"Amino Acid Evidence Indicating Two or More Ages of Pre-Holocene Nonglacial Deposits In Hudson Bay Lowland, Northern Ontario"

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Note

AMINO ACID EVIDENCE INDICATING TWO OR MORE AGES OF PRE-HOLOCENE NONGLACIAL DEPOSITS IN HUDSON BAY LOWLAND, NORTHERN ONTARIO

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ABSTRACT Amino acid studies have identified pre-Holocene nonglacial sediments in the Hudson Lowland which are significantly younger than Bell Sea sediments of the Missinaibi Formation. This younger unit is represented by marine sediments on the Severn and Abitibi rivers. Buried organic material on Beaver River is correlated with the younger Severn and Abitibi river marine sediments based on amino acid evidence. Assuming that Bell Sea sediments are of last interglacial (130-120 ka) age, the younger nonglacial sediments may have been deposited late in ^{18}O stage 5 (80-75 ka). Paleoecologic studies of the Beaver River organics indicate climate at least as warm as present.

RÉSUMÉ *Établissement par les acides aminés d'au moins deux époques de mises en place avant l'Holocène de dépôts non glaciaires dans les basses terres de la baie d'Hudson, nord de l'Ontario.* Les études par les acides aminés ont permis d'identifier des sédiments non glaciaires d'avant l'Holocène passablement plus jeunes que les sédiments de la Mer Bell de la Formation de Missinaibi. L'unité plus jeune est représentée par des sédiments marins des rivières Severn et Abitibi. Les matériaux organiques enfouis de la Beaver River sont corrélés avec les sédiments marins plus jeunes des rivières Abitibi et Severn grâce aux analyses des acides aminés. En tenant pour acquis que les sédiments de la Mer Bell datent du dernier interglaciaire (130-120 ka), les sédiments non glaciaires plus récents ont pu être mis en place tard au cours du stade isotopique 5 (80-75 ka). Les études paléoécologiques menées sur les sédiments organiques de Beaver River montrent que le climat était au moins aussi chaud que maintenant.

INTRODUCTION

Hudson Bay Lowland is located near the geographic centre of the area occupied by the Laurentide Ice Sheet and the occurrence of pre-Holocene nonglacial deposits in this area therefore has marked implications regarding ice volume change.

Relative age constraints for buried peat on the Beaver River (Fig. 1) have been obtained using amino acid analysis of reworked shells from fluvial gravels which underlie the peat. *The resulting chronologic interpretation places significant con*straints on regional climate history.

PREVIOUS RESEARCH

McDonald (1969, 1971) conducted the first comprehensive study of Quaternary stratigraphy in the Hudson Bay Lowland. He reported a two till sequence overlying nonglacial deposits that were best exposed in the Moose River basin (Fig. 1). This suite of nonglacial deposits, originally studied by Terasmae and Hughes (1960), was formally named the Missinaibi Formation by Skinner (1973) and assumed to be last interglacial in age (Prest, 1970). The Missinaibi Formation includes marine sediments of the Bell Sea (marine incursion immediately following deglaciation), forest and peat member beds, and overlying laminated silts deposited in a proglacial lake environment. McDonald concluded that the central part of the Lowland and Hudson Bay proper were likely occupied by ice from Missinaibi time until deglaciation about 7500 BP. This conclusion was not, however, supported by later amino acid studies of Shilts (1982) and Andrews *et al.* (1983). They inferred that Hudson Bay had probably been deglaciated two or three times since Missinaibi time. Such a series of glacial/nonglacial events could not be reconciled with the reported two-till stratigraphy.

Analysis of amino acid geochronology by Wyatt (1989) and lithostratigraphy by Thorleifson (1989) have refined the relative chronology and stratigraphy of sediments in the Central Lowland, identifying a four till sequence which *postdates* sediments of the Missinaibi Formation.

As outlined by Miller (1982), and Miller and Hare (1980), the amino acid technique involves measuring the degree of degradation of indigenous proteinaceous residues preserved in the carbonate shells of molluscs. Degradation progresses with time elapsed since the organism died. The reaction used in these studies is the racemization or epimerization of L-amino acids, the form found in original protein, to their D-configuration. Not all amino acids are suitable for geochronologic studies due to various competing decomposition reactions. In this study, the reaction used is the epimerization of the protein amino acid L-isoleucine to its non-protein diastereomer D-alloisoleucine. The ratio of the two isomers in a shell is expressed as alle/Ile (alloIsoleucine/Isoleucine). The epimerization reaction is reversible; the alle/Ile ratio increases from near zero in a living shell, to an equilibrium ratio of about 1.30.

