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A NEW FRAMEWORK FOR THE PLEISTOCENE STRATIGRAPHY OF THE CENTRAL ST. LAWRENCE LOWLAND, SOUTHERN QUÉBEC

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ABSTRACT For three decades, a stratigraphic framework involving one glaciation with two major ice advances (represented by the Bécancour Till and Gently Till), separated by one brief interstade (represented by the St. Pierre Sediments), has been invoked to explain the lithostratigraphic succession of Pleistocene sediments exposed in the St. Lawrence Lowland of southern Québec. New exposures found along the bluffs of the St. Lawrence River and recent borehole data provide evidence that the Pleistocene depositional sequence is the result of three glacial advances and two nonglacial events, each represented by organic-bearing units. 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?) but it is now believed to be pre-Sangamonian. 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 Wisconsin Glaciation, ca. 90-70 ka BP. This sequence may correlate with marine isotope stage 5a, stage 4, and the earliest part of stage 3. The age of the onset of the last glacial advance (Gently Till) is problematic, possibly ranging from 60 to 30 ka BP.

RÉSUMÉ *Nouveau schéma stratigraphique pour les sédiments pléistocènes des basses terres du Saint-Laurent, sud du Québec.* Depuis trois décennies, le schéma stratigraphique du Pléistocène des basses terres du Saint-Laurent repose sur une séquence de deux tills (Till de Gently et Till de Bécancour) séparés par un ensemble de dépôts non glaciaires, les Sédiments de Saint-Pierre. On estime que ce complexe stratigraphique est associé à la Glaciation du Wisconsin et représentatif de deux avancées glaciaires et d'un court interstade. L'examen détaillé de nouvelles coupes le long des falaises du Saint-Laurent et des forages récents démontrent que la séquence sédimentaire représente plutôt trois avancées glaciaires et deux événements non glaciaires définis par des sédiments organiques. Deux unités lithostratigraphiques (Sables de Lotbinière et Till de Lévrard) et trois unités climatostratigraphiques (Stade du Saint-Laurent, Interstade de Grondines et Interstade Les Becquets) sont introduits dans la nomenclature stratigraphique. Le till inférieur (Bécancour?) appartient probablement à une glaciation pré-sangamonienne, mais son âge ne peut être démontré. Les observations de terrain et les nouvelles données géochronologiques disponibles laissent croire que les sédiments interstadiaires inférieurs et supérieurs ainsi que les dépôts glaciaires intercalés témoignent de changements brefs mais radicaux des conditions paléoenvironnementales, lors de l'englaciation du Wisconsinien inférieur, datée à ca 90-70 ka BP. Cette partie de la séquence peut être corrélée avec les stades isotopiques marins 5a, 4 et la partie inférieure du stade 3. Enfin, l'âge de la dernière avancée glaciaire demeure problématique et se situerait entre 60-30 ka BP.

ZUSAMMENFASSUNG *Ein neuer Rahmen für die Pleistozän-Stratigraphie des zentralen Sankt-Lorenz Tieflandes, südliches Québec.* Drei Jahrzehnte lang berief man sich auf einen stratigraphischen Rahmen mit einer Vereisung und zwei Haupteisvorstößen (vertreten durch die Bécancour Grundmoräne und die Gently Grundmoräne), die durch ein kurzes Interstadial (vertreten durch die St. Pierre Sedimente) getrennt wurden, um die lithostratigraphische Abfolge von Pleistozän-Sedimenten zu erklären, die im Sankt-Lorenz Tiefland im südlichen Québec ausgesetzt sind. Neue Aufschlüsse, die entlang den Steilufnern des Sankt-Lorenz Stroms gefunden wurden und Ergebnisse neuerer Bohrungen erbringen den Beweis, dass die Pleistozän-Ablagerungs-Sequenz das Ergebnis von drei glazialen Vorstößen und zwei nichtglazialen Ereignissen ist, welche jeweils durch organisches Material enthaltende Einheiten vertreten sind. Zwei lithostratigraphische Einheiten (Lotbinière Sand und Lévrard Grundmoräne) und drei klimatostratigraphische Einheiten (Sankt Lorenz Stadium, Grondines Interstadium und Les Becquets Interstadium) werden in die stratigraphische Nomenklatur eingeführt. Das Alter der tiefstgelegenen Grundmoräne (Bécancour?) kann nicht genau bestimmt werden, doch hält man sie für prä-sangamonisch. Feldbeobachtungen und geochronologische Daten legen nahe, dass die tiefergelegenen und oberen interstadialen Sedimente und eine dazwischen liegende glaziale Einheit kurze aber starke Umweltveränderungen darstellen, die zu Beginn der Wisconsin Vereisung auftraten, etwa 90 — 70 ka v.u.Z. Diese Sequenz könnte mit dem marinen Isotop-Stadium 5a, Stadium 4 und dem frühesten Teil von Stadium 3 korrelieren. Das Alter des Beginns des letzten glazialen Vorstosses (Gently Grundmoräne) ist problematisch, möglicherweise zwischen 60 und 30 ka v.u.Z.

INTRODUCTION

In the central St. Lawrence Lowland of southern Québec, a strongly entrenched stratigraphic framework based on a single glaciation, interrupted by a brief nonglacial event, the St. Pierre Interstade, has been developed through the pioneering work of Gadd (1955, 1971), Karrow (1957) and Terasmae (1958). The St. Pierre Interstade has become a classical reference unit for the Early Wisconsinan of northeastern North America (Dreimanis and Karrow, 1972) and consistently appears in stratigraphic literature concerned with global correlations, such as the Late Cenozoic deep sea sedimentary record, the Greenland ice cores, or the Pleistocene stratigraphic sequence of continental western Europe (see for example Turekian, 1971). All sub-till organic sediments documented in the St. Lawrence Lowland have been dated at or beyond the limit of the ^{14}C dating method and were assumed to represent a single interstadial event.

This paper presents evidence from the type area that the organic-bearing sediments thought to have been deposited during the St. Pierre Interstade represent two distinct non glacial events separated by a glacial event that had not been recognized in previous work.

OCCURRENCES OF ST. PIERRE SEDIMENTS AND CORRELATIVES IN THE ST. LAWRENCE LOWLAND

St. Pierre Sediments is a formal lithostratigraphic unit that has been mapped in the central part of the St. Lawrence Lowland (Gadd, 1955, 1960, 1971) where it occurs within pre-Quaternary topographic depressions (Batiscan and Yamachiche basins of Lamothe, 1985) at elevations slightly above present sea level (Fig. 1). St. Pierre Sediments are well exposed along the south shore of the St. Lawrence River near Saint-Pierre-les-Becquets (Fig. 2), with isolated occurrences along its tributaries, e.g. along the Rivière Saint-François near Pierreville and along the Rivière Saint-Maurice at Les Vieilles Forges (Karrow, 1957; Occhietti, 1979).

Interstadial sediments correlated with the St. Pierre Sediments have been described in many parts of the St. Lawrence River watershed, e.g. the Massawippi Formation in the Eastern Townships (McDonald and Shilts, 1971) and the Anse-aux-Hirondelles formation in the Québec City area (LaSalle, 1984).

