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The Sangamonian Stage and the Laurentide Ice Sheet
Le Sangamonien et la calotte glaciaire laurentidienne
Die sangamonische Zeit und die laurentische Eisdecke

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Résumé de l'article

La présente revue des travaux sur le Sangamonien (jusqu'à juin 1986) effectués dans des régions clés démontre qu'il n'y a pas encore de réponse satisfaisante à la question suivante: « À quel moment la glace, qui allait devenir la calotte glaciaire laurentidienne, a-t-elle commencer à s'accumuler? » Dans la plupart des régions, la séquence stratigraphique ne fait que signaler l'existence probable d'une période interglaciaire, sans toutefois permettre de déterminer le moment où la glace a commencé à s'accumuler après l'intervalle climatique chaud. Il existe toutefois quelques indices. Les sédiments d'un delta glaciolacustres de la Formation de Scarborough, dans la région de Toronto, et le Till de Bécancour, dans la région de Trois-Rivières, datent probablement du Sangamonien (sous-phases isotopiques marines 5d-b). Le Till d'Adam, dans les basses terres de la baie James, leur est probablement corrélatif. Dans les régions atlantiques du Canada, en particulier à l'île du Cap-Breton, des restes de plantes indiquent que le climat au cours du Sangamonien moyen aurait été très semblable à celui de la période de 11 000 à 12 000 ans BP. À l'île de Baffin, une transgression marine qui a eu lieu au Sangamonien moyen aurait pu être le résultat d'une importante accumulation de glace dans la région. Ces diverses interprétations régionales témoignent d'une importante croissance des glaciers dans plusieurs régions du continent nord-américain au cours du Sangamonien. On ne peut toutefois pas préciser si ces accumulations de glace ont survécu à la période plus chaude qui a prévalu à la fin du Sangamonien pour ensuite s'intégrer à la calotte glaciaire laurentidienne.

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THE SANGAMONIAN STAGE AND THE LAURENTIDE ICE SHEET*

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ABSTRACT This review of the most recent studies (up to June 1986) dealing with the Sangamonian in some key areas clearly indicates that, as yet, there is no definitive answer to the question: "When did the ice which eventually became the Laurentide Ice Sheet begin to accumulate?" In most areas the stratigraphic record simply identifies a probable interglacial period; the record yields no information on when ice growth may have started following that warm climatic interval. However the deltaic glacial lake sediments of the Scarborough Formation in the Toronto area and the Bécancour Till in the Trois-Rivières area are thought to possibly date from the Sangamonian (marine isotope substages 5d-b). The Adam Till in the James Bay Lowland may be correlative. In Atlantic Canada, mostly in Cape Breton Island, plant fossils suggest a mid-Sangamonian climate roughly comparable to that which prevailed 11-12 ka ago. On Baffin Island a marine transgression of mid-Sangamonian age is thought to result from important ice accumulation in the area. These stratigraphic interpretations suggest significant glacier expansion in several areas of the North American continent during part of the Sangamonian Stage. Whether or not any of this ice survived a warmer climate period near the end of the Sangamonian to become part of the Laurentide Ice Sheet is a matter of speculation.

RÉSUMÉ *Le Sangamonien et la calotte glaciaire laurentidienne.* La présente revue des travaux sur le Sangamonien (jusqu'à juin 1986) effectués dans des régions clés démontre qu'il n'y a pas encore de réponse satisfaisante à la question suivante : « À quel moment la glace, qui allait devenir la calotte glaciaire laurentidienne, a-t-elle commencer à s'accumuler? » Dans la plupart des régions, la séquence stratigraphique ne fait que signaler l'existence probable d'une période interglaciaire, sans toutefois permettre de déterminer le moment où la glace a commencé à s'accumuler après l'intervalle climatique chaud. Il existe toutefois quelques indices. Les sédiments d'un delta glaciolacustres de la Formation de Scarborough, dans la région de Toronto, et le Till de Bécancour, dans la région de Trois-Rivières, datent probablement du Sangamonien (sous-phases isotopiques marines 5d-b). Le Till d'Adam, dans les basses terres de la baie James, leur est probablement corrélatif. Dans les régions atlantiques du Canada, en particulier à l'île du Cap-Breton, des restes de plantes indiquent que le climat au cours du Sangamonien moyen aurait été très semblable à celui de la période de 11 000 à 12 000 ans BP. À l'île de Baffin, une transgression marine qui a eu lieu au Sangamonien moyen aurait pu être le résultat d'une importante accumulation de glace dans la région. Ces diverses interprétations régionales témoignent d'une importante croissance des glaciers dans plusieurs régions du continent nord-américain au cours du Sangamonien. On ne peut toutefois pas préciser si ces accumulations de glace ont survécu à la période plus chaude qui a prévalu à la fin du Sangamonien pour ensuite s'intégrer à la calotte glaciaire laurentidienne.

ZUSAMMENFASSUNG *Die sangamonische Zeit und die laurentische Eisdecke.* Dieser Überblick über die neuesten Studien (bis Juni 1986) zur sangamonischen Zeit in einigen Schlüsselgebieten zeigt deutlich, daβ es bis heute keine endgültige Antwort auf die Frage gibt: "Wann begann sich das Eis anzuhäufen, das schlieβlich zur laurentischen Eisdecke wurde?" In den meisten Gebieten zeugen die stratigraphischen Spuren von einem wahrscheinlichen interglazialen Zeitabschnitt; die Spuren geben keine Auskunft darüber, wann der Eiswuchs nach diesem warmen klimatischen Zwischenspiel begonnen haben mag. Die Sedimente der deltaförmigen Eis-Seen der Scarborough-Formation in der Gegend von Toronto und die Bécancour-Grundmoräne in der Gegend von Trois-Rivières stammen vermutlich beide aus der sangamonischen Phase (Meeres-Isotopische Unterstadien 5d-b). Die Adam-Grundmoräne im James-Bay-Tiefland hängt damit möglicherweise zusammen. In Ost-Kanada, vor allem auf der Cap-Breton-Insel, legen Pflanzen-Fossilien nahe, daβ dort ein Klima der mittleren sangamonischen Phase herrschte, das dem von vor 11 bis 12 ka ungefähr glich. Auf der Baffin-Insel hält man die Ufer-Bewegung in der sangamonischen Zeit für die Auswirkung groβer Eisanhäufung in der Gegend. Diese Deutungen der Stratigraphie legen eine umfangreiche Gletscher-Ausdehnung in mehreren Gegenden des nordamerikanischen Kontinents während eines Teils der sangamonischen Zeit nahe. Ob Teile dieses Eises eine wärmere Phase gegen Ende der sangamonischen Zeit überdauerten, um ein Teil der laurentischen Eisdecke zu werden, oder ob dies nicht der Fall war, bleibt offen.

