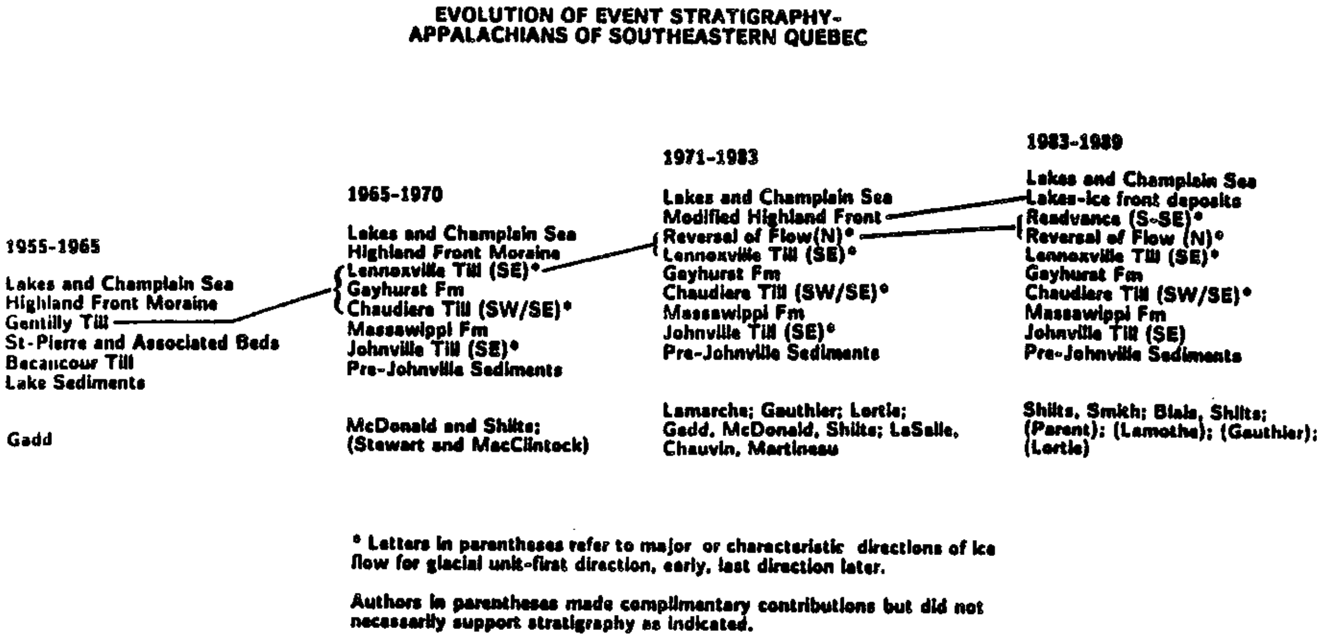

Figure 1. Increasing complexity of concepts of Appalachian stratigraphy since first modern studies.

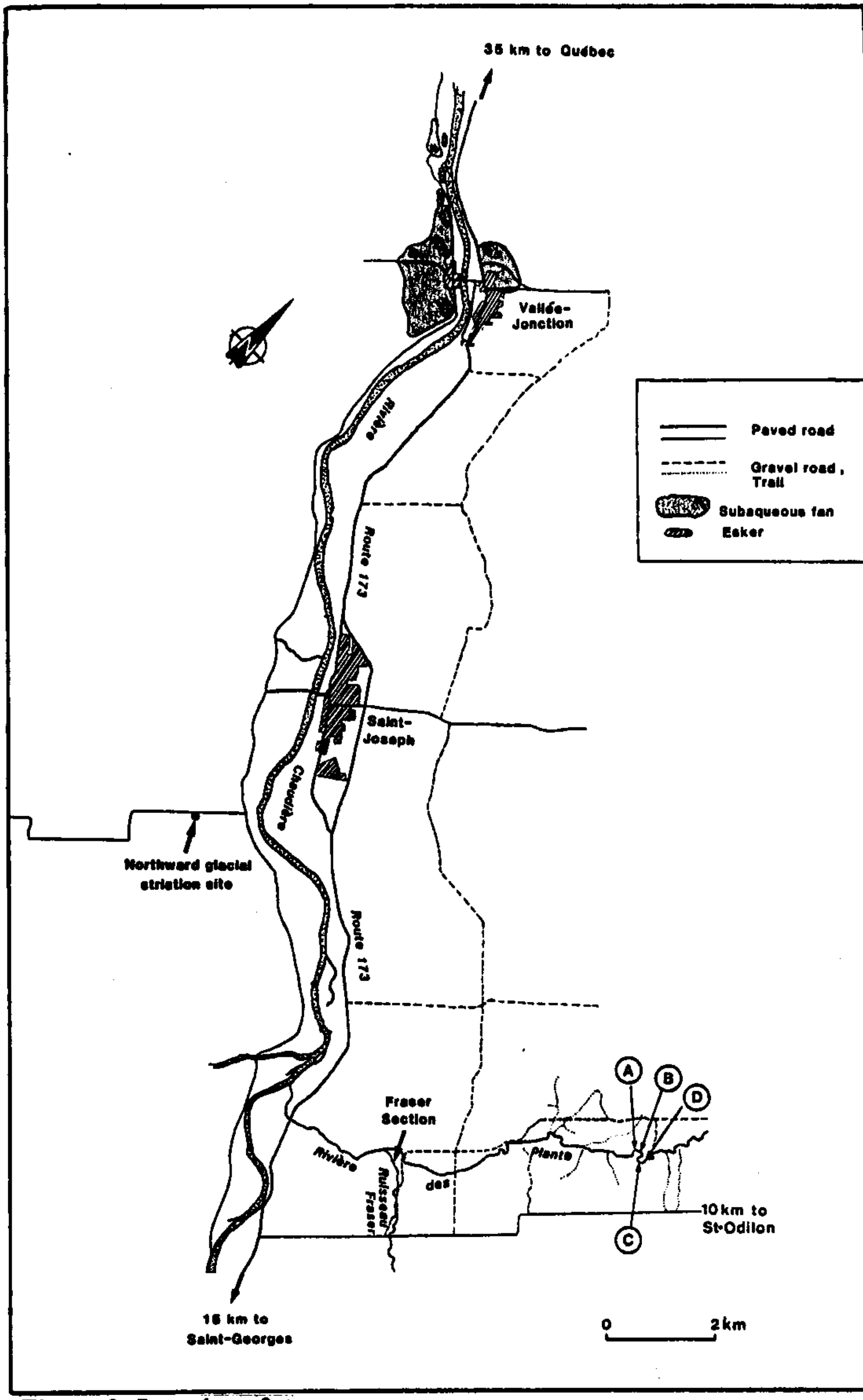

Figure 2. Location of stops.

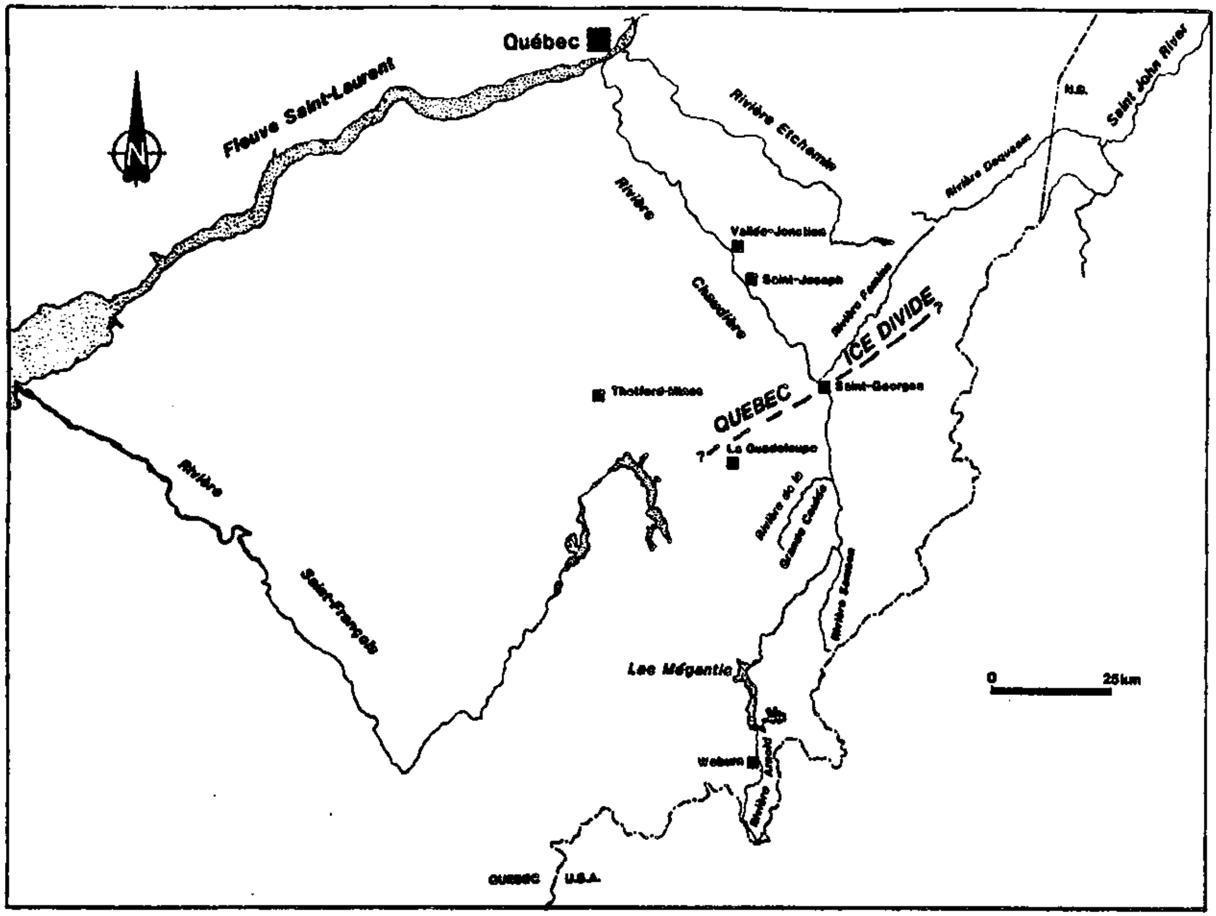

Figure 3. Location map with place names mentioned in text.

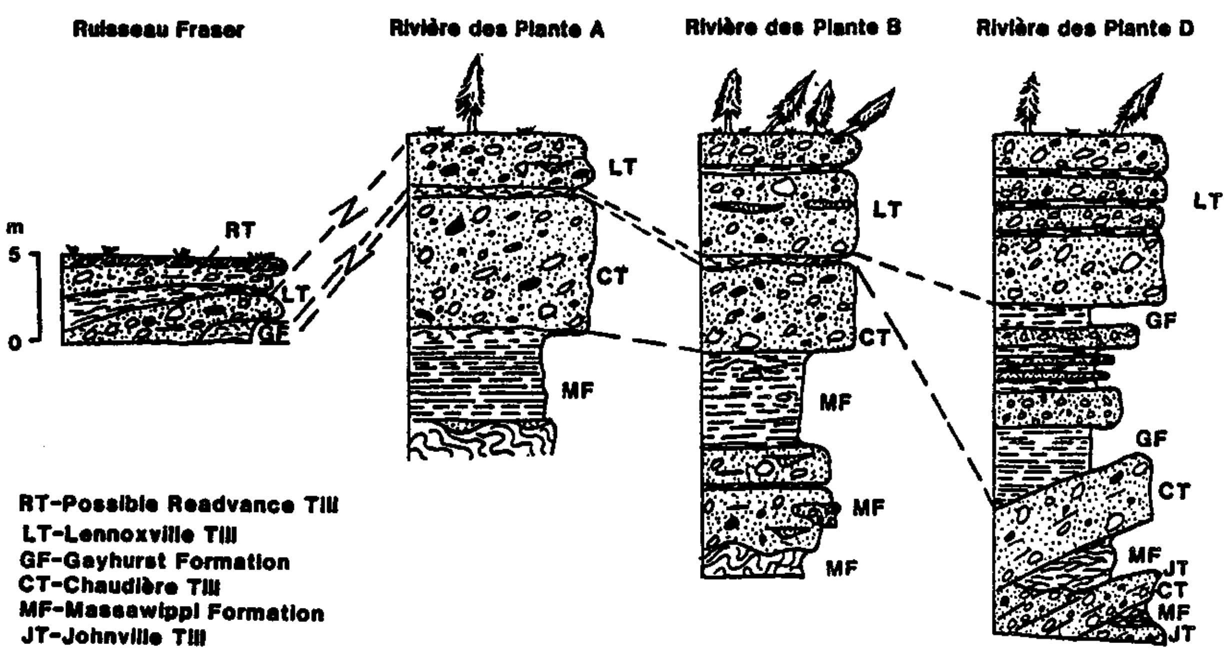

Figure 4. Proposed correlations of stratigraphic units exposed in sections along Rivière des Plante-Ruisseau Fraser. Sections not drawn exactly to scale.

organic beds, known from the Quebec Appalachians. Their fortuitous location just southeast of chemically and lithologically distinctive ultramafic bedrock outcrops permits many compositional constraints to be brought to bear on discussions of the ice flow events responsible for deposition of the various sediment facies, glacial and nonglacial, that are exposed here. Along a 500 m reach of central Rivière Des Plante, four sections, A, B, C, and D, have been studied (Figures 2, 4). Although C is badly slumped and will not be discussed further, A, B, and D are generally well exposed right to river level. The glacial and nonglacial sediments exposed in them will be described from oldest to youngest.

Johnville Till: Johnville Till (McDonald and Shilts, 1971) is well exposed in section D and was at one time exposed in a window through slump near the base of section B. It is presumed to have been deposited by a southeastwardly flowing glacier as observed elsewhere in the Chaudière and St-François valleys. In section D it is an olive grey to tan, matrix supported diamicton with an abnormally high clast to matrix ratio. Over 40% of the pebble and cobble sized clasts are serpentinized periodotite from the ultramafic complex that crops out a few hundred metres northwest of the sections. Many of the stones have been shattered after deposition and appear to have been rotated within the matrix. A fabric measured in 1988 showed a wide scatter of orientations with a preferred orientation striking northwest-southeast. Johnville till at section B is very compact, grey, and sandier than at section D. It is overlain by a deposit of large boulders with sandy silt matrix, apparently washed or injected into what was originally an open work boulder gravel. It cannot be traced laterally across the section in spite of excellent fresh exposures of the lower 5 metres of the section made by the floods of 1988.

At section D, Johnville Till appears to be weathered to a yellow-brown or tan colour and contains none of the fresh sulphides that are ubiquitous in unweathered tills of all ages in this part of the Appalachians. It does, however, contain 10-15%

kaolin (C. de Kimpe, pers. comm.), a component that is derived from reworking of the preglacial, gold-bearing regolith that is preserved in pockets in buried bedrock valleys of the region (Shilts and Smith, 1988). In nearby boreholes drilled through the regolith, which is yellow brown in colour, immediately overlying tills were tan or brown and contained abundant kaolinite due to reworking of the regolith. The tills from boreholes contained both unaltered pyrite and pseudomorphs of goethite after pyrite. Thus, the colour of Johnville Till at section D could in part be derived from a buried regolith; preglacial regolith at one time outcropped and was exploited in the lower reaches of Rivière Des Plante. The lack of fresh pyrite, however, suggests that regardless of the origin of the colour, the till has been subjected to subaerial weathering. The principal identifying feature of Johnville Till at both section D and B is its high concentration of nickel, chromium, cobalt, and other ultramafic components. The clay (<2 µm) fraction commonly contains over 1000 ppm nickel, not surprising considering that over 40% of the erratics in Johnville Till at this site are ultramafic rocks.

<u>Glaciotectonism of section D</u>: In the upper Chaudière Valley, Shilts (1981) suggested that many stratigraphic sections consist of two or more "shear plates" of sediment packages stacked one upon the other. The base of section D illustrates this concept in spectacular fashion, being composed of slabs of Johnville and younger Chaudière Till intercalated with each other and with fluvial gravel and fine-grained laminated sediments of the Massawippi Formation. The slabs dip 12° toward 005° and are overlain with sharp angular unconformity by laminated sediments of the Gayhurst Formation. One prominent slab can be seen to be made up of a stack of different sedimentary units with contacts at a sharp angle to the primary slab. The structural complexity of the base of this section is staggering and should give glacial stratigraphers pause, because virtually none of the structures visible after the 1988 floods were obvious before the water etched them out. Compositional or fabric studies

of such a structurally disrupted section would be extremely difficult to evaluate without the excellent exposures produced by water washing. We have encountered or suspected this style of deformation so often in this part of the Appalachians, that we wonder how often it has gone unrecognized in both our and others' studies.

Section B (Fig. 5), which seems to be more-or-less structurally intact compared to D, nevertheless exposes some confusing stratigraphy at its upstream end. It appears that at least part of the upstream end of the section has been thrust over the downstream end along a high angle fault.

The attitude of the intercalated slabs in section D and the fact that post-Chaudière deposits are not involved in the deformation, suggest that the stacking of sediment slabs was effected by basal drag or by freezing on and subsequent upshearing of subglacial deposits at a time when the Chaudière glacier was flowing from 005°, a direction represented by several fabrics measured in the Chaudière Till at section B (Fig. 5; Poliquin, 1987).

Massawippi interstadial or interglacial deposits: Underlying Chaudière Till and presumably overlying Johnville Till in sections A, B, and D is a sequence of nonglacial and proglacial sediments that are the most complete record of facies of the Massawippi Formation (McDonald and Shilts, 1971) yet known from the Appalachians. The Massawippi sequence in section B is best exposed and least disturbed.

Sediment facies of the Massawippi Formation comprise a lower, highly deformed, crudely laminated silty clay which is in turn overlain by an alluvial/colluvial complex overlain by largely undeformed, thinly bedded varves with dropstones. It is not clear what deformed the lowermost clayey sediment; possibly it served as a zone of décollement during the general deformation effected by the Chaudière glacier.

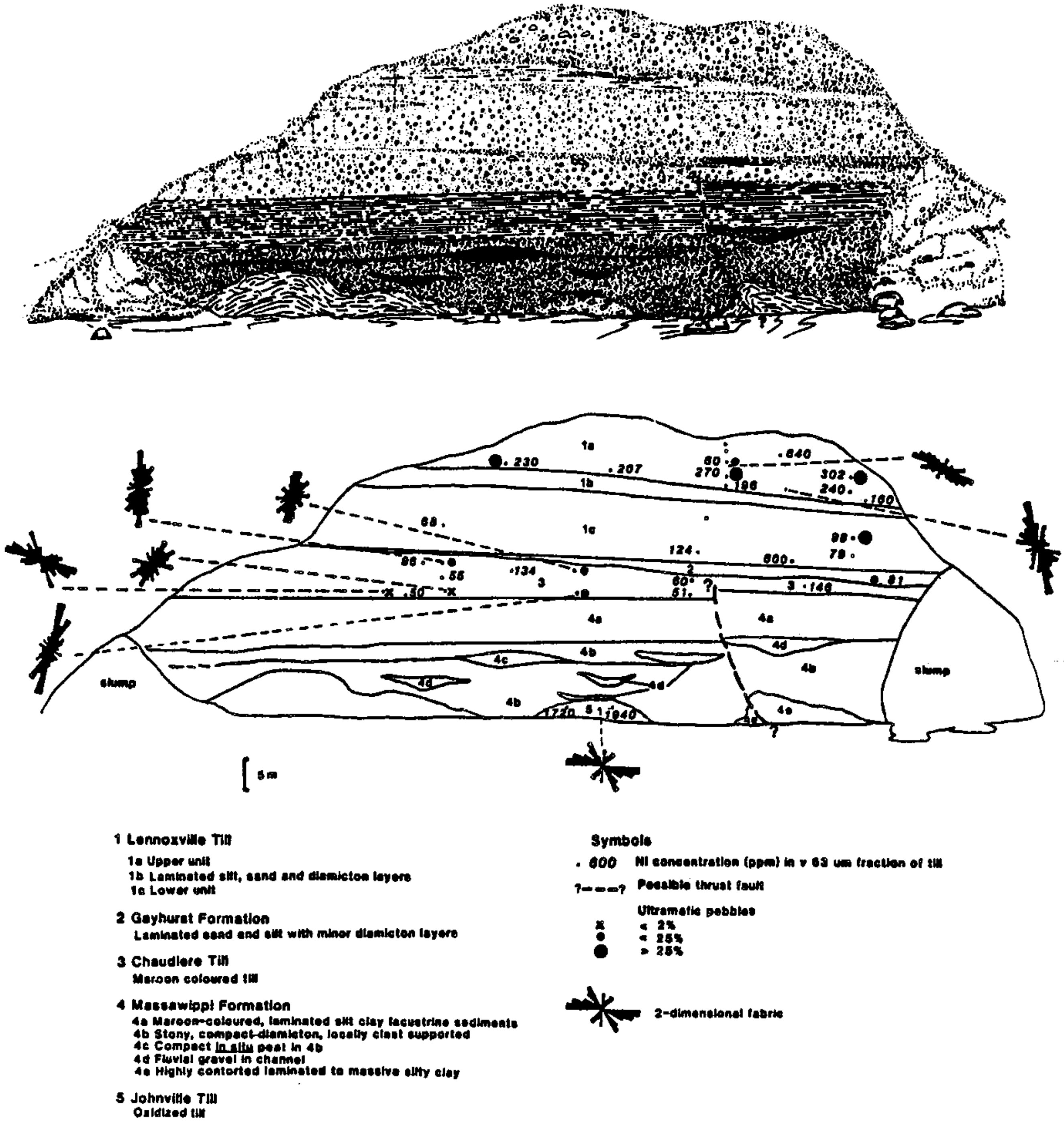

Figure 5. Sketch, interpretation, and selected quantitative data for section B along Rivière des Plante. Modified from an original sketch by Sharon Smith. See text for sources of data.

The lower laminated member is not exposed in section D. In sections B and A the lower laminated member has what appear to be small fluvial channels cut into its surface, but exposure is so poor that the relationship of the channels to the laminae is unclear. In section B, the deformed clay forms the base of the section from end to end, and its undulating upper surface is overlain by a stoney (cobbly) matrix – supported diamicton with minor lenses of sorted gravel and sand – the latter probably representing sediment deposited in stream channels. Erosion of the centre of section B during the 1988 floods exposed a continuous bed of highly compressed peat, varying from <1 to 30 cm in thickness. The peat is completely enclosed within and near the middle of the 2-4 m thick stoney diamicton. Examination of disseminated organic detritus from this bed led Matthews (1987, p. 170) to state that it contained "A rich fossil insect and plant assemblage that clearly resembles St-Pierre assemblages from the classic localities ..." He concluded that during Massawippi time, this part of Quebec was covered by a spruce forest that contained some larch and a species of Alnus typical of northern boreal forests. Furthermore, the deposits contain a larger number of insect taxa than the classic St-Pierre localities, including several species that do not presently occur in southern Quebec.

