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Paleoecology of Organic Deposits of Probable Last Interglacial Age in Northern Ontario

La paléoécologie des dépôts organiques du nord de l'Ontario datant probablement du dernier interglaciaire

Paläoökologie der organischen Ablagerungen im Norden Ontarios, wahrscheinlich aus dem letzten Interglazial

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Résumé de l'article

Les dépôts non glaciaires du nord de l'Ontario qui datent peut-être du dernier interglaciaire sont bien connus dans les basses terres de la baie d'Hudson où ils ont été décrits dans des coupes le long de plusieurs vallées. Les horizons de sols, les lits de tourbes et autres séquences de sédiments organiques comprennent la Formation de Missinaibi dans le bassin de Moose River dont on a étudié le pollen et les macrofossiles. Les résultats indiquent que le climat était aussi chaud, sinon plus, que maintenant et que les forêts d'épinettes dominaient de vastes étendues de tourbières minérotrophes et ombrothrophes. Les données sur la tourbe de Beaver River révèlent des conditions similaires à celles d'aujourd'hui dans la région de Fort Severn où les forêts ouvertes d'épinettes sont dispersées dans les tourbières. Dans la région de Timmins, au sud des basses terres, se trouve un horizon de silt organique étendu (les lits de Owl Creek), qui est l'équivalent stratigraphique de la Formation de Missinaibi. La fin de l'intervalle chaud y est représentée. Ie climat étant au début probablement aussi chaud qu'aujourd'hui puis, par la suite, beaucoup plus froid. La corrélation de la Formation de Missinaibi avec le stade isotopique 5e est corroborée par les résultats des acides aminés sur des coquillages marins de quelques unités associées. Les analyses faites sur des coquillages recueillis sous le lit de tourbe de Beaver River indiquent que cet intervalle pourrait être plus jeune, probablement du stade 5c ou mieux du stade 5a. Les lits de Owl Creek pourraient être associés au stade 5e ou à un intervalle plus récent, 5c ou 5a.

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PALEOECOLOGY OF ORGANIC DEPOSITS OF PROBABLE LAST INTERGLACIAL AGE IN NORTHERN ONTARIO*

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ABSTRACT Nonglacial deposits in northern Ontario that may date to the last interglacial interval are well known from the Hudson Bay Lowlands where they have been described in sections along several river valleys. Soil horizons, peat beds and other organic sediment sequences comprise the Missinaibi Formation of the Moose River Basin studied for pollen and macrofossils. Results suggest that the climate was as warm or warmer than present, and spruce woodlands prevailed among broad expanses of bog and fen. The Beaver River peat records conditions similar to the present in the Fort Severn area with open spruce woodlands dispersed in peatlands. South of the Lowlands in the Timmins area, a widespread organic-silt horizon termed the Owl Creek beds is stratigraphically equivalent to the Missinaibi Formation. The waning phase of a warm interval is represented, with early climate possibly similar to the present and the later climate much cooler. Correlation of the Missinaibi Formation with substage 5e of the deep-sea oxygen isotope record is corroborated by amino acid results on marine shells from some associated units. Analysis of shells from beneath the Beaver River peat bed indicate that this interval may be considerably younger, possibly substage 5c or, more likely, 5a. The Owl Creek beds may relate to substage 5e, or to one of the younger intervals, 5c or 5a.

RÉSUMÉ *La paléoécologie des dépôts organiques du nord de l'Ontario datant probablement du dernier interglaciaire.* Les dépôts non glaciaires du nord de l'Ontario qui datent peut-être du dernier interglaciaire sont bien connus dans les basses terres de la baie d'Hudson où ils ont été décrits dans des coupes le long de plusieurs vallées. Les horizons de sols, les lits de tourbes et autres séquences de sédiments organiques comprennent la Formation de Missinaibi dans le bassin de Moose River dont on a étudié le pollen et les macrofossiles. Les résultats indiquent que le climat était aussi chaud, sinon plus, que maintenant et que les forêts d'épinettes dominaient de vastes étendues de tourbières minérotrophes et ombrothrophes. Les données sur la tourbe de Beaver River révèlent des conditions similaires à celles d'aujourd'hui dans la région de Fort Severn où les forêts ouvertes d'épinettes sont dispersées dans les tourbières. Dans la région de Timmins, au sud des basses terres, se trouve un horizon de silt organique étendu (les lits de Owl Creek), qui est l'équivalent stratigraphique de la Formation de Missinaibi. La fin de l'intervalle chaud y est représentée, le climat étant au début probablement aussi chaud qu'aujourd'hui puis, par la suite, beaucoup plus froid. La corrélation de la Formation de Missinaibi avec le stade isotopique 5e est corroborée par les résultats des acides aminés sur des coquillages marins de quelques unités associées. Les analyses faites sur des coquillages recueillis sous le lit de tourbe de Beaver River indiquent que cet intervalle pourrait être plus jeune, probablement du stade 5c ou mieux du stade 5a. Les lits de Owl Creek pourraient être associés au stade 5e ou à un intervalle plus récent, 5c ou 5a.

ZUSAMMENFASSUNG *Paläoökologie der organischen Ablagerungen im Norden Ontarios, wahrscheinlich aus dem letzten Interglazial.* Nichtglaziale Ablagerungen im nördlichen Ontario, die möglicherweise aus dem letzten Interglazial stammen, sind aus dem Tiefland der Hudson Bay wohlbekannt, wo sie in Schnitten entlang mehrerer Flusstäler beschrieben worden sind. Boden-Horizonte, Torfbetten und andere organische Ablagerungssequenzen umfassen die Missinaibi Formation des Moose River-Beckens, welche auf Pollen und Makrofossile untersucht wurde. Die Ergebnisse deuten darauf, dass das Klima so warm wie gegenwärtig oder wärmer war und dass Rottannenwälder zwischen weiten Flächen von Sümpfen und Mooren vorherrschten. Der Torf von Beaver River belegt der Gegenwart ähnliche Bedingungen im Gebiet von Fort Severn, wo offene Rottannenwälder zwischen die Torfmoore verteilt sind. Südlich des Tieflands im Gebiet von Timmins ist ein ausgedehnter organischer Schlamm-Horizont, genannt die Betten von Owl Creek, das stratigraphische Gegenstück zur Missinaibi Formation. Die Endphase eines warmen Intervalls ist festgehalten, mit einem frühen Klima, das wahrscheinlich dem heutigen ähnlich war, und einem späteren viel kälteren Klima. Die Korrelation der Missinaibi Formation mit dem Unterstadium 5e des Tiefsee Sauerstoff Isotop-Belegs wird durch Aminosäuren-Ergebnisse auf marinen Muscheln von einigen verbundenen Einheiten bestätigt. Analysen von Muscheln, die unter dem Torfbett von Beaver River gefunden wurden, zeigen, dass dies Interval sehr viel jünger sein könnte, möglicherweise Unterstadium 5c oder noch eher 5a. Die Owl Creek-Betten könnten mit dem Unterstadium 5e oder einem der jüngeren Intervalle 5c oder 5a verbunden sein.

* Geological Survey of Canada Contribution No. 10689

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INTRODUCTION

Buried organic-bearing nonglacial deposits are well-known in northern Ontario where they occur in the extensive Quaternary sediments of the Hudson Bay Lowland. Recent work in areas south of the Lowland has revealed a prominent organic horizon that may correlate with Lowland deposits. To which interstadial or interglacial interval these deposits relate has been a continuing problem since their discovery by R. Bell over a century ago (R. Bell, 1877).

