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Stratigraphie et paléoécologie des sédiments quaternaires le long des rives de la rivière Pasley, péninsule de Booth, Arctique canadien

Stratigraphie und Paläoökologie von Quartär-Sedimenten entland des Pasley-Flusses, Boothia-Halbinsel, zentralkanadische Arktis

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Article abstract

Quaternary sediments exposed along Pasley River consist of a lower marine deltaic sand overlain in succession by complexly interbedded tills and glaciomarine sediments (the lower glacigenic assemblage), by a mid-section fluvial gravel, by an upper marine deltaic sand, and by glaciomarine sediment and till (the upper glacigenic assemblage). The midsection fluvial gravels contain plant and insect fossils indicating a climate as warm as and perhaps warmer than present. The top of the gravel is more than 55 000 years old ; the unit is probably of Sangamonian age (>75 000 ka) and separates Wisconsinan from lllinoian glacial deposits. The deltaic sands that underlie both glacigenic assemblages indicate substantial crustal depression during glacial buildup episodes prior to arrival of ice at the site. This implies that the process of buildup was slow and involved glacier expansion into major marine basins. Glaciomarine beds of the lower glacigenic assemblage locally contain abundant detrital terrestrial organic material as well as marine molluscs. The terrestrial organic detritus, an unusual constituent of glaciomarine sediment, is thought to have been released into the sea from glacier ice. These terrestrial fossil asemblages exhibit compositional differences which vary with the sediment faciès and probably reflect taphonomic factors such as differential buoyancy of the fossils. The upper marine deltaic sands contain some "old " rebedded plant detritus and amber indicating a nearby source of Tertiary sediment, possibly equivalent in age to the Beaufort Formation. Other rebedded fossils from the upper deltaic unit may be the same age as the mid-section fluvial gravels.

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STRATIGRAPHY AND PALEOECOLOGY OF QUATERNARY SEDIMENTS ALONG PASLEY RIVER, BOOTHIA PENINSULA, CENTRAL CANADIAN ARCTIC

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ABSTRACT Quaternary sediments exposed along Pasley River consist of a lower marine deltaic sand overlain in succession by complexly interbedded tills and glaciomarine sediments (the lower glacigenic assemblage), by a mid-section fluvial gravel, by an upper marine deltaic sand, and by glaciomarine sediment and till (the upper glacigenic assemblage). The mid-section fluvial gravels contain plant and insect fossils indicating a climate as warm as and perhaps warmer than present. The top of the gravel is more than 55 000 years old ; the unit is probably of Sangamonian age (>75 000 ka) and separates Wisconsinan from Illinoian glacial deposits. The deltaic sands that underlie both glacigenic assemblages indicate substantial crustal depression during glacial buildup episodes prior to arrival of ice at the site. This implies that the process of buildup was slow and involved glacier expansion into major marine basins. Glaciomarine beds of the lower glacigenic assemblage locally contain abundant detrital terrestrial organic material as well as marine molluscs. The terrestrial organic detritus, an unusual constituent of glaciomarine sediment, is thought to have been released into the sea from glacier ice. These terrestrial fossil asemblages exhibit compositional differences which vary with the sediment facies and probably reflect taphonomic factors such as differential buoyancy of the fossils. The upper marine deltaic sands contain some « old » rebedded plant detritus and amber indicating a nearby source of Tertiary sediment, possibly equivalent in age to the Beaufort Formation. Other rebedded fossils from the upper deltaic unit may be the same age as the mid-section fluvial gravels.

RÉSUMÉ *Stratigraphie et paléoécologie des sédiments quaternaires le long des rives de la rivière Pasley, péninsule de Booth, Arctique canadien.* Les berges de la rivière Pasley montrent des séquences de sédiments quaternaires qui comprennent de la base vers le sommet : un sable marin d'origine deltaïque, un ensemble complexe de couches de till interstratifiées avec des sédiments glaciomarins (assemblage inférieure de sédiments glacigéniques), un gravier fluviatile vers le milieu, un sable deltaïque marin supérieur et, au sommet, des sédiments glaciomarins et du till (assemblage supérieur de sédiments glacigéniques). Le gravier fluviatile dont la partie supérieure a été datée à plus de 55 000 ans contient des fossiles de plantes et d'insectes indicateurs d'un climat aussi chaud ou plus chaud que celui d'aujourd'hui. Cette unité date probablement du Sangamonien (> 75 000 BP) et sépare les dépôts glaciaires du Wisconsinien de ceux de l'Illinois. Les sables deltaïques à la base des deux assemblages glacigéniques signalent qu'un affaissement important de la croûte terrestres, lié à un épisode de croissance glaciaire, s'est produit avant l'arrivée du glacier. Les couches des dépôts glaciomarins de l'assemblage glacigénique inférieur renferment parfois d'abondants débris organiques d'origine terrestre et des mollusques marins. Le matériel d'origine terrestre, une composante inhabituelle des sédiments glaciomarins, représente probablement un apport direct du glacier à la mer. Les différentes compositions de ces assemblages de fossiles terrestres sont liées au changement de faciès des sédiments et sont le reflet de facteurs taphonomiques comme la différence d'apesanteur entre les fossiles. Le sable marin deltaïque supérieur contient d'anciens débris de plantes et de l'ambre restratifiés, un indice d'une source proche de sédiments tertiaires, probablement d'un âge comparable à celui de la Formation de Beaufort.

ZUSAMMENFASSUNG *Stratigraphie und Paläoökologie von Quartär-Sedimenten entland des Pasley-Flusses, Boothia-Halbinsel, zentralkanadische Arktis.* Die entlang dem Pasley-Fluß freiliegenden Quartär-Sedimente bestehen aus einer unteren marinen Delta-Sandschicht, überlagert von einer Folge von komplex geschichteten Tills und glaziomarinen Sedimenten (die untere glazigenen Ablagerung), aus einer mittleren Fluß-Kies-Schicht, einer höheren marinen Delta-Sandschicht und einem glaziomarinen Sediment und Till (die obere glazigene Ablagerung). Der Flußkies der mittleren Schicht enthält Pflanzen- und Insektenfossile, welche auf ein ebenso warmes oder vielleicht sogar wärmeres Klima als gegenwärtig hinweisen. Der obere Teil der Kiesschicht ist mehr als 55000 Jahre alt, diese Schicht stammt möglicherweise aus dem Sangamon (älter als 75 000 ka) und trennt Ablagerungen aus dem Wisconsin von den glazialen Ablagerungen des Illinois. Der Delta-Sand, der unter beiden glazigenen Schichtungen liegt, läßt auf bedeutende Krustensenkungen während der glazialen Aufbauphase schließen, vor dem Auftreten von Eis an dieser Stelle. Das bedeutet, daß der Prozeß des Aufbaus langsam war und mit Gletscher-Ausdehnung in größere marine Becken verbunden war. Die glaziomarinen Betten der unteren glazigenen Schichtung enthalten örtlich umfangreiches organisches Erdgeröllmaterial sowie marine Weichtiere. Das organische Erdgeröll, ein ungewöhnlicher Bestandteil glaziomariner Sedimente, soll vom Gletscher-Eis in das Meer geschoben worden sein. Diese Erd-fossilschichtungen zeigen Unterschiede in der Zusammensetzung, von einer zur anderen Sediment-Fazies und spiegeln möglicherweise taphonomische Faktoren, wie unterschiede in der Tragfähigkeit der Fossile. Der obere marine Delta-Sand enthält einige "alte" neugeschichtete Pflanzenpartikel und Bernstein, was auf eine nahegelegene Quelle tertiären Sediments hinweist, die vermutlich ebenso alt ist wie die Beaufort-Formation.

* Geological Survey of Canada Contribution 11486.

INTRODUCTION

Reconnaissance and systematic Quaternary geological mapping in the central Arctic since the early 1960's has documented the rarity of stratigraphic sections exposing sediments below the surface till. To date only three significant sections have been located and none of these have been reported in the formal literature. Two sections on Prince of Wales Island are under active study ; the third and best exposed sections, those along Pasley River on northern Boothia Peninsula were first encountered by A.N. Boydell's party from the Geological Survey of Canada during reconnaissance mapping in 1974. They described a lower and upper till separated by sand. Wood fragments (*Salix* sp.) from the basal part of the inter-till sand were dated at older than 33 000 BP (GSC-2207, Table V). Their preliminary descriptions were never published.

In 1979, one of us measured a section cut by a tributary to Pasley River, north of the main exposures described below, and subsequently reported three tills separated and underlain by waterlaid sediment (DYKE, 1982). In that abstract, Dyke suggested that erratic shells in the lowest till were 76 ka old, that all sediments in the section were of Wisconsinan age and that they recorded a sequence of stades and interstades with massive deglaciations *ca.* 75 ka, 35 ka and at some intermediate time (*ca.* 50-60 ka ?)[1]. That interpretation was based on the reasoning that shells from the section and erratic shells in the surface till on neighbouring Somerset Island (DYKE, 1983) had existed either in seas with temperatures close to 0°C or beneath warm based ice sheets, again with temperatures close to 0°C, and therefore, that their absolute ages could be derived from their amino acid ratios, identical to the reasoning being applied to the Hudson Bay Lowlands (SHILTS *et al.*, 1981 ; ANDREWS *et al.*, 1983).

In 1982, Dyke examined the main exposures along Pasley River in some detail and collected samples of marine shells and plant detritus. This paper reports the stratigraphic measurements, radiocarbon ages of plant detritus, amino acid ratios on shells, and paleoecological analysis (JVM) of organic samples. Although a completely unambiguous interpretation of the stratigraphy is not possible, it seems likely that the interpretation of DYKE (1982), reiterated above, was premature and that the sediments record two glaciations separated by an interglaciation rather than multiple advances and retreats of Wisconsinan ice.

LOCATION, GENERAL GEOLOGY AND BIOTIC SETTING

Pasley River flows northwestward into Pasley Bay on west-central Boothia Peninsula (Fig. 1), where Quaternary deposits are extensive and thick (DYKE, 1984, Map 1570A). The postglacial valley follows the preglacial valley cut in Paleozoic carbonate rocks but the postglacial river has exposed bedrock in few places. The valley trends parallel to the western margin of the Boothia Plateau, a northern salient of the Churchill Province of the Canadian Shield. The stratigraphic exposures are located along a short segment of the river which is about 60 m a.s.l. and only 5 km west of the Precambrian contact. The tops of the sections are about 100 m a.s.l.

During the last glacial maximum, ice flowed eastward across the region, and west of the Precambrian contact it laid down an exceedingly calcareous till with less than 1 % Precambrian clasts. During deglaciation, ice flow swung northward and briefly westward ; the postglacial sea invaded to a well defined marine limit at 136 m about 8800 years ago (DYKE, 1984).

THOMPSON (1980) has provided a brief summary of the climate of Boothia Peninsula. In general it possesses an arctic continental climate ameliorated by maritime effects near the coast. Mean temperatures for the months between December and March average below −18°C. In the Pasley

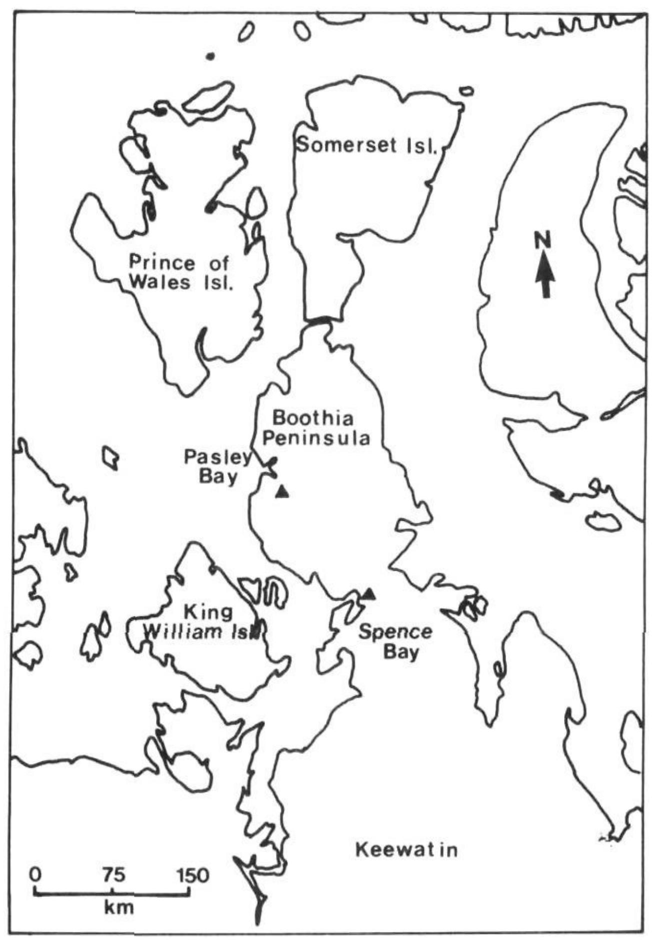

FIGURE 1. Location of study area and place names used in text (see Fig. 2 for general location).

Carte de localisation et noms de lieux mentionnés dans le texte (voir la fig. 2 pour la localisation générale).

1. Dyke (1982) was following the definition of "Wisconsinan Stage" which places the Wisconsinan/Sangamonian boundary at the boundary between marine isotopic Stages 5e and 5d (*ca.* 15 000 BP). In this paper we follow the definition which places the boundary between marine isotopic Stages 5 and 4 (*ca.* 75 000 BP). Middle Wisconsinan is the interval 64 000 to 23 000 BP.

River area the mean daily maximum and minimum for February, the coldest month, are about −31°C and −38°C respectively. Mean daily screen temperatue for July, the height of the short growing season, falls between 5° and 10°C (DANKS, 1981). Mean annual precipitation ranges from 15 cm in the northern part of the peninsula to about double that in the south.