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INTRODUCTION

In order to properly discuss the temporal aspects of the development and decay of the Laurentide Ice Sheet it is important to identify when ice which resulted in the Laurentide Ice Sheet started to grow. This necessitates studying the stratigraphic record of the Sangamonian Stage, the time stratigraphical unit which includes the interglaciation which preceded the Wisconsin Glaciation, to determine when and where Laurentide Ice Sheet build up started.

As will be seen, the information available is often meagre, and because of a lack of reliable dating techniques, is highly speculative. Much more work is required before lithostratigraphic units can be assigned to the Sangamonian Stage with confidence. Whether or not glaciogenic sediments of presumed Sangamonian age were deposited by glaciers which survived into the Wisconsinan to become part of the Laurentide Ice Sheet is still largely speculative. It is a tantalizing possibility and a challenge for present and future Quaternary geoscientists.

In this paper, studies of important areas (Fig. 1) are reviewed in order to determine how closely the start of growth of the Laurentide Ice Sheet can be defined and what evidence is presently available on the extent of ice during the Sangamonian Stage. The intent is not to carry out a comprehensive review of the abundant literature on the Sangamonian but, more specifically, to provide a lower time limit for the Laurentide Ice Sheet and to determine if there is any evidence from the period included within marine isotope stage 5 for ice buildup that would have given birth to the Laurentide Ice Sheet.

DEFINITION

The Sangamon Interglaciation was originally defined by LEVERETT (1898) and is represented by an extensive and well defined soil profile that is developed on Illinoian till and is covered by Wisconsinan loess or till. The type section was in Loveland, Iowa (FLINT, 1957, p. 339) until a type area with reference sections in central Illinois (Fig. 1) was defined by FOLLMER (1978). It is postulated that the Eemian Interglaciation is the northern European equivalent. The definition of the last interglaciation in Canada has been discussed by FULTON (1984, p. 3) who concludes that the broad global approach should be adopted and that the chronostratigraphic unit, the Sangamonian Stage which includes most or all of the last interglaciation should be defined as beginning about 128 ka BP and lasting until 75 ka BP, these numbers have here been rounded off to 130 ka and 80 ka. This general definition is adopted here. However, as will be discussed later, there are differing views on where nonglacial units at the base of Laurentide Ice Sheet deposits should be located in the stratigraphic sequence of the Late Pleistocene. In the absence of reliable absolute dating techniques this is not surprising. Each stratigraphic column in the chart of Figure 2 reflects the reasoning and assumptions made by the authors of the papers used in this synthesis. This divergence of views is illustrated in the recent volume on the Quaternary Stratigraphy of Canada (FULTON, 1984). Although in the general summary Quaternary stratigraphy at the beginning of that book the Sangamonian Stage is defined as corresponding to "the limits of oxygen isotope stage 5" (p. 3), several authors take the more restricted view that the Sangamonian Stage corresponds to marine isotope stage 5e, 128 to approximately 120 ka (see Canadian Prairies chart, FENTON, 1984, p. 62; Hudson Bay Lowland chart, SHILTS, 1984, p. 122; Arctic correlation diagram, ANDREWS *et al.*, 1984, p. 130; Great Lakes-St. Lawrence region chart, KARROW, 1984, p. 146). It would seem that this restricted view is adopted by some because the marine isotopic record indicates the presence of moderately extensive glacier ice during the period 120 ka to 85 ka (5b-c-d). The significant point in this discussion however is not whether ice buildup occurred during stage 5 but whether or not any significant amount survived beyond stage 5 into the Early Wisconsinan Substage.

It is one thing to define the chronostratigraphic limits of a period such as the Sangamonian Stage and quite another to assign specific sediments to that time interval. The reader must bear this in mind when evaluating the reasons why various workers have assigned certain lithostratigraphic units to the Sangamon Interglaciation and other units either glacial or nonglacial to other parts of the Sangamonian Stage as discussed below.

In regions other than the southern margin of the Laurentide Ice Sheet, deposits are generally assigned a Sangamonian age if they contain fossils indicating climate equal to, or warmer than the present, and if they are overlain by glacial deposits and/or by nonglacial deposits representing cooler than present climatic conditions. A problem with this approach is that climate during the Sangamonian Stage was variable so that at times the climate was cooler (5c) to much colder (5d and 5b) than present, at times it was equal or warmer (5e) than present, and at other times somewhat cooler (5a) than present.

This "counting downward" approach to stratigraphic classification clearly has its pitfalls in continental environments. In most cases, it is not possible to demonstrate that the first lithostratigraphic unit from the top that represents a climate equal to or warmer than present necessarily corresponds to the Sangamonian Stage; it could be much older with intervening units missing for any of a large number of reasons. This problem, which is due to the lack of reliable dating techniques beyond the radiocarbon range should incite a very cautious approach to stratigraphy but, as will be discussed later, this is not always the case, with the result that regional stratigraphic sequences are difficult to correlate. In a sense the units beyond the limits of radiocarbon dating are floating. They can be moved up or down the stratigraphic column depending on the basic assumptions made by the various authors.

Nevertheless, the attempt to summarize the evidence in the terrestrial record regarding timing of inception of the Laurentide Ice Sheet must be made. There is no such thing as an unbiased opinion; the best that can be hoped for is an honest one and that is the basis on which this attempt to trace the origin of the Laurentide Ice Sheet is made.

