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LATE QUATERNARY STRATIGRAPHY AND DEPOSITIONAL HISTORY OF THE PARRY PENINSULA-PERRY RIVER AREA, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

Daniel E. Kerr

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Late Holocene Franklin Sea sediments, consisting of sublittoral and intertidal silty sand rhythmites, exposed along the Hiukitak River, Bathurst Inlet region. GSC 1993-209A

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Preface

The Parry Peninsula-Perry River area, Northwest Territories is currently experiencing important economic development based primarily on mineral resource exploration for base and precious metals and diamonds. Economic growth is likely to increase in the future in view of renewed interest in a transportation corridor linking Yellowknife to Coronation Gulf and Bathurst Inlet. Improved accessibility to the Central Arctic coast through construction and upgrading of roads, airports, docks, harbours, rail connections, and pipelines creates greater opportunities for travel, trade, tourism, fishing, mining, and development of renewable and non-renewable resources. Potential development of these natural resources will be accompanied by the need for increased knowledge of unconsolidated sedimentary materials.

This report contains a description and interpretation of the stratigraphic record of Late Quaternary sediments found along and near the Arctic coast from Cape Parry to the Perry River and summarizes the glacial and postglacial history of the region. This information provides a framework for the understanding of the nature, character, and distribution of surficial materials as they apply to land use planning. It responds to a need for a greater awareness of essential background data relating to drift prospecting and mineral exploration, the location and extent of construction aggregate reserves, and engineering design.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

Préface

La région de la péninsule Parry et de la rivière Perry, dans les Territoires du Nord-Ouest, connaît actuellement un important développement économique qui se fonde principalement sur la prospection des ressources minérales, notamment des métaux communs, des métaux précieux et des diamants. La croissance économique se poursuivra sans doute à l'avenir. compte tenu du renouveau d'intérêt manifesté pour une voie de communication reliant Yellowknife au golfe Coronation et à l'inlet Bathurst. En améliorant l'accessibilité à la côte de l'Arctique central grâce à la construction et à la remise en état de routes, d'aéroports, de quais, de ports, de liaisons ferroviaires et de pipelines, on créera de meilleures conditions pour les voyages, le commerce, le tourisme, la pêche, l'exploitation minière et la mise en valeur de ressources renouvelables et non renouvelables. Afin de pouvoir éventuellement mettre en valeur ces ressources naturelles, il faudra mieux déterminer la nature des matériaux sédimentaires meubles.

Dans le présent rapport, on donne une description et une interprétation de la stratigraphie des sédiments du Quaternaire supérieur rencontrés sur la côte arctique et à proximité, à partir du cap Parry jusqu'à la rivière Perry, et l'on résume l'histoire glaciaire et postglaciaire de la région. Cette information aide à comprendre la nature, le caractère et la distribution des matériaux en surface, et la manière dont ils peuvent être utilisés pour planifier l'aménagement des terres. Elle répond au besoin de mieux connaître les données fondamentales essentielles à la prospection minière et glacio-sédimentaire, à la détermination des sites et de l'étendue des réserves de granulats pour la construction, et à la conception de projets techniques.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

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LATE QUATERNARY STRATIGRAPHY AND DEPOSITIONAL HISTORY OF THE PARRY PENINSULA-PERRY RIVER AREA, DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

Abstract

Knowledge of the glacial geology of the Parry Peninsula-Perry River area, Northwest Territories is largely based on large-scale physiographic reconnaissance surveys and more rarely, on detailed mapping or stratigraphy in a few isolated areas. Although general physiographic effects of glaciation are known, the extent of marine transgression, mode of emergence, and regional stratigraphy have received little attention. Late Quaternary deglaciation history is reconstructed from a regional study of stratigraphy and glacial landforms. The stratigraphic record in this isostatically-depressed coastal area consists of a well-defined succession of seven sedimentary facies: (A1) massive diamicton; (A2) stratified diamicton with sorted sediments; (B) small-scale horizontal and cross-stratified sand and gravel; (C) interlaminated sand, silt, and clay; (D) massive silty clay; (E) thinly bedded sand, silt, and clay; (F) poorly bedded to massive sand; and (G) large-scale horizontal and cross-stratified sand and gravel.

Ice retreat has left a relatively orderly, consistent, and predictable sedimentary succession over 1000 km. Two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (facies A, B, C), and a conformably overlying coarsening-upward regressive marine sequence (facies D, E, F, G). The distribution and lateral extent of each facies falls within a sequence in which ice-proximal sediments (diamicton, outwash, rhythmites) migrate landward during ice retreat, whereas marine sublittoral and littoral deposits (silty clay, sandy rhythmites, sand, and gravel) migrate seaward during the marine regression.

Résumé

Nos connaissances de la géologie glaciaire de la région de la péninsule Parry et de la rivière Perry, dans les Territoires du Nord-Ouest, se fondent largement sur des levés de reconnaissance physiographiques et, plus rarement, sur la cartographie détaillée ou sur la stratigraphie de quelques secteurs isolés. Bien que l'on connaisse les effets physiographiques généraux des glaciations, on a peu étudié l'étendue de la transgression marine, les modes d'émersion et la stratigraphie régionale. On a pu reconstituer l'histoire de la déglaciation du Quaternaire supérieur à partir de l'étude régionale de la stratigraphie et des modelés glaciaires. Dans ce secteur côtier enfoncé par isostasie, la colonne stratigraphique comprend une succession bien définie de sept faciès sédimentaires : (A1) du diamicton massif; (A2) du diamicton stratifié à sédiments granoclassés; (B) des sables et graviers à stratification horizontale et oblique à petite échelle; (C) des sables, silts et argiles interstratifiés; (D) de l'argile silteuse massive; (E) des sables, silts et argiles finement lités; (F) du sable mal lité à massif; et (G) des sables et graviers à stratification horizontale et oblique à grande échelle.

Le retrait des glaces a laissé une succession sédimentaire relativement ordonnée, uniforme et prévisible, sur une distance de plus de 1 000 km. On a observé deux tendances granulométriques distinctes : une séquence positive créée par le retrait de l'inlandsis dans un milieu glaciomarin (faciès A, B, C), que recouvre en concordance une séquence marine négative, régressive (faciès D, E, F, G). La distribution et l'étendue latérale de chaque faciès correspondent à une séquence dans laquelle les sédiments juxtaglaciaires (diamicton, dépôts d'épandage fluvioglaciaire, rythmites) ont migré en direction des terres pendant le retrait des glaces, et les dépôts marins sublittoraux et littoraux (argile silteuse, rythmites sableuses, sable et graviers) ont migré vers le large durant la régression marine.

SUMMARY

This report deals with the Quaternary geology and stratigraphy along the Arctic mainland coast of the Northwest Territories, extending from Cape Parry south of Amundsen Gulf to the Perry River south of Queen Maud Gulf. A thorough understanding of the stratigraphic record of unconsolidated sediments is essential in planning for future economic development. This region is experiencing renewed economic activity in the fields of renewable and non-renewable resources, and most notably in mineral resource exploration. New economical construction aggregate reserves will become important factors in the development, implementation, and maintenance of future transportation infrastructure. Stratigraphic descriptions and interpretations provide a framework for the understanding of the nature, character, and distribution of surficial materials as they apply to land use planning.

The physiography of the coastal terrain of the Northwest Territories mainland reflects the influence of both the nature of the underlying bedrock and the events of the last glacial episode. Much of Parry Peninsula consists of flat-lying carbonates and sandstone, lying below 30 m elevation. South and east of Darnley Bay, the land rises to form rocky uplands of sandstone and carbonates known as the Melville Hills. They extend inland towards the southeast and decrease gradually in elevation south of Clinton Point. Southeast of the Melville Hills, the Rae and Richardson rivers form a broad east-trending basin underlain by gently inclined dolomites and basalts. Along the southern shore of Coronation Gulf west of Bathurst Inlet, a rocky inland plateau of metamorphosed sediments and granite attains about 400 m elevation. The land surrounding Bathurst Inlet rises steeply from the water to form rugged gneiss and granite hills at elevations of at least 300 m and in some places 600 m. Gently inclined carbonates underlie the relatively featureless terrain that forms Kent Peninsula. Southeast of the peninsula, a broad coastal plain extends up to 125 km inland where elevations attain 215 m. Most of the region consist of extensive outcrops of granite and gneiss of low relief, rarely exceeding 60 m a.s.l.

Stratigraphic investigations have defined the nature and distribution of surficial sediments, deposited during the retreat of the Late Wisconsin Laurentide Ice Sheet through to Late Holocene times. A well-defined succession of distinct sedimentary facies is recorded in this isostatically-depressed coastal region. Massive diamicton (till, subfacies A1) produced mainly by lodgement of glacial debris by thin, active ice, was initially deposited on bedrock. Stratified glacial diamictons (subfacies A2), often overlying lodgement till, resulted from a combination of debris flows and iceberg rain-out modified by subglacial meltwater processes near the ice/sea interface during ice retreat. Subaqueous outwash deposits issuing from subglacial

SOMMAIRE

Dans le présent rapport, on étudie la géologie et la stratigraphie du Quaternaire sur la côte continentale arctique des Territoires du Nord-Ouest, à partir du cap Parry au sud du golfe Amundsen jusqu'à la rivière Perry au sud du golfe Queen Maud. Il essentiel de comprendre de façon complète la stratigraphie des sédiments meubles afin de pouvoir planifier le développement économique. La région connaît un renouveau d'activité économique dans les domaines des ressources renouvelables et non renouvelables, et surtout dans le domaine de la prospection des ressources minérales. De nouvelles réserves de granulats pour la construction, d'exploitation rentable, deviendront des facteurs importants pour ce qui est de la réalisation, de la mise en oeuvre et de l'entretien de l'infrastructure des transports que l'on prévoit d'installer. Les descriptions et interprétations stratigraphiques aideront à comprendre la nature, le caractère et la distribution des matériaux en surface dans le contexte des projets d'aménagement des terres.

La physiographie du terrain côtier de la partie continentale des Territoires du Nord-Ouest traduit l'influence de la nature du substratum rocheux sous-jacent et des événements du dernier épisode glaciaire. La péninsule Parry se compose en grande partie de couches subhorizontales de roches carbonatées et de grès, qui se trouvent à une altitude inférieure à 30 m. Au sud et à l'est de la baie Darnley, le terrain monte pour former des hautes terres rocheuses de grès et de roches carbonatées connues sous le nom de collines Melville. Elles se prolongent vers le sud-est à l'intérieur des terres et leur altitude baisse progressivement au sud de la pointe Clinton. Au sud-est des collines Melville, les rivières Rae et Richardson forment un vaste bassin à direction est sous lequel se trouvent des dolomies et des basaltes légèrement inclinés. Sur le littoral sud du golfe Coronation à l'ouest de l'inlet Bathurst, un plateau intérieur rocheux composé de sédiments métamorphisés et de granite atteint environ 400 m d'altitude. Les terres entourant l'inlet Bathurst émergent de l'océan en pente forte et forment des collines accidentées de gneiss et de granite qui atteignent au moins 300 m et parfois 600 m d'altitude. Des roches carbonatées faiblement inclinées constituent le sous-sol du terrain relativement uniforme de la presqu'île Kent. Au sud-est de cette presqu'île, une vaste plaine côtière se prolonge jusqu'à 125 km à l'intérieur des terres, où l'altitude maximale est de 215 m. La plus grande partie de la région comporte de vastes affleurements de granite et de gneiss au relief peu accentué, dont l'altitude dépasse rarement 60 m au-dessus du niveau de la mer.

Les études stratigraphiques ont permis de définir la nature et la distribution des sédiments en surface déposés pendant le retrait de l'inlandsis Laurentidien (Wisconsin tardif) jusqu'à l'Holocène tardif. Une succession bien définie de faciès sédimentaires distincts se rencontre dans cette région côtière enfoncée par isostasie. Un diamicton massif (till, sous-faciès A1) produit surtout par le dépôt de débris glaciaires par de la glace active mince, s'est accumulé d'abord sur le substratum rocheux. Des diamictons glaciaires stratifiés (sous-faciès A2), qui recouvrent souvent le till de fond, ont été produits à la fois par des coulées de débris et par la libération de débris transportés par des icebergs; ces débris ont été remaniés par des eaux de fonte sous-glaciaires près de l'interface entre la glace et la mer au cours du retrait des glaces. Des dépôts d'épandage fluvioglaciaire subaquatique provenant de conduits sous-glaciaires

Crossbedded sand and gravel, massive sand, and planar to cross-laminated fine sand and silt (facies B) are deposited near the mouth of the ice tunnel. The transition to interlaminated sand, silt, and clay rhythmites (facies C) represents a progressive decrease in current velocity in the downflow direction. Sedimentation dominated by sediment-laden underflows, interflows, and overflows, both near the ice margin and at a distance, led to the deposition of these glaciomarine rhythmites. Beyond the influence of the ice sheet and following deglaciation, massive silty clay (facies D) was deposited in the open marine environment. As the sea regressed to lower elevations due to crustal rebound, sublittoral (facies E) and littoral (facies F) deposits completed the postglacial sequence. Raised glaciomarine and postglacial marine deltas (facies G) are common features along the coast. High concentrations of sediments were deposited by meltwater early in the deglacial glaciomarine phase over a short period of time, and sedimentation was significantly reduced following this initial influx of sediment.

Ice retreat has left a well-defined, orderly sedimentary succession which is generally consistent along the coast for 1000 km. The distribution and lateral extent of each facies is such that ice-proximal sediments (facies A, B, C) and marine sediments (facies D) migrated landward during ice retreat, whereas marine sublittoral and littoral deposits (facies E, F, G) migrated seaward during the marine regression. Within this complete sequence, two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (diamicton, outwash, rhythmites) and a conformably overlying coarsening-upward regressive marine sequence (silty clay, sandy rhythmites, sand, and gravel).

The Cape Parry to Perry River area records evidence of only one glacial advance, but represents a region which extends from near the western limit of Late Wisconsin ice to well inside this limit, closer to a centre of ice loading near Bathurst Inlet. Regional ice flow was towards the west and northwest as defined by glacial landforms and striae. Deglaciation is characterized by a series of ice marginal positions, marking the initial Late Wisconsin glacial limit at 18 ka, through successive patterns of ice retreat towards the east, to approximately 8.7 ka southeast of Bathurst Inlet. Deglaciation of the mainland coast was accompanied by synchronous marine incursion of isostatically depressed terrain. A relatively rapid invasion of the sea from west to east and disintegration of the ice mass led to the formation of a diachronous marine limit. As a result, a well-defined pattern of marine limit was produced, rising relatively consistently in elevation from west to east due to differential isostatic uplift. Marine limit ranges from 10 m a.s.l. on the north end of Parry Peninsula to over 225 m in the Bathurst Inlet area.

constituent une séquence de faciès qui peut présenter plusieurs variations. Des sables et graviers à stratification oblique, des sables massifs, et des silts et sables fins à lamination plane à oblique (faciès B) se sont accumulés près de l'embouchure du tunnel sous-glaciaire. Le passage à des rythmites de sable, silt et argile interstratifiés (faciès C) correspond à une diminution progressive de la vitesse du courant vers l'aval. La sédimentation, principalement par des courants hypopycnaux, interpycnaux et épipycnaux chargés de sédiments, à proximité et à distance de la marge glaciaire, a donné lieu à ces rythmites glaciomarines. Au-delà du domaine d'influence de l'inlandsis et de la déglaciation ultérieure, il y a eu dépôt d'argile silteuse massive (faciès D) dans le milieu marin à circulation libre. À mesure que la mer reculait, par suite du relèvement isostatique de la croûte terrestre, des dépôts sublittoraux (faciès E) et littoraux (faciès F) ont complété la séquence postglaciaire. Des deltas glaciomarins et postglaciaires marins soulevés (faciès G) se rencontrent fréquemment sur la côte. Les eaux de fonte ont déposé des quantités importantes de sédiments sur une courte période de temps au début de la phase glaciomarine de déglaciation, et la sédimentation a fortement diminué après cet apport initial de sédiments.

Le retrait des glaces a produit une succession sédimentaire ordonnée, bien définie et généralement uniforme sur une distance de 1 000 km le long de la côte. La distribution et l'étendue latérale de chaque faciès sont tels que les sédiments juxtaglaciaires (faciès A, B, C) et les sédiments marins (faciès D) ont migré en direction des terres pendant le retrait des glaces, tandis que les dépôts sublittoraux et littoraux marins (faciès E, F, G) ont migré vers le large au cours de la régression marine. À l'intérieur de cette séquence complète, on a observé deux tendances granulométriques distinctes : une séquence positive créée par le retrait de l'inlandsis dans un milieu glaciomarin (diamicton, dépôts d'épandage fluvioglaciaire, rythmites), que recouvre en concordance une séquence marine négative, régressive (argile silteuse, rythmites sableuses, sable et gravier).