The Pasley River valley lies within an ecoregion characterized by sparse vegetation, active cryoturbation and only weak soil development (TARNOCAI *et al.*, 1975). The entire Boothia Peninsula is treeless and beyond the limit of shrub birches (Fig. 2c) and alders. The northern part of the peninsula also lacks all ericaceous plants, except for *Cassiope* (SAVILE, 1959). Spruce (*Picea*) and larches (*Larix*) grow at tree line approximately 650-800 km south of Pasley River valley (ROWE, 1972 and Fig. 2), while the nearest record for shrub birches (*Betula glandulosa*) is no closer than 500 km (Fig. 2c). In terms of the diversity of its vascular plant flora, northern Boothia Peninsula probably falls between Somerset Island with 98 species and King William Island with 104 species (DANKS, 1981).

Several schemes exist for subdivision of Arctic regions based on floristics. Under the subdivision proposed by POLUNIN (1948), the Pasley River area falls within the mid-arctic zone, which is approximately comparable to Alexandrova's "Arctic Tundra" region (ALEKANDROVA, 1980). One of the characteristics of the Arctic Tundra zone is complete absence of shrub birches. Furthermore, Alekandrova states that the Arctic Tundra in Eurasia was not invaded by trees during the warmest phases of the present interglacial. This is also true of the mid-Arctic or Arctic Tundra zone in North America, and provides one standard for interpretation of the fossil floras discussed below. YOUNG (1971) divides tundra into four zones according to the richness of the flora and finds a good correlation with the total accumulated degree days above 0°C. According to his scheme (Fig. 2), Pasley River lies within tundra zone 2, the second most depauperate zone in the Northern Hemisphere.

Most of the organics discussed below come from alluvial or deltaic deposits, hence it is to be expected that they would include, in some cases be dominated by, fossils of plants that presently grow on or near such sites. According to the data given in THOMPSON's (1980) discussion of vegetation types on Boothia Peninsula and SAVILE's (1959) notes on the vegetation of Somerset Island, it should be expected that alluvial samples will contain an abundance of purple saxifrage (*Saxifraga oppositifolia*), willow (*Salix*), and arctic avens *(Dryas integrifolia)*.

In addition to macroremains of plants, the Pasley River section contains fossils insects. For purposes of comparison it would be desirable to have information on the present insect fauna, especially that of beetles, for northern Boothia Peninsula. Unfortunately this is not available at this time. Most cited records come from either Spence Bay, south of Pasley River (Fig. 2), which falls within Young's tundra zone 3 or from various localities on the Queen Elizabeth Islands north of Boothia Peninsula. Despite this impediment, it is possible to make some educated guesses on the composition of the present insect fauna of the Pasley River area. The 7.2°C mean daily July isotherm, which DOWNES (1964) considers to be an appropriate entomo-faunal boundary between low Arctic and high Arctic, crosses Boothia Peninsula just south of the Pasley River (Fig. 2 ; BLAKE, 1974). For practical purposes it is equivalent to DANKS' (1981) boundary between High Arctic (HA) and Low Arctic (LA). Using Danks' annotated list supplemented by unpublished information (JVM), we suggest that the beetle fauna of northern Boothia is very impoverished compared to that of mainland areas south of Spence Bay. It probably lacks all leaf beetles (Chrysomelidae) and has only a few species of rove beetles (among them *Micralymma*). The carabid (ground-beetle) portion of the fauna includes the arctic species *Amara alpina* (LINDROTH, 1963, Fig. 58) and probably at least two species of the northern subgenus *Pterostichus (Cryobius)* (BALL, 1966 ; MATTHEWS, unpublished collection records).

STRATIGRAPHY

The Quaternary sediments are well exposed in two deeply gullied river bluffs, freshened annually by nival floods and separated by a vegetated, fairly stable slope about 1 km wide. In the South Bluff thick lower and thin upper glacigenic assemblages are separated by sand ; in the North Bluff the two glacigenic assemblages are separated by gravel and sand, and an older unit outcrops at the base of one spur below the lower glacigenic assemblage (Figs. 3 and 4). The individual columns in Figure 3 represent measured profiles that are separated by 100 to a few hundred metres. Here beds or assemblages of related beds are assigned numbers and described below. The mid-section gravel (Unit 3) in the North Bluff is an important unit, and its absence in the South Bluff hampers detailed correlation. Nevertheless, the correlation of the two glacigenic asseemblages (Units 2 and 5) and the ripple laminated sand (Unit 4), below the top glacigenic assemblage, both from spur to spur within the individual bluffs and between the two bluffs is obvious, simply from their stratigraphic position.

UNIT 1 (BASAL MARINE DELTAIC SAND)

Unit 1 is exposed only at the base of Section 3 of the North Bluff where it consists of 8 m of compact, horizontally bedded, tan coloured, calcareous, silty sand with both planar and cross lamination. Tiny layers and lenses of organic detritus are marked by rusty bands throughout the sediment. Vertical casts, about 10 cm long and 2-4 mm wide, are possibly worm burrow fillings.

Fossils from the organic lenses are listed in Table I. The detritus consists predominantly of moss fragments but also includes seeds of sedges (*Carex* sp.), *Ranunculus* and *Potentilla* as well as leaves or leaf fragments of willow (*Salix*), purple saxifrage (*Saxifraga oppositifolia*) and arctic avens (*Dryas integrifolia*). All of these plants occur or are expected to occur on the northern part of Boothia Peninsula today (PORSILD and CODY, 1980). Purple saxifrage and *Dryas integrifolia* are particularly abundant in areas with calcareous substrates (THOMPSON, 1980), and on dry to wet gravel (SAVILE, 1959).

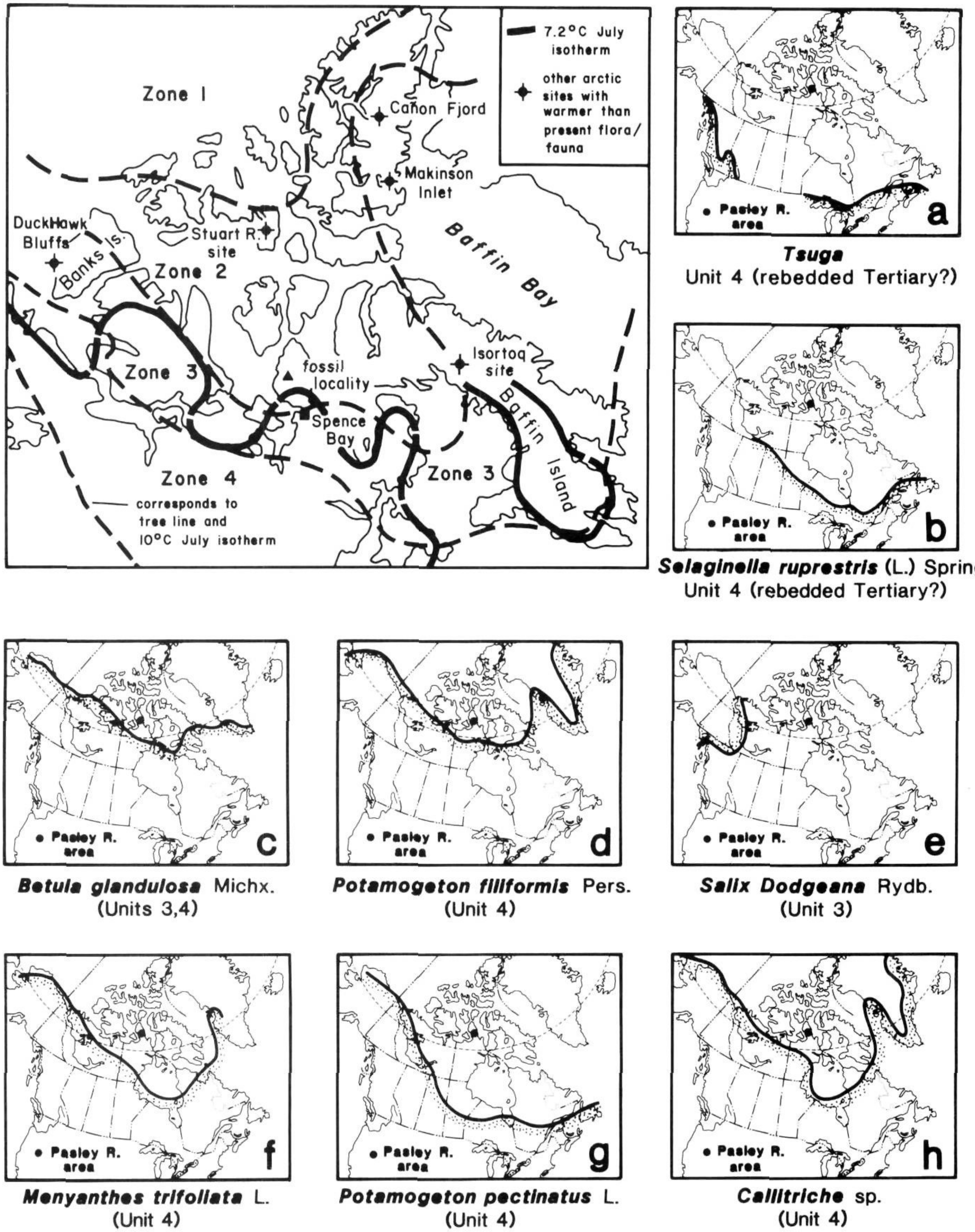

FIGURE 2. Map showing location of stratigraphic site relative to tundra zones of YOUNG (1971) and DOWNES (1964). Smaller maps (modified from PORSILD and CODY, 1980 and EDLUND, 1982, 1983) show approximate northern limits of plant taxa found as fossils at the Pasley River exposure.

Carte de localisation du site stratigraphique par rapport aux zones de toundra de YOUNG (1971) et de DOWNES (1964). Les cartons (modifiés à partir de PORSILD et CODY, 1980 et de EDLUND, 1982, 1983) montrent les limites septentrionales approximatives des taxons de plantes fossiles trouvés dans la coupe de la rivière Pasley.

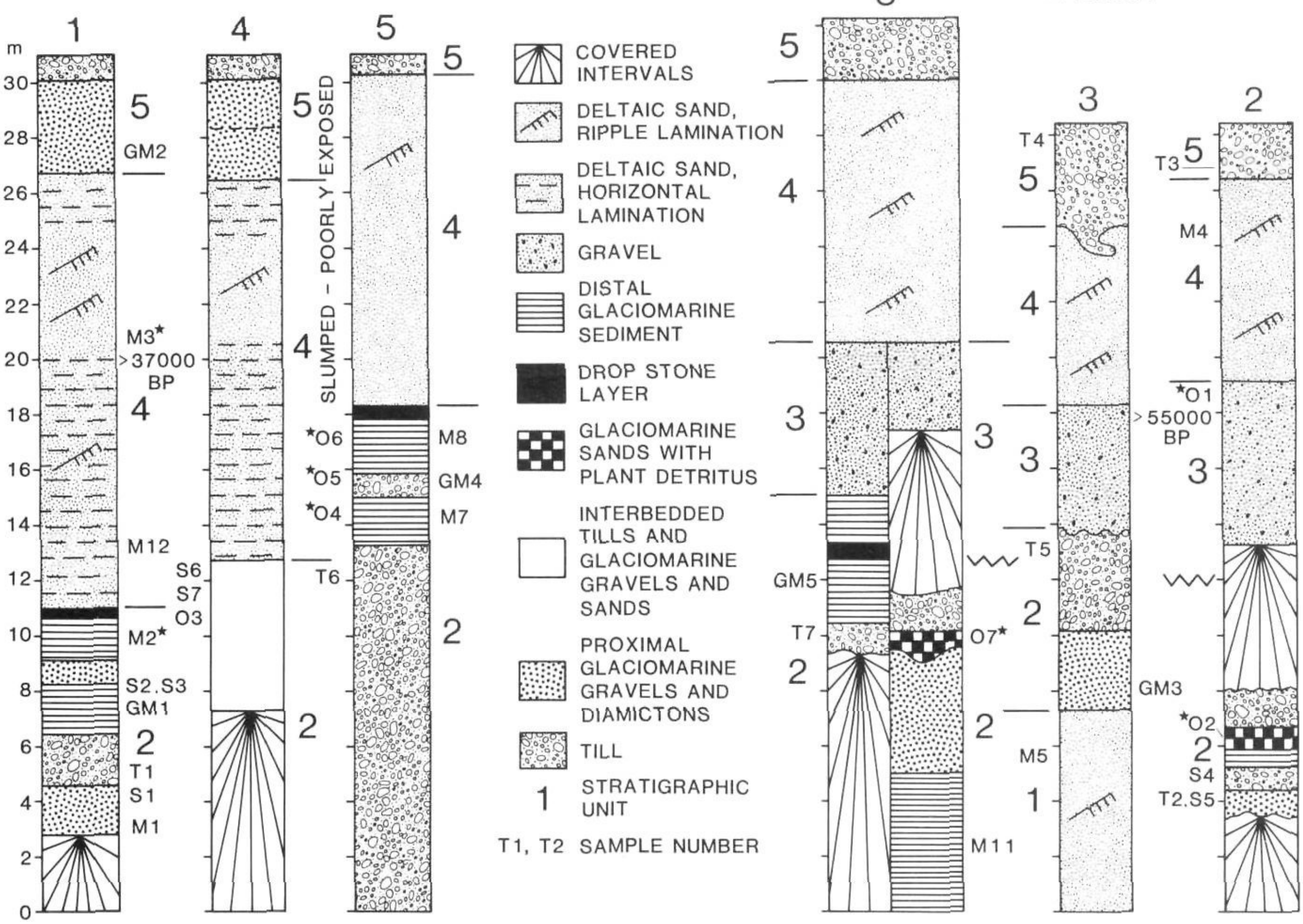

FIGURE 3. Measured stratigraphic sections along west side of Pasley River, showing samples discussed in the text and samples from which plant and insect macrofossils were obtained (*). Sample M6 is from Section 4 at the same level as Sample M3.