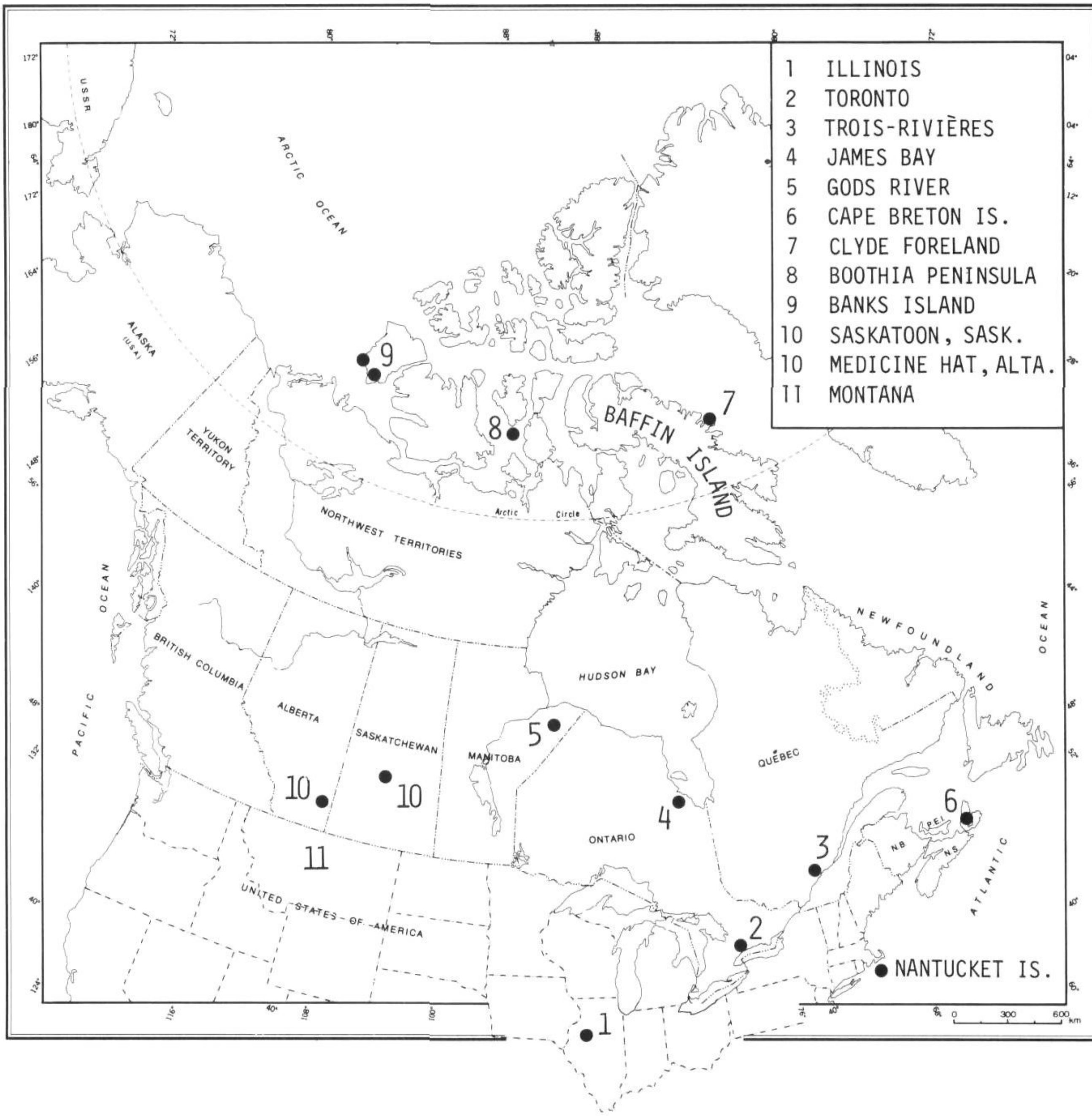


FIGURE 1. Location of areas for which Sangamonian stratigraphic information is presented in Figure 2.

Localisation des régions qui contiennent les indices d'ordre stratigraphique présentés dans la figure 2.

ICE BUILDUP DURING THE SANGAMONIAN

As indicated earlier the purpose of this paper is not to review all of the literature which deals with Sangamonian time but to provide a broad overview of the evidence pertaining to the lower limit of the Laurentide Ice Sheet. This will be done by reviewing the most recent literature pertaining to specific sites within major regions, once occupied by the Laurentide Ice Sheet.

1. ILLINOIS (Fig. 2, Col. 1)

The Sangamon Soil (LEVERETT, 1898) developed throughout the entire Sangamonian Stage in the region where it was originally defined and, in central Illinois, radiocarbon dates indicate that the pedogenic evolution of this exceptional stratigraphic marker may have continued up to 42 ka (JOHNSON, 1986). Kettle holes developed in Illinoian drift "...contain a nearly continuous record of late Illinoian to Holo-