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The rate at which this reaction proceeds is strongly temperature dependent, approximately doubling for every 4°C increase in temperature between −10 and +20°C. Thus, the aIle/Ile ratio in shells from different deposits can be directly compared only if the shells have experienced closely similar thermal histories. The reaction rate of different taxa may also vary so that data from a single species are required for direct comparison (Miller, 1982).

The amino acid geochronology of Hudson Bay Lowland was first established by Shilts (1982) and Andrews *et al.* (1983). They determined that epimerization ratios of *in situ* and transported shells recovered from till and marine and fluvial sediments, clustered into at least four groups. Of these four groups, the highest ratios were in shells from Bell Sea sediments, the youngest ratios were in shells from Holocene Tyrrell Sea sediments, and at least two groups of ratios indicated that Hudson Bay was colonized by molluscs for certain periods between the incursion of Bell and Tyrrell seas. These data implied a departure from the concept of a stable Laurentide Ice Sheet existing through most of the Wisconsinan Stage, because Bell Sea sediments are considered to be part of the Missinaibi Formation deposited during the last (Sangamon) interglaciation (Skinner, 1973).

Andrews *et al.* (1983) proposed alternate interpretations of the cluster groups, although their preferred interpretation was that Bell Sea sediments were deposited at the onset of the last interglacial period, about 130,000 yr BP. This required a long-term average diagenetic temperature for Bell Sea shells of +0.6°C. Using this temperature, the ages of the intermediate shells with ratios between those of the last interglacial Bell Sea and Tyrrell Sea were calculated. It was concluded that Hudson Bay may have been ice-free along its southern shore about 35,000, 75,000 and 105,000 yr ago.

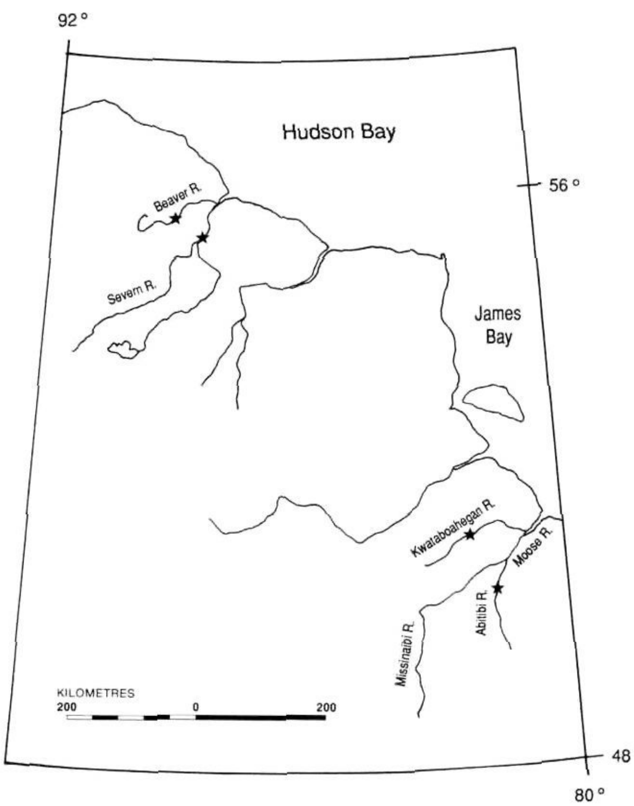

FIGURE 1. Location map of Hudson Bay Lowland, encompassing central Lowland and Moose River basin.

Localisation des basses terres de la baie d'Hudson, y compris les basses terres centrales et le bassin de Moose River.

The principle hypothesis of Andrews *et al.* (1983), derived from the fact that aIle/Ile ratios of bivalves from glacial units were intermediate between ratios from Bell Sea sediments and Tyrrell Sea sediments. They concluded that there must have been marine incursions at intermediate time(s) during the Wisconsinan. Objections to this interpretation were raised by Dyke (1984) including the argument that glacially transported shells would have experienced significantly different thermal environments which might account for all the variations in ratios in the Lowland. Dyke (1984) stressed that all we know of the age of the Missinaibi Formation is that it is >72,500 years old (Stuiver *et al.*, 1978), and that no marine sediments of Wisconsinan age are known from any part of the Lowland. Several pieces of new information allow us to address these concerns.