Other possible correlatives have been reported at Pointe-Fortune, in the Ottawa Valley (Gadd *et al.*, 1981; Veillette and Nixon, 1984), and at Île aux Coudres, in the middle St. Lawrence Estuary (Brodeur and Allard, 1985).

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

Lithostratigraphic units introduced by Gadd (1960, 1971) were formally defined at type sections located in the Saint-Pierre-les-Becquets area. There, terrace bluffs (≈ 30 m asl) display a complex stratigraphy which has long attracted at-

tention of geologists (Logan, 1863). Modern stratigraphic classification has been synthesized by Gadd (1971) and this stratigraphic framework is shown in Figure 3. The depositional sequence was interpreted as the result of one glaciation consisting of two major glacial advances, separated by one brief interstade.

The older till (Bécancour Till) lies between two units of varved glaciolacustrine clay and was thought to be an Early Wisconsinan unit since no overlying interglacial sediments have yet been observed in this area. However, this glacial sequence might be older (Gadd, 1976).

A nonglacial fluvial and lacustrine unit, the St. Pierre Sediments, unconformably overlies the lower glacial sequence. The unit contains peat layers and organic-rich sand characterized by boreal-type pollen assemblages (Terasmae, 1958). They were dated at $65\,300 \pm 1400$ (GrN-1799) and $67\,000 \pm 2000$ years BP (GrN-1711) by De Vries (Dreimanis, 1960; Vogel and Waterbolk, 1972). An age of $74\,000 \pm 2700$ years BP (QL-198) was obtained from wood collected at the Pierreville section (Stuiver *et al.*, 1978; Fig. 1), in a unit correlated with the St. Pierre Sediments.

Glacial Lake Deschailons sediments conformably overlie organic-bearing sand at the Deschailons brickyard (section 400 of Karrow, 1957). This glaciolacustrine unit was correlated with the "Gray Varves" overlying the peat-bearing unit at the Saint-Pierre-les-Becquets type section on the basis of lithologic continuity (Gadd, 1955, p. 106) from the exposures available in the 1950's. The interpretation therefore was that the St. Pierre Interstade ended when the glacier that ultimately deposited the upper till blocked the lower portion of the St. Lawrence River, thus impounding a glacial lake in the St. Lawrence Lowland upstream of Québec City. The Pleistocene sequence is topped by the Gentilly Till which grades into lateglacial glaciolacustrine and marine sediments of the Champlain Sea.

The Pleistocene stratigraphy described above is based on the lithostratigraphic succession exposed in the Saint-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 nonglacial 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) by applying the following reasoning (Fig. 4):

1. Nonglacial sediments radiocarbon-dated at 65 ka are exposed at the St. Pierre Sediments type section (Section 58).
2. The St. Pierre Sediments are underlain by a red till at sections 59 and 50; this till was correlated with Bécancour Till, whose type section is located along Rivière Bécancour (section 23 of Gadd, 1955; 1 in Fig. 1).
3. The lower pinkish grey till at Cap Lévrard sections 60 and 65, was also correlated with Bécancour Till.
4. Varves underlying this till, named Cap Lévrard Varves, were believed to be the oldest Quaternary sediments in the area.

5. A grey till directly overlies St. Pierre Sediments at sections 56, 50 and 65, and it was correlated with the surface till in the Gentilly area (Gentilly Till); this unit was defined in excavations in the village of Gentilly (2 in Fig. 1);
6. Varves overlying St. Pierre Sediments at section 58 were originally known as the Gray Varves (Gadd, 1955); these varves are covered by a thin (60 cm) layer of grey till at section 53.

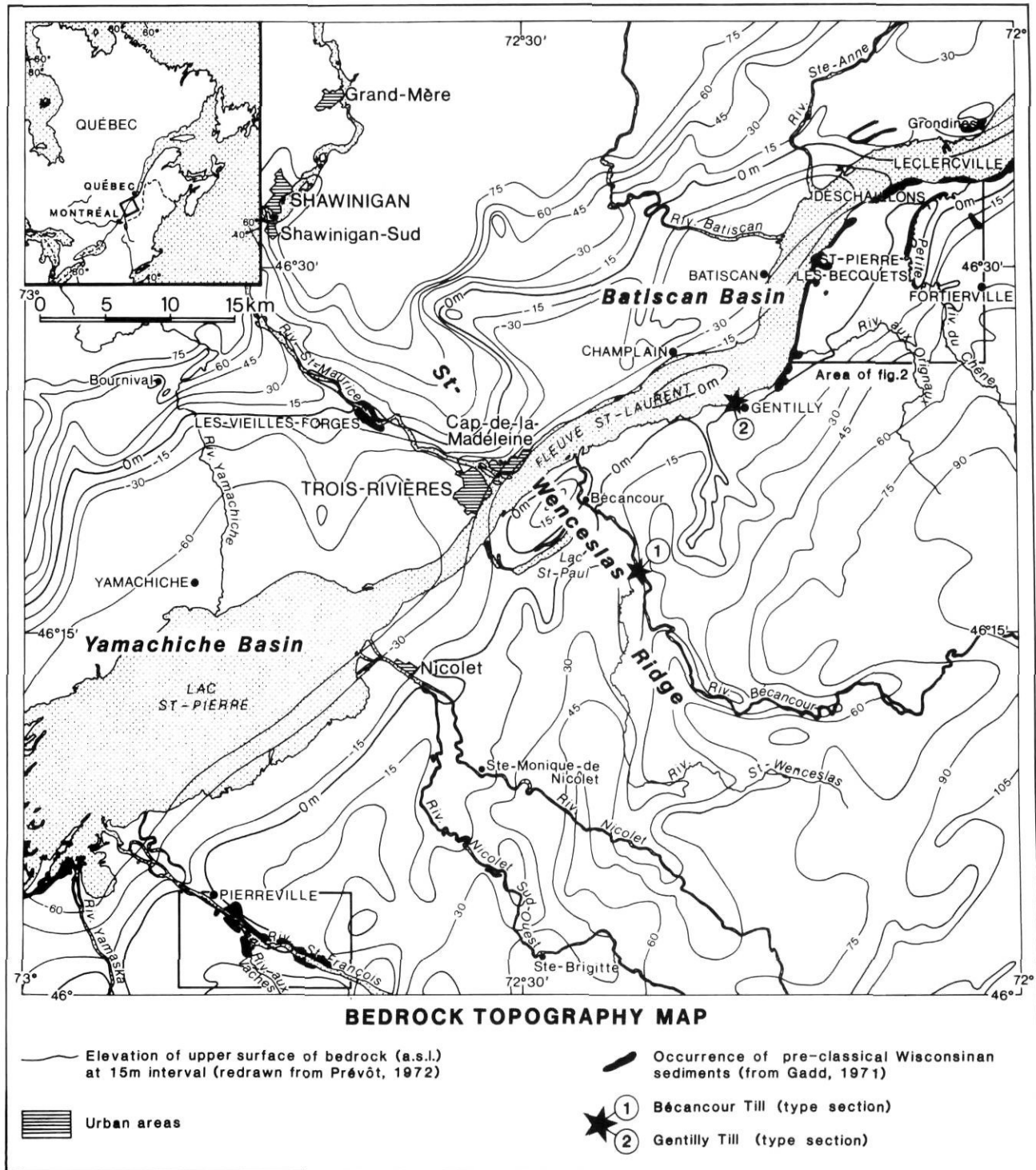


FIGURE 1. Location of the study area and bedrock topography map with occurrences of pre-classical Wisconsinan sediments in the central St-Lawrence Lowland.