Originally confused with Mesozoic "lignites" by early workers, J. M. Bell (1904) established the Pleistocene age for some of the deposits. McLearn (1927) showed that three types of organic deposits were present: (1) Mesozoic lignite, (2) Pleistocene deposits of redeposited lignite, and (3) Pleistocene interglacial deposits. Auer (1927) examined samples of McLearn's nonglacial peats, and pollen and macrofossils led him to conclude that climatic conditions were similar to the present. Terasmae (1958) analysed samples collected by Hughes from a locality on the Missinaibi River and correlated them with the St. Pierre deposits of the St. Lawrence Lowlands with a somewhat cooler interstadial climate. The organic-bearing deposits along Missinaibi and Opisatika Rivers in the James Bay Lowlands were named the Missinaibi Beds by Terasmae and Hughes (1960), and more extensive palynological and radiocarbon analyses led them to confirm an interstadial rank for the beds. Subsequent stratigraphic studies (Prest, 1966; McDonald, 1969) showed marine sediments associated with the Missinaibi beds that indicated an open Hudson Bay and, therefore, interglacial conditions. However, the possibility of correlation with the St. Pierre deposits and interstadial rank was retained (McDonald, 1971). Skinner (1973) addressed this controversy in a detailed study of Quaternary deposits of the Moose River Basin, and concluded from the stratigraphy and further pollen and macrofossil analyses that the Missinaibi Formation represented an interglacial cycle.

Recently, other buried deposits of nonglacial origin have been discovered. A drilling program for Quaternary stratigraphic studies in the Timmins area has revealed a prominent and widespread organic silt deposit, the Owl Creek beds, that were tentatively interpreted as an interglacial deposit and correlated with the Missinaibi Formation farther north (DiLabio *et al.*, 1988). During a thesis stratigraphic study in the Severn River area of the central Hudson Bay lowland, Wyatt (1989) uncovered a buried peat deposit. Contained pollen spectra are similar to those of the Missinaibi Formation, but amino acid racemization analyses of shells in the underlying marine unit suggest a much younger age than those for shells in the Bell Sea sediments, the marine member of the Missinaibi Formation.

Whether all of the organic deposits are correlative and belong to the same nonglacial interval, or whether more than one interval of interglacial or interstadial rank is represented is still unclear. Amino acid racemization analyses suggest that more than one interval may be recorded in the Lowlands (Shilts, 1982; Andrews *et al.*, 1983; Wyatt, 1989). However, the paleoecological results are not diagnostic enough to discern whether intervals of differing age rather than one interval with slight variations in climate, topography and vegetation are represented.

This paper will review the published palynological and macrofossil results for various deposits and present new data that relate to the character and stratigraphy of pre-Late Wisconsinan nonglacial episodes, particularly the last interglacial interval in northern Ontario.

VEGETATION AND CLIMATE

Both the Moose River Basin, within which the Missinaibi Formation is located, and the Beaver River area are within the Hudson Bay Lowlands Section of the Boreal Forest Region (Rowe, 1972), a broad area of muskeg and patterned fen formed on the thick glacial and nonglacial deposits covering the mainly Paleozoic sedimentary bedrock. The Lowlands Section forms the transition zone between the Boreal Forest and the tundra (Fig. 1). Open woodlands of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) characterize the land-

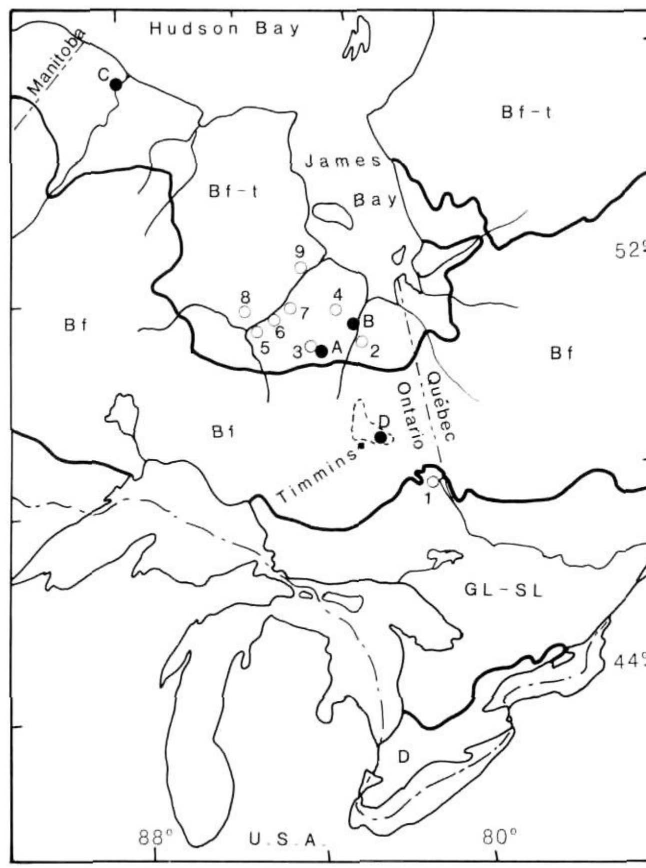

FIGURE 1. Map showing location and vegetation regions. Vegetation regions after Rowe (1972): Bf-t = Boreal forest-tundra; GL-SL = Great Lakes-St. Lawrence forest; D = deciduous forest. 1-9 = Surface sample sites (Skinner, 1973). A) Sites 24M and 26M (Terasmae and Hughes, 1960); B) Moose River Crossing site (Skinner, 1973); C) Beaver River site (Wyatt, 1989); D) site SMO-65 (DiLabio *et al.*, 1988). Dashed line = area underlain by Owl Creek beds.

Carte de localisation et zones de végétation. Zones de végétation de Rowe (1972): Bf-t = forêt boréale-tundra; GL-SL forêt du Saint-Laurent et des Grands Lacs; D = forêt de feuillus. 1-9 = Sites d'échantillonnage (Skinner, 1973). A) sites 24M et 26M (Terasmae et Hughes, 1960); B) site de Moose River Crossing (Skinner, 1973); C) site de Beaver River (Wyatt, 1989); D) site SMO-65 (DiLabio et al.*, 1988). Tirets = région où se trouvent les lits de Owl Creek.*

scape. Better drained sites, particularly along rivers, support white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*) and white birch (*Betula papyrifera*). South of James Bay, sporadic occurrences of white elm (*Ulmus americana*), black ash (*Fraxinus nigra*) and eastern white cedar (*Thuja occidentalis*) are seen along major rivers. Jack pine (*Pinus banksiana*) is sparse.

The Owl Creek beds lie in an area included within the Northern Clay Section of the Boreal Forest proper (Rowe, 1972) (Fig. 1). Relatively level topography results from thick deposits of glacial lacustrine clays covering the glacial deposits and the gently northward sloping Abitibi Upland of Precambrian igneous and metamorphic bedrock. The low relief and poor drainage of the "Clay Belt" promote large areas of black spruce on shallow organic soils alternating in lowland areas with extensive sedge fens and sphagnum-heath bogs. Tamarack is not as abundant as it is in the Lowlands to the north, and white cedar is more abundant. Better drained sites support stands of trembling aspen, balsam poplar, balsam fir and white spruce. Jack pine is prominent on drier sites, and white birch is prominent on sandy soils.

The climate of the region is cool and wet (Meteorological Branch, 1967; National Atlas of Canada, 1985). Both temperature and precipitation values increase toward the south and away from the maritime influence of Hudson Bay which exerts its strongest cooling effect during the summer months when the Bay is free of ice. The mean annual temperature along the coast is −5.5°C, whereas, at Timmins it is +1.4°C. January mean daily temperature over this range varies from −25°C to −15°C, and mean daily July temperature ranges from 12.5°C to 17.5°C. Mean total precipitation of about 54 cm in the north increases to 85 cm in the Timmins area. Annual water deficit for the region is zero, and the length of growing season increases southward from <140 days to about 160 days.

