LATE QUATERNARY GLACIAL AND SEA LEVEL HISTORY OF THE BERNIER BAY AREA, NORTHWESTERN BAFFIN ISLAND, N.W.T.

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Abstract

During the 1988 field season data were gathered for an investigation of the glacial and sea level history of the Bernier Bay area, northwestern Baffin Island. Twenty-eight new radiocarbon dates were obtained on samples of marine shells and whalebone. The dates indicate that the area was deglaciated by about 8200 BP by ice receding toward the east. Marine limit in the field area is approximately 120 m asl and decreases in age towards the east. Dates on whalebone collected from raised beaches have been used to construct three emergence curves. The curves show an exponential decline in the rate of postglacial emergence from an early Holocene maximum. The radiocarbon dates and geomorphic evidence are consistent with the interpretation that the bay was occupied by a large ice stream which flowed westward from the Foxe Dome. Prior to the Cockburn Phase (8000-9000 BP), the ice tongue uncoupled from the seabed to form an extensive ice shelf. Large lateral moraines along the north and south coasts of the bay, deposited during this interval, have a near horizontal profile indicating deposition by an ice shelf rather than grounded ice. An independent ice cap was also present on southern Brodeur Peninsula during this interval.

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Table of Contents

List of Tables

List of Figures

Chapter One: Introduction

Research conducted around Bernier Bay Area during the months of July and August 1988 has enabled the reconstruction of the glacial history of the area and measurement of Holocene sea level fall. This work was conducted as part of the requirements for an M.Sc. degree in physical geography from Memorial University of Newfoundland. Logistical support for fieldwork was provided by the Terrain Sciences Division of the Geological Survey of Canada as part of an ongoing research project on the glacial history of Baffin Island.

Twenty-eight new radiocarbon dates are available and these have been used to date deglaciation, the Holocene marine limit and to construct three emergence curves. Fourteen dates are on bones of the bowhead whale, ***Balaena mysticetus***, with eight on shells of the common arctic molluscs *Mya truncata* and *Hiatella arctica*. Textural and granule lithological analyses were conducted on seventy samples of till, weathered glaciofluvial gravel and residuum and these, together with field observations, are used to characterize the major surficial units of the area.

The field area on northwestern Baffin Island lies between 70°45' N and 71°30' N and between 87°00' W and 90°00' W (Fig. 1-1). Consisting of areas along the north and south shores of Bernier Bay, it encompasses some 4000 square kilometers. Bernier Bay is a long (100 km), shallow bay at the southern end of Brodeur Peninsula. The head of the bay is separated from Berlinguet Inlet to the east by a narrow isthmus. Bernier Bay and Berlinguet Inlet occupy a large east-west trending valley which connects with Admiralty Inlet to the north of the study area (Fig. 1-2).

The climate of the study area is characterized by long, dark and extremely cold winters and short, cool summers. It is also relatively dry with a summer precipitation maximum. Data from two stations are used to approximate the climate of the study area, located midway between Arctic Bay on the west side of Borden Peninsula, and Spence Bay on the west side of Boothia Peninsula. The location of the climate stations is shown in Figure 1-1; climate data are given in Table 1.

Table 1. Climate Data for Arctic Bay and Spence Bay

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average daily mean temperatures (°C)													
AB	-29.7	-31.2	-28.7	-20.3	-8.0	1.5	5.6	4.6	-1.7	-11.4	-22.4	-27.4	-14.1
SB	-33.7	-35.1	-31.5	-22.1	-9.5	1.1	7.4	6.4	-1.0	-12.1	-23.4	-30.3	-15.3
Average monthly rainfall (mm)													
AB	0.0	0.0	0.0	0.0	0.0	4.1	19.1	23.1	8.4	0.0	0.0	0.0	54.6
SB	0.0	0.0	0.0	0.0	0.0	6.9	24.9	29.0	11.9	0.3	0.0	0.0	72.9
Average monthly snowfall (cm)													
AB	5.8	4.3	5.6	4.1	6.6	3.6	0.3	0.8	13.5	15.2	6.9	4.6	71.1
SB	4.6	5.6	6.1	5.6	8.1	8.4	0.3	0.0	10.2	19.3	7.6	5.1	80.8
Average monthly precipitation (mm)													
AB	5.8	4.3	5.6	4.1	6.6	7.6	19.3	24.1	21.6	15.2	6.9	4.6	125.7
SB	4.6	5.6	6.1	5.6	8.1	15.2	25.1	29.0	21.8	19.6	7.6	5.1	153.4

AB Arctic Bay

SB Spence Bay

Source: Atmospheric Environment Service 1973, 1982.

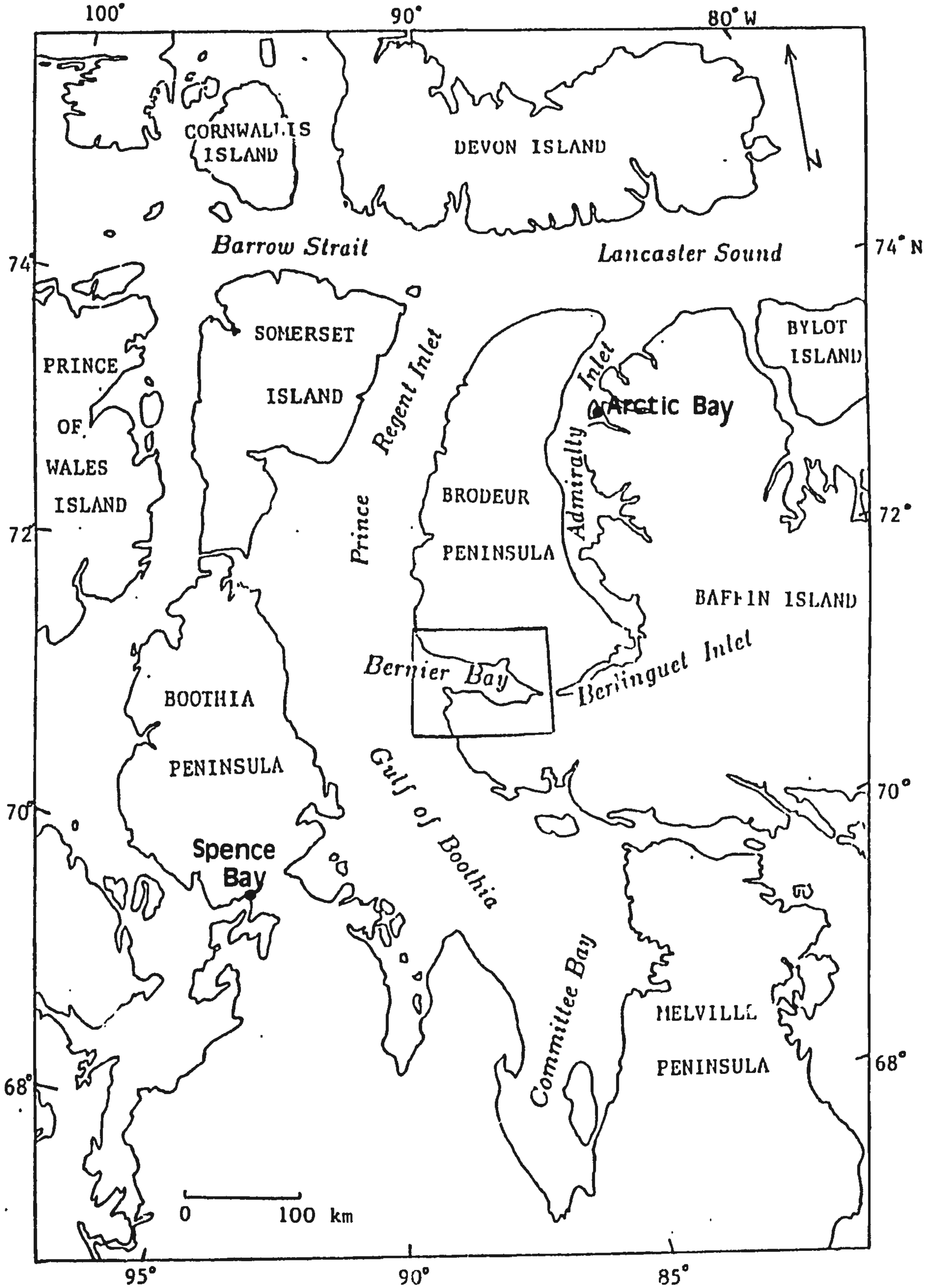


Figure 1-1. Location of the Study Area.

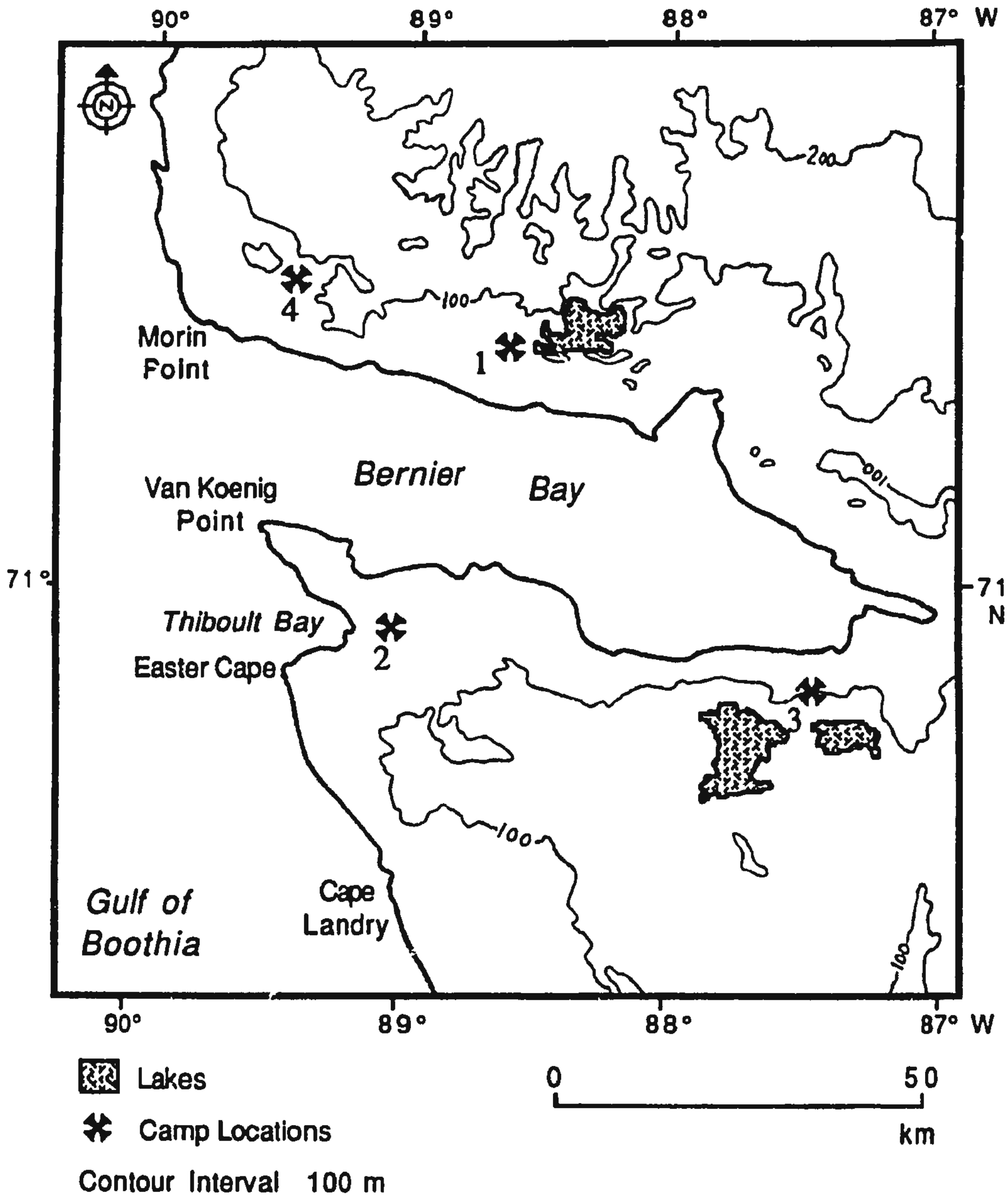


Figure 1-2. The Study Area

Bedrock Geology

The field area is underlain by flat-bedded dolomitic limestones of Ordovician to Silurian age which are part of the Arctic Platform (Thorsteinsson, 1970). The western part of the area is underlain by undifferentiated rocks of the Brodeur Group. The eastern part of the area is underlain by dolomites of the Ship Point Formation and the Admiralty Group (Trettin, 1969). Precambrian gneisses and granites occur beyond the eastern margin of the area as well as on the west side of Prince Regent Inlet and the Gulf of Boothia (Fig. 1-3).