Localisation de la région à l'étude et topographie du substratum rocheux avec les zones d'affleurement des sédiments pré-wisconsinniens classiques dans la partie centrale des basses terres du Saint-Laurent.

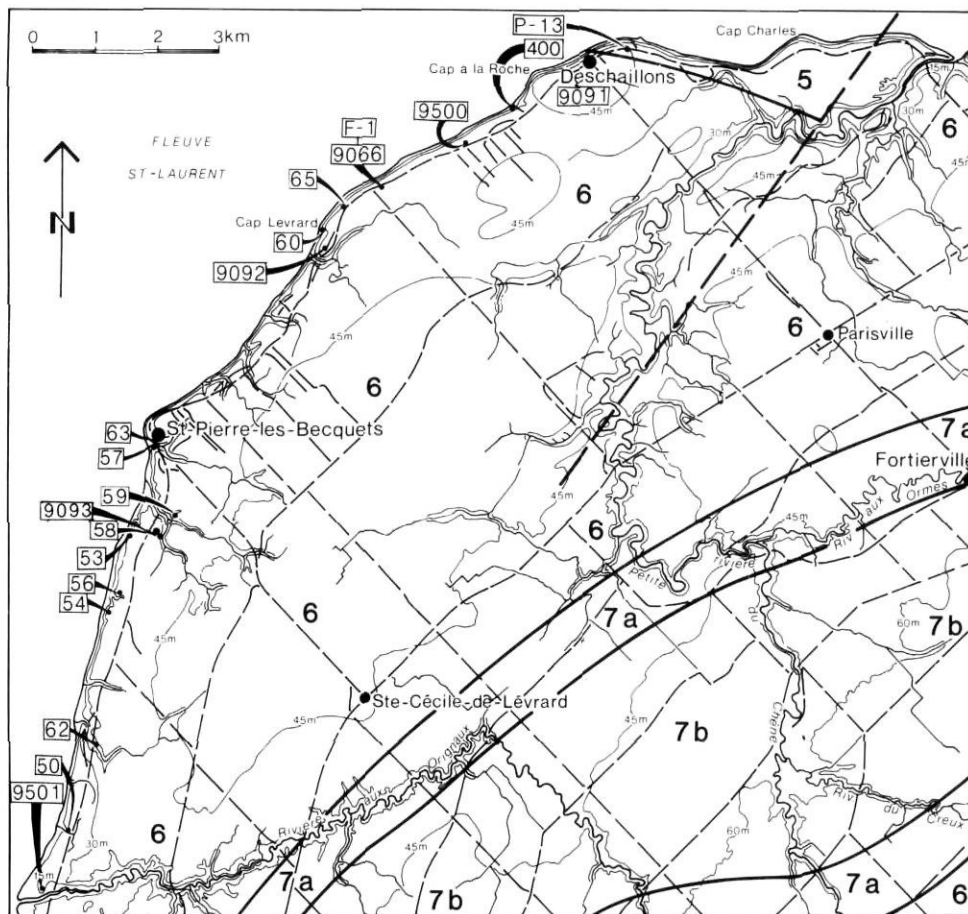


FIGURE 2. Location of the Saint-Pierre-les-Becquets sections and boreholes: numbers 5, 6, 7a, and 7b refer to the bedrock units (see Lamothe, 1985, for details).

Localisation des coupes et des forages de la région de Saint-Pierre-les-Becquets, les numéros 5, 6, 7a et 7b se rapportent aux unités de la roche en place (voir Lamothe, 1985, pour les détails).

7. The Gray Varves were correlated with Deschailions Varves (section 400) because: a) of equivalent stratigraphic succession (Karrow, 1957) e.g. organic sediments overlain by varves in turn overlain by till; and b) "varves occupy the entire escarpment below the Roman Catholic Church at St. Pierre les Becquets, about 75 feet are exposed; these are in continuous outcrop with an eighty-foot vertical section of varves in the brickyard at Deschailions" (Gadd, 1955, p. 106).
8. By way of consequence, the lower organic-bearing sand at the brickyard was correlated with the St. Pierre peat-bearing sediments of the type section, and the upper grey till was correlated with the Gently Till.

This stratigraphic framework was characterized by a single nonglacial interval. In general, till deposition at each site was preceded and followed by glaciolacustrine sedimentation. This symmetry found in both the lower and upper glacial sequences suggested that, except for the base of the St. Pierre Sediments, no major discontinuity was present in the Pleistocene stratigraphic sequence of the St. Lawrence Lowland (Gadd, 1976).

RECENT EXPOSURES ALONG THE BLUFFS OF THE ST. LAWRENCE RIVER AND BOREHOLE DATA

During the course of research carried out since 1980, all sections located along a 20 km segment along the south

shore of the St. Lawrence River, between Rivière aux Orignaux and Deschailions have been examined (Lamothe, 1985; Fig. 2). Most of the original interpretations of Gadd and Karrow were confirmed. It was found, however, that the (post-St. Pierre) Deschailions 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 Gray Varves do not. The concretions are thought to be the result of early diagenesis (Hillaire-Marcel and Pagé, 1981). The calcareous concretions are geological objects that are characteristic of the units in which they occur, but the radiocarbon dates measured on these carbonates (Hillaire-Marcel and Pagé 1981; Lamothe *et al.*, 1983) do not represent the age of glaciolacustrine deposition. Their minute radiocarbon activity is due to some poorly understood secondary precipitation (see discussion in Lamothe, 1985). Furthermore, Deschailions and Cap Lévrard varves yield similar apparent TL ages (≥ 70 and > 60 ka respectively; Lamothe, 1985; Lamothe and Huntley, 1988). Therefore, these two units appear as correlatives. This correlation implies that two distinct nonglacial sequences are present: the lower organic-bearing sand in the Deschailions 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 Deschailions (9091),