Macrofossils isolated from the peat collected in 1988 were examined by Dr. Lynn Ovenden. She stated that "All of the plants ... are common in boreal fens, and occur in a broad latitudinal zone from northern New England to northern Quebec. The lack of diversity and the interwoven, highly organic nature of the peat indicates (that it is) an in situ peat deposit. The mosses suggest a fairly calcareous, ground-water fed wetland, and the abundance of needles and wood suggest that larch and black spruce occurred in the fen." (Ovenden, pers. comm., 1989). This peat is significant in that it is the first in situ peat deposit found in the Appalachians and represents subaerial conditions at this site during the Massawippi nonglacial period.

All other organic sites in the Appalachians are in lacustrine or fluvial environments, and much if not all of the organic detritus is allocthonous.

Along the upper surface of the most prominent thrust plate at section D, what appears to be authochtonous moss and other organic detritus is interbedded with glaciolacustrine silt laminae in a band <1 cm thick. The palynology of this band is similar to that of the organic layer at section B.

In summary, the organic detritus in sections B and D suggests that the region was somewhat cooler than present during the Massawippi interval (Mott, personal comm., Matthews, 1987) and that these beds correlate with the St-Pierre nonglacial interval of the nearby St. Lawrence Lowlands. Organic remains in the glaciolacustrine facies that overlies the peat-bearing colluvium contain evidence of arctic flora and fauna, as do several nearby organic horizons in Massawippi (?) glaciolacustrine sediment at Vallée-Jonction (LaSalle et al., 1977), Rivière du Moulin (Matthews, et al., 1987) Rivière Abenakis (Matthews, et al., 1987), and Rivière de la Grande Coulée (Matthews, et al., 1987; McDonald and Shilts, 1971). Tundra conditions apparently prevailed in this area as the Chaudière glacier impinged on local drainage, ponding lakes in the Chaudière Valley.

Overlying the peat-bearing colluvium and alluvium is a thin-bedded, varved silty clay. Where well-exposed and undisturbed in section B, this unit can be seen to contain small (<1 cm-diameter) dropstones and balls of till in its upper laminae. For the most part the laminated sequence is overlain with sharp contact by Chaudière Till which at some spots in this section has deformed the laminae immediately beneath the contact and at others has caused virtually no deformation. The laminated sequence is also well-preserved at section A, but at section D it is highly deformed and forms a discreet, wedge-shaped slab of sediment intercalated between slabs composed of Chaudière Till. The clay "winter" layers in this laminated sequence range from grey to maroon in colour, with maroon dominating. Overlying

Chaudière Till has a distinctly maroon tint because of reworking of the Massawippi Formation.

At this site the Massawippi Formation includes all of the major nonglacial and proglacial facies that might be expected during glacier-free intervals at altitudes above marine limit in the Appalachians. Glaciolacustrine sediments deposited in lakes expanding in front of a glacier (Johnville) that retreated downslope are overlain by a variety of fluvial, palludal, and colluvial facies, representing a period of free drainage toward the St. Lawrence. These nonglacial deposits are overlain in turn by sediments deposited in a lake dammed by the advancing Chaudière glacier which ultimately deposited Chaudière Till.

Chaudière Till: Chaudière Till forms a prominent bed across sections A and B, where it lies with sharp contact on the upper glaciolacustrine member of the Massawippi Formation. In section D, it is intercalated with Johnville Till and with deformed Massawippi laminated sediment in a series of thrust plates. In sections A, B and D, Chaudière Till ranges in colour from grey to grey with a mauve or maroon tint and is distinguishable from Johnville Till in section D by virtue of the tan colour of the latter.

Two dimensional fabrics in Chaudière Till at sections A and B seem to strike WNW-ESE at the base swinging to NNE at the top. In section D the entire Chaudière and pre-Chaudière sediment sequence is intercalated in thrust plates dipping toward 005°, a direction compatible with the maxima of several fabrics measured in sections A and B (Fig. 5). Elsewhere in SE Quebec, fabric of Chaudière Till tends to vary from WSW at the base to SE at the top. In the Chaudière Valley, fabric measured in the few sites when Chaudière Till has been identified ranges from SSW to 110°, the latter being the direction of striae on the surface of Chaudière Till at Rivière Samson (Shilts, 1978).

On Rivière des Plante, Chaudière Till is impoverished in ultramafic clasts compared to Johnville Till and overlying Lennoxville Till. It is equally impoverished in chemical elements typical of ultramafic rocks. The reason for this is probably the location of these sections just a few hundred metres southeast of the known area of ultramafic outcrops that lie along the northwest side of Rivière Des Plante valley. The compositional evidence provides strong support for a WNW to WSW to SSW sequence of shifting ice flows during at least part of the Chaudière phase of glaciation. Only the SSW flow trajectory would have transported ultramafic erratics across these sections. An additional source of low concentrations of ultramafic debris in Chaudière Till is probably ultramafic rich Johnville Till, reworked by the Chaudière glacier. In sections analyzed by Poliquin (1987), ultramafic clasts, Ni, Cr, and Co tend to be enriched near the top of the till (Fig. 5), suggesting that ice flow was southerly at the time the uppermost debris was deposited.

Elsewhere in SE Quebec, the shift of fabric and composition evident in Chaudière Till is taken as evidence that, at the onset of the Chaudière glacial phase, an independent ice cap grew in the eastern Appalachians, in Maine and/or New Brunswick. That ice cap was eventually overwhelmed by southeastwardly advancing Laurentide ice. The geological setting of these sections is such that such a history of ice flow is strongly supported both by fabric and by the unique compositional constraints derived from the till. It should be pointed out that Chaudière Till also contains a small, but noticeable percentage of Precambrian crystalline erratics, presumably derived from the Canadian Shield north of the St. Lawrence River. Elsewhere in this region it has been reported that Chaudière Till is devoid of these erratics, an observation that is often interpreted to mean that no Laurentide ice was involved in Chaudière deposition. Poliquin (1987) has suggested that the crystalline erratics in Chaudière Till on Rivière des Plante were derived from underlying Johnville Till and Massawippi Formation sediments or were transported by

Laurentide Ice from the Canadian Shield during the latter phases of Chaudière deposition. It is not possible to say which of these possibilities is most compelling, and it is likely that both contributed to the presence of Precambrian erratics.

Gayhurst Formation: At section D, the irregular surface of the tectonized lower part of the section is overlain with sharp angular unconformity by grey laminated sediments of the Gayhurst Formation (McDonald and Shilts, 1971). The Gayhurst Formation comprises a variety of glaciolacustrine facies deposited in a large proglacial lake that filled the Chaudière and Saint-François River valleys during the interval between deposition of Chaudière Till and the readvance that deposited Lennoxville Till. The altitudes of its water surfaces were strongly constrained by the altitudes of two of the lowest possible outlets through this area of high relief. When the Chaudière or Lennoxville ice fronts stood south of Saint-Georges, the lake stood at 427 m and overflowed through a pair of outlets into the Dead River basin in Maine. When ice fronts stood north of the contiguous Famine-Daquaam River Valleys (Fig. 3), Lake Gayhurst fell to 394 m, the level of the divide in the valley occupied by these two underfit rivers. Although these outlets probably carried overflow several times during various glaciations, they are particularly well-tied to the Lake Gayhurst event by altitudes of Gayhurst Formation deltaic facies.

Because the Rivière Des Plante sections are well below the lowest altitudes of Glacial Lake Gayhurst, the Gayhurst Formation consist primarily of deep-water, laminated facies. At section D, the laminated facies is interbedded with several till-like diamictons ranging in thickness from a centimetre to over a metre. These are interpreted as mud flows of englacial debris that melted from the submerged ice front. The intercalation of mudflows and laminated sediments is characteristic of the Gayhurst Formation throughout the Chaudière Valley (Shilts, 1981). The mud flows characteristically have conformable, horizontal contacts with enclosing silt-clay laminae and are thus differentiated from beds of till, which usually have erosive basal contacts and an irregular upper surface shaped by processes associated with the release from ice of the debris of which the till is composed.

At sections B and A, the Gayhurst Formation is a thin, discontinuous, laminated sandy-silt with gravel and diamicton lenses. Whether it was removed by the overriding Lennoxville glacier or was not deposited to any great thickness is unknown.

It is characteristic of deep water facies of the Gayhurst Formation to vary from thicknesses of <1 metre to over 100 metres over short distances in boreholes and sections farther south in the Chaudière Valley. This is probably because the main source of sediment in the lake was subglacial drainage exiting from ice tunnels. This internal drainage may have injected large quantities of basal debris into the lake as dense, bottom-hugging slurries (density underflows) in cycles of short, perhaps even diurnal, duration. These underflows, exiting at specific localities at or near the interface between the glacier base and the lake's bottom, preferentially would have filled depressions and would have left little or no sedimentary record over the positive features of the lake bottom. Mud melting from the basal, debris-rich zones of the ice would have flowed into the depressions at irregular intervals along with the water-sorted slurries of cold, rock-flour-laden meltwater.

<u>Lennoxville Till</u>: Lennoxville Till caps sections A, B, C, and D. It is grey, weathering brown or tan, cobbly till with some lenses of gravel and numerous sub-horizontal partings that give it a fissile appearance where washed by water. The gravel lenses are thought to be dewatering channels cut in stagnant, basal, debris-rich ice from which till was released by meltout. Most of the structures seen in tills of this region are thought to have formed as a result of the release of debris by slow meltout and not by lodgment.

Lennoxville Till has fabric reflecting the southeastwardly flow direction of its depositing glacier, and, like the Johnville Till, it is rich in ultramafic clasts and geochemical indicators. Because of similarities to the Samson River section, Paul (1987) has divided the Lennoxville Till into upper and lower members at sections B and D on the basis of the presence of water sorted sediments that occur as continuous bands in the middle of the Lennoxville sequence in both sections. At section B, two 7 m (±) thick till beds are separated by a 2 m-thick complex of laminated silty clay, sand, diamicton lenses, and carbonate-cemented gravel. At section D, the two tills are separated by 3.4 m of laminated silt and sand with diamicton layers. Laminae in the upper few centimetres of the waterlain sequence are contorted, presumably by an overriding glacier.

The lower part of the lower member of Lennoxville Till is grey, but becomes brown near the contact with overlying sorted sediments. The upper member is compact and oxidized to a tan-brown colour. The great apparent depth of oxidation in sections B and D is probably related to the oxidizing power of groundwater flowing through the numerous sorted layers and lenses in the till.

Near the surface of sections A, B, and D, there is some evidence of minor washing or reworking of the till, but no clear evidence of any sort of glaciolacustrine or glaciofluvial deposition.

Till-coated ultramafic clasts: At this section as well as at several other sections in Quebec and Vermont, the colluvium and alluvium at the base of the section is littered with cobbles and boulders that appear to be composed of cemented till. When these clasts are broken open they can be seen to be cored with one or more ultramafic erratics. The ultramafic erratics have apparently reacted with the matrix of the enclosing till to form some sort of cement. Tills in which this phenomenon has been noted range from slightly calcareous ($<4\%$ total matrix carbonate) to non-calcareous.

Stop 2 – Rivière Fraser

Rivière Fraser Section: A 5 to 6 m high section cut into a broad alluvial plain extends southward about 500 m upstream along the east bank of Rivière Fraser from its confluence with Rivière des Plante (Fig. 2). At the north end, at least 2 m of hard grey till with 2-15 cm interbeds of laminated silt-clay overlies deformed laminated sediment and underlies a massive, 20-30 cm thick red clay which is in turn overlain by thinly laminated silty clay with grey to maroon clay layers (Fig. 4). At the Fraser-Des Plante confluence and in the bed of Rivière Des Plante for more than 100 m downstream, the till-laminated sediment sequence can be seen to be deformed into folds with steeply dipping to overturned limbs. Without the silty clay interlayers, the till would appear massive and undeformed. A fabric measured in this till dipped northward, but without correction for the folding, the true dip is impossible to assess. It is presumed that the folding was caused by basal drag of northward flowing ice because of the prevalence of northward striae on bedrock outcrops in the vicinity. On Rivière Fraser, the surface of the grey till dips gently southward, upstream, eventually disappearing below river level. It is overlain directly throughout its exposure by the massive red clay with overlying silt-clay laminae. At the downstream end of the section the laminated sequence is overlain by 0.5-1 m of fluvial gravel which forms the surface of the alluvial plain into which the section is cut. Upstream from where the grey till disappears, however, the laminated sequence is over 2 m thick and individual laminae are deformed progressively upward until they pass into a massive clay with few clasts and some blocks or wisps of laminated sediment. This massive clay is hard to find and is usually obscured by the overlying modern fluvial gravel. Deformation in the laminated sequence has a peculiar "brittle" quality; folding is accompanied by small-scale faulting or fracturing of the clay layers.

Both the lower till and the deformed laminae require detailed structural study to clarify the principal vectors of the forces that acted to deform them. Until such studies are made, we propose the following tentative interpretation of this section: The grey till represents debris carried by the Lennoxville glacier and, whether actually deposited or just passively entrained near the base of the glacier, was deformed during the period of reversal of flow toward the north. The origin of the laminated bands is not known, but such structures, though relatively rare in this region, are often associated with decollement accompanying thrust stacking of till and associated glaciolacustrine sediments (Shilts, 1981). Ice retreat southward to an ice divide at Saint-Georges may have briefly exposed the till subaerially or may have left it submerged in a lake, depending on the configuration of the Laurentide ice front standing against the Appalachian front to the north.

A wedge of fine gravel, texturally similar to fluvial gravels covering terraces formed during modern fluvial excavation of the Chaudière and its tributary valleys, lies between the grey till and the overlying massive red clay in a ditch on the southwest flank of Fraser River, 1.5 km SE of the section. If this sediment is truly fluvial, it indicates that any ponding in the Chaudière Valley was controlled by outlets below 228 m a.s.l. and possibly below 200 m. In any case, the massive red clay and overlying laminated silt-clay are thought to have been deposited in a rising proglacial lake dammed by Laurentide ice readvancing southward, up the Chaudière Valley. Although depositional evidence for such a readvance is clear in the subaqueous fans of the Chaudière Valley, several sites such as this must be found in order to provide supporting evidence. Nevertheless, with the recent boom in construction and accompanying excavations in the Chaudière Valley, several sites with thin, apparently late glacial till overlying Lennoxville Till have been identified, and it is hoped that more will be found.

Stop 3 – Striae at Saint-Joseph-de-Beauce

Northward Striae: If time permits, we will stop at an outcrop along the road just west of the Chaudière River at Saint-Joseph (Fig. 2). This outcrop of red slate is cut by quartz veins from which rat-tail striae extend toward 028°. The rat-tail striae on this outcrop are typical of those on hundreds of outcrops located north of the Quebec Ice Divide. In many cases the northward striae can be seen to cut southeastward striae.

Stop 4 – Subaqueous Fan – Vallée-Jonction

Glacial Lakes in Chaudière Valley

The northward draining Chaudière Valley was filled with lakes any time ice advanced up it and across the Appalachian Front. Because of the relief of the terrain on either side of the valley, only a limited number of lake outlets were possible. The lowest of these could have carried water westward from a lake standing at about 305 metres a.s.l. Though no evidence of erosion by overflow channels is found in a col at this altitude near La Guadeloupe, Quebec (Fig. 3), it is possible that a lake could have existed at 305 m(±), particularly in late glacial time. Water draining from such a lake ultimately would have reached the Atlantic Ocean along a tortuous route via the Saint-François Valley, Lake Champlain basin, and Hudson River. The lack of any evidence of meltwater deposition or erosion at this altitude, however, suggests that any time the Chaudière Valley was blocked, the Saint-François Valley to the west was blocked, too, forming a large lake that covered both basins to altitudes well above the La Guadeloupe col.

The next lowest outlet in the Chaudière basin is along the eastwardly trending valley presently occupied by Rivière Famine, which flows westward into the Chaudière at Saint-Georges, and Rivière Daquaam, which flows eastward into

St. John River (Fig. 3). This valley is a classic overflow channel with a wide, flat bottom, steep sides, and two under-fit rivers flowing in opposite directions from a barely discernible divide on the floor of the valley. It has already been established that this valley carried meltwater eastward into the Atlantic via the St. John River valley during the existence of Glacial Lake Gayhurst, just prior to the Lennoxville readvance. It is probable that it carried late glacial drainage too, but the record of nearshore deposition in late glacial lakes is too poor to allow any link to be made between the col and lake levels.

The only other major outlets that controlled lake levels in the Chaudière Valley proper (many local high-altitude lakes may have been ponded in its eastern, westward-flowing tributaries) are two cols, each at approximately 429 m altitude east and southeast of Woburn in the Arnold River valley south of Lac Mégantic (Fig. 3). These outlets only functioned when ice stood south of the lower, Famine-Daquaam outlet.

Ice front deposits: Vallée-Jonction subaqueous fan

Several ice-contact sand and gravel deposits lie in the Chaudière Valley and appear to mark ice front positions from the Appalachian Front at least as far south as Saint-Georges. They all bear structures indicating southerly paleo-currents and lie well below altitudes of any of the outlets discussed above. The most impressive of these is the kettled, flat-topped mass of sand and gravel which has been dissected by the modern Chaudière River at Vallée-Jonction, where we will stop.

An apparent paradox was created concerning these deposits at the time that northward ice flow was first documented in Quebec (Lamarche, 1971). These features, obviously built southward into proglacial lakes from the fronts of southward-flowing ice masses were surrounded by highlands with hundreds of outcrops on which northward or westward pointing striae clearly postdate the southeastward striae of the Lennoxville glaciation. The paradox was pointed out by

Gauthier (1975), by Lortie (1976), and during the Friends of the Pleistocene excursion in 1982 at a stop to observe similar ice-contact sediments in the Saint-François Valley to the west.

The present authors have concluded (Blais and Shilts, 1989) that the ice front deposits in the Chaudière Valley, at least as far south as Saint-Georges, were deposited by a lobe of ice that readvanced from a Laurentide ice front that had lain more or less passively against the northwest facing flank of the Appalachians from the time that the Laurentide and Appalachian residual ice masses separated until a time at or near the final melting away of the last vestiges of the residual Appalachian ice in the highlands. The readvance probably marks a regional climatic deterioration that caused increased alimentation of the eastern Laurentide Ice Sheet, resulting in augmented flow of ice southward across the St. Lawrence River. While not vigorous enough to penetrate very far into the foothills of the Appalachians, it was strong enough to push lobes up the major valleys, such as the St-François, Chaudière, and Etchemin. This may have been the first of several such minor readvances that are marked immediately to the north by such deposits as the fossiliferous St. Nicholas till and the St. Narcisse moraine.

The deposit at Vallée-Jonction is the largest of the ice front deposits that mark the retreat of a late glacial Chaudière Valley lobe. Morphologically it has a smooth delta-like foreslope and a level to gently rolling surface with numerous undrained depressions. To the north it becomes more hummocky and passes into a ridge interpreted as an esker, deposited in the conduit that supplied sediment to the fan. On the east side of the valley, only a small remnant of the deposit was left after postglacial down cutting by the Chaudière River. This remnant has been so thoroughly excavated that its original morphology is impossible to determine.

The sediments that compose the subaqueous fan are coarse sand and gravel in beds that dip gently southward and carry southward paleo-current indicators. In the pits on the eastern side of the valley, the coarse debris can be seen to have prograded over laminated silt and clay which has been deformed by the loading. In pits in the northern part of the deposit, bedding is much more chaotic, being faulted and deformed by ice collapse. Lithologically, the gravel has very low concentrations of ultramafic erratics even though the valley sides adjacent to the deposit have high concentrations of ultramafic erratics according to Gadd (1978). The erratics on the valley sides were presumably transported northward from the ultramafic outcrops northeast and southwest of the Chaudière River at Rivière des Plante. This suggests that in the lowest parts of the valley, ultramafic-poor debris carried southward by the readvance either covered or diluted ultramafic-rich drift deposited during northward flow.

<u>Summary of late glacial events</u>

To summarize the results of our most recent research on the latest glacial events in the Chaudière River valley, we can conclude the following:

1) The Lennoxville glaciation is marked throughout SE Quebec and New England (with the possible exception of parts of N. Maine) by southeastward to eastward flow of ice that crossed the highest peaks of the Appalachians from a centre of ice flow on the eastern Canadian Shield. This is presumably the main Wisconsinan advance that reached the New England coast and New York City.

2) At some time when a substantial part of the glacier still existed south of the St. Lawrence Valley, accelerated melting where the sea was in contact with the glacier in the lower St. Lawrence Estuary caused drawdown that was strong enough to divert flow northeastward along the valley, toward the point of enhanced wastage. The flow diversion created a depression in the ice sheet that propagated westward along the axis of the St. Lawrence Valley past Quebec city, effectively cutting off ice flow from the Canadian Shield across the St. Lawrence to the Appalachians. As a result, flow in the Appalachians was directed northward ($\pm 30°$) toward the St.

Lawrence depression from a zone with an axis extending from the vicinity of Thetford Mines, eastward through Saint-Georges. We call this zone the Quebec Ice Divide (Shilts, 1981).

3) The ice mass south of the St. Lawrence eventually thinned to the point that it separated from the Laurentide mass along the Appalachian front. The residual ice shrank toward the ice divide and eventually disappeared.

4) Laurentide ice, resting against the Appalachian Front while the remnant ice ablated, thickened due to increased flow from the ice flow centre (s) of the eastern Laurentide Ice Sheet, pushing lobes up the major valleys in deep proglacial lakes.

5) As these lobes retreated they slowed or halted several times, building subaqueous deposits into the lakes. These deposits are composed of sediments that range from chaotically bedded, poorly sorted beds of gravel and diamicton where pauses were brief or subglacial drainage was not well developed to the massive, 100 m(+) accumulations of sand and gravel which blocked the valley completely at Vallée-Jonction.