Coupes stratigraphiques mesurées sur la rive ouest de la rivière Pasley montrant la localisation des échantillons décrits dans le texte et des échantillons qui ont fourni des macrorestes de plantes et d'insectes (*). L'échantillon M6 provient de la coupe n° 4, au même niveau que l'échantillon M3.

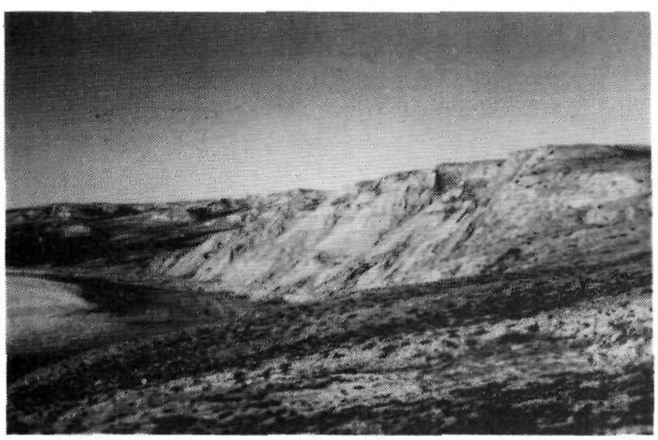

FIGURE 4. Southward view of North Bluff. Scree-forming fluvial gravels occupy the middle third of the face and are overlain by a similar thickness of deltaic sand which is capped by a cliff-forming till. The shoulder of the spurs below the gravel marks outcropping till beds of the lower glacigenic assemblage (GSC-203537-B).

Vue vers le sud de l'escarpement nord. Des graviers fluviatiles occupent le tiers central de la pente. Ils sont recouverts d'une épaisseur comparable de sable deltaïque qui est coiffé d'une couche de till en forme d'abrupt. Les lignes horizontales à la base des éperons sous les graviers soulignent les affleurements de till de l'assemblage inférieur de sédiments glacigéniques (cliché GSC-203537-B).

The organic residue contained sparse remains of terrestrial arthropods, representing Coleoptera such as the rove beetle *Micralymma*, Diptera in the form of larval head capsules of chironomids (midges), a few oribatid mites and statoblasts of Bryozoa. All of these taxa probably occur in the Pasley River area today.

The fossil assemblage also contains a few hydrozoan thecae fragments and several foraminifera tests. Thecate hydrozoans are almost exclusively marine (PENNAK, 1978; FRASER, 1944), and like the foraminifera tests suggest that the sands accumulated in a marine environment. Of course it could be argued that the few marine fossils are rebedded from an older marine unit, and that the sands are fluvial. But it must be noted that the only sands accumulating in the region today occur in a marine environment — the estuarine delta at the mouth of Pasley River. Modern fluvial deposits consist of gravels rather than sands.

By the end of deposition of Unit 1 sea level had risen to about 70 m above present sea level. Because the unit is overlain by glacial sediments, it probably records a marine transgression brought on by ice sheet buildup. If so, this amount of glacioisostatic crustal depression indicates that

TABLE I

Plant and invertebrate (mainly arthropod) fossils from the lower marine deltaic sand (Unit 1) at Section 3 (sample M5, Fig. 3)

PLANTS	
BRYOPHYTA	+ +
PTEROPHYTA	
Cyperaceae	
Carex spp.	+ sd
Salicaceae	
Salix sp.	+ cp,lf
Ranunculaceae	
Ranunculus trichophyllus type	+ sd
Ranunculus sp.	+ sd
Saxifragaceae	
Saxifraga oppositifolia L.	+ + lf
Rosaceae	
Dryas integrifolia Vahl.	+ + lf
Potentilla sp.	+ sd
ANIMALS	
PROTOZOA	
FORAMINIFERA	+ ts
COELENTERATA	
HYDROZOA	+ th
BRYOZOA	
Cristatella mucedo L.	+ st
ARTHROPODA	
INSECTA	
COLEOPTERA	
Carabidae	
Pterostichus sp.	+ el
Staphylinidae	
Micralymma sp.	+ pr,el
DIPTERA	
Chrironomidae	
Chironomus type	+ lv(hd)

+ = taxon present ; + + = taxon abundant ; sd = seed (fruit, samara, nutlet, achene etc) ; cp = capsule ; lf = leaf or leaf fragment ; ts = test ; th = thecae ; st = statoblast ; el = elytra ; pr = pronota ; hd = head ; lv = larval.

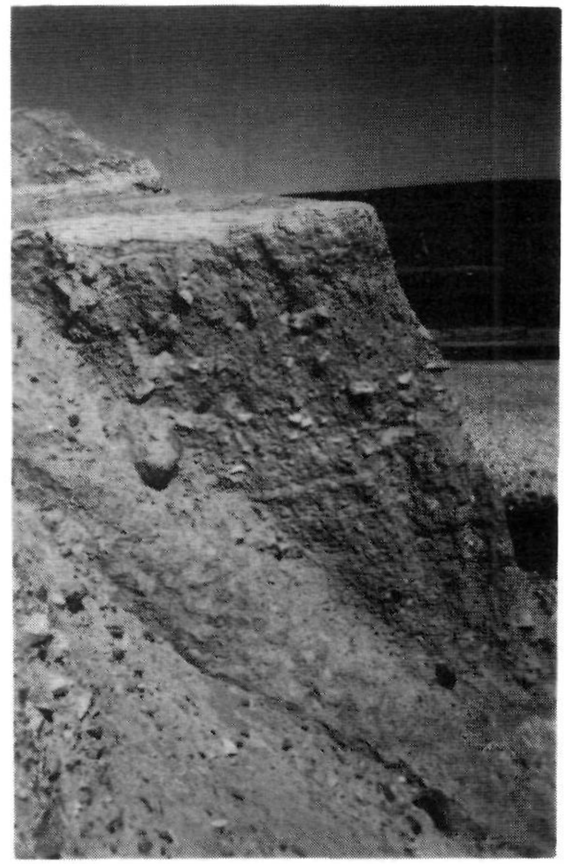

FIGURE 5. Top 6 m or so of thick diamicton at base of Section 5. Slight horizontal stratification produced by thin sand/silt laminae between till-like beds. Diamicton is capped by rythmically bedded, plane laminated fine sand and silt (distal glaciomarine sediment) (GSC-203536-Z).

Les six mètres supérieurs d'un diamicton épais, à la base de la coupe n° 5. La faible stratification horizontale est le résultat de la présence de lamines de sable et de silt entre les couches de till (?). Le diamicton est recouvert de rhytmites de sable fin laminé et de silt (sédiment glaciomarin distal) (cliché GSC-203536-Z).

ice buildup was slow, at least in the central Arctic, and that it involved the infilling of major marine basins.

UNIT 2 (LOWER GLACIGENIC ASSEMBLAGE)

Unit 2 consists of a laterally varied sequence of diamictons (labelled till in Fig. 3) and water sorted sediments which display little apparent consistency in the sequence of vertical facies change, at least at this scale of study. The unit comprises the lower third to one-half of most sections and in all sections includes at least one diamicton layer.

The diamicton layers are compact cliff formers and show little or no sign of internal stratification. The thickest diamicton, at the base of Section 5, however, has slight horizontal stratification imparted by thin sand/silt laminae (Fig. 5). Clast content of the diamictons is high, perhaps ranging from 30 to 60 per cent by volume (Fig. 5) ; more than 90 % of clasts are from Paleozoic carbonate rock, and many of these are heavily striated. The matrix (2 mm), based on complete grain size curves for 5 samples, is very poorly sorted and the grain size distribution tends to be fine-skewed and bimodal or polymodal (Fig. 6). Sand/silt/clay ratios for the five samples range from 23/42/25 to 57/32/11. The diamictons are mostly non-fossiliferous but in places they contain small quantities of fragmented marine mollusc shells and, more rarely, fragments of wood (*Salix* sp.). The diamicton can occur in contact with any other facies in Unit 2. In places the lower contact is erosional.

This unit is interpreted as a till. Its properties and composition are indistinguishable from those of the widespread surface till of the region (DYKE, 1984). Alternatively, it is a very coarse and almost entirely non-sorted glaciomarine sediment, but in either case deposition occurred in close

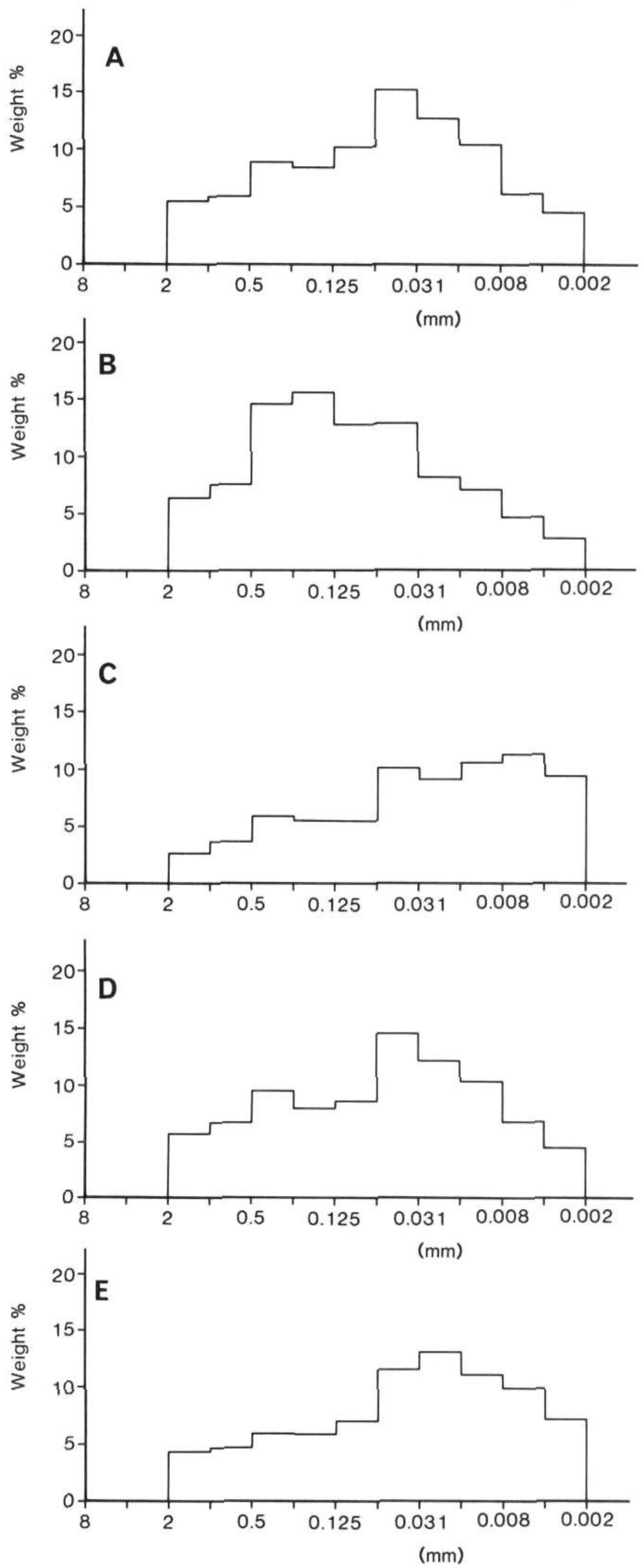

FIGURE 6. Grain size histograms for 5 samples of "till" from lower glacigenic assemblage (sample T1(a), T2(b), T5(c), T6(d), and T7(e) located on Fig. 3).

Histogrammes de la granulométrie de cinq échantillons de « till » provenant de l'assemblage inférieur de sédiments glacigéniques (échantillons T1(a), T2(b), T5(c), T6(d) et T7(e) de la fig. 3).

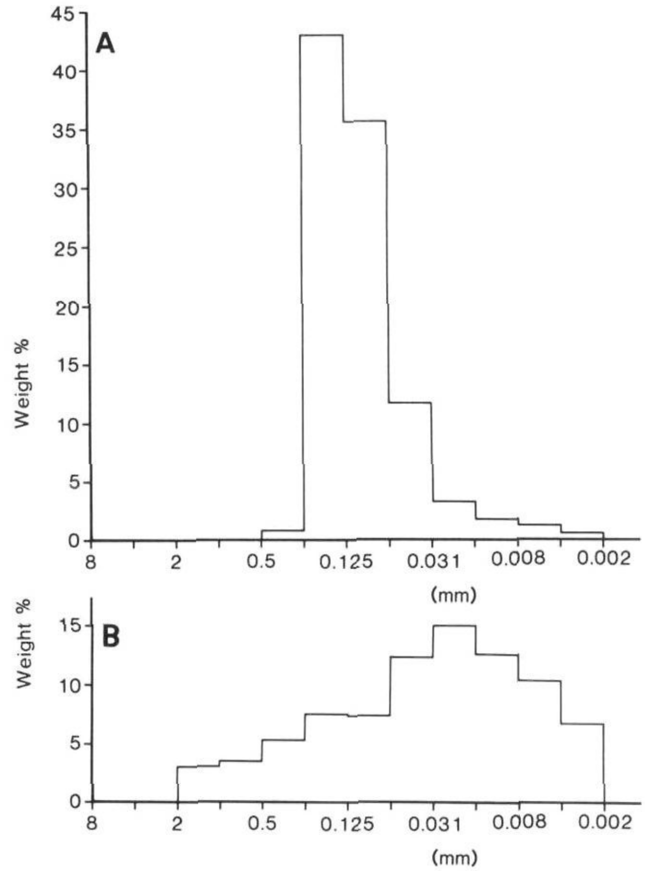

FIGURE 7. Grain size histograms for two samples from the "proximal glaciomarine gravel" facies of Unit 2 illustrating the range of matrix textures whithin the facies. Sample M1 (Fig. 7a) has a matrix of well sorted sand, possibly representing depletion of fines by current winnowing (Section 1) ; sample GM3 (Fig. 7b) is from a thin till-like bed between coarse loose gravel beds (Section 3).