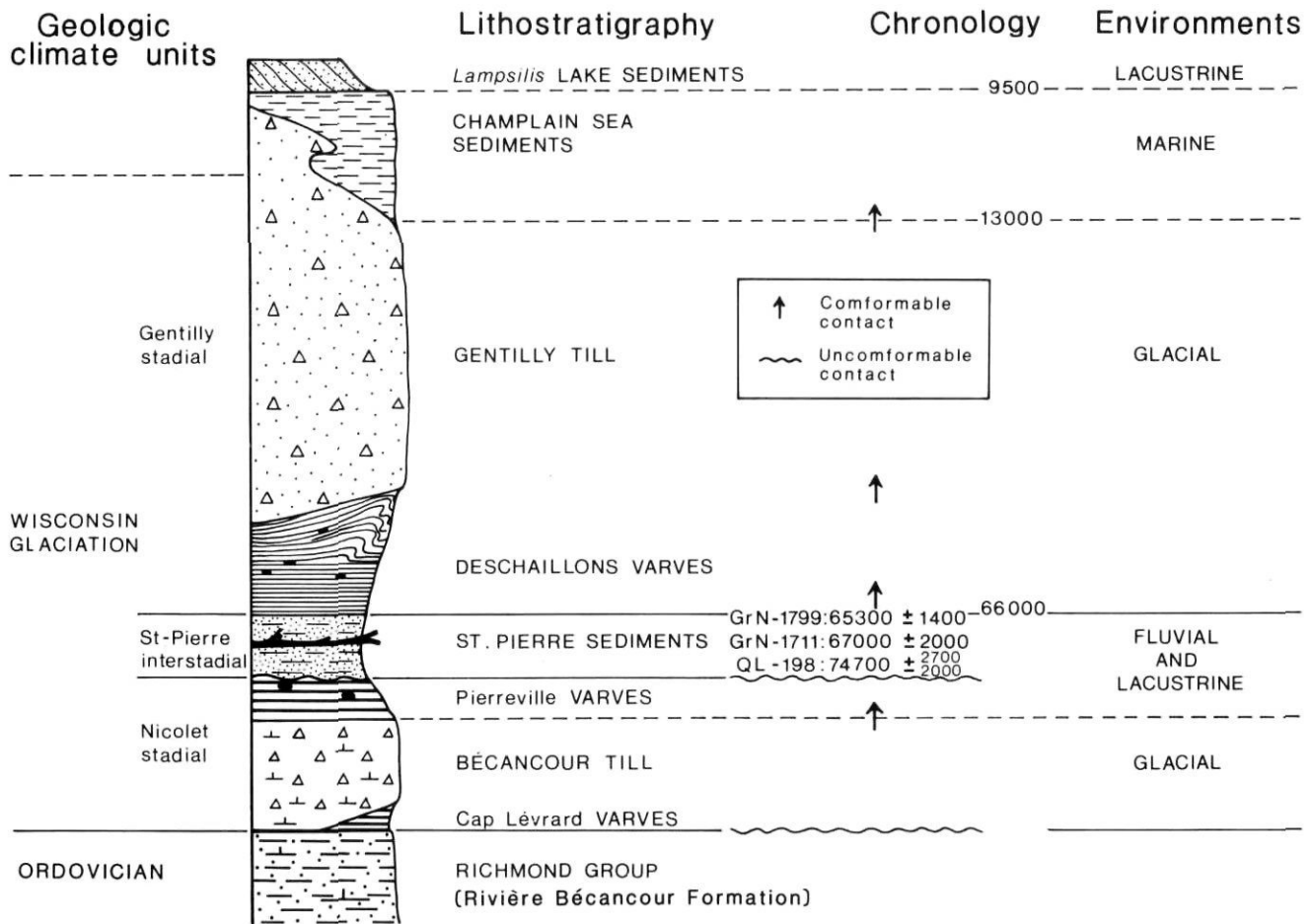


FIGURE 3. The traditional concept of Pleistocene stratigraphy in the St. Lawrence Lowland, from Gadd (1955, 1971, 1976) and Karrow (1957); the Nicolet Stadial was introduced by Dreimanis and Karrow (1972).

Le concept traditionnel de la stratigraphie du Pléistocène des basses terres du Saint-Laurent selon Gadd (1955, 1971, 1976) et Karrow (1957); l'unité «Stade de Nicolet» a été introduite par Dreimanis et Karrow (1972).

Cap Lévrard (9092), and Saint-Pierre-les-Becquets (9093) (Fig. 2). 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, as observed in boreholes 9091, 9093, P-13, and F-1, can be traced almost continuously from the Deschaillons brickyard (section 400 of Karrow, 1957) to the St. Pierre type section (section 58 of Gadd, 1971), where they occur beneath the peat-bearing sediments (Fig. 5). This demonstrates that the lower organic sand at the brickyard represents an older nonglacial 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 borehole, and it underlies the nonglacial sand exposed at the brickyard. Finally, at Cap Lévrard (section 9066), organic silt (dated at > 35 ka BP, GSC-4330) has been discovered and this organic unit overlies till that in turn overlies Cap Lévrard Varves.

REVISED PLEISTOCENE LITHOSTRATIGRAPHIC SUCCESSION AND EVENTS IN THE ST. LAWRENCE LOWLAND AND HYPOTHETICAL CORRELATION WITH THE DEEP-SEA RECORD

The fence diagram discussed in the next section shows that the sediments exposed along the shore of St. Lawrence River fill paleo-channels and that several of these pinch out laterally over very short distances. Consequently, no single section contains all lithostratigraphic units. Recent exposures and borehole data in the Saint-Pierre-les-Becquets area reveal, however, an almost complete succession in the vicinity of the Cap Lévrard sections (Fig. 5 and 6). The succession of lithostratigraphic units, a description of the corresponding climatostratigraphic units, and a correlation with the deep-sea record follow (Fig. 7). Correlations with the deep-sea record (Shackleton and Opdyke, 1973) are based on the assumption that the St. Lawrence Lowland is a sensitive region in terms of ice sheet growth since any significant build-up of glacier ice on the continent will affect drainage routes by blocking