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STRATIGRAPHY AND GLACIAL HISTORY OF THE QUEBEC CITY REGION*

(P. LaSalle)

Introduction

The St.Lawrence channel is narrowest at the height of Quebec City. Because of that, the glaciers, while retreating, controlled the mode and timing for the entrance of the sea in the St.Lawrence Lowland, west of Quebec City and consequently, the opening of the drainage to the Atlantic. Each time the glacier advanced or retreated, it caused the build-up or ponding of glacial lakes northeast, south and southwest of Quebec City from as far as Baie St.Paul (some 100 km northeast of Quebec City) or possibly even from further east, to the Lake Champlain Valley and the Montreal area. Without this blocking of the St.Lawrence channel by glacier ice northeast of Quebec City or at least at the height of it, glacial lakes could not be ponded during a readvance. In the same way, during a glacial retreat, with a high sea level and an isostatically depressed terrane, the sea waters could not be kept out of the St.Lawrence Lowland, without the ice occupying the Quebec City area.

Examples of those events are:

(1) The build-up of glacial Lake Deschaillons (and other unnamed glacial lakes) which was initially controlled by an ice lobe diverted in the St. Lawrence channel and advancing upstream into it, northeast of Quebec City. Deposits of that lake are found today from L'Ile-aux-Coudres (Brodeur and Allard, 1985) to Deschaillons (Gadd, 1971; Lamothe, 1985) and Rivière Noire (LaSalle et al., 1986). This lake was presumably dammed at the beginning, by glacier ice abutting (Coleman, 1922) against the south shore escarpment of the St.Lawrence estuary and progressing upstream maybe under the form of a lobe. It was finally swallowed by the part of the ice sheet advancing from the northwest.

In the Quebec City area, that glacial lake episode is recorded by the presence of glacio-lacustrine deposits at several places; these varved sediments are correlative with those of Glacial Lake Deschaillons emplaced after the St.Pierre interglacial period. Other varved sediments observed

* Parts of this text have been borrowed from previous field guides, in particular from LaSalle in Lamothe(1987).

at the bottom of the Beauport River Valley, north of the St.Lawrence River, may be related to an early glacial advance, possibly the Becancour glaciation or some older glacial event.

(2) The damming of glacial lake Vermont in late-glacial time. The latter occupied the Lake Champlain Valley but eventually reached, and probably extended to the northeast (LaSalle et al., 1982) and to the northwest (Anderson et al., 1985), perhaps even merging with Lake Iroquois, before the Champlain Sea reached the Montreal area.

(3) Similarly, the ice front had to be located south of Quebec City to pond glacial lakes in the Appalachians, south and southwest of Quebec City, during the Gayhurst episode (McDonald and Shilts, 1971). There is no evidence for the Gayhurst ice front to have retreated as far north as Quebec City. To the southwest, the Gayhurst ice front apparently retreated at least as far north as the Montreal area (Prest and Hode-Keyser, 1977; LaSalle, 1985). East and northeast of Montreal, it retreated as far as St. Cesaire (LaSalle, 1981; LaSalle et al., 1982) and may even have retreated as far as the central St.Lawrence Lowland, without unblocking the drainage to the Atlantic.

(4) And finally and most important, the timing and mode of inception of the Champlain Sea as explained above.

Stratigraphy of the Quebec City area

The lithostratigraphic succession observed in the Quebec City area has been described by LaSalle (1984) and is recalled briefly below:

Charlesbourg Saprolite

Charlesbourg saprolite, exposed in a quarry in Charlesbourg, north of Quebec City, is described by LaSalle et al. (1983). It is developed in part on a mylonite derived from a precambrian biotite-hornblende gneiss and in part of the gneiss itself. Biotite has been altered to vermiculite and then to smectite; hornblende in the fine fraction has been transformed into swelling clay minerals; kaolinite is abundant and results from a degradation of the swelling minerals. In places, the alteration (depth:

15 m.) has reached the gibbsite stage. The saprolite is located south of a bedrock knob, which has protected it from glacial erosion. It is probable that it predates the earliest glaciation in the Quebec City area.

Chateau-Richer Kaolinite

The Chateau-Richer kaolinite is exposed in a small stream valley about 20 km northeast of Quebec City. It has developed on anorthosite and related rocks. The alteration reaches a depth of about 25 m in places. The white colour of the kaolinite is conspicuous in all the exposures. It is overlain by a sandy brown till, the lower part of which is enriched with glacially derived kaolinite. This kaolinite predates the last glacier advance in the Quebec City area and was probably developed during Tertiary.

Pointe St.Nicolas Till

The oldest glacially derived sediment observed in the Quebec City area is exposed at the base of a section at Pointe St.Nicolas, about 15 km west of Quebec City. The unit is about 2.0 m thick. In places it is green on fresh exposure because it contains chlorite, but is generally reddish gray and contains a minor proportion of precambrian clasts. This till, which is overlain by the Anse-aux-Hirondelles Formation, is presumably correlative with the basal unit of the St.Augustin gravel pit.

Anse-aux-Hirondelles Sediments

This stratigraphic unit is exposed at Pointe St.Nicolas, about 15 km west of Quebec bridge, on the south shore of St.Lawrence River. It consists of horizontally stratified sand and gravel with organic beds. The organic beds are exposed at the base of the formation, immediately above Pointe St.Nicolas Till. Wood fragments recovered from the organic beds have yielded a ^{14}C age of 60 Ka BP (QL-1909, 60 200 ± 700 BP). Cross-stratification indicates flow towards the present St.Lawrence River, parallel to the flow direction of the modern local streams. It is possible that the sediments at Anse-aux-Hirondelles occupy a local tributary valley eroded in bedrock. This ravine would have been formed before deposition of the Pointe St.Nicolas Till and its longitudinal profile might possibly have been graded to the Micmac Terrace (Goldthwait, 1911). The thickness of the Anse-aux-Hirondelles sediments is in the order of 20-25 m. Beaupre varved sediments overlie the Anse-aux-Hirondelles Formation.

Plant and Arthropod Macrofossils from Pointe St.Nicolas, PQ

PLANTS

Taxa	Fossils
Bryophytes	+
Isoetaceae......"Quillwort family"	
Isoetes sp.	+
Pinaceae......"pine family"	+
Larix sp.	+
Picea sp.	+
Najadaceae......"pondweed family"	
Potamogeton sp.	+
Najas gracillima (A.Br.) Magnus	+
Najas guadalupensis (Spreng.) Magnus	+
Najas flexilis (Willd.) R.S.	+
Cyperaceae......"sedge family"	
Carex sp.	+
Scirpus sp.	+
Eleocharis sp.	+
Papaveraceae......"poppy family"	
Papaver sp.	+
Rosaceae......"rose family"	
Rubus sp.	+
Gentianaceae......"gentian family"	
Menyanthes trifoliata L.	+

ARTHROPODS

INSECTA

COLEOPTERA......"beetles"	
Carabidae......"ground beetles"	
Notiophilus sp.	+
Dyschirius sp.	+
Hydrophilidae......"water scavenger beetles"	
Hydrobius sp.	+
Staphylinidae......"rove beetles"	
Acidota quadrata Zett.	+
Arpedium cribratum Ful.	+
Stenus sp.	+
Lathrobium sp.	+

Chrysomelidae......"leaf beetles"	
Donacia sp.	+
Curulionidae......"weevils"	
genus?	+
DIPTERA......"flies"	
Family?	+
HYMENOPTERA......"wasps and ants"	
Ichneumonoidea......"Ichneumons and braconids"	
Family?	+
ARACHNIDA	
Araneae......"spiders"	
Family?	+

Identified by J.V. Matthews and R.J. Mott,
Geological Survey of Canada

COMMENTS BY J.V. MATTHEWS (1987)

"The Pointe St.Nicolas site near Quebec City has yielded a small assemblage of plant macrofossils and insects. They indicate a poorly drained sedge-dominated site within a region containing spruce. The macrophyte **Najas gracillima** is an eastern species that, in the Ontario-Quebec region, is known from only one site on the upper Ottawa River. **Najas quadalupensis** has a similar distribution.

However, because Najas is often overlooked by field botanists or misidentified in botanical collections it must be assumed that the present published distribution of Najas species is poorly known, especially near their northern limit. Hence, the Najas fossils should not be considered by themselves as a definitive climatic indicators.

The insect fossils provide additional climatic information. **Apredium cribratum** is eastern in distribution with its northermost records in central Ontario. **Acidota quadrata** is a widely distributed northern species with relict populations at high elevations in New Hampshire, Maine, and Colorado (Campbell, 1982). Some of its southern Quebec localities are at higher elevations (Lac Sainte.Anne-46 m and Parc des Laurentides-610 m, a.s.l.) which is in accord with its overall northern distribution. Therefore, it is unlikely that climate at the Pointe St.Nicolàs Site at the time of deposition was much warmer than today, and it may have been slightly colder."

Beaupre Varved Sediments

These sediments were exposed during road construction at Beaupre, near Mont Ste.Anne, 30 km east of Quebec City. About 10 m of silty varved sediments with load and glaciotectonic structures were present at this site; coarser sediments, probably proximal varves were exposed in a separate section. These deposits contain bryophyte assemblage which is probably redeposited Tertiary material. The Beaupre varved sediments are presumably correlative with the Deschaillons Formation.

Bryophyte flora identified at the Beaupre Section

Eurhychium sp. sec. Swartzii; Dry, forested habitats. Well preserved.

Ceratodon purpurues. Cosmopolit. Polyedaphic.

Pogonatum alpinum. Arctic-alpine. Pan-continental. Common moss.

Polytrichum junipernium. Pan-continental. Dry places, often in forest.

Polytrichum sp.

Anomodon sp. On rocks and rocky ground. It needs more taxonomical studies.

Mniobryum wahlonbergi. Holarctic. Pan-continental. Differentiated habitats near polyedaphic moss. Nearly whole specimens.

Pohlia sp. Several types. Some of them perfectly preserved.

Amphidium sp. Rocky soil or rocks. Alpine-arctic.

Tortula sp. of **ruralis.** Holarctic, dry habitats.

Drepanoclaudus revolvens. Holarctic bogs.

Drepanoclauds exannulatus. Pan-continental. Bogs, water bodies, streams. Well preserved.

Drepanocladus sp.

Aulacomnium. Holarctic bogs.

Aulacomnium p. var. **imbricatum.** Alpine-arctic. Bogs.

Aulacomnium tungidum. Alpine-arctic. Tundra: mesic and dry growths.

Rhacomitrium sudeticum. Alpine-arctic. Rocks, streams, tundra.

Rhacomitrium sp.

Bartramia ithyphyla. Holarctic, wide-ranging. Bare grounds, tundra and forests.

Ditrichum flexicaule. Holarctic. Dry, open rocky soils.

Calliergon sp. **cf. sarmentosum.** Arctic-alpine. Tundra: stream, bogs, water.

Calliergon sp.

Hygrohypnum sp.

Sphagnum sp. Two types. Bogs.

Philonotis fontana (sensu lato) Holarctic bogs, streams, tundra: wet and mesic.

Thuidium sp. It needs more taxonomical studies.

Pottiaceae

Amblystegiaceae

Brachytheciaceae

Bryum sp.

Identified by Marian Kuc, formerly with the Geological Survey of Canada

Quebec City Till

This material which overlies the Beaupre varved sediments, is the surface till in most of the Quebec City area. Generally, it is a very compact calcareous till containing mainly striated clasts of limestone and other local rock types; precambrian erratics are also present. It is locally clayey where the glacier overrode varved sediments.

The uppermost unit of the St.Augustin ice-contact drift complex, exposed in a pit about 6 km south of the village of St.Augustin on the north shore of St.Lawrence River, is assumed to be a local facies of the Quebec City Till. This unit is approximately 10 m thick and is composed of well rounded clasts of cobble to boulder size, almost exclusively of precambrian origin, and a matrix of poorly sorted angular sand. Boulders are also scattered in the forest to the east of the pit. Large clasts of till are also present near the base of this unit. This unit rests in part on bedrock, and in part on sand that are tentatively correlated with the Anse-aux-Hirondelles sediments. Short sequences of varved sediments (50 cm to 1 m thick) are present in the sequence.

To this author, the interpretation of the sequence at St.Augustin is very tentative and requires more field work. It is not at all certain that the stratified sands and gravels present in this pit are correlative with l'Anse-aux-Hirondelles sediments. They may be in part glacio-fluvial in origin, and may have been deposited by an ice lobe advancing upstream from the northeast as is suggested by current structures. The upper bouldery and cobbly unit may be related to the St.Nicolas readvance and may have been deposited at the northern edge of an ice lobe (fig. 9b) as a mass deposit. The sequence is overlain by Champlain Sea sediments in turn covered by peat (see section, Stop 8).

List of radiocarbon dates obtained on interglacial organic sites, Quebec City area:

Date (Years BP)	**Sample**	**Location**	**Material**	**Reference**
>44 000	Y-463	Donnacona	Organic debris	Karrow, 1957
>39 000	QU-327	Vallee Jonction	Bryophyte remains	LaSalle, 1984
>39 000	GSC-1539	Beaupre	Bryophyte remains	LaSalle, 1984
>37 000	GSC-1478	Beauport	Wood	LaSalle, 1984
36 560±4690	QU-439	Pointe St.Nicolas	Organic debris	LaSalle, 1984
28 375±775	UGa-463	Pointe St.Nicolas	Organic debris	LaSalle, 1984
>42 000 BP	GSC-3420	Pointe St.Nicolas	Organic debris	LaSalle, 1984
60 200±700	QL-1909	Pointe St.Nicolas	Wood	LaSalle, 1984

Dates obtained on organics from L'Ile-aux-Coudres site (Brodeur and Allard, 1985) circa 100 km northeast of Quebec City:

26 400±960	UL-10	Ile-aux-Coudres	Peat	Brodeur and Allard, 1985
28 170±800	I-13549	Ile-aux-Coudres	Peat	Brodeur and Allard, 1985
30 220±1060	UL-12	Ile-aux-Coudres	Peat	Brodeur and Allard, 1985

All the finite ages reported above should be considered as minimum.

Breakyville Morainic Ridges

Those morainic ridges are located south of the St.Lawrence River, well within the limit of the Goldthwait or Champlain Sea. The exposures near Breakyville shows ice contact sediments, at the northern end of the pit, and glacio-lacustrine sediments in a distal position to the south. Mass (?) deposits with uncomformable lower boundaries have been observed in the section on the eastern side of the pit near the bush. No marine fossils have been observed in those sediments yet and they have been interpreted as representing the last stand of the Laurendide ice in a glacial lake, extending to the south in the Chaudiere and Lac Etchemin valleys. Varved sediments belonging to that glacio-lacustrine episode were well exposed during recent excavation in Ste.Marie, and are also present in a brickyard in Scott Junction. A small delta, built during one of those lake stages, can be seen on the west side of the Chaudiere River, between Scott Junction and Ste.Marie.

It is unlikely that the sediments observed in those ridges are related to the St.Nicolas glacial readvance because there is no conclusive evidence that, at that time (St.Nicolas readvance) the ice blocked the drainage to the Atlantic, in part or otherwise. The St.Nicolas ice advanced only in the Champlain Sea. To the south its influence seems to die out in marine sediments at the height of St.Lambert or a little to the north of it. C.G. Rodrigues has examined marine sediments in that area and variations in the micro-fauna suggests a readvance of the ice in the marine basin. Further west, at section 17 along Riviere-du-Chene, in a distal position, the St.Nicolas readvance is represented by a layer of coarse gravel about 30 cm above the base of the Champlain Sea sequence.

Lac St.Charles Moraine

The Lac St.Charles Moraine was first thought to be part of the St.Narcisse Morainic System and was briefly described by LaSalle (1970). The expansion of exploitation have opened many new sections in the moraine. Besides the original sequence of gravel and sand at the base, overlain by marine (presumably) sediments, units (lenses?) of glacial diamicton can be observed, intercalated in what is presumably a non-fossiliferous marine sequence. A large group of dish structures could be observed on the occasion of a visit last November. The presence of those structures at the marine limit or close to it, is consistent with the currently accepted hypothesis concerning their origin: dewatering of sediments (sand or silt) following episodes of high sedimentation rates (Cheel and Rust, 1986). The presence of glacial diamicton suggests the proximity of the glacier nearby in the marine waters when the sediments were "dumped". It is not possible to pond a glacial lake with the ice front at or near the position of the Lac St.Charles Moraine: The drainage to the Atlantic would then presumably be opened.

A similar sequence of sediments is found on the opposite side (east side) of Lac St.Charles valley (Tonio's Gravel pit): Shells of **Mya truncata** collected in growth position in the glacial diamicton in that pit have yielded an age of 11 600±160 BP (GSC-1235). It dates a stand of the ice front in the Champlain Sea before the St.Nicolas readvance which occured some time after 11.0 Ka BP (see St.Nicolas readvance in this guidebook).

St.Nicolas Drift and the St.Nicolas Readvance

This term "St.Nicolas drift" designates (LaSalle, 1984) a compact fossiliferous and calcareaous diamicton that has been observed at several localities in the Quebec City area and west of it. This material has an abundance of local lithologies and contains **Balanus hameri**, commonly with basal plates still attached to the clasts. Dates obtained on **Balanus hameri** are all in the range 11-11.2 Ka BP (e.g. 11 200±160 years BP, GSC-1176; LaSalle et al., 1977; see list of dates). The deposition of this fossiliferous drift is associated with the St.Nicolas ice readvance into the Champlain Sea but predates the construction of the St.Narcisse Moraine and is considered equivalent in age to some of the St.Narcisse glacio-marine sediments (LaSalle and Elson, 1975).

The St.Nicolas glacial readvance has been referred to only tangentially in LaSalle and Elson (1975), LaSalle et al. (1977) and LaSalle (1984). New sections and excavations have rendered necessary further discussion of this glacial event. Originally, it was thought that this glacial readvance had taken the form of a lobe (fig. 9a), extending to the east and northeast in the St.Lawrence channel, since fossiliferous compact glacio-marine diamicton had only been found on both sides of it, in a seemingly lateral position with respect to a lobe occupying the central part of the channel. New sections in reactivated gravel pit tend to confirm: (1) that ice was grounded south of the present St.Lawrence channel, at least on low bedrock ridges, and (2) that mass flow subaqueous deposits

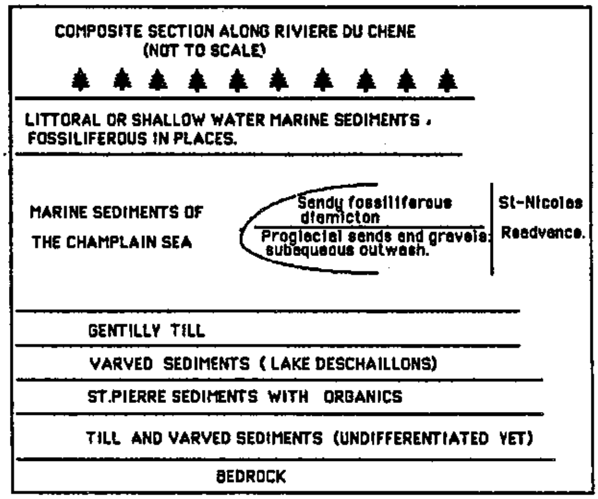
(Rust and Romanelli, 1975) are associated with that readvance to points of a few kilometers south of the present St.Lawrence River.

Evidence for the St.Nicolas readvance and its terminal position in the Champlain Sea are the following:

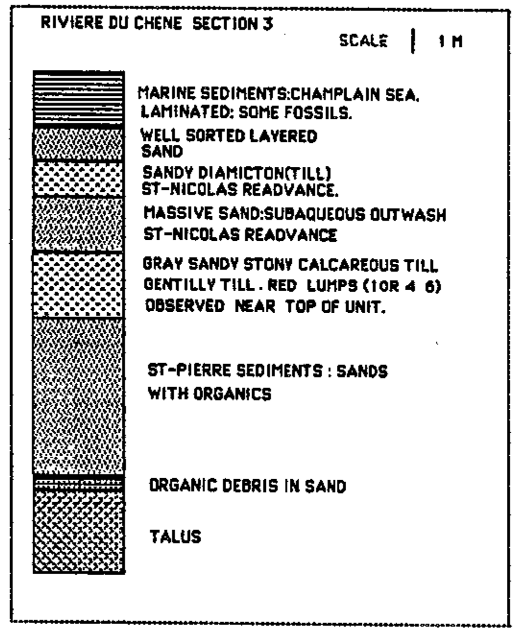
Evidence 1: The presence of a low morainic ridge and scarp approximately 5 km west of St.Edouard-de-Lotbiniere, west of Riviere-du-Chene, southwest of Quebec City. That ridge is made of a sandy diamicton overlying a sandy deposit akin to mass flow subaqueous deposit similar to the one described by Rust and Romanelli (1975) and Rust (1977) in the Ottawa area. These sediments were emplaced slightly ahead of an advancing ice front or at the edge of a stagnating or idle ice shelf. The till (or rather glacio-marine diamicton) shows some pseudo-stratification and low angle thrust planes suggesting a readvance from the north in the marine waters of the Champlain Sea, though no indication of former life is observed in the sediments of the ridge itself. It is probable that marine organisms were not "encouraged" (Rust and Romanelli, 1975) to live in such unstable environment; shells, if ever present, may also have been leached from such a porous sediment.

The section in the morainic ridge is about 4 m high; very few stones are present in the diamicton which is rather well sorted. The sediments underlying the diamicton are barely visible in this section. One may suspect that the glacier advanced on pro-glacial sands in the Champlain Sea for some distance. The surface of the ridge has been reworked during late Champlain Sea time.

Evidence 2: At several sections along Riviere-du-Chene, sandy till can be observed overlying well sorted sand. There is virtually no large stones in the till at one of the sections. At another section, the diamicton is more stony at the top. The pro-glacial sand is resting on gray stony calcareous till. The sandy diamicton is correlated with the St.Nicolas event, on the base of stratigraphic position in the sequence, which makes it correlative with fossiliferous diamicton further east. At one of the sections mentioned above, the sandy diamicton is overlain by deep water marine sediments of the Champlain Sea.



COMPOSITE SECTIONS ALONG
RIVIERE-DU-CHENE



RIVIERE-DU-CHENE SECTION 3

Evidence 3: More evidence is found in the sections of the three pits located along the Bourret stream. These pits (Bourret 1, 2, 3) have been reactivated after approximately 20 years of inactivity in the fall of 1987.

<u>**The Bourret (2) sections**</u> shows the following:

THE BOURRET (2) SECTION SHOWS THE FOLLOWING:

LITTORAL SANDS AND GRAVELS, FOSSILIFEROUS, APPROX. 1 M THICK.	<u>MACOMA BALTICA</u> <u>MYTILUS EDULIS</u> <u>HIATELLA ARCTICA</u> <u>MYA ARENARIA</u>
GRAY CALCAREOUS COMPACT DIAMICTON CONTAINING <u>BALANUS HAMERI</u>; APPROX. 1 M THICK.	
STRATIFIED SAND AND GRAVEL WITH LARGE CHANNEL STRUCTURES, SIMILAR TO THOSE DESCRIBED BY RUST AND ROMANELLI (1975). MASSIVE SAND UNITS ARE ALSO OBSERVED. ABOUT 3 M OBSERVABLE.	