Histogrammes de la granulométrie de deux échantillons d'un sédiment provenant du faciès des « graviers glaciomarins de position proximale » de l'unité n° 2 et illustrant la diversité texturale du faciès. L'échantillon M1 (fig. 7a) montre une matrice de sable bien trié, résultant probablement du lessivage des grains fins par le courant (coupe 1). L'échantillon GM3 (fig. 7b) provient d'une mince couche de till (?) entre deux couches de gravier meuble et grossier (coupe 3).

proximity to ice. Very slight sorting of the matrix during depósition through a water column might explain the weak stratification of the diamicton at the base of Section 5.

Another coarse grained facies of Unit 2 is gravel with a highly variable matrix to clast ratio and with a variably sorted matrix. It varies from a coarse, loose gravel with a sorted sand matrix to clasts bedded in horizontally laminated sand and silt to unsorted, compact diamictons, the three being commonly interbedded (Fig. 7). Clasts are predominantly from Paleozoic carbonate rocks and are normally heavily striated. The basal unit exposed in Section 4 consists of gravel with compact till-like beds up to 1m thick (see Unit 1, above) interbedded with loose gravel in a coarse sand matrix. The unit is shell bearing throughout although shells are more abundant in the cleaner gravel beds. Detrital plant material is also present but rare.

This unit is interpreted as a glaciomarine gravel deposited in close proximity to the front of a tidewater glacier or beneath an ice shelf. The thin diamicton beds within the unit could represent temporary advances of the ice front or grounding line. More likely, because of the number of beds present and their conformability with the cleaner gravels, they represent debris flows from an ice front or from valley sides.

The next finer facies of Unit 2 is a clean, plane laminated, tan sand or sand and silt with plant detritus, including abundant wood. This unit was observed in two sections. At Section 2 the contact with underlying fossiliferous marine sediment is gradational. At Section 8 it consists of a single sand/silt couplet, which, along with the upper beds of the underlying glaciomarine gravel appear to have been folded into a single syncline with 1 m amplitude. The contact between the sand and gravel is apparently conformable. The fold could represent deformation by ice which emplaced the overlying till or the sand and the top of the underlying gravel could have been deposited as a channel fill.

Wood (*Salix* sp., identified by R.J. Mott) from the sand is very well preserved, most of it still retaining bark and buds. Mosses are present in a sample from Section 2 (Table II), but aside from a few achenes of *Kobresia*, the sample contains very few plant macrofossils. A cursory examination of a small sample of organics in sample 07, from the same facies, reveals a similar assemblage — nearly devoid of identifiable seeds.

Arthropod fossils in the sample from Section 2 are more scarce than in Unit 1 or the other units (see below), yet outnumber plant fossils other than mosses. They suggest a cold arctic climate similar to that of the present. Tadpole shrimp (*Lepiduris* sp.) occur in small arctic ponds ; the weevil *Rhynchaenus arcticus*, probably the only weevil living in the area today, feeds on arctic willow (A. Downes, pers. comm. ; W.J. Brown, unpublished ms) ; and the mite *Iugoribates gracilis* is typical of the dry sites that support *Dryas-Saxifraga* communities (BEHAN-PELLETIER, 1985).

The sediments are tentatively interpreted as glaciomarine in origin because they are conformable with underlying fossiliferous glaciomarine sediments and lie stratigraphically lower than other glaciomarine sediments (left side, Section 8) which in places (*e.g.*, below the drop-stone layer, Section 5) also contain organic detrital zones.

The reason for the abundance of wood in this facies is not clear. Possibly the wood was released from a glacier front standing in the sea or from the base of an ice shelf and incorporated into a sand-carrying current on the sea bed. Alternatively, the sand and organic detritus was carried to the sea by a short proglacial meltwater stream. This interpretation requires the fossiliferous unit to have been deposited early in a glacial cycle, before the site was fully ice covered, but after the sea had transgressed to 70+ m above its present level. In this case, the lowest "till" in Section 2 would be best interpreted as a glaciomarine diacmicton. Of the five samples of lower till, sample T2 from that bed had the coarsest matrix (Fig. 6), possibly indicating partial removal of fines during rapid sedimentation through water.

The finest grained facies of Unit 2 ("Distal Glaciomarine Sediment" in Fig. 3) consists of horizontally bedded tan to dark grey sand, silt and clay with a variable constituent of drop stones, marine shells and organic detritus. Figure 8 compares the grain size distribution of two samples from Section 8, one with and one without dropstones (GM5 and M11). This facies differs from the proximal glaciomarine gravels and diamictons described above by the obvious predominance of matrix over clasts and by the generally smaller dropstones, which are commonly granule-sized. However, distinct dropstone layers with cobble-sized clasts occur at the top of this facies in Sections 1 and 5 and in the middle of the top occurrence of the facies in Section 8. These layers are conspicuous and persist for 10's of metres laterally. Most outcrops of this facies show parallel lamination caused by alternating grainsize changes, commonly fine sand to silt. The outcrop in Section 2 is massive with a

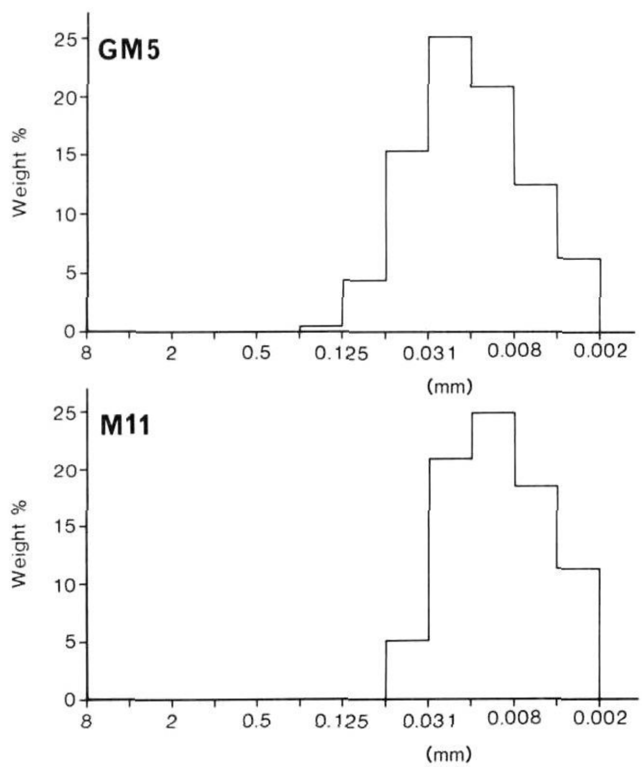

FIGURE 8. Grainsize histograms for two samples of "distal glaciomarine sediment" from Section 8. Sample GM5 is from horizontally laminated silt with few dropstones other than those within a distinct dropstone layer in the middle of the unit. Sample M11 is from a unit that is free of dropstones and represents the most distal glaciomarine sediment recognized at Pasley River.

Histogrammes de la granulométrie de deux échantillons d'un « sédiment glaciomarin de position distale » de la coupe n° 8. L'échantillon GM5 provient de lamines horizontales de silt contenant quelques cailloux délestés différents de ceux qui sont contenus au centre de cette unité dans une couche distincte de cailloux délestés. L'échantillon M11 provient d'une unité sans cailloux délestés et représente le sédimemt glaciomarin de plus distal reconnu au site de la rivière Pasley.

fine blocky structure and oxidized block faces. Where the facies contacts coarser glaciomarine facies described above, the contacts are conformable and in places gradational.

Some outcrops of this facies (*e.g.* Sections 1 and 2) are rich in marine shells (mostly the common arctic bivalves, *Hiatella arctica*, *Mya truncata*, *Portlandia arctica*, and *Astarte borealis*), in detrital plant material (Section 5), or in both (Section 1) ; other outcrops (Section 8) contain no macrofossils. Shells occur as fragments, individual valves, and as paired bivalves ; periostracum is commonly retained and mother-of-pearl fragments occur in Section 1.

The small insect assemblage (Table II) is very similar to that from the tan sands. The plant assemblages differ, however. The samples from the distal glaciomarine facies contain abundant leaves, buds and twigs of both *Salix* and *Dryas integrifolia*. Some of the leaves of the latter species are exceptionally well preserved, in contrast with the mosses which appear to be relatively more degraded than those from the tan sands. The sediments containing these well preserved leaves represent a distal facies of glaciomarine sedimentation. Why then do they contain better preserved and different fossils from the tan sands which undoubtedly accumulated nearer the ultimate source of the fossils ? A taphonomic bias may be involved. In other words, leaves in the distal sediments could have been selectively winnowed by bottom currents from the organics incorporated in the tan sands. If so, the fossils most likely to be carried to deeper water are those that are more buoyant or more susceptable to current transport. *Dryas* and *Salix* leaves are of this type. Furthermore, they are known to be preferentially transported on water or by wind across barren frozen surfaces (GLASER, 1981). If either of these processes were occurring at the time of deposition of Unit 2, leaves of *Salix* and *Dryas* growing near shoreline might have been carried well offshore to be deposited in distal or deep-water marine sediments. Their preservation would be enhanced if sea level was rising at the time, floating the leaves off a transgressed tundra surface. This interpretation requires that unglaciated, vegetated sites existed on shore throughout the deposition of Unit 2. Alternatively, some or all of the plant detritus in Unit 2 might have been released from frozen sub-glacial organics during glacial retreat toward the end of a glacial cycle. This would explain the fact that the finer facies occurs at the top of Unit 2 at most stations, and it would still allow the possibility for certain types of plants to be preferentially transported offshore and deposited in distal marine sediments.

Sea level during deposition of the distal facies was more than 80 m above its present level, above the elevation of the dropstone layer in Section 5. Sea level exceeded 80 m, the paleo sea floor, by a sufficient amount to float ice bergs or an ice shelf.

TABLE II

Plant and invertebrate (mainly arthropod) fossils from the plant-bearing sands and bedded, sand, silt and clay (with dropstones) in the lower glacigenic assemblage (Unit 2) at Sections 1, 2 and 5 (samples 02, M2, 06, 05, 04 Fig. 3)

PLANTS	Sample 02	M2	04-06
BRYOPHYTA	+ +		+
PTEROPHYTA			
Cyperaceae			
Carex sp.		+ sd	
Kobresia type	+ sd		
Salicaceae			
Salix sp.		+ cp,lf	+ bd
Cruciferae			
Draba sp.			+ sd
Saxifragaceae			
Saxifraga oppositifolia L.		+ lf	? lf
Rosaceae			
Dryas integrifolia Vahl.			+ + lf,bd
Potentilla sp.		+ sd	+ sd
ANIMALS			
ARTHROPODA			
INSECTA			
COLEOPTERA			
Curculionidae			
Rhynchaenus arcticus Kor.	+ el,pr	+ el	+ el
DIPTERA			
Tipulidae	+ hd		
Chironomidae	+ hd		
CRUSTACEA			
Cladocera			+ eh
Notostraca			
Lepiduris sp.	+ md		
ARACHNIDA			
Acari : Oribatei			
Iugoribates gracilis Sellnick	+ +		

ABBREVIATIONS : + = taxon present ; + + = taxon abundant ; sd = seed (fruit, samara, nutlet, achene etc) ; lf = leaf or leaf fragment ; cp = capsule ; bd = bud or bud fragment or twig with buds (*Salix*) ; el = elytra ; pro = pronota ; hd = head ; md = mandible ; eh = ephippium.

UNIT 3 (MID-SECTION FLUVIAL GRAVEL)

Unit 3 consists of coarse loose gravel which crosses the entire middle face of the North Bluff (Fig. 4). It overlies either till or marine sediment of Unit 2 but the lower part of the unit and its basal contact are scree-covered because of its low resistance to mass wastage. The approximate position of the base is marked by a shoulder on the spurs of the bluff and the top of the unit is a distinct nearly horizontal line as viewed from across Pasley River. It is about 10-13 m thick. The gravel consists largely of cobble and small boulder-sized Paleozoic carbonate clasts, and the top, where best exposed, is horizontally bedded with coarse sand interbeds. In Section 2 several of these coarse sand beds contain mats of plant material interbedded with sand. This gravel does not occur in the South Bluff. Possibly its correlative there is the lower part of the thick sand unit that separates the lower and upper glacigenic assemblages. Another possibility is that it correlates with an uncomformity or disconformity at the base of the sand, which was not recognized in the field.

Sample 01 (Table III) comes from the organic mats within Unit 3 at Section 2. The concentration of organics is much greater than is the case in Units 1 or 2, and preservation of many of the fossils is exceptional. In addition to an abundance of well preserved bryophytes (not identified) and very fragile fragments of bluegreen algae (*Gloeocapsa/Chroococcus*, Table III), the organic residue includes complete willow catkins with capsules that still contain seeds (*Salix Dodgeana*, Table III), and some of the *Dryas integrifolia* leaves still possess the tometnum found on the undersides of living leaves. Although arthropod fragments are not as abundant as those of plants, they too exhibit features that are not ordinarily seen on fossils.

Since the assemblage appears to consist mostly of autochthonous organics, lacks marine fossils such as hydrozoa or foraminifera, and occurs in gravels similar in texture to those presently being deposited on the Pasley River braidplain, we conclude that the Pasley River valley was above sealevel at the time of deposition. Furthermore, the excellent state of preservation of the fossils suggests that they represent *Dryas-Saxifraga*-willow communities on or adjacent to the active floodplain where the host gravels accumulated. The fact that such sites often trap allochthonous fossils carried during periods of high water explains the inclusion in the assemblage of aquatic fossils such as those of chironomid fly larvae and tadpole shrimp (*Lepiduris*) mandibles.