The origin of the broad bedrock trough containing Bernier Bay and Berlinguet Inlet is uncertain. This broad depression separates Brodeur Peninsula from the rest of Baffin Island and connects with Admiralty Inlet on the east. The trough is about 200 km in length. Uplands adjacent to the valley are rolling plateaus generally having only a thin veneer of surficial sediments, with the exception of areas within two belts of morainic deposition which parallel the north and south sides of Bernier Bay. Plateau surfaces north and south of the trough are approximately 120-200 m asl.

The trough probably shares a common origin with the inter island channels which characterize the Arctic Archipelago. Two competing interpretations of the genesis of the channels exist in the literature. It was originally suggested (Fortier and Morley, 1956) that the channels were relicts of an extensive Tertiary drainage system which crossed the once-contiguous landmass of the Canadian Arctic Archipelago and which were later deepened by glacial erosion. Alternatively, the channels are interpreted as grabens formed during a Late Tertiary rifting episode (Bird, 1967; Kerr, 1980).

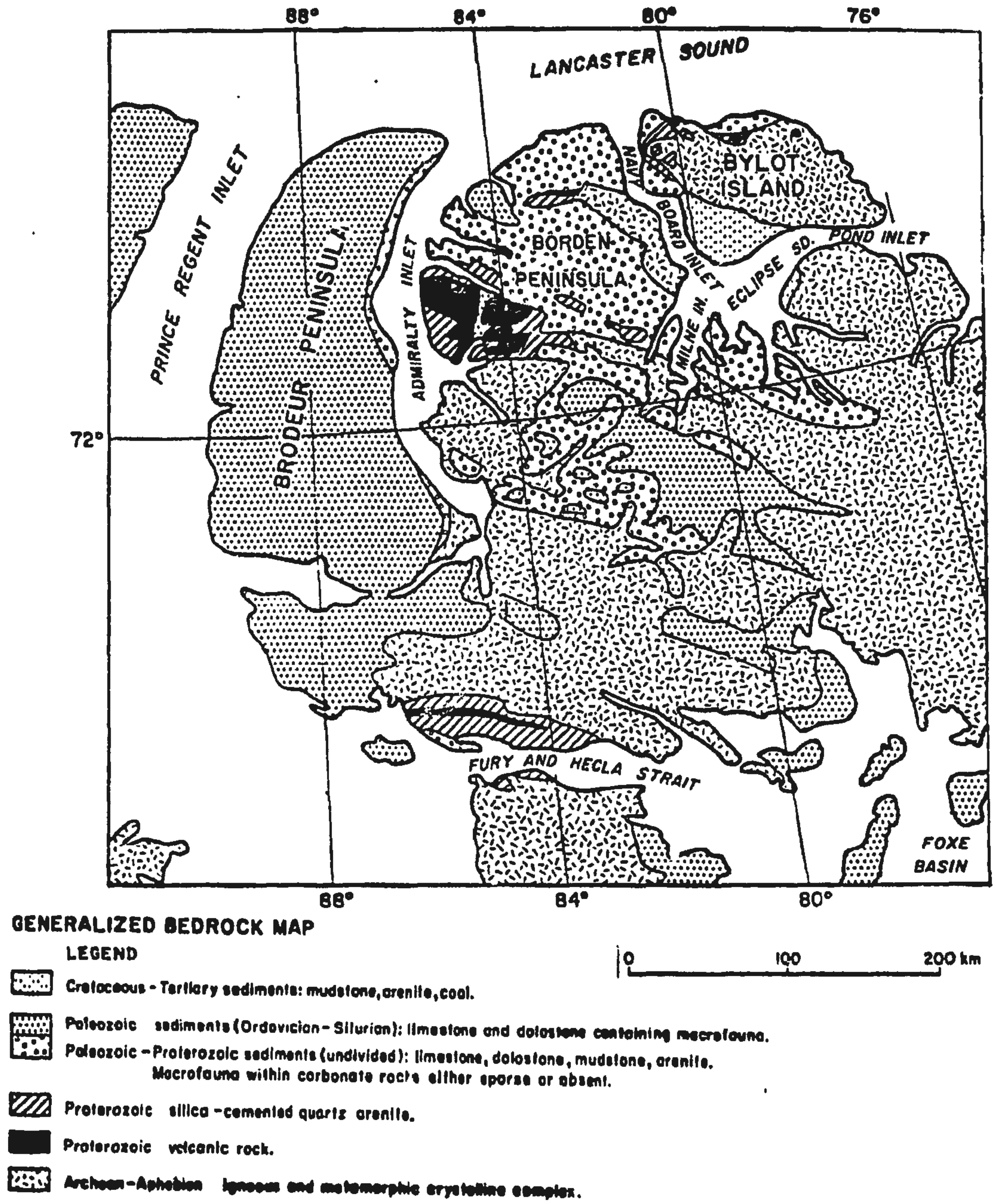


Figure 1-3. Bedrock Geology of the Area
(from Klassen, 1981)

Previous Research on the Laurentide Ice Sheet

The term Laurentide Ice Sheet refers to the largest North American ice sheet as it existed during the Wisconsinan glaciation which began at the end of the Sangamon Interglacial approximately 110,000 BP (St. Onge, 1987). During the Wisconsin glacial maximum, about 18,000 BP, the Laurentide Ice Sheet is estimated to have been approximately 12.6 x 10^6 km^2 in extent and between 2 and 4 km thick (Andrews, 1987). The earlier glaciations, Kansan, Illinoian, Nebraskan, and equivalents, of the Pleistocene were presumably similar in extent, but our knowledge of them is limited by the range of radiocarbon dating and because the sedimentary record has been largely erased by subsequent events. Presently, amino acid ratios, uranium series dates and thermoluminescence dating are being used to develop tentative chronologies extending back as far as 500,000 BP (eg. Brigham, 1983) for areas where older sediments can be found. No pre-Wisconsin sediments were found in the field area.

Research on the Laurentide Ice Sheet began during the late nineteenth century. Tyrrell (1898) proposed a three dome model for the ice sheet with dispersal centres in Labrador, Keewatin and northern Ontario. Flint (1943) proposed a monolithic ice sheet with a single dispersal centre over Hudson Bay. A debate between proponents of a single versus a multi-domed ice sheet has persisted since these reconstructions were first proposed (eg. Denton and Hughes, 1981; Dyke et al., 1982). This controversy is understandable because different researchers have emphasized different lines of evidence and assumed different boundary conditions for the former ice sheet. Proponents of the single-dome model generally ascribe greater importance to the record of ocean sediments, early isobase maps, studies of the Antarctic ice sheet and glaciological theory , whereas workers mapping the surficial geology of different regions have put forward a variety of multi-domed reconstructions (Andrews, 1987). The reconstruction of Dyke and Prest (1987) includes a complex system of mobile ice divides and saddles with large parts of the ice sheet grounded below sea level and ice streams calving rapidly into seawater during deglaciation.

The existence of former ice shelves has been proposed for several areas in Arctic Canada. England et al. (1978) describe 2 km long horizontal moraines on Judge Daly Promontory, northeastern Ellesmere Island. Low moraines and the concordant upper boundary of a distinctive till sheet on Banks, Melville and Victoria Islands were also thought to reflect deposition from floating ice (Hodgson and Vincent, 1984; Dyke, 1986). Modern analogs for the large ice shelves which likely existed in Arctic Canada during the Pleistocene glaciations are found in Antarctica where horizontal moraines 120 km long exist along the edge of the George VI Ice Shelf (Sugden and Clapperton, 1981).

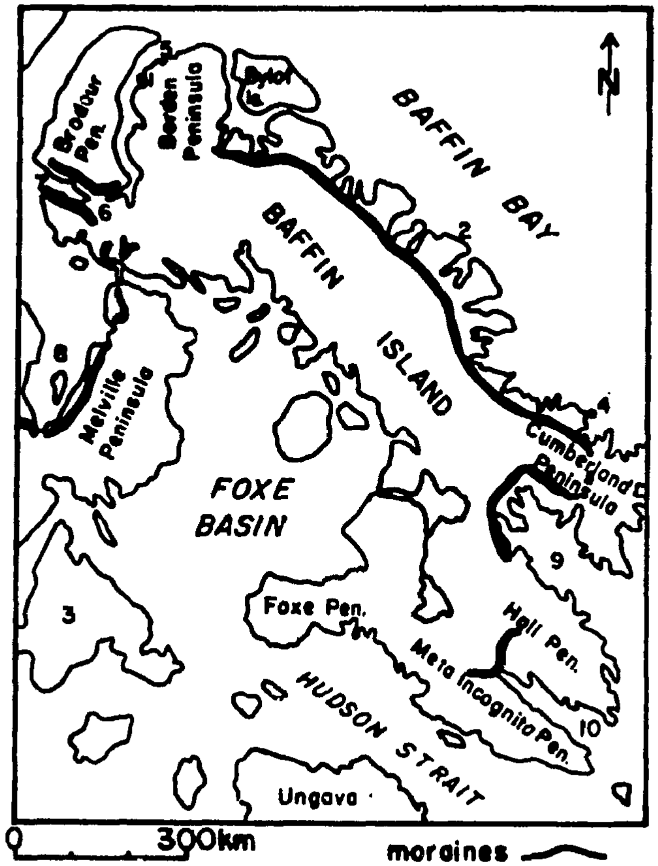
The idea of a marine based ice sheet allows for rapid deglaciation in response to rising sea level triggered by slightly warmer conditions. (Hare, 1976) demonstrated that continental ice sheets are important modifiers of climate because of the considerable topographic relief of the ice mass, amongst other things, so that an understanding of the demise of the Laurentide Ice Sheet requires accurate modelling of the associated climate changes and potential feedback mechanisms which would lead to the rapid wasting of the ice sheet and a shift to ice free conditions in North America over a short time interval. To date, most of the climate models for the Laurentide Ice Sheet have relied on the single dome model of Flint (1943).

Ruddiman and Duplessy (1985) have partially resolved the question as to the heat source for melting the Laurentide Ice Sheet by invoking a two-stage deglacial sequence in which melting of the ice sheet, possibly in response to slight global warming caused by orbital variations, begins about 17,000 BP. This resulted in significant thinning, but not areal retreat, of the ice sheet as well as rising global sea level. Increased sea level resulted in rapid areal retreat of the ice sheet by calving and marine downdraw beginning about 13,000 BP.

Previous Research on Baffin Island

The glacial history of Baffin Island received considerable attention beginning in the 1960's when it became the major project of the former Geographical Branch of the Department of Energy, Mines and Resources of the Canadian Federal Government. Ives and Andrews (1963) described the geography of the Cockburn Land Map Sheet and mapped the Cockburn Moraines, a major system of end moraines which parallels the fiord heads across much of northeastern Baffin Island (Fig. 1-4). At that time it was recognized that the mountainous eastern rim of Baffin Island was not the locus of initiation of regional glacierization but that the uplands had been penetrated by eastward flowing ice. Nunataks and local ice caps existed in the eastern uplands during the Late Wisconsin (Løken, 1966), though there were no nunataks on the western part of the island.

After mapping the moraines from air photographs, Ives and Andrews (1963) proposed three Wisconsin glacial stages for the area: an early Maximum Stage when the inland plateau was inundated by ice and ice breached the eastern highland through troughs and fiords and extended to sea level, a Cockburn I Stage in which ice from a dispersal centre over eastern Foxe Basin inundated the inland plateau but terminated at or near the fiord heads, and a Cockburn II Stage during which ice flowed from a dispersal centre over the inland plateau but terminated well inland of the fiord heads.



1. Arctic Bay
2. Clyde Foreland
3. Southampton Island
4. Broughton Island
5. Admiralty Inlet
6. Berlinguet Inlet
7. Bernier Bay
8. Committee Bay
9. Cumberland Sound
10. Frobisher Bay
11. Fury and Hecla Strait

Figure 1-4. Generalized location of Cockburn Moraines and correlatives (after Blake, 1966; Andrews and Ives, 1978). Numbers refer to locations mentioned in the text.

Falconer et al. (1965b) suggested that the Cockburn Moraines be correlated with the Bernier Bay Moraines, moraines on the west side of Melville Peninsula and the MacAlpine moraine which stretches from the south end of Committee Bay west to a point near Back River southwest of MacAlpine Lake. The resulting moraine system is over 2000 km long. From the length and continuity of the moraines, the above authors suggested an important and previously unrecognized glacial episode in northern Canada. Radiocarbon dates on shells from marine deposits associated with the Cockburn and MacAlpine moraines suggested that the margin of a residual Late Wisconsin ice sheet stood at the location of the moraines between about 8000 and 9000 BP. These authors proposed the terms "Cockburn Phase" for the above period and "Cockburn Ice Sheet" for the residual ice mass.

Sim (1960) described the moraines of western Melville Peninsula and consistently referred to the west side of the moraines as the ice proximal side. Without the benefit of radiocarbon dates, he interpreted the single moraine ridge in the southern part of the peninsula as an interlobate moraine deposited along the contact between two wasting remnants of the former ice sheet, one of which was centred over Committee Bay; the other over Melville Peninsula.