The Bourret (3) section shows well sorted stratified sand capped by gray stony calcareous till. It also shows high angle reverse faults that suggest that ice was buried under the sandy proglacial deposit during the readvance. Well laminated sediments intercalated between the sand and the till suggest also quiet deposition in deep water at some point during the readvance. **Balanus hameri** shells have not been observed yet in the diamicton at the Bourret (3) site.

The Bourret (1) sections shows much the same stratigraphy. However, the glacial diamicton that contains the **Balanus hameri** shells is intercalated between two short sequences of apparently well layered marine sediments. Some of the strata are very sandy.

Evidence 4: At pointe St.Nicolas, and at two other sites, east of Quebec City area, till containing **Balanus hameri** has been observed; the shells have yielded the following ages: 11 100±160 BP (GSC-1232), 11 200±160 BP (GSC-1295) and 11 200±170 BP (GSC-1476). Low-angle thrust faults planes and other deformation structures have been also observed in the till and in the associated sediments at Pointe St.Nicolas.

At the time of the St.Nicolas readvance, the ice shelf extended beyond the shore of the present St.Lawrence River and was grounded in marine waters at least where low bedrock ridges were present. Subaqueous mass flow sediments were emplaced. Shells of **Balanus hameri** are the only abundant shells in this till because, prior to the readvance at about 11.2 Ka BP (GSC dates on **Balanus**) or slightly after, these organisms were presumably the only ones forming large colonies in deep waters of the Champlain Sea. Today, they can be observed as marker horizons in many sections north of the St.Lawrence River, west of Quebec City. Some of these horizons may postdate the St.Narcisse event in some places. On the south shore and inland, within the limit of the St.Nicolas readvance, the shells are observed in the till or they are stratigraphically buried below the mass flow deposits.

Given the maximum age of the St.Nicolas readvance, which is also a maximum age for the emplacement of the St.Narcisse Moraine (at least for a sector northwest of Quebec City), it is likely that the St.Nicolas readvance and, associated deposits together with the St.Narcisse Moraine in part, are correlative with the Younger Dryas of the European climatic sequence. Paterson and Hammer (1987) have placed the end of the Younger Dryas in the Greenland ice core Dye no. 3 at about 10 750 BP. (Paterson and Hammer, 1987, p. 100).

Similar deposits of approximately the same age as the St.Nicolas diamicton and associated sediments have been reported by Stea and Mott (1988) for the late Wisconsinan-Holocene in Nova Scotia. Mott et al. (1986) have also reported the presence of the Younger Dryas oscillation in lake sediments cores in the Maritime Provinces (see also Boothroyd and Lawson, 1989). Finally, environmental conditions during the emplacement of the St.Eugene organic deposit, which has been dated at 11.1 Ka BP (QU-448, 11 050±130 BP, Mott and Matthews, 1984) and has yielded an arctic flora and beetle fauna, are rather likely related to the proximity of the St.Nicolas ice front than to the proximity of the ice front at 12.0 Ka BP, as depicted by Morgan (1987).

I would suggest that the St.Nicolas diamicton was deposited in a subglacial position in deep water in an environment similar to one described by McAbe et al. 1984; 1987). I would also suggest that in places where the marine sequence overlying till starts at approximately 11.0 Ka BP, it is likely to be post-St.Nicolas, and the underlying glacial diamicton is correlative with the St.Nicolas drift (glacial diamicton and associated sediments). The St.Nicolas drift must be present west of the Portneuf (21L/12) - Becancour (31I/9) NTS boundary. Deep water sediments of the Champlain Sea, deposited before the St.Nicolas readvance, are not always present under the subaqueous outwash.

General discussion

The sequence of glacial and non-glacial events in the Quebec City area should resemble in a broad sence the sequence further to the west in the St.Lawrence Lowland at least as far as the Montreal area, unless some of those events (like the St.Nicolas readvance) are restricted to the Quebec City area or east of it. Except for the St.Nicolas drift, there is no evidence yet for that kind of dichotomy in the glacial sequence especially in view of the new date obtained on wood from Pointe St.Nicolas by the enrichment method, 60 200±700 years BP (QL-1909). The sequence in the Quebec City area is made of at least two glacial events (perhaps three, excluding the St.Nicolas) separated by a non-glacial episode (Anse-aux-Hirondelles) during which the sea apparently did not enter the St.Lawrence Lowland, and presumably did not occupy the estuary at least as far as l'Ile-aux-Coudres. The sedimentary sequence at l'Ile-aux-Coudres, 100 km northeast of Quebec City, as recorded in a section described by Brodeur and Allard (1985), appears to fit well the sequence observed in the Quebec City area.

However, the finite radiocarbon dates obtained (at l'Ile-aux-Coudres) by Brodeur and Allard (1985) in the 25 to 32 Ka BP range are at variance with the expected age (74 700$\pm^{2700}_{2000}$ years BP, QL-198, Stuiver et al., 1978) and with the age obtained on the organic beds at Pointe St.Nicolas (60 200±700 BP; QL-1909). There, the finite dates 36 560±4690 (QU-439), 28 375±7 775 (UGa-463) years BP, were obtained from laboratories using the benzene dating method. Serious reservations are being entertained about finite radiocarbon dates in the 30-40 Ka range obtained by the benzene method (Radnell and Muller, 1980). Also, QU-439 and UGa-463 were never published because of the strong possibility of contamination by modern rootlets. This was not the case for GSC-3420 and QL-1909, which were collected from a section exposed recently, and with no apparent possibility of contamination by rootlets.

Seawaters seem to have inundated the lowlands west of Quebec City only after the last glaciation. During the St.Pierre interglacial, base level was approximately 20 m higher than the present one and sea level was also higher. That event appears to correlate with Oxygen Isotope Stage 5 (Shackleton and Opdyke, 1973) and also with the upper part of the Sangamonian Stage. The St.Pierre Interglacial was a period of aggradation and deposition of peat and sand in the form of an estuarine plain. It should be pointed out that during the Gentilly glacial stage, after the St.Pierre Interglacial, there was partial deglaciation (Gayhurst) in the northeast of North America and the ice front retreated as far north as the Appalachians of southeastern Quebec (McDonald and Shilts, 1971). It however remained south of Quebec City (Vallee Jonction?), but it apparently reached the Montreal area (Prest and Hode-Keyser, 1977).

An important morphological feature in the Quebec City area is the Micmac terrace. It is a prominent rock platform that is well displayed on the north shore for some 30 km between Quebec City and Beaupre. It is also well displayed around the Anticosti Island and on the south shore of the St.Lawrence River around the Gaspe Peninsula (e.g. Pointe St.Pierre area) and in the Baie-des-Chaleurs area. In the Quebec City area and at many other points where it is observed, it is covered by glacial, and/or marine and/or fluvial sediments.

The development of this rock platform is presumably related to a high sea level during an interglacial like the Sangamonian (of which the St.Pierre is part) as reported above. In some places, glacial sediments are lying directly on the rock platform and this indicates clearly that its development precedes the last glaciation. The Micmac terrace has been described and discussed by Goldthwait (1911) and he thought that it had formed in post-glacial time during the Champlain Sea episode. As has been explained above, the formation of the Micmac terrace certainly precedes the last glacial advance, as Gentilly Till and varved sediments of Lake Deschaillons which are resting directly on it at Beaupre.

As the reentrant produced in the ice sheet or ice shelf progressed towards Quebec City, there was a reversal of ice flow in the Appalachians (Chauvin et al., 1985). This reversal of ice flow was transgressive in time from the eastern part of Gaspesie to the Thetford-Mines area (Lamarche 1971, 1974). It was the result of drawdown caused by the calving of the ice in the sea in the St.Lawrence estuary. The separation of the Laurentide ice and the Appalachian ice east of Quebec City occurred on land approximately at the position of the Highland Front Moraine (Gadd, 1964). There is no evidence yet for a readvance of the ice in the sea prior to or attendant upon the emplacement of the Highland Front Moraine.

The inception of the Champlain Sea in the Quebec City area is dated at about 12.5 Ka BP (GSC-1533, 12 400±160 BP). It must be remembered here that shells from the same collection that yielded GSC-1251 (12 800±100 BP, outer fraction; 12 700±100 BP, inner fraction) have been dated by the accelerator method at 12 180±90 years BP (TO-245, Fulton and Richard, 1987, p. 24). It would thus appear that GSC-1251 is too old, unless we are looking at minimum ages (Karrow, 1981) in some parts of the Champlain Sea basin. At this point, TO-245 and GSC-1533 (12 400±160 years BP) seem consistent with one another, since, in all probability and logic, dates on marine shells related to the inception of the Champlain Sea should be progressively younger from east to west, if the event was spread over a period of a few hundred years or a time interval longer than the resolution normally given by radiocarbon dates.

After reaching Quebec City, the sea waters appear to have merged with a large glacial lake that existed in the Montreal area (possibly Lake Iroquois) or some other glacial lakes that occupied the larger valleys in the Appalachians (e.g. Glacial Lake Orford, McDonald, 1967), or an extension of Lake Vermont to the northeast and northwest (Anderson et al., 1985).

During the Champlain Sea episode, circa 11 Ka BP (GSC-1232: 11 100±160 BP; GSC-1295: 11 200±160 BP; 11 200±170 BP; LaSalle et al., 1977) the ice readvanced in the Champlain Sea in the Quebec City area but did not block the entrance of the marine waters. This is demonstrated by the presence of fossiliferous glacio-marine drift at several sites in the Quebec City area. This readvance (St.Nicolas readvance) preceded the emplacement of the St.Narcisse moraine at least in the area northwest of Quebec City. All shells dated for GSC-1232, 1295 and 1476 belong to the species **Balanus hameri** and suggest a deep water phase prior to the emplacement of the St.Narcisse moraine north of the St.Lawrence River. Shoaling and freshening of the waters seem to have proceeded gradually in the Quebec City area and in the St.Lawrence Lowland west of it, following the St.Narcisse episode. Freshwater shells **Elliptio complanatus**, 9 730±190 BP, GSC-1796) have been recovered in estuarine sediments in the Cap-Rouge area.

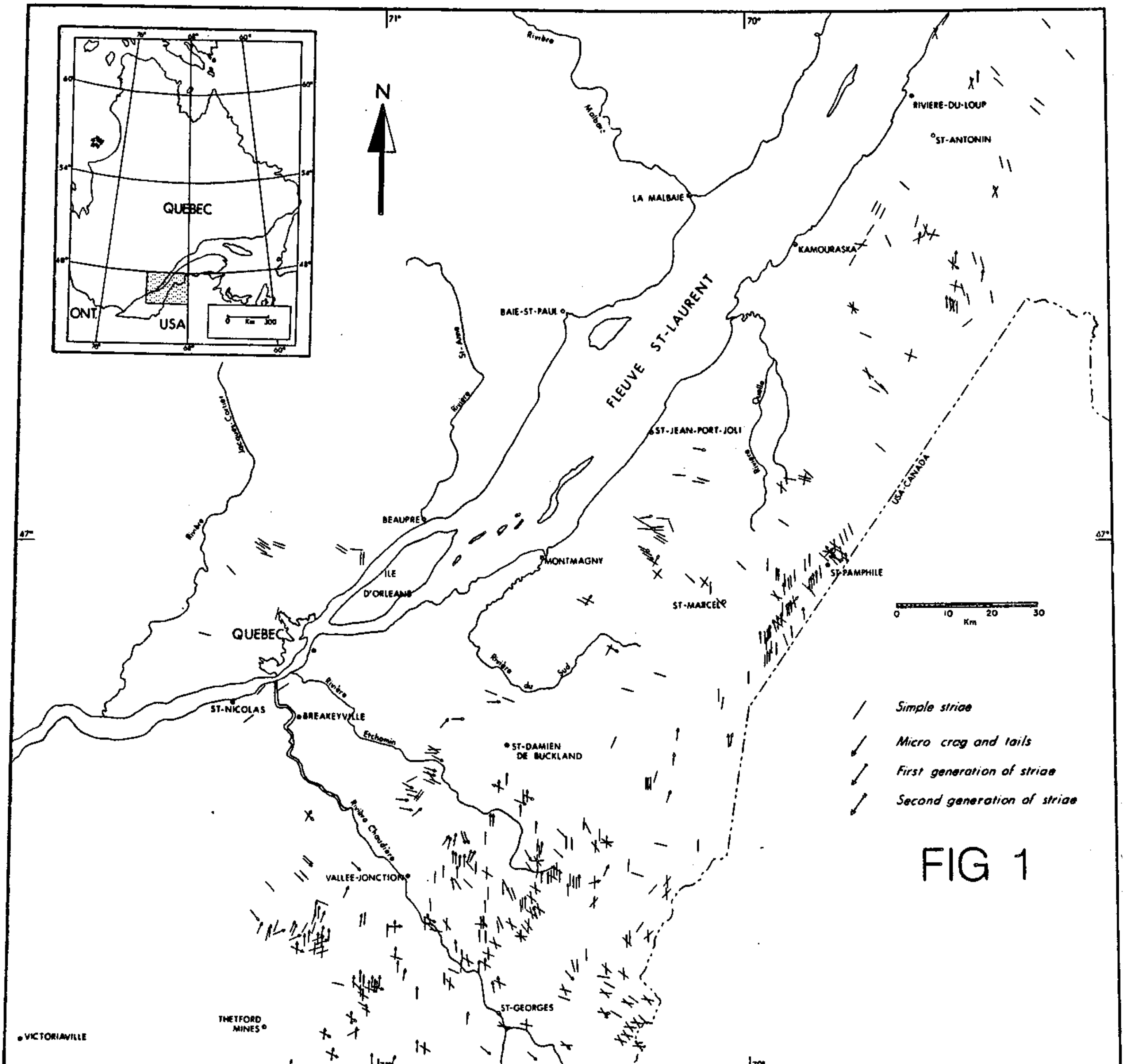
There is also evidence for the existence of a freshwater lake west of Quebec City, after the marine waters receded east of it and the Champlain Sea episode ended. This lake has been named Lake Lampsilis after the freshwater mollusk **Lampsilis siliquoidea** (Elson and Elson, 1959; Richard, 1978). Erosion in the St.Lawrence channel near Quebec City, as the present drainage was being established, put an end to the lake (Elson and Elson, 1959; Elson, 1982).

Radiocarbon dates pertinent to deglaciation of Quebec City region at large

LOCALITY	LAB. No.	^{14}C AGE BP	LONG W	LAT. N	ELEVATION (Metres)	MATERIAL AND REFERENCES
ST.NICOLAS	QU-98	11120±220	71°27.2	46°14.7	70	Balanus hameri in glacio-marine diamicton. St-Nicolas readvance. (LaSalle, unpub.)
OTTAWA (Clayton, Lanark County, Ontario)	GSC-2151	Inner fraction: 12700±100 Outer fraction: 12800±100				Hiatella arctica (Richard, 1978)
OTTAWA (Clayton, Lanark County, Ontario)	TO-245	12180±90	Accelerator date			Hiatella arctica, same collection as GSC-2151 (Fulton and Richard, 1987)
ST.EUGENE	QU-448	11050±130	70°19.3	47°04.2	145	Organic debris in deltaic sand and gravel (Mott & al, 1981)
BEAUPORT	GSC-1232	11100±160	71°12.5	46°53.7		Balanus hameri in glacio-marine diamicton. St-Nicolas readvance
LAPOINTE	GSC-1295	11200±160	71°56	47°01.1	68	Balanus hameri in glacio-marine diamicton. St-Nicolas readvance
ST.NICOLAS	GSC-1476	11200±170	71°27	46°41.8	70	Balanus hameri in glacio-marine diamicton. St-Nicolas readvance
CHARLESBOURG	GSC-1533	12400±160	71°17	46°51.2	110	Articulated shells of Portlandia arctica in clayey sand below
ST.NAZAIRE	GSC-312	12640±190	70°36.3	46°35.8	±400	Non-calcareous gyttja at base of organic core (Gadd, 1964)

LOCALITY	LAB. No.	^{14}C AGE BP	LONG W	LAT. N	ELEVATION (Metres)	MATERIAL AND REFERENCES
NOTRE-DAME DES LAURENTIDES	GSC-1235	11600±160	71°17	46°54.4	177	<u>Mya</u> <u>truncata</u> in glacio-marine diamicton
ST.NICOLAS	QU-20	11260±290	71°13	46°41.8	70	<u>Balanus</u> <u>hameri</u> in glacio-marine diamicton
ST.HILAIRE	GSC-419	12570±220	73°08.5	45°33.5	260	Non-calcareous gyttja at base of organic core
ST.HENRI-DE-LEVIS	QU-93	12230±250	71°07.5	46°38.4	103	<u>Hiatella</u> <u>arctica</u>
TROIS-PISTOLES	GSC-102	12720±170	69°07.9	48°07.7	98.5	<u>Portlandia</u> <u>arctica</u> (Lee, 1962)
ST.ANACLET	QU-263	12220±450	68°22.8	48°29.0	82-105	<u>Mya</u> sp. in silt (Locat, 1977)
ST.DONAT	QU-264	13360±320	68°15.9	48°30.1	90-126	<u>Hiatella</u> <u>arctica</u> in clayey marine silt (Locat, 1977)
ST.FABIEN	QU-270	12300±260	68°51.2	48°18.4	138-155	Several species of marine shells in glacio-marine diamicton (Locat, 1977)
ST.FABIEN	QU-271	13390±160	68°51.2	48°18.4	138-155	<u>Hiatella</u> <u>arctica</u> in glacio-marine diamicton (Locat, 1977)
NEWINGTON (Ontario)	GSC-2108	11200±100				Shells in glacio-marine diamicton (Richard, 1977)