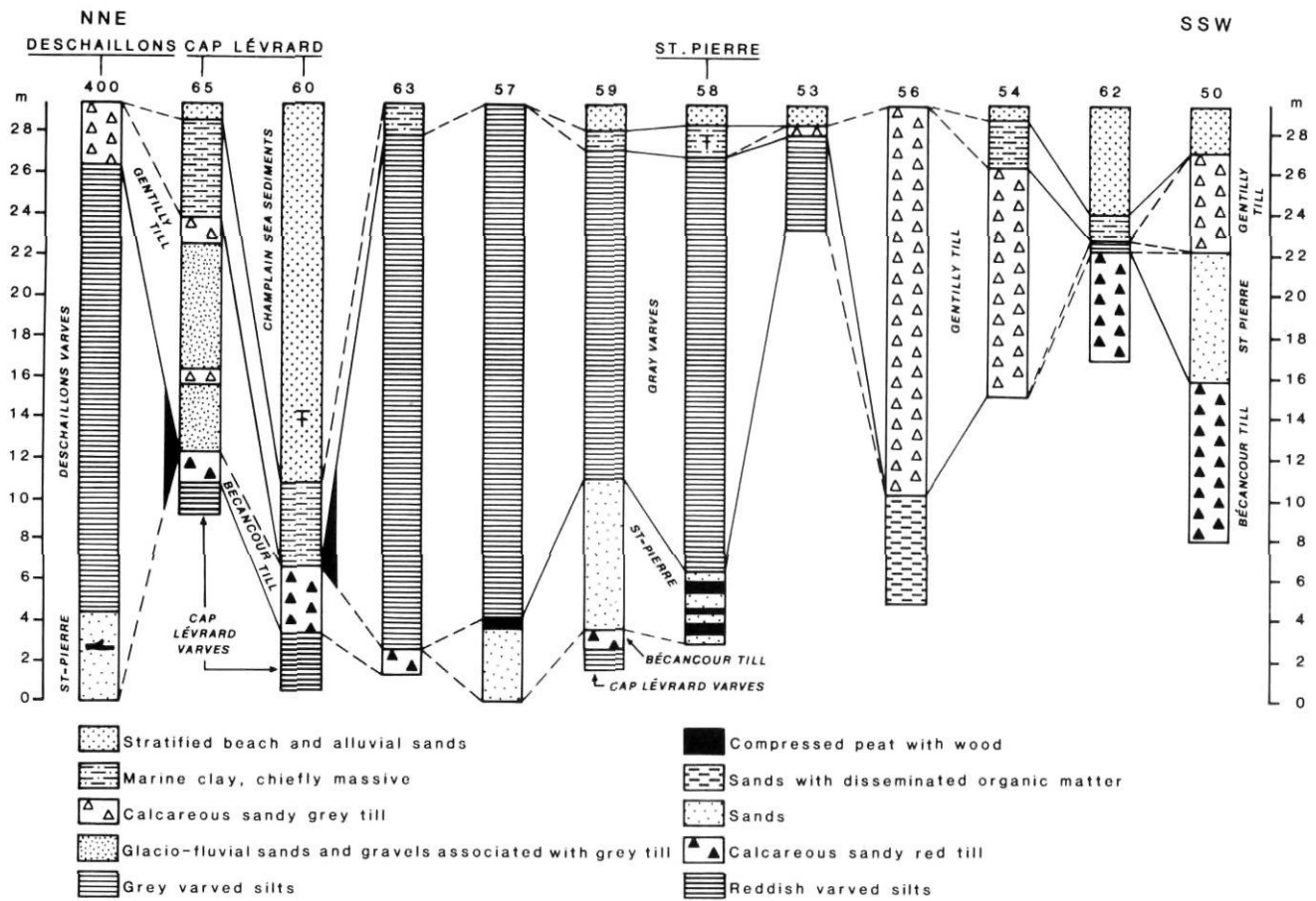


FIGURE 4. Correlation of the St. Lawrence River sections according to Gadd (1971). His Figure 8 is slightly modified: section 400 of Karrow (1957; Deschaillons brickyard), and the black pinchouts are added.

Corrélation des coupes le long du Saint-Laurent selon Gadd (1971). Sa figure 8 est légèrement modifiée: la coupe 400 de Karrow (1957; briqueterie de Deschaillons) et les tronçatures noires ont été ajoutées.

the lower St. Lawrence Valley, causing large ice-dammed lacustrine basins to form in the central part of the lowland (Gadd, 1971).

In this section, a new stratigraphic nomenclature is introduced. Two lithostratigraphic units are defined from sections and borehole data at Cap Lévrard and at the Deschaillons brickyard (Fig. 5). Sedimentological characteristics of these units can be found in Lamothe (1985). Three climatostratigraphic (or geologic events) units are presented in order to adequately name regional geologic events during which the physical units were deposited. These climatostratigraphic units are herein considered as diachronic units as defined by the North American Commission on Stratigraphic Nomenclature (1983).

ST. LAWRENCE STADE

The name St. Lawrence Stade was introduced by Lamothe (1985) as the geologic event responsible for deposition of the oldest glacial deposits in the area. The earliest recorded glacial event is represented by a sandy till overlying bedrock. Geotechnical data available from the Bécancour area (Maranda, 1977) indicate that the lowermost till observed in boreholes is the till exposed at the Bécancour Till type section. A clayey

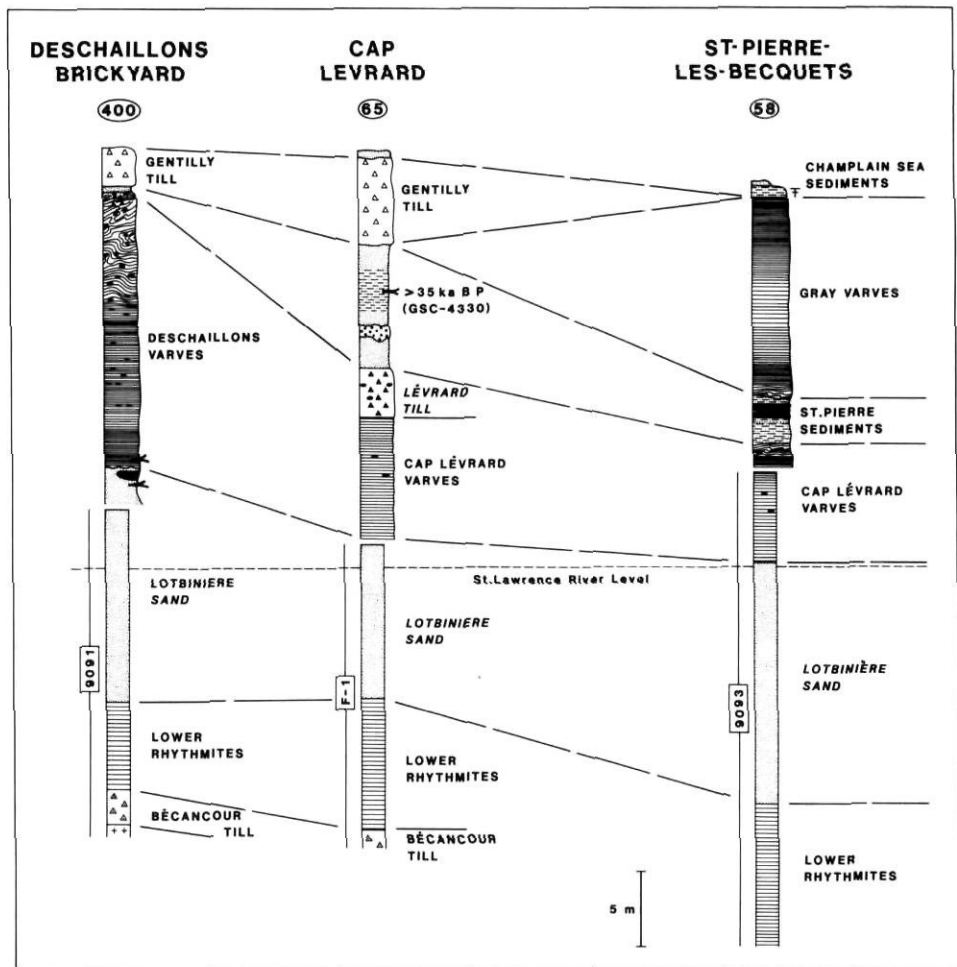
rhythmically bedded unit overlies the till. This suggests that glaciolacustrine sedimentation prevailed during ice retreat. No name is suggested at the moment for this unit since it can only be observed in boreholes. This sequence is thought to be Illinoian, particularly in the light of the discovery of interglacial sediments overlying till at Pointe-Fortune, west of Montréal (Anderson *et al.*, 1988). There, till units both overlie and underlie a sequence of nonglacial organic-bearing sediments in which the fossil biota is interpreted as reflecting climatic conditions at least as warm as today. The lower and upper tills are correlated with the Bécancour and Gently tills of the central St. Lawrence Lowland by Veillette and Nixon (1984). No "warm" interglacial sediments have yet been observed above these sediments in the central part of the St. Lawrence Lowland. The lower time boundary of this geologic event is unknown. The upper boundary is set a 128 ka. This glacial event is tentatively correlated with isotopic stage 6 of Shackleton and Opdyke (1973).