Le secteur du cap Parry à la rivière Perry témoigne d'une seule avancée glaciaire; toutefois, il correspond à une région allant des abords de la limite occidentale des glaces du Wisconsin tardif à un secteur bien à l'intérieur de cette limite, plus près d'un centre de surcharge glaciaire proche de l'inlet Bathurst. D'après l'étude des modelés et des stries glaciaires, l'écoulement glaciaire régional s'effectuait vers l'ouest et le nord-ouest. La déglaciation se caractérise par une série de positions de la marge glaciaire, qui marquent la limite glaciaire initiale du Wisconsin tardif à 18 ka, puis des étapes successives de retrait des glaces vers l'est, jusqu'à environ 8,7 ka au sud-est de l'inlet Bathurst. La déglaciation de la côte continentale a été accompagnée d'une inondation marine synchrone du terrain enfoncé par isostasie. L'invasion relativement rapide de la mer d'ouest en est et la désagrégation de la masse glaciaire ont entraîné la formation d'une limite marine diachrone. Par conséquent, est apparu un schéma bien défini de limites marines qui augmentent d'altitude de façon relativement régulière d'ouest en est par suite du relèvement isostatique différentiel. L'altitude de la limite marine varie de 10 m au-dessus du niveau de la mer à l'extrémité nord de la péninsule Parry, à plus de 225 m dans le secteur de l'inlet Bathurst.

INTRODUCTION

Numerous reconnaissance geomorphic studies have been undertaken dealing with the glacial history of the Parry Peninsula to Perry River area, Northwest Territories (Fig. 1), but few have looked at land/sea interactions in coastal regions. The Quaternary history of this region is poorly known and no detailed regional stratigraphic investigations have been carried out. The purpose of this paper is to study the stratigraphy of Late Quaternary deposits exposed in the study area and to relate it to the regional geomorphology. This study defines ice-front positions during ice retreat, elucidates the history of marine incursion and subsequent regression, and establishes the succession of depositional environments during deglaciation and in the Holocene. Stratigraphic investigations focus on glacial, glaciofluvial, glaciomarine, and marine sediments, deposited over a period extending from the retreat of the Late Wisconsin Laurentide Ice Sheet through to Late Holocene. Regional lithostratigraphic correlations are presented in order to show the extent of Late Quaternary deposits and their relationships with one another.

This region is experiencing renewed economic activity in the fields of renewable and nonrenewable resources, and most notably in mineral exploration. New economical aggregate reserves will become important factors in the development, implementation, and maintenance of future transportation infrastructure.

The study area extends approximately 1000 km along the coast, from 125° to 104° west longitude, and southward from the coast to over 125 km inland. Research was undertaken in co-operation with Geological Survey of Canada and Indian and Northern Affairs Canada (N.W.T. Geology Division) mappers whose presence in certain areas facilitated logistical support in this relatively inaccessible region. A total of 128 sections were examined, and for purposes of discussion, 20 are presented in detail in this paper. These 20 sites are considered to be representative of the stratigraphic record in their respective locations. They characterize a wide range of environments and can be lithostratigraphically corelated to the remaining sections.

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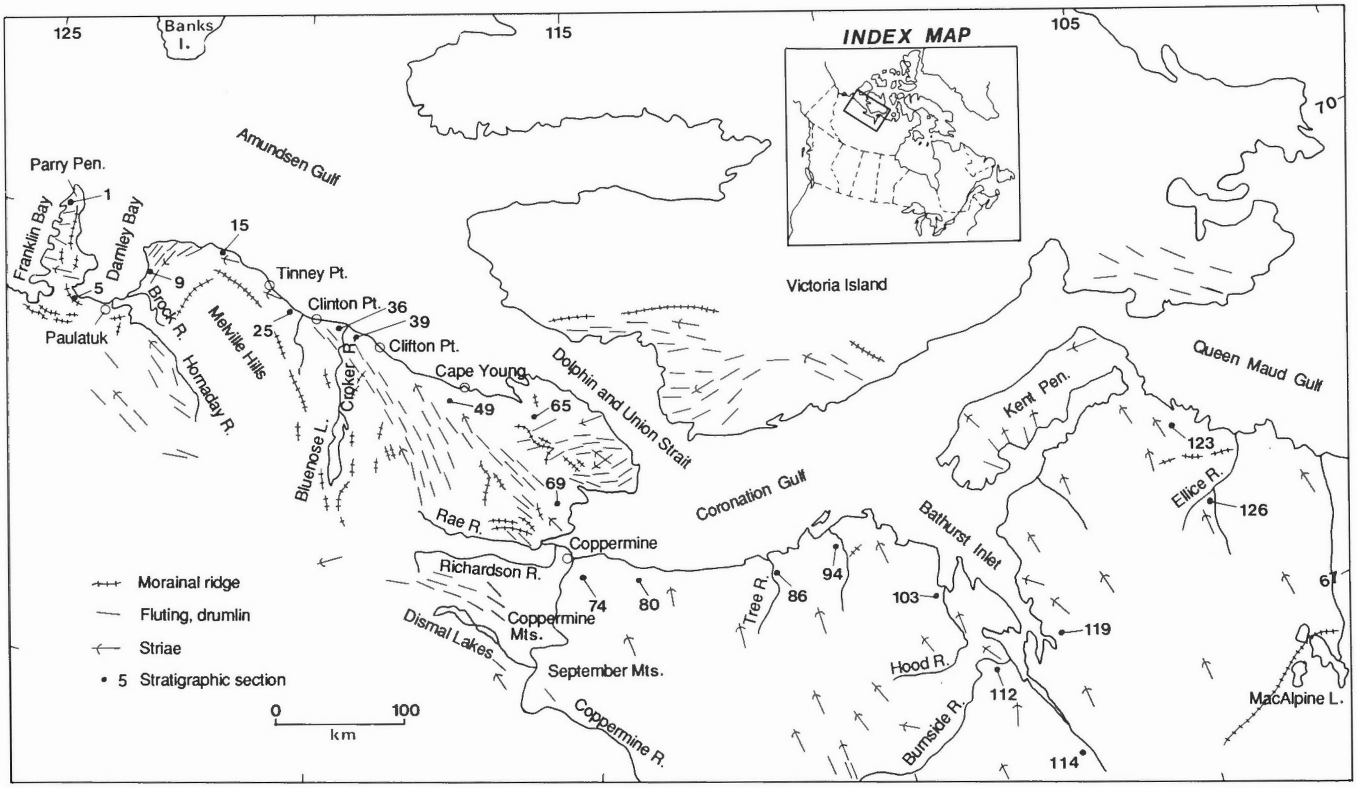

Figure 1. Location map of the study area, illustrating glacial features and location of selected stratigraphic sections referred to in Figure 3. Modified in part from Blake (1963), Craig (1960), Kerr (1989), Klassen (1971), Sharpe (1988a), and St-Onge and McMartin (1987).

METHODS

Fieldwork was carried out from several base camps over the summers of 1986 to 1989. Rotary-wing and fixed-wing aircraft were used to gain access to most sites. Preliminary interpretation of the surficial geology of the study area was carried out using aerial photographs. Large-scale flow directional features (drumlins, flutings) and glacial landforms (moraines, eskers, ice-contact deltas) were plotted on 1:50 000 and 1: 250 000 maps. Flow directions were also obtained from crag-and-tail features and from striation measurements of exposed bedrock. Stratigraphic studies included detailed descriptions of the nature and extent of lithostratigraphic units exposed in coastal sections and river banks. Characteristics described included types of contacts, lateral and vertical extent of units, internal structures and bedding style, sediment texture, as well as clast lithologies, shape, and size. In places with little or no slumped material on a cliff face, sections were cleared, measured, and sampled for grain size and fossil analyses. Samples were carefully chosen so as to be representative of each unit as a whole. Wherever possible, organic matter such as wood and peat, and marine bivalves were collected for radiometric dating. Elevation of these and other marine features were determined by helicopter altimeter[1]. Geographic locations of sections are illustrated in Appendix 1 and their description by sedimentary facies is summarized in Appendix 2. Grain size analyses were carried out in the Sedimentology Laboratory of the Geological Survey of Canada, using dry sieving and pipette methods.

BEDROCK GEOLOGY

The bedrock geology in the study area consists of Archean to Cretaceous rocks. A generalized bedrock map is presented in Figure 2. Archean gneiss and granite are found outcropping over extensive areas along the southern shore of Queen Maud Gulf, and on the west, south, and east sides of Bathurst Inlet. Archean rocks are also found south of Coronation Gulf (Blackadar and Fraser, 1960; Fraser, 1963). On Kent Peninsula, Archean granite is overlain by flat-lying dolomite, limestone, and sandstone of Proterozoic age which are locally overlain by Lower Paleozoic dolomite and sandstone. Proterozoic greenstone belts occur on the west, south, and east sides of Bathurst Inlet. Sedimentary and volcanic Proterozoic rocks also outcrop south of Coronation Gulf (Blackadar and Fraser, 1960; Fraser, 1963). Proterozoic dolomite and sandstone underlie Paleozoic sandstone from Darnley Bay to Tinney Point (Blackadar and Fraser,1960). Flat-lying Paleozoic carbonates and sandstones occur south of Dolphin and Union Strait (Campbell, 1983), in the Coppermine area, where they are intercalated with gabbroic sills (Baragar and Donaldson, 1973), and on Parry Peninsula where they consist

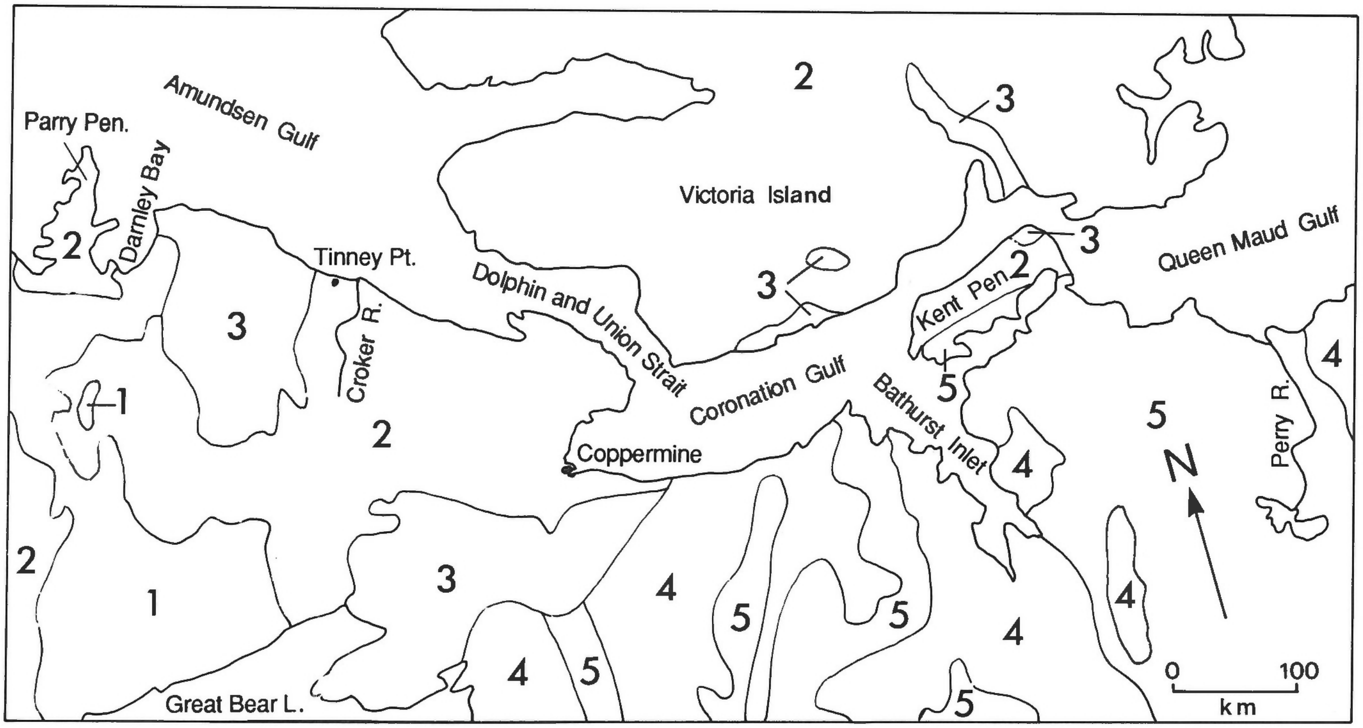

Figure 2. Simplified bedrock geology map of the study area. 1 – Mesozoic (Cretaceous): shales, sandstone, coal; 2 – Paleozoic (Silurian, Ordovician, Cambrian): carbonates, shales, sandstone; 3 – Proterozoic: carbonates, shale, sandstone; 4 – Proterozoic: greenstone belts, metamorphosed sediments; 5 – Archean: gneiss, granite. Modified after Douglas (1969) and Fraser et al. (1978).

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[1] Probable accuracy ±6 metres (Stan Smith, Canadian Helicopters, pers. comm., 1992).

of Upper Cambrian to Lower Ordovician dolomite, shale, sandstone, and gypsum with minor quartz and chert (Yorath and Cook, 1981). Mesozoic (Lower Cretaceous) rocks south of Parry Peninsula and east of Darnley Bay, consist principally of moderately indurated sandstone, mudstone, and coal (Yorath et al., 1969, 1975). The author noted poorly indurated Cretaceous sandstone and siltstone, with coal horizons exposed along the Croker River.

PHYSIOGRAPHY

The physiography of the coastal terrain of the Northwest Territories mainland is highly variable, and reflects the influence of both the nature of the underlying bedrock and the events of the last glacial episode. In the western region, Parry Peninsula (Fig. 1) has been subdivided into the Parry Plain Peninsula and the Parry Peninsula Moraine (Yorath et al., 1969). Much of Parry Peninsula is flat-lying and lies below 30 m elevation. South and east of Darnley Bay, the land rises to form the rocky uplands known as the Melville Hills. They extend inland towards the southeast and decreases gradually in elevation south of Clinton Point. The Rae and Richardson rivers form a broad east-trending drainage basin south of the Melville Hills. West and south of this basin, the terrain rises slowly becoming increasingly rocky towards the Coppermine and September mountains. Along the southern shore of Coronation Gulf, west of Bathurst Inlet, a rocky inland plateau attains about 400 m elevation and slopes northward 5 km to 10 km down to the sea. Bathurst Inlet is a 225 km long, southeastern extension of Coronation Gulf. On both its east and west sides, the land rises steeply from the water to form rugged hills at elevations of at least 300 m and in some places 600 m. Kent Peninsula, to the northeast of the inlet, is a relatively featureless plain where the descent to the sea is gradual, but some regions in the central and eastern areas are higher. Southeast of the peninsula, a broad coastal plain extends up to 125 km inland where elevations attain 215 m. In the vicinity of Ellice River and eastward, relief is generally low, rarely exceeding 60 m a.s.l.

PREVIOUS STUDIES

Knowledge of the glacial geology of the study area, and more specifically the last marine episode is limited. A literature review indicates that many previous surficial geology studies have focused on large-scale physiographic reconnaissance surveys and more rarely, on detailed mapping or stratigraphy in a few isolated areas. Although the general physiographic effects of glaciation are known, the extent of the marine transgression and mode of emergence have received little attention. No attempt has been made to undertake a regional study and synthesis of Quaternary stratigraphy, sedimentology, and glacial history.

Early explorers of the nineteenth century performed geographical investigations of the region, travelling by ship from the Mackenzie Delta to Kent Peninsula (Franklin, 1828; Richardson, 1851), during which notes on the local natural history were taken. It was not until the Canadian Arctic Expedition of 1913-18 that general observations were made regarding the Pleistocene deposits along the Arctic coast by O'Neill (1924). He reported the presence of diamictons on the east side of Darnley Bay, as well as a raised beach at 21 m a.s.l., and gravel terraces at 36 m, 52 m, and 61 m a.s.l. south of Paulatuk. Gravel terraces along the Brock River at 30 m, 43 m, and 67 m a.s.l., as well as at Clinton Point (91 m a.s.l.) were also noted. Marine shells were found at elevations of 52 m at Clifton Point and 152 m at the mouth of the Tree River. O'Neill (1924) deduced marine emergence of approximately 180 m in the Darnley Bay-Brock River area. The present study, however, suggests a much lower elevation for the marine limit of inundation. Mackay (1952) mapped the major glacial features such as lineations in ground moraine, eskers, and postglacial drainage channels and terraces in the Darnley Bay area. Terraces are attributed to fluvial and lacustrine processes, formed when drainage was initially southwest towards the Hornaday River, which is perpendicular to the present drainage. Proglacial lakes were impounded between the Amundsen Gulf lobe (Mackay, 1958) and the Melville Hills to the south. As the ice front retreated, proglacial lakes were successively lowered as evidenced by deltas at progressively lower altitudes. Two such deltas were noted by the present author along the Brock River at 73 m and 98 m a.s.l. Recessional moraines on Parry Peninsula record successive frontal positions of the Amundsen Gulf lobe which flowed around the Melville Hills. These investigations were based on minimal supporting stratigraphic observations and did not include discussions of late glacial and postglacial marine phases. Major morainal deposits of the Melville Hills and Parry Peninsula were also noted by Yorath et al. (1969, 1975) and Yorath and Cook (1981) during bedrock geology investigations, but descriptions are limited to broad physiographic divisions.