Craig (1965) noted the distinct lack of continuity in the moraines between northern Melville Peninsula and Milne Inlet, and that some of the moraines in this area are at right angles to the presumed ice margin. The Bernier Bay moraines are interpreted as the result of a valley ice tongue flowing west through the Bernier Bay-Berlinguet Inlet trough during deglaciation. The distal (west) and proximal (east) sides were radiocarbon dated at 8830 +/- 700 and 7576 +/- 500 BP, respectively, indicating that the area within the moraines was deglaciated later. Craig (1965) cautioned that the opening of Hudson Strait and Hudson Bay to the sea, which had not at that time been dated, would render the concept of a residual Late Wisconsin ice sheet centred over Hudson Bay invalid if it was clear of ice by 9000-8000 BP.

In a review of radiocarbon dates of the deglaciation of Arctic Canada Blake (1966) concluded that the sea had penetrated Hudson Bay by 8000 BP and suggested that moraines of Foxe Peninsula are correlatives of the Cockburn Moraines but were deposited by an ice mass which persisted over Foxe Basin long after the sea had penetrated Hudson Bay. Radiocarbon dates indicate open water in James Bay by about 7900 BP (Craig, 1968); therefore the residual ice sheet proposed by Falconer et al. (1965b) must have disintegrated before that time, if it ever existed.

Blake (1966) stated that the period 8000 - 9000 BP was not a period of ice marginal stability, rather there were significant changes in the margin of the Laurentide Ice Sheet during the Cockburn Phase. In fact, the ice sheet had already deteriorated into separate residual ice masses with ice remaining in Foxe Basin until long after Hudson Bay was deglaciated. He recommended that "Future work be concentrated in those fiords and lowland areas where moraine ridges are more widely spaced and where dating of individual moraine ridges may be possible."

Bryson et al. (1969) used the available radiocarbon dates and palynological evidence to construct an isochrone map for the disintegration of the Laurentide Ice Sheet. Their reconstruction was in good general agreement with Blake (1966) and showed a rapid disintegration of the ice sheet beginning with the formation of the Tyrrell Sea at about 8000 BP followed by the persistence of remnant ice masses in the interiors of Keewatin and northern Quebec for another 3000 years. A third remnant over northern Foxe Basin gradually receded inland and continued to diminish, eventually forming the Barnes Ice Cap. The authors noted the remarkable internal consistency of the 289 dates used to construct the isochrone map. The map indicates deglaciation of the Bernier Bay area beginning about 9000 BP along the west coast of Brodeur Peninsula and recession beyond the head of Bernier Bay by 8000 BP. These authors also suggested the existence of local ice on northern Brodeur Peninsula at this time. Several thin, inert ice fields exist on the north end of the peninsula at present and, in 1962, appeared to be slowly receding (Falconer, 1962). The importance of Brodeur Peninsula ice during the last stages of the Wisconsin remained unclear.

Andrews and Ives (1978) attempted to clarify the nomenclature for the Cockburn Moraines noting that 12 different usages of the term "Cockburn" had arisen in the literature. To resolve ambiguity and prevent the confusion of morpho- and lithostratigraphic units, they suggested that the term "Cockburn Substage" be used to denote the period between 8000 and 9000BP and the term "Baffinland Drift" be used to denote the entire complex of moraine ridges, till, outwash deposits and glaciomarine sediments which parallels the fiord heads of the northeastern Baffin Island. The time interval given for the deposition of the Baffinland Drift is 5000-9000 BP. Thus, the Cockburn Moraines were formed during a substage of the much longer series of ice marginal fluctuations termed the Baffinland Stade during which the entire width of the moraine system and the related depositional features were formed. In this paper the term Cockburn substage is used for the period of deposition of the Bernier Bay Moraines which ended about 8000 BP.

Miller and Dyke (1974) commented on the lack of radiocarbon dates from northeastern Baffin Island for the period 10,000 to 25,000 BP, and on the existence of raised glaciomarine deltas dating >25,000 BP in 36 localities along the northeast coast of Baffin Island. They also noted the existence of old marine limits above the Holocene marine limit. On the basis of this and other evidence, they proposed that the Cockburn Moraines mark the maximum extent of Late Wisconsin Laurentide Ice on Baffin Island. Moraines relating to the expansion of local ice were observed distal to the Cockburn Moraines but were absent within the moraine; patterned ground was much better developed outside the moraines. These phenomena were not observed in the Bernier Bay area, and it is likely that the entire area was inundated by ice until about 9000 BP.

The idea of a less extensive Foxe (last) Glaciation is also supported by the existence of older tills and interglacial sediments beyond the Cockburn Moraines in the area of Clyde

Foreland (Miller et al., 1977). Echo soundings of the northeast coast of Baffin Island reveal submerged deltas and beach ridges formed during the Foxe Glacial Maximum when sea level was below present (Miller and Dyke, 1974). This finding may explain the dearth of 10,000 to 25,000 BP dates on northeastern Baffin Island, since these materials would now be submerged.

Relative Sea Level History

The relative sea level history of an area which is undergoing postglacial isostatic adjustment is a valuable line of corroborative evidence for reconstructing its glacial history. The pattern of postglacial recovery can even be used to independently model the glacial events which produced the initial depression of the crust. Isostatic recovery consists of instantaneous and delayed components: the instantaneous component is the elastic recovery of the crust and the disappearance of the gravitational effect of the ice sheet. The prolonged isostatic recovery which has been documented for various areas in the Canadian Arctic is primarily a result of the viscous flow of mantle material back under the depressed zone (Clark, 1976).

Since a large portion of the Laurentide Ice Sheet, including much of the ice covering the field area, was grounded below sea level, an accurate conception of sea level history is essential to reconstructing deglacial events. In the flat terrain of western Baffin Island and the western arctic generally, the pattern of glacial deposition reflects a complex interaction of marine and terrestrial systems. Studies of glacioisostatic rebound, which are largely a contribution of Quaternary scientists, show considerable potential for modelling the properties of the aesthenosphere.

The understanding of glacioisostatic recovery has been refined in recent years by two important discoveries. It had generally been assumed that sea level change would be uniform as water was removed from and added to the global ocean by the growth and decay of ice sheets. Walcott (1972) published the results of geophysical modelling indicating a dynamic response of the crust to both ice loads on land and water loads in the ocean basins. This means there is no simple, bathtub-like response of sea levels to changes in the volume of the water in the ocean basins. Thus, the practice of correcting emergence curves showing postglacial recovery for 'eustatic' sea level changes measured along supposedly stable coastlines was dropped, and results are expressed solely in terms of relative sea level change.

The above finding did little to explain the large amounts of observed early Holocene emergence in some areas, particularly Greenland where more than 300 m of emergence had occurred. Clark (1976) accounted for up to 80 m of rapid postglacial emergence by modelling the effect of gravitational attraction between the terrestrial ice mass and the mass of water in the adjoining ocean. The results demonstrate that the gravitational force exerted by the ice mass on the adjoining seawater increases exponentially proximal to an ice sheet.

Andrews (1980) summarized the progress of sea level reconstruction for Baffin Island for the period 115,000 BP to the present. Most of the evidence for these reconstructions derives from local studies conducted during the last three decades. He noted that three different interpretations of the same general type of stratigraphic sequence had been made by researchers in different areas but that evidence continued to accumulate indicating that the large moraines along the outer coast were deposited during a more extensive Early Wisconsin glaciation, the Clyde Stade. This was followed by a less extensive and shorter Ayr Lake Stade which preceded a long and complex interstadial interval culminating in the Late Wisconsin event which deposited the Cockburn Moraines. Each major ice advance in the sequence is accompanied by a marine transgression.

A detailed review of Early Wisconsin events on eastern Baffin Island, which includes a whole series of sections for which amino acid ratios and uranium series dates have been used to draw correlations and measure the absolute age of the deposits is beyond the scope of this project. The number of infinite dates for the raised marine sediments of the outer coast of Baffin Island (Løken, 1966; Ives and Buckley, 1969; Pheasant and Andrews, 1973; Miller et al., 1977) proves beyond any reasonable doubt that the complex of marine limit features and raised marine sediments of the east coast are the product of multiple transgressive/regressive cycles. The preservation of this type of evidence also suggests, but does not conclusively prove, that the successive ice advances of the Foxe Glaciation were less, rather than more, extensive.

Dyke (1979) presented a series of radiocarbon-dated emergence curves for Somerset Island. The curves were based on 36 dates: 17 on shells, 13 on whalebone, 5 on driftwood and 1 on a walrus tusk. The elevation of the marine limit (9200 BP shoreline over the north and east coasts) increases towards the west-southwest from 90 m in the northeast to about 160 m in the southwest part of the island. Dyke (1979) also observed that the area of steepest gradient on the marine limit shoreline has the greatest number of ice-marginal features. The tilt of this shoreline supports the idea of an ice margin occupying the area during Late Wisconsin time.

Andrews (1970) constructed an equidistant shoreline diagram for western Baffin Island showing tilt toward the southwest, suggesting that the centre of the ice load was southwest of Baffin Island. The shorelines were dated by reference to a radiocarbon-controlled emergence curve.

Summary of Research Objectives

The first main objective of this research was to map and interpret the glacial landforms of the area and to establish a chronology of glacial events. This required conducting ground traverses during which samples of surficial sediments and descriptions of site conditions and landforms could be obtained. Also, samples of high elevation marine shells were collected which could be dated to provide the minimum age of deglaciation for different parts of the area. The second main objective was to document, as accurately as possible, the Holocene sea level history of the area by dating whalebone and wood from raised beaches and also shells from marine limit deltas. By drawing a set of radiocarbon-controlled emergence curves for the area, it was hoped that differential emergence could be documented for different parts of the coast and that the resulting pattern could be related to the distribution of the Late Wisconsinan ice load. Methods used to accomplish these objectives are described in detail in the following chapter.

Chapter Two: Field and Laboratory Methods

Logistical Arrangements

Support for the fieldwork component of the study was provided by the Technical Field Support Services Division of the Geological Survey of Canada, Ottawa, and the Polar Continental Shelf Project, in Resolute Bay, N.W.T. These agencies supplied equipment, food and transportation. Travel from the south was by commercial airliner to Resolute Bay on Cornwallis Island and then by Twin Otter to the field area.

During the six week field season, from early July to mid August 1988, four base camps were established in different parts of the field area. These were occupied for approximately 10 days each before moving to the next location by Twin Otter. Camp locations (Fig. 2-1) were chosen in advance with the aim of visiting the various parts of the field area to collect samples and check features identified on the air photographs. The availability of potential landing sites and the need to minimize aircraft time were important secondary considerations in choosing camp locations. All of the field gear, including two Honda ATC's for conducting traverses, is slightly less than one Twin Otter load. This aircraft is well suited for landing on short, rough landing areas after a brief aerial inspection.

The Honda all-terrain tricycles proved very reliable and greatly increased the areal coverage of the research over that accessible by foot. The proximity of the study area to the magnetic north pole makes compass readings unreliable. Careful scrutiny of 1:60,000 scale air photographs was required to avoid getting lost in featureless or confusing areas. Weather during the 1988 season was exceptionally fine and very little time was lost due to inclement conditions.