GRONDINES INTERSTADE

The name Grondines Interstade is introduced herein for the first time. It represents a time interval during which free drainage was re-established in the lowland, after the retreat

FIGURE 5. Lithostratigraphic succession and correlation, Deschailions brickyard, Cap Lévrard and Saint-Pierre-les-Becquets sections and borehole data.

Succession et corrélation lithostratigraphique, selon les coupes et données de forage disponibles aux sites de la briqueterie de Deschailions, du cap Lévrard et de Saint-Pierre-les-Becquets.



of the glacier that deposited Bécancour Till and associated rhythmites. During this period, the organic-bearing sand exposed at the base of the Deschailions brickyard section was deposited. It is herein suggested that this unit be known as the *Lotbinière Sand*, from the name of the local county. This unit outcrops at the base of the St. Lawrence River bluffs between Cap Lévrard and Cap Charles (Fig. 2). The type section for this unit is the Deschailions brickyard (section 400, of Karrow, 1957; NTS 31 I/9; 46°33'00"N, 72°08'00"W; Fig. 5). There, the Lotbinière Sand outcrop at river level. It is conformably overlain by the Deschailions Varves (Gadd, 1971). The Gentilly Till is found at the top of the sequence. Borehole data confirm that the Lotbinière Sand overlies the unnamed lower rhythmites and Bécancour Till. The unit is defined as oxidized yellow (10 YR 5/5) sand with parallel, cross-bedded and rippled stratification, indicating they were deposited by a stream flowing towards the northeast. The sedimentology of this unit is discussed in further details by Lamothe (1985). Gadd (1955) discovered a thin (2 cm) discontinuous layer of compressed *Sphagnum* peat and flattened twigs of wood, near the top of this unit at the east end of the brickyard. In the course of this investigation, a layer of organic silt (50 cm) was discovered in the sand, 1 m below the base of Deschailions Varves. According to Matthews (GSC Fossil Arthropod Report 86-19) who made a preliminary investigation of the organic

detritus in this unit, the climate at the time of deposition was colder than today, but the assemblage differs slightly from the typical St. Pierre assemblages. The age of this unit is older than the radiometric ages obtained on the St. Pierre Sediments peats (see below) *i.e.* at least 65 ka, and more probably closer to *ca.* 90-80 ka, as indicated by thermoluminescence (Lamothe and Huntley, 1988) and uranium-thorium age determination (Hillaire-Marcel and Causse, in press) obtained on sediments and carbonate concretions of the overlying Deschailions Varves. Sedimentological, paleoecological, and geochronological data from this unit suggest that the corresponding climatostratigraphic unit is an interstade that is tentatively placed in the latest part of marine isotope stage 5 (5a of Shackleton and Opdyke, 1973). Following the Canadian Quaternary stratigraphic framework presented by Fulton (1984), this geologic event would be part of the Sangamonian Stage (*sensu lato*).

NICOLET STADE

Nicolet Stade is a climatostratigraphic unit introduced by Dreimanis and Karrow (1972) and it is defined as the earliest Wisconsinan stade in the Eastern Great Lakes — St. Lawrence region. The Cap Lévrard Varves and the overlying till were deposited during this glacial event.

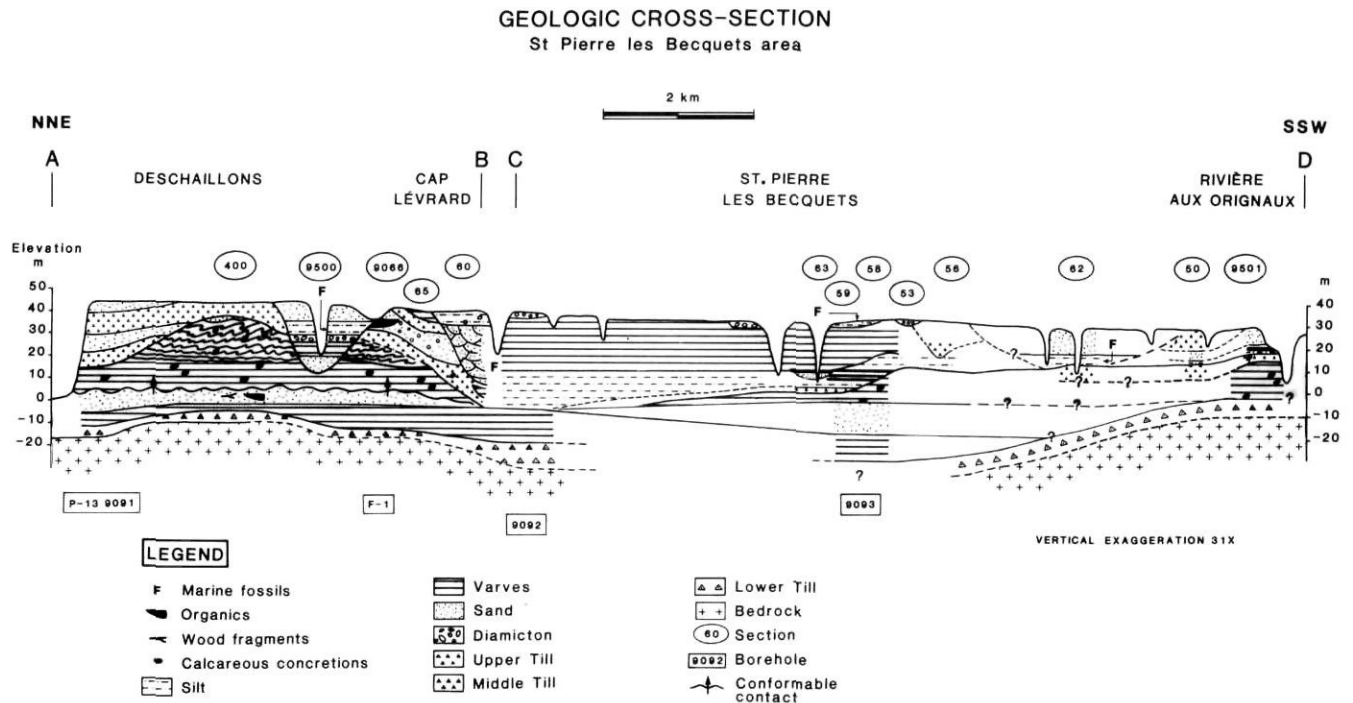


FIGURE 6. Geologic cross-section along the St. Lawrence River; numbers shown above the profile are sections; numbers below are boreholes; note the vertical exaggeration. Concretions and deformations in the Deschailions and Cap Lévrard varves are indicated.

Coupe topogéologique le long du Saint-Laurent; les numéros à la surface du profil se rapportent aux coupes et les numéros à la base, aux forages; à noter l'exagération verticale. Les concrétions et les déformations dans les varves de Deschailions et du cap Lévrard sont indiquées.