Bird (1955) made preliminary studies of postglacial marine submergence in the Bathurst Inlet area, based on evidence from elevations of marine shells, beaches, and washing limits. Emergence deduced from ground moraine, strandlines, and molluscs varies from 170 m to 220 m a.s.l. at the mouth of the Inlet, to 196 m to 225 m a.s.l. at the southwest extremity. A series of dominant strandlines between 200 m and 189 m, 65 m, and possibly 23 m a.s.l. may be related to periods of temporary halts or slowing down in emergence, although emergence has been essentially continuous in postglacial times (Bird, 1955). A regional reconnaissance survey by Craig (1960) from the Hornaday River to the Tree River identified a peripheral zone of marginal fluctuation, from Darnley Bay to Coppermine, and a central zone of regular ice-retreat extending into the mainland interior towards the southeast. Based on the distribution of glacial landforms, a summary of the pattern of ice retreat was presented for the Darnley Bay-Coppermine region, although no temporal framework was included. It was postulated that the ice-margin along Coronation Gulf may have been static for a period of time, although no moraines were noted to support this interpretation. Approximate limits of postglacial marine submergence were initially identified at 213 m at the Tree River, decreasing to 146 m east of Coppermine, 91 m west of Cape Young, and 45 m near Tinney Point. No raised marine features were reported west of this last site.

A similar reconnaissance investigation was undertaken by Blake (1963) who mapped the regional directions of ice flow and major end moraines in the Tree River to Perry River region. A brief review of major glacial features is presented, along with a preliminary interpretation of their significance. Evidence of marine submergence is based on beach ridges, wave-cut benches, deltas, and changes in nature of drift cover. Blake confirmed that marine limit was 213 m a.s.l. at Tree River, between 213 m and 228 m in Bathurst Inlet, and approximately 198 m near MacAlpine Lake further east. Radiocarbon data suggest that the Tree River area was ice free by 10.2 ka and that ice had retreated to MacAlpine Lake by at least 8.2 ka. Preliminary sea level studies showed that recent uplift was slightly lower at the north end of the Inlet than in the southern region. In the Parry Peninsula and northern Melville Hills region, Klassen (1971) produced preliminary surficial geology maps, indicating the limits of Late Wisconsin glaciation. However, no glaciomarine or marine sediments were identified, except for isolated beach ridges along Amundsen Gulf.

More recent studies of glacial history, focusing on glaciolacustrine reconstructions, were carried out by Mercier (1984) in the Richardson and Rae river basin west of Coppermine. The glaciolacustrine to marine transition in this region was described through stratigraphic and sedimentological studies (Kerr, 1987). J.-S. Vincent (GSC, pers. comm., 1988) recognized evidence for marine submergence in the form of raised fossiliferous deposits south of Darnley Bay, and provided age estimates for deglaciation. South of Coppermine, St-Onge (1987, 1988) mapped and interpreted the surficial deposits of the Coppermine River valley. In the Bluenose Lake region, south of Amundsen Gulf, six morphosedimentary zones were identified (St-Onge and McMartin, 1987) on the basis of landforms and dominant sediment types. Potschin (1989) provided a detailed morphological description and discussion on the origin of drumlins south of Dolphin and Union Strait. Based on geomorphic evidence, deglaciation history of the Bluenose Lake-Coppermine area was discussed by McMartin and St-Onge (1990). However, events were not related to a chronological or stratigraphic framework.

SURFICIAL GEOLOGY

Unconsolidated deposits are common in the study area. Surficial sediments include morainal, glaciofluvial, glaciolacustrine, glaciomarine, and marine. The northern and central regions of Parry Peninsula are thinly mantled by discontinuous till, forming hummocky moraine and north-south end moraine segments (Fig. 1). Extensive morainic belts 30 to 60 m in elevation extend eastward from the southern part of Parry Peninsula. Darnley Bay coastlands consist of continuous deposits of ground moraine giving rise to a drumlin field oriented northeast-southwest, which curves around the Melville Hills; to the southeast, this joins a second large drumlin field south of Clifton Point. The more elevated terrain of the Melville Hills is surrounded by exposed rock with thin and discontinuous till patches, whereas kettled terraces and outwash deposits occur on its flanks. Moraine ridges are curvilinear to the northwest, north, and northeast of the Melville Hills (Fig. 1). Discontinuous drift and marine deposits are found at lower elevations.

East of the Croker River, surficial deposits can be divided into three broad zones: (1) a moraine complex associated with the Melville Hills, (2) a belt of highly sculptured ground moraine (streamlined drift forms), and (3) a coastal plain composed of marine sediments, washed till, and outwash deposits whose upper limit is characterized by a series of perched deltas. Between Dolphin and Union Strait and the Rae River, a series of arcuate morainal ridges occur, consisting of diamicton, sand, and gravel. Smaller, transverse morainal ridges are found in isolated localities south of Dolphin and Union Strait to Queen Maud Gulf below the limit of marine submergence. Thick deposits of sand, silt, and clay occur in the Rae and Richardson river basins. Marine and glaciolacustrine sediments extend from Bluenose Lake to the Coppermine River along the southern shore of Coronation Gulf. Marine sediment is variable in extent and thickness. The coastal zone, however, as well as the more elevated uplands to the south, are rocky with little to moderate amounts of drift.

Similar conditions exist around Bathurst Inlet where veneers of marine sand, silt, and clay mantle the terrain, except for the tops of bedrock hills. Eskers are widespread and commonly associated with kames and outwash complexes. Continuous deposits of till and moraine ridges are rare. Flights of raised beaches a few tens of metres above present-day sea level are a common feature along the coastal plains, frequently associated with the flanks of eskers and hillsides.

SEDIMENTARY FACIES

Numerous sedimentary units identified in stratigraphic sections have been subdivided into facies (Walker, 1984). The location of 20 of these is shown in Figure 1. The stratigraphic data were projected onto a base line oriented east-west as seen in Figure 3. Seven sedimentary facies have been classified, representing a range of depositional environments. Their characteristic properties are summarized in Table 1.

Facies A: diamicton

Facies A, diamicton, has two subfacies: massive, structureless, pinkish grey diamicton (subfacies A1), and stratified brownish grey diamicton interbedded with sand and gravel (subfacies A2).

Subfacies A1: massive diamicton

Description

Subfacies A1 has a silty sand matrix and is matrix-supported. It is generally less than 3 m thick, but varies from 1 m to 15 m, and forms distinct structureless units. Clasts are angular to well-rounded cobbles and boulders with striae and facets; lithology varies with local bedrock. Angular slabs of dolomite, siltstone, and sandstone accompanied by minor granite gneiss and gabbro are predominant in the west part of the study area whereas granite, gneiss, siltstone, and sandstone are generally more common in the east. Diamicton is compact and a few isolated clasts aligned parallel to ice flow were

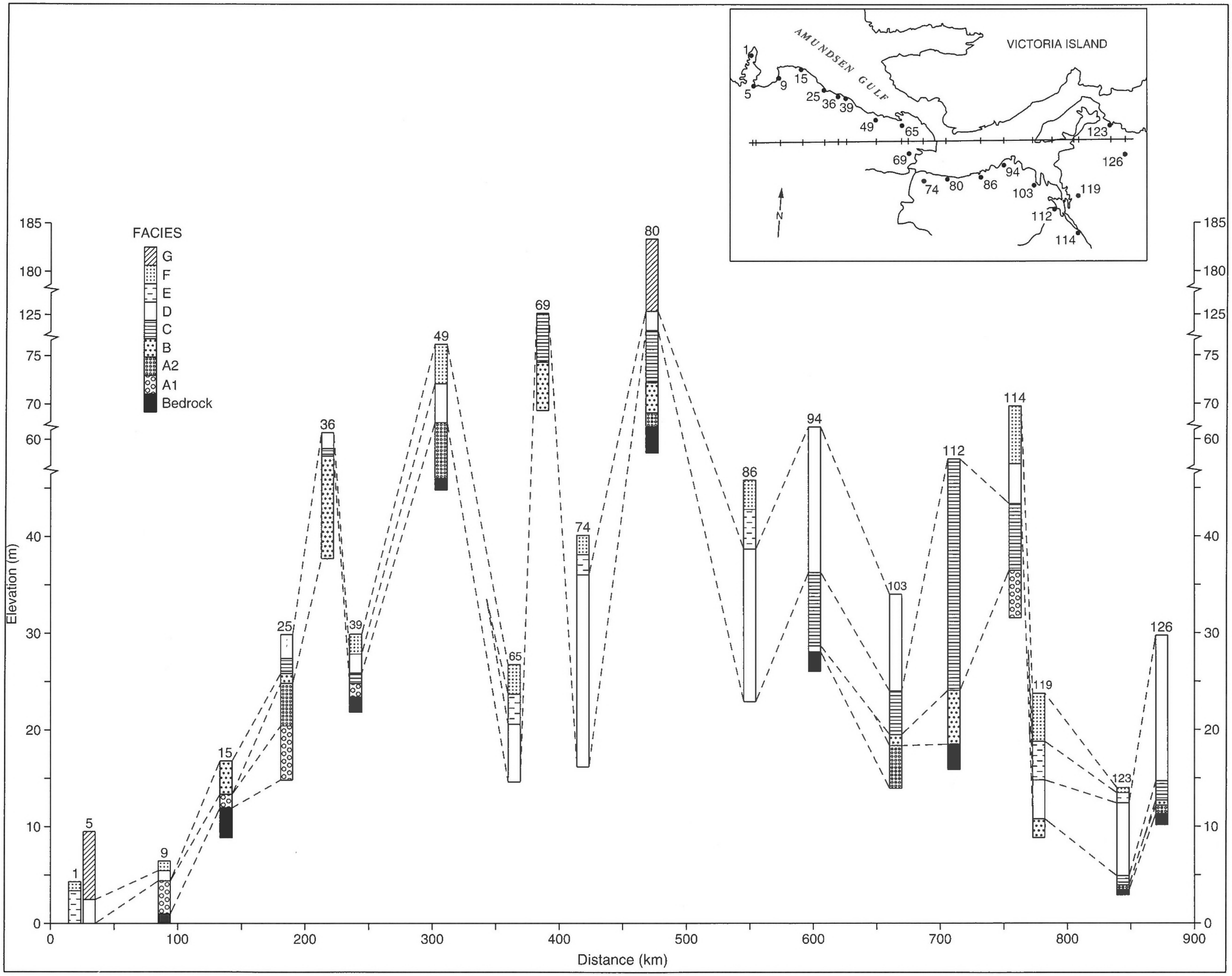

Figure 3. *Lithostratigraphic correlation of sedimentary facies.*

Table 1. Sedimentary characteristics of facies A to G

Facies/ subfacies	Thickness (m)	Grain size (%)* G	S	Si	C	Matrix texture**	Munsell colour	Sedimentary structures
A1	1.0-15	24	48	35	17	silty sand	7.5 YR 7/2	massive
A2	0.5-30	25	48	41	11	silty sand	10 YR 6/2	poorly to well stratified
B	0.2-25	1	82	6	12	sand	10 YR 6/2	massive or stratified; planar tabular and trough crossbeds; horizontal bedding
C	0.5-30	0	17	47	36	clayey silt	7.5 YR 7/2	planar and crosslaminated
D	1.0-20	0	1	33	66	silty clay	7.5 YR 6/2	massive
E	0.5-20	0	43	40	17	silty sand	10 YR 5/2	laminated to thinly bedded
F	1.0-4.0	1	71	17	12	silty sand	10 YR 5/3	massive to poorly stratified
G	4.0-37	6	77	19	4	sand	10 YR 6/2	large-scale crossbeds

* G-gravel, % of whole sample
S-sand, Si-silt, C-clay, % of < 2 mm fraction
** After Shepard (1954)

observed. Lower contacts with bedrock are either sharp or the shattered bedrock grades upward into stony diamicton. The upper contacts of this subfacies are sharp and planar to irregular. Diamicton beds are relatively uniform in texture, and weathered surfaces do not appear to differ in colour or texture from fresh exposures. Although this subfacies is found throughout the study area, it is not particularly abundant (Fig. 3). Diamicton of subfacies A1 is restricted to the base of sections and is not found interbedded with other facies.

Interpretation

Subfacies A1 is interpreted as lodgement till, deposited by actively flowing ice (Dreimanis, 1988). The massive, compact nature of this matrix-supported diamicton, abundance of striated clasts, and the abundance of angular, local lithologies suggest basal deposition. The absence of stratified horizons (Boulton, 1972) indicates a lack of running water during basal melting or lack of preservation of sediments. The lodgement process deposits or plasters individual abraded or faceted clasts or frozen aggregates to the subglacial floor during pressure melting (Boulton, 1976; Shaw, 1982). The lateral correlation and textural similarities of subfacies A1 to surficial diamicton that is fluted or drumlinized may also suggest this diamicton is a subglacial basal till.

Subfacies A2: stratified diamicton with sorted sediments

Description

Subfacies A2 consists of diamicton beds with sand-rich horizons. This matrix-supported diamicton (Fig. 4) has a silty sand matrix and contains clasts ranging from pebbles to boulders up to 2.5 m in diameter. As in subfacies A1, it incorporates a wide variety of rock types, from angular clasts of fragmented bedrock to well rounded clasts of variable composition, some of which are striated. Although not as compact as subfacies A1, subfacies A2 diamicton beds often exhibit weak internal stratification and, rarely, normal grading. Subfacies A2 varies in thickness from 0.5 m to 30 m. These sediments are found near the base of sections and locally are interbedded with deposits of facies B and C. Individual diamicton beds are variable in texture and commonly 1 m in thickness but range from 0.15 m to 4 m. Sorted sediments consist of thin beds of silt, sand, and pebbles, less than 10 cm thick, as well as discontinuous lenses. These are found within and between diamicton beds and are sometimes associated with boulder pavements. Locally, small clasts depress underlying strata and are overlain by draped laminations. Upper and lower boundaries between diamictons and sand-rich horizons may be sharp or gradational. Subfacies A2 occurs throughout the study area, but not in significant amounts.

Interpretation

Subfacies A2 occurs within the coastal belt of marine submergence which was established during deglaciation. It underlies, and is interbedded with, other facies deposited in glaciomarine environments. Several sedimentary processes are attributed to the deposition of subfacies A2. Some diamictons are interpreted as glacially-derived debris flows that moved along the sea bottom, and whose sediment source was derived from the glacier base as indicated by predominantly local lithologies. In other cases, different structures and more diverse clast lithologies of subfacies A2 suggest that it is not only the product of sediment gravity-flow processes, but a

Figure 4. Poorly bedded diamicton of subfacies A2 sharply overlain by horizontal stratified sand of facies B. Cobbles in lower part of photo are about 15 cm in diameter (section 103). GSC 1993-209B

combination of subglacial meltwater sedimentation and possibly ice-rafting. The release of debris aggregates by overturning icebergs produce diamictons that may undergo reworking by bottom traction currents originating from subglacial meltwater (Domack and Lawson, 1985). Such meltwater currents are believed to be responsible for sand and gravel lenses and layers associated with diamicton beds of this facies. These ice-proximal currents induced local erosion as evidenced by small cut-and-fill structures. Gravel lags observed in numerous sections may have resulted from preferential removal of finer fractions or may have been produced directly from high in-flow discharge carrying coarse material.

Facies B: small-scale horizontal and cross-stratified sand and gravel

Description

This facies consists of stratified fine to coarse sand to pebbly gravel with minor amounts of silt and clay. It is light brownish grey and is found throughout the region. Beds vary in thickness from 0.5 m to 25 m. This facies is most commonly underlain by subfacies A1 and A2 and overlain by facies C (Fig. 3). Sedimentary structures associated with this facies include tabular and trough crossbeds composed of medium to coarse sand with clasts up to 15 cm in diameter, horizontally stratified to structureless fine to coarse sand beds, and lenses of silty clay to coarse sandy gravel. This facies also exhibits ripple-drift cross-laminations, sinusoidal ripple laminations, and planar laminations; a typical sequence consists of type A climbing ripples (lower angles of climb) grading into type B climbing ripples (high angle of climb) (Jopling and Walker, 1968), overlain by draped undulating laminae which may in turn grade up into, or be truncated by, horizontally laminated sands. Type B ripples, with high angles of climb, may also grade up into type A ripples, with lower angles of climb (Fig. 5). Beds are generally from 0.1 m to 1.5 m thick, exhibiting both sharp and gradational upper and lower boundaries. Paleocurrent directions are variable, but generally indicate deposition from currents flowing oceanward in a westerly to northerly direction throughout the study area.