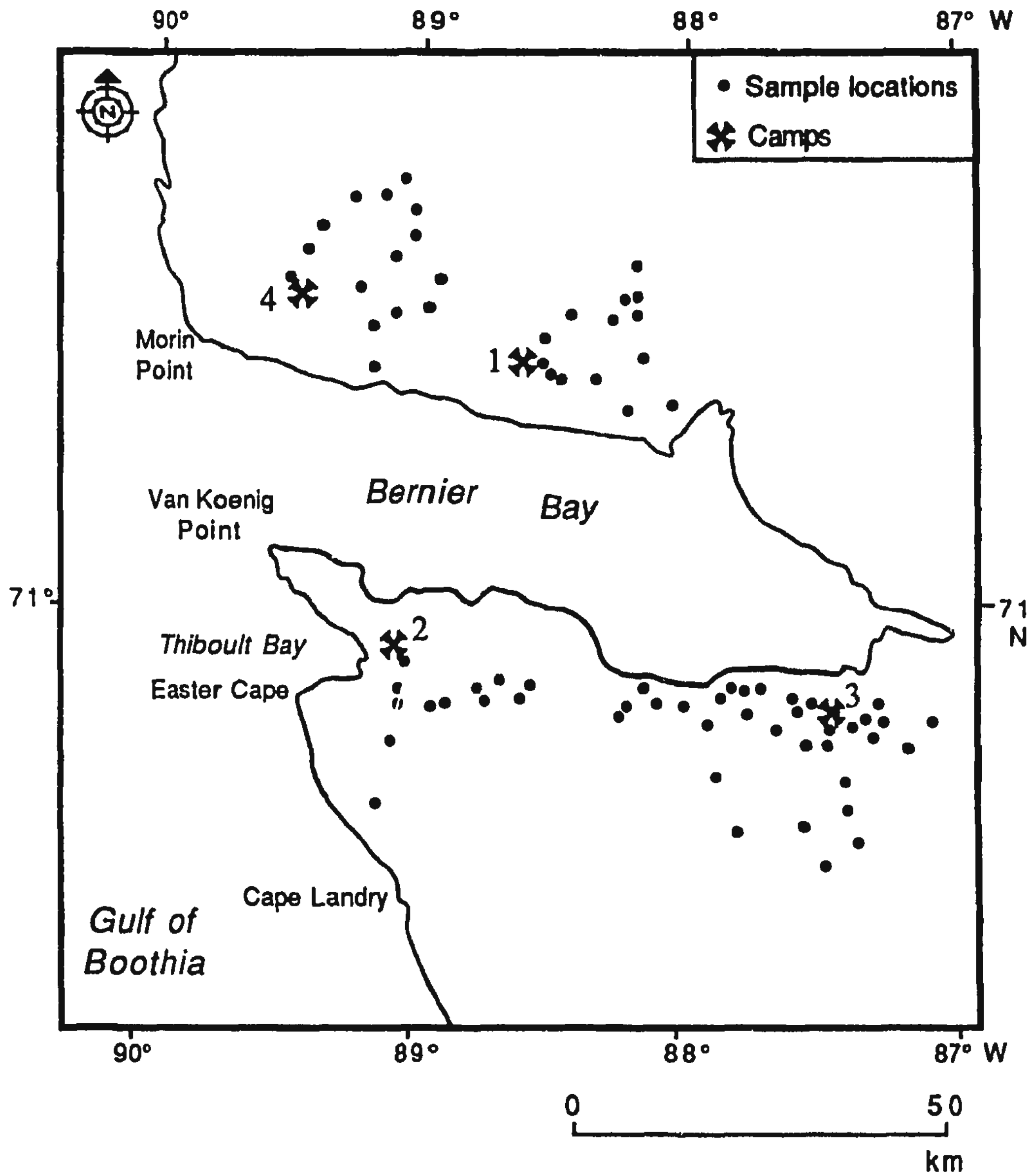


Figure 2-1. Location of camps and drift sample sites

Drift Sampling Program

The main objective of the drift sampling program was to characterize the surficial sediments from each camp area. Accordingly, during sampling traverses, an attempt was made to traverse as much of the terrain as possible collecting samples every 3-5 km. Significant gaps exist in the areal coverage of surficial sediment sampling between camp areas (Fig. 2-1). Of the 78 samples collected, 72 have been classified as drift, 4 as glaciofluvial gravel and one as glaciomarine diamict.

Individual sample sites were chosen with the aim of obtaining a sample which typified the type of material crossed on that leg of the traverse. Where possible, the samples were collected from barren moraine crests, rather than adjacent lowlands. Level, well drained sites were preferred, and extremely rocky or anomalous deposits were avoided. In areas of coarse, bouldery drift, the centres of mudboils provided good samples of matrix material. Samples of surficial sediment from several sub-parallel moraine ridges around the third camp were collected so that differences in the texture and composition of sediments relating to different depositional phases might be documented.

At each sample site notes were taken on the nature of the sediment and the site conditions. The former included the color and texture of the matrix, the stoniness of the deposit, and the size, type and roundness of clasts. The numbers and types of erratics were estimated by taking a short walk around the site. Site observations included the topographic setting, estimates of the percentage of the surface covered by boulders and vegetation and a brief description of patterned ground forms present in the immediate vicinity. The location of sample sites and other points of interest were recorded on 1:60,000 scale air photographs. The quality of these subjective observations varied from site to site and improved somewhat as the work progressed.

Collection of Sea Level Samples

Approximately two thirds of the available time was spent searching for whalebone, driftwood and shells embedded in raised beaches. The main objective of collecting these materials was the construction of radiocarbon-controlled emergence curves for each of the four camp areas. Areal coverage was not a priority in collecting sea level samples since each curve ideally represents the emergence history of a single point. The best results are obtained where a large number of samples are found within a small area, preferably spanning the entire elevation range between modern sea level and marine limit. Accordingly, the initial beach searches in a camp area were conducted randomly and the same areas were often visited more than once. After several finds had been made the searches became more systematic because of the need to find material at elevations which would fill potential gaps in the curve.

Bone Samples

Most of the finds were skulls of the bowhead whale, *Balaena mysticetus*. The skulls were usually found in association with other bones. Nearly complete, but not articulated, bowhead skeletons were found at several sites. Whenever possible earbones (otic capsules and periotic bones) were collected. These bones can usually be found within, or buried immediately below, the skull. They are the best part of the skeleton for dating because they consist of extremely dense bone and so resist penetration by plant rootlets. Rootlets introduce radiometrically young carbon into the sample resulting in an erroneous young age. Calcareous beach gravels are deficient in plant nutrients so that vegetation tends to preferentially locate on bone sites (Fig. 2-2). Rootlets and other organic contaminants were ubiquitous in porous bone (i.e. virtually all bone except earbone). With few exceptions, earbone samples were much easier to clean than other bone samples and gave dates with the smallest error terms. Other bowhead bones, vertebrae, mandibles and ribs, were found in the vicinity of skulls or individually. The quality of these bones was usually poor with serious contamination by plant rootlets and dirt. All but the poorest bone finds were collected since it was not known whether better samples would be found later at a similar elevation.

Figure 2-2. Scatter of bowhead vertebrae on a barren raised beach north of Camp 3. Note the well developed oases of vegetation around the vertebrae. The skull (undated) was found at the same elevation about 200 m away.

The abundance of bowhead bones on beaches throughout the area varied dramatically with elevation and finding bone became increasingly difficult outside the recognizable "bowhead levels". Minor excavation was often required to retrieve samples and in a few cases the find was partially excavated and then left for several days to thaw so that bones frozen into permafrost could be retrieved.

Several tusks and bones of walrus, *Odebenus rosmarus,* were collected. All of these were found lying on the surface or very shallowly embedded. Tusks were generally well preserved except for small amounts of contamination in hairline cracks. One severely decomposed skull of a narwal, *Monodon monocerus,* was found at the second camp. The skull contained a single unerupted tusk about 25 cm long.

In all, 52 samples of bowhead bones, 12 samples of walrus bones and tusks and one narwal tusk were collected. Unfortunately no driftwood was found in the field area. Possible explanations for the absence of driftwood are discussed in Chapter 5. The size and condition of the samples, site conditions, and depth of burial were recorded for each sample and their locations marked on 1:60,000 scale air photographs. The width of bowhead skulls, between the ends of the temporal bones, was estimated to gauge the approximate size and maturity of the animal. Most of the skulls were in the 150 - 185 cm range. Whalebones associated with Inuit kill sites and flensing beaches generally contain a distinctive overrepresentation of small bowhead skulls about 1 m across (Dyke, pers. comm., 1989).

An important assumption implicit in the use of marine mammal remains for studying emergence is that the remains washed ashore after the animals died, or that the animals died at sea level, so that the age of the material truly dates the paleoshoreline where it was found. If this assumption were incorrect, one would expect considerable scattering of points when plotting emergence curves, with some of the points falling well below the curve (i.e. being significantly older than suggested by their elevations) due to the carcasses sinking in deep water. Bones of whales which died at sea and sank in deep water cannot be related to a particular shoreline and are useless for this type of research. Unlike whalebone, bones or tusks of walrus are occasionally younger than their elevation suggests because an aging or sick walrus will sometimes crawl inland a considerable distance (Dyke, 1979). Fortunately, these occurrences are rare and the internal consistency of a set of radiocarbon dates is such that they are easily recognized.

Shell Samples

In total, 28 shell samples were collected from a large number of available shell collecting sites. Observations of species, stratigraphic context and state of preservation, particularly the presence of intact periostraca and whether the shells were found lying on the surface or in growth position, were noted and the location of the sample recorded on air photographs. The arctic molluscs *Mya truncata* and *Hiatella arctica* were the most common species collected. Other species encountered in mixed collections were *Astarte borealis, Cerripes groenlandicum, Portlandia arctica* and an unidentified species of *Balanus*, or barnacle. Shell dates are more problematic than whalebone dates because of the ability of the organisms to grow in water up to 100 m deep (Andrews, 1986).

Altimetry and Surveying

All of the elevation measurements for bone and shell sites given in this study were made using a Wallace and Tieman surveying altimeter. In most instances it was possible to travel to sea level soon after measuring the site elevation and then return to the site for a corroborative reading. In this way the elapsed time between readings, and hence the possibility of errors due to changes in barometric pressure, were minimized.

When collecting at high elevations away from the coast, it was usually impractical to return to sea level after measuring the height of a sample site. In these cases it was necessary to correct the readings for barometric pressure changes which occurred during the traverse. This was done by taking reference readings when leaving and returning to the camp. The change in barometric pressure (expressed as a change in the measured elevation of the camp) could then be averaged over the time taken for the traverse. This allowed a correction factor to be applied to each sample site reading according to the time the reading was taken. On some traverses the elevation of modern sea level and the elevation of NTS benchmarks were used for reference readings.

This method is inferior to the first method, above, since it assumes a linear change in pressure between the two reference readings. (The first method also requires this assumption, however the time elapsed between readings is so short that the possibility of non-linear changes in barometric pressure can safely be ignored.) Non-linear pressure changes, i.e. changes in the rate of rise or fall or fluctuations, introduce errors which cannot be detected during or after the traverse. Camp elevations were measured by averaging the results of several sets of altimeter readings taken at the camp and at sea level. This means that any errors in measuring elevation of the camps are incorporated in the results of altimeter traverses which used camps as reference points. As with the other elevation measurements, the accuracy of the measured camp elevations probably decreases with camps located further inland.

Errors were subjectively assigned to elevation measurements following the method of Dyke (1979), with errors of ± 4 m applied to elevations above 40 m, ± 3 m to elevations between 10 and 40 m, and ± 1 m to elevations below 10 m.

A useful technique for minimizing altimeter errors on long traverses is to take one reading upon arrival at a collecting site and a second reading when leaving the site so that the time spent sampling can be subtracted from the total elapsed time. This technique also allows the researcher to observe the tendency of pressure change. A crude indication of the reliability of altimeter measurements is provided by weather conditions: lengthy altimeter traverses on days of storms or squalls should be avoided.

Raised shorelines were levelled in two locations, one near Van Koenig Point and another near Morin Point. This was done using a surveyor's level and standard survey techniques. The Van Koenig Point survey runs along a well defined sandy raised beach for

1600 m in a southeasterly direction. The Morin Point Survey runs along a similar beach for about 760 m in an easterly direction. Both surveys are at 20 m elevation, by altimeter, and neither of the surveys was closed to the point of origin, so collimation errors could not be calculated. Both surveys detected small changes in the elevation of the shoreline between the endpoints of the transect. The measured elevation change is close to the observed fluctuations in the height of individual survey stations along the traverse. The two beaches surveyed were among the longest continuous features observed during fieldwork, and were clearly recognizable on air photographs.

Preparation of Radiocarbon Samples

All samples collected in the course of fieldwork were shipped via air freight to the south. Radiocarbon samples were shipped to Ottawa for cleaning in the radiocarbon preparation laboratory run by the Terrain Sciences Division of the Geological Survey of Canada. Surficial sediment samples were shipped to St. John's, Newfoundland and analyzed in the Geography Department of Memorial University and the sediment laboratory of the Newfoundland Department of Mines and Energy.

In the laboratory, samples were selected for radiocarbon dating on the basis of their stratigraphic significance, state of preservation, and quantity of material. Stratigraphic significance refers to the elevation and location of bones found on raised beaches and, in the case of shell samples, their potential for dating marine limit/deglaciation or at least the possibility that they can be related to a former sea level. This selection process was required because, for reasons of cost, less than one quarter of the samples could be dated. Careful selection of radiocarbon samples allowed the maximum amount of information to be extracted from the available dates.

After selecting the samples for submission they were cleaned to remove organic contaminants. Bowhead earbones were cleaned using a sandblaster to remove humic acid staining and encrustations of calcium carbonate from the surface of the bone. Other bone samples were cleaned by sawing them into small cubes with a bandsaw so that the porous interiors of the bones could be examined. Sometimes contaminants present in spongy bone could be removed by blasting with compressed air. Thirteen earbone samples were submitted as well as three other bone samples. One of these was a small vertebra which had been deeply buried in barren beach gravels below the zone of penetration of plant rootlets. The remaining two were collections of dense skull fragments.