This glacial assemblage was informally called Lévrard formation by Lamothe (1985). In order to avoid difficulties that may arise from grouping both the till and the varves into a single lithostratigraphic unit, it is herein proposed to keep the name Cap Lévrard Varves of Gadd (1971) for the clayey rhythmites that outcrop at river level at the Cap Lévrard section (section 60, Gadd, 1955). The varved sediments exposed at Cap Lévrard and in the Deschailions brickyard are correlated and they conformably overlie the Lotbinière Sand. At the Cap Lévrard section (section 65; Gadd, 1955), the rhythmites are overlain by 5 m of till, 6 m of sand (St. Pierre Sediments) and 5 m of till (Gentilly Till). Recently, a thin (30 cm) layer of sand was observed under the Cap Lévrard Varves. The till overlying the Cap Lévrard Varves is here named the Lévrard Till. The type section for Lévrard Till is the Cap Lévrard section (sections 60 and 65, of Gadd, 1955; NTS 31 1/9; 46°32'15"N, 72°10'00"W; Fig. 5). This unit is defined as a pinkish grey (10 R 5/1) silty and clayey, compact till. The till contains 20% clasts, which consist of Ordovician limestone and Precambrian gneiss and granite. Striated calcareous concretions glacially derived from the underlying varves can be found in the till. One of these have been dated at > 40 ka BP (I- 13317; Lamothe, 1985). The till is overlain by organic-bearing sediments correlated with the St. Pierre Sediments of the type section. At the Cap Lévrard section (sub-section 9066, Fig. 2, 5 and 6), a layer of organic silt was observed in the fall of 1986. A piece of wood collected in this unit was dated at > 35 ka BP (GSC-4330; *Picea*; GSC Wood Identification Report 86-59).

During deposition of these sediments, free drainage in the St. Lawrence Valley was once again blocked by an advancing

glacier. Based on varve counts, Hillaire-Marcel and Pagé (1981) suggested the Deschailions Varves represent 4000 years of glaciolacustrine sedimentation. Lamothe (1985) presented evidence that the total number of couplets does not exceed 2500. At Cap Lévrard, the varved sediments are overlain directly by till deposited by this glacier. Apparent TL dates measured on pre-St. Pierre glaciolacustrine sediments are in the range of 86-70 ka (Lamothe, 1985; Lamothe and Huntley, 1988). These apparent TL ages are only slightly older than the TL and ¹⁴C ages measured on the overlying St. Pierre Sediments (see below). These ages are thus consistent with the stratigraphic succession and may be close to the true geological age of the unit. This glacial event is likely Early Wisconsinan and it is believed to correlate with marine isotope stage 4 of Shackleton and Opdyke (1973). There seems to be no equivalent geologic event recorded at the Pointe-Fortune site (Veillette and Nixon, 1984).

LES BECQUETS INTERSTADE

Since the name St. Pierre Sediments defines the organic-bearing sediments first described at the Saint-Pierre-les-Becquets type section, a new name is needed for the corresponding climatostratigraphic unit. It is herein proposed that this nonglacial event be known as the Les Becquets Interstade, from the name of the Saint-Pierre-les-Becquets village.

The organic-bearing sediments found near the top of the Cap Lévrard section are correlated with the St. Pierre Sediments of Gadd (1971) as defined in the type section at Saint-Pierre, and with organic-bearing sediments found in similar stratigraphic position at Rivière aux Orignaux (Section 9501,

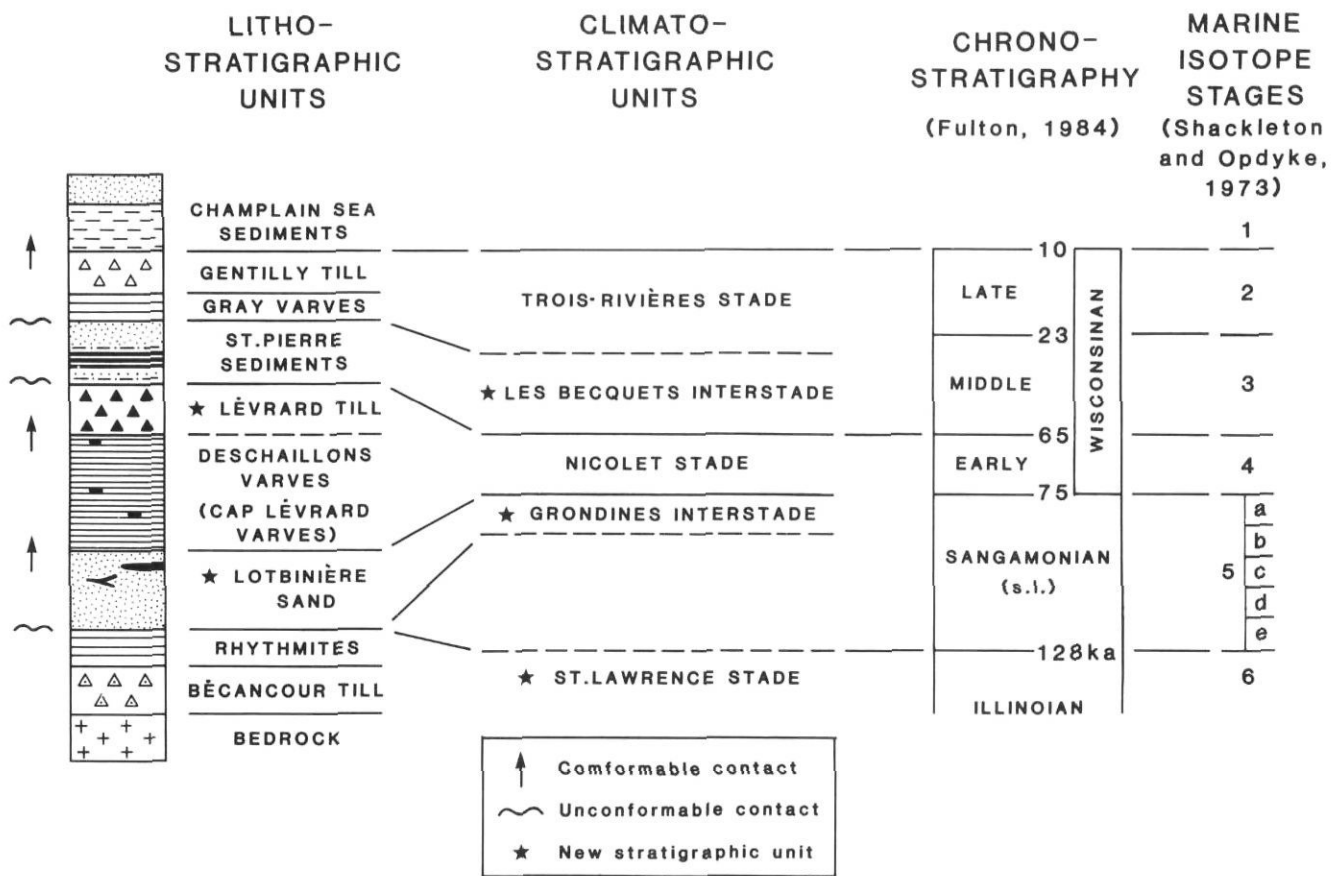


FIGURE 7. Revised Pleistocene stratigraphic framework, in the St. Lawrence Lowland, and suggested correlations with the oceanic record.