At least two of the taxa listed in Table III (*Betula glandulosa* and *Salix Dodgeana*) do not occur in the Pasley River area today. The present northern limit of shrub birches is several hundred kilometres to the south (Fig. 2c) (EDLUND, 1982, 1983). Although rare outliers may occur somewhat closer at favourable sites, it can be confidently assumed that shrub birches do not occur anywhere within tundra Zone 2. Thus even the rare occurrence of shrub birch fossils as far north as Pasley River implies a warmer summer climate than now. Otherwise the assemblage is quite typical of plant communities in the Queen Elizabeth Islands where mean July temperature is at least 3.5°C and soils are alkaline (S. Edlund, pers. comm., 1986). *Salix Dodgeana* is presently found on calcareous plateaux and scree-slopes in the Richardson and Mackenzie Mountains, west of the Mackenzie River (Fig. 2e) (PORSILD and CODY, 1980). Its occurrence at the Pasley River site is in accord with the alkaline requirements of other plants in the assemblage, but nevertheless represents a totally unexpected extension of its present range.

Insect fossils from sample 01 provide tentative support for the conclusion that climate was warmer. For example, the only genus of the saldid bugs (Saldidae) to occur as far north as the Queen Elizabeth Islands (and presumably northern Boothia) is *Chiloxanthus* (DANKS, 1981). The fossil listed in Table III, though not identified to genus, is not *Chiloxanthus*. As indicated earlier, leaf-beetles (Chrysomelidae) are probably absent on northern Boothia and the only weevil to be expected there is *Rhynchaenus arcticus*. Both leaf-beetles (*Chrysolina*) and another weevil (*Lepyrus*) occur in the assemblage and suggest warmer climate.

UNIT 4 (UPPER MARINE DELTAIC SAND)

This unit is a conspicuous, cliff-forming, tan-coloured fine sand to sandy silt which is exposed continuously in the upper part of both bluffs (Fig. 9). The unit is horizontally bedded throughout. In the North Bluff it is about 10 m thick and overlies the gravel of Unit 3 (Fig. 4). The contact with the underlying gravel is gradational ; the bottom 0.5 m of the sand contains rounded cobbles of the same type as those in the underlying gravel, and their abundance decreases upward until the sand is stone-free.

In the South Bluff the sand directly overlies the lower glacigenic assemblage and in Sections 1 and 5 sits on a stony layer described above as a dropstone layer. It is possible that this stony layer is, in fact, a lag marking the disconformity whose presence was speculated above. Insufficient attention was paid to this layer in the field.

The basal half of this unit in the South Bluff is thick bedded (*ca.* 20 cm) fine sand and coarse silt (Fig. 10) with thin fine silt interbeds. The coarser beds are mostly massive or planar laminated or more rarely climbing-ripple cross-laminated. In all exposures examined these sands were completely devoid of macrofossils.

The basal sands in the South Bluff are overlain by sands of identical colour and grain size, but different stratification. The higher sands almost everywhere display climbing-ripple cross-lamination or small-scale trough cross-lamination. It is this subfacies of the sand that continues across all of the North Bluff. In both bluffs this subfacies contains very fine grained detrital plant material, mostly moss and sedge pieces with rare tiny woody bits a few millimetres across and as much as five centimetres long. This detritus is concentrated in the lee side troughs of the climbing-ripple successions.

In Section 4 in the South Bluff, the climbing-ripple subfacies passes upward into thinner bedded horizontally laminated fine sand and silt couplets. In Section 1 the very top of the sand becomes coarser and includes a few stones. The top of the unit appears to have been deformed and intruded by clastic dykes (Fig. 11) and by a structure resembling a sand wedge or sandy ice wedge cast. Attempts to adequately expose these structures, however, led to extensive slumping.

Organics occur in the troughs of ripples throughout the upper part of Unit 4 at all sections. A large sample (5 L) of the organic sand was collected from equivalent positions at Sections 1 and 4 (Samples M3 and M6, Fig. 3). The richest assemblage of fossils comes from sample M6, but the con-

TABLE III

Plant and invertebrate (mainly arthropod) fossils from the mid-section fluvial gravels (Unit 3) at Section 2 (sample 01, Fig. 3)

PLANTS	
CYANOPHYTA	
Chroococcaceae	
Gloeocapsa or *Chroococcus* (1)	+
BRYOPHYTA	+ +
SPHENOPHYTA	
Equisetaceae	
Equisetum arvense L.	+ st
PTEROPHYTA	
Cyperaceae	
Carex aquatilis Wahlenb.	+ sd
Carex sp.	+ sd
Eriophorum Scheuchzeri Hoppe	+ sd
Kobresia sp.	+ sd
Juncaceae	
Luzula sp.	+ sd
Salicaceae (2)	
Salix arctica Pall.	+ cp,lf,bd
Salix Dodgeana Rydb.	+ lf,bd
Betulaceae	
**Betula glandulosa* type	+ sd
Polygonaceae	
Polygonum viviparum L.	+ sd
Caryophyllaceae	
Minuartia Rossii (R.Br.) House	+ sd
Stellaria sp.	+ sd
Melandrium sp.	+ sd
Cruciferae	
Draba type	+ sd
Parrya arctica R.Br.	+ sd
Saxifragaceae	
Saxifraga oppositifolia L.	+ + lf
Rosaceae	
Dryas integrifolia Vahl.	+ + lf
Potentilla sp.	+ sd

ANIMALS	
TURBELLARIA	+ cc
ARTHROPODA	
INSECTA	
HEMIPTERA	
Saldidae (excl. *Chiloxanthus*)	+ pr
COLEOPTERA	
Carabidae	
Pterostichus (Cryobius) arcticola Chaud.	+ pr
P. (Cryobius) tareumiut Ball	? pr
P. (Cryobius) pinquedineus Eschz.	+ pr
P. (Cryobius) sp.	+ el,pr,hd
Amara alpina Payk.	+ pr,el
Dytiscidae	
genus?	+ hd
Chrysomelidae	
**Chrysolina* sp.	? el
Curculionidae	
**Lepyrus* sp.	+ hd,pr
Rhynchaenus arcticus Kor.	+ el,hd
DIPTERA	
Tipulidae	
genus?	? lv
Chironomidae	
Chironomus type	+ lv(hd)
Family-muscoid type	+ hd
HYMENOPTERA	
Ichneumonoidea	+ hd
Cynipoidea	? hd
CRUSTACEA	
Notostraca	
Lepiduris sp.	+ md
ARACHNIDA	
Araneae	
Erigone sp.	+ cth

* indicates taxa not now or probably not now occurring on northern Boothia Peninsula. "?" means that identification is tentative.

ABBREVIATIONS: + = taxon present ; + + = taxon abundant ; sd = seed (fruit, samara, nutlet, achene etc) ; cp = capsule ; lf = leaf or leaf fragment ; st = stem fragment ; el = elytra ; pr = pronota ; hd = head ; md = mandible ; cc = cocoon ; lv = larval ; cth = cephalothorax.

(1.) Identified by E. Brodo, National Museum of Natural Sciences, Ottawa.

(2.) Identified by G. Argus, National Museum of Natural Sciences, Ottawa.

tent of sample M3 appears to be similar and for the purposes of this report fossils from both have been pooled (Table IV).

The table shows that the organics in the sands include a few hydrozoan thecae and foram tests, supporting the interpretation that Unit 4 represents a marine delta. The gradational nature of the Units 3/4 contact further suggests that there is no great time difference between Units 3 and 4. The nature of this transition and texture of the sediments suggests Unit 4 sediments were deposited during a period of cooling climate as sea level rose in response to crustal depression associated with an encroaching ice sheet. Consequently, one might except the organics from Unit 4 to portray a climate no warmer than that of the present. However, uncritical interpretation of Unit 4 plant fossils (Table IV) calls for a much warmer climate — warm enough in fact for conifers such as *Tsuga* in the Pasley River region. Clearly, one of these interpretation is wrong, and we suspect that it is the plant fossils which are providing the erroneous data. The key to this suspicion is the fact that Unit 4 organics include abundant amber. Because amber is present in Tertiary sediments from the Arctic Archipelago, it is a signal

FIGURE 9. Outcrop of upper marine deltaic sand near top of Section 1. Sands are horizontally bedded and predominantly ripple cross lamitated in this interval (GSC-203537-S).

Affleurement de sable deltaïque marin près de la partie supérieure de la coupe n° 1. Dans cet intervalle, les sables forment des strates horizontales et surtout des rides entrecroisées (cliché GSC-203537-S).

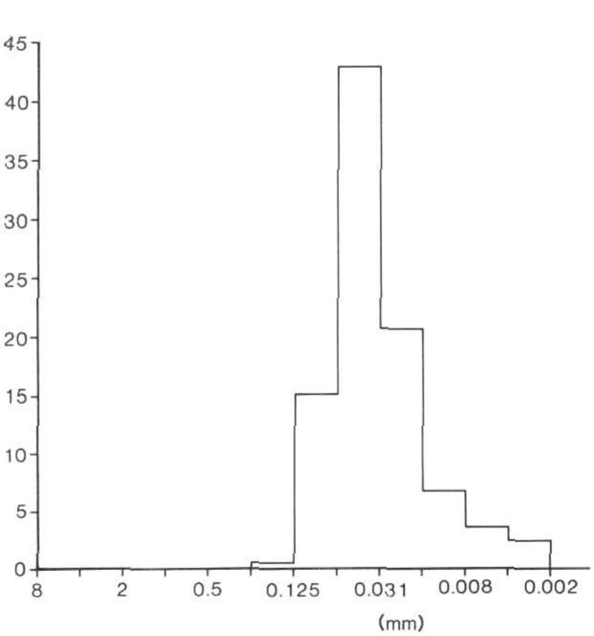

FIGURE 10. Grainsize histograms for sample M12 from the base of Unit 4, upper marine deltaic sand, in Section 1. Sample is from a 20 cm thick bed of massive sand between 3 cm thick silt beds.

Histogrammes de la granulométrie de l'échantillon M12 à la base de l'unité n° 4, soit le sable marin deltaïque supérieur de la coupe n° 1. L'échantillon provient d'une couche de sable massif de 20 cm d'épaisseur entre deux couches de 3 cm d'épaisseur.

that the Unit 4 assemblage may include rebedded Tertiary plant and insect macrofossils. Supporting this conclusion is that needles of spruce (*Picea*), larch (*Larix*) and hemlock (*Tsuga*) (see Table IV) are also known to occur in the Miocene Beaufort Formation on Banks Island (MATTHEWS *et al.*, 1986), and some other plants listed in Table IV, *e.g.*, *Hypericum* and *Selaginella ruprestris* (Fig. 12h, 12f) have

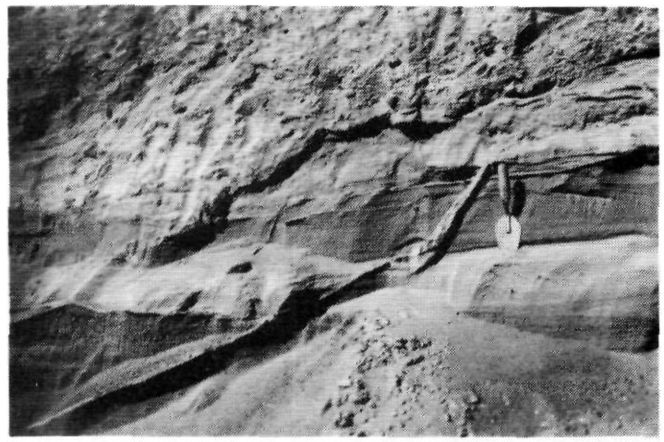

FIGURE 11. Clastic (sand) dykes in a minor gravelly coarse sand interval at top of Unit 4, Section 1, unconformably overlain by stony glaciomarine sediment of Unit 5. Wedge shaped sand bodies also intrude this coarse sand and are thought to represent either sand fillings of frost fissures or ice wedge casts. Interval could represent subaerially exposed topset beds later submerged (GSC-203537-Y).

Dykes clastiques (sable) dans une petite couche de sable grossier et gravelleux au sommet de l'unité n° 4 de la coupe n° 1, en discordance avec l'unité de sédiment glaciomarin caillouteux qui la recouvre. Les coins de sable qui pénètrent ce sable grossier sont probablement des remblais de fissures de gel ou de fentes en coin. Cette couche pourrait représenter les couches sommitales exposées en milieu-sub-aérien et submergées par la suite (cliché GSC-203537-Y).

present day distributions (*e.g.*, Fig. 2b) that parallel those of other plant taxa that occur commonly in the Beaufort Formation (HILLS, 1975 ; HILLS and MATTHEWS, 1974 ; MATTHEWS, 1987 ; MATTHEWS *et al.*, 1986). Such plants are too temperate in their distribution to have ever occurred in the Arctic Archipelago during the Pleistocene.

Some of the other plants from Unit 4 now grow to within a few hundred kilometres of Pasley River (Fig. 2c, d, f, g and h) and could probably grow there if climate were only slightly warmer. Only one of them, *Betula glandulosa*, also occurs in Unit 3. Nevertheless we suspect that some or all of these taxa may have grown in the Pasley River area during deposition of Unit 3 because all of the fossils from the Unit 4 sands are allochthonous, meaning that some could have been eroded from sediments of the underlying unit as shoreline transgressed the area. If so the explanation for their absence from organics in Unit 3 gravels is probably due to the different history of those organics compared to those in Unit 4. The Unit 3 organics are authochthonous and therefore portray only the vegetation on or near the floodplain of an arctic river. In contrast, unit 4 organics are allochthonous and thus, whatever their origin, represent a more complete sample of vegetation of the Pasley River region.