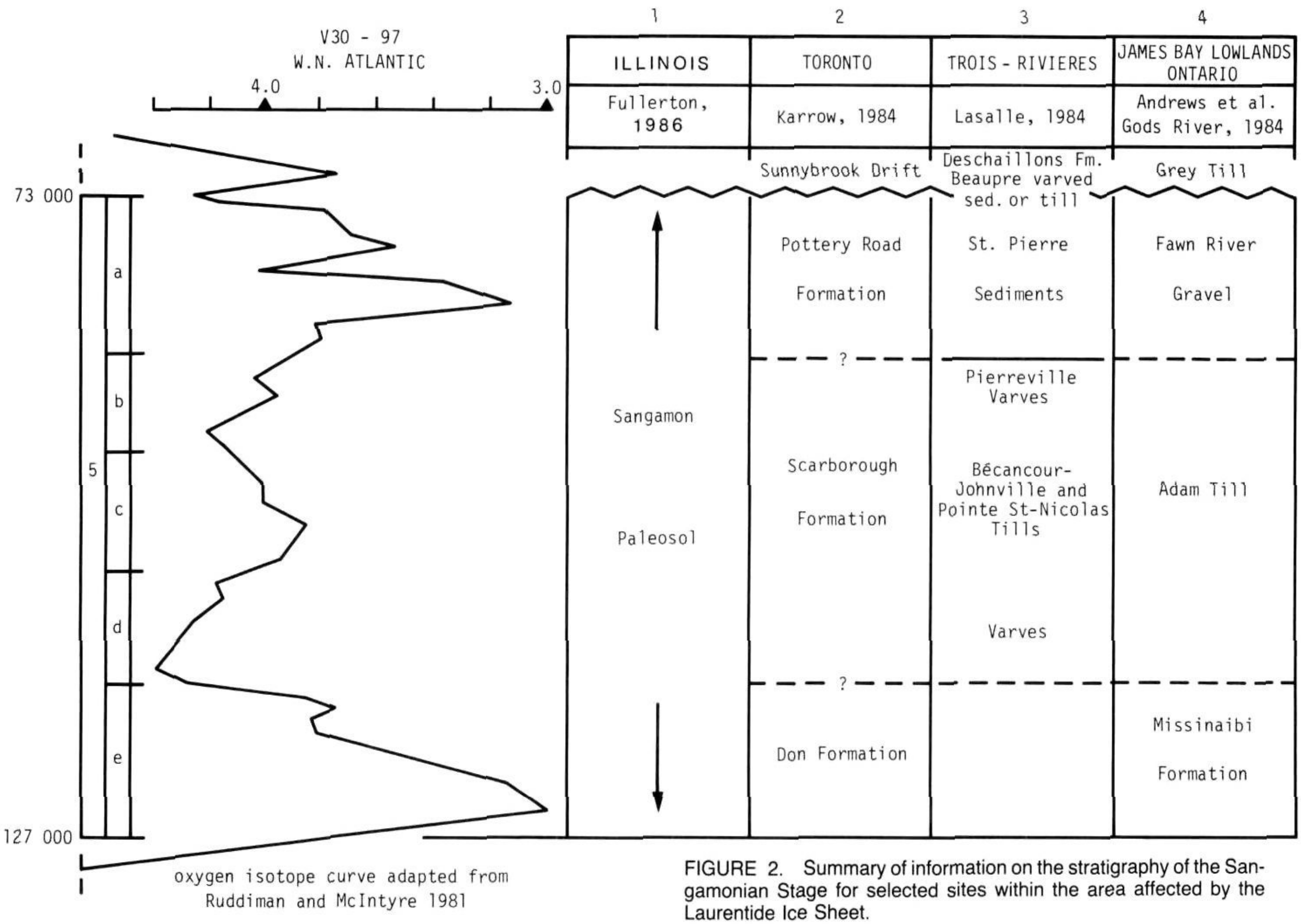


FIGURE 2. Summary of information on the stratigraphy of the Sangamonian Stage for selected sites within the area affected by the Laurentide Ice Sheet.

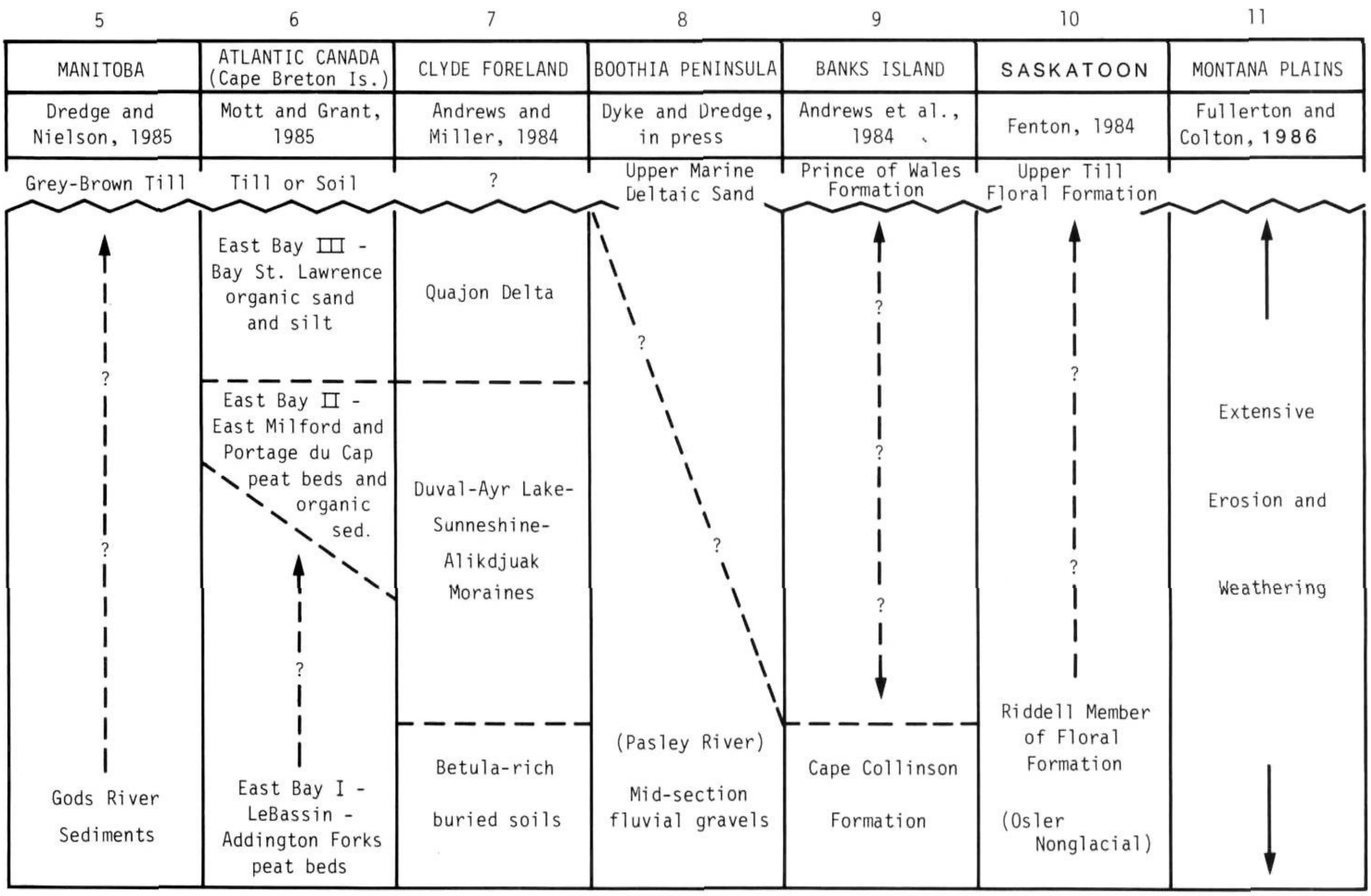
Résumé des données sur la stratigraphie du Sangamonien pour quelques sites choisis dans la zone recouverte par la calotte glaciaire laurentidienne.

cene sedimentation"; pollen records from these sediments document only one interglacial climatic event below the Holocene record which, because of its stratigraphic position, is assumed to be correlative with the Sangamon Soil. In this type area there is no reported evidence for a cooling within the Sangamonian Stage which could be related to ice sheet growth in the north.