Figure 5. Cross-laminated sands of facies B in which type B climbing ripples grade upward into type A ripples. Trowel measures 25 cm. GSC 1993-209C

Interpretation

In a regional context, facies B occurs below marine limit and is interpreted to be subaqueous outwash (Rust and Romanelli, 1975). This interpretation is supported in part by the position of facies B within a stratigraphic sequence (underlain by coarse glacial diamictons and overlain by fine grained glaciomarine rhythmites), which suggests that these sediments were deposited in a proglacial environment at an ice-sea interface. Planar and cross-stratified sand and gravel were transported by subglacial meltwater discharges, released as efflux jets (Powell, 1990), and deposited in tunnels or into standing water at the ice margin. Deposits of this type are characteristic of glaciofluvial (eskerine) environments where deposition at the mouth of ice tunnels forms a subaqueous fan (Anderson and Ashley, 1991; Boothroyd, 1984; Domack, 1984; Dowdeswell and Scourse, 1990; Harrison, 1975; Powell, 1981; Powell and Molnia, 1989; Rust and Romanelli, 1975; Saunderson, 1975; Smith and Ashley, 1985). The sedimentary succession consists of small-scale planar tabular crossbeds resulting from bedforms that migrated across the fan surface. Coarser meltwater sediments are deposited near the mouth of subglacial tunnels by seaward-moving turbulent jets as the competency of these flows decreases away from the mouth (Mode et al., 1983). Massive coarse sands are deposited from suspension due to turbulent discharge at the point of exit. Flat-bedded and cross-laminated sand and silt are transported by traction and suspension from decelerating flow away from the ice front. Gently sloping submarine fan surfaces permit density underflows to transport large amounts of fine- to coarse-grained sediment during melt seasons (cf. Leckie and McCann, 1982; Powell, 1981).

Facies C: interlaminated sand, silt, and clay

Description

The main diagnostic characteristic of facies C is thinly bedded to laminated, sand, silt, and clay rhythmites. This facies occurs throughout the study area, most commonly above facies B (Fig. 3) or, more rarely, overlying subfacies A1 or A2. These deposits consist of rhythmically bedded fine sand, silt, and clay horizons, 0.1 cm to 1.5 cm thick, having either sharp or gradational upper and lower contacts (Fig. 6). Each rhythmite is defined by cyclic changes in colour and texture giving rise to striking, repetitive interbeds. Where the rhythmite sequences gradationally overlie the coarser sand deposits of facies B, beds may attain thicknesses of 10 cm to 50 cm and consist of graded fine sand to silty clay with internal sand or clay laminae, 0.1 cm to 1 cm thick. These thicker basal rhythmites may, in places, exhibit thin sequences of type A and B climbing ripples. Beds may exhibit intraformational, soft sediment deformation structures such as convolute bedding and diapir and flame structures. Diamicton pods and striated clasts up to 30 cm in diameter also occur. The clasts depress underlying strata, occasionally truncating them, and are overlain by draped laminations. In general, beds of facies C, overlying sandy deposits of facies B, become progressively thinner and finer grained towards the top of sections but those overlying subfacies A1 and A2 show no obvious trends. In addition, laminations do not appear to thin or thicken laterally over a distance of up to 20 m. Where this facies overlies subfacies A1, lower contacts are sharp, whereas lower gradational boundaries occur over subfacies A2. The thickness of units comprised entirely of facies C is quite variable, ranging from as little as 0.5 m to 24.5 m. The upper contact of facies C with facies D (Fig. 3) is a gradational one. In this upper zone, the rhythmic character becomes indistinct, and the poorly laminated silt and clay grade up into massive mud of facies D. Facies C is locally fossiliferous, containing marine foraminifera and bivalves.

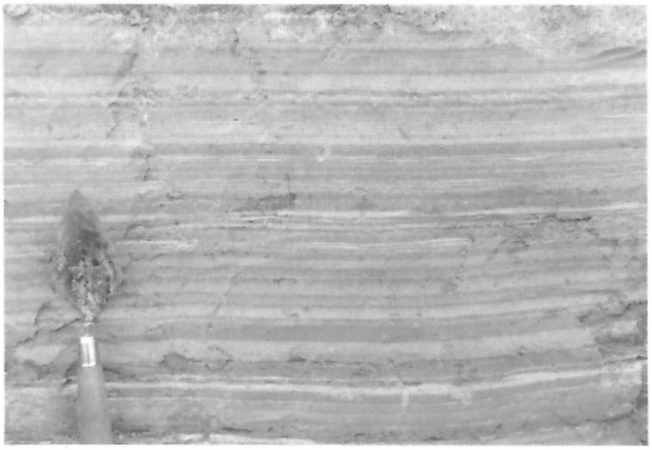

Figure 6. *Interlaminated sand (white), silt (medium grey), and clay (dark grey) rhythmites of facies C (section 112). GSC 1993-209D*

Interpretation

Deposits of this facies are interpreted as glaciomarine sediments resulting from meltwater discharging in subglacial and ice-marginal environments forming underflows, interflows, and overflows. Numerous studies on cyclic or interlaminated sand and mud units have shown that similar deposits characterize glaciomarine sedimentation (Domack, 1984; Domack and Lawson, 1985; Dowdeswell and Scourse, 1990; Drewry and Cooper, 1981; Elverhoi et al., 1983; Eyles and McCabe, 1989; Gilbert, 1982; Mackiewicz et al., 1984; Orheim and Elverhoi, 1981; Powell, 1981; Stevens, 1985).

Subglacial meltwater discharge may introduce large amounts of sand and gravel into the marine environment. If the discharge of subglacial meltwater has a sufficiently high sediment load, flow occurs along the seafloor forming an underflow. These underflows transport sand, silt, and clay away from the ice front, leaving only the coarser sediments near it. The nature of the underflows may be that of high concentration turbidity currents (Middleton, 1966), because laminae are poorly sorted and individual laminae are not always graded. Thick laminae and thin beds of sand are formed as the coarse grained sediment is deposited in a proximal environment; current ripples and erosional contacts suggest traction currents which are more abundant closer to the ice front. Although subglacial systems may have greater suspended sediment concentrations than within supraglacial or englacial flows (Hammer and Smith, 1983), underflows are difficult to generate because abnormally high suspended sediment concentrations are required (~ 40 g/L) in order to overcome the buoyancy effects of seawater (Gilbert, 1979, 1982; Mackiewicz et al., 1984).

If subglacial meltwater discharge has a moderate to low sediment concentration, it may be buoyed up because of density differences between it and the marine water column, into which it may spread laterally forming an interflow or an overflow. Coarse grained sediment is dropped out of suspension from the turbid plumes more quickly than fine grained sediment, resulting in a higher sand content in the proximal environment; suspended sediment begins to settle as the meltwater spreads out and current velocities decrease. Consequently, the interlaminated sand, silt, and clay of facies C would imply fluctuating conditions where bottom current sediments alternate with relatively slow settling of suspended silty and clay. A sharp boundary between laminae reflects a sudden change in depositional process, whereas the gradational nature of a contact is interpreted as transitional shift of sedimentary conditions. Changes in the depositional environment can be brought upon by fluctuations in meltwater velocity, duration of flow, and sediment concentrations which is consistent with observations made by Arnborg (1955), Boothroyd and Ashley (1975), Cohen (1979), and Pickrill and Irwin (1983) regarding glaciofluvial systems.

A proximal to distal relationship, due to the retreat of the ice, is inferred by the fining upward trend towards the stratigraphic top of facies C in terms of the thickness of laminae and their textural composition, as finely laminated silt and clay dominate distal sediment deposition. Sediment settling from turbid surface plumes is probably the main source of fine grained glaciomarine deposits (Gilbert, 1982; Syvitski and Murray, 1981). This interpretation is suggested by the lack of bottom current structures in sediments of facies C, the fine grain size, and relatively poor sorting which is indicative of deposition in quiet water primarily by settling from suspension.

Isolated striated clasts are locally present within the fine grained rhythmites of facies C. As they are too large to have been transported by traction currents, a glacial origin is probable. These clasts are believed to be dropstones, and provide evidence for floating ice. Ice-rafted debris may melt out individually or may be dumped by the turning over of an iceberg or floe producing debris lenses (Anderson et al., 1980; Keys and Williams, 1984; Ovenshine, 1970). The irregular masses of diamicton occasionally interbedded with rhythmites suggest that these materials represent ice-rafted sediment melted out or dumped from floating ice. A rainout origin is further indicated by the downfolded and draped nature of the laminate sediments surrounding the clasts (Thomas and Connell, 1985).

The soft sediment deformation structures associated with this facies are believed to have been formed in response to differential downward pressure exerted by the weight of overlying sediment (vertical loading). Compaction and dewatering of oversaturated sediments results in diapirs and mass movement down very gentle slopes between horizontally bedded deposits (Banerjee and McDonald, 1975; Lowe, 1975; Rust, 1977).

Facies D: massive silty clay

Description

Facies D consists of mottled, pinkish grey silty clay which is for the most part massive and structureless; rare thin silt or fine sand stringers and small gravelly lenses are restricted to the lower part of this facies. Facies D, by volume, is the most significant sedimentary unit within the study area. It is found all along the coast, varying in thickness from 1.5 m to commonly 20-25 m (Fig. 3). Upper contacts are gradational with facies E and G; lower boundaries are gradational with facies C, but sharp and planar to irregular with facies A1, A2, and B. This unit, like facies C, is fossiliferous and contains several species of marine ostracodes, foraminifera, and bivalves.

Interpretation

Facies D is a marine deposit resulting initially from suspension in quiet water environments of proximal to distal glaciomarine settings, but predominantly in the relatively deep waters of the open marine conditions which existed following deglaciation. The rare occurrence of sandy gravel lenses and sand partings at the base of facies D in some sections (sections 86, 94, Fig. 3) are thought to be ice-rafted debris or deposits of subglacial discharge interrupting periods of suspension deposition. Although clays can be deposited in proximity to ice margins (Sharpe, 1988b), it is believed that facies D, a product of flocculation and agglomeration of silts and clays, has generally a postglacial marine origin as indicated by its fine texture, lack of current structures, microfossil content and its stratigraphic position. The mixing of meltwater streams and the rivers draining deglaciated coastal regions is characterized by flocculation of suspended clay sediment leading to the formation of floccules which settle together to form massive silt deposits (Kranck, 1981; Torrance, 1983). Furthermore, the lack of significant and abrupt changes in grain size suggest that the sea was not in contact with the ice margin throughout most of the depositional stage. Paleoenvironmental interpretations based on rich and diverse foraminiferal, ostracode, and bivalve assemblages suggest bottom-water temperatures of approximately 0°C and salinities of 33-34 ppt for these nonglacial, deep-water sediments. Modern-day faunal counterparts have been reported in relatively deep waters of Frobisher Bay and in coastal waters of Greenland, Alaska, and Norway (Kerr, 1993).

Facies E: thinly bedded sand, silt, and clay

Description

Facies E consists of interbedded sediments composed of sand, silt, and clay mixtures; individual strata range from 1 mm to 15 cm in thickness. The cyclic variations in grain size and colour of each horizon define the rhythmic nature of this deposit. Strata have gradational and sharp upper and lower contacts and may be either massive or show internal stratification. Locally, these rhythmites grade up vertically into lenticular, undulatory, and more rarely, flaser bedding; asymmetrical current ripples associated with the undulatory or wavy bedding are overlain by bifurcated-wavy flaser bedding, which are in turn succeeded by thinly interlayered sand, silt, and clay (Fig. 7). The sediments of facies E are particularly rich in organic plant debris (twigs, leaves, rootlets), as well as in situ marine macro- and microfauna. Bioturbation, in the form of burrows, and soft sediment deformation structures are also generally common throughout the facies (Fig. 8). Facies E varies in thickness from 0.5 m to 20 m, although average thicknesses are in the range of 5-10 m (Fig. 3). The lower boundary of this facies is gradational with facies D, as is the upper contact with facies F. Where facies E occurs as the uppermost stratigraphic unit in sections, cryogenic and pedogenic alteration have destroyed most of its primary sedimentary characteristics.

Interpretation

The rhythmic nature of facies E, and its stratigraphic position and fossil content, all suggest a shallow water marine environment in which bedding resulted, in part, from variations in sedimentation due to variable cycles of fluvial discharge in response to short-term climatic changes. Rivers draining the coastal regions are responsible for the introduction of terrestrial plant fragments into the marine environment. Deposits similar to these described by Hillaire-Marcel (1979) are characteristic of shallow, isolated marginal marine basins in which they often complete a regressive marine sequence. The sedimentary structures encountered in facies E also suggest a tidal influence as lenticular, wavy, and flaser bedded sequences overlying the rhythmites are characteristically found in tidal environments (Dalrymple, 1992; Reineck and Singh, 1980). Lenticular and wavy structures are formed where alternating periods of moving and slack water occur as in tidally influenced regimes or where the process of sediment supply is rhythmic or periodic (Leeder, 1982; Terwindt, 1981). Flaser bedding results from the alternation of bedload transport and suspension settlement during slack water periods, which may also give rise to complex varieties of tidal bedding (Klein, 1977). Comparable rhythmic deposits described by Domack (1984) have been interpreted as having a tidal origin resulting in cyclic deposition. Marine laminations have also been described by Clifton (1983) and Smith et al., (1990) from tidal marine and glaciomarine environments with tidal ranges of 2 m to 7 m. In the present study, it is difficult to determine the degree of influence tides have had on marine sedimentation because the tidal range in the Coppermine area is only 0.17 m (tidal data, Institute of Ocean Sciences, Department of Fisheries and Oceans, Sidney, British Columbia, 1983). Under these conditions, it is likely that tidal processes are not as active as in meso- and macrotidal environments.

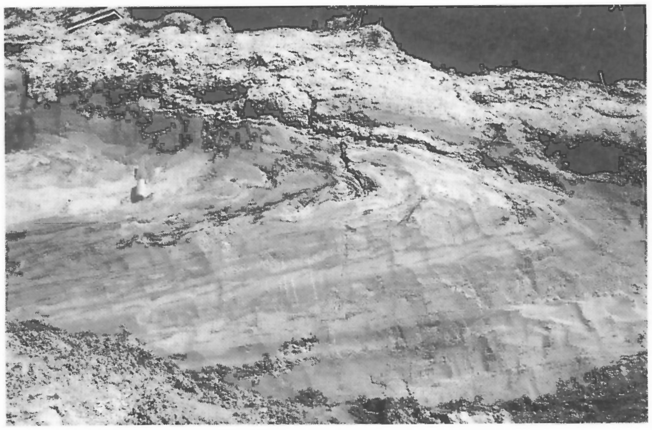

Figure 7. Thinly bedded sand grading upward into sandy transitional undulatory/flaser bedding, overlain by organic-rich cross-laminations. Note deformed beds. Trowel, centre left of photo shows scale. GSC 1993-209E

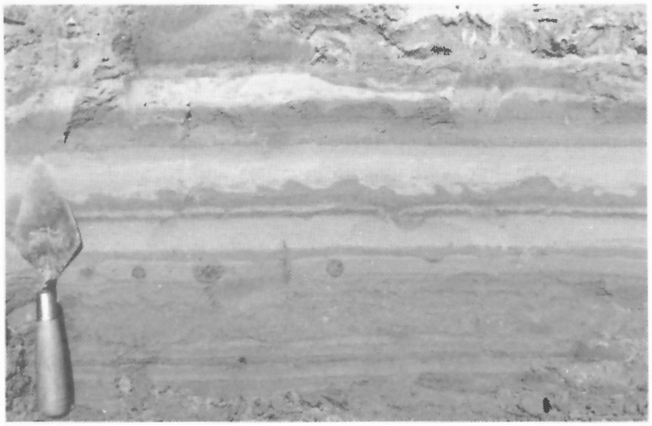

Figure 8. Flame structures and round horizontal burrows within silty sand rhythmites of facies E. GSC 1993-209F

Load and flame structures, as well as involutions associated with the rhythmites of facies E are evidence of post-depositional deformation. While dewatering and differential loading are responsible for flame-type sedimentary structures, frost action and thermokarst processes, which achieve their greatest intensity in areas currently experiencing periglacial climatic conditions (French, 1976), are responsible for heaving and churning of sediments in the top of stratigraphic sections.