MISSINAIBI FORMATION

Numerous sections along the banks of various rivers in the Moose River Basin expose the Missinaibi Formation and several have been described in detail. Two sites on the Missinaibi River, localities 24M and 26M reported by Terasmae (1958) and Terasmae and Hughes (1960), and one site on the Moose River reported by Skinner (1973), have been analysed for pollen (Fig. 1). The latter site was also examined for macrofossils. Skinner also reported the pollen spectra from buried soils of the Missinaibi Formation at five sites within the Moose River Basin.

STRATIGRAPHY AND CHRONOLOGY

The general stratigraphic sequence of the Quaternary units for the Moose River Basin described by Skinner (1973) includes three similar tills with associated intertill sediments below the Missinaibi Formation. Gravel, sand and clay as well as peat, organic silt of freshwater and marine origin, and a buried soil comprise the Missinaibi Formation, with the subunits or members represented varying with the site. Two tills, the lower Adam till and the upper Kipling till, in some places separated by sands and silts and sand/silt rythmites of glaciofluvial origin, overlie the Missinaibi Formation. Overlying the upper till is a glaciolacustrine unit consisting of diamicton, sand and gravel and silt-clay rythmites, which represents a proglacial lake that formed as the ice retreated downslope. Fossiliferous clay and silt and associated sands and gravels deposited in the offlapping Tyrrell Sea overlie the glaciolacustrine unit and are in turn overlain by terrestrial alluvium, eolian sands and peat. At the Missinaibi River sites, only two tills were exposed below the Missinaibi Beds, and only one till was present above (Terasmae and Hughes, 1960).

Radiocarbon dating of Missinaibi Formation organics does not define the age of the deposits as all dates obtained have been non-finite (McDonald, 1971). Wyatt (1989) has, however, demonstrated differing ages in Missinaibi marine sediment using amino acid data from shells. Shells in marine sediment exposed along the Abitibi River are younger than Bell Sea sediment shells of the type section on the Kwataboahegan River. Unfortunately, it is not clear whether the Missinaibi organic beds date to the older, younger or both intervals.

PALYNOLOGY AND MACROFOSSILS

Locality 24M pollen diagram (Fig. 2) is shown as originally plotted with percentages based on a pollen sum of arboreal pollen only. The diagram for Locality 26M (Fig. 3) has been replotted using a pollen sum of all taxa exclusive of aquatics and pteridophytes. The adjusted base makes little difference to the values for the Locality 26M diagram where arboreal taxa dominate, but at 24M where nonarboreal pollen are abundant near the base of the profile, the values for arboreal taxa would be lowered and nonarboreal values raised significantly if the percentages were recalculated.

Locality 24M appears to have the most complete sequence which begins with high values for *Picea* (spruce), nonarboreal pollen (NAP) taxa and *Lycopodium* (club-moss) and Polypodiaceae (fern) spores. Well below the contact with the peat horizon, NAP and spore values decline, and *Pinus* pollen increases considerably. The profiles for both sites are similar above this level with *Picea* remaining dominant until near the top of the diagram where it decreases and *Pinus* increases. A small decline in *Picea* and increases in *Pinus* and *Betula* are seen near the top of the peat layer in both profiles.

The Moose River Crossing Section profile (Fig. 4) from Skinner (1973) is also dominated by *Picea* pollen throughout. *Pinus* values are lower than *Picea*, and small amounts of *Betula* are present. Values for other shrubs and herbs are low. The basal sample from mineral sediment underlying the peat has abundant Cyperaceae pollen and a lesser amount of *Picea*. Macrofossils recovered include *Picea*/*Larix* (spruce/tamarack) wood, two aquatic beetle genera, four unidentified mollusc species, seeds of several aquatic plants and birch, a catkin of either *Betula pumila* or *B. glandulosa* (swamp or resin birch) and various mosses.

Very similar spectra characterize the soil horizon at several localities (Fig. 5). (Skinner, 1973). Polypodiaceae (fern) spores, Cyperaceae pollen and Musci (moss) spores are somewhat more abundant than in the Moose River Crossing section, but *Picea*, *Pinus* and the other taxa of lesser abundance are strikingly similar.

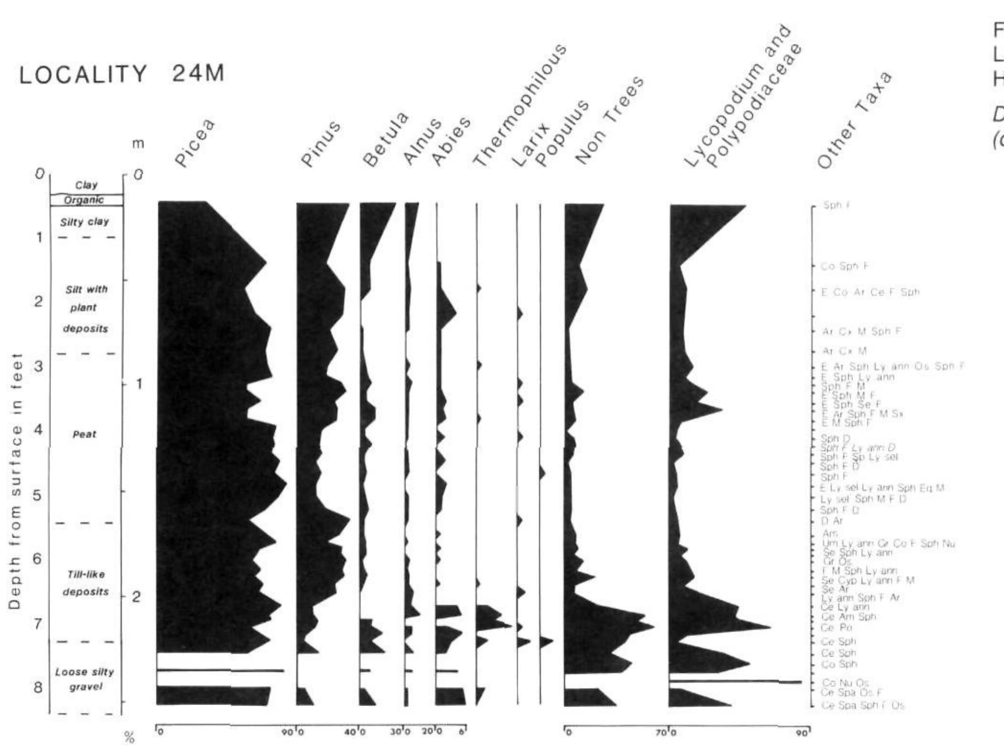

FIGURE 2. Pollen diagram for Locality 24M (from Terasmae and Hughes, 1960).

Diagramme pollinique du site 24M (de Terasmae et Hughes, 1960).