2. TORONTO AND TROIS-RIVIÈRES (Fig. 2, Col. 2 and 3)

In his book published thirty years ago, FLINT (1957, p. 340) wrote: "One of the best known of the units ascribed to the Sangamon Interglacial is the Toronto Formation...". Although the name Toronto Formation is no longer used the statement is still correct. The 7-metre thick stratified clay and sand of the Don Formation with its warm climate flora and fauna has been a well known stratigraphic unit since the studies of COLEMAN (1933). The study of pollen and other plant fossils by TERASMAE (1960) suggested a climate 2°C warmer than present. The basis for the interglacial assignation is the warm climate (KARROW, 1984, p. 141) and its assignment to the Sangamonian Stage is generally accepted today. If the age and climatic significance of the Don Formation seem to create few difficulties, the altitude of the deposit, 20 m above the level of present day Lake Ontario, raises problems in paleogeographic reconstructions. The Don Formation is made up mostly of fluvial sediments but there is evidence for deposition in a shallow lacustrine environment. This implies that during Sangamonian time "water in the Ontario basin was as much as 20 m higher than the present Lake Ontario level" (KARROW, 1984, p. 142). All other known high stages in the Lake Ontario basin are ascribed to ice blocking drainage by occupying parts of the lower St. Lawrence valley. There is no known mechanism by which lake level can be maintained at a significantly higher elevation during an interglaciation so there is no entirely satisfactory explanation for this "discrepancy".

The Don Formation is overlain by the Scarborough Formation which consists of deltaic sand overlying clay that were implaced by a large river flowing from the north into a lake 45 m above present Lake Ontario level. Plant remains suggest "a climate 6°C cooler than present..., which is compatible with the idea of ice present in the St. Lawrence valley" (KARROW, 1984, p. 142).



The Pottery Road Formation is made up of fossiliferous sediments partly filling valleys cut into the Scarborough Formation. Sparse pollen suggest a cool interstadial climate (KARROW, 1984, p. 143).

In the Toronto area, the Sunnybrook Drift marks the end of the nonglacial interval represented by sediments of the Don, Scarborough and Pottery Road formations, which together may represent all of Sangamonian Stage time (FULTON *et al.*, 1984, p. 206).

In the region of Trois-Rivières in the central St. Lawrence Lowland nonglacial sediments with organic remains, which overlie Bécancour Till and Pierreville Varves and underlie Wisconsinan varves of the Deschaillons Formation and the Gentilly Till, have been named the St. Pierre Sediments (GADD, 1955, 1971; OCCHIETTI, 1982). They were deposited on a broad alluvial plain with a base level as much as 20 m above the present one. The cooler than present climate indicated by fossils in the St. Pierre Sediments (ANDERSON, 1985, p. 284-285) results in this unit being given an interstadial rather than interglacial rank, and it possibly corresponds to isotope stage 5a. A date of 74 700 $^{+2700}_{-2000}$ BP (QL-198, STUIVER *et al.*, 1978) has been obtained for wood included in these sediments. This should be considered as a minimum age for the St. Pierre Sediments but, as is discussed by Dredge and Thorleifson in another part of this publication a case has been made for extending the nonglacial St. Pierre Interval through Middle Wisconsinan time. The absence of marine material associated with St. Pierre Sediments is an unresolved problem. At the end of the deglaciation which occurred before deposition of St. Pierre Sediments, the area should have been depressed as it was at the close of the Late Wisconsinan (FULTON, 1983, p. 76).

The elevation of the sediments of the Scarborough Formation at 45 m above present Lake Ontario can only be explained by an ice dam blocking the St. Lawrence River Valley. KARROW (1984, p. 146) considers the Scarborough Formation as time equivalent of the Bécancour Till in the St. Lawrence valley and both units are included in the Nicolet Stade. The Pottery Road Formation and the St. Pierre Sediments, which overlies the Bécancour Till, are included in the St. Pierre Interstade. Since KARROW (1984) limits Sangamonian time to the warmest part of the last interglaciation (*i.e.* 5e), he places the Nicolet Stade and the St. Pierre Interstade in the Early Wisconsinan although the age of these units is > 75 ka. Based on the definition adopted here, both the Nicolet Stade and the St. Pierre Interstade fall within the Sangamonian Stage and, we are left with the conclusion that during Sangamonian time ice buildup was sufficiently important to block the St. Lawrence valley as far south as Montréal (OCCHIETTI, 1982).

Whether or not the extensive ice mass responsible for the deposition of the Bécancour Till and associated sediments completely disappeared during a Late Sangamonian Interstade (5a) is not known, it remains as an intriguing possibility.

3. THE JAMES BAY LOWLAND AND THE HUDSON BAY LOWLAND OF MANITOBA (Fig. 2, Col. 4 and 5)

In the James Bay Lowland, the Missinaibi beds were described as interglacial lignites by BELL (1904). In 1920 they were assumed by KEELE to be Mesozoic. Seven years later they were reassigned to a Pleistocene interglaciation (McLEAN, 1927). More detailed work led TERASMAE and HUGHES (1960) to conclude that "as there is no evidence that the climate during deposition of the Missinaibi beds was warmer than the present and, as inferred from the studies made, the time interval was rather short, an interstadial rank is proposed for the Missinaibi beds" (p. 11). In a later study McDONALD (1969) concluded that the Missinaibi interval was an interglaciation of the Pleistocene (p. 87-88). Following a very detailed and thorough study of the Moose River basin, SKINNER (1973) divided the Missinaibi beds and related nonglacial sediments into four members (Fig. 3): (a) marine, (b) fluvial, (c) forest-peat and (d) lacustrine; he proposed "... to refer to all members collectively as the Missinaibi Formation" (p. 10) and concluded that the Missinaibi Formation was deposited during an interglaciation which was probably the Sangamon. SHILTS' (1984, p. 121) conclusion in his comprehensive summary of previous work is worth quoting: "Currently the Missinaibi Interval is thought by some to be "interstadial" in rank, but it is my opinion that SKINNER's (1973) careful study has established beyond the shadow of a doubt that at and near its type section it is interglacial, probably correlative with the Sangamon of the mid-continent and within part of oxygen isotope stage 5."