The shallower waters of the postglacial sea are characterized by foraminiferal, ostracode, and bivalve assemblages which are distinct from those associated with the deeper, more open-marine offshore environment of facies D. The fauna associated with facies E represent only the most tolerant shallow-water species capable of successfully colonizing rigorous sublittoral and littoral environments. Paleotemperatures may have attained 5-10°C in summer, whereas paleosalinities were likely in the range of 10 to 34 ppt, depending on climatic (seasonal) conditions (Kerr, 1993).

Facies F: poorly bedded to massive sand

Description

Deposits of facies F consist of a brown silty sand which is structureless to crudely bedded. Locally, these sands contain horizons of coarse sand to pebbles which may, locally, form planar crossbedded strata (Fig. 3, section 39) where pebbly sands compose the 10-15 cm thick strata which dip 10° towards 205°. Facies F consistently overlies facies D and E, where its lower boundaries are gradational, and is found at the stratigraphic top of many sections (Fig. 3). These deposits are fossiliferous, containing both marine bivalves and foraminifera and may exhibit convolute bedding where stratification is evident.

Interpretation

The stratigraphic position of facies F and its surface expression as raised marine beach ridges indicate a shallow water to littoral origin. Facies F, however, lacks the high degree of sorting which is representative of a constant energy level over a relatively long period in the littoral environment (Folk, 1980). The poorly sorted nature of deposits of facies F is the result of several factors: (1) the availability of sand for littoral structures was limited, hence, reworking of these deposits by waves could only result in sands with varying amounts of silt and clay; (2) Arctic shorelines are affected by wave action for only six months or less each year and often undergo reworking by sea ice during much of this time (Jefferies, 1977); and (3) the ability of waves to effectively sort sediments is inhibited by protective layers of snow and ice on beach surfaces (Hume and Schalk, 1964; Greene, 1970) in early fall.

Only rarely is planar cross-stratification observed. Where present, it is interpreted to be a beach bar whose landward slope facies (i.e., towards the south), is preserved. Longshore bars typically consist of crossbedding dipping landward and seaward (Davidson-Arnott and Greenwood, 1976). It is possible that high wave activity during a relatively short period of time was involved in its formation.

More typically, facies F consists of planar laminated and poorly bedded silty sand, which contrasts with the trough and tabular crossbedding and crosslaminations associated with other nearshore settings (Clifton et al., 1971; Howard and Reineck, 1981). A reason for these differences could be that a low-energy environment existed at the time of deposition and as discussed above, wave action may have been relatively limited. Paleoenvironmental conditions similar to those associated with facies E are inferred from marine bivalves and foraminifera.

Facies G: large-scale cross-stratified sand and gravel

Description

Sediments of facies G consist primarily of light brownish grey, fine to coarse sand with variable amounts of silt and clay, as well as gravel and cobbles. Large-scale tabular crossbedding is the dominant structure in which internal bedding varies from 10 cm to 30 cm in thickness and sometimes shows fining upward cycles. The strata at the base of a typical sequence are generally finer grained, have low angles of dip of 2° to 5°, and may contain sequences of type B climbing ripples 5 cm to 10 cm thick. These are overlain by planar crossbedded coarse sand to gravel with higher angles of dip from 7° to 32° and have sharp, planar lower boundaries. Unconformably overlying these crossbedded strata are massive to planar bedded coarse sand which may locally contain abundant gravel and cobbles. Within this uppermost unit may also be found lenses of sand to gravel as well as trough crossbedding infilled by planar laminations of medium to coarse sand. Marine bivalves occur in some sections, occasionally in life position, but more commonly as single valves. Facies G is found in isolated areas overlying facies D (Fig. 3) and varies in thickness from 4 m to 37 m. Paleocurrents associated with the cross-stratification vary from section to section but suggest flow directions towards 275° through to 360° and 090°.

Interpretation

Facies G is considered as a deltaic complex on the basis of its sedimentary characteristics and its morphology. Deltas are referred to as glaciomarine if they were built during the period of ice retreat, or as marine if they are associated with the postglacial stage. Most deltas in the study area have their apex to the south and extend northward in a fan shape, giving rise to a lobate form with an arcuate front. This form is typical of deltas composed of coarse material, as opposed to digitate forms which tend to comprise finer grained sediments (Miall, 1984; Selley, 1970). Many glaciomarine deltas exhibit collapse structures suggesting they were formed in contact with glacier ice and fed by meltwater streams. The structures associated with facies G are typical of Gilbert-type deltas (Shaw, 1977). The topset deposits of facies G, consisting of crudely planar beds with occasional trough crossbedding or scour and channel-fill structures are believed to be of fluvial origin, representing braided stream deposits (Rust, 1978). This interpretation is supported on the basis of braided stream paleochannels preserved on the subaerial surface of deltas. The contact between topset and foreset beds is often erosional and may correspond to the elevation of the sea into which the delta was built (Gustavson et al., 1975). Foreset bedding in the middle to lower portions of deltas consists of subparallel beds of sand and gravel, showing dips typically in the order of 20° to 30° (Fig. 9). In glaciomarine deltas, the absence of ripples and the coarse nature of the sediment suggest the rapid

Figure 9. *Perched marine delta showing thin topset beds, steeply inclined foresets dipping north-northeast, and lower bottomset beds, total thickness 37 m; view is to the southeast. GSC 1993-209G*

deposition of a large amount of sediment over a relatively short period of time. Braided streams with large bedloads are associated with early postglacial conditions as the ice is melting (Cohen, 1979; Miall, 1984). The contact between foreset and bottomset bedding in facies G may either be sharp or more gradational such as in cases where stratification is not well defined due to the fine grained nature of the sediment. Occasional climbing ripples found in bottomset strata are attributed to higher current velocities capable of transporting slightly coarser sediment farther out to sea. The distribution of the sediments in the deltaic environment is the result of a decrease in current velocity as sediment-laden fluvial waters enter a standing body of water (Coleman and Prior, 1981). This process is responsible for the coarsening upward sequence resulting from the progradation of the delta.

FACIES ASSOCIATIONS

As noted by Karrow (1984), individual facies are sometimes difficult to interpret when considered alone, but the recognition of facies associations and vertical sequences is a useful analytical tool. It is therefore helpful to define specific associations which group together different sedimentary facies that are environmentally or genetically related. Any preferred vertical position of a facies may also have an important bearing on the interpretation of a sequence and should be considered (Shaw, 1975; Walker, 1984). In addition, sequences of deposition are established on the basis of sediment distribution, frequency, and thickness of each facies.

In this study, three different facies associations have been identified from sedimentary successions:

1. Subfacies A1 and A2: massive and stratified glacial diamictons.
2. Facies B and C: stratified glaciofluvial clayey silt, sand, and gravel.
3. Facies D, E, and F: massive to stratified marine sand, silt, and clay.

The first two are the direct result of glacial processes. During the retreat of the Laurentide Ice Sheet, marine waters were in contact with the ice front, inundating the isostatically depressed coastal lowlands. Till, debris flow, and meltwater sediments were deposited beneath and along the ice margin in subglacial and glaciomarine environments. The third is the product of the marine regression resulting from postglacial uplift of the land. This period is characterized by a coarsening-upward off-lap sequence.

The first association, between subfacies A1 and A2, is suggested by their lithological similarities, clast shapes and markings, and stratigraphic characteristics. They are predominantly subglacial diamictons, commonly overlying glacially abraded and striated bedrock (Fig. 3), and represent the oldest known unconsolidated deposits in the region. The sharp contacts associated with some deposits of glacial drift are the result of erosive flows of subglacial meltwater (Fig. 3, sections 49 and 103). Subfacies A1 and A2 may be abruptly overlain by facies D (Fig. 3, sections 9 and 49), or more commonly succeeded by facies B and C respectively (Fig. 3, sections 25, 80, 103, and 126).

A second facies association is expressed in sections 25, 36, 69, 80, 103, 112, and 126 (Fig. 3) where facies B appears to grade up vertically into facies C. Facies B is believed to have a subaqueous glaciofluvial origin, because it overlies subfacies A1 and A2, and is closely related to the laminated sediments of facies C. Facies C sediments are interpreted to be the result of subglacial and englacial meltwater discharge in a proglacial setting deposited during ice retreat in the region. Consequently, these deposits may be found overlying glacial diamictons and underlying proximal to distal glaciomarine and postglacial marine silty clays. Cheel and Rust (1982) described a similar vertical succession of sediments from a retreating ice front, comprising a fining-upward sequence, with gravelly sands at the base and increasingly distal fine grained sediment at higher stratigraphic levels, passing into a marine environment. Thus facies B and C are associated with proximal positions close to an ice margin which are transitional between glaciofluvial and glaciomarine environments. Each facies association can be related to changes in sedimentary processes which are generally a function of distance from the ice front, current velocity, and water depth; this can best be explained by a series of depositional processes which may generate a number of different facies in the downcurrent direction. Although lateral gradations between facies B and C were not directly observed, field evidence suggests that lateral transitions are probable, in which facies B grades downstream into facies C. Similar transitions between sedimentary structures associated with these two facies have been described by Smith and Ashley (1985) in glaciolacustrine environments.

The third sedimentary relationship is that of facies D, E, and F which conformably overlie facies C. Facies D, E, and F form a coarsening-upward cycle in which deep-water silty clay of glaciomarine and marine origin grades upward into shallower stratified sand, silt, and clay, through to massive and stratified silty sand. These three facies occur in a variety of gradationally associated sequences, although one or more of the three facies within this sedimentary association may be absent at any one locality (Fig. 3, sections 9, 39, 49, and 114). Where facies D is directly overlain by facies F, it is believed that fluvial and tidal influences were minimal. The interpretation of facies F as a littoral deposit explains its frequent surface occurrence as raised beaches, as well as its stratigraphic position above facies E and/or D, which are associated with progressively deeper water environments.

LITHOSTRATIGRAPHIC CORRELATION

A lithostratigraphic correlation of facies (Fig. 3) is presented in order to establish a more thorough reconstruction of the areal distribution of depositional environments which evolved during the retreat of the last glacier and in postglacial time. A chronostratigraphic correlation has not been attempted because of differential uplift, resulting in a number of different depositional environments existing at any one time.

The oldest unconsolidated deposits in the region are the glacial diamictons of subfacies A1 and A2. Pre-last glaciation deposits have been observed along the Croker River, but their exact age is unknown (St-Onge and McMartin, 1987; Kerr, unpub. data, 1986). Subfacies A1 commonly lies directly on bedrock and is generally confined to the western regions of the study area. It can be correlated almost continuously from sections 9 through 39 (Fig. 3), although its continuity to the west of section 9 and to the east of section 39 cannot be determined. This region is also characterized by the high concentration of drumlinized landforms developed in till.

Subfacies A2 appears to have a more regional distribution as it occurs at a number of sites along the coast, near or at the base of sections. It can be correlated locally between sections 94 and 103, and 123 and 126 in the east, but is generally found as isolated occurrences. Subfacies A2 is not considered to be laterally extensive. Its presence has been noted at elevations from 1 m to 2 m (section 123) to 163 m (section 80) in stratigraphic sections, but may be found up to at least 200-220 m a.s.l. as a surficial deposit.

The subaqueous outwash deposits of facies B may occur as thin, isolated occurrences which makes it impossible to trace them laterally. Thicker sequences, as seen in sections 15, 36, and 69 are indicative of proximal, ice-marginal environments where major sources of sediment would be expected. Their proximity to surficial kames and eskerine complexes suggests a close association with these features. Facies B can be correlated over tens of kilometres in the west, between sections 15, 25, and 36 and in the east, from sections 103 to 112. In the central to eastern part of the study area, there is an overlap of the two most volumetrically significant sedimentary facies, the predominantly marine deposits of facies D and the glaciomarine rhythmites of facies C. Facies C attains its greatest thickness in the Bathurst Inlet region where it can be correlated in sections 94, 103, 112, and 114. Thinner sequences of facies C may be traced laterally further east, sections 123 and 126, as well as in the west, sections 25, 36, and 39. Units of facies C in sections 69 and 80 appear isolated because of their relatively high elevation, although facies C occurs as high as 190 m down to 1-2 m.

The dominant sedimentary unit in the central and eastern regions is facies D which can be correlated from sections 25 to 65, 74 to 103, and 114 to 126. These silty clay deposits, whose microfossils reflect a marine environment, persisted throughout much of the Holocene. Noticeable regional variations in thickness of this facies have been observed in the lowlands along the coast. In general, maximum thickness in the west is 2-3 m, whereas it increases towards the east attaining 15-20 m. The greatest accumulations were recorded in sections along rivers draining broad, shallow depressions which extended locally considerable distances inland. It is likely that erosion of facies D has taken place in certain areas (sections 15, 69, and 112) as it once may have mantled most

Table 2. Late Quaternary history regional correlation chart

Chronostratigraphic units		Lithostratigraphic units							
		BANKS ISLAND[1] (north, west, east zones)		14 C ka	N.W. VICTORIA I.[2]	14 C ka	MAINLAND COAST[3] west east		14 C ka
Holocene 10 ka		Postglacial sediments		7.8			NECHILIK FM.	Franklin Sea sediments	8.2
Wisconsin Stage	Late 23 ka	PRINCE OF WALES FM.	Schuyter, Passage Pts. sea sediments	11.2		9.9			
					Winter Harbour till	11.3		Richardson drift	11.8
					Unnamed sea	11.6			
			Investigator, Meek Pt. and East Coast sea sediments	> 19				Unnamed sea	32.7
	Middle 64 ka			> 41					
			Bar Harbour, Mercy Jessy, Carpenter and Sachs tills	> 37	Unnamed till				
	Early 75 ka								
Sangamon Stage		Cape Collinson Fm.		> 49 > 61					

[1] Vincent (1984)
[2] Vincent (1989)
[3] This study

regions below the marine limit of inundation; furthermore, stony and shelly lag deposits atop certain sections suggest the removal of some unknown amount of surficial deposits.

Although facies E forms part of a common coarsening-upward sequence observed in many sections reflecting the marine regression, it is difficult to correlate from one location to the next. Facies E is frequently associated with present-day settings which would indicate protected, paleogeographic marine embayments into which rivers drained. Such environments occurred along the coast, but only in restricted areas which are often separated by significant distances from one another (sections 1, 65, 74, and 86). Only in section 119 and 123 can a lithostratigraphic correlation be made, representing two distinct settings.

Facies F represents the last stage of marine deposition, overlying facies E and D. These littoral sediments are rare above 150 m a.s.l. and are most commonly observed in sections below 75 m a.s.l. In most localities however, they occur as isolated surficial deposits (sections 1, 9, 74, and 86) of limited extent. This facies is absent from many sections as it is the most susceptible to erosion due to its stratigraphic position, making widespread correlation difficult. Similarly, the deltaic deposits of facies G are not easily correlated due to their isolated locations and the nature of their depositional environment.

For purposes of regional correlation and discussion, the sediments of facies A to G occurring in the Parry Peninsula-Perry River area are informally being named herein the Nechilik formation, in which "formation" rank refers to the various deposits collectively laid down during the last glacial and postglacial stages. The Nechilik formation is composed of two principal members informally named the Franklin Sea sediments and Richardson drift (Table 2).

Richardson drift

These glacial deposits were laid down during the advance and retreat of the Laurentide Ice Sheet during the Late Wisconsin glaciation. Richardson drift consists of till and glaciofluvial deposits, as well as glaciomarine units which are considered to be of glacial origin, and therefore related to this glacial event.

Franklin Sea sediments

These are predominantly marine sediments with minor fluvial contributions, deposited on an isostatically depressed coast, up to 225 m a.s.l., following the withdrawal of Laurentide ice from the region. These sediments are Late Wisconsin/Holocene in age, based on shell radiocarbon dates; marine bivalves located east of Darnley Bay dated at 11 790 BP (AECV-643Cc), and those collected from MacAlpine Lake dated at 8160 BP (GSC 110) give a maximum age for these sediments in the western and eastern regions respectively. The Franklin Sea sediments are chronologically correlated with the Schuyter Point sediments (11.2-7.8 ka), the Passage Point sediments (10.6-7.8 ka) and postglacial sediments (7.8 ka to present) of Banks Island (Vincent, 1984, 1989).