List of Abbreviations

Am - Ambrosia	E - Ericaceae	Eq - Equisetum	Ly sel - Lycopodium selago
Ar - Artemisia	Gr - Gramineae	F - Fungus	Os - Osmunda
Ce - Chenopodiaceae	Nu - Nuphar	M - Moss	Se - Selaginella
Co - Compositae	Spa - Sparganium	Ly ann - Lycopodium annotinum	Sph - Sphagnum
Cx - Carex	Sx - Salix		
Cyp - Cyperaceae			

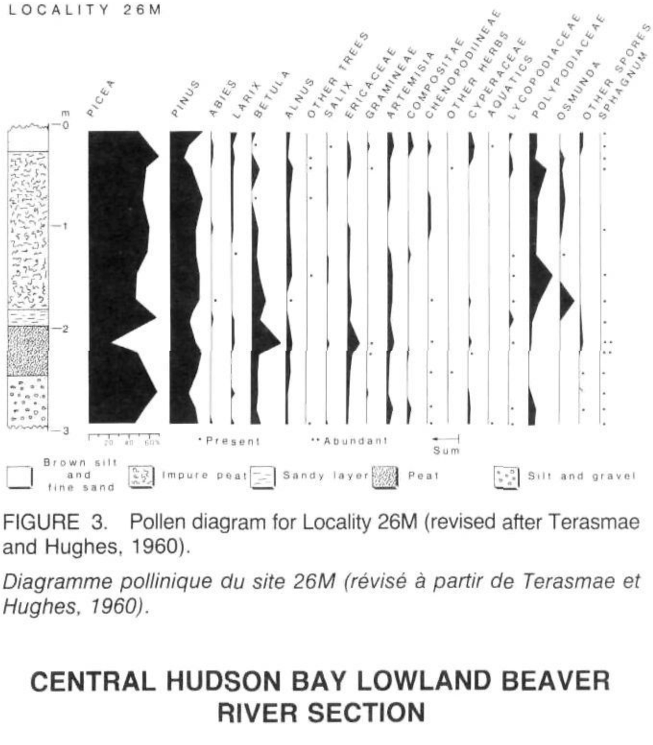

FIGURE 3. Pollen diagram for Locality 26M (revised after Terasmae and Hughes, 1960).

Diagramme pollinique du site 26M (révisé à partir de Terasmae et Hughes, 1960).

CENTRAL HUDSON BAY LOWLAND BEAVER RIVER SECTION

The Beaver River section (Wyatt, 1989) is located on the north bank of the Beaver River, a tributary of the Severn River, about 40 km west of Fort Severn in the central Hudson Bay Lowland (Fig. 1).

STRATIGRAPHY AND CHRONOLOGY

The near-vertical river banks at the site exposed an ancient stream bed cut into a diamicton of undetermined affinity that was infilled by a 0.5 m thick peat unit on top of 1 m of fluvial sand and gravel. Overlying the peat was 4.7 m of till capped by 2.3 m of stratified coarse and fine sand deposited by the Tyrrell Sea (Wyatt, 1989). A monolith of peat 34 cm thick from the base of the peat horizon was collected for analyses and dating.

The first radiocarbon analysis on the peat unit produced an age of 37,400 ± 1660 yrs BP (WAT-1378). A second date from peat at the top of the block, however, gave an age of >38,000 yrs BP (GSC-4146). A third attempt was made on basal peat, and a date of >43,000 yrs BP (GSC-4154) was obtained. To resolve the problem of whether the unit was within the dating range or not, a fourth sample was dated and produced an age of >51,000 yrs BP (GSC-4453) for the top of the peat.

Amino acid data on shells from the fluvial sediments underlying the Beaver River peat indicate an age similar to the 'Missinaibi' marine sediments of the Abitibi River, but they are clearly younger than the 'Missinaibi' Bell Sea sediments of Kwataboahegan River (Wyatt, 1989). Sediments exposed along the Severn River have *in situ* marine shells with amino acid ratios equivalent to those below the Beaver River peat and give an age estimate of about 76,000 years. An average thermoluminescence age estimate of 73 ± 10 ka on the enclosing sediments corroborates the amino acid estimate (Forman *et al.*, 1987).

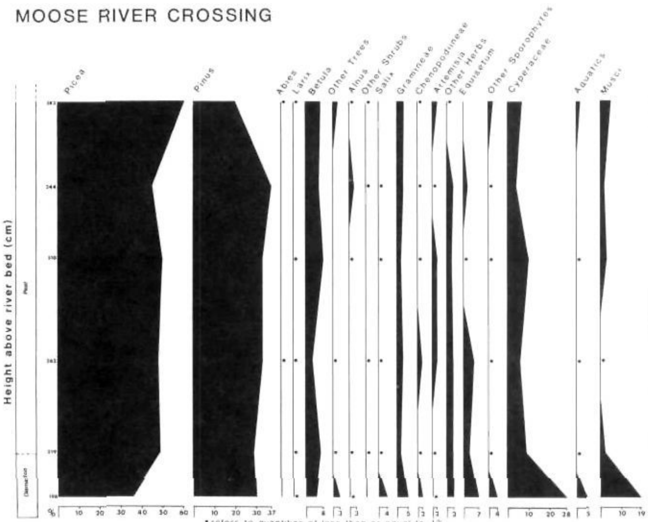

FIGURE 4. Pollen diagram for Moose River Crossing site (from Skinner, 1973).

Diagramme pollinique du site de Moose River Crossing (de Skinner, 1973).

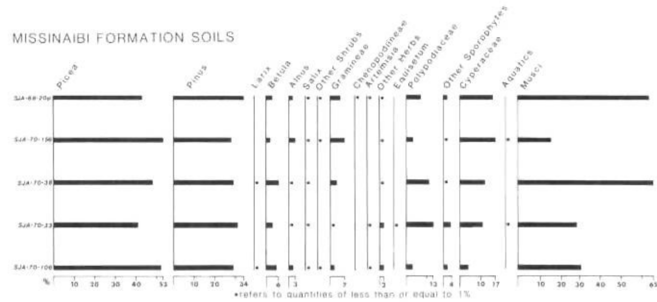

FIGURE 5. Pollen spectra for Missinaibi Formation soils (from Skinner, 1973).

Spectre pollinique des sols de la Formation de Missinaibi (de Skinner, 1973).

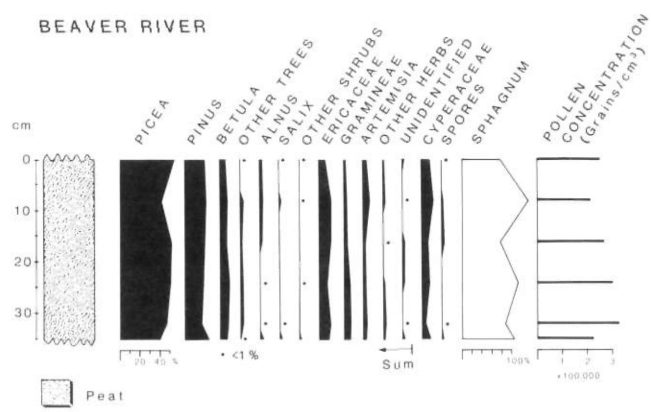

FIGURE 6. Pollen diagram for Beaver River peat (from Wyatt, 1989).

Diagramme pollinique de la tourbe de Beaver River (de Wyatt, 1989).

PALYNOLOGY AND MACROFOSSILS

The results of pollen analysis of six samples from the peat monolith are shown in Figure 6 (R. J. Mott, GSC Palynological Report No. 88-13; Wyatt, 1989). Very little variation is seen throughout the profile even among the concentration values that range between about 200,000 and 300,000 grains/cm^3. *Picea* is the dominant pollen taxon ranging between 40 and 55%. *Pinus* is second in abundance with values close to 20%. *Betula,* Ericaceae (heath) and Gramineae (grass) pollen are approximately 11% or less, and other pollen taxa are even less well represented. *Sphagnum* spores are very abundant with values between 75 and 130%.

OWL CREEK BEDS

The Owl Creek beds have been encountered in one exposure and numerous drill holes covering an area of about 2000 km^2 in the Timmins, Matheson, Cochrane triangle of northern Ontario (Fig. 1). The beds are not present in all cores but seem to occupy depressions that suggest deposition in numerous small lakes or basins in a network of sluggish rivers, or in a larger shallow lake with many bays, peninsulas and islands, and not in one large open lake (DiLabio *et al.*, 1988).