GEOCHRONOLOGICAL ANALYSES

MARINE SEDIMENT

Although pre-Holocene subtill marine sediments are rare in the Lowland, two occurrences with intermediate shell ratios have been identified. Subtill marine sediments occur approximately 50 m above present sea level, on the Severn River (Fig. 1). These sediments contain abundant *Hiatella arctica* with aIle/Ile ratios averaging 0.138 ± 0.014 (n=29, Fig. 2). Thermoluminescence dating of these sediments by Forman *et al.* (1987) produced an age of 74,000 ± 10,000. Subtill marine deposits on Abitibi River (Fig. 1), were previously correlated with Bell Sea sediments (Prest, 1970; Skinner, 1973). Amino acid analyses of *Hiatella arctica* collected from this unit yielded aIle/Ile ratios of 0.119 ± 0.015 (n=20; Fig. 2). A collection of *Hiatella arctica* obtained from Bell Sea sediments on the Kwataboahegan River yielded a mean aIle/Ile ratio of 0.243 ± 0.035 (n=16, Fig. 2), slightly higher than the result of 0.202 quoted by Andrews et *al.* (1983).

Tyrrell Sea sediments from various locations throughout the Lowland yielded *Hiatella* with aIle/Ile ratios of 0.033 ± 0.006 (n=17). Results of amino acid analyses for the four marine units are plotted in the frequency histogram (Fig. 2).

BEAVER RIVER PEAT

Peat and fluvial gravel on Beaver River (Figs. 1 and 3), were deposited in a channel cut into brownish-grey till of undetermined position in the stratigraphic sequence. Stratified diamicton overlying the peat, contains reworked organic matter, and has shell fragments with Severn River marine unit ratios or lower. The peat unit has a maximum thickness of 0.75 m.

The untreated peat was first dated by the University of Waterloo Isotope Laboratory, yielding an age of 37,040 ± 1660 years BP (Wat-1378, $\delta^{13}C$ = −27.7% modern carbon = 0.99%). Dating of the Beaver River peat with rigorous pretreatment (NaOH, HCl) at the G.S.C. radiocarbon lab

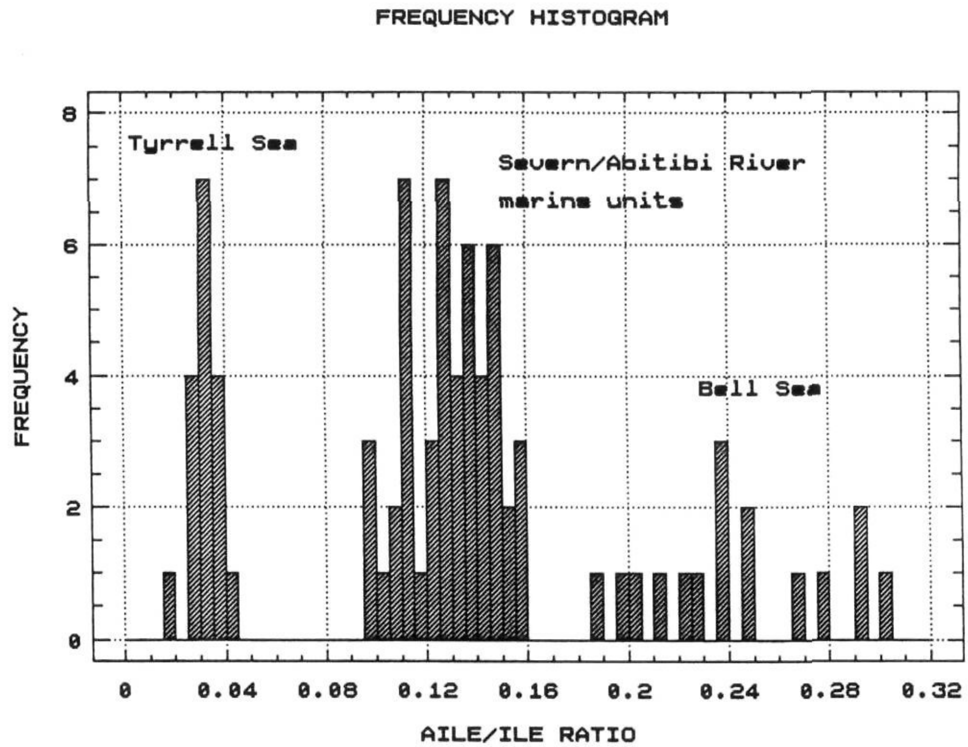

FIGURE 2. Alle/Ile ratios of *Hiatella arctica* taken from *in situ* marine units in the Hudson Bay Lowland.