In a recent paper ANDREWS *et al.* (1983) argue that the Sangamonian Stage in the Hudson Bay Lowland was composed of the following events: an interglaciation represented by the Missinaibi Formation, a glacial event which deposited a "brownish gray till", and a nonglacial event during which the Fawn River Gravels were deposited. This sequence was all referred to isotopic stage 5 with the Missinaibi Interglaciation correlating with 5e, the till with 5d to b, and the Fawn River Gravels with 5a. However, in a later paper, ANDREWS and MILLER (1984) suggest that shells defining an aminozone (T.18) were deposited during a "deglaciation" at 105 ka midway between the Missinaibi and the Fawn River Gravels events (Fig. 6, p. 111). In another paper in the same volume however ANDREWS *et al.* (1984, p. 130) go back to the position of a single glacial event, represented by Adam Till, separating the Missinaibi Formation and the Fawn River Gravels.

In the Manitoba part of the Hudson Bay Lowland, organic rich silt and sand (1-4 m thick) referred to as Gods River Sediments, are thought to have been deposited during the Sangamon Interglaciation and to represent all of isotope stage 5 (DREDGE and NIELSEN, 1985, p. 257). Similar organic rich sediments, thought to be correlative, are exposed at other places in the Hudson Bay Lowland (DREDGE and COWAN, in press).

The sequence of events indicated by the Missinaibi Formation and stratigraphic equivalents such as God's River Sediments are: 1) a postglacial marine inundation followed by a marine offlap sequence, 2) stream erosion and deposition, 3) peat and forest growth, 4) transgression by a proglacial lake and 5) glacial overriding (Fig. 2; SKINNER, 1973). As yet there is no agreement amongst workers on the age and duration of the glacial advance which followed the Sangamon Interglaciation. ANDREWS *et al.* (1983) believe that the glacial advance represented by Adam Till was followed by a recession and, possibly, by a re-opening of the Hudson Bay during which the Fawn River Gravels were deposited. McDONALD (1969) originally correlated these gravels with the Missinaibi Formation and Sangamon Interglaciation. WYATT and THORLEIFSON (1986) support the view of an open Hudson Bay in Late Sangamonian time with total amino acid ratios which they believe represent an age of 75 ka BP.

On the other hand, DREDGE and NIELSEN (1985) argue that the Sangamon Interglaciation, represented by Gods River Sediments, occupied all of isotope stage 5, which was followed by a glaciation which lasted through Late Wisconsinan time. Here again there are two very different opinions concerning the glacial history of the Hudson Bay basin during Sangamonian Stage: an open Hudson Bay during all of Sangamonian (DREDGE and NIELSEN 1985) and a major glacial cover during the middle Sangamonian time (ANDREWS *et al.*, 1984). The latter view is more consistant with the presence of ice in the Montréal area during the Nicolet Stade as postulated by FULTON *et al.*, 1984. However this does not constitute a proof, it merely accentuates the need for more reliable dating methods.

The extent of deglaciation during late Sangamonian is not discussed beyond the requirement that Hudson Strait was ice free during deposition of Fawn River Gravels. This would require an important shrinking of all major ice centres. In a diagram ANDREWS *et al.* (1984, Fig. 3, p. 131) suggest that this did occur although significant portions of the North American continent may have been continually covered since the end of substage 5e.

4. NANTUCKETT ISLAND

The Sankatay Head Cliff of Nantuckett Island, Massachusetts exposes a marine sand bracketed by two glacial drift sequences (OLDALE *et al.*, 1982). The marine deposit is believed to correlate with early oxygen-isotope stage 5. The study of ostracodes and mollusc fossils contained in the sand has yielded paleoenvironmental data suggesting a climate warmer than present at the base but cooling to conditions similar to present towards the top of the unit. The sequence is thought to have been deposited as a result of a transgression during early Sangamonian Stage.

It is not possible to infer presence or absence of continental ice cover from this sequence which is probably correlative with marine isotope substage 5e. It is however significant that only one glacial drift unit (probably Late Wisconsinan) overlies the interglacial deposits.