Core SMO-65, in Stock Township west of Matheson (lat. 48°39′14″N., long. 81°07′W.), has received the most study to date, and will be discussed here as a representative site for the area. Several other cores have produced similar results.

STRATIGRAPHY AND CHRONOLOGY

Detailed logging of the cores shows the following general stratigraphic sequence. Overlying the bedrock are at least two tills with associated stratified sediments. Owl Creek beds overlie the till sequence and consist of overconsolidated organic-rich silts, clays and sands as seen in the stratigraphic column for Core SMO-65 adjacent to the pollen diagram (Fig. 7). Only one till, the Matheson till, a pebbly silty sand till and associated sands and gravels, overlies the Owl Creek beds, and is overlain in turn by varved clays and silts of glacial lakes Barlow and Ojibway and by the clayey Cochrane till.

Organic matter from Owl Creek beds at three different sites has been radiocarbon dated. One date on moss is >37,000 yrs BP (GSC-2148, Brereton and Elson, 1979); a second on woody organic silt is >51,000 yrs BP (GSC-3875, DiLabio *et al.*, 1988); and the third, also on organic silt, is 41,400 ± 720 yrs BP (GSC-4491). The latter date, although finite, is suspect because of the sample's minimal organic content, lack of normal pretreatment and a mixing requirement, and is, therefore, considered a minimum age estimate.

PALYNOLOGY AND MACROFOSSILS

Palynological results are shown on the pollen diagram (Fig. 7) along with the stratigraphy for the part of the core analysed. Pollen concentrations increase above the base of the profile in the fine sandy silt to about 200,000 grains/cm^3, decline in the laminated organic silt, and then increase to values greater than 600,000 grains/cm^3 in the organic silt before dropping to minimal values in the overlying laminated clay.

Pollen spectra at the base have abundant *Pinus* (pine), up to 10% *Juniperus* (juniper) and lower values for *Betula* (birch pollen. *Picea* (spruce) values are low, as are values for the other more thermophilous hardwood genera such as *Quercus* (oak) and *Ulmus* (elm), but values for these genera are slightly higher toward the top of the fine sandy silt. Most shrub and herb values are low with some taxa such as *Artemisia* (sage) declining slightly upward in the profile.

At the boundary of the sandy silt with the laminated organic silt are small peaks in Gramineae (grass) pollen and Polypodiaceae (fern) spores, which are followed by increasing percentages for *Pinus* and *Picea*. The latter two genera remain fairly constant throughout the organic sediments with *Pinus* values (ranging between 15 and 30%) consistently exceeding those of *Picea* (which range between 15 and 20%) except at one level (about 33.5 m depth) where *Picea* barely exceeds *Pinus* values. *Betula* declines as *Picea* and *Pinus* increase and remains low until near the top of the profile where it increases slightly. Other tree genera have minimal values, but they are more consistent and in greater variety early in the sequence. Cyperaceae pollen and *Sphagnum* (moss) spores increase above the base of the laminated organic silt with the former at some levels exceeding 30% and the latter approaching that value near the top of the profile. Gramineae and Polypodiaceae decline above the base. Most other herb and shrub genera are poorly represented. Despite a marked decrease in pollen concentration in the overlying clay, the pollen spectrum does not change greatly. *Picea* is somewhat lower, *Sphagnum* increases, Cyperaceae declines somewhat, and the variety of taxa represented declines.

Numerous small waterworn wood fragments were recovered from the organic sediments, but many were too small and too poorly preserved to identify with certainty. The fragments appear to be coniferous wood, mainly spruce (*Picea*), with possibly some tamarack (*Larix laricina*) and balsam fir (*Abies balsamea*), but identification of the latter taxon is uncertain.

Numerous other plant and insect macrofossils were recovered from the Owl Creek beds (DiLabio *et al.*, 1988; R. Miller, personal communication 1988). Plant macrofossils include spruce and tamarack needles, and seeds of a birch species and a variety of aquatic and bog plants (Table I). One sedge species, *Cladium mariscoides*, found near the base of the

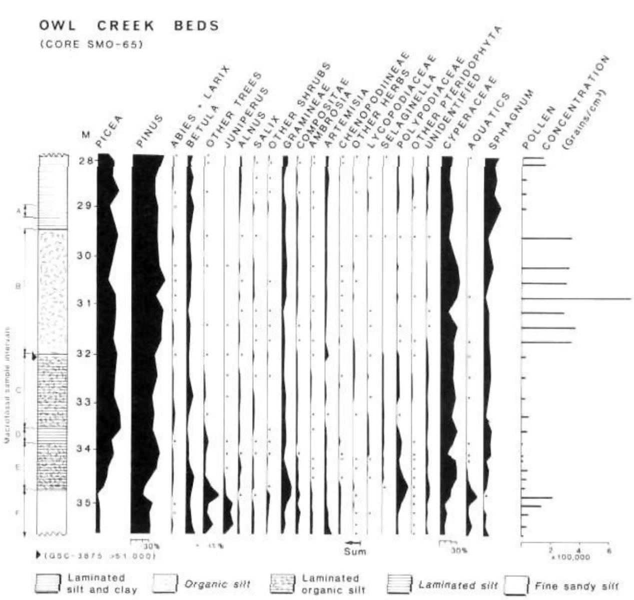

FIGURE 7. Pollen diagram for Owl Creek beds Core SMO-65 (from DiLabio *et al.*, 1988).

Diagramme pollinique de la carotte SMO-65 des lits de Owl Creek (de DiLabio et al., *1988).*

TABLE I

Plant macrofossil list from core SMO-65 divided into levels based on sedimentology

TAXA	INTERVALS (as shown on Fig. 7) A	B	C	D	E	F
Characeae						
Chara or *Nitella* spp.		*	*	*	*	*
Bryophytes						
Isoetaceae						
Isoetes sp.		*				
Selaginellaceae						
Selaginella spp.		*	*	*		
Pinaceae						
Larix laricina (DuRoi) Koch.						*
Larix sp.		*	*	*	*	
Picea spp.		*		*		
Potamogetonaceae						
Potamogeton filiformis Pers.		*			*	*
Potamogeton foliosus Raf.		*				*
Potamogeton richardsonii (Benn.) Rybd.		*				*
Potamogeton spp.		*			*	*
Najadaceae						
Najas flexilus (Willd.)		*	*		*	*
Cyperaceae						
Cladium mariscoides (Muhl.) Torr.					*	
Eleocharis spp.			*			
Scirpus validus Vahl.					*	*
Scirpus subterminalis type						*
Carex spp.		*		*	*	*
Carex rostrata type			*			
Betulaceae						
Betula spp.		*			*	
Caryophyllaceae						
cf. *Silene* sp.		*				
Nymphaeaceae						
Nuphar sp.						*
Ranunculaceae						
Ranunculus sp.		*				
Cruciferae						
Rorippa sp						*
Saxifragaceae						
cf. *Saxifraga* sp.					*	*
Rosaceae						
Rubus idaeus L.		*				
Rubus sp.					*	
Callitrichaceae						
Callitriche sp.		*	*	*	*	*
Violaceae						
Viola sp.		*				*
Haloragidaceae						
Hippuris vulgaris L.					*	
Myriophyllum farewellii Morong.						*
Compositae						
genera indet.		*				

organic sediments is noteworthy because of its present more southerly distribution (Raymond, 1971). Table II lists the insect macrofossils identified from Core SMO-65. The taxa identified include representatives of a broad range of habitats from open tundra to boreal forest. One species in particular, *Diacheila polita*, is presently known from subarctic Alaska, and has been recovered in late-glacial and interstadial deposits in eastern North America (Morgan and Morgan, 1980).