Rapports Alle/Ile de Hiatella arctica *prélevés dans les unités marines* in situ *des basses terres de la baie d'Hudson.*

yielded an age of >38,000 years BP (GSC-4146, $\delta^{13}C = -27.9\%$) with subsequent high pressure analysis yielding an age of >51,000 years BP (GSC-4423). The alle/Ile ratios of shell fragments taken from fluvial gravels underlying the peat, are however, significantly lower than Bell Sea ratios. Two fragments with *Hiatella* amino acid assemblages have alle/Ile ratios of 0.105 and 0.153. Three other fragments with similar but unidentified amino acid assemblages, have ratios of 0.092, 0.141, and 0.145. It is inferred from these ratios, that the Beaver River peat was deposited during the nonglacial episode which began with the marine incursion represented by the Severn River marine unit.

PALEOECOLOGICAL ANALYSES

Palynological data for the Beaver River peat reported by Mott (unpublished GSC Palynological Report 88-13) are similar throughout the profile suggesting that climate varied little during time of deposition of the peat. *Sphagnum* (sphagnum moss) spores dominate the spectra indicating that deposition occurred in a bog environment. Ericaceae (heath plants), Gramineae (grass) and Cyperaceae (sedge) pollen values show that these taxa occurred on the wet bog surface as well. Low values for *Alnus* (alder) and *Salix* (willow) attest to the presence of these shrubs in suitable locations nearby. Small amounts of *Artemesia* (sage) and other herbaceous pollen taxa indicate that open, drier upland areas were not locally abundant.

Picea (spruce) pollen, which ranges between 40 and 50% of the pollen sum, indicates that spruce trees were abundant in the area and probably covered somewhat drier uplands in the region and may have been present on the bog surface as well. Other tree taxa represented include *Pinus* (pine) at approximately 20%, *Betula* (birch) at 10% or less, and minor amounts of other tree taxa. These values indicate that pine and birch trees were sparsely represented, if present at all.

FIGURE 3. Buried peat occurrence on the Beaver River. Note the gravel underlying the peat unit.

Unité de tourbe enfouie de la Beaver River. À noter le gravier sous l'unité de tourbe.

The pollen spectra from the Beaver River site are very similar to those obtained for other buried organic deposits in the Hudson Bay Lowland (Terasmae and Hughes, 1960; Skinner, 1973; Dredge and Nielsen, 1985; Nielsen *et al.*, 1986). It is the opinion of Mott (1988), based on palynological findings, that correlation of these sediments with the "Missinaibi Formation" is suggested, with northern boreal to forest tundra conditions and climate as warm or warmer than the present. The question which arises from the aminostratigraphic work is whether or not there exists two (or more) paleoecologically similar but stratigraphically different organic marker units.

Fossil arthropod (unpublished GSC Report 88-13) and plant macrofossil (unpublished GSC Report 88-28) analysis of the Beaver River peat by Matthews were not as revealing as pollen work due to dominance of mosses in the sample and the commensurately low abundance and poor preservation of insect and higher plant remains. Fossil insects found included beetles such as Carabidae (ground beetles), Staphylinidae (rove beetles), and Scolytidae (bark beetles). Specimens of Diptera (flies), Hymenoptera (wasps and ants), and Arachnida such as Oribatei (oribatid mites) were also present. Matthews stated that the only conclusion possible, given the limited evidence, is that climate at the time of deposition was probably no colder than present.

DISCUSSION

The Abitibi River marine unit and Bell Sea sediments along the Kwataboahegan River are in similar thermal environments due to their close proximity. Their difference in alle/Ile ratios, 0.119 vs. 0.243 can therefore only be attributed to a different age for the sediments. If the shells were the same age, a diagenetic temperature difference of more than 4°C would be required between sites to produce the difference in ratios. The Abitibi River marine unit of the Moose River basin, is here considered to be time correlative with the Severn River marine unit (alle/Ile = 0.138) of the Central Lowland. The slight difference in alle/Ile ratios may be due to subtle thermal contrasts. Both intermediate age marine units were deposited over isostatically depressed land, indicating an episode of glaciation postdated deposition of the Bell Sea.

The four till sequence of the Central Lowland postdates the Bell Sea sediments (Fig. 4). Based on amino acid results, the buried peat deposits along the Beaver River have been correlated with the Severn River marine unit. The Beaver River peat and Severn River marine unit represent a significant period of climate amelioration which postdates the Bell Sea sediments of the Missinaibi Formation. Assuming an early ^{18}O Stage 5 age (Chappell and Shackleton, 1986) for the Missinaibi Formation (130-120 ka), the Beaver River peat may have been deposited in Stage 5a (approx. 80 ka.) It is also possible that *in situ* Bell Sea sediments and overlying organics on the Kwataboahegan River are of pre-Sangamonian age, perhaps belonging to ^{18}O Stage 7. The stratigraphy of the Moose River basin is likely more complex than presented by Skinner (1973), based on the occurrence of two pre-Holocene marine units of different age.