Shell samples were selected using the same criteria as bone samples. Priority was given to samples which could date the Holocene marine limit and the time of deglaciation. This required dating the highest-elevation shells which could be found in an area, particularly those associated with marine-limit deltas. Several samples of *in situ* shells from below marine limit were submitted which, it was hoped, would fill gaps in the emergence curve between the highest bone samples and the marine limit dates. Eight shell samples were submitted to the GSC's radiocarbon laboratory. The shells were cleaned using a cavitron, a machine similar to those used by dentists in which ultrasonic vibrations are combined with a fine jet of water to produce a scouring effect. Cleaning the shells thoroughly before submitting them to the lab minimizes the loss of shell material during leaching. At the radiocarbon lab the shells were leached with hydrochloric acid to remove the outer 20% of the shell material before being gassified and placed in the counter.

counted and placed in size classes according to perturbations induced in an electric field across the aperture. Results are continuously recorded by the machine's computing system. Several drops of dispersant were added to a few milligrams of the dried fine fraction which was then diluted to the desired volume with a special solution used for the counter. During each run, a motorized stirrer was used to keep particles from settling out. In each sample, approximately 300,000 grains were counted and assigned to 14 size classes ranging from 32.0 microns to 1.59 microns. These results were grouped to produce 6 larger classes for the purpose of drawing grain size histograms.

Granule Counts

After weighing the fractions produced by sieving, the 2-4 mm, or granule, size particles were saved for the mineralogical analysis. One hundred grains of each sample were counted and identified as dolostone, limestone, granite, gneiss, sandstone, red sandstone and others. Difficulty was encountered separating limestone and dolostone by visual inspection. The problem occurs because of the variable carbonate content and texture of the local bedrock. Many of the samples were tested for reactivity with HCl as one indicator of the relative amounts of calcium and magnesium carbonate. Reactivity to HCl was clearly affected by the presence of sand grains in the sample clasts. Thus, the percentages of of shield rocks and sandstone are probably more accurate than those of dolostone and limestone.

Textural Analysis of Surficial Sediment Samples

The samples were first air dried and split to remove 100 g aliquots. These were placed in paper bags and oven dried overnight to allow measurement of their dry weight. The fractions were then placed in pails and a small quantity of hydrogen peroxide added as a dispersant. Oven drying of samples and treatment with hydrogen peroxide are not part of the commonly used preparation techniques. Oven drying can cause clay-rich sediments to form clumps which resist later attempts at disaggregation, but allows accurate measurement of the dry weight of the sample before sieving. Treatment with a dilute solution of hydrogen peroxide adequately dispersed the samples after they had been weighed.

After sitting overnight in hydrogen peroxide, the samples were wet sieved using as little water as possible, to separate the fraction smaller than 4 Ø (< 0.0625 mm). This corresponds to silt and clay sized particles. The coarse fraction caught by the sieve was then oven dried and placed in the sieve stack. Eight sieves were used to separate the grains at 1Ø intervals over the range -3Ø to 4Ø (8 mm to 0.0625 mm). After 10 minutes in a mechanical shaker, the stack was disassembled and each sieve meticulously cleaned onto a piece of paper and the fractions weighed. With practice, two shakers could be run simultaneously and about 12 samples analyzed per day.

Most of the tills sampled had a considerable component of angular gravel in the pebble and cobble range. To obtain statistically significant samples of these clasts would require collecting very large samples in the field. Discrepancies between the initial weight of the sample and the total weight of the dry sieved fractions averaged 0.54% of the initial sample weight with only three cases where the percent error exceeded 5%.

The silt and clay fraction was analyzed using a Coulter Apparatus which works by drawing a stream of solution containing suspended particles through a 100 micron aperture equipped with an electronic sensor. As they pass through the aperture, the particles are

Geomorphic Mapping

After returning from the field the preliminary interpretations made on 1:60,000 air photographs were refined and the information transferred to a 1:250,000 topographic base. Mapped landforms include moraines, kettle holes, meltwater channels, eskers, kames, ice contact deltas, drumlins, flutings, striations, bedrock escarpments, canyons and deposits of marine silt and alluvium. A surficial geology map was not constructed, due to time constraints and gaps in the the areal coverage of ground truthing and sediment sampling. The geomorphic map provides an adequate framework for reconstructing the glacial and sea level history of the area, although a surficial materials map would probably have been even more useful.

Chapter 3: Surface Materials and Landforms

The following sections are a brief description of the main surficial units of the study area to accompany the geomorphic map (Fig. 3-1, insert). The most prominent elements of the Quaternary landscape are the two belts of morainic deposits which flank Bernier Bay. The cover of unconsolidated surface material within these morainic zones is more complete and probably considerably thicker than in the adjoining upland plateaus to the north and south. Most of the area is covered by drift with smaller areas of glaciofluvial gravel, glaciomarine diamicton, and younger deposits of colluvium and alluvium. Beach sands and gravels cover much of the area below marine limit. In presenting the results of the drift sampling program, the different sectors of the field area are referred to according to the number, from 1 to 4, of the field camps located there (Fig. 2-1, page 17).

Since ice retreat probably occurred in contact with the sea over much of the broad, low-lying coastal zone, unstratified stony surficial deposits from below marine limit may be interpreted as either washed tills or stony glaciomarine diamictons. In most cases, these materials are probably tills as they strongly resemble purely terrestrially derived sediments above marine limit. The term drift is used here to refer to the surficial materials collectively and where it is desirable to avoid the genetic connotation implied by the word till. Sediments collected above marine limit are also termed drift since they could conceivably consist entirely of weathered bedrock residuum.

Within the morainic zone, the estimated depth of unconsolidated sediments over bedrock is between 2 and 30 m. In interior plateau areas, beyond the moraines, surficial materials are usually less than 2 m thick and contain more cobbles and boulders, except around camp 4 where the drift cover consists predominantly of silt and fine sand. Large kettles occur in the moraines in several areas (Fig. 3-1).

An estimate of the gradient of the moraines was made by reference to 1:250,000 scale topographic maps and recorded heights of NTS benchmarks. Crests of moraine ridges are highest in the eastern part of the study area where they exceed 180 m asl. Fifty kilometres to the west, where the moraines are smaller and beginning to become indistinct, the maximum height of the crests is about 60 m. This yields an estimated gradient of less than 2.4 m/km.

Glaciofluvial landforms, such as kames, eskers and meltwater channels, are found throughout the study area but are largest within the moraines. Small kames, 2-6 m high, are widely dispersed on the inland plateaus. Large ice-contact deltas graded to the Holocene marine limit (Figs. 3-2 and 3-3) occur at three locations and there are numerous smaller outwash deposits within the morainic zones. The deltas occupy gaps cut through the moraines by meltwater flows. Meltwater channels and eskers occur inland of these deltas. The larger meltwater channels are frequently floored by coarse, frost-shattered debris.

Figure 3-2. Large ice-contact delta east of camp 1. The surface of the delta is at 110 m asl. Ice in the background (north) is lake ice.

Figure 3-3. Surface of ice-contact delta shown in 3-2, above. The gravels have been subjected to frost action and solution weathering since deglaciation.

Around camp 4 the surface is mantled by thick, silty drift forming low discontinuous ridges. To the east, in the vicinity of Camp 1, these ridges coalesce into a series of high, relatively continuous, subparallel moraines (Fig. 3-4). East of camp 1 the moraines give way to a field of NNE to SSW trending drumlins. A gradual transition occurs between these drumlins and a small area of De Geer moraines immediately to the east. East of the De Geer moraines, the large moraines resume and continue beyond the margin of the field area. North of camps 1 and 4, the mantle of surficial sediments becomes progressively thinner, merging into a gently rolling bedrock plateau mantled by thin drift with areas of thin, weathered rock residuum and felsenmeer.

Figure 3-4. Moraine east of camp 1, looking southwest. The moraine is about 15 m high; the ice-proximal side faces left (south).

On the south side of Bernier Bay, a similar pattern is observed. The moraines begin as a single discontinuous ridge northeast of Thiboult Bay, becoming larger and diverging into a series of steep-sided subparallel ridges to the east (Fig. 3-5) A large embayment, approximately 10 km wide, occurs in the moraines east of camp 3.

South of the moraine belt, the flat surface of the interior plateau is thinly veneered by coarse drift and residuum. Unlike the pattern seen on the north side of the bay, the transition from areas of thick drift within the morainic zone to the flat interior plateaus further south is relatively abrupt. This contrast is easily recognized along the entire length of the moraine south of the bay and corresponds to the southern terminus of the outermost moraine ridge.

Several small bedrock cuestas about 2 m high are the most obvious features of the interior plateau surface. These are the result of very gently dipping dolostone strata which intersect the surface to form arcuate outcrops clearly visible on air photographs. Any striations which may have once been present on the outcrops have been removed by frost shattering and solution weathering. The degree of surface weathering of the exposed bedrock suggests that the cuestas have existed throughout the postglacial and are not a result of more recent tectonic activity.

In addition to the drumlins mentioned above, a second large drumlin field occurs on the floor of the main valley south of the head of Berlinguet Inlet, beyond the eastern margin of the study area. These drumlins trend E-W and are aligned with the main valley. They are considerably larger than the drumlins north of the head of Bernier Bay. Two small drumlins, or drumlinoid ridges, occur on the inland plateau east of camp 2. One of these features is oriented NNW—SSE, the other has a NW—SE orientation. On the other side of the bay, north of camp 4, are two more small drumlins both trending NW—SE.

Two sets of E—W trending striations were found, in different locations, on large *in situ* frost-shattered blocks near camp 2. By far the best preserved striations were found west of camp 3 where a polished bedrock surface has recently been exhumed by a small stream. A single set of NE—SW striations was documented at the site.

Figure 3-5. Steep-sided moraine ridge south of Camp 3. Note the coarser material and lack of vegetation compared with Figure 3-4, above. The ridge shown is about 25 m high and is symmetrical with slopes of about 30°.

Description of Sediments and Site Conditions

Observations recorded at each sample site are described in Chapter 2. These included preliminary notes on the type of sediment found at each location as well as the topographic setting of the site and estimates of the percentage of the surface covered by boulders and vegetation. Surface boulder cover provides a rough estimate of the quantity of large clasts present in the material since the frequencies of large clasts could not be included in the grain size analysis. For sites below marine limit, the percent boulder cover is also a reflection of the amount of ice-rafted material deposited there; most of the ice-rafted boulders are gneiss and granite. Limestone and dolostone boulders are more easily comminuted by frost shattering and so less likely to withstand periods of ice abrasion and exposure to moist conditions at or near former sea levels.

In the first camp area, eleven samples of drift and one sample of weathered glaciofluvial gravel were collected from within the main zone of morainic deposition. These were moderately stony and had a sandy silt matrix, except for the glaciofluvial gravel which had a matrix of silty sand. Surface boulder cover averaged about 5% by area. Two drift samples were collected from a conspicuous linear ridge, interpreted as a grounding line deposit. The ridge samples contained more rounded clasts and were sandier than sediments from adjoining moraines.

Nine samples of drift, one sample of glaciofluvial gravel, one sample of stony glaciomarine sediment and one sample of residuum were collected from the second camp. No drift samples were collected from Van Koenig Point, since the surface in this area consists entirely of coarse, gravelly beach sand. All but one of the samples had a sandy silt matrix; the exception was a sample from an area of thin muddy sand from below marine limit (the terms mud and muddy are here used in reference to poorly sorted sediments containing significant amounts of sand, silt and clay). Two of the drift samples were extremely stony as were the samples of glaciofluvial gravel and residuum. Toward the east, surficial sediments in this area are thicker and the proportion of fine material increases. Boulder cover on surfaces around camp 2 was slightly greater than around camps 1 and 3, but was still less than 10% by area.

Thirty-five samples of drift and two samples of weathered glaciofluvial gravel were collected around camp 3. More samples were collected in this area than in the other camp areas in part due to improvements in the efficiency of sampling. Twenty-one of the samples had matrixes of sandy silt, fifteen had matrixes of silty sand, two had matrixes of sandy mud and one sample had a matrix of muddy sand. The two samples of glaciofluvial gravel were, again, texturally similar to drift. Surficial sediments around camp 3 were usually moderately stony with surface boulder cover less than 10%.

Sixteen samples of drift were collected from the area around camp 4, northeast of Morin Point. These were the most uniform surface materials of the study area and were generally moderately stony. Thirteen samples had matrixes of sandy silt and twelve had matrixes of silty sand. Surface boulder cover around Camp 4 was much less than around the other three camps, averaging less than 1% by area.

Texture of Surficial Sediments

Figures 3-6 to 3-9. show the grain size distributions of drift samples collected at the four camp areas; the mean frequency and standard deviation for each size class is shown by the centre line and dark shaded zone, respectively. Generally, these materials have a bimodal distribution with broad peaks in the granule (4-8 mm) and fine silt (7 Ø) size ranges. The coarse silt (4-5 Ø) class was almost universally low. A possible cause of the bimodal distributions is that clasts of intermediate size are most susceptible to comminution during transport at the base of the ice sheet. Larger clasts are more easily entrained in the ice and small particles tend to resist comminution.