DISCUSSION OF SEDIMENTARY ENVIRONMENTS

The succession of sedimentary facies recorded in stratigraphic sections is the result of glacio-isostatic influences on the marine environment, beginning with coastal subsidence during glaciation, and then in the following period of glacio-isostatic recovery. Figure 10 illustrates the relative thickness and stratigraphic position of facies along a regional transect perpendicular to the coastline, during ice retreat and throughout marine regression. The rate of emergence and the position of sea level are important factors in controlling the nature of depositional environments. Ice retreat resulted in a deglacial sedimentary succession of relatively consistent thickness, in which facies A, B, C, and D migrate landward. In the regressive marine sequence, facies G, F, E, and D migrated seaward from marine limit. The thickness of certain facies such as D and E at a particular site depended in part on the duration of submergence. Marine sedimentation would be ongoing for a longer period of time in a submerged eastern region of low elevation. Facies C, D, E, and F become thinner towards marine limit and are not present above this level. On a more local scale, the position of ice fronts and subglacial meltwater tunnels were the dominant controls on glaciomarine deposition.

Throughout all phases of deglaciation, ice-meltwater-sea interactions played an important role in the deposition of glacial, glaciofluvial, and glaciomarine sediments. Extensive areas in the low-relief coastal margins north of the Melville Hills and south of Dolphin and Union Strait (Fig. 1) are characterized by drumlin swarms which are the dominant subglacial landform in these regions. Field evidence suggests that the drumlins record late stages of variable ice flow along the ice sheet margin, associated with high sea level in isostatically depressed regions. Drawdown of the ice took place in order to maintain ice lost by calving at unstable ice

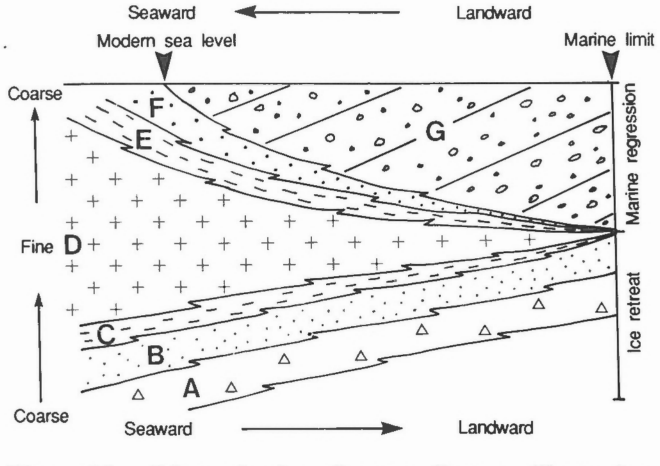

Figure 10. Schematic time-distance diagram illustrating relative thickness and position of facies with respect to sea level. Curved facies boundaries during marine regression phase reflect increased rates of emergence in early postglacial times. In the lower half, facies A to D advance landward up to the limit of marine inundation during ice retreat. In the upper half, facies D to G migrate seaward during emergence.

margins (Eyles and McCabe, 1989). Diamictons of subfacies A1 may have been deposited subglacially at this time or perhaps during the initial advance of the ice sheet. Basal debris is released as subglacial till under the glacier and is then covered by debris melted out from the floating terminus or which has been remobilized from slumping or flows. The stratified diamictons of subfacies A2 exhibit a greater contribution of sediments from underflows and meltwater plumes; upper and lower boundaries of these diamictons are often interbedded with stratified sands, recording episodic traction currents.

When ice retreat is rapid, an acceleration of flow takes place because of rapid steepening in longitudinal gradient (Powell, 1983). Although calving results along the marine ice margin, extensive areas of dead ice are left on the highlands inland. As noted by Borns and Matsch (1988) and in this study, ice which terminates on land contributes significantly to the marine environment by generation of glaciofluvial streams draining into the sea. Ice-contact deltas often result at the ice-sea interface where glaciofluvial outwash complexes terminate at the marine limit.

The presence of morainal ridges in the study area suggest stationary periods or perhaps readvances of ice margins. Moraine complexes of variable dimensions are preserved along the coast and those below marine limit record ice-contact marine deposition at the margins of the ice sheet. Similar features have been described by Powell (1981) as morainal banks – individual ridges to arcuate belts of hummocky topography marking the former positions of ice sheet margins. During winter months when calving ceases, the ice front may remain stationary or advance tens of metres (Elverhoi et al., 1983). These slight readvances of the ice margin can produce moraines, as can an ice front which slows during its retreat (Mode et al., 1983; Powell, 1983). Transverse and cross-valley moraines (Fig. 11) have also been observed south of both Dolphin and Union Strait and Coronation Gulf.

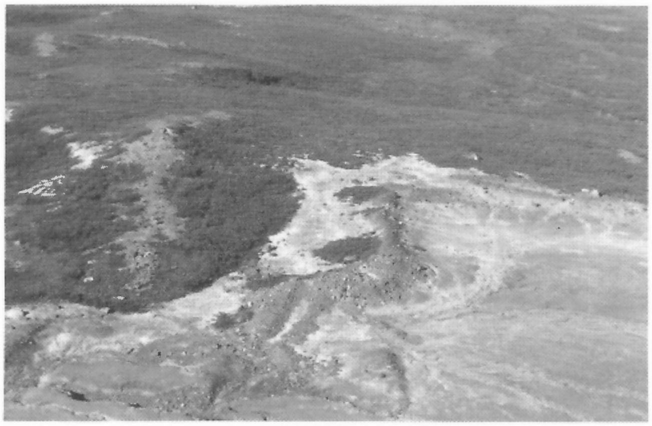

Figure 11. *Cross-valley moraine segments 50 m in length, once buried by postglacial marine sediments and now exposed due to erosion; view is to the north. GSC 1993-209H*

Meltwater produced by temperate glaciers is the predominant transporting mechanism for delivering sediments to the glaciomarine environment. Subglacial meltwater contributes coarse grained material that builds subaqueous outwash fan complexes in ice-marginal environments. These consist of structureless, planar bedded and cross-stratified sand and gravel (facies B) which may accumulate at or beyond the ice front. Occasionally, ice-rafted debris may be incorporated between periods of traction currents and rain-out from suspension. These fans, however, rarely attained large sizes because of the mobile ice front, and the change in location and flow direction of subglacial discharge from one meltwater season to the next.

Relatively thick sequences of facies C suggest that sedimentation of these glaciomarine rhythmites may have been rapid. The interlaminated characteristics and local draping nature of the laminae suggest periods when sedimentation was dominated by fall-out from suspension of fine grained material. These periods were interrupted by intervals of flows and pulses of subglacial, englacial, and supraglacial meltwater. Current-rippled sand layers and fine sand partings represent bottom-water traction currents possibly generated by density underflows. The upward decrease in pebbles and sand, and the lack of dropstones records the retreat of the ice margin. The character of uppermost zone of facies C indicates that ice-rafted debris contributed in decreasing amounts from ice-proximal to ice-distal areas. The laminated sediments of facies C may grade vertically and horizontally into the massive marine silty clay of facies D which was deposited at and beyond the ice front. This transition records progressively more distal conditions as the ice margin retreated; comparable facies are reported from modern tidewater settings in Alaska and Spitsbergen (Elverhoi, 1984; Mackiewicz et al., 1984; Powell, 1983). Following the retreat of the ice sheet, the deposition of facies D dominated in the offshore environments of the postglacial sea.

Ice-contact glaciomarine deltas define a progressively higher and younger marine limit towards the east, from approximately 10 m a.s.l. in the northern half of Parry Peninsula to 225 m a.s.l. in southern Bathurst Inlet (Fig. 12 and 13). Following the establishment of marine limit during deglaciation, a significant decrease in delta building occurred. Few truly marine deltas were constructed in postglacial time, save those associated with the larger rivers draining into the sea. This suggests that a high concentration of sediments were deposited by meltwater early in the deglacial glaciomarine phase over a short period of time. Sedimentation was significantly reduced following this initial influx of sediment. During deglaciation, sedimentation at any one site is generally related to the proximity of the former ice. However, it is the duration of submergence and the proximity to sediment sources that primarily controlled marine sedimentation in postglacial time, notably in the eastern regions of the study area. Only in relatively deep coastal embayments with important fluvial input were marine sediments of facies D permitted to accumulate to significant thicknesses. Where large amounts of fresh water entered the marine environment and tidal influence was greatest, sublittoral and littoral rhythmites (facies E) were deposited. Coarser debris formed the littoral deposits such as beaches, capping the fines and completing a coarsening upward off-lap marine sequence.

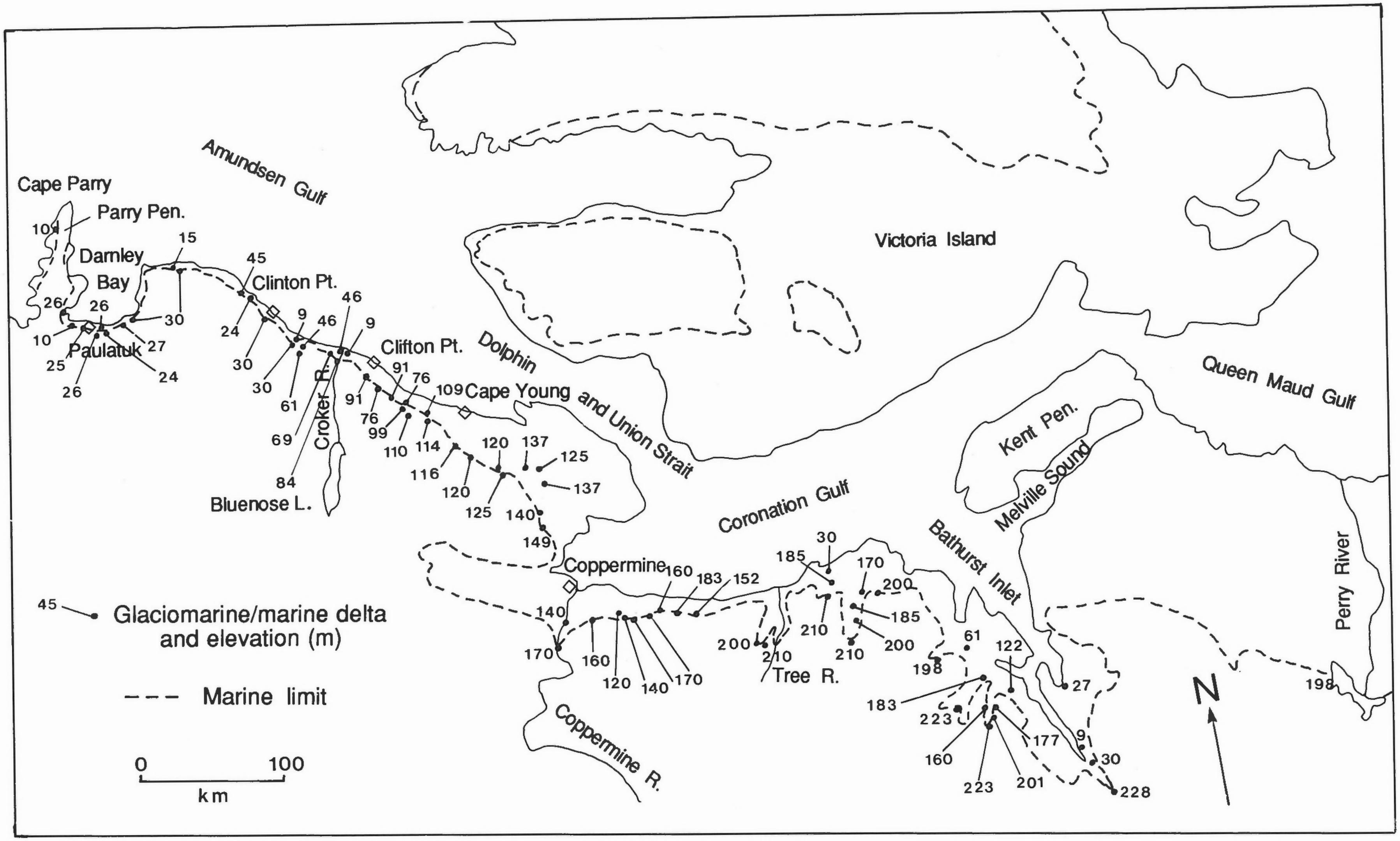

Figure 12. *Location map of the study area showing position of marine limit, and glaciomarine and marine deltas. Marine limit is extrapolated between deltas, strandlines, and washing limits of known elevation. Data for Victoria Island modified from Sharpe (1984, 1988a) and Dyke and Prest (1987a, b).*

Throughout the marine regression, marine action led to wave washing of the progressively emerging landscape, as occurs along the present-day coastline (Fig. 14). Rapid postglacial emergence exposed the sediments to extensive subaerial erosion, giving rise to locally extensive gullying and the formation of badland topography, notably in areas characterized by thick accumulations of glaciomarine and marine silt and clay.

LATE QUATERNARY DEGLACIATION RECONSTRUCTION

A correlation of successive Laurentide ice-margins during deglaciation between the present study region and adjoining areas is presented in Figure 15. Correlations are based on the present study and previous interpretations by Klassen (1971), Vincent (1984), Hughes (1985), Dyke and Prest (1987a, b), McMartin and St-Onge (1990), and Sharpe (1992). Selected existing radiocarbon dates (Table 3) provide minimum ages for the diachronous deglaciation of the coastal lowlands and surrounding area. Approximately seven major provisional ice front positions have been identified and assigned tentative ages for the purpose of discussion. Within the study area, these ice margins have been defined on the basis of isolated landforms such as moraines, kames, glaciofluvial outwash complexes, meltwater channels, and washing limits. In regions with little or no geomorphic evidence, extrapolations have been made for purposes of discussion.

Position 1 delineates the Late Wisconsin glacial limit at 18 ka. Some of the moraines of Parry Peninsula (Fig. 1) and meltwater channels in the western Melville Hills formed subsequently (position 2). At position 2, marine limit was established at 10 m a.s.l. on the north end of Parry Peninsula. As inferred from Dyke and Prest (1987a), the Late Wisconsin maximum ice front remained stationary for at least 5000 years (18 ka to 13 ka) and by 12 ka, had receded to position 3. Although no radiocarbon data are available to date position 2,

Figure 13. Perched glaciomarine delta at 1) 221 m a.s.l. and marine deltas at 2) 200 m a.s.l. and 3) 177 m a.s.l., near the mouth of the Burnside River valley; view is to the south. GSC 1993-209I

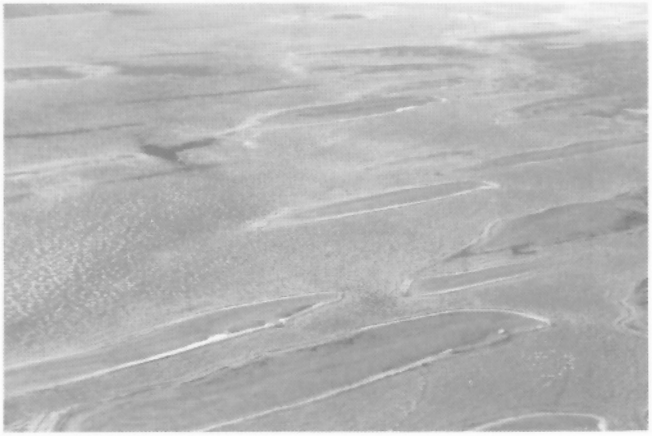

Figure 14. Drumlin field east of the study area in which drumlins have been reworked into raised beaches as a result of coastal emergence; drumlins display increasing degrees of modification by wave action with decreasing elevation; view is to the northeast. Approximate length of drumlin in centre of photo is 1.5 km. GSC 1993-209J

Table 3. Selected radiocarbon dates from the study area. See Figure 15 for locations.

No.	Laboratory No.	Age (years BP)	Elevation (m)	Material dated	Reference
1	AECV-643Cc	11 790 ± 160	5	*Hiatella arctica*	This paper
2	GSC-4318	10 700 ± 100	30	*Hiatella arctica*	D.A. St-Onge (pers. comm., 1990)
3	I(GSC)-25	10 530 ± 260	74	marine shells	Craig, 1960
4	GSC-3663	10 300 ± 240	90	*Macoma calcarea*	Mercier, 1984
5	TO-1231	11 170 ± 80	125	*Portlandia arctica*	D.A. St-Onge (pers. comm., 1990)
6	I(GSC)-17	10 215 ± 220	85	*Macoma calcarea*	Craig, 1960
7	GSC-42	9710 ± 150	158	marine shells	Dyck and Fyles, 1963
8	GSC-3584	9620 ± 130	198	*Hiatella arctica*	Blake, 1983
9	GSC-125	9190 ± 210	186	*Mya truncata*	Blake, 1963
10	GSC-115	8370 ± 100	198-204	*Hiatella arctica*	Blake, 1963
11	GSC-110	8160 ± 140	183	*Hiatella arctica*	Blake, 1963

its age has been tentatively inferred to be approximately 12.5 ka, as it lies outside of the radiocarbon date number 1 (Table 3, Fig. 15) site constrained by a date of 11.79 ka. The stratigraphic position and age of these shells near the base of marine sediments overlying glacial diamicton suggest the east side of Darnley Bay was deglaciated by at least 11.8 ka. Glaciomarine deltas south and east of Darnley Bay at 24-30 m a.s.l. mark local marine limits established during deglaciation (Fig. 12).