SEQUENCE OF MAPS SHOWING FACTS AND HYPOTHETICAL SEQUENCE OF EVENTS DURING THE DEGLACIATION OF THIS AREA



Directions of ice flow as indicated by striations and micro-crag-and-tails

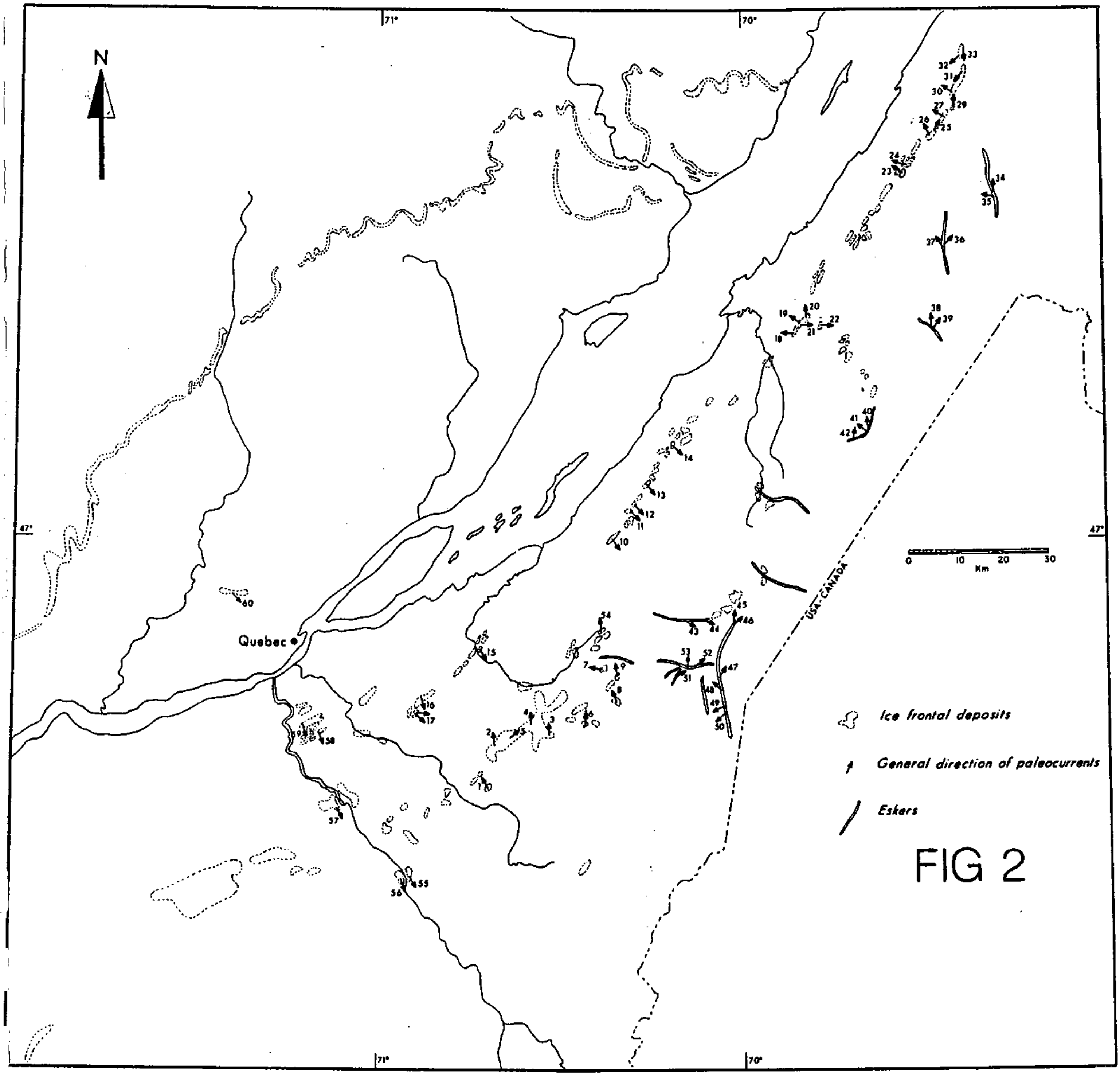
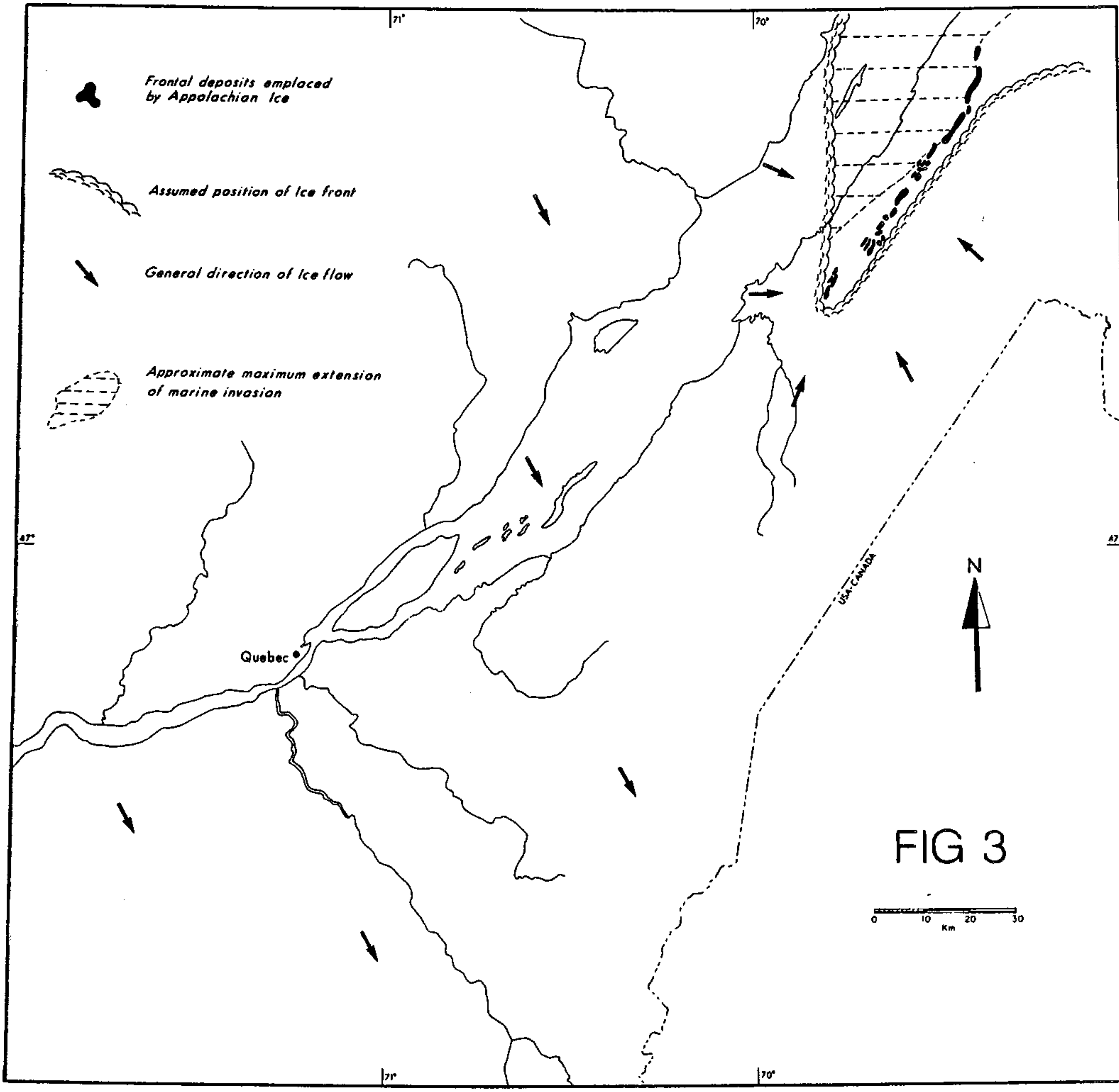
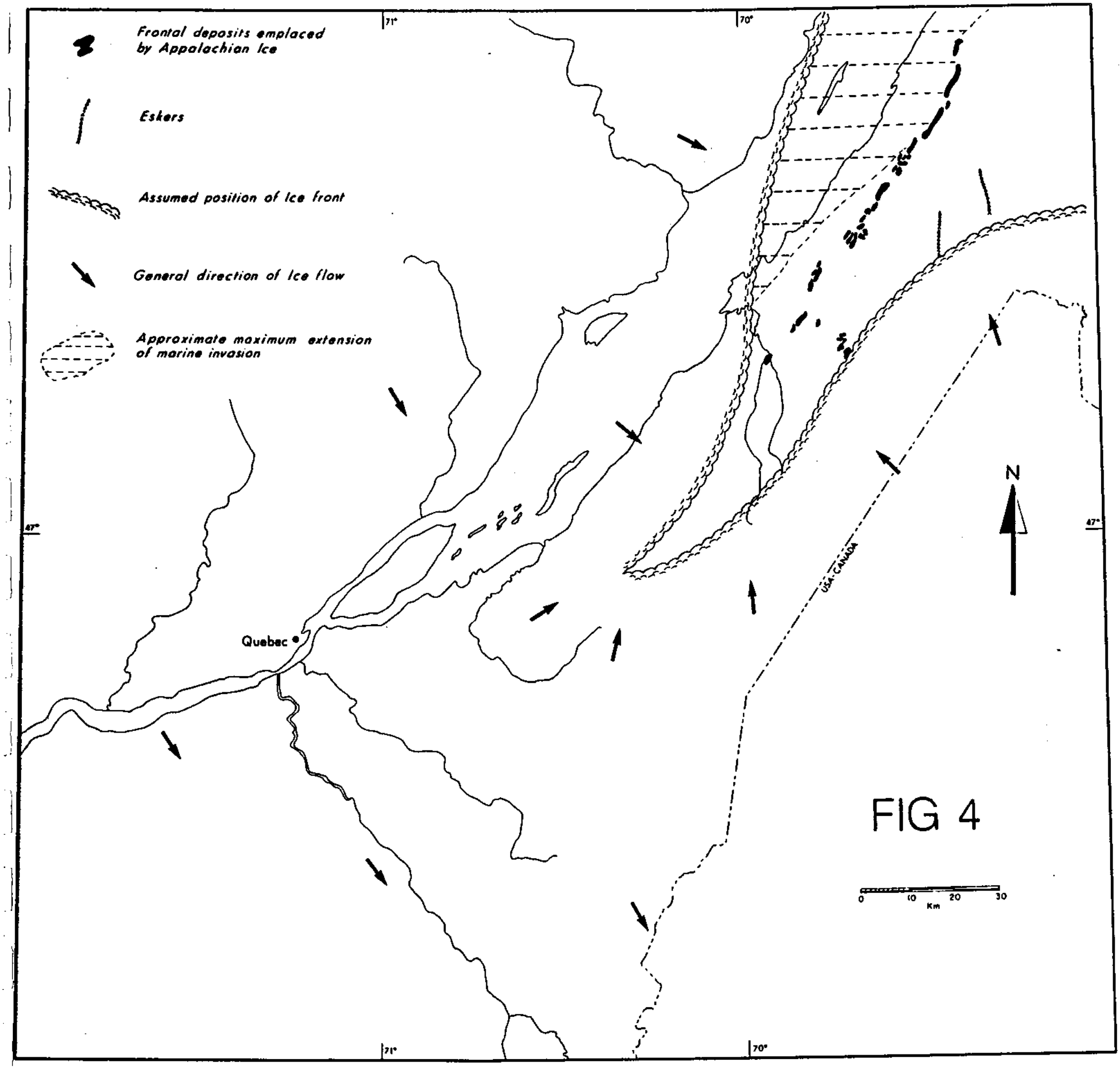


FIG 2

Ice frontal deposits and directions of meltwater flow
as indicated by various types of cross-bedding



Ice frontal position at time of emplacement of St.Antonin moraine circa 13.5 Ka BP



Ice frontal position showing line of separation of
ice masses in axis of St.Antonin moraine circa 13.4 Ka BP

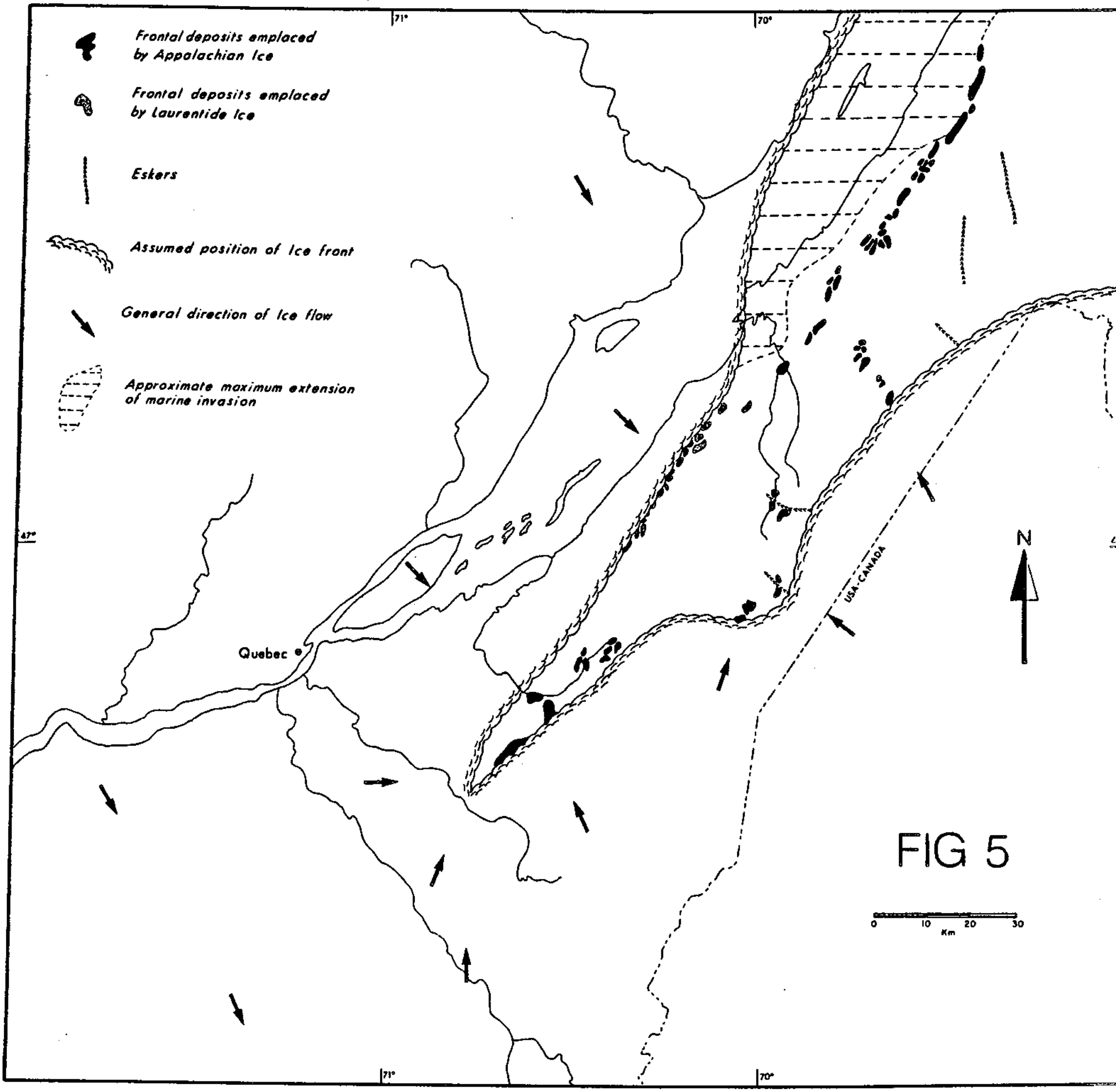


FIG 5

Ice frontal position at time of emplacement of St.Jean-Port-Joli moraine and beginning of St.Damien complex episode circa 13.2 Ka BP

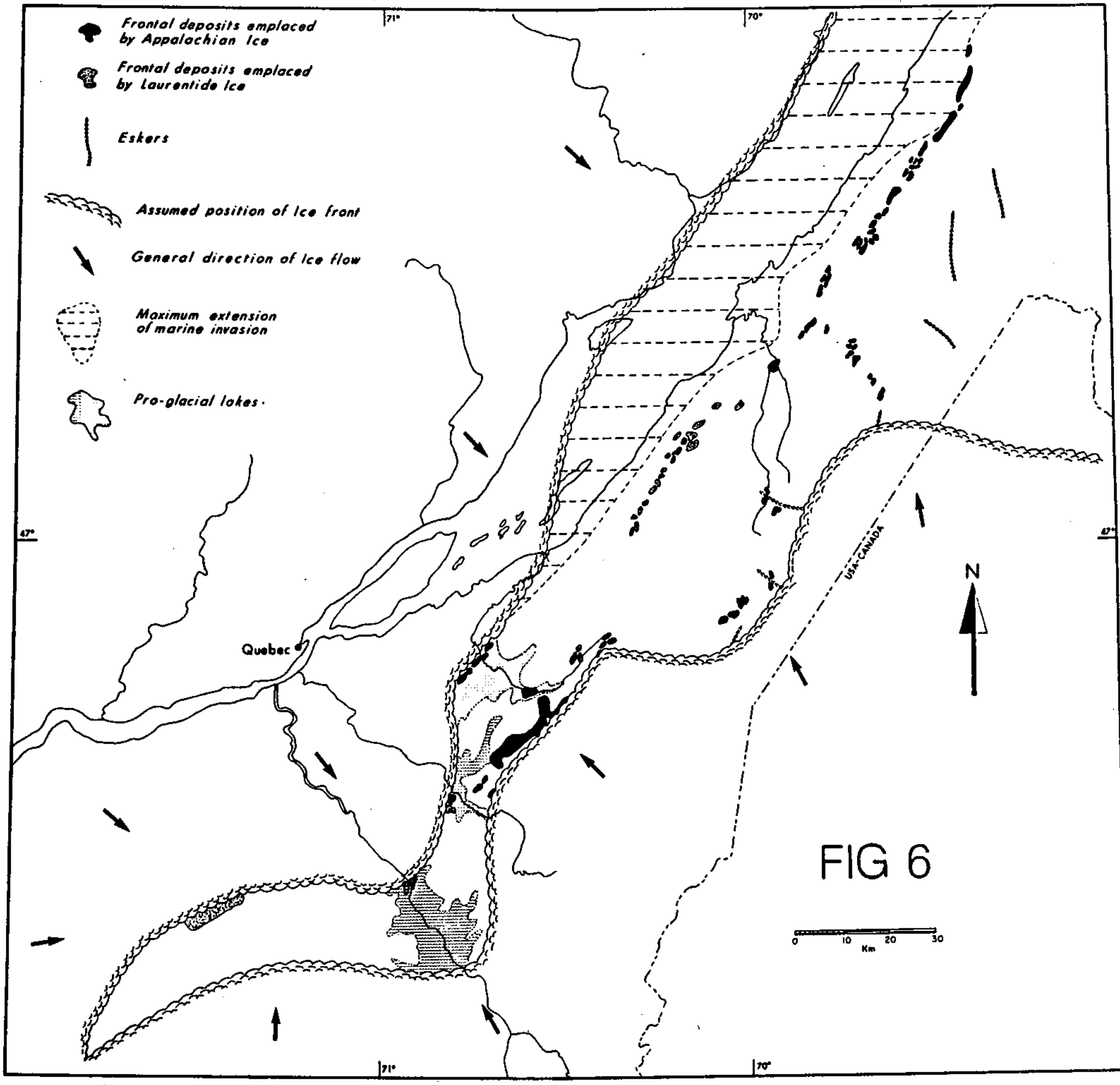
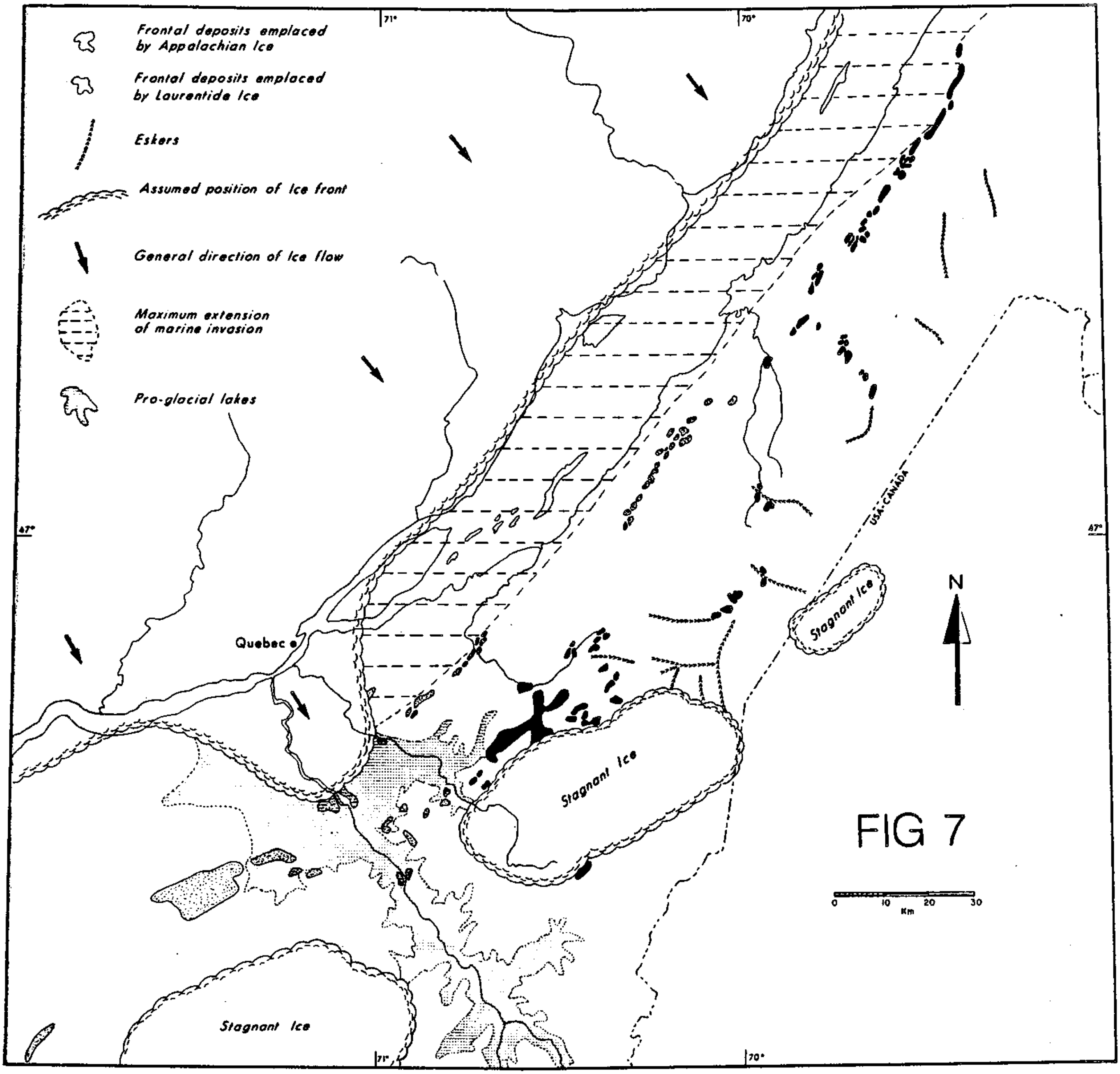
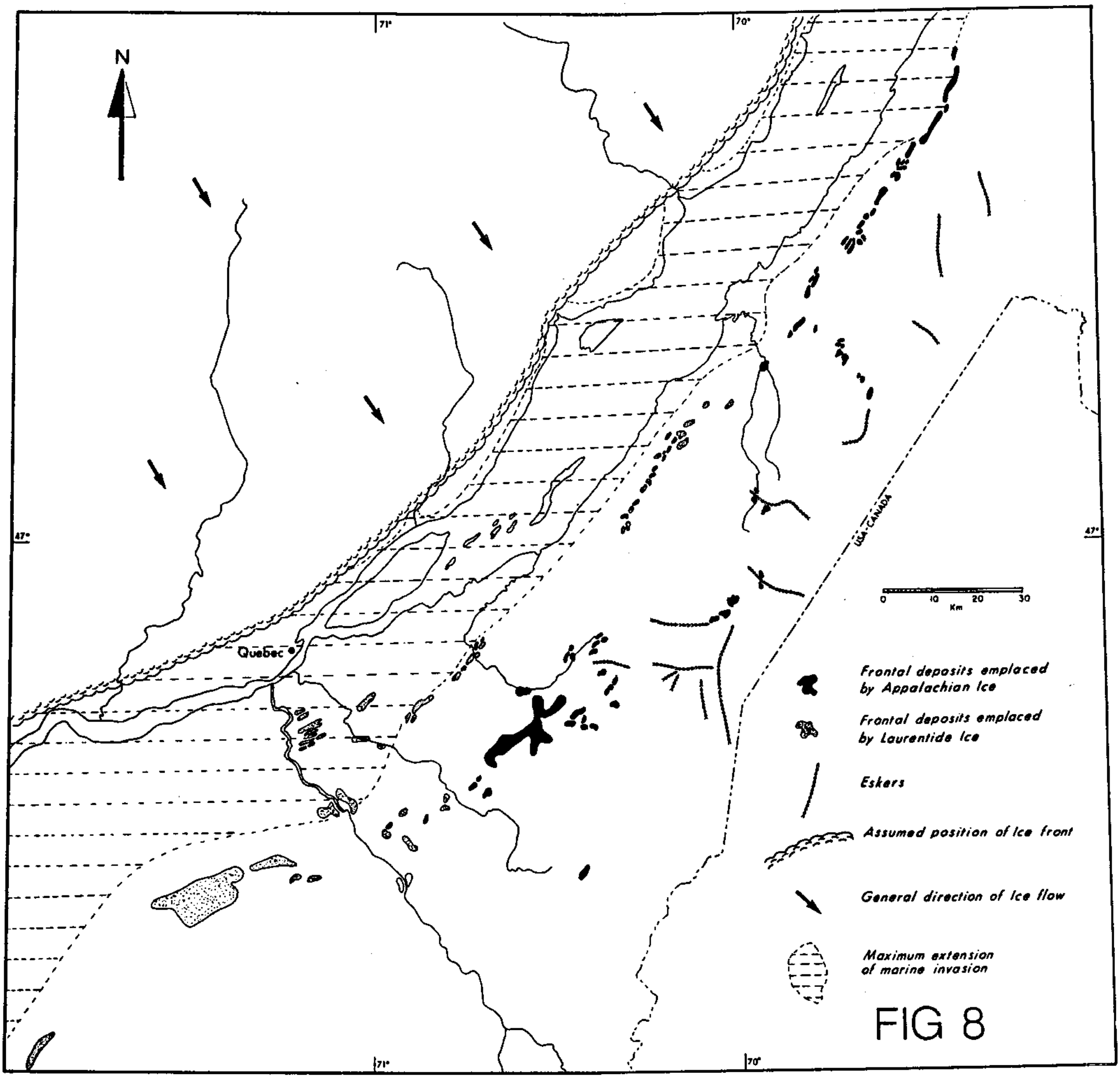