Even though it is highly probable that some of the fossils from Unit 4 probably represent the warmer climate during which the mid-section Unit 3 gravels accumulated, to use such evidence in reconstructing Unit 3 climate would entail a highly circular argument. All that can be said is that Unit 4 is comprised of a mixture of allochthonous organics, some

TABLE IV

Plant and invertebrate (mainly arthropod) fossils from the upper marine deltaic sands (Unit 4) at Sections 1 and 4 (samples M3, M6 Fig. 3)

PLANTS	
MYCOTA	
Fungal sclerotia	+
CHLOROPHYTA	
Characeae	
Chara/Nitella	+ og
BRYOPHYTA	+ + !
LYCOPHYTA	
Selaginellaceae	
**Selaginella ruprestris* (L.) Spring	+ mg
PTEROPHYTA	
Pinaceae	
***Tsuga* sp.	+ lf
***Larix* sp.	+ lf
***Picea* sp.	+ + lf,sd
Potamogetonaceae	
**Potamogeton filiformis* Pers.	+ sd
**Potamogeton pectinatus* L.	+ sd
Gramineae	
Genus?	+ sd!
Cyperaceae	
Carex aquatilis Wahlenb.	+ sd
Carex membranaceae Hook.	+ sd
Carex sp.	+ sd
**Eleocharis* sp.	? sd
Salicaceae	
Salix sp.	+ cp,lf
Betulaceae	
**Betula glandulosa* type	+ sd
Polygonaceae	
Rumex sp.	+ sd
Polygonum viviparum L.	+ sd
Caryophyllaceae	
Melandrium apetalum type	+ sd
Nymphaeaceae	
**Nuphar* sp.	? sd
Ranunculaceae	
Ranunculus sp.	+ sd
Ranunculus lapponicus L.	? sd
Ranunculus trichophyllus type	? sd
Cruciferae	
Draba type	+ sd
Saxifragaceae	
Saxifraga oppositifolia L.	+ + lf
Rosaceae	
Dryas integrifolia Vahl.	+ lf
Potentilla sp.	+ sd
Callitrichaceae	
**Callitriche* sp.	+ sd
Hypericaceae	
***Hypericum* sp.	+ sd
Haloragaceae	
Hippuris sp.	+ + sd
Cornaceae	
**Cornus* sp.	+ sd
Ericaceae	
**Empetrum* sp.	? sd
Gentianaceae	
**Menyanthes trifoliata* L.	+ sd
Compositae	
Taraxicum sp.	+ sd

ANIMALS	
COELENTERATA	
Hydrozoa	+ th
BRYOZOA	
Cristatella mucedo L.	+ st
Fredericella type	+ st
ARTHROPODA	
INSECTA	
COLEOPTERA	
Carabidae	
Pterostichus (Cryobius) arcticola Chaud.	+ pn,el
**Pterostichus (Cryobius) pinguedineus* Eschz.	? pn
Pterostichus (Cryobius) sp.	+ pn,el
Amara (Curtonotus) sp.	+ el
Dytiscidae	
Hydroporus sp.	+ ab
Staphylinidae	
Micralymma sp.	+ pn
Curculionidae	
Rhynchaenus arcticus Kor.	+ el
**Lepidophorus lineaticollis* Kby.	+ el
**Notaris* sp.	+ el
TRICHOPTERA	
Family?	+ lv,hd
DIPTERA	
Tipulidae	
Genus?	+ hd,ov
Chironomidae	
Pseudodiamesa type	+ lv
Corynocera sp.	+ lv
CRUSTACEA	
Cladocera	
Daphnia sp.	+ eh
Notostraca	
Lepiduris sp.	+ md
Ostracoda	
Genus	+
ARACHNIDA	
Araneae	
Erigone sp.	+ cth

* Indicates taxa not now or probably not now occurring on northern Boothia Peninsula.

** Indicates taxa suspected to be of Tertiary age. "?" Means that identification is tentative.

ABBREVIATIONS : + = taxon present ; + + = taxon abundant ; ! = well preserved ; sd = seed (fruit, nutlet, samara, achene etc) ; mg = megaspore ; cp = capsule ; lf = leaf or leaf fragment ; ts = test ; th = thecae ; st = statoblast ; el = elytra ; pr = pronota ; hd = head ; ab = abdominal fragment ; lv = larval ; cth = cephalothorax ; ov = oviposíter ; og = oogonia.

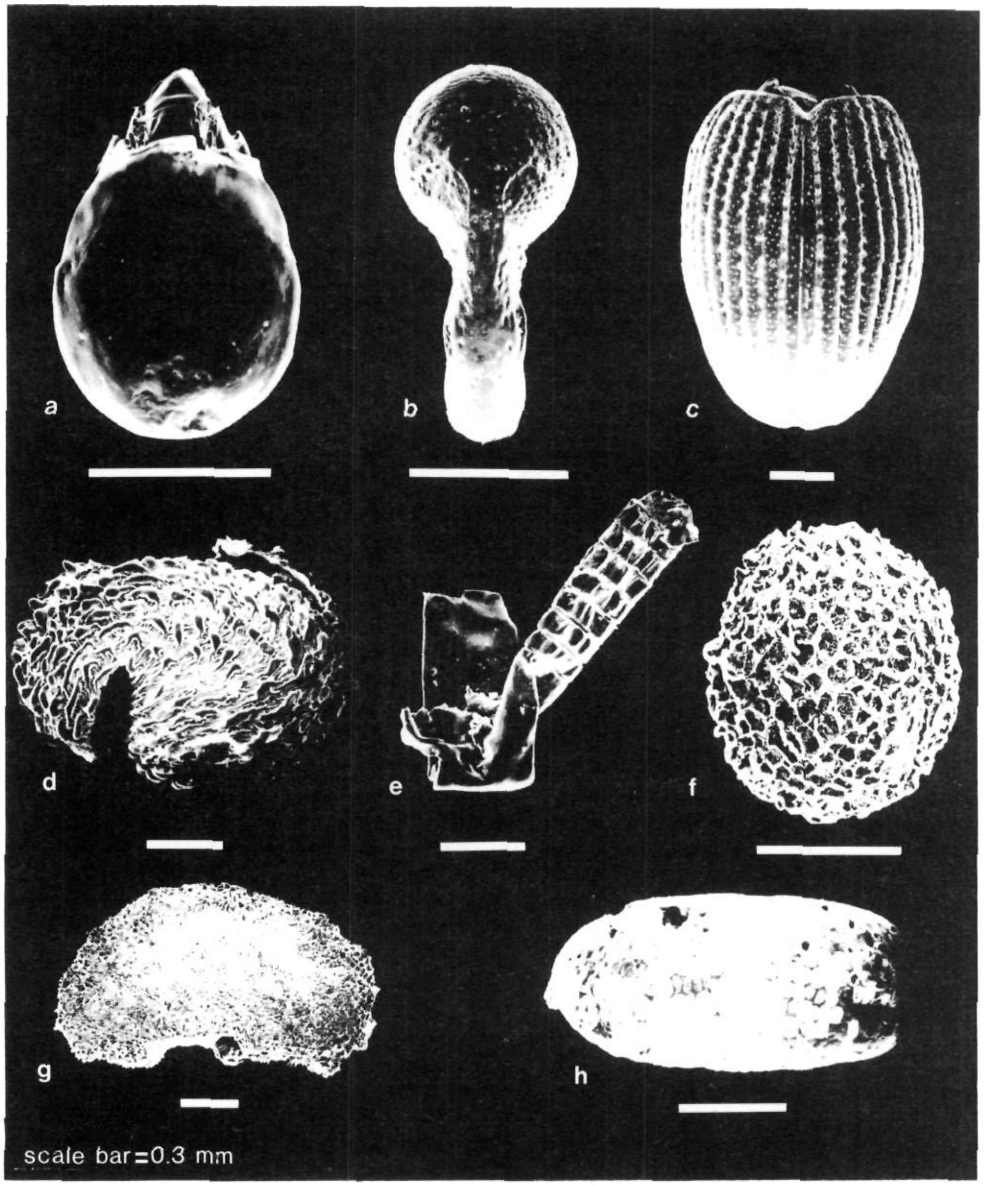

FIGURE 12. Selected plant and animal macrofossils from the Pasley River sections. a) Oribatid mite (*lugoribates gracilis* Sellnick) (GSC-85091), dorsal view, from sample 02, Section 2 ; b) head, *Rhynchaenus arcticus* Kor. (GSC-85089) from Sample 01, Section 2 ; c) fused elytra of *Rhynchaenus arcticus* Kor. (GSC-85090) from sample 01. Section 2 ; d) "seed" of *Minuartia Rossii* (R.Br.) House (GSC-85093), from Sample 01, Section 2 ; e) *Hydrozoan* thecal fragment (GSC-85088), from Sample M6, Section 4 ; megaspore of *Selaginella rupestris* (L.) Spring (GSC-85092), abaxial face, from Sample M6, Section 4 ; g) "seed" of *Callitriche* (GSC-85095), from Sample M6, Section 4 ; h) "seed" of *Hypericum* sp. (GSC-85094), from Sample M3, Section 1.

Quelques macrorestes de plantes et d'animaux des coupes de la rivière Pasley. a) Mite (lugoribates gracilis *Sellnick) (GSC-85091), vue dorsale, échantillon 02, coupe n° 2 ; b) tête de* Rhynchaenus arcticus *Kor. (GSC-85089), échantillon 01, coupe n° 2 ; c) élytre fusionné de* Rhynchaenus arcticus *Kor. (GSC-85090), échantillon 01, coupe n° 2 ; d) « graine » de* Minuartia Rossii *(R.Br.) House (GSC-85093), échantillon 01, coupe n° 2 ; e) fragment de thèque d'hydrozoaire (GSC-85088), échantillon M6, coupe n° 4 ; f) mégaspore de* Selaginella rupestris (L.) *Spring (GSC-85092), vue de face (axe ab), échantillon M6, coupe n° 4 ; g) « graine » de* Callitriche *(GSC-85095), échantillon M6, coupe n° 4 ; h) « graine » de* Hypericum *sp. (GSC-85094), échantillon M3, coupe n° 1.*

of which are obviously of Tertiary age, others representing taxa that now live slightly south of Pasley River, and some such as *Saxifraga oppositifolia* and *Polygonum viviparum* that are typical of the region today.

Among the insect fossils listed in Table IV, those of the weevils *Lepidophorus lineaticollis* and *Notaris* and possibly the chironomid fly *Corynocera* indicate warmer than present climate. Unlike the plant fossils, none of the arthropod remains are obvious Tertiary contaminants.

The sediment of Unit 4 is nearly identical to that of Unit 1 in colour, texture, stratification, and even in size and distribution of organic detritus, and like it is interpreted as an estuarine deltaic deposit. This would explain the transition from massive to planar laminated lower sands (deeper water, sedimentation from suspension) to climbing-ripple laminated sands (shallow water, sedimentation from suspension under the influence of a tractive current) in Sections 1 and 4. This was a large delta which probably spread across the entire valley and was several kilometres long. The conformable contact with the fluvial gravels in the North Bluff (Unit 3) indicates that the delta was deposited during a transgression, by the end of which relative sea level must have stood more than 100 m above present sea level. The gravelly coarse sand interval with clastic dykes and possible frost crack fillings could represent topset beds that had been subaerially exposed and later submerged. The upward fining and thinning of beds recorded near the top of the unit in Section 4 probably represents a transition from deltaic to deeper water (prodelta) sedimentation.

As with Unit 1, this large amount of relative sealevel rise could only have been caused by crustal depression in front of an advancing ice sheet. Therefore, sedimentation probably occurred near the end, locally, of the nonglacial interval whose earlier part is recorded by Unit 3.

UNIT 5 (UPPER GLACIGENIC ASSEMBLAGE)

Unit 5 comprises the upper glacigenic assemblage and consists of two facies, a non sorted, non stratified stony diamicton and a sorted, stratified stony diamicton. The former occurs at the top of all sections shown in Figure 3, although in places along the top of the bluffs it is absent and either the stratified diamicton facies or the sand of Unit 4 outcrops at the surface.

The non stratified diamicton is essentially identical to the non stratified diamicton of the lower glacigenic assemblage (Unit 2) and, like it, is interpreted as a till. The deposit has 30-60 per cent clasts by volume (top half, Fig. 13), almost all of which are derived from Paleozoic carbonates and are heavily striated. The matrix is non sorted, slightly fine skewed and silty (Fig. 14 ; sand/silt/clay ratios for two samples of 25/48/27 and 32/48/20). In the North Bluff and parts of the South Bluff the till sits directly and unconformably upon the sands of Unit 4. In Sections 2 and 3 the top of Unit 4 is disturbed and sands are tightly folded into the base of the till (Fig. 15) with the direction of folding indicating eastward ice movement.

The stratified diamicton facies underlies the surface till in Sections 1 and 4. This facies has a highly variable stone content and variable bedding. In Section 1, the bottom 30 cm of this facies has a 30-40 per cent stone content, whereas above that the stone content is only about 10 per cent. Just above the stony basal bed (30 cm thick) the beds are 10 cm thick, mostly planar laminated fine sandy silt ; the middle of the facies has 4 cm thick silt beds, with planar to wavy laminae and two beds which exhibit convolute lamination (Fig. 16) ; the upper 0.5 m of the facies is very thinly bedded (1 mm beds) and has a laterally variable stone content (Figs. 13, 17). The basal 2 m of the facies in Section 4 is very stony and poorly stratified, whereas the upper part is thinly bedded and much less stony. Clasts in this sediment are commonly heavily striated and laminae are deformed beneath and drape over them (Fig. 18). A sample of the lower thickly bedded material in Section 1 shows a coarse-skewed, moderately sorted coarse silt (Fig. 19 sand/silt/clay ratio : 24/64/12). The degree of sorting is likely underestimated in this sample because material was collected from several laminae of sand and silt.

This facies is interpreted as a proximal glaciomarine sediment, similar to that described from the lower glacigenic assemblage. No fossils are present to confirm a marine (versus lacustrine) origin, but this seems the simplest interpretation if the underlying deltaic sand, the top of which indicates deepening water conditions, is marine. The clast/matrix relationship is typical of dropstones (Figs. 17, 18), and the wavy and convolute lamination (Fig. 16) indicates rapid deposition accompanied by soft sediment deformation. Sea level during deposition of this facies must have stood sufficiently above the present section tops to float an ice shelf or icebergs. The most remarkable difference be-

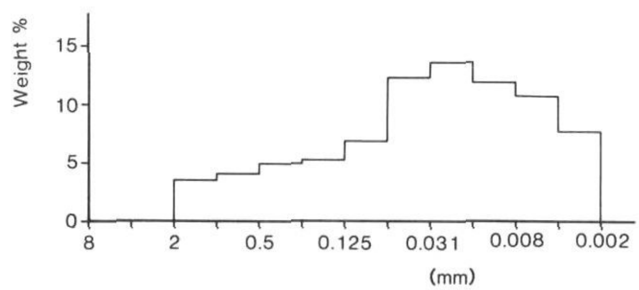

FIGURE 14. Grainsize histogram for sample T4 from till of Unit 5 at top of Section 3.