PALEOECOLOGICAL INTERPRETATION

Examination of the pollen diagrams presented above shows that those from the Hudson Bay Lowland, the Missinaibi Formation and the Beaver River section, are very similar in that they are characterized by abundant *Picea* pollen, less *Pinus*, and a variety of other shrub and herb taxa in lesser abundance. Cyperaceae pollen and *Sphagnum* spores are often very abundant. The Owl Creek beds spectra are generally very similar as well, with the exception that *Picea* and *Pinus* values are in the reversed order, and *Pinus* is invariably the dominant.

What vegetation communities were present to produce these pollen spectra, and hence, what type of climate prevailed during the time of deposition of the sediments? Terasmae and Hughes (1960) compared the Missinaibi spectra with those of postglacial deposits in the same region and concluded that the vegetation was similar to that now present in the region. Indeed, the three postglacial diagrams they presented for comparison do for the most part have *Picea* more abundant than *Pinus* pollen, particularly in the later Holocene. In the profile for the most

TABLE II

Fossil fauna from core SMO-65 divided into levels based on sedimentology

TAXA	INTERVALS (as shown on Fig. 7) A	B	C	D	E	F
TUBELLARIA						
"flatworms"		*				
BRYOZOA						
Fredericella type		*				
ARTHROPODA						
INSECTA						
Coleoptera (beetles)						
Carabidae						
Bembidion spp.		*		*		
Diacheila polita Faldermann		*				
Dyschirius sp.		*			*	
Elaphrus sp.		*				
Pterostichus sp.		*				
genera indet.		*				
Dytiscidae						
Colymbetes sp.		*				
Hydroporus sp.		*				
genera indet.		*				
Hydrophilidae						
Cercyon herceus Smetana		*				
Helophorus sp.			*			
Staphylinidae						
Acidota quadrata (Zetterstedt)		*				
Acidota cf. *A. quadrata* (Zetterstedt)		*				
Acidota sp.		*				
Arpedium cribatum Fauvel		*				
Bledius sp.		*				
Eucnecosum cf. *E. tenue* (LeC.)		*				
Eucnecosum sp.		*				
Gymnusa sp.		*				
Lathrobium sp.		*				
Olophrum boreale (Payk.)		*			*	
Olophrum consimile Gyll.		*				
Olophrum rotundicolle (C.R. Sahlberg)		*				
Olophrum spp.		*				
Omaliinae		*	*		*	
Pycnoglypta sp.		*				
Tachinus elongatus Gyll.		*				
Tachyporus sp.		*				
Stenus spp.		*	*			
Aleocharinae			*			
genera indet.		*	*	*		
Pselaphidae						
genera indet.		*				
Hydraenidae						
Hydraena sp.		*			*	
Scarabaeidae						
genera indet.		*				
Byrrhidae						
Cytilus alternatus Say		*				
genera indet.		*				
Chrysomelidae						
Donaciinae		*				*
Neohaemonia sp.					*	
genera indet.		*				
Curculionidae						
Hylobius sp.		*				
genera indet.		*				*
THICHOPTERA (caddisflies)						
Family indet.		*	*	*	*	
DIPTERA (flies)						
Chironomidae (midges)		*	*			
HYMENOPTERA						
Formicidae (ants)		*				
CRUSTACEA						
Cladocera (water fleas)						
Daphnia sp.		*				
Notostraca (tadpole shrimp)						
Lepiduris sp.		*				
ARACHNIDA						
Acari (mites and ticks)						
Prostigmata						
Oribatei (oribatid mites)		*	*	*	*	

southerly site near Cochrane, the spectra are a little different with *Pinus banksiana* (jack pine) type pollen more abundant at the base but replaced later by *Picea*. In addition, *Pinus strobus* (white pine) is more abundant as are *Abies balsamea* (balsam fir) and *Betula*, and nonarboreal pollen, particularly *Cyperaceae*, is much less abundant. However, they concluded that the climate was slightly cooler than the present during deposition of the Missinaibi beds.

Skinner (1973) compared the Moose River Crossing profile and buried soil spectra with modern pollen spectra from several sites in northern Ontario. All of the modern samples were from the Lowlands except site 1 which was from a more southerly location in the Temagami area (Fig. 1). *Picea* exceeds *Pinus* at all locations (Fig. 8) except site 1 were the reverse is true. Also noteworthy are the generally higher values for *Betula* and *Alnus* in the modern spectra. Unfortunately, the nonarboreal content of the spectra was not included. Of the macrofossils recovered from the Moose River section, seeds of *Najas flexilis* suggest somewhat warmer conditions than the present. Skinner's interpretation was that boreal forest dominated by spruce trees prevailed in the area, and that the climate was at least as warm, if not warmer than at present.

A subsequent study of modern pollen spectra in the James Bay Lowland showed that at most sites *Picea* exceeded *Pinus* pollen (Farley-Gill, 1980). A few sites east of James Bay showed the opposite, but these sites may have been more open and closer to larger concentrations of pine trees in western Québec. Generally, both Cyperaceae pollen and *Sphagnum* spores are very abundant. Otherwise the spectra resemble those of the Missinaibi Formation with the difference that the modern spectra, as with postglacial spectra, have more *Betula* pollen.

The opposite situation of *Pinus* pollen more abundant than *Picea* as seen in the Owl Creek beds is apparent in both modern and postglacial spectra in some areas. Modern pollen spectra from a mid Boreal Forest region in northwestern Ontario are dominated by *Pinus* (Mott, 1975). The contrasting *Picea*/*Pinus* pattern can be readily seen in north-south transects of modern pollen spectra through northern Ontario (Liu, 1982). However, the Owl Creek spectra contain abundant Cyperaceae pollen and *Sphagnum* spores, components not well represented in spectra from the main Boreal Forest. Modern pollen spectra with *Pinus* more abundant than *Picea* along with high values for Cyperaceae do characterize tundra areas just beyond the forest-tundra boundary (Lichti-Federovich and Ritchie, 1968). The main difference between such spectra and the Owl Creek spectra, however, is that the modern spectra contain relatively large amounts of shrub pollen, particularly *Betula*, that are noticeably lacking in the fossil spectra. Trend surface analyses of contemporary pollen spectra from central North America also show this pattern (Webb and McAndrews, 1976; Elliot-Fisk *et al.*, 1982). Highest values for *Picea* occur in the forest/tundra transition zone with values falling off towards the north into the tundra and to the south into the main Boreal Forest where *Pinus* increases (Fig. 9a and b). A north-south transect of postglacial sites in Ontario shows *Pinus* exceeding *Picea* in the main Boreal Forest region and the reverse in the woodland transition region to the north (McAndrews, 1981; Liu, 1982). Sites within the tundra zone are lacking, however.

Differences between the modern and postglacial spectra and spectra from the older deposits, particularly those of the Owl Creek beds, are apparent and must be considered when interpreting the results. As mentionned above, *Betula* is not abundant in the Owl Creek spectra, whereas it is a prominent element in postglacial diagrams and modern spectra. *Abies* and Cupressaceae are much less prominent in the older spectra. The Core SMO-65 profile has relatively high herbaceous pollen values along with abundant Cyperaceae and *Sphagnum*. Do these higher values indicate that climatic conditions were cooler than the present in the area, or are they a reflection of the abundance of bog and fen areas that surrounded the large, shallow lake in which the sediments were deposited? Large bog and fen areas characterize the area today and may have been even more abundant during the interval in question. Peatlands in northern Minnesota, for example, on the southern edge of the Boreal Forest produce pollen profiles with extremely large values for Cyperaceae (Griffin, 1977). Sampling sites for modern spectra and postglacial profiles are usually small lakes and bog or fen surfaces and not large lakes with fluvial input which may account for some differences.