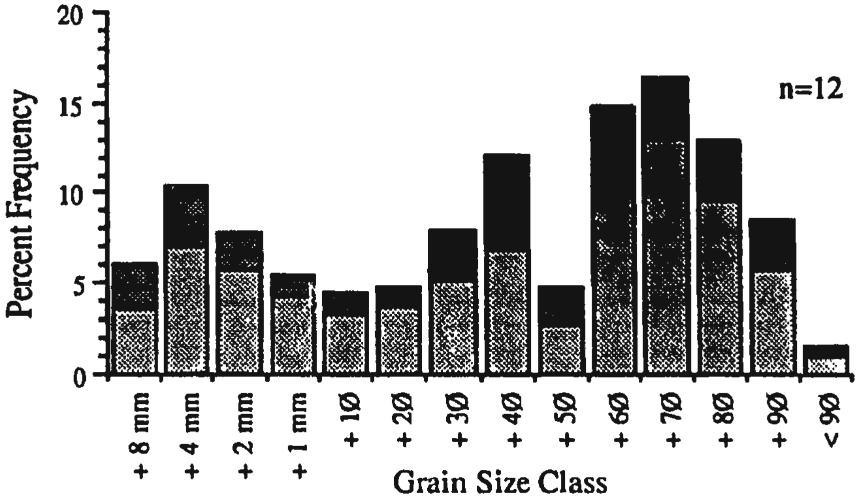


Figure 3-6. Grain size histogram for drift samples collected around Camp 1. Mean frequency for each class is shown by the line in the centre of the shaded zone. The shaded zone shows the standard deviation.

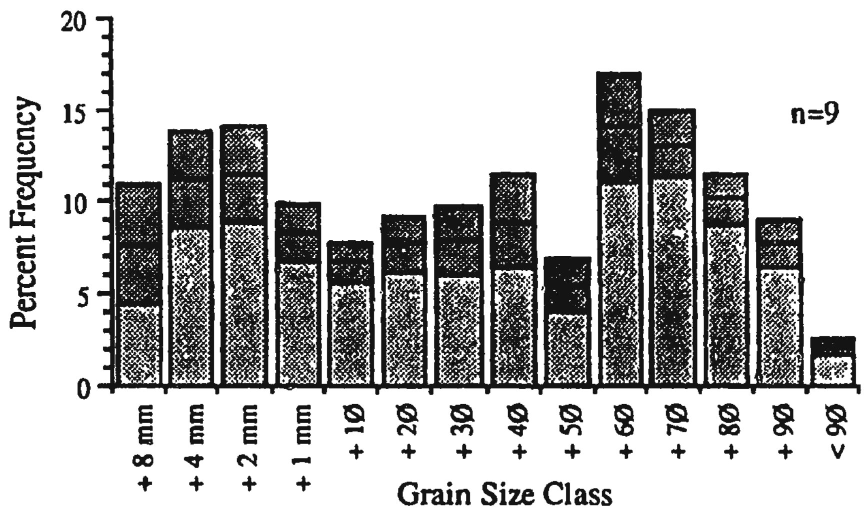


Figure 3-7. Grain size histogram for drift samples collected around Camp 2.

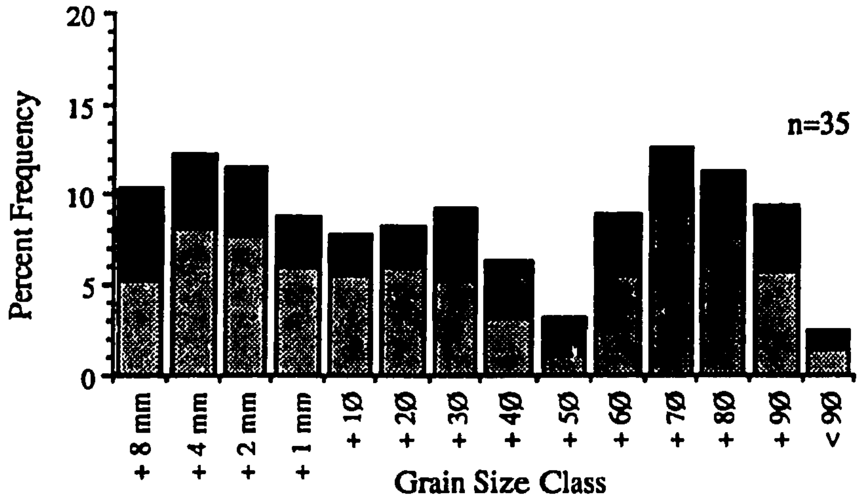


Figure 3-8. Grain size histogram for drift samples collected around Camp 3.

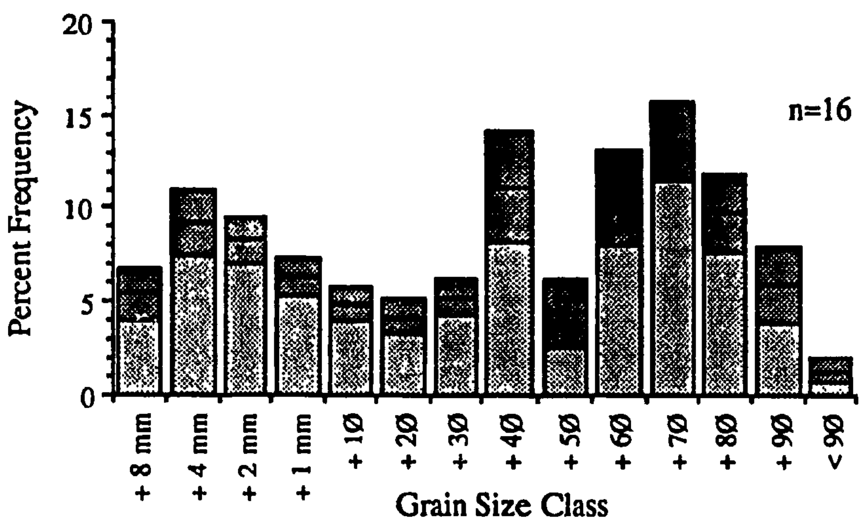


Figure 3-9. Grain size histogram for drift samples collected around Camp 4

Classification of material as weathered glaciofluvial gravel was made when the sample was clearly associated with landforms such as ice-contact deltas, kames, eskers and meltwater channels. Figure 3-10 summarizes the grain size distributions of these sediments. The most significant feature of this distribution is the increase in the coarse sand fraction reflecting removal of silt and clay from the sediment during fluvial transport.

Figure 3-11 shows the grain size distribution of a single sample of glaciomarine stony clay collected from a section north of the head of Thiboult Bay. The light color and elevated clay content of this sample are distinctive. The deposit where the sample was collected is massive, unstratified and contains numerous angular clasts of ice rafted material.

Despite variation in thickness and vegetation cover, textural properties of surficial sediments are relatively uniform throughout the field area. Textures of weathered glaciofluvial gravels were similar to textures of drift. Thus, the texture data are not sufficient, by themselves, to unequivocally distinguish sediments. Their main application here is simply to characterize surficial sediments. Thus, given the lack of exposures revealing sedimentary structures in the study area, the best way to make genetic interpretations is through the landforms found at the sample sites. Since many of the drift samples described above were collected from ridges within the main belt of morainic deposition, it is felt that most of them are probably tills.

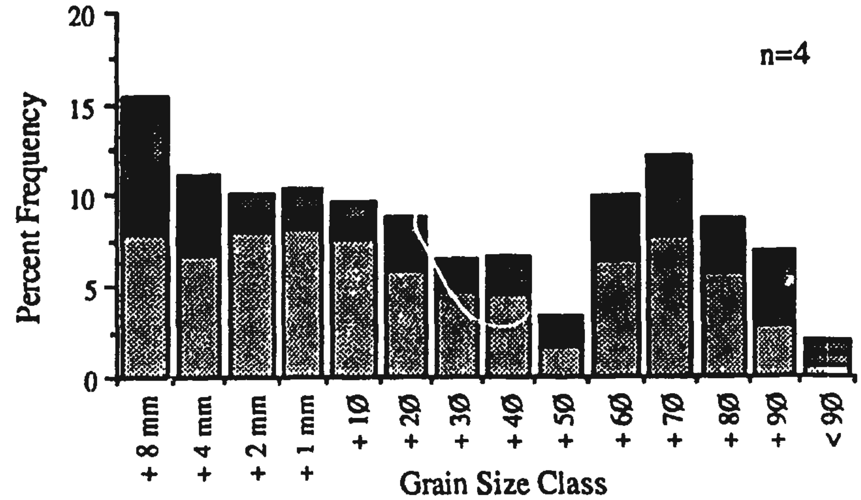


Figure 3-10. Grain size histogram for glaciofluvial gravels.

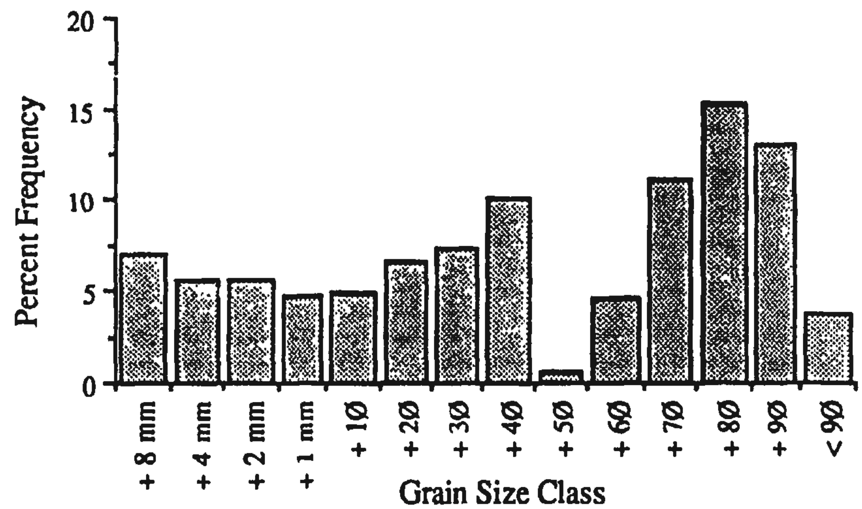


Figure 3-11. Grain size histogram for glaciomarine stony clay collected east of Camp 2.

Lithologic Constituents of Sediments

All of the surficial materials in the field area are primarily derived from local light brown and light grey dolostone and limestone and reflect the character of rock visible in local outcrops. The primary source of the small amounts of erratic materials present, granite and gneiss, is the Precambrian crystalline complex east of the study area on the main part of Baffin Island and Borden Peninsula. Some of the erratics probably represent material reworked from preexisting sediments during the last glaciation, which helps to explain their presence in all but five of the samples.

Table 2 shows the average percentages of nine rock types counted in the granule size class of sediments. Camp areas were chosen as natural divisions for presenting the data since variations in the content of different rock types are greater between camp areas than amongst individual samples from a given area. Generally, the percentage of erratics in the samples was considerably higher in samples from south of Bernier Bay (Camps 2 and 3).

Table 2. Rock Types Present in Drift Samples (n=72)

Rock Type	Camp 1	Camp 2	Camp 3	Camp 4
Dolostone	86.2%	69.1%	66.8%	73.4%
Limestone	14.4%	26.5%	33.8%	35.7%
Gneiss	0.9%	2.6%	1.5%	1.0%
Granite	+	6.7%	3.6%	1.8%
Quartz	1.0%	1.8%	2.3%	2.3%
Red Sandstone	1.5%	1.3%	1.3%	1.3%
Sandstone	0.0%	0.0%	0.6%	+
Shell Fragments	+	6.7%	1.0%	2.6%
Other	0.0%	0.8%	0.7%	0

+ material present but below 0.1 %

Dolostone and limestone are the dominant rocks in all samples. Percentages of erratic clasts are low, typically 5% or less. The frequency of granite and gneiss erratics in tills collected around camp 1 (Fig. 3-12) is significantly lower than in the other three areas. The number of Precambrian erratics in the granule size fraction of tills from different parts of the morainic zone were compared for the area around camp 3. Tills from the middle of the zone had the lowest numbers of erratics; those from the inner part of the zone, closest to the coast, had some erratics and those from the outermost moraine ridges also had some erratics. Samples from the interior plateau had by far the most erratics in the granule fraction.