FIG 6

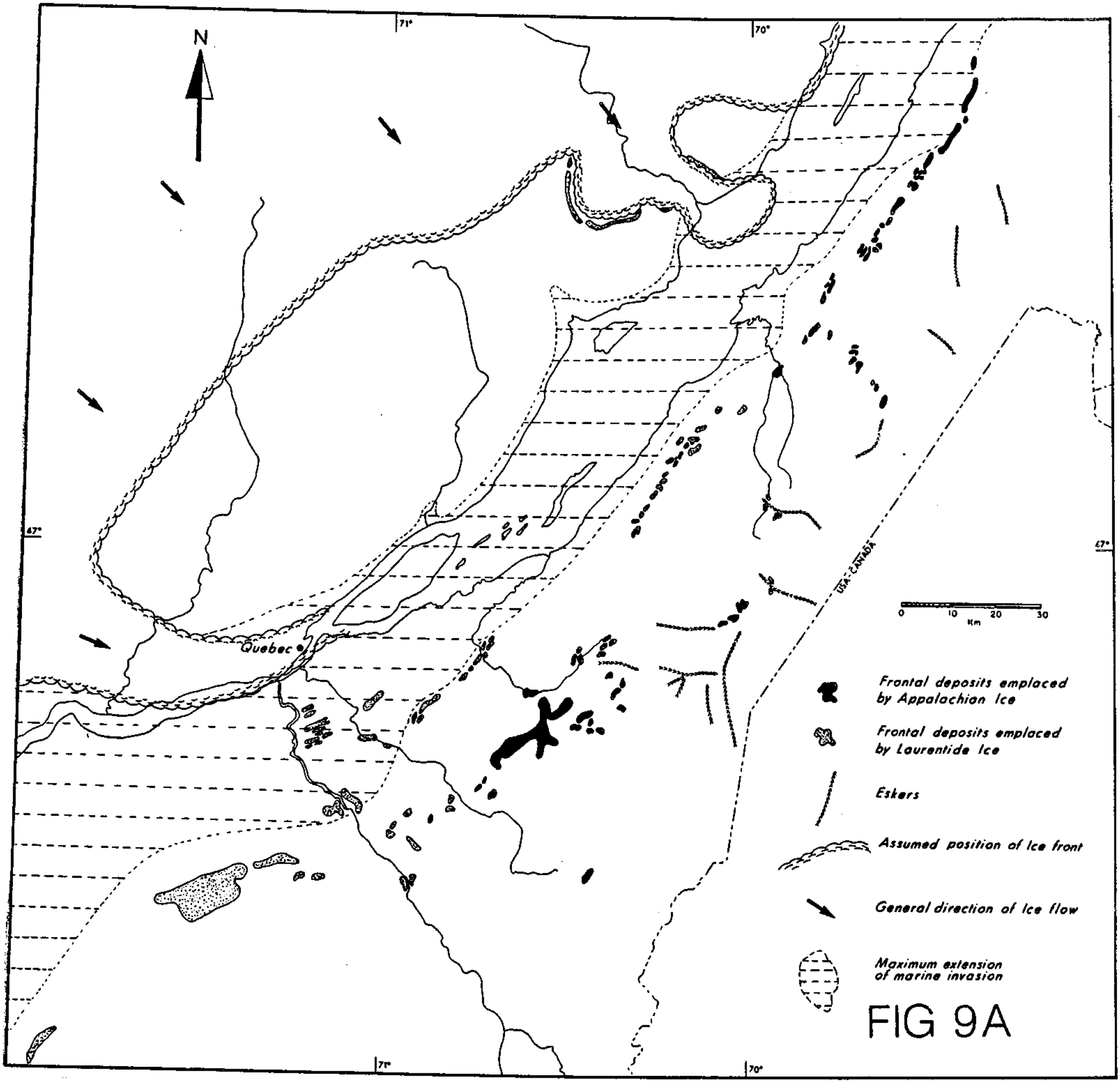
Ice frontal position at time of emplacement of part of Highland Front and St.Damien complexes circa 13.0 Ka BP



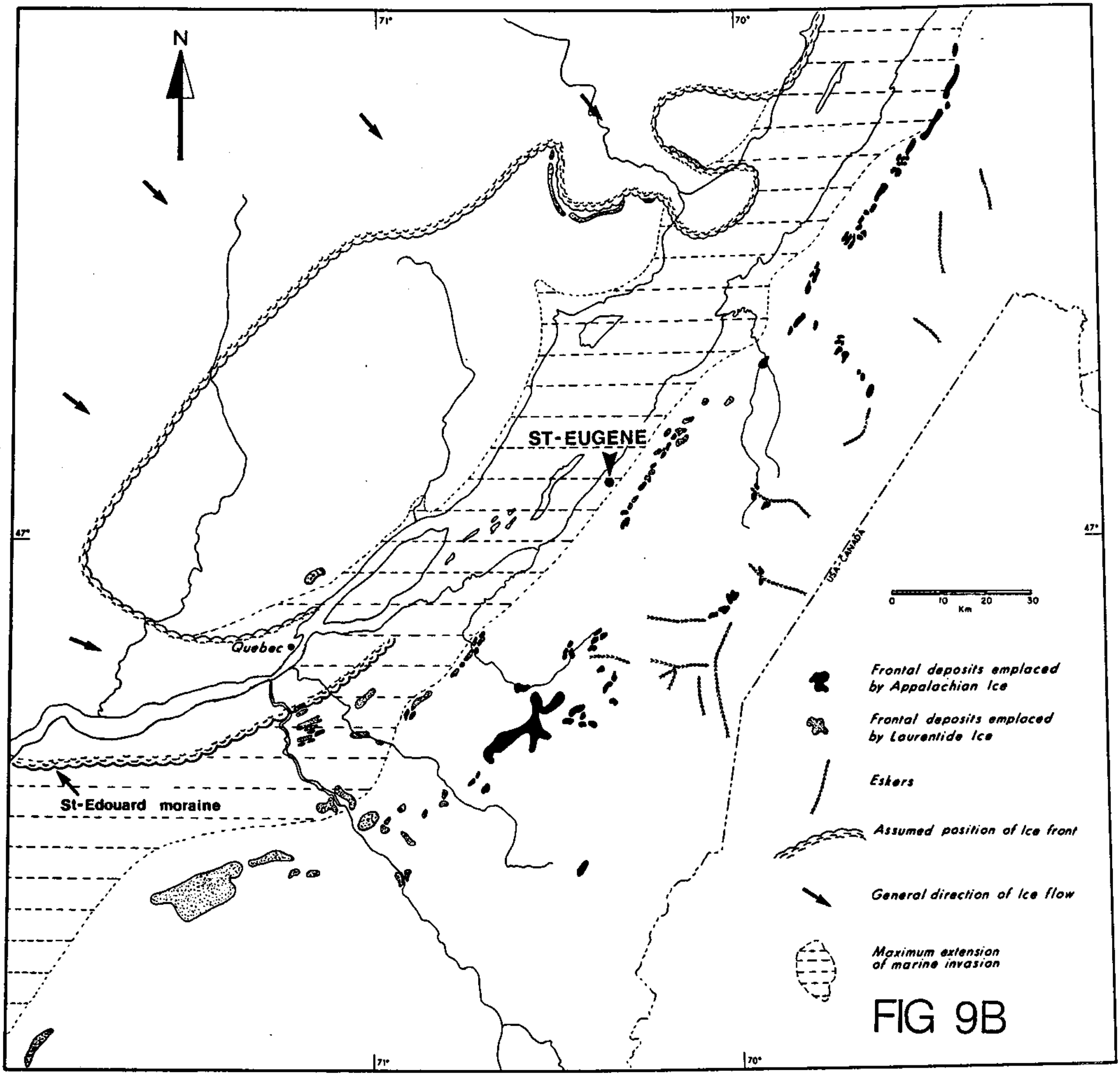
Ice frontal position at time of final desintegration of ice south of St.Lawrence River circa 12.5 to 12.8 Ka BP



Ice frontal position circa 11.6 Ka BP



Ice frontal position at the time of the St.Nicolas readvance some time after 11.0 Ka BP (1977 version)



Ice frontal position at the time of the St.Nicolas readvance some time after 11.0 Ka BP (1988 version)

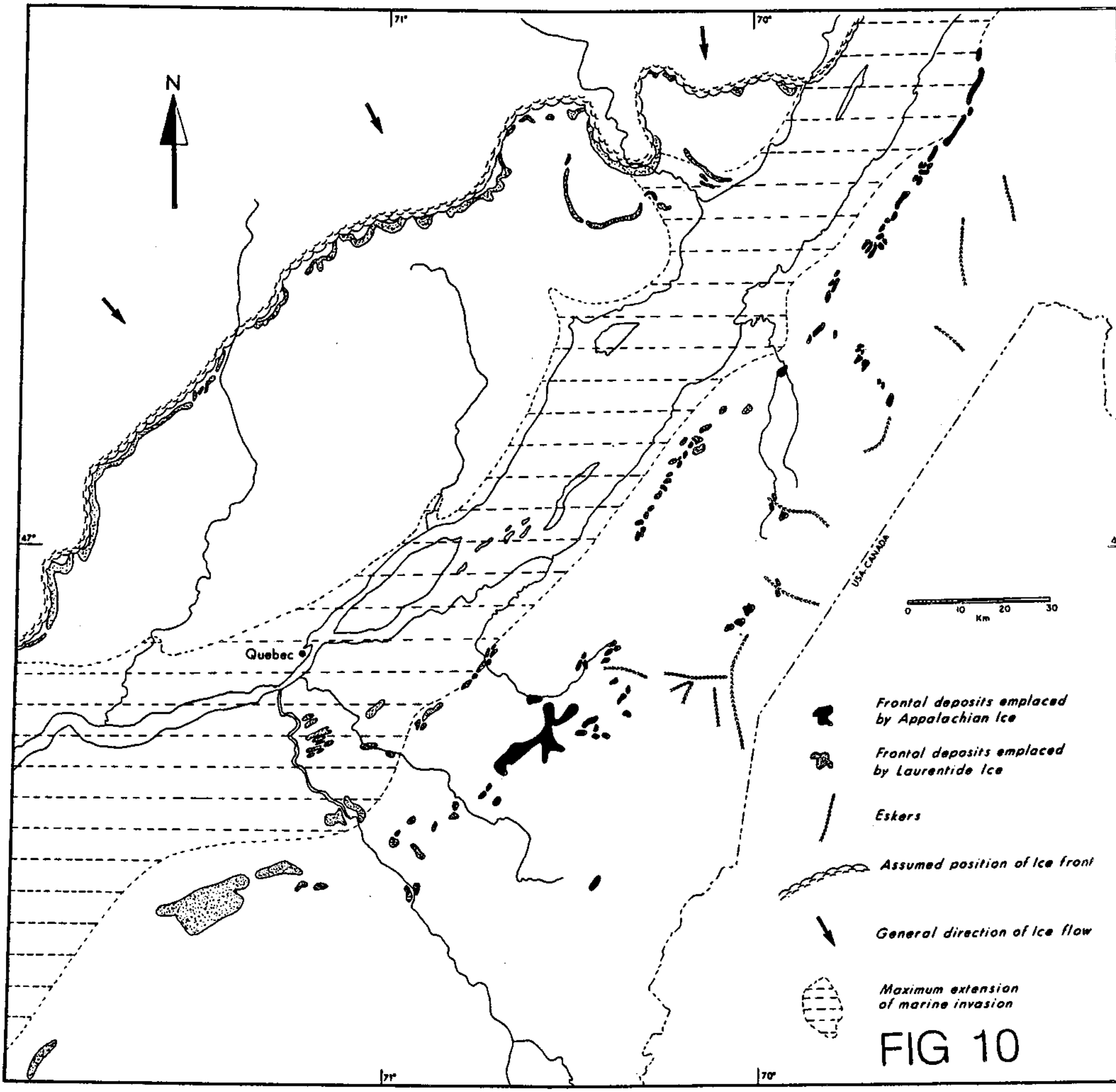
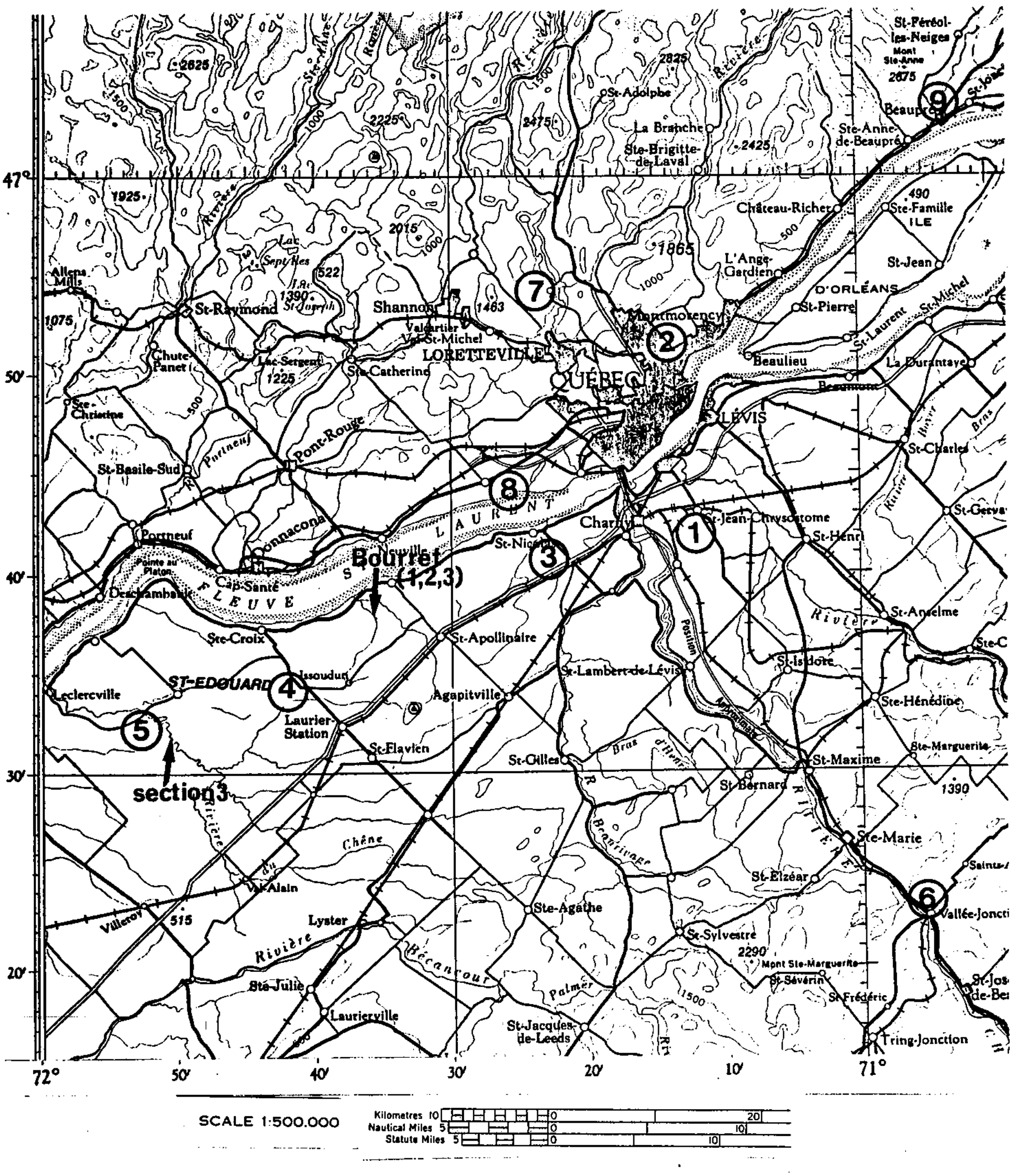


FIG 10

Ice frontal position at the time of emplacement of St.Narcisse moraine between 11.0 Ka BP and 10.7 Ka BP

STOPS FOR THIS EXCURSION

They will not be visited necessarily in the order in which they are listed nor will they all be visited



Breakyville Moraine **(Stop 1).** This ridge belongs to a series of small partly concealed ridges, emplaced at the edge of a glacial lake, extending to the south. We can see here ice-contact and glacio-lacustrine sediments. Marine fossils have not been found. So, this ridge is interpreted as marking the last recognizable stand of the Laurentide ice, before the breaking of the ice barrier in this area and before the entrance of the marine waters to the west. Channel (?) structures and sediments were also observed here in the past. The deposition of those sediments must have occurred some time before 12.4 Ka BP (GSC-1533, 12 400±160 BP).

Beauport **(Stop 2).** This site is very close to a section that Lyell visited during his travels in North America and reported on in 1845 (Lyell, 1845). Lyell's sketch was reproduced in Gadd et al. (1972a). Mr. Ryan's house is still there in rather good shape, though it has changed hands many times. On the banks of the small river, close to the falls, one can observe varved sediments resting on bedrock and sloping gently to the southeast. Those sediments may be correlative with the varved sediments that were observed at the first stop, and consequently they may have been emplaced during the Lake Deschaillons episode. However, their position at the bottom of a small river valley, partly incised in bedrock, and the presence of the channel-like features filled with sand in the quarry, suggest also that the varved sediments observed in the river may be much older and may be related to an early ice advance in pre-St.Pierre time.

The deposition of those varved sediments has to be related to an ice advance, because it does not seem physically possible to have their deposition during a deglaciation. The small river valley appears to have been graded to the Micmac terrace formed in Sangamonian time or earlier.

St.Nicolas **(Stop 3).** This site was visited by J.W. Dawson probably several times (Gadd et al., 1972a). It shows a large variety of Champlain Sea fossils among them the brachiopod **Hemithyris psittacea**. Some of those shells have valves still paired, but likely they have been somewhat transported. A radiocarbon date of 10 000±150 years BP (GSC-1451) was obtained on shells of **Hemithyris psittacea** and of 9 960±150 years BP (GSC-1508) on shells of **Mytilus edulis**. The shells are found in sand or gravelly sand showing some current structures and were probably deposited in a shallow water estuarine environment. They are (as reported below) probably all rebedded from a nearby source, especially Balamus hameri. Several vertebrae of beluga whales (Delphinapterus leucas) were also found in this gravel pit.

The fossiliferous sandy material is underlain by marine clay of the Champlain Sea and overlain in places by rhythmically interbedded fine sediments. The latter may have been emplaced during a fresh water episode at the end of the Champlain Sea or possibly as slack-water deposits in a channel meander or in the lee of a bedrock obstacle. There are other sites in this area showing the same sequence and our explanation is not entirely satisfactory.

List of fossils described at the St.Nicolas gravel pit (Wagner, 1967):

Macoma balthica	Natica clausa
Hiatella arctica	Natica sp.
Mytilus edulis	Serripes groenlandicus
Balanus crenatus	Mysella planulata
Balanus hameri	Hemithyris psittacea
Macoma calcarea	Epitoneum greenlandicum
Mya truncata	Tachyrhynchus erosum
Neptunea despecta tornata	Buccinum plectrum
Mya sp.	Chalamys islandicus
Lepeta caeca	Balanus balanus

Issoudun (Stop 4). In this gravel pit located about 5 km west of Issodun, we can see a fossiliferous compact calcareous gray diamicton overlying sandy subaqueous outwash. Shells of Balanus hameri can be seen in the diamicton. In some cases, the plates of Balanus hameri are still assembled. The process by which the shells have been incorporated in the diamicton must have been very gentle(!); otherwise those shells would have been dispersed. At other sites where Balanus hameri is present in the diamicton, plates are generally dispersed and isolated.

The term subaqueous outwash is used following Rust and Romanelli (1975) and Rust (1977): Outwash sediments deposited below wave base showing good sorting, some stratification and channel structures. Some of the channels are filled with massive sands. Gravel is also present. See also McAbe et al. (1984, 1987).

St.Edouard Morainic ridge (Stop 5). Calling this feature a morainic ridge might be an abuse of the geological terminology. However, we can see here a low ridge and a scarp that marks the limit of the sediments associated with the St.Nicolas readvance in this area. The limit of the St.Nicolas ice shelf was also very near this point at the time. This position is not at all clear elsewhere. The low scarp can be traced for a short distance to the northwest. The St.Nicolas drift (diamicton and associated outwash) is certainly present west of the Portneuf (21L/12) - Becancour (31I/9) NTS boundary.

Marine fossils have not been found in this pit. According to Rust and Romanelli (1975), this type of depositional environment is "inimical" to marine life.

Vallee Jonction (Stop 6). This section is interpreted as indicating more than one glacial advance. The upper part, not exposed, is presumed to be a colluvium developed from a till. The visible part of the section exposes 2.5 m of fine oxidized sand with cross-bedded laminations indicating flow towards the NW, i.e. parallel to the present river flow (Riviere Morency). There are numerous layers of organic material from which a date of 39 Ka BP (QU-402) was obtained. At the interface between the layers, one can observe sinuous furows interpreted here as lebenspurren (LaSalle et al., 1979). The lowermost unit, which rests on bedrock, is a diamicton containing precambrian cobbles. The organic material does not show evidence of wear or breakage due to transport and presumably dates the deposition of the sediments which contain it. The colluvium below the stratified beds contains precambrian cobbles and presumably developed from a till during a non-glacial period. This, it seems reasonable to think that the pseudo-rhytmites were deposited during a readvance in a shallow bay of a proglacial lake equivalent to Lake Deschaillons. It is also possible that it is related to the Gayhurst episode (McDonald and Shilts, 1971).

Bryophyte flora identified at Vallee Jonction Section[1]:

Racomitrium canescens var. ericoides	**Dicranum sp.**
Aulacomnium trugidum	**Didymodon asprifolius**
Drepanocloaudus revolvens	**Campylium stellatum**
Aulacomnium palustre	**Ditrichum flexicaule**
Drepanocladus fluitans	**Hypnum sp.**
Distichium capillaceum	**Aulacomnium acuminatum**
Polytrichastrum alpinum var.	**Campylium stellatum**

Lac St.Charles Moraine (Stop 7). We can see here fluvio-glacial sediments likely subaqueous outwash overlain in places by unfossiliferous diamicton in turn overlain by marine well laminated sediments. Large collapse structures could be observed at some time in the past suggesting that some of those sediments may have been deposited in part on ice. A large group of dish structures could be observed last fall. Their origin has been discussed elsewhere in this guidebook.