As the ice lobe occupying Amundsen Gulf retreated from position 1 to position 2, active ice flowed west into the gulf and southwest into Darnley Bay. St-Onge and McMartin (1987) interpreted the drumlin fields east of Bluenose Lake as the result of ice-moulding by late glacial, westward flowing ice being redirected towards a calving bay in Amundsen Gulf and undergoing rapid extensive flow. An alternative hypothesis is suggested by Potschin (1989) for drumlin formation south of Dolphin and Union Strait. Briefly, she proposes that they may have resulted from glaciofluvial meltwater erosion of lodgement till during ice stagnation as opposed to ice moulding. As the theory of drumlin formation is beyond the scope of this paper, the reader is referred to Potschin (1989) and references therein for a detailed morphological description and discussion on the origin of these drumlins. Kames and outwash fans northwest, north, and east of the Melville Hills indicate that the ice lobe receded towards successively lower elevations. Some of the morainic ridges east of Bluenose Lake (Fig. 1 and position 3) may coincide with the Inman River Phase of McMartin and St-Onge (1990). The association of position 3 with the ice marginal positions south of Bluenose Lake identified by Prest (1985) is uncertain as no radiometric dates are available for correlation.

The ice front between positions 3 and 4 corresponds to moraines in the region north of the Rae River, whereas position 4 is associated with a series of arcuate morainal segments southwest of Dolphin and Union Strait (Fig. 1). During the period of ice retreat from positions 3 to 4, northwestward flowing ice eventually separated into distinct lobes occupying Dolphin and Union Strait and the Rae and Richardson river basin. Northwest-trending drumlins were subsequently modified by west-northwest ice flow resulting from a redirection of ice caused by the marine incursion (McMartin and St-Onge, 1990). Deglaciation of the coast and synchronous marine incursion of the isostatically depressed terrain east of Darnley Bay occurred prior to 11.8 ka (No. 1, Table 3) whereas south of Dolphin and Union Strait, the marine incursion took place before 11.2 ka (No. 5, Table 3). Ice at position 4 at 11 ka differs from the model proposed by Dyke and Prest (1987a) for the same period who show a slightly more extensive ice cover towards the west at this time.

Following a minor retreat of the ice front from position 4, marine waters inundated the basin of the Rae and Richardson rivers from the northeast by means of a corridor between the

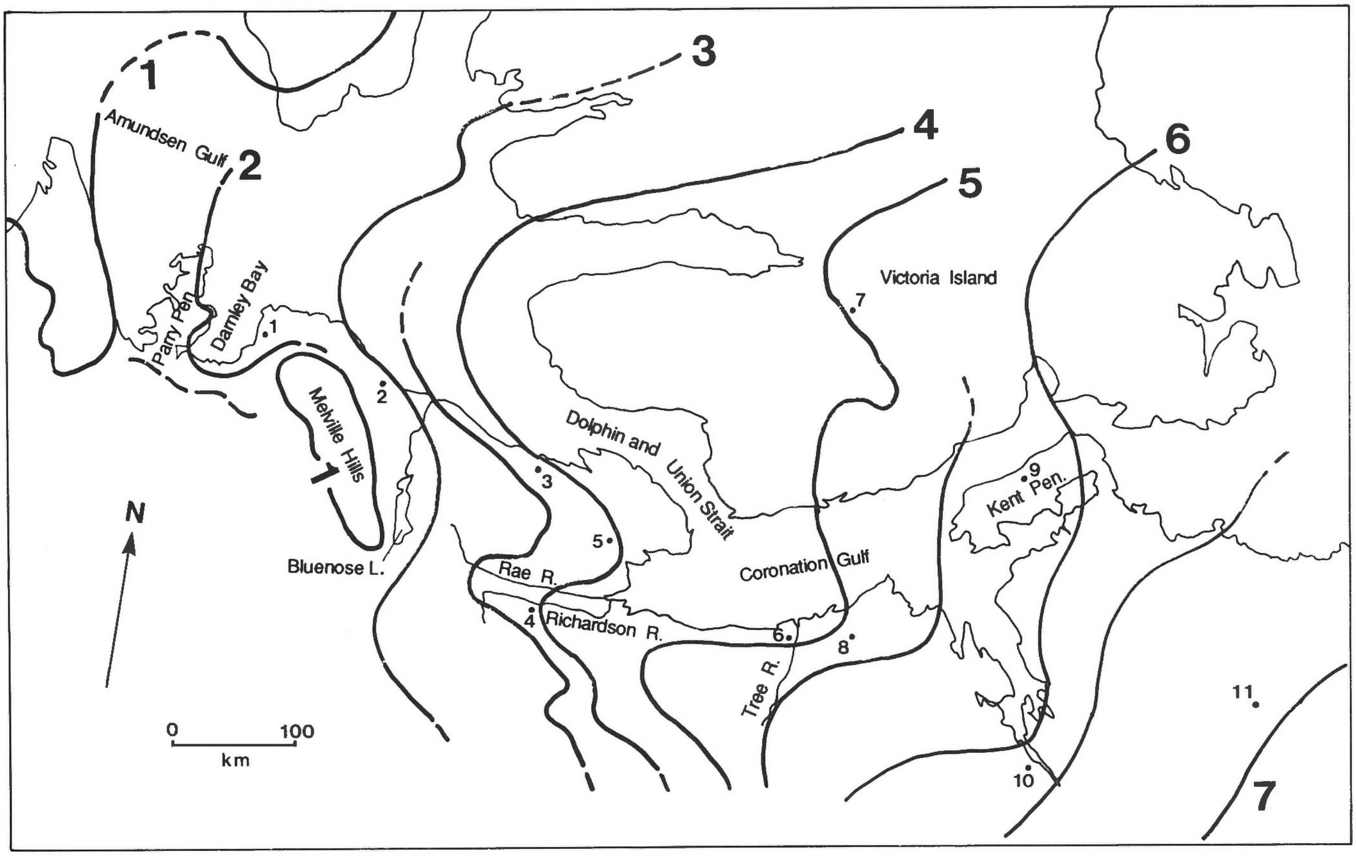

Figure 15. Late Wisconsin and Early Holocene provisional patterns of ice retreat. Modified in part from Dyke and Prest (1987a, b), McMartin and St-Onge (1990), and Sharpe (1992).

higher uplands inland and the ice lobe occupying Dolphin and Union Strait. The marine invasion occurred before 10.3 ka which is the oldest date obtained in the basin from marine shells at 90 m a.s.l. (No. 4, Table 3). Southeastern retreating ice occupying Dolphin and Union Strait was redirected to a southwestern flow coming from Victoria Island to the northeast. This flow direction crosses striae originating from the previous northwestward flow (McMartin and St-Onge, 1990). South of Dolphin and Union Strait, a series of discontinuous, arcuate morainic ridges (Fig. 1) mark the northeastward retreat of the Victoria Island ice lobe occurring both above and below the local marine limit of 130-140 m a.s.l. (Fig. 12). Ridges composed of stratified sandy gravel are interpreted as subaqueous outwash deposits. Those formed of matrixsupported diamicton are inferred to be ice-deposited moraines. Two glaciomarine ice-contact deltas associated with these ridges were constructed in the narrow arm of the sea between land and ice occupying Dolphin and Union Strait. Immediately to the east of these morainic ridges, several smaller diamicton ridges are found, and are interpreted as moraines formed by the receding ice front which then terminated in the sea. These smaller moraines are superimposed on drumlins and they are oriented perpendicular to the long axis of the drumlins (Fig. 16).

Invasion of the sea into the area west of Coronation Gulf led to a rapid disintegration of the ice mass and a reduction of the two distinct ice lobes of position 4. This allowed the sea to occupy the coastal lowlands on the southern shore of Coronation Gulf. At Coppermine, marine limit was established at 170 m a.s.l. (St-Onge, 1987). Two radiocarbon dates help reconstruct the ice marginal position of position 5 at 10 ka (No. 6 and 7, Table 3); the ice front must have been located west of the 9.7 ka site on Victoria Island, and east of the 10.2 ka location at the Tree River on the mainland where marine limit is about 200 m a.s.l. The ice margin between positions 5 and 6 is marked by a moraine south of Coronation Gulf (Fig. 1) that probably formed between 9.6 ka (No. 8, Table 3) and 9.2 ka (No. 9, Table 3). The ice sheet continued its eastward retreat so that by 9 ka, it had reached position 6 in the Bathurst Inlet region. During this period, a series of ice-contact glaciomarine deltas with collapse structures on their landward side were formed along the ice margin.

Figure 16. Transverse morainal ridges superimposed perpendicular to drumlins, southwest of Dolphin and Union Strait; centre drumlin is 0.5 km in length; view is to the west. GSC 1993-209K

The period from positions 6 to 7 is characterized by rapid ice retreat between 9 ka and 8.7 ka (No. 10 and 11, Table 3), although at least one period of stillstand occurred during which moraines were built (Fig. 1) southeast of Kent Peninsula. From 9 ka to 8.4 ka Laurentide ice retreated from central Boothia Peninsula a few hundred kilometres to the east of the study area, south to the mainland coast (Dyke, 1984). Position 7 represents the last ice marginal position in the study area at approximately 8.7 ka. This ice front is associated with a large end moraine known as the MacAlpine Moraine (Blake, 1963) which extends over a distance of 320 km. Whether this moraine is related to the Chantry Moraine System (Dyke, 1984) south of Boothia Peninsula is unknown at present.

ECONOMIC ASPECTS OF SURFICIAL GEOLOGY

This region is experiencing renewed economic interest as new transportation infrastructure development and upgrading has been proposed. An understanding of Quaternary sediments and landforms provides baseline data for future economic activity. A description or model of the surficial geology, constructed from geomorphic and stratigraphic sequences, provides a predictive geological tool to infer changes in subsurface sediment type, distribution, thickness, and continuity. This aids in the implementation of territorial land use regulations, economic and environmental planning, and terrain sensitivity rating. Improved accessibility to the Central Arctic coast through construction of new roads, airports, docks, harbours, rail connections, and pipelines would create greater opportunity for travel, trade, tourism, fishing, mining, and development of renewable and nonrenewable resources. Such programs require corridor studies early in the planning stages to assess the potential for economic sources of accessible aggregate reserves for construction and maintenance purposes.

The Kitikmeot region south of Coronation Gulf and Bathurst Inlet is an area with thin drift cover, known mineral reserves and high mineral potential for base metals and polymetallic deposits. Road access to this region would connect Yellowknife to currently defined base metal and precious metal deposits and stimulate further mineral exploration and mining activity.

Surficial glaciofluvial complexes are major sources of granular materials inland. Raised glaciomarine and glaciolacustrine deltas and beaches, as well as buried outwash sediments, are also important aggregate deposits. In coastal areas which experienced marine submergence, the overall stratigraphic record consists of a coarsening-upward sequence, capped by sandy littoral sediments. Aggregate distribution, quality, and quantity vary greatly throughout the area. Deposit thickness ranges from 0.0 m to >25 m, and includes poorly sorted to well sorted, silt- and clay-sized particles to large cobbles and boulders. Factors which may influence the mining of sand and gravel pits and make certain reserves uneconomical at the present time are a thick overburden cover, the presence of permafrost from as little as 0.2 m to greater than 1.0 m below ground level, and consequently water ponding on pit floors. Excavations during late summer would coincide with maximum depth of thaw.

It is essential to achieve an understanding of the geology in order to guide any studies and make informed decisions regarding engineering construction. Consultation with appropriate authorities and consultants experienced in geotechnical investigations in Arctic environments is recommended prior to any development and reclamation.

CONCLUSIONS

Stratigraphic studies in the Parry Peninsula-Perry River region, Northwest Territories help elucidate the Late Quaternary deglaciation history, as knowledge of the glacial geology is generally based on large-scale physiographic reconnaissance surveys. A well-defined successions of distinct sedimentary facies is recorded. Beginning with the retreat of the Laurentide Ice Sheet through to its progressive collapse, these facies resulted from a wide variety of rapidly changing environmental conditions. The latter are related to unstable, dynamic ice-lobe margins terminating in the sea. In this environment, high concentrations of sediments were deposited by meltwater early in the deglacial glaciomarine phase over a short period of time. Although sedimentation was significantly reduced following this initial influx of sediment, considerable thicknesses of marine silty clay accumulated in deep-water environments throughout the marine regression. Massive till produced mainly by lodgement of glacial debris by thin, active ice, was initially deposited on bedrock. Stratified glacial diamictons, often overlying lodgement till, resulted from a combination of debris flows and iceberg rain-out modified by subglacial meltwater processes near the ice front during ice retreat.

Subaqueous outwash deposits issuing from subglacial conduits form a facies sequence which may show several variations. Crossbedded sand and gravel, massive sand, and planar to cross-laminated fine sand and silt are deposited near the mouth of the ice tunnel. The transition to interlaminated sand, silt, and clay represents a progressive decrease in current velocity in the downflow direction. Sedimentation dominated by sediment-laden underflows, interflows, and overflows both near the ice margin and at a distance, led to the deposition of glaciomarine rhythmites. Beyond the influence of the ice sheet and following deglaciation, massive silty clay was deposited in the open marine environment. As the sea regressed to lower elevations due to crustal rebound, sublittoral and littoral deposits completed the sedimentary succession.

Ice retreat has left a well-defined, orderly sedimentary succession which is generally consistent along the coast for a distance of 1000 km. The distribution and lateral extent of each facies falls within a sequence in which ice-proximal sediments (facies A, B, C) and marine sediments (facies D) would be expected to migrate landward during ice retreat, whereas marine sublittoral and littoral deposits (facies E, F, G) would migrate seaward during the marine regression. Within this complete sequence, two distinct grain size trends have been observed: a fining-upward sequence formed by the retreat of the ice sheet in a glaciomarine environment (diamicton, outwash, rhythmites), and a conformably overlying coarsening-upward regressive marine sequence (silty clay, sandy rhythmites, sand, and gravel).

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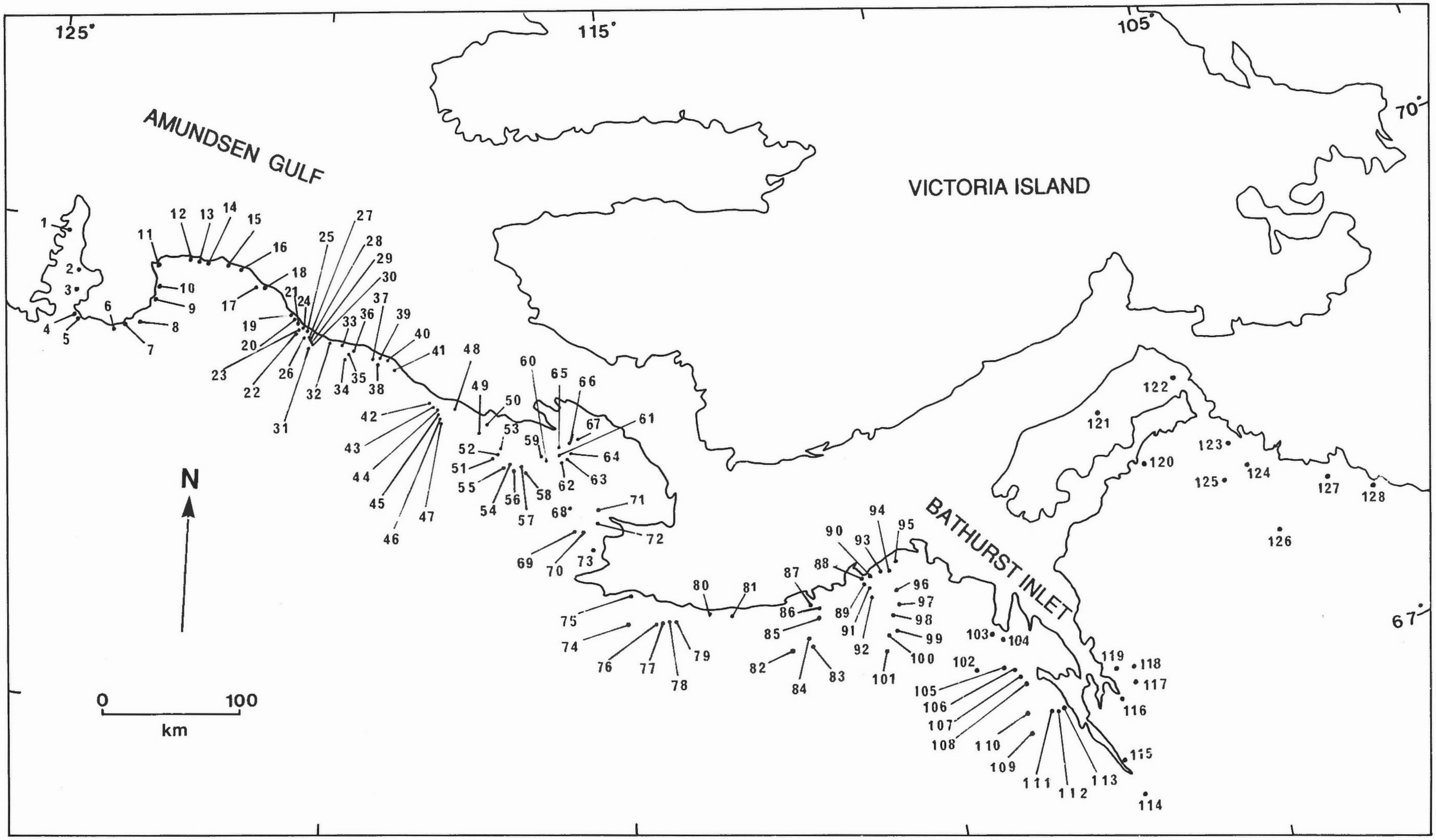
APPENDIX 1