Histogramme de la granulométrie de l'échantillon T4 provenant du till de l'unité n° 5, au sommet de la coupe n° 3.

FIGURE 13. Upward thinning rhythmically bedded glaciomarine sediment at top of Section 1 overlain by 0.5 m of till, both facies of Unit 5 ; freshly cleaned damp face (*cf.* Fig. 17) (GSC-203537-U).

Rhythmites de sédiments glaciomarins s'amincissant vers le haut dans la partie supérieure de la coupe n° 1 et recouvertes par 0,5 m de till ; les deux faciès appartiennent à l'unité n° 5. La surface humide de la coupe a été nettoyée récemment (voir la fig. 17) (cliché GSC-203537-U).

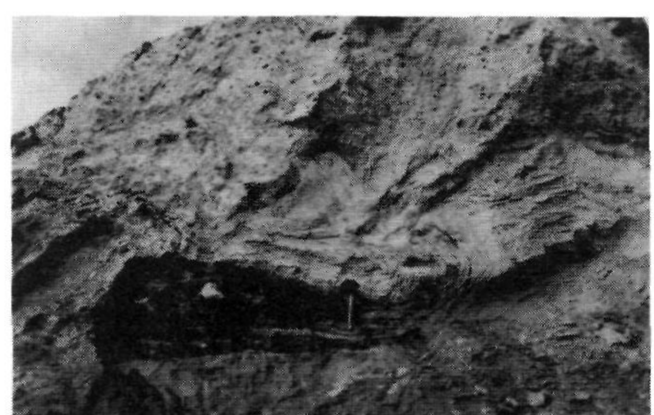

FIGURE 15. Sands of Unit 4 folded into base of till of Unit 5 near top of Section 3. Large boulder to right of shovel occupies the nose of the fold ; thin stringers of sand have been sheared into the till at and below the shovel handle (GSC-203537-R).

Sables de l'unité n° 4 plissés à la base de l'unité n° 5 près du sommet de la coupe n° 3. Le gros bloc à droite de la pelle est dans la partie saillante du pli ; de minces couches de sable ont été incorporés au till au niveau de la poignée de la pelle et en dessous (cliché GSC-203537-R).

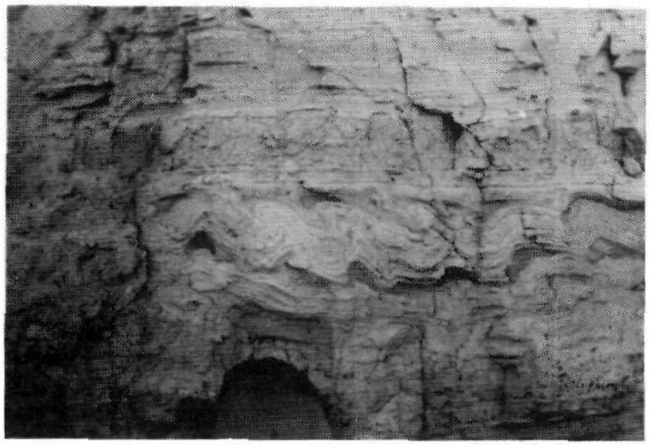

FIGURE 16. Convolute lamination in the middle zone of the stratified glaciomarine diamicton facies of Unit 5 at top of Section 1 ; note abundant dropstones. Trowel blade is about 8 cm wide (GSC-203537-W).

Lamination contournée dans la partie médiane du faciès de diamicton glaciomarin stratifié de l'unité n° 5 au sommet de la coupe n° 1. À noter les nombreux cailloux délestés. La lame de la truelle fait environ 8 cm de largeur (cliché GSC-203537-W).

FIGURE 18. Details of clast/matrix relationship in glaciomarine sediment of Unit 5. Note deformation of laminae below and adjacent to clast and draping of sediment over clast ; clast is about 15 cm diameter (GSC-203537-T).

Détails structuraux de l'agencement entre un fragment de roche et la matrice des sédiments glaciomarins de l'unité n° 5. À noter les déformations des lamines situées en dessous et tout près du fragment ainsi que des couches le recouvrant. Le fragment a un diamètre d'environ 15 cm (cliché GSC-203537-T).

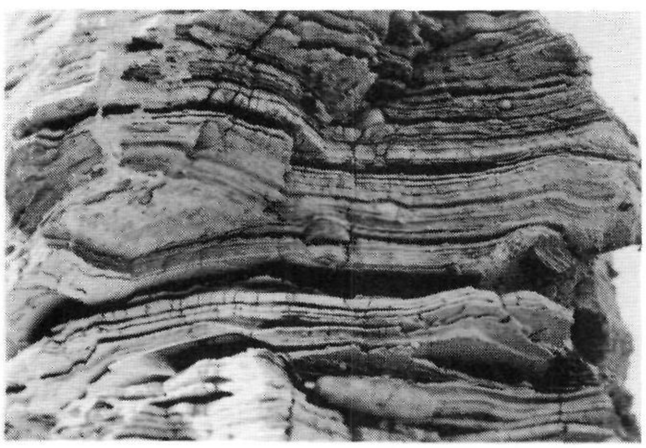

FIGURE 17. Thinly bedded glaciomarine silts with abundant dropstones, Unit 5, Section 1 ; dry wind eroded face (*cf.* Fig. 13). Trowel handle is about 19 cm long (GSC-203537-X).

Minces couches de silt glaciomarin contenant de nombreux cailloux délestés, unité n° 5, coupe n° 1. La surface est sèche et érodée par le vent (voir fig. 13). Le manche de la truelle fait environ 10 cm de longueur (cliché GSC-203537-X).

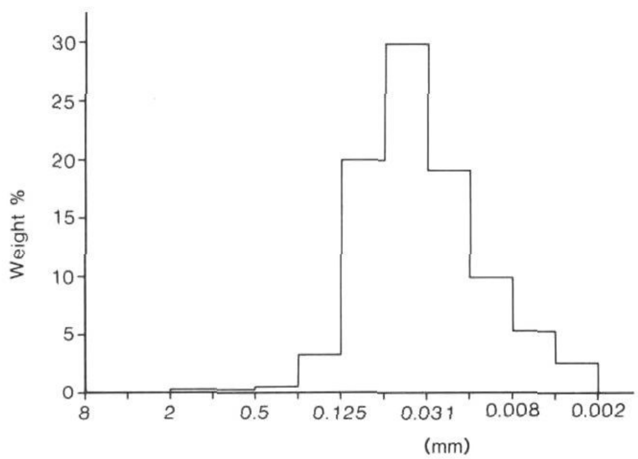

FIGURE 19. Grainsize histogram for sample GM2 from stratified glaciomarine diamicton of Unit 5, Section 1. Sample is from a 10 cm thick bed from the base of an upward thinning sequence which rests on a very stony basal bed.

Histogramme de la granulométrie de l'échantillon GM2 du diamicton glaciomarin stratifié de l'unité n° 5, coupe n° 1. L'échantillon provient d'une couche de 10 cm d'épaisseur à la base d'une séquence d'épaisseur décroissante vers le haut et qui repose sur un lit rocheux.

tween the upper and lower glacigenic assemblages is the abundance of both marine and terrestrial fossils in the lower and the complete absence of both in the upper. It seems that the second ice advance occurred in a much more barren environment.

CHRONOLOGY

The chronological control presently available is provided by four radiocarbon dates and a series of amino acid analyses.

Radiocarbon dates have been obtained on the detrital plant material from the upper marine deltaic sand and on the plant mats from the mid-section fluvial gravel. In addition, a nearby postglacial marine limit delta has been radiocarbon dated providing a good fix on time of local deglaciation (Table V). The dates show that the glacier that deposited the upper till retreated from the area about 8800 years ago and that deposition of the mid-section fluvial gravel (Unit 3) terminated more than 55 000 years ago. It follows that the last glacial advance, which caused the marine transgression (crustal depression) recorded by the upper

TABLE V

Radiocarbon dates from the Pasley River Section and a nearby marine limit (postglacial) delta

Laboratory No.	Date, Uncorrected	Comment
GSC-2927	8820 ± 80 (8790 ± 80)	From marine limit delta near Pasley River
GSC-3508	>37 000	From Upper Marine Deltaic Sands
GSC-3510	>37 000	From Mid-Section Fluvial Gravels
QL-1767	>55 000	Same sample as GSC-3510
GSC-2207	>33 000	From top of or just above Lower Glacigenic Assemblage ; Collected by J.A. Netterville for A.N. Boydell, 1974 ; exact position relative to sections described here unknown but somewhere within South Bluff

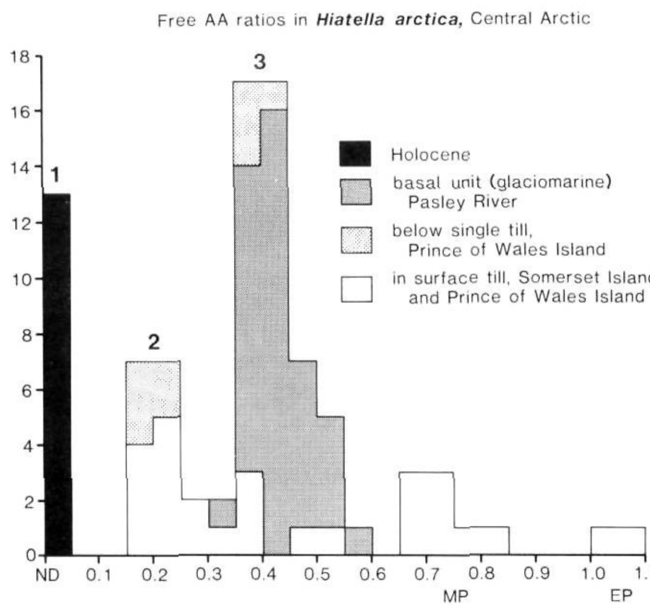

FIGURE 20. Histogram of alloisoleucine to isoleucine ratios in the free fraction in marine shells from the Central Arctic (Table VI). Ratios close to unity probably represent Early Pleistocene ages (EP) and ratios of 0.7 to 0.8 probably represent Middle Pleistocene ages (MP). Group 1 is of Holocene age and Groups 2 and 3 are possibly Sangamonian and Illinoian, respectively.

Histogramme des rapports d'alloïsoleucine à l'isoleucine dans la fraction libre de coquillages marins de l'Arctique central (tabl. VI). Les rapports qui s'approchent de 1 représentent probablement des âges du Pléistocène moyen (MP). Le groupe 1 est d'âge holocène et les groupes 2 et 3 sont probablement sangamonien et illinoien, respectivement.

marine deltaic sand (Unit 4) also occurred more than 55 000 years ago because there is no apparent hiatus between deposition of the upper part of the gravel and the lower part of the sand. Therefore, the upper glacigenic assemblage, and in particular the upper till, represents all of Late and likely all of Middle Wisconsinan time. At present, the most straightforward interpretation of the sequence is that the mid-section fluvial gravel is of Sangamon Interglaciation age and that it separates Illinoian and Wisconsinan glacial sediments. The alternative permitted by the radiocarbon dates is that the gravel records an Early Wisconsinan interstade of sufficient duration or degree of warming to cause northward movement of plants that normally fail to grow north of Keewatin. Such an interval has been recorded in the Yukon and Alaska (SCHWEGER and MATTHEWS, 1985). To invoke such an explanation in this case would imply complete demise of the Keewatin Sector of the Laurentide Ice Sheet, a conclusion that is considerably more monumentous than can be supported by the evidence from Pasley River.

Amino acid ratios, specifically the ratio of alloisoleucine to isoleucine, were measured in several shell samples from Pasley River (Table VI). Unfortunately, shells were recovered only from the lower glacigenic assemblage. It is instructive, however, to compare these ratios with ratios from other shells from Boothia Peninsula, Somerset Island, and Prince of Wales Island (Table VI and Fig. 20).

Shells from five samples (S1, S2, S4, S7, M2) collected in 1982 from the lower glacigenic assemblage (Unit 2) have been analyzed. As well, a single sample collected in 1979 (79 DCA PR12) and a recollection from the same bed (82 DCA S8) of glaciomarine sediment exposed near the base of a bluff north of the main sections (see Introduction), and now considered a facies of the lower glacigenic assemblage, have been analysed. A sample collected from the main bluffs (74 BNA 118, exact location unknown), undoubtedly from a glaciomarine bed of the lower glacigenic assemblage, by Boydell's party in 1974 also has been analysed. These samples came from below, within, and above the main "till" beds of the lower glacigenic assemblage but are statistically indistinguishable in either the free or total fractions.

Ratios within the free fraction are tightly clustered about a peak at 0.425 but range from 0.34 to 0.57 (range of 0.23, Fig. 20). Because samples came from both low and high in the assemblage, this range could represent the duration of deposition of the unit. However, nearly half of that range occurs within a subsample of paired valves from a single thin bed (82 DCA M2, Table VI) so the total range may be more a measure of the resolution of the technique than of a time interval. Nevertheless, samples from lower in the succession (84 DCA S1, S4) plot on the higher side of the distribution, and samples from higher in the succession (84 DCA S2, M2, S7) plot on the lower side.