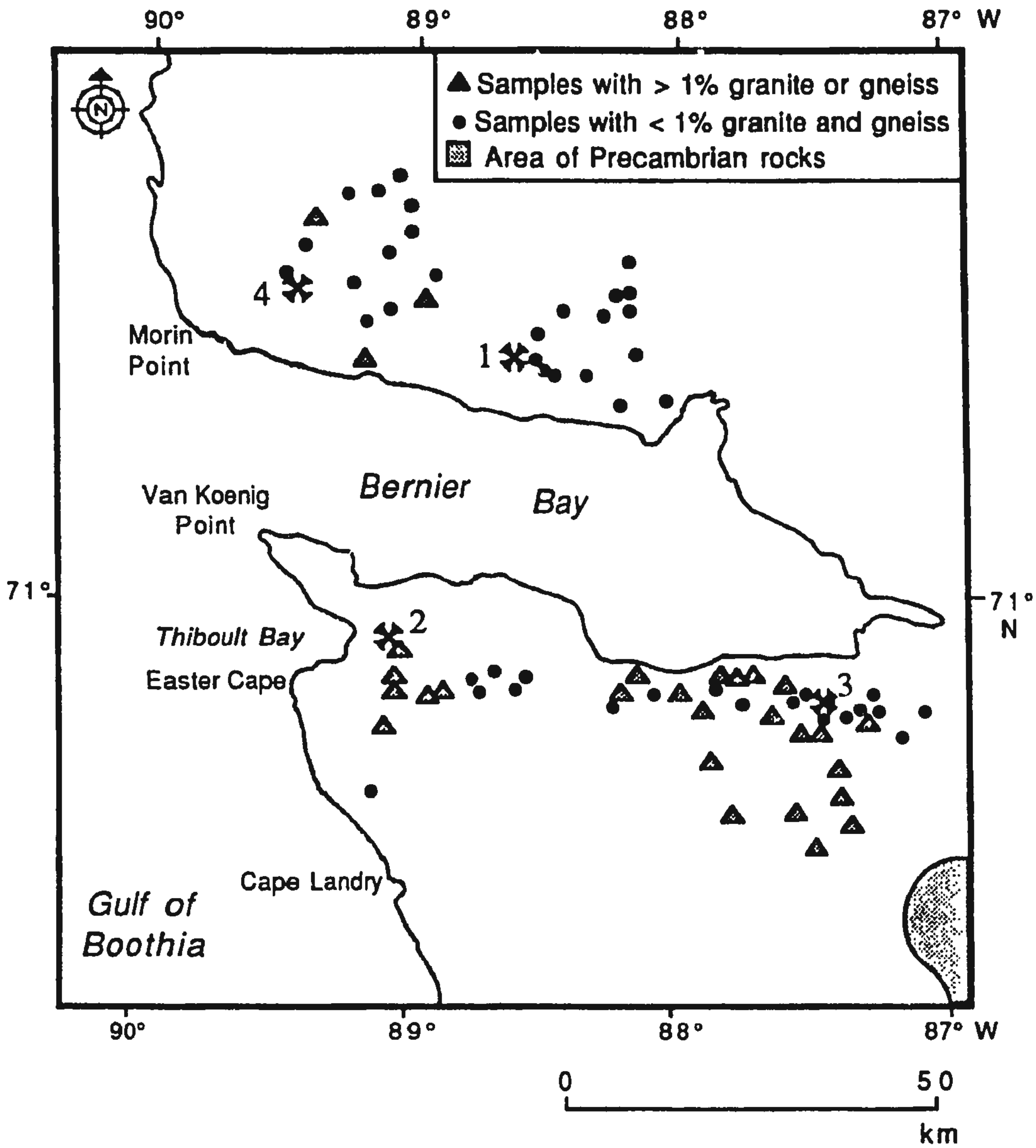


Figure 3-12. Distribution of Precambrian erratics. The triangles indicate the presence of Precambrian granite and gneiss at 1% or greater of the granule fraction. Solid circles represent samples where both granite and gneiss are below 1%.

The source of the quartz grains is unknown; they may derive from quartz grains weathered out of granites. Some small inclusions of quartz were observed in sandy dolostone northeast of Morin Point. They were also observed in gneiss outcrops on the south side of Berlinguet Inlet during the 1989 field season.

Red sandstone is a distinctive lithology traceable to the Gallery Formation on the west side of Admiralty Inlet, east of the study area. Outcrops of brown sandstone occur along the west side of the contact with the Precambrian crystalline rocks east of the study area. The occurrence of these materials in tills around Bernier Bay reflects transport of material by ice flowing westward into the field area. This material is present, at uniform low levels, in most of the samples.

Shells were occasionally found as fragments on drift surfaces above marine limit, and this is reflected by the small amounts of shell fragments counted in the granule fraction. These glacially transported shells became scarcer at higher elevations and further inland. Samples collected around Camp 2 had the highest numbers of shell fragments: this is likely reflects the fact that most of the Camp 2 samples were collected below marine limit.

Permafrost Features and Vegetation

Patterned ground forms of one kind or another are nearly ubiquitous in the study area. The degree of development and regularity of these surface phenomena varies according to the texture of the material, drainage and the duration of subaerial exposure. Tundra polygons occur on surfaces covered by the thickest drift and are also found on some alluvial surfaces and raised beaches. These are the largest permafrost features and are typically 10-14 m across with bounding ice wedge troughs up to 1 m deep. The interiors of tundra polygons ar ; usually flat. Small levees frequently occur alongside large ice wedge troughs where material has been upthrust by the growth of the ice wedge. Polygons are the only periglacial features clearly recognizable on air photographs. On the ground, they are less noticeable than the smaller raised-centre polygons, typically 60-200 cm in diameter with cracks 8-10 cm deep. These smaller features usually exhibit some sorting of material with pebbles being displaced into the cracks and fines upwelling in the centres (Fig. 3-13). The best development of sorted circles is found on level, poorly drained surfaces of coarse drift where the active layer is saturated. Regular, flat-topped polygons occur on surfaces covered by clay-rich marine silt. Very small, about 30 cm diameter, regular nets of well-sorted pebbles form on surfaces of thick, silty drift. This type of patterned ground is relatively rare and occurs only on flat, moderately drained sites where the overall surface relief, arising from permafrost features, is less than about 3 cm.

On slopes, patterned ground forms are elongated by solifluction producing parallel stripes on steep slopes and garlands on gentler slopes. Small peat palsas, 1-2 m high, occur in bogs where the growth of large bodies of segregated ice is favoured by an insulating mat of vegetation. Small sorted polygons were occasionally be observed on the bottom of shallow lakes and in shallow water along the coast. These features can only develop within the range of water depth which freezes and thaws annually along sheltered shorelines where they are not obliterated by ice-push events.

Estimated plant cover at sample sites ranged from 0 to 60% and averaged 10%. Values of 100% are common in sedge meadows, seepage slopes and bogs. Dryas, grass, arctic willow, sedge, mosses and lichens are common. Because of the harsh climate, the plants adopt a prostrate or cushion growth form and tend to preferentially locate in cracks between raised-centre polygons or stripes.

Figure 3-13. Sorted polygons developed on stony drift northeast of Morin Point. Note the virtual absence of erratics in this locally derived material.

Raised Beaches

Flights of raised beaches cover large areas below marine limit. Ice push, as opposed to wave action, has been the dominant beach-forming process during postglacial time. The beach gravels are formed by winnowing and ploughing of some preexisting sediment, usually till, by water and sea ice, respectively, producing structureless deposits of angular pebbles and cobbles typically 1-2 m thick. Ice push combined with falling relative sea level has created a characteristic topography of repeating ridges and swales which often extends several kilometres inland (Fig. 3-14). The intensity of ice-push activity is greatest along exposed stretches of the coastline and varies greatly from year to year according to the vagaries of winds and sea ice conditions.

Figure 3-14. Large ice-pushed ridge northwest of the head of Bernier Bay.

The degree of patterned ground development on raised beaches correlates well with the elevation, and hence age, of the beach. Beaches close to modern sea level have well defined ridges and swales, numerous rounded pebbles, and are covered by polygonal networks of ice wedge troughs. At higher elevations, ridge and swale topography has been smoothed by solifluction and well developed patterned ground forms are found, typically small raised-centre polygons and mudboils. Most rounded clasts have been broken by frost action, and clast surfaces are pitted from solution weathering. At elevations approaching marine limit, beach ridges are seldom recognizable. Poor definition of beach forms at higher elevations is probably due to obliteration by cryoturbation, solifluction and slopewash. Because of more rapid initial emergence following deglaciation, the uppermost beach ridges developed over much shorter time spans. Finally, the possible existence of semi-permanent landfast ice during the early postglacial period may have inhibited beach development. Level terrains below marine limit may be masked beneath a veneer of marine silt. These sediments occur as a drape of fine material, similar to that associated with the bottomset beds of raised deltas, and are characterized by the development of steep-sided hummocks perhaps due to the enhanced moisture-retaining characteristics of this material.

Gently sloping beaches around the head of Bernier Bay, in the isthmus area between Bernier Bay and Berlinguet Inlet and beaches north of Morin Point are covered by lags of ice-rafted boulders up to 1 m in diameter. The scattered boulders form irregular heaps and lines (Fig. 3-15). Recognizable strandlines are virtually absent in these areas. Drainage is poor and the terrain is a mosaic of shallow ponds and bogs. In a few areas boulder ramparts up to 2 m high have formed. The ramparts form when a particular site, for instance a slight topographic rise, becomes a favourable site for sea ice grounding. A feedback effect is created when the sea ice melts depositing any boulders it may be carrying so that the site becomes even more favoured for the grounding and melting of more sea ice, deposition of more boulders and so on (Dyke et al., 1982). The best examples of these features are relict forms abandoned by falling sea level (Fig. 3-16). The above areas represent a unique terrain type where reworking of material, particularly boulders, by ice-rafting is the dominant geomorphic process.

Figure 3-15. An area of gently sloping boulder-strewn beaches immediately west of the head of Bernier bay.

Figure 3-16. Boulder rampart south of the head of Bernier Bay. The rampart is over 3 m high and occurs at about 30 m asl. The degree of lichen growth on the boulders suggests that this is a relict feature.

Other Landforms

Pavements of weathered, horizontally bedded limestone were occasionally encountered where the mantle of surficial sediments is thin. One example occurs north of Thiboult Bay where a large limestone ridge has been eroded by the westward moving ice. The surface of the ridge has been smoothed and is covered by a thin residual lag of frost-shattered and solution-pitted limestone cobbles. Some erratics are commonly found amongst lags on limestone pavements.

Small bedrock canyons occur in three areas: east of Morin Point, east of the head of Thiboult Bay, and north of Cape Landry. These can be explained as an erosional response of local rivers to base level (sea level) lowering during the postglacial. These features are commonly encountered in areas where local streams cross rock outcrops as they flow into the main valley. These small canyons and knickpoints are most likely Holocene in age whereas the age of the large canyons in the northwest part of the area could predate the last glaciation. The largest canyon is northeast of Morin Point and is about 20 m deep. Several small canyons, about 4 m deep, were examined north of Cape Landry (Fig.3-17). Some of the mapped meltwater channels also occupy bedrock canyons.

Figure 3-17. Bedrock canyon north of Cape Landry.

Chapter 4: Results of the Radiocarbon Dating Program

The main objectives of the radiocarbon dating program were to find the age of the Holocene marine limit and to measure the pattern of postglacial isostatic emergence.

Four shell dates were obtained pertaining to the Holocene marine limit and are between 8240 and 8600 BP. Four other shell dates were obtained pertaining to lower elevations. The eight shell dates range in age from 4310 to 8600 BP. The locations, elevations and ages of these samples, as well as the locations and heights of three marine limit deltas are given in Figure 4-1.

Sixteen samples of whalebone and four samples of walrus tusk were dated. The ages of these materials ranged from 1110 BP to 6585 BP. These were used to draw three independently-controlled emergence curves for different parts of the Bernier Bay coastline, one per camp area, with the exception of Camp 1. Few high quality bone samples were collected in the first camp area. Consequently it was decided to devote the available dates to building curves for the remaining three areas.