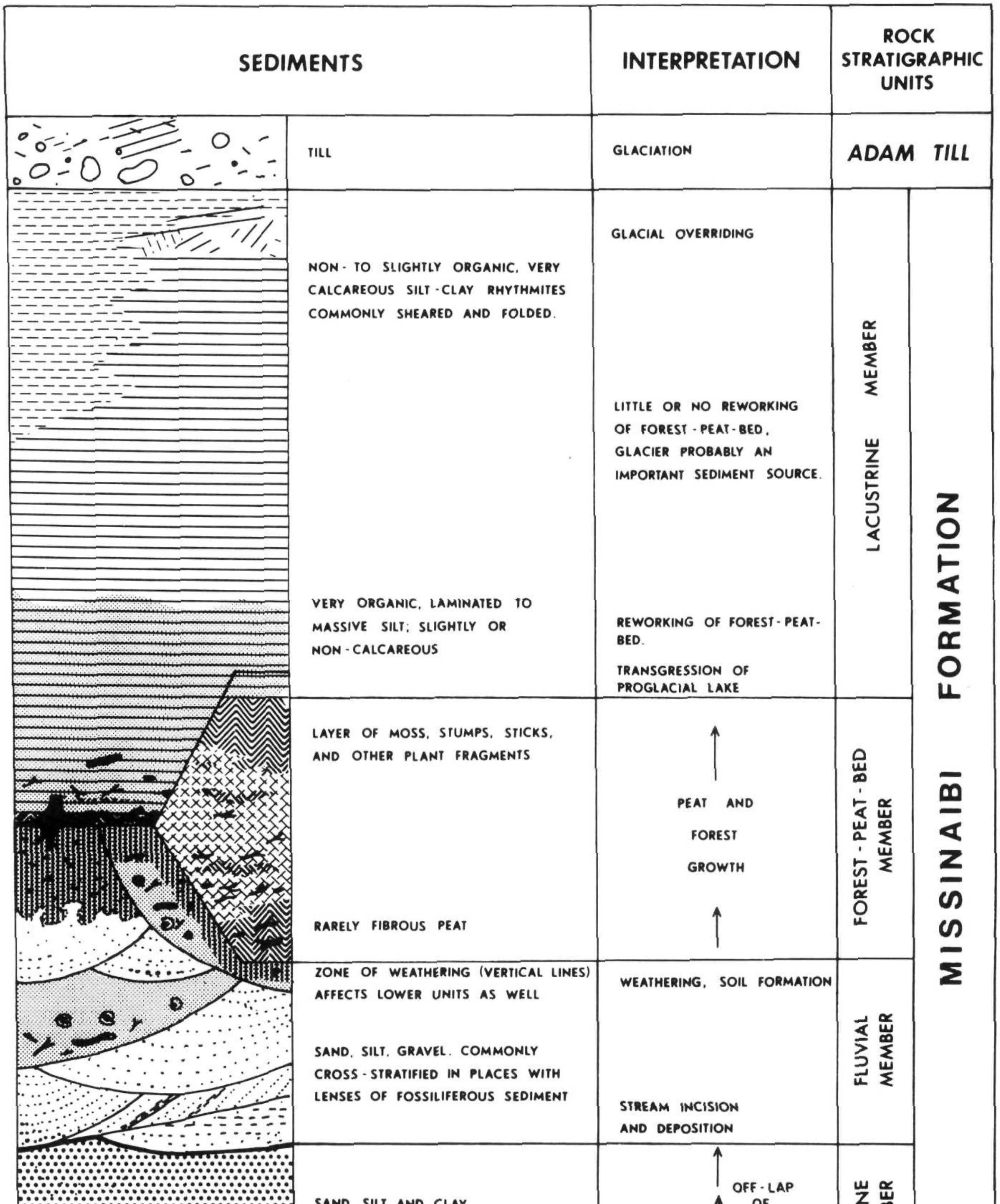


FIGURE 3. Composite section of the Missinaibi Formation (SKINNER, 1973).

Coupe composite de la Formation de Missinaibi (SKINNER, 1973).

5. ATLANTIC CANADA (Fig. 2, Col. 6)

Over 30 sites in eastern Canada with organic material beyond the limits of radiocarbon dating have yielded fossil records which indicate warmer than present climatic conditions (MOTT and GRANT, 1985). On this basis these sediments "most likely" represent the Sangamon Interglaciation or, as succintly put by GRANT and KING (1984, p. 180); "deposits are... assigned to the last interglaciation providing they predate or underlie the oldest tills of the last glacial stage and also meet the criteria of mild climate and high sea level".

In addition to these deposits, raised shorelines, which are 2-6 m in elevation, are thought to represent the high sea level stand of the last interglaciation and are considered the most useful regional stratigraphic datum.

GRANT and KING (1984) have proposed that in Atlantic Canada the last integlacial climatic event be named the Magdalen Island Interglaciation. They divided it into cold (glacial) stades corresponding to substages 5b, c and d, and two interstades. The lower interstade, representing the warmest period of the Sangamonian Stage, they called the Isle Royal Interstade (substage 5e) while the upper is the Bras d'Or Interstade (5a). The cold stades, are thought to have been as frigid as the period 11-12 ka BP with ice covering highland parts of Nova Scotia while a soil was forming over the Îles de la Madeleine and over most of Newfoundland. In their 1985 paper MOTT and GRANT clearly indicate that this stratigraphic reconstruction is based on climatic reconstruction from pollen assemblages in profoundly disturbed peat sediments underlying till. Despite the slight ambiguity in the deciphering of the stratigraphy, the interpretation that the cold stadial period (5d, c, b) was as cool as the 11-12 ka period clearly implies the presence of extensive ice cover over central North America (see PREST, 1969). However the Atlantic region record provides no clear indication on whether or not any of the ice mass survived the warmer period at the end of the Sangamonian to become part of the Laurentide Ice Sheet.

6. BAFFIN ISLAND, BOOTHIA PENINSULA AND BANKS ISLAND (Fig. 2, Col. 7, 8 and 9)

A lithostratigraphic unit corresponding to the last interglaciation has not been found on Baffin Island although "soils with high *Betula*" are assigned to this time period. The Sangamon Interglaciation came to an end with the onset of the Foxe Glaciation which, on the east coast of Baffin Island is marked by transgressive marine sediments, the "Kogalu aminozone" which "may span much of marine isotope stage 5" (ANDREWS and MILLER, 1984, p. 110). Further the oxygen isotopic record indicates that: "Extensive glaciation occurred in the western sector of Baffin Bay during the latter part of marine isotope stage 5 and continued (expanded?) into 4" (ANDREWS *et al.*, 1985, p. 350). Ice buildup would account for crustal depression and marine transgression at the base of the Kogalu aminozone at a time when world oceans were either stable or in a lowering phase corresponding to the major continental ice buildup towards the end of stage 5. ANDREWS *et al.* (1985, p. 352) believe "that the Laurentide and high Canadian Arctic ice sheets initially developed in stage 5 and extended into stage 4".

In a section along Pasley River on Boothia Peninsula, complexly interbedded till and glaciomarine sediments are overlain by fluvial gravel, marine deltaic sand, and glaciomarine sediment and till. The gravels contain plant and insect fossils dated at > 55 ka BP and indicate a climate as warm as and perhaps warmer than present. The unit is probably of Sangamonian age and separates Wisconsinan from Illinoian glacial deposits (DYKE and DREDGE, in press). There is however no way of determining the time at which the interglacial sediments were first overridden by ice.

In two localities of southern Banks Island, buried organic tundra pond sediments, underlying glacial and marine deposits of Wisconsinan age, have been assigned to the interglacial Cape Collinson Formation. Plants, particularly a rich birch flora (now absent from the island) and arthropod remains indicate a climate "distinctly warmer" than today. The fossil evidence of warm climate, stratigraphic position and > 61 ka BP and > 49 ka BP ages for wood found in the peats led VINCENT (1983, p. 61) to assign the Cape Collinson Formation to the Sangamon Interglaciation.

In the Arctic only the Baffin Island record yields information concerning possible fluctuations in ice cover during the Sangamonian Stage. ANDREWS *et al.* (1984, p. 131) suggest that the ice buildup which depressed Baffin Island sufficiently to initiate a marine transgression likely survived to become part of the Laurentide Ice Sheet.