Ratios within the total fraction are also fairly tightly clustered but the distribution is bimodal or perhaps polymodal. Measurements range from 0.085 to 0.128 (range of 0.043) and within sample 83 DCA M2 there is a range of 0.036, 84 per cent of the total range. Within the total ratios, unlike the free, there is no tendency for samples from low in

TABLE VI

Central Arctic amino acid ratios (allo/isoleucine) in shells, mainly Hiatella arctica

Field Sample No.	Lab. No.	Free	Total	Prep. Type	Group Fig. 20	Comments
			SOMERSET ISLAND			
75 NJ 142	AA1-162	N.D	0.020	B	1	9310 ± 90 BP (GSC-2272)
		N.D.	0.018			
77 DCA S13	AAL-411	N.D.	0.031	B	1	9270 ± 90 BP (GSC-2596)
		N.D.	0.040			
75 NJ 97 a(I)	AAL-367	N.D.	0.019	B	1	From beach at 104 m
75 NJ 97 a(II)	AAL-366	N.D.	0.033	B	1	From beach at 104 m
		N.D.	0.043			
75 NJ 251 b	AAL-1051	0.354	0.0420	B	1	From till surface at 389 m
		0.232	0.0296		2	
		0.173	—		2	
75 NJ 254	AAL-1049	0.272	0.075	B	—	From till surface at 214 m
		0.188	0.024		2	
		0.362	—		3	
77 DCA S11	AAL-410	0.13	0.048	B		From beach of 145 m
		0.17	0.050		2	
77 DCA S1	AAL-537	0.21	0.10	B	2	From till surface at 365 m
		0.36	0.066		3	
		0.32	0.047			
75 NJ 170	AAI-1050	0.724	0.0834	B		From till surface at 226 m
		0.699	0.0927			
		0.675	0.0710			
75 NJ 136	AAL-161	0.53	0.080	B	3	From till surface at 217 m
75 NJ 178	AAL-1052	0.815	0.182	B		From till surface at 254 m
		0.723	0.120			
		0.721	0.106			
75 NJ 171b	AAL-364	—	0.33	B		From till surface at 184 m
		—	0.20			
		—	0.23			
			PASLEY RIVER			
82 DCA S4	AAAL-3133	0.48	0.099	A	3	All from Unit 2
		0.42	0.085		3	except 82 DCA S10
		0.48	0.108		3	
82 DCA S2	AAL-3134	0.42	0.096	A	3	
		0.48	0.114		3	
		0.40	0.091		3	
82 DCA M2 A	AAL-3135	0.42	0.121	A	3	
		0.44	0.115		3	
		0.44	0.090		3	
		0.42	0.102		3	
		0.42	0.121		3	
		0.43	0.110		3	
82 DCA M2 B	AAL-3136	0.38	0.101	A	3	
		0.37	0.095		3	
		0.38	0.090		3	
		0.34	0.086		3	
		0.37	0.100		3	
		0.36	0.093		3	
82 DCA M2 C	AAL-3129	0.43	0.122	A	3	
		0.38	0.100		3	
		0.40	0.097		3	
		0.40	0.106		3	
82 DCA S1	AAL-3137	0.45	0.111	A	3	
		0.57	0.097		3	
		0.53	0.089		3	

Field Sample No.	Lab. No.	Free	Total	Prep. Type	Group Fig. 20	Comments
82 DCA S8	AAL-3131	0.51	0.121	A	3	
		0.42	0.128		3	
		0.55	0.121		3	
82 DCA S7	AAL-3132	0.40	0.085	A	3	
		0.49	0.087		3	
		0.41	0.093		3	
82 DCA S10	AA1-3130	N.D.	0.027	A	1	From Holocene marine
		N.D.	0.025		1	sediments overlying till of Unit 5
		N.D.	0.015		1	1 km from sections.
74 BNA 118	AAL-22	0.36	0.122	B	3	
79 DCA PR12	AAL-1217	0.43	0.067	B	3	
		0.44	0.076		3	
		0.48	0.086		3	
		0.53	0.100		3	
		0.42	0.070		3	
		0.42	0.070		3	
		0.47	0.086		3	
			BOOTHIA PENINSULA			
79 DCA S11	AAL-1216	0.70	0.27	B		From core of Late Wisconsinan
		0.78	0.41			end moraine
79 DCA S15	AAL-1504	0.78	0.22	C		From delta overlain by till
		0.83	0.19			
		0.94	0.24			
79 DCA S8	AAL-1215	0.50	0.718	B	3	From till surface just
		1.07	0.913			below Holocene marine limit.
		1.01	0.940			
79 DCA S8	AAL-1642	N.D.	0.021	B	1	
		N.D.	0.020		1	
		N.D.	0.025		1	
			PRINCE OF WALES ISLAND			
84 DCA 8S[3]	AAL-4305	0.40	0.106	A	3	From gravel below till
		0.39	0.126		3	
		0.41	0.117		3	
84 DCA 26S[3]	AAL-4306	0.16	0.044	A	2	From gravel below till
		0.20	0.048		2	
		0.20	0.042		2	
84 DCA 805B	AAL-4304	0.24	0.076	A	2	From till surface at 150 m
		0.27	0.056		2	
		0.24	0.063		2	
84 DCA 856	AAL-4302	0.24	0.050	A	2	From gravel below till
		0.25	0.048		2	and marine sediment
		0.37	0.097		3	
84 DCA 896	AAL-4203	0.17	0.048	A	2	Redeposited in Late
		0.17	0.050		2	Wisconsinan glaciolacustrine
		0.24	0.053		2	sand

1. 79 DCA S11 utilized *Mya truncata* valves which racemize at a rate similar to *Hiatella*. All other valves, other than 79 DCA S15, were of *Hiatella arctica*.

2. *Astarte borealis*.

3. Samples collected by Tom Morris, University of Alberta.

the succession to plot on the higher side of the distribution ; rather they are randomly distributed within the cluster.

Based only on the ratios from the Pasley River sections, it is not possible to suggest an age for the lower glacigenic assemblage. The similarity of ratios from low and high in the assemblage, however, does seem to rule out the possibility that the minor sand beds rich in plant detritus within the assemblage are interglacial deposits and this supports the interpretation of these beds as glaciomarine deposits (see above).

All amino acid ratios measured to date by the University of Colorado laboratory (AAL) on samples of *Hiatella arctica* and *Mya truncata* from the Central Arctic are presented in Table VI and Figure 20. These samples were analysed using two different preparation techniques which substantially affect the measurements of the "total" ratios but not the "free" ratios (MILLER, 1985).

Other than the Pasley River samples already discussed, shells from three other stratigraphic contexts have been analysed. Shells from known early Holocene marine sediments, in some cases radiocarbon dated, have been run to provide values on samples of known age ; erratic shells from the fossiliferous surface till on Somerset Island and Prince of Wales Island have been run in an attempt to provide some control on the timing of the last ice advance ; and redeposited shells from low elevation fluvial gravels below a single till at three sites on Prince of Wales Island have been run to provide data on timing of the last ice advance and rank (interglacial/interstadial) of the buried gravels.

The histogram of free amino acid ratios (Fig. 20) shows several groups of shells : (1) Holocene samples are clearly differentiated from older samples. (2) A wide range of ages of erratic shells are present in the surface till of Somerset and Prince of Wales islands, but the most abundant appear to be the youngest (DYKE, 1983). The youngest shells in the surface till, which correlates with the till at the top of the Pasley River sections (Unit 5, above), have distinctly lower ratios than the shells from the lower glacigenic assemblage at Pasley River. The oldest shells in the surface till have ratios approaching equilibrium values of unity and may be Early Pleistocene in age or older. The group of shells from the surface till with ratios intermediate between the oldest and those from Pasley River are also highly racemized and could be of Middle Pleistocene age or older. (3) The shells from gravels below till on Prince of Wales Island yielded two sets of values, one corresponding to the shells from the lower glacigenic unit at Pasley River and one corresponding to the youngest group of erratic shells in the surface till. Surprisingly, shells from two neighbouring and similar sections along Fisher River on southern Prince of Wales Island fall in the two groups, rather than in a single group as expected, and a single sample from a section near Back Bay, northern Prince of Wales Island, also contained shells that plot in both groups (84 DCA 856). Because the shells have been redeposited in the gravels this does not mean that two ages of gravel can be identified.

Because amino acid racemization is a highly temperature-dependent and leaching-dependent process and especially because shells were not found above the mid-section fluvial gravel at Pasley River, a single exclusive interpretation of these data is not yet possible. However, the most likely interpretations are : (1) The peaks labelled 2 and 3 on Figure 20 represent two major events of widely separate age ; or (2) all shells in groups 2 and 3 date from a single interval and have since experienced different temperature or leaching conditions.

Using the second alternative, all shells in the two groups could be of Sangamonian or Early Wisconsinan age, for example, but have existed under warm-based Wisconsinan ice (group 3) and under cold-based Wisconsinan ice (group 2) in different parts of the region. However, the presence of shells of both groups in a single sample (84 DCA 856), and the unlikelihood that a single occurrence of such fossils would fortuitously include individuals brought together from sites with vastly different thermal histories, seems to favour the interpretation that the two groups represent two different ages.

Accepting that groups 2 and 3 represent different ages, it seems likely that group 2, not found at Pasley River, represents the Sangamon, simply because some of the shells come from low elevation fluvial gravels which requires that relative sea level had fallen to present interglacial levels or perhaps lower. That is not an entirely safe assumption, however, because sea level fell to present levels during the postglacial in only 10 000 years or so, and hence, group 2 could date from a Wisconsinan interstade. In either case, it is likely that the low level, subtill gravels on Prince of Wales Island from which the shells came correlate with the mid-section fluvial gravels (Unit 3) at Pasley River, and hence are more than 55 000 years old.

Given the poor constraints on a choice between alternative interpretations, it is possible that group 3 could date from anywhere between the beginning of the last (Wisconsinan) glaciation to the beginning of the penultimate glaciation. It is unlikely that they correlate with a full interglaciation because all the samples from Pasley River came from glaciomarine sediments 60-70 m above present sealevel, indicating ice proximal environments and a considerable duration is isostatic loading. Whether group 3 dates from early or late in a glacial cycle is difficult to say. The presence of abundant plant detritus in the glaciomarine sediments of the lower glacigenic assemblage suggests glaciers advancing across vegetated tundra. On the other hand, *in situ* shell samples such as 82 DCA S2, M2 and S7 came from beds at the top of the lower sequence indicating a deglacial hemicycle. Because the shells are *in situ* and the plant fossils are detrital, the weight of evidence favours the deglacial interpretation.

CONCLUSION AND DISCUSSION

The lithostratigraphy of Quaternary sediments exposed along Pasley River, the first important Quaternary stratigraphic succession to be described from the entire Central Arctic, is straightforward and most major units or assemblages of facies can be readily distinguished, identified genetically, and correlated between the two major exposures. A mid-section fluvial gravel in the North Bluff represents a significant interval when the site was emerged and climate was as warm as present and perhaps warmer. The gravel separates a lower succession—marine deltaic sand overlain by complexly interbedded tills and proximal and distal glaciomarine sediments — from a similar upper succession—marine deltaic sands overlain by proximal glaciomarine sediment and till. It is likely that some of the fossils in the sediments of this upper succession are derived from the mid-section gravels, but it is difficult to specify which ones.

Lower and upper marine deltaic assemblages record marine transgressions to 70 and 100 m above present prior to arrival of ice at the site, and hence demonstrate that the process of glacial buildup was sufficiently slow to cause a large amount of crustal depression peripheral to the ice sheet. This amount of crustal depression is comparable to the depression attained at the ice sheet limit in central and eastern Arctic Canada during the last glacial maximum, a value which supposedly reflects equilibrium marginal depression attained over an interval substantially longer than 10 000 years.

Amongst several possible interpretations of the ages of the sediments, the one that best accommodates the fossils, physical stratigraphy and dating is that the mid-section fluvial gravels (Unit 3) record the Sangamon Interglaciation (>75 000 ka) and separate Illinoian and Wisconsinan glacial assemblages. If the mid-section fluvial gravels are of Sangamonian age, then the upper till records a continuous Wisconsinan ice cover over the site. At the minimum, the upper till records continuous ice cover during all of Late and most of Middle Wisconsinan time.

The Pasley River site joins several other arctic localities that have yielded a fossil fauna and/or flora which includes taxa now occurring only farther south (BLAKE, 1974, 1982 ; BLAKE and MATTHEWS, 1979 ; HODGSON, 1985 ; TERASMAE *et al.*, 1966 ; VINCENT *et al.*, 1983 ; MATTHEWS *et al.*, 1986). At least one of these, from Cañon Fiord on Ellesmere Island is suspected of being of Holocene age (HODGSON, 1985). Most of the others are older than the limit of the ^{14}C method. In such cases it has been common practice to assume that the fossils represent the last interglacial. We feel that this practice is ill-advised unless supported, as it is here, by ancillary stratigraphic and dating data. It is instructive to note that Unit 4 might have been assigned to the early Quaternary or Tertiary on the basis of its fossils were it not for conflicting stratigraphic and amino-acid evidence.

The Unit 4 assemblage shows how rebedded fossils can cloud paleoclimatic interpretation, a particularly serious problem in the Arctic where the yield of rebedded fossils from Tertiary sediments, such as the of the Beaufort Formation, can easily swamp the indigenous fossils in an interglacial unit. An example of this problem occurs at Duck Hawk Bluffs on Banks Island (MATTHEWS *et al.*, 1986), but there the source of the "old" fossils is obvious because the Quaternary sediments are underlain by richly fossiliferous sediments of the Beaufort Formation and Worth Point Formation. At Pasley River the source of the putative Tertiary plant fossils is obscure. Fossiliferous Tertiary deposits have not been mapped in the area. Nevertheless, we suspect an outcrop may exist, and judging from the excellent preservation of the amber (*i.e.*, too well preserved to have undergone fluvial transport), we further suggest that the outcrop, if it still exists, will be found below the Holocene marine limit.

This paper should not and probably will not be the last one on the important Pasley River exposure. Moss fossils are spectacularly preserved in some of the units and merit study at the earliest opportunity. Larger samples from Unit 4 would also help to show if the Beaufort Formation really is the source of rebedded "old" plant fossils. The discovery of the source of such fossils, or barring that, recovery of more rebedded fossils from Unit 4, will aid considerably in the study of the pre-glacial boreal environment of northern North America.

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