This moraine has probably been emplaced around 11.6 Ka BP (GSC-1235, 11 600±160 BP). The date was obtained on Mya truncata collected in a pit on the eastern side of the Lac St.Charles Valley. The shells were collected in a compact glacial diamicton.

The St.Augustin gravel pit (Stop 8). The picture in this pit has changed many times during the last ten years or so. As the situation has evolved, new units have been revealed. After several visits last fall and this spring, a composite section has been made. Three units of diamicton and three units of laminated sediments (glacio-lacustrine) have been recorded. No names are given to the units and no correlation of varved sediments and diamictons is attempted. Their interpretation at this point is very tentative. However, as explained elsewhere, the bouldery unit at the top appears to have been deposited at the northern edge of the St.Nicolas ice lobe (Fig. 9b) probably as a mass deposit. A column from the peat section, at the top of the sequence, has been submitted to the GSC laboratories for pollen analysis and macrofossils identification. A sample collected at base of the section has also been submitted for radiocarbon dating. The result is not available at time of writing.

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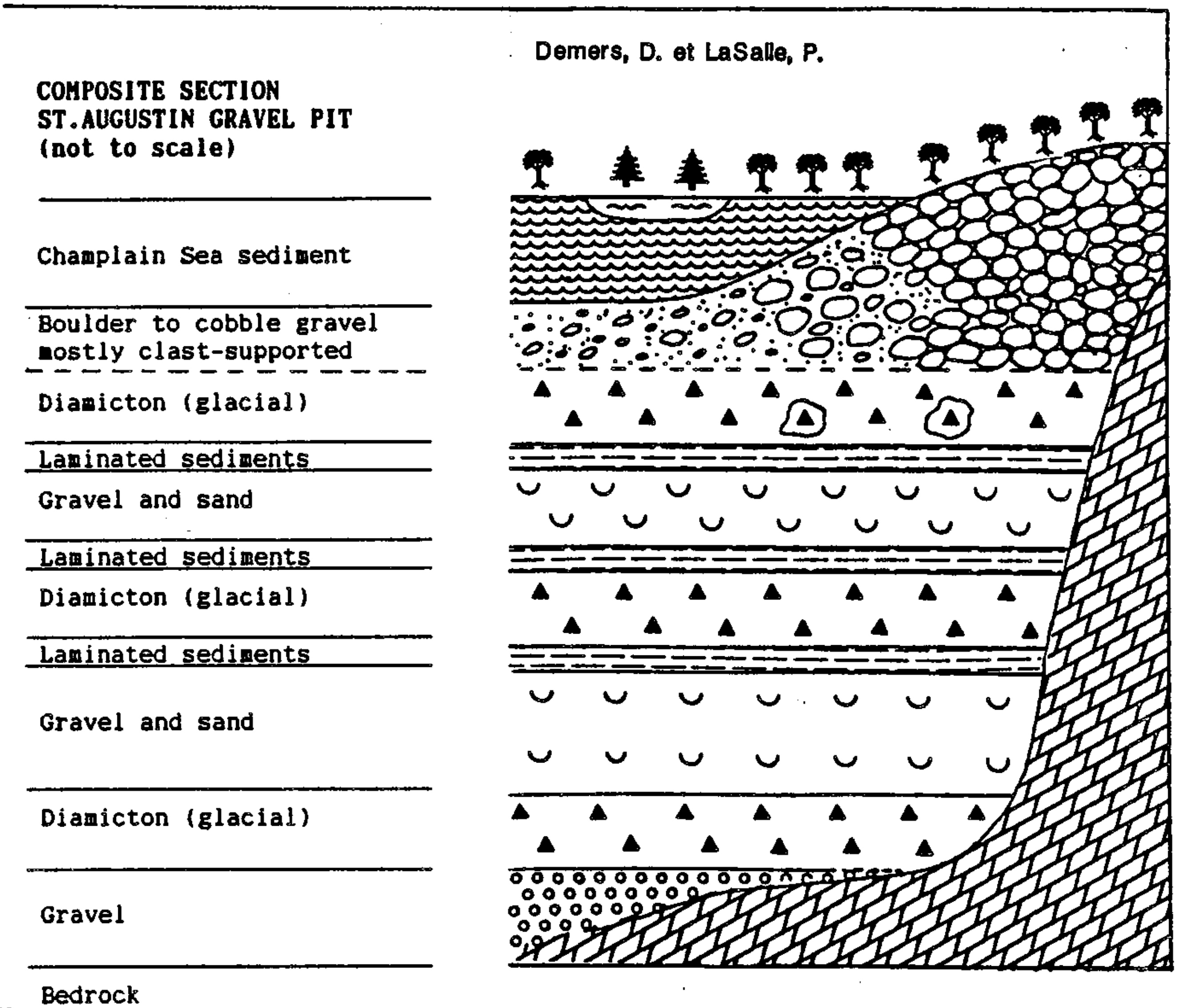
1. Identification by W.C. Steere of New York Botanical Garden.



Beaupre (Stop 9). Approximately 10 m of varved sediments have been observed during the construction of the overpass for the road to the Mont Ste.Anne ski resort. Organic debris have been recovered from the upper part of the varved sequence and have yielded a ^{14}C age of 39 Ka BP (GSC-1539). Dr. Marian Kuc, formerly with the Geological Survey of Canada, has examined this material. Most of it is made of mosses which do not grow in Canada today, and belong to Pliocene-Pleistocene floras.

Some elements of the bryophyte flora may be related to interglacial periods like the same flora of Vallee Jonction. Some of the elements may also be related with preglacial times, when conditions were presumably favorable for the formation of deep oxisols. The till is correlative of the Gentilly Till and the varved sediments are assigned to the Lake Deschaillons Formation.

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Pleistocene Stratigraphy along the southern shore of the St. Lawrence River

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INTRODUCTION

This leg of the field trip is devoted to visiting those sections that are exposed on the south shore of the St. Lawrence River in the vicinity of the St. Pierre les Becquets area (Fig. 1). These sections were originally described by Gadd (1955, 1971) and Karrow (1957). Recently, they were reinvestigated (Lamothe, 1985) and a new stratigraphic framework for the regional Pleistocene depositional sequence was proposed (Lamothe, 1989).

THE TRADITIONAL CONCEPT OF PLEISTOCENE STRATIGRAPHY IN THE ST. LAWRENCE LOWLAND

In the St. Lawrence Lowland of southern Quebec, modern stratigraphic classification was synthesized by Gadd (1971) and this stratigraphic framework is illustrated in figure 2 . The depositional sequence was interpreted as the result of two major glacial advances, separated by one brief interstade.

The older till (Bécancour Till) was believed to be early Wisconsinan since no overlying interglacial sediments have yet been observed in this area. This glacial event could be older. Varved clay underlies (Cap Lévrard Varves) and overlies (Pierreville Varves) the till.

A nonglacial fluvial and lacustrine unit, the St-Pierre Sediments, unconformably overlies the lower glacial sequence. Peat layers and organic-rich sand are dominated by boreal-type pollen (Terasmae, 1958). They have been dated at 65 300 $\pm$ 1400 (GrN-1799), and 67 000 $\pm$ 2000 (GrN-1711) years BP by DeVries (in Dreimanis, 1960). A date of 74 700 + $^{+2700}_{-2000}$ (QL-198) has also been obtained by Stuiver *et al.* (1978), from wood collected at the Pierreville section, in a unit correlated with the St. Pierre Sediments.

Glacial Lake Deschaillons sediments conformably overly organic sand at the Deschaillons brickyard. Since the organic unit is believed to be a St. Pierre correlative and the laminated sediments are interpreted as glaciolacustrine deposits, Gadd (1971) suggested that the end of the St. Pierre Interstade is marked by glacier damming of the lower portion of the St. Lawrence Valley by ice that ultimately deposited the upper till.

The Pleistocene sequence (sensu lato) is topped by the Gentilly Till which grades into sediments of the Champlain Sea.

This stratigraphic framework was characterized by a single nonglacial interval. In general, till deposition at each site was preceded and followed by glaciolacustrine sedimentation.

The Pleistocene stratigraphy described above is based on the lithostratigraphic succession exposed in the St.Pierre les Becquets area in the early 1950's. The lithostratigraphic units were defined at different type localities, none of which shows the full stratigraphic succession. However, no more than one non glacial and two glacial units are present at any locality. The sections exposed along the St. Lawrence River were correlated by Gadd (1955, 1971) and Karrow (1957) as shown on figure 3. A brief description of the St. Pierre , Cap Lévrard , and Deschaillons type sections follows.

The St. Pierre type section

Section 58 is located along a small brook, 500 m upstream from its intersection with highway 132 . This is the type-section for the St. Pierre Sediments.

At the base, 2.25 m of well sorted sediments composed of clayey silt interbedded with 3 peat layers and some sand, are defined as the St. Pierre Sediments . Fossil biota indicate that during deposition of these sediments, the climate was colder than today (Terasmae, 1958, Matthews, 1987). At least 16.5 m of rhythmites overly the non glacial unit. The couplets are dark grey clay and light grey silt . The rhythmites are not calcareous in the first 5 m although eight Fe rich calcareous lenses were counted (41% total Fe-Mg-rich carbonate). Upward, the silt laminae become calcareous where thicker and show parallel stratification. The upper part of the unit contains *Candona subtriangulata* (C.G. Rodriguez, pers. comm., 1987). Some of these laminae are rich in biogenic tracks. At the base, those rhythmites unconformably overly the St. Pierre unit, and they exhibit numerous penecontemporaneous deformations cemented by the same Fe-Mg-rich carbonate observed in lenses. Some lenses of the underlying silt are found interstratified in the basal rhythmites. This unit was correlated with the Deschaillons Varves, formally described at the Deschaillons brickyard.

These rhythmites are overlain by 1 m of massive yellowish brown silt. Staplin (in Gadd, 1955) described a foraminiferal assemblage in this unit. The Gentilly Till is not present at this section.

At 160 m downstream from section 58, section 59 exposes concretions-bearing glaciolacustrine sediments (Cap Lévrard Varves) that underly sand and peat. In his original work, Gadd (1955) described a red till (Bécancour Till) overlying the varves.

The Cap Lévrard type section

The Cap Lévrard section is located mid-way between the St. Pierre type section and the Deschaillons brickyard. Section 60 is large due to the presence of a small lateglacial marine delta incised into the glacial deposits. Diamictons dominate the northeastern part of the section. They gradually thin southwestward and are reduced to a two-diamicton complex with rhythmites underlying each diamicton. Section 60 is the type section for the Cap Lévrard Varves.

The lowermost unit is exposed at low tide, and comprises 30 cm of slightly oxydized yellow sand . It is overlain by 3.5 m of thinly bedded weakly calcareous, light grey clayey silt . In the upper 2 m, these rhythmites are contorted .

This unit grades into 5 m of silty and clayey slightly pinkish grey till , containing a few striated concretions. One of these was dated at >40 ka BP (I-13317). The top of the till is discontinuously covered by laminated silt. The upper surface is oxidized as is the base of the overlying unit, suggesting that ,at least, part of this is due to recent groundwater activity. This till was correlated with the Bécancour Till by Gadd (1955, 1971).

A 4.5 m thinly bedded light grey and greenish clayey silt is draped over the till. Bedding thickness increases to the southwest where a large block of the rhythmites is slumped and contorted. A mat of organic matter and a small (3 cm) piece of peat was found in the lowermost laminae. This unit grades into 1 m of light grey clayey and silty diamicton oxidized at the top. This diamicton is likely the result of reworking of the underlying diamicton.

This unit is overlain by a thick sequence of deltaic sand, in which fragments of *Macoma balthica* have be found.

A second section of interest in the area is section 65, located 500 m down river from section 60 . The lower units of section 60 can be traced laterally. In the middle part of the section, 8 m of yellowish grey sand and some gravel overly the pinkish grey till. It is overlain by 5 m of grey sandy and silty till . A recent landslide exposed the inter-till sand approximately 500 m further down river. At this site, a silt unit (3 m) was found to contain organic debris, from which a piece of wood was dated at >35 ka BP (GSC-4233). This indicates that the upper till exposed at section 65 is indeed the Gentilly Till and the underlying sand, St. Pierre Sediments.

The Deschaillons brickyard type section

This is the type section for the Deschaillons Varves. This section has been described by Karrow (1957). Hillaire-Marcel and Pagé (1981) presented a new interpretation of the timing of glacial Lake Deschaillons through stable isotope analysis and radiocarbon dating of the calcareous concretions found in the rhythmites.

In the lower part of the brickyard, a non glacial unit can be observed. It is composed of 5 m of slightly oxidized yellow sand exhibiting parallel stratification ,small scale ripples, and some silty layers at the top . Pieces of wood have been found in this sand by Gadd (1955) and a lens of organic silt was discovered in fall of 1986 by this author. This unit was correlated with the St. Pierre Sediments by Karrow (1957) and Gadd (1971).

A thick sequence (17 m) of laminated clayey silt, the Deschaillons Varves, conformably overlies the non glacial sand. The contact with the underlying sand is conformable and is marked by a slightly asymmetrical undulating surface. Disseminated organic matter and vivianite are present at the base of the rhythmites. From the middle part of the section, the rhythmites are frequently reddish-brown and may contain 5% carbonate as well as numerous calcareous concretions. Some silt laminae are bioturbated. The upper 11 m are deformed. According to Hillaire-Marcel and Pagé (1981), 1800 couplets can be counted in the undeformed part of the section. They suggest the deformed part contains at least the same number of laminations. If these rhythmites are annual, the sequence may represent 4000 years of glaciolacustrine deposition. Lamothe (1985) believes that absence of micro-varves at the top and reduced stratigraphic thickness due to folding indicate that the total number of couplets cannot exceed 2500.

A thin layer (20 cm) of oxidized greenish and brownish yellow sand overlies the rhythmites. The upper part of the section exposes 1.5 m of brownish grey silty till. This is the Gentilly Till.

Discussion

During the course of research carried out since 1980, all sections located along a 20 km segment of the south shore of the St. Lawrence River, between Rivière aux Orignaux and Deschaillons have been reinvestigated (Lamothe, 1985) for sedimentological and geochronological analysis. Most of the original stratigraphic interpretations of Gadd and Karrow were confirmed. It was found however, that the (post-St. Pierre) Deschaillons Varves and the (pre-St. Pierre) Cap Lévrard Varves are in *almost lithologic continuity* (Lamothe, 1985, p. 69). Both units contain calcareous concretions whereas the rhythmites overlying the St. Pierre peat, at the type section (the Gray Varves of Gadd, 1955) do not. The concretions are thought to be the result of early diagenesis (Hillaire-Marcel and Pagé, 1981). Their minute radiocarbon activity is due to some poorly understood secondary precipitation. However, it is believed the concretions are geological objects that are characteristic of the units in which they occur, even though the radiocarbon dates measured on these carbonates (Hillaire-Marcel and Pagé, 1981; Lamothe *et al.*, 1983; Lamothe, 1985), do not represent the age of glaciolacustrine deposition (see discussion in Lamothe, 1985). Furthermore, Deschaillons and Cap Lévrard varves yield similar apparent TL ages ($\geq$70 and >60 ka, respectively; Lamothe, 1985; Lamothe and Huntley, 1988). Therefore these two units appeared then as correlatives. This correlation implies that two distinct non glacial sequences are present: the lower organic sand in the Deschaillons brickyard, and the St.Pierre Sediments at the type section. Because of the far-reaching implications of this proposed correlation, Lamothe (1985) suggested that further supporting evidence be obtained.

In an attempt to resolve this stratigraphic problem, three boreholes were drilled in the vicinity of Deschaillons (9091), Cap Lévrard (9092), and St.Pierre les Becquets (9093). A core collected earlier by Ministère des Transports du Québec at the Cap Lévrard site was also examined (borehole F-1). Stratigraphic information obtained from hydrogeological reports was also compiled and synthesized as borehole P-13. The borehole data show that the Deschaillons Varves can be traced almost continuously from the Deschaillons brickyard to the St. Pierre type section (Fig. 4) where they occur beneath the peat-bearing sediments. This demonstrates that the lower organic sand at the brickyard represents an older non glacial event, much as Lamothe (1985) had anticipated. Also, at the bottom of every borehole, a rhythmically bedded clayey unit overlies till resting on bedrock. This sequence is observed only in boreholes and it underlies the non glacial sand exposed at the brickyard.

The information now available in the central part of the St. Lawrence Lowland provides evidence that the Pleistocene depositional sequence is the result of three glacial advances and two non glacial events, each represented by organic-bearing units (Fig. 5). The succession of the lithostratigraphic and climatostratigraphic units, and a correlation with the deep-sea record is shown on Figure 6 . The major aspects are summarized below.

In this revised stratigraphic framework, two lithostratigraphic units (Lotbinière Sand and Lévrard Till) and three climatostratigraphic units (St. Lawrence Stade, Grondines Interstade, and Les Becquets Interstade) are introduced in the stratigraphic nomenclature. No definite age can be assigned to the lowermost till (Bécancour Till ?) but it is now believed to be presangamonian, particularly in the light of the discovery of interglacial sediments overlying till at Pointe-Fortune, west of Montréal (Anderson *et al.*, 1988). Field observations and geochronological data suggest the lower and upper interstadial sediments, and an intervening glacial unit represent brief but severe environmental changes that occurred at the beginning of the Wisconsinan glaciation, ca. 80-70 ka ago. This sequence may correlate with marine isotope stage 5a, stage 4, and the earliest part of stage 3. The age of the last glacial advance (Gentilly Till) is problematic ranging from 60 to 30 ka. The rhythmites overlying the St. Pierre Sediments at the type section are younger than the Deschaillons Varves. Because it is uncertain the Gray Varves underly or overly Gentilly Till, the glaciolacustrine episode may have either preceded (hypothesis shown on Fig. 6) or followed the Late Wisconsinan advance in the area. The latter interpretation should not be ruled out even though it imposes severe constraints on the current hypothesis on the existence of a lateglacial marine calving bay which is thought to have bisected the Laurentide Ice Sheet in the St. Lawrence Lowland (Gadd, 1976).

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LIST OF FIGURES

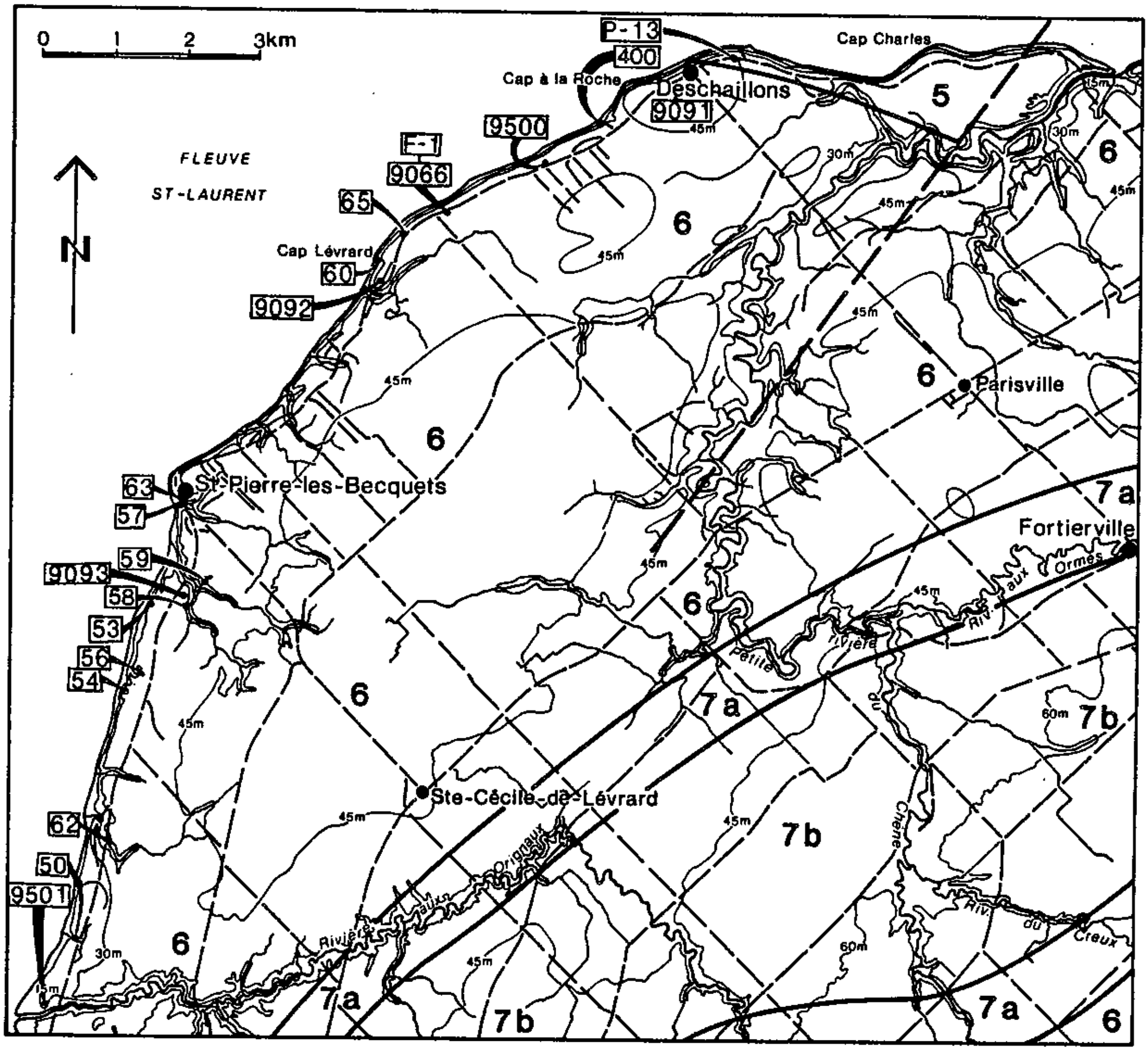
0 1 2 3km
FLEUVE
ST-LAURENT
N
P-13
400
Cap Charles
Cap à la Roche
Deschaillons
9091
9500
F-1
9066
65
Cap Lévrard
60
9092
5
6
Parisville
St-Pierre-les-Becquets
63
57
9093
59
58
53
56
54
Fortierville
7a
7b
Ste-Cécile-de-Lévrard
62
50
9501
Petite Rivière du Chêne
Riv. aux Ormes
Rivière aux Orignaux
Riv. du Creux
45m
30m
60m
15m