Differences between the pollen spectra of the Owl Creek beds and the Missinaibi Formation are explicable when com-

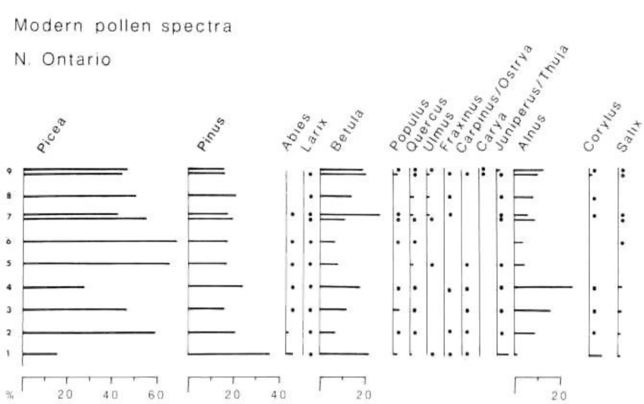

FIGURE 8. Modern pollen spectra for northern Ontario (from Skinner, 1973).

Spectre pollinique moderne du nord de l'Ontario (de Skinner, 1973).

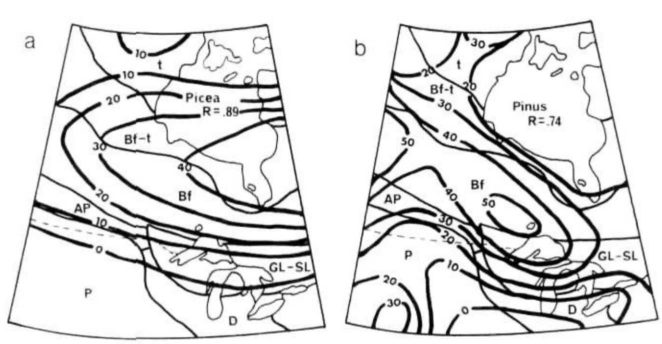

FIGURE 9. Trend surface contours for *Picea* and *Pinus* (from Webb and McAndrews, 1976).

Les courbes d'abondance de Picea *et de* Pinus *(de Webb et McAndrews, 1976).*

pared to modern and postglacial spectra. Two scenarios are possible. One is that the Owl Creek beds were deposited within a region of boreal type forest of some pine along with abundant spruce, but with widespread peatlands, probably similar to what occurs in the area today. The other alternative is that deposition occurred under tundra conditions close to the forest/tundra transition. Relatively high percentages of Cyperaceae and *Sphagnum* and the presence of remains of *Diachelia polita* favour the second alternative, at least for the upper part of the profile and indicate that the climate was cooler than present in the area. Conversely, low values for Cyperaceae and *Sphagnum* along with other somewhat more thermophilous taxa and macrofossils of the sedge *Cladium mariscoides* tend to indicate that the climate was at least as warm as the present for the time represented by the lower portion of the profile.

The Missinaibi beds data suggest an area of predominantly open spruce forest with very little pine within the forest/tundra transition where bogs and fens were abundant. Macrofossils confirm this interpretation implying the climate was similar to the present in the respective areas.

The Beaver Creek spectra indicate open spruce woodlands with widespread boggy areas similar to those occurring along the northern border of the Boreal Forest. Climate may have been similar to the present in the area.

DISCUSSION

Based on studies in southern Ontario, St. Lawrence Lowlands and northern Canada, Terasmae and Hughes (1960) stated that: "... as these studies are extended northward it is progressively more difficult to distinguish interglacial and interstadial deposits on the basis of palynological and paleobotanical evidence". This is only too apparent when the fossil results presented herein are analyzed. As noted above, the pollen spectra for the various sites are not grossly different from those of the region today, although some taxa, such as *Abies, Betula* and Cupressaceae, were not nearly as prominent. The *Picea*/*Pinus* ratio and the abundance of Cyperaceae pollen and *Sphagnum* spores are useful criteria for interpreting the results. Other taxa involved are generally those that are widespread in the region today with fluctuations and variations accounted for by the composition of the local communities. *Betula* is noted as one taxon that was much less abundant, but this seems to be the case for other areas, and birch may not have been as prominent during the last interglacial interval as it is in the Holocene (Mott and Grant, 1985).

The point made previously by Terasmae and Hughes (1960) that there was no evidence to indicate that the climate was warmer than the present for the Missinaibi beds, and therefore, the interval should be ranked as an interstadial, is questionable. Any interval that attained climatic conditions warmer than the present must have been preceded and followed by cooler conditions as the cycle waxed and waned. In fact, it is often the cooling phase of an interglacial interval that is better preserved as noted by Mott and Grant (1985). Of several sites in Atlantic Canada related to the last interglacial interval, only one records the warming phase prior to optimum warmth, whereas, most others record the waning phase of climatic cooling and peat deposition. The same is true in the Toronto area, where the Don Beds record the later part of the warm interval and the early part is missing (Karrow, 1990). Skinner (1973) suggested that the requirement for climate warmer than present for the Moose River Basin region for the last interglacial may not be justified as the maritime affect of Hudson Bay may have ameliorated the climate. Also, as is the case in Atlantic Canada, the climate may have already been cooling when the organic sediments, particularly peats, were deposited and the preceding warmer interval is recorded as the soil profile that had already developed.

Deep-sea sediment oxygen isotope studies indicate that the last interglacial cycle began with rapid warming to a peak, substage 5e, that lasted only a relatively short time before cooling began again (Shackleton, 1969). The Missinaibi Formation, or at least some of the deposits assigned to it, may relate to this interval. The Owl Creek beds may also be correlative, and if not recording the optimum warmth, they may relate to the period following as the climate cooled. The Beaver River deposit seems to indicate relatively warm conditions, but amino acid and thermoluminescence data, if valid, negate correlation with the Missinaibi Formation. The deep-sea record shows other temperate intervals, none of which attained climatic conditions equal to the warmest interval, followed over the next 35 ka until glacial conditions returned. Terrestrial deposits seem to corroborate this record (Guiot, 1989), although substages 5c and 5a may have attained conditions almost similar to today. Therefore, the Beaver River peat may well have been deposited during one of these younger substages. The Owl Creek beds may also relate to one of these younger cycles even though the stratigraphic constraints suggest correlation with the Missinaibi Formation.

If the organic beds discussed here relate to only one or two temperate intervals within stage 5, with glaciation beginning in stage 4, a considerable length of time is not recorded by the known organic deposits. An even longer interval is involved if glaciation didn't occur until stage 2. Did the climate deteriorate to such an extent that vegetation was limited and erosion removed much of the previously deposited sediments? Was Hudson Bay still open, and therefore, capable of supporting aquatic life, particularly marine fauna whose shell remains would give amino acid racemization evidence of other nonglacial intervals younger than the Missinaibi Formation? These, and many other questions remain to be answered, and considerably more work will be required before definitive answers can be obtained.

CONCLUSIONS

Stratigraphic, palynologic and macrofossil evidence for the Owl Creek beds, Missinaibi Formation and Beaver River organic bed are not definitive enough to unequivocally assign these deposits to the same or some different climatic interval. Evidence from the Missinaibi Formation sites discussed above favour correlation with a warm climatic interval equivalent to substage 5e of the deep-sea record.