7. SASKATOON AND MEDICINE HAT (Fig. 2, Col. 10)

In the Prairies of western Canada several sites show spectacular exposures of stacked glacial and nonglacial sediments which may encompass all of the Quaternary (STALKER and CHURCHER, 1982). However, here again, age in many cases is assigned by counting from the top and is dependent on assigning nonglacial units to climatic events (interglacial, interstadial).

The name Osler Nonglacial Interval has been given to the nonglacial event which FENTON (1984) assigned to the Sangamonian. He points out that this is the oldest nonglacial interval generally recognized at sites throughout the Prairie regions and that the Sangamonian age is based on vertebrate and invertebrate fossils, stratigraphic position (*i.e.* the next nonglacial deposits below Middle Wisconsinan Interstade) and record of a climate warmer than present.

At the Riddell reference section near Saskatoon, Saskatchewan, up to 8 m of stratified and cross-bedded sands contain molluscs, and other fossils indicative of an open grassland habitat with trees and shrubs in low areas and along river valleys. The majority of the extant mammals presently cohabit at least 500 km south of the Ridell site "and the vertebrate fauna is believed to represent Late Rancholabrean time" (isotope stage 6 and later), and SKWARA-WOOLF (1981, p. 321) concludes that "palaeoecological evidence, however, indicates that the composite Riddell fauna is not likely older than what is classically called Sangamon".

Sediments of the Mitchell Bluff Formation (STALKER, 1976, p. 397) in the Medicine Hat area have been intensely studied because of their abundant fossil content. The large variety of vertebrate fossils in mostly fluvial deposits indicate a moderate climate changing to a colder climate with periglacial activity (STALKER and CHURCHER, 1982). The Mitchell Bluff Formation is bracketed by tills and is thought to represent the last part of the Sangamon Interglaciation (STALKER, 1976, p. 400). Deposits at a number of other sites in the Prairie Provinces are assigned to the Sangamonian, generally because they represent the first nonglacial interval below Middle Wisconsinan deposits (FENTON, 1984, p. 62-63).

Contrary to this age assignment, FULLERTON and COLTON (1986) state that "None of the vertebrate species in the Fort Qu'Appelle, Riddell, or Medicine Hat 'Sangamon' faunas is demonstrably diagnostic of a Sangamon interglacial (post-Illinoian and pre-Wisconsin) age". They suggest that the Riddell Member and correlated units at Medicine Hat should be tentatively correlated "with marine oxygen isotope stage 7 within the complex Illinoian glaciation".

Given the uncertainty of the age assigned to nonglacial sediments of the Osler Nonglacial Interval and the Mitchell Bluff Formation it would be hazardous to speculate on the age of the glaciogenic deposits which overlie them. Although FENTON (1984, p. 62, Fig. 3) suggests that till may have been deposited by overriding ice as early as 90 ka BP there is really no hard evidence to support the presence of ice as far south and west as southeast Alberta in Late Sangamonian time (marine isotope substage 5a). At the present it is simply not known when glacier ice advanced over Western Canada following the Sangamon Interglaciation.

8. NORTHWESTERN UNITED STATES (Fig. 2, Col. 11)

From published literature it can only be concluded that nonglacial deposits are not commonly found between Illinoian and Wisconsinan age glacial deposits in the Great Plains area of United States. A recent synthesis on the glacial deposits (FULLERTON and COLTON, 1986) contain no systematic discussion of lithologic units or of weathering zones which could be assigned to the Sangamonian Stage; the correlation chart simply mentions that there was a period of extensive erosion and weathering which extended from roughly 132 ka to 23 ka. Thus there is no data from the region that might help resolve the problem of when the ice accumulation which culminated in the Laurentide Ice Sheet began.

DISCUSSION

This overview of continental deposits assigned to the Sangamonian Stage begs the very important question of when the glaciation responsible for the Laurentide Ice Sheet began. Was it during Stage 5 or later during Stage 4? Present evidence is generally ambiguous. In some areas fossil material indicates that conditions during Sangamonian time were cooler than present but not glacial in nature. Scarborough Formation near Toronto and East Bay II and equivalent organic beds in Atlantic Canada are the prime examples. Elsewhere till units have been placed in positions where they apparently are within part of stage 5. This is the case with the Adam Till of the Hudson Bay Lowland. However, the difficulties with this interpretation are far from resolved and it is quite possible that this till unit was emplaced by a Wisconsinan, rather than a Sangamonian glacial event, as has been suggested for the till resting on top of God's River Sediments.

On Baffin Island the current interpretation of the glacial record indicates that ice buildup started after substage 5e and extended into stage 4. The implications are that in its northeastern sector at least, the Laurentide Ice Sheet started to grow as early as 110 ka ago.

In the St. Lawrence valley the Bécancour Till and equivalent units have also been assigned a position within stage 5. This age is largely based on the "finite" date of 74.7 ka for the St. Pierre Sediments and on the assumption that the record is continuous from the Bécancour Till through the St. Pierre Sediments. If the "finite date" is considered a minimum date, the Bécancour and equivalent tills could be part of the Illinoian glacial complex and the St. Pierre Sediments could be early stage 5. However, as speculated in the paper in this volume by Dredge and Thorleifson, these sediments could be much younger so that the Laurentide Ice Sheet may not have invaded the St. Lawrence valley until as late as Middle Wisconsinan time. The prevailing opinion however is that the Gentilly Till was emplaced by Laurentide Ice which occupied the St. Lawrence Lowland from Early Wisconsinan time. Keeping the ice sheet out of the St. Lawrence Valley until later would produce a record that contradicted that in southern Ontario.

Overall there is no clear answer to the question "When did the glaciation responsible for the Laurentide Ice Sheet begin?" In a number of the areas where glaciers might have grown during cooler periods of the Sangamonian Stage (oxygen isotope stage 5) this ice probably disappeared prior to major growth of the Laurentide Ice Sheet (oxygen isotope stage 4). However there is the evidence from Baffin Island which could suggest that ice which accumulated during Sangamonian time could have survived to become part of the ice mass which eventually covered a significant part of the globe during the Late Pleistocene, the Laurentide Ice Sheet.

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