FIG. 1

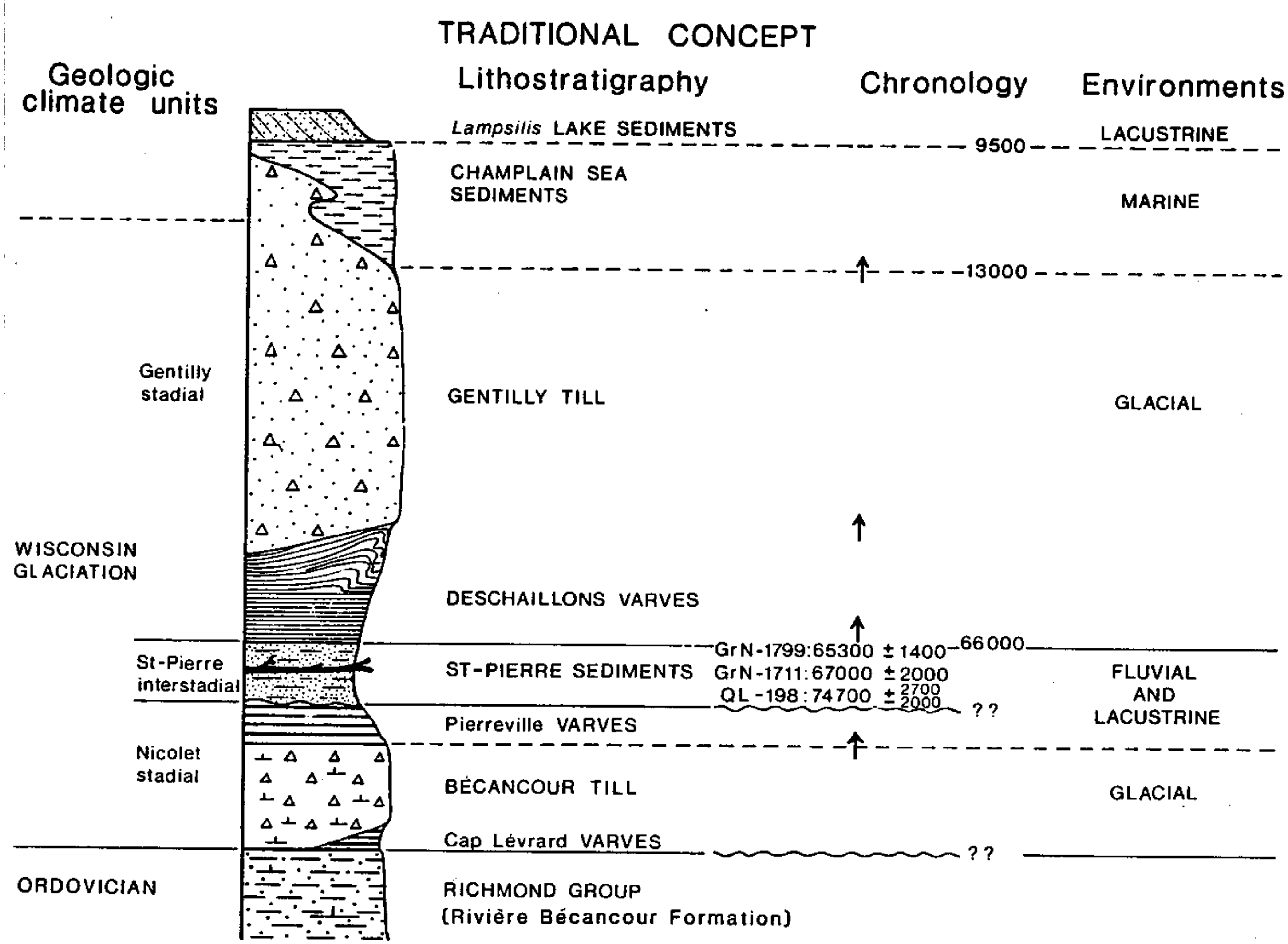
TRADITIONAL CONCEPT
Geologic climate units
Lithostratigraphy
Chronology
Environments
Lampsilis LAKE SEDIMENTS
9500
LACUSTRINE
CHAMPLAIN SEA SEDIMENTS
MARINE
13000
Gentilly stadial
GENTILLY TILL
GLACIAL
WISCONSIN GLACIATION
DESCHAILLONS VARVES
St-Pierre interstadial
ST-PIERRE SEDIMENTS
GrN-1799:65300 ± 1400
GrN-1711:67000 ± 2000
QL-198:74700 ± 2700 2000
66000
??
FLUVIAL AND LACUSTRINE
Pierreville VARVES
Nicolet stadial
BÉCANCOUR TILL
GLACIAL
Cap Lévrard VARVES
??
ORDOVICIAN
RICHMOND GROUP
(Rivière Bécancour Formation)

FIG.2

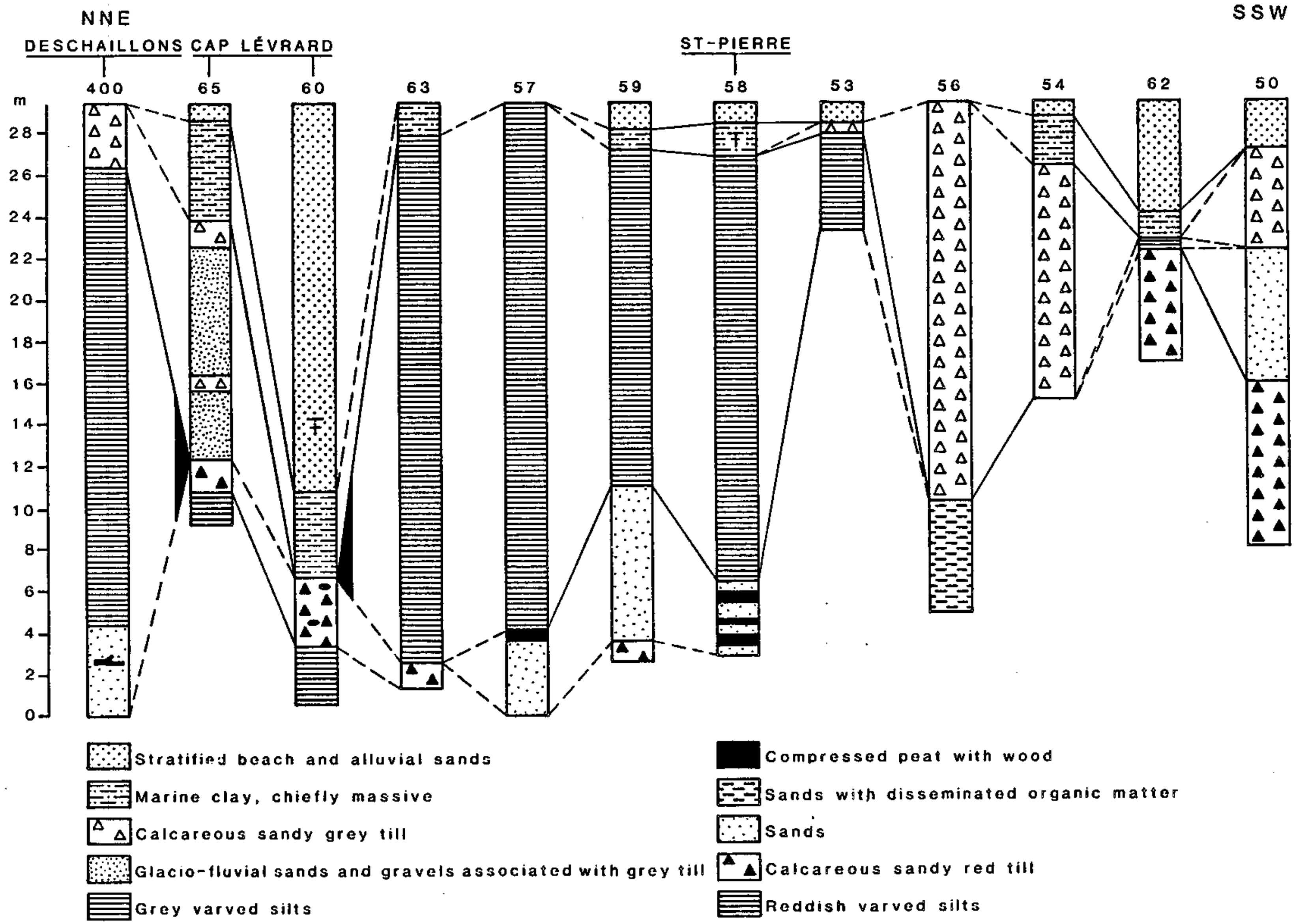
NNE
SSW
DESCHAILLONS
CAP LÉVRARD
ST-PIERRE
400
65
60
63
57
59
58
53
56
54
62
50
m
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Stratified beach and alluvial sands
Marine clay, chiefly massive
Calcareous sandy grey till
Glacio-fluvial sands and gravels associated with grey till
Grey varved silts
Compressed peat with wood
Sands with disseminated organic matter
Sands
Calcareous sandy red till
Reddish varved silts

FIG.3

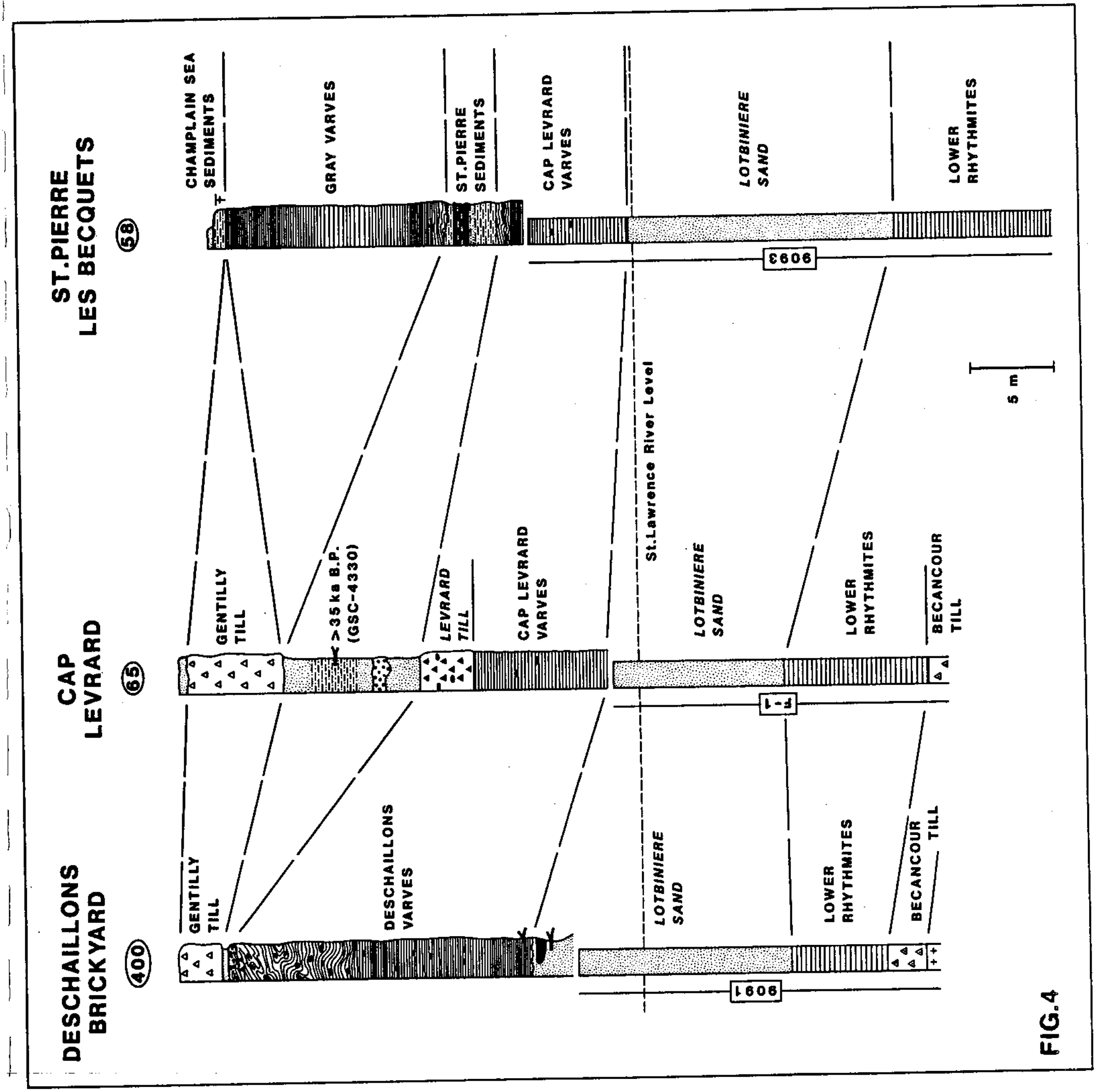
DESCHAILLONS BRICKYARD
400
CAP LEVRARD
65
ST.PIERRE LES BECQUETS
58
GENTILLY TILL
DESCHAILLONS VARVES
LOTBINIERE SAND
LOWER RHYTHMITES
BECANCOUR TILL
9091
GENTILLY TILL
>35 ka B.P. (GSC-4330)
LEVRARD TILL
CAP LEVRARD VARVES
LOTBINIERE SAND
LOWER RHYTHMITES
BECANCOUR TILL
F-1
St.Lawrence River Level
5 m
CHAMPLAIN SEA SEDIMENTS
GRAY VARVES
ST.PIERRE SEDIMENTS
CAP LEVRARD VARVES
LOTBINIERE SAND
LOWER RHYTHMITES
9093

FIG.4

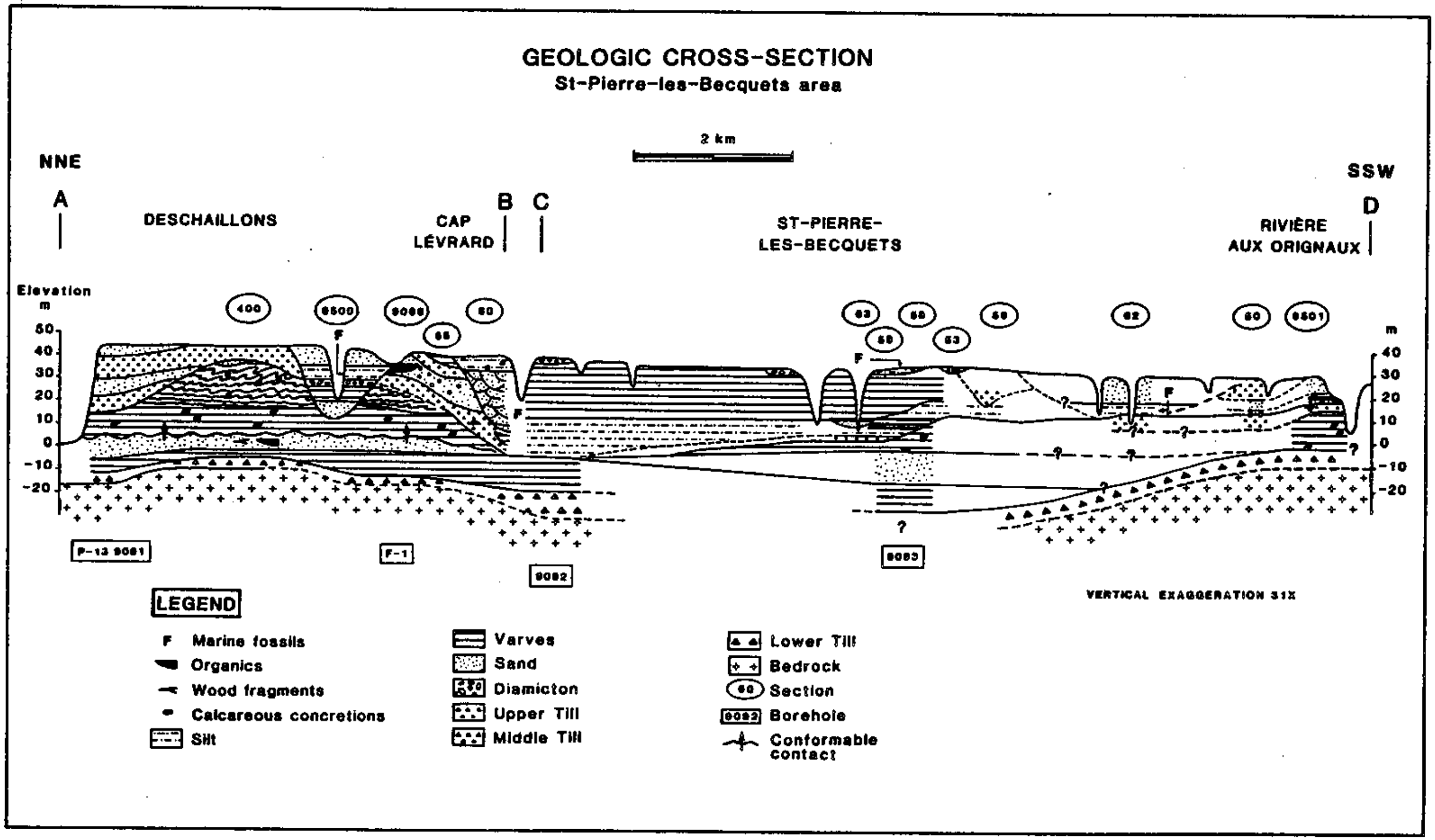
GEOLOGIC CROSS-SECTION
St-Pierre-les-Becquets area
2 km
NNE
SSW
A
B
C
D
DESCHAILLONS
CAP LÉVRARD
ST-PIERRE-LES-BECQUETS
RIVIÈRE AUX ORIGNAUX
Elevation m
50
40
30
20
10
0
-10
-20
m
400
F
P-13 9081
F-1
9082
9083
VERTICAL EXAGGERATION 31X
LEGEND
Marine fossils
Organics
Wood fragments
Calcareous concretions
Silt
Varves
Sand
Diamicton
Upper Till
Middle Till
Lower Till
Bedrock
Section
Borehole
Conformable contact

FIG.5

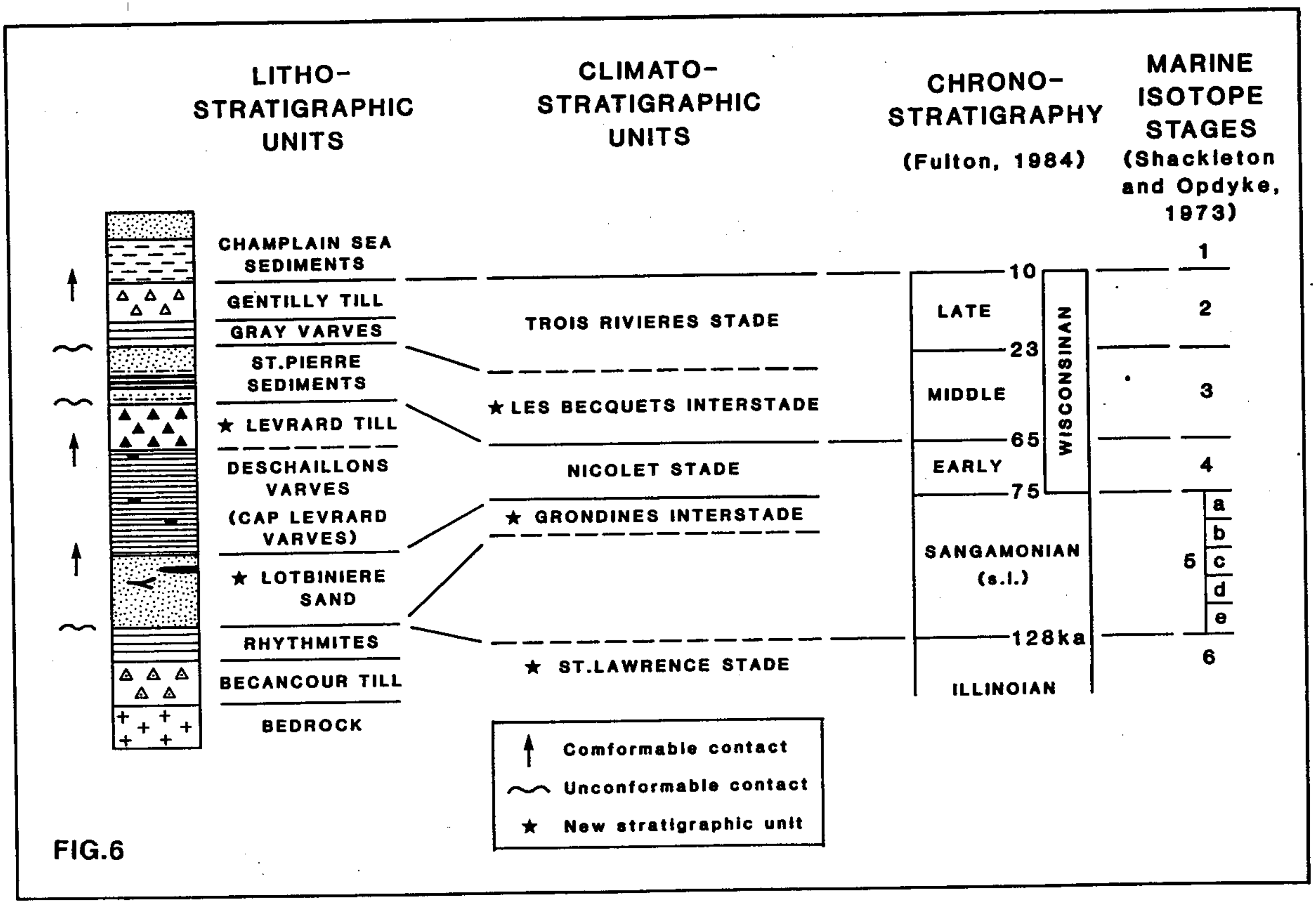
LITHO-STRATIGRAPHIC UNITS
CLIMATO-STRATIGRAPHIC UNITS
CHRONO-STRATIGRAPHY (Fulton, 1984)
MARINE ISOTOPE STAGES (Shackleton and Opdyke, 1973)
CHAMPLAIN SEA SEDIMENTS
GENTILLY TILL
GRAY VARVES
ST.PIERRE SEDIMENTS
★ LEVRARD TILL
DESCHAILLONS VARVES
(CAP LEVRARD VARVES)
★ LOTBINIERE SAND
RHYTHMITES
BECANCOUR TILL
BEDROCK
TROIS RIVIERES STADE
★ LES BECQUETS INTERSTADE
NICOLET STADE
★ GRONDINES INTERSTADE
★ ST.LAWRENCE STADE
10
LATE
23
MIDDLE
65
EARLY
75
WISCONSINAN
SANGAMONIAN (s.l.)
128ka
ILLINOIAN
1
2
3
4
5
a
b
c
d
e
6
Comformable contact
Unconformable contact
★ New stratigraphic unit

FIG.6