It has been established that Severn and Abitibi marine sediments are correlative and have been dated by thermoluminescence at approximately 74 ka (Forman *et al.*, 1987). Bell Sea sediments are older as revealed by amino acid data and are possibly ^{18}O Stage 5e age. Amino acid data from shells extracted from gravel below the Beaver River peat, indicate that the peat is of similar age or younger than the Severn/Abitibi marine sediments, but >51 ka according to radiocarbon dating. Mott (unpublished GSC Report 88-13) indicated that the paleoecology of the Beaver River peat is equivalent to that of the Moose River basin Missinaibi sites.

The simplest interpretation of this data is that Severn/Abitibi marine sediments and Beaver River peat are ^{18}O Stage 5a age, about 80-75 ka based on thermoluminescence dating. By extrapolation based on amino acid data, Bell Sea sediments are ^{18}O Stage 5e age, about 130-120 ka. The paleoecology of Beaver River peat is indistinguishable from Moose River basin Missinaibi sites. There are at least two alternative interpretations including: 1) a possibility that there are two ages of organic deposits in the Moose River Basin which are paleoecologically indistinguishable, and 2) the thermoluminescence date is flawed and Bell Sea sediments are ^{18}O Stage 7 or older and Severn/Abitibi marine units and Beaver River peat are ^{18}O Stage 5e age.

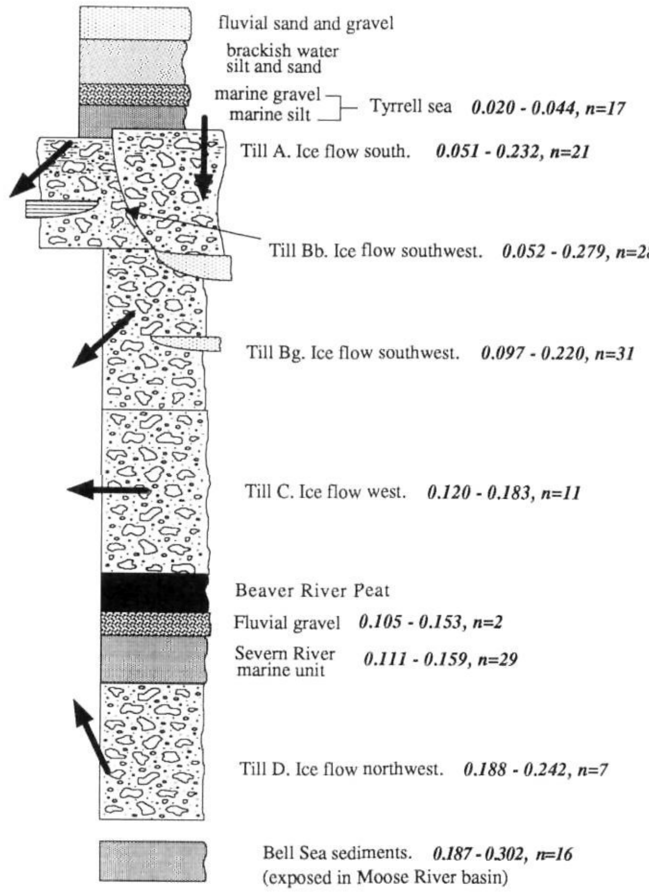

FIGURE 4. Composite column for the central Lowland (after Wyatt, 1989). Italicized numbers indicate the range of Alle/Ile ratios for *Hiatella arctica* fragments extracted from a unit.

Stratigraphie des basses terres centrales (d'après Wyatt, 1989). Les nombres en italique donnent l'étendue des rapports Alle/Ile des fragments de Hiatella arctica *prélevés dans une unité.*

SUMMARY

In conclusion it is inferred that at least two pre-Holocene nonglacial units exist in the Hudson Bay Lowland. The preferred interpretation is that Bell Sea sediments and associated organics on the Kwataboahegan River are last interglacial in age (approx. 130-120 ka). Significant glaciation was established through the middle of ^{18}O Stage 5, waning later in Stage 5 (around 75 ka) to permit marine incursion and deposition of the Severn/Abitibi River marine units. This was followed by isostatic uplift and the growth of organics represented by the Beaver River peat. No other stratigraphically younger nonglacial units have been discovered so far.

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