Schéma stratigraphique révisé du Pléistocène des basses terres du Saint-Laurent et corrélations proposées avec la stratigraphie océanique.

Fig. 6). They are also correlated with the organic sediments exposed at Pierreville (Fig. 1), which were radiocarbon dated at 75 ka (Stuiver *et al.*, 1978). A series of apparent TL ages measured on this unit suggests a slightly younger age of ca. 60 ka (Lamothe, 1984). These sediments are all dated at or beyond the limit of the radiocarbon method. These geochronological data suggest the lower time boundary of this geologic event is ca. 65-60 ka so that Les Becquets Interstade can be correlated with the earliest part of marine isotope stage 3 of Shackleton and Opdyke (1973). Fossil biota indicate that during deposition of these sediments, the climate was colder than today (Terasmae, 1958; Matthews, 1987).

TROIS-RIVIÈRES STADE

This climatostratigraphic unit has been introduced in the central St. Lawrence Lowland stratigraphic nomenclature by Occhietti (1982). The Gray Varves and overlying Gentilly Till were deposited during this geologic event.

The unconformity between the St. Pierre Sediments and the overlying glacial sediments suggests an erosional interval of unknown duration. The minimum age for the beginning of this glacial advance has become the subject of some controversy among Quaternary stratigraphers in northeastern North America, mainly because of its implication for estimates of the extent of the ice sheet in Eastern Canada during Middle

Wisconsinan time. The ¹⁴C ages of 35 ka obtained on striated concretions in Gentilly Till (Lamothe *et al.*, 1983) and an apparent TL date of 28 ka at the top of the St. Pierre Sediments on a sample thought to have been zeroed by subaerial exposure (Lamothe, 1985; Lamothe and Huntley, 1988), suggest a late Middle Wisconsinan age for the inception of the last glacial advance. This age assignment would agree with an estimated age of 32 ka for the boundary between stages 3 and 2 of the marine isotope stratigraphy (Shackleton and Opdyke, 1973), as well as with radiometric ages of marine shells from Anticosti Island suggesting that the Gulf of St. Lawrence was ice-free at this time (Gratton *et al.*, 1984).

The rhythmites (Gray Varves) overlying the St. Pierre Sediments (section 58) are younger than the varved sediments at the Deschailions brickyard unlike the earlier suggestion by Gadd (1971). The name Gray Varves (Gadd, 1955) is re-introduced in the stratigraphic framework, shown in Figure 7 and it should be considered as an informal unit. Because it is uncertain whether the Gray Varves underlie or overlie Gentilly Till, the glaciolacustrine episode may have either preceded (hypothesis shown on Fig. 7) or followed the Late Wisconsinan glacial advance in the area. The latter hypothesis would imply that glaciolacustrine conditions existed in the central part of the St. Lawrence Lowland following deposition of Gentilly Till. This hypothesis should not be ruled out since 1) the Gray

Varves are commonly found at the top of the Quaternary sequence, 2) they are in some cases overlain by Champlain Sea sediments (e.g. section 58) and 3) they contain *Candona subtriangulata* (C. G. Rodrigues, pers. comm., 1987), an ostracode commonly found in pre-Champlain Sea freshwater deposits, in the southern part of the St. Lawrence Lowland (Anderson *et al.*, 1985; Parent, 1987; Rodrigues, 1987). However, the latter interpretation imposes severe constraints on the current hypothesis about 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; Shiels, 1981; Thomas, 1977).

CONCLUSION

The lithostratigraphic succession exposed in the Saint-Pierre-les-Becquets area clearly shows that the Pleistocene depositional sequence of the central St. Lawrence Lowland results from three glacial and two nonglacial events. The existence of two nonglacial breaks within the Pleistocene sequence of the St. Lawrence Lowland and the assignment of the Bécancour Till to the Illinoian Glaciation require major changes in correlation schemes in Eastern Canada. For example, units exposed in the Scarborough Bluffs, Toronto, have been correlated with the St. Lawrence traditional stratigraphic framework on the assumption that Bécancour Till is Early Wisconsinan and that the ice which deposited it raised Lake Ontario water level, resulting in aggradation of the Scarborough delta (Dreimanis and Karrow, 1972; Karrow, 1984). However, because Bécancour Till is more likely a correlative of the (Illinoian) York Till, that correlation is probably invalid. At present, correlation of units in the St. Lawrence Lowland with the Toronto sequence is hampered by a lack of chronological control in the latter region prior to 45 ka and by continuing dispute over the origin of some of the units in the Toronto area (Eyles and Eyles, 1983).

The Lotbinière Sand, the Deschaillons Varves and the Cap Lévrard Varves, the Lévrard Till and the St. Pierre Sediments are tentatively correlated with the latest part of marine isotope stage 5 (5a), stage 4, and the earliest part of stage 3 of Shackleton and Opdyke (1973) on the basis of the apparent thermoluminescence dates (86-70 ka) obtained on the Deschaillons Varves and other correlatives of the Cap Lévrard Varves, uranium-thorium dating on the concretions (Hillaire-Marcel and Causse, in press) and the assignment of the beginning of the Les Becquets Interstade at ca. 65-60 ka. The gradational contact between the Lotbinière Sand and the Deschaillons Varves suggests that, in this part of the St. Lawrence Lowland, transition to full glacial severity was accomplished in a relatively short time. The hiatus between the Lévrard Till and the overlying St. Pierre Sediments may be of short duration since evidence of sub-aerial weathering is lacking. These units apparently reflect brief but severe environmental changes that occurred at the beginning of the last glaciation and may indicate rapid ice sheet growth at the end of the last interglacial. Such a drastic change of ice volume might be recorded, also, in the marine oxygen isotope stratigraphy from the North Atlantic at the 5/4 transition (Ruddiman *et al.*, 1980).

Comparison between ice volume changes indicated by the isotopic composition of deep-sea benthic foraminifera and the Quaternary record of the St. Lawrence Lowland seems to favour correlation of the Nicolet Stade (Dreimanis and Karrow, 1972) with marine isotope stage 4. Minor time discrepancies between the two records may be attributed to uncertainties in the terrestrial chronology and to a non-linear linkage between the isotopic record and regional ice volumes (Mix and Ruddiman, 1984). In the St. Lawrence Lowland, glaciolacustrine conditions may have lasted for some 3000 years prior to deposition of Lévrard Till, if one believes in varve counts (Hillaire-Marcel and Pagé, 1981; Lamothe, 1985). This glacial event is apparently not recorded at Pointe-Fortune (Veillette and Nixon, 1984). When compared to the last glacial maximum, glacial units now thought to be associated with the Nicolet Stade and the amplitude of the marine isotope stage 4 anomaly both suggest a less extensive glacial cover on land in Early Wisconsinan time.

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