Location of stratigraphic sections



APPENDIX 2

Description of stratigraphic sections

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
1	5	0.0 - 0.5		cliff top dunes
		0.5 - 1.5	F	
		1.5 - 5.0	E	
2	27.5	0.0 - 13.5	B	paleocurrent towards 205°, 315°
3	30.5	0.0 - 12.0	B	paleocurrent towards 345°-045° rare coal fragments
4	9	0.0 - 9.0	E	abundant organic detritus
5	9.5	0.0 - 7.0	G	paleocurrent towards 335°
		7.0 - 9.5	D	
6	26	0.0 - 26.0	G	paleocurrents towards 060°, 065° rare coal fragments
7	6	0.0 - 6.0	F	paleocurrent towards 065°
8	30.5	0.0 - 12.0	G	paleocurrent towards 345°
		12.0 - 15.0	A1	
9	6.5	0.0 - 1.0	F	
		1.0 - 3.0	D	fossiliferous
		3.0 - 5.5	A1	
		5.5 - 6.5		dolomite
10	12	0.0 - 3.0	D	fossiliferous
		3.0 - 5.0	A1	
		5.0 - 12.0		shale
11	6	0.0 - 0.5	D	
		0.5 - 3.5	A1	
		3.6 - 6		covered
12	15	0.0 - 4.0	E	
		4.0 - 11.0	D	
		11.0 - 15.0		covered
13	15	0.0 - 8.0	G	paleocurrent towards 270°
14	31.6	0.0 - 5.0	C	
		5.0 - 6.0	B	paleocurrent towards 345°
		6.0 - 7.0		covered
15	16.5	0.0 - 3.5	B	fossiliferous
		3.5 - 5.0	A1	
		5.0 - 8.0		dolomite
16	28	0.0 - 8.0		covered
		8.0 - 18.0	C	
		18.0 - 26.0	B	paleocurrent towards 020°-060°
		26.0 - 28.0		covered
17	24	0.0 - 12.0	E	fossiliferous
		12.0 - 18.0	D	
18	21	0.0 - 6.0	F	
19	25	0.0 - 20.0	A1	
		20.0 - 23.0		dolomite
		23.0 - 25.0		covered

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
20	24	0.0 - 6.0	A2	
		6.0 - 8.0	A1	
21	15	0.0 - 13.0	A1	surface fossiliferous
22	45	0.0 - 8.0	A1	
23	25	0.0 - 6.0	D	surface fossiliferous
24	15	0.0 - 2.0	F	fossiliferous
		2.0 - 6.0		covered
25	30	0.0 - 2.5	D	fossiliferous
		2.5 - 4.0	C	
		4.0 - 5.0	B	paleocurrent towards 325°
		5.0 - 9.5	A2	
		9.5 - 15	A1	
26	46	0.0 - 4.0	G	paleocurrent towards 220°, 035°
		4.0 - 7.5	B	
		7.5 - 17.5	A1	
27	30	0.0 - 7.5	F	
		7.5 - 20.0	C	
		20.0 - 24.0	B	
		24.0 - 26.0	A2	
		26.0 - 28.0	B	
		28.0 - 29.0	A2	
		29.0 - 31.0	B	
		31.0 - 32.0	A2	
28	46	0.0 - 32.0	G	paleocurrent towards 025°-080°
29	39	0.0 - 30.0	A2	fossiliferous
30	43	0.0 - 3.0	F	
		3.0 - 7.0	E	
		7.0 - 11.0	D	
		11.0 - 30.0	A2	
31	61	0.0 - 8.0	G	paleocurrent towards 005°
		8.0 - 15.0	A2	
		15.0 - 30.0	A1	
32	45	0.0 - 13.0	G	paleocurrent towards 000°-020°
		13.0 - 19.0	D	
33	30	0.0 - 5.0	C	
		5.0 - 9.0	B	paleocurrent towards 010°
34	61	0.0 - 9.0	B	paleocurrent towards 240°-340°
35	61	0.0 - 2.0	D	
		2.0 - 5.5	C	
		5.5 - 13.0	B	paleocurrent towards 230°, 250°
36	61	0.0 - 1.5	D	
		1.5 - 2.0	C	
		2.0 - 13.0	B	paleocurrent towards 320°-010° soft sediment deformation
37	52	0.0 - 2.0	D	fossiliferous
		2.0 - 10.0	C	

Appendix 2. (cont'd.)

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
38	46	0.0 - 3.5	D	fossiliferous
		3.5 - 4.0	B	
		4.0 - 6.0	A1	
39	30	0.0 - 2.0	F	fossiliferous, paleocurrent towards 205°
		2.0 - 4.0	D	fossiliferous
		4.0 - 5.0	C	
		5.0 - 6.5	A1	
		6.5 - 8.0		dolomite, striae 310°
40	15	0.0 - 4.5	F	
41	14	0.0 - 1.0	F	
		1.0 - 4.2	E	fossiliferous
42	53	0.0 - 12.0	C	
		12.0 - 15.0	B	
		15.0 - 16.0	A1	
43	53	0.0 - 5.0	C	
		5.0 - 8.5	B	
		8.5 - 9.0	A1	
		9.0 - 12.0		dolomite, striae 330°
44	75	0.0 - 5.0	E	
		5.0 - 27.0	C	
		27.0 - 28.0	B	
		28.0 - 29.0	A1	
		29.0 - 30.0		dolomite
45	61	0.0 - 12.0	C	
		12.0 - 12.5	B	
		12.5 - 13.0	A1	
		13.0 - 17.0		dolomite, striae 330°
46	69	0.0 - 22.0	C	
		22.0 - 28.0	B	
		28.0 - 29.0	A1	
47	91	0.0 - 12.0	G	paleocurrent towards 348°
48	107	0.0 - 17.0	G	paleocurrent towards 000°-035°
49	76	0.0 - 4.0	F	fossiliferous
		4.0 - 8.0	D	
		8.0 - 14.0	A2	paleocurrent towards 039°, 050°
		14.0 - 15.0		dolomite, striae 310°, 340°
50	30	0.0 - 4.0	E	fossiliferous
		4.0 - 6.0	D	
51	90	0.0 - 10.0	G	paleocurrent towards 030°
		10.0 - 17.0	B	
		17.0 - 19.0	C	
		19.0 - 21.0	B	
52	75	0.0 - 1.0	F	
		1.0 - 11.0	D	fossiliferous
53	75	0.0 - 1.0	F	
		1.0 - 11.0	D	
		11.0 - 12.0	A1	
		12.0 - 13.0		dolomite, striae 310°, 332°

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
54	110	0.0 - 2.0	F	
		2.0 - 11.0	C	
		11.0 - 20.0	B	rip-up clasts paleocurrent towards 275°, 295°
55	100	0.0 - 14.0	C	
		14.0 - 16.0	B	
56	90	0.0 - 19.0	C	
57	105	0.0 - 1.0	F	
		1.0 - 16.0	C	paleocurrent towards 315°
		16.0 - 21.0	B	
58	110	0.0 - 5.0	G	paleocurrent towards 190°-335°
		5.0 - 12.0	C	paleocurrent towards 195°
59	100	0.0 - 15.0	C	
60	110	0.0 - 5.0	D	
		5.0 - 12.0	C	
61	125	0.0 - 2.0	A2	
		2.0 - 12.0	B	paleocurrent towards 090°-115°
62	118	0.0 - 10.5	B	paleocurrent towards 292°, 330°
63	115	0.0 - 1.0	D	
		1.0 - 5.0	C	
		5.0 - 8.0	B	paleocurrent towards 125°-140°
64	137	0.0 - 11.0	B	paleocurrent towards 200°-330°
65	27	0.0 - 3.0	F	cryoturbated
		3.0 - 6.0	E	
		6.0 - 12.0	D	
66	27	0.0 - 2.0	F	
		2.0 - 12.0	D	
67	18	0.0 - 3.0		cliff top dunes
		3.0 - 7.0	F	fossiliferous
		7.0 - 17.0	E	fossiliferous
68	152	0.0 - 19.0	G	paleocurrent towards 015°-035°
		19.0 - 22.0	D	
69	125	0.0 - 5.0	C	fossiliferous paleocurrent towards 264°
		5.0 - 10.0	B	paleocurrent towards 222°-358°
70	116	0.0 - 2.0		cliff top dunes
		2.0 - 8.0	C	paleocurrent towards 048°
		8.0 - 16.0	B	paleocurrent towards 070°, 075°
		16.0 - 20.0		covered
71	45	0.0 - 10.0	D	
72	21	0.0 - 13.0	D	
73	30	0.0 - 10.0	B	
74	40	0.0 - 2.0	F	
		2.0 - 4.0	E	organic detritus
		4.0 - 24.0	D	fossiliferous

Appendix 2. (cont'd.)

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
75	20	0.0 - 5.0	G	paleocurrent towards 090° fossiliferous
		5.0 - 13.0	D	fossiliferous
76	140	0.0 - 9.5	G	paleocurrent towards 250°
		9.5 - 12.0	A1	
		12.0 - 14.0		sandstone
77	140	0.0 - 35.0	G	
78	100	0.0 - 3.0	D	
		3.0 - 25.0	C	fossiliferous
79	110	0.0 - 6.0	B	fossiliferous
80	183	0.0 - 7.5	G	paleocurrent towards 310°-320° fossiliferous
		7.5 - 9.5	D	fossiliferous
		9.5 - 15.0	C	
		15.0 - 18.0	B	
		18.0 - 19.5	A2	
		19.5 - 22.0		bedrock, striae 350°
81	152	0.0 - 5.0	G	paleocurrent towards 310°-360° fossiliferous
		5.0 - 7.0	D	fossiliferous
		7.0 - 32.0	C	fossiliferous
82	177	0.0 - 3.5	D	fossiliferous
83	137	0.0 - 5.0	D	fossiliferous
84	91	0.0 - 10.0	A2	
		10.0 - 12.0		granite
85	55	0.0 - 10.5	D	fossiliferous
86	46	0.0 - 3.0	F	
		3.0 - 7.0	E	fossiliferous
		7.0 - 23.0	D	fossiliferous, sandy lenses
87	30	0.0 - 12.0	E	abundant organic detritus
88	23	0.0 - 9.0	G	paleocurrent towards 340°
89	30	0.0 - 12.0	G	paleocurrent towards 000°
90	31	0.0 - 1.0	F	
		1.0 - 7.0	E	organic detritus, fossiliferous
91	91	0.0 - 5.0	D	fossiliferous
92	225	0.0 - 17.5	G	paleocurrent towards 320°-010°
93	30	0.0 - 2.5	G	paleocurrent towards 010°
		2.5 - 7.0	E	
		7.0 - 22.5	D	
94	61	0.0 - 15.0	D	
		15.0 - 22.5	C	dropstones
		22.5 - 23.0	A2	
		23.0 - 25.0		granite, striae 310°
95	30	0.0 - 2.0	G	paleocurrent towards 285°-005°
		2.0 - 8.0	E	organic detritus
		8.0 - 21.0	D	fossiliferous

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
96	145	0.0 - 30.0	C	
97	122	0.0 - 23.0	G	paleocurrent towards 310°-330°
		23.0 - 38.0	D	fossiliferous
		38.0 - 40.0	A1	
98	152	0.0 - 14.0	G	paleocurrent towards 020°
99	205	0.0 - 7.0	D	
100	210	0.0 - 11.0	G	
101	210	0.0 - 12.0	G	
102	198	0.0 - 8.0	G	paleocurrent towards 010°-020°
		8.0 - 18.0	C	
		18.0 - 20.0	B	paleocurrent towards 060°-090°
		20.0 - 22.0		granite, striae 345°
103	34	0.0 - 10.0	D	fossiliferous
		10.0 - 14.5	C	dropstones
		14.5 - 15.5	B	paleocurrent towards 005°
		15.5 - 20.0	A2	
104	35	0.0 - 5.0		cliff top dunes
		5.0 - 15.5	E	paleocurrent towards 300°-340° organic detritus
		15.5 - 31.0	D	
		31.0 - 34.0	C	
105	61	0.0 - 9.0	E	
		9.0 - 27.5	C	fossiliferous, dropstones
		27.5 - 34.0	A1	
106	91	0.0 - 4.0	A2	
		4.0 - 16.0	C	
		16.0 - 23.0	A2	
		23.0 - 26.0		siltstone, striae 355°
107	152	0.0 - 10.0	F	
		10.0 - 23.0	C	fossiliferous, dropstones
		23.0 - 31.0	A2	
		31.0 - 34.0		siltstone
108	183	0.0 - 8.0	G	paleocurrent towards 275°-020°
		8.0 - 17.0	C	fossiliferous, sand lenses
		17.0 - 19.0	A2	
		19.0 - 24.0	A1	
109	171	0.0 - 2.0	A2	
		2.0 - 27.5	B	paleocurrent towards 355°-070° dropstones
110	182	0.0 - 15.0	C	
		15.0 - 22.0	B	
		22.0 - 31.0	A2	paleocurrent towards 065°
111	91	0.0 - 14.0	C	fossiliferous
		14.0 - 16.0	B	
		16.0 - 38.0	A1	
		38.0 - 42.0		covered
112	58	0.0 - 24.0	C	soft sediment deformation dropstones, fossiliferous
		24.0 - 29.5	B	paleocurrent towards 300°
		29.5 - 32.0		siltstone, striae 320°

Appendix 2. (cont'd.)

Section	Elevation of top (m)	Depth below top (m)	Facies	Characteristics
113	33	0.0 - 3.5		cliff top dunes
		3.5 - 7.0	F	
		7.0 - 27.0	E	fossiliferous
114	70	0.0 - 6.0	F	
		6.0 - 10.0	D	
		10.0 - 17.0	C	
		17.0 - 22.0	A1	
115	30	0.0 - 15.0	G	paleocurrent towards 310°-320° organic detritus
116	9	0.0 - 9.0	E	fossiliferous, organic deritus
117	67	0.0 - 6.0	F	
		6.0 - 8.0	D	
		8.0 - 12.0	C	fossiliferous
		12.0 - 19.0	A1	
118	18	0.0 - 7.0	E	organic detritus, soft sediment deformation
119	24	0.0 - 5.0	F	
		5.0 - 9.0	E	
		9.0 - 13.0	D	fossiliferous, dropstones
		13.0 - 15.0	B	paleocurrent towards 305°
120	9	0.0 - 1.0		cliff top dunes
		1.0 - 9.0	E	fossiliferous, organic detritus
121	128	0.0 - 9.0	B	
122	62	0.0 - 6.5	E	fossiliferous
123	14	0.0 - 0.5	F	cryoturbated
		0.5 - 1.5	E	
		1.5 - 9.0	D	fossiliferous
		9.0 - 10.0	B	
		10.0 - 10.5	A2	
		10.5 - 11.0		granite, striae 305°
124	20	0.0 - 11.0	D	fossiliferous
125	27	0.0 - 2.0	D	fossiliferous
		2.0 - 2.5	A2	
		2.5 - 7.5		gneiss, striae 358°
126	31	0.0 - 15.0	D	fossiliferous
		15.0 - 17.0	C	
		17.0 - 17.5	B	
		17.5 - 18.5	A2	
		18.5 - 19.5		granite, striae 345°
127	22	0.0 - 9.0	D	fossiliferous
128	7	0.0 - 0.5	E	organic detritus
		0.5 - 6.0	D	
		6.0 - 6.5		covered
		6.5 - 7.0		gneiss, striae 325°