Despite the similarity of the Beaver River spectra to those of the Missinaibi Formation, they may not be correlative. Amino acid results suggest that a separate younger interval is involved. If this is true, then this interval must have at least approached conditions prevalent during substage 5e. Substages 5c and 5a are possible intervals with the latter being the most likely if age estimates are valid.

Stratigraphic evidence favours correlation of the Owl Creek beds with the Missinaibi Formation, that is substage 5e of the deep-sea record. If valid, then the waning phase of the interval is represented when the climate was cooling. Another plausible alternative is that the Owl Creek beds relate to the waning phase of the same cycle to which the Beaver River peat could be assigned.

This intrepretation does not exclude the possibility that other deposits have been, or will be found that represent older or younger nonglacial intervals. Northern Ontario, and particularly the Hudson Bay Lowland with its abundant Quaternary deposits, is a prime area for continued study to address many of the questions that require resolution before the complete story is known.

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REFERENCES

Andrews, J. T., Shilts, W. W. and Miller, G. H., 1983. Multiple deglaciations of the Hudson Bay Lowlands, Canada, since deposition of the Missinaibi (last-interglacial?) Formation. Quaternary Research, 19: 18-37.

Auer, V., 1927. Botany of the interglacial peat beds of Moose River Basin, p. 45C-47C. *In* F. H. McLearn, ed., The Mesozoic and Pleistocene deposits of the Lower Missinaibi, Opisatika and Mattagami Rivers, Ontario. Geological Survey of Canada, Summary Report 1926, Part C.

Bell, J. M., 1904. Economic resources of Moose River basin. Ontario Bureau of Mines, 13, pt. 1, 1904, p. 135-179.

Bell, R., 1877. Report on exploration in 1875 between James Bay and Lakes Superior and Huron. Geological Survey of Canada, Report of Progress, 1875-1876, p. 294-342.

Brereton, W. E. and Elson, J. A., 1979. A Late Pleistocene plant-bearing deposit in Currie Township, near Matheson, Ontario. Canadian Journal of Earth Sciences, 16: 1130-1136.

DiLabio, R. N. W., Miller, R. F., Mott, R. J., Matthews, J. V., Jr. and Coker, W. B., 1988. The Quaternary stratigraphy of the Timmins area, Ontario, as an aid to mineral exploration by drift prospecting. *In* Current Research, Part C. Geological Survey of Canada, Paper 88-1C: 61-65.

Elliot-Fish, D. L., Andrews, J. T., Short, S. K. and Mode, W. N., 1982. Isopoll maps and an analysis of the distribution of the modern pollen rain, eastern and central northern Canada. Géographie physique et Quaternaire, 36: 91-108.

Farley-Gill, L. D., 1980. Contemporary pollen spectra in the James Bay Lowland, Canada, and comparison with other forest-tundra assemblages. Géographie physique et Quaternaire, 34: 321-334.

Forman, S. L., Wintle, A. G., Thorliefson, L. H. and Wyatt, P. H., 1987. Thermoluminescence properties and age estimates for Quaternary raised marine sediments, Hudson Bay Lowlands. Canadian Journal of Earth Sciences, 24: 2405-2411.

Griffin, K. O., 1977. Paleoecological aspects of the Red Lake Peatland. Canadian Journal of Botany, 55: 172-192.

Guiot, J., Pons, A., de Beaulieu, J. L. and Reille, M., 1989. A 140 000-year continental climate reconstruction from two European pollen records. Nature, 338: 309-313.

Karrow, P. F., 1990. Interglacial beds at Toronto. Géographie physique et Quaternaire, 44: 289-297

Liu, Kam-Biu, 1982. Postglacial vegetational history of Northern Ontario: a palynological study. Unpublished PhD Thesis, University of Toronto, Department of Geography, 338 p.

McAndrews, J. H., 1981. Late Quaternary climate of Ontario: temperature trends from the fossil pollen record, p. 319-333. *In* W. C. Mahaney, ed., Quaternary Paleoclimate. Geo Abstracts, University of East Anglia.

McAndrews, J. H., Riley, J. L. and Davis, A. M., 1982. Vegetation history of the Hudson Bay Lowland: a postglacial pollen diagram from the Sutton Ridge. Naturaliste canadien, 109: 597-608.

McDonald, B. C., 1969. Glacial and interglacial stratigraphy, Hudson Bay Lowlands, p. 78-99. *In* P. J. Hood, ed., Earth Science Symposium on Hudson Bay. Geological Survey of Canada, Paper 68-53.

——— 1971. Late Quaternary stratigraphy and deglaciation in eastern Canada, p. 331-353. *In* K. K. Turekian, ed., The Late Cenozoic Glacial Ages. Yale University press.

McLearn, F. H., 1927. The Mesozoic and Pleistocene deposits of the Lower Missinaibi, Opisatika, and Mattagami Rivers, Ontario. Geological Survey of Canada, Summary Report 1926, Part C: 16-47.

Meteorological Branch, 1967. Temperature and precipitation tables for Ontario. Canada Department of Transport, vol. IV, 44 p.

Morgan, A. V. and Morgan, A., 1980. Faunal assemblages and distributional shifts of Coleoptera during the late Pleistocene in Canada and the northern United States. The Canadian Entomologist, 112: 1105-1128.

Mott, R. J., 1975. Modern pollen spectra from northwestern Ontario. Geological Survey of Canada, Paper 75-1B: 147-150.

Mott, R. J. and Grant, D. R., 1985. Pre-Late Wisconsinan paleoenvironments in Atlantic Canada. Géographie physique et Quaternaire, 39: 239-254.

National Atlas of Canada, 5th Edition, 1985. Geographical Services Division, Surveys and Mapping Branch, Department of Energy, Mines and Resources, Map UCR 4058F.

Prest, V. K., 1966. Glacial studies, northeastern Ontario and northwestern Québec. *In* Report of Activities, May to October 1965. Geological Survey of Canada, Paper 66-1: 202-203.

Rowe, J. S., 1972. Forests Regions of Canada. Department of Environment, Canadian Forestry Service, Publication No. 1300, 172 p.

Shilts, W. W., 1982. Quaternary evolution of Hudson/James Bay region. Naturaliste canadien, 109: 309-332.

Shackleton, N. J., 1969. The last interglacial in the marine and terrestrial records. Proceedings of the Royal Society of London, 174: 135-154.

Skinner, R. G., 1973. Quaternary stratigraphy of the Moose River Basin, Ontario. Geological Survey of Canada, Bulletin 225, 77 p.

Terasmae, J., 1958. Contributions to Canadian Palynology. Part I- The use of palynological studies in Pleistocene stratigraphy. II- Non-glacial deposits in the St. Lawrence Lowlands, Quebec. III- Non-glacial deposits along Missinaibi River, Ontario. Geological Survey of Canada Bulletin 46, 35 p.

Terasmae, J. and Hughes, O. L. 1960. A palynological and geological study of Pleistocene deposits in the James Bay Lowlands, Ontario (42 N 1/2). Geological Survey of Canada, Bulletin 62, 15 p.

Webb, T. III and McAndrews, J. H., 1976. Corresponding patterns of contemporary pollen and vegetation in Central North America, p. 267-299. *In* R. M. Cline and J. D. Hays, eds., Geological Society of America Memoir 145.

Wyatt, P. H., 1989. The stratigraphy and amino acid chronology of Quaternary sediments in central Hudson Bay Lowland. Unpublished M. Sc. Thesis, University of Colorado, 117 p.

——— 1990. Amino acid evidence indicating two or more ages of pre-Holocene nonglacial deposits in Hudson Bay Lowland, northern Ontario. Géographie physique et Quaternaire, 44: 389-393.