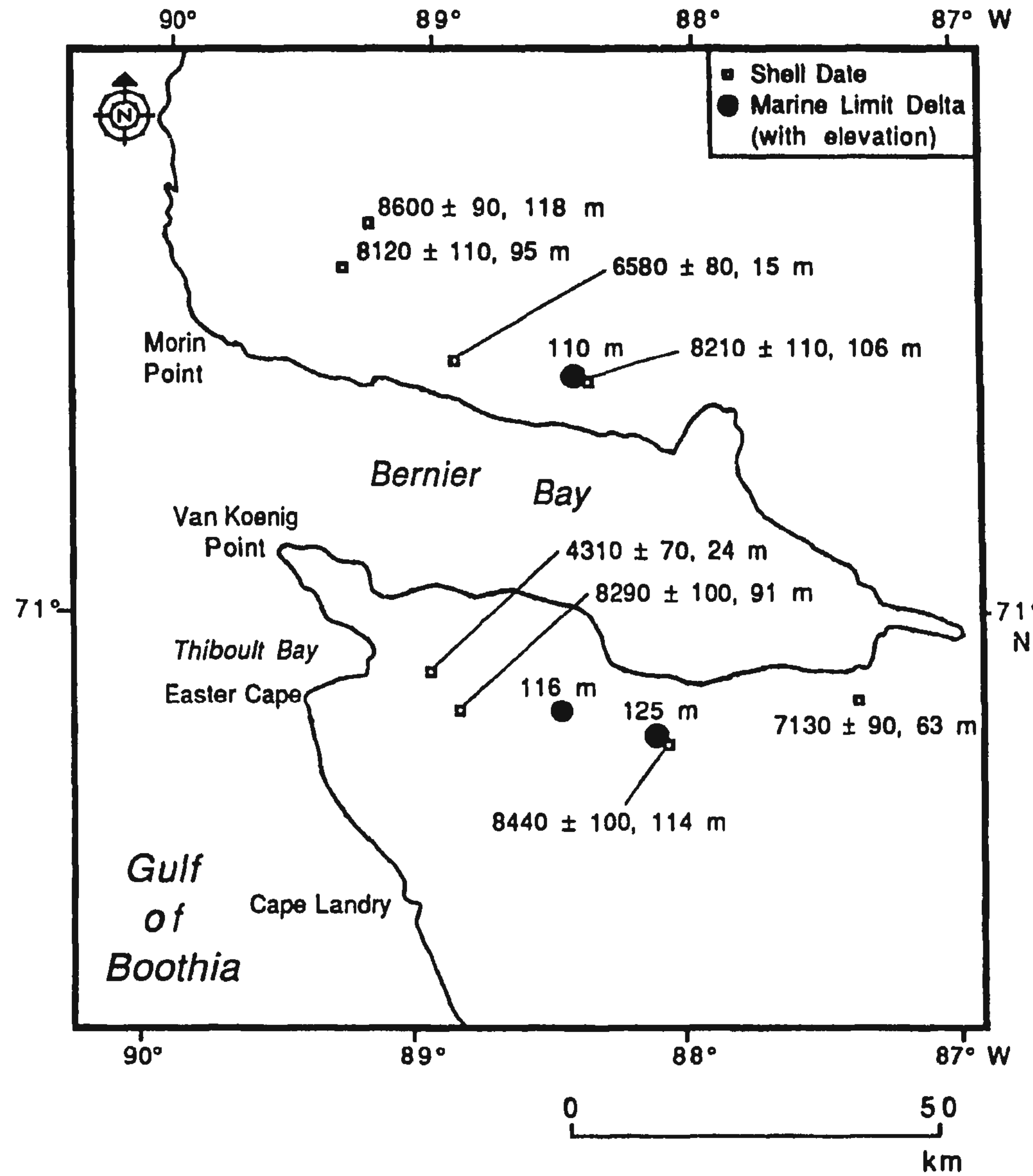


Figure 4-1. Location of shell dates and marine limit deltas.

appropriate for dates on wood than marine shells (Dyke, pers. comm., 1990). Corrected shell dates from the GSC laboratory have been "normalized" for ^{13}C fractionation of 0 ‰ (Lowden, 1984).

Another possible source of error in the radiocarbon dates is the reservoir effect. This is an increase in the apparent age of shells caused by the slow exchange of atmospheric and marine ^{14}C. Due to radioactive decay and the slow circulation of water in the ocean basins, old water in the deep ocean basins contains less ^{14}C than surface waters. Since the ^{14}C contained in shells comes from the surrounding waters, modern shells usually date considerably older than expected. Mangerud and Gulliksen (1975) compared radiocarbon dates on collections of modern shells from from Norway, Spitsbergen and Ellesmere Island. Shells from these areas had apparent ages of 440, 510 and 750 years, respectively. It is probable that shells dates from the field area are about 400 years younger than suggested by their radiocarbon ages; no correction has been made for the reservoir effect in this study.

Significant problems arise when attempting to correct radiocarbon dates for fractionation and other effects. The different dating labs have evolved different protocols over the years. The supply of Peedee Belemnite has been exhausted. Thermonuclear explosions in recent decades have enriched the ^{14}C content of the atmosphere so that the reservoir effect on shells can only be gauged by measuring the apparent age of museum collections made before 1950. Such collections are limited in number and spatial distribution. The uncorrected age has been chosen when discussing the dates presented here since it offers the best chance of being comparable with dates from other localities. A more complete discussion of the complexities involved in applying corrections to radiocarbon dates is given in Bradley (1985). For the dates presented below, it is sufficient to note that correction for ^{14}C fractionation results in a small, positive change in the age of the sample.

Table 3 summarizes the radiocarbon data, including the material, sample site elevations, elevations of related former sea levels, age and stratigraphic context to which each date pertains. The heights of former sea levels were assigned based on the assumption, mentioned earlier, that the whale and walrus carcasses grounded at or slightly below the former sea level. The internal consistency of the emergence curves validates this assumption. For whale and walrus finds, the proposed related sea levels were likely less than two metres above the sample elevations. In the case of shell dates, other information, particularly the height of nearby marine limit features, was used in delimiting the elevation range of the contemporaneous paleo sea level. For comparison purposes, all of the ages discussed in the text and used to draw emergence curves are uncorrected. Corrected ages, available for shell dates only, are given in Table 3.

In these cases, a correction factor has been applied to compensate for fractionation of the $^{14}C/^{12}C$ ratio that occurs as $^{14}CO_2$ is dissolved, at a slightly faster rate, into seawater. This results in a slight difference between the atmospheric and marine $^{14}C/^{12}C$ ratios. Fractionation also occurs during uptake of carbon from the environment by organisms depending on the particular biochemical pathways utilized and is therefore different for different types of organisms.

Fractionation of ^{14}C is measured indirectly by first measuring the ratio $^{13}C/^{12}C$ in the sample. This is done because the greater abundance of the inert isotope ^{13}C is allows more accurate measurement using a mass spectrometer. Since the fractionation of $^{14}C/^{12}C$ is very close to twice that of $^{13}C/^{12}C$, the fractionation of $^{14}C/^{12}C$ and a correction factor in years can then be calculated. Fractionation of ^{13}C in a radiocarbon sample is expressed as the departure from the ^{13}C fractionation measured in a Cretaceous Belemnite standard (PDB). This is an extinct squid-like organism from the Peedee Formation of southern California. Typical values obtained for ^{13}C fractionation are -25 ‰ for wood, between +2 and -2 ‰ for marine shells and -13 ‰ for bone. Most radiocarbon laboratories, but not the GSC laboratory, apply the -25 ‰ correction value to shells. This correction is really more

Table 3. Radiocarbon Dates from the Bernier Bay Area.

NORTHEAST BERNIER BAY (CAMP 1):

Laboratory No. (Field No.)	Material	Elevation	Related Sea Level	Age (yrs BP) (corrected)	Stratigraphy	Latitude Longitude
GSC-4777 (405)	*Mya truncata*	15 m	≥15 m	6580 ± 80 (6600 ± 80)	marine silt	71° 19' N 88° 50' W
GSC-4695 (409)	*Mya truncata*	92 m	106 m	8210 ± 110 (8240 ± 110)	surface of marine silt	71° 18' N 88° 28' W

VAN KOENIG POINT (CAMP 2):

S-3099 (440*)	carbone	4 m	≥ 4 m	1110 ± 60	raised beach	71° 02' N 89° 22' W
S-3044 (434*)	carbone	11 m	≥ 11 m	2570 ± 60	raised beach	71° 01' N 89° 20' W
S-3096 (454*)	carbone	23 m	≥ 23 m	4250 ± 70	raised beach	70° 55' N 89° 06' W
S-3011 (477†)	walrus tusk	23 m	≥ 23 m	4320 ± 90	raised beach	71° 03' N 89° 02' W
GSC-4776 (471)	*Hiatella arctica*	24 m	~ 25 m	4310 ± 70 (4330 ± 70)	muddy gravel	70° 57' N 89° 02' W
S-3094 (446†)	walrus tusk	26 m	≥ 26 m	4440 ± 70	raised beach	71° 03' N 89° 22' W
S-3098 (444*)	carbone	27 m	≥ 27 m	5520 ± 70	raised beach	70° 55' N 89° 03' W
S-3045 (450*)	carbone	28 m	≥ 28 m	4500 ± 80	raised beach	70° 58' N 89° 07' W

VAN KOENIG POINT (Cont.)

Laboratory No. (Field No.)	Material	Elevation	Related Sea Level	Age (yrs BP) (corrected)	Stratigraphy	Latitude Longitude
S-3095 (469†)	walrus tusk	30 m	≥ 30 m	4810 ± 90	raised beach	70° 44' N 89° 06' W
S-3093 (449†)	walrus skull	38 m	≥ 38 m	6200 ± 80	raised beach	70° 58' N 89° 57' W
GSC-4703 (458)	*Mya truncata*	91 m	> 91 m ≤116 m	8290 ± 100 (8310 ± 100)	surface of marine silt	70° 53' N 88° 54' W

SOUTHEAST BERNIER BAY (CAMP 3):

Laboratory No. (Field No.)	Material	Elevation	Related Sea Level	Age (yrs BP) (corrected)	Stratigraphy	Latitude Longitude
S-3016 (530*)	earbone	7 m	≥ 7 m	2220 ± 75	raised beach	70° 56' N 87° 30' W
S-3015 (505*)	earbone	20 m	≥ 20 m	4115 ± 85	raised beach	70° 56' N 87° 45' W
S-3097 (527*)	skull fragments	22 m	≥ 22 m	4010 ± 70	raised beach	70° 57' N 87° 19' W
S-3075 (528*)	bone	22 m	≥ 22 m	3930 ± 80	raised beach	70° 56' N 87° 14' W
S-3040 (503*)	earbone	28 m	≥ 28 m	5050 ± 165	raised beach	70° 56' N 87° 56' W
S-3014 (502*)	earbone	37 m	≥ 37 m	5670 ± 100	raised beach	70° 56' N 87° 47' W
S-3013 (501*)	earbone	49 m	≥ 49 m	6585 ± 105	raised beach	70° 56' N 87° 42' W
GSC-4775 (531)	*Hiatella arctica*	63 m	~ 64 m	7130 ± 90 (7140 ± 90)	marine silty clay	70° 55' N 87° 23' W
GSC-4721 (523)	*Mya truncata*	114 m	~ 125 m	8440 ± 100 (8470 ± 100)	glaciomarine silt	70° 52' N 88° 12' W

MORIN POINT (CAMP 4):

Laboratory No. (Field No.)	Material	Elevation	Related Sea Level	Age (yrs BP) (corrected)	Stratigraphy	Latitude Longitude
S-3041 (549*)	vertebra	5 m	≥ 5 m	2175 ± 130	raised beach	71° 19' N 89° 31' W
S-3043 (537*)	earbone	21 m	≥ 21 m	3950 ± 70	raised beach	71° 21' N 89° 52' W
S-3074 (540*)	earbone	24 m	≥ 24 m	4350 ± 70	raised beach	71° 22' N 89° 41' W
S-3042 (546*)	earbone	33 m	≥ 33 m	5600 ± 90	raised beach	71° 28' N 89° 52' W
GSC-4754 (566)	*Hiatella arctica*	95 m	> 95 m < 100 m	8120 ± 110 (8140 ± 110)	surface of marine silt	71° 23' N 89° 18' W
GSC-4742 (569)	*Mya truncata* *Hiatella arctica*	118 m	~ 118 m	8600 ± 90	surface of marine silt	71° 26' N 89° 07' W

* Bowhead whale: *Balaena mysticetus*

† Walrus: *Odebenus rosmarus*

Dates on Marine Limit/Deglaciation

Because ice retreat occurred simultaneously with marine inundation, the age of the highest and oldest shells provides a minimum age on deglaciation of the area (Bryson et al, 1969), as well as the uppermost point on an emergence curve. Thus, deglaciation dates rely on the assumption that the molluscs reached the area within a few hundred years of deglaciation. The earliest shell dates indicate that the area was deglaciated from west to east beginning slightly before 8600 and over a time span of about 600 years.

Tilting of the marine limit shoreline is an indication of the direction of maximum ice loading. In the field area, the relationship is complicated because the marine limit elevations measured are of different ages. This time-transgressive marine limit becomes younger and increases in elevation towards the east and south.

The oldest shell date from the study area is on a mixed sample of *Mya truncata* and *Hiatella arctica* (GSC-4742) containing numerous whole valves from the surface of marine silts north of Camp 4. The shells were collected at an elevation of 118 m, slightly below the upper limit of silts in an unnamed valley, and dated 8600 ± 90 BP. The upper limit of silts near the collection site is estimated at 124 m and is probably the marine limit. The site was the highest point in the area where sufficient shells for a radiocarbon sample could be found. A similar collection of *Mya truncata* and *Hiatella arctica* (GSC-4754) was made a few kilometres to the south at an elevation of 95 m. In this case, paired whole valves were found eroding from the surface of the silts (Fig. 4-2), indicating an essentially *in situ* sample. These shells dated 8120 ± 110 BP.

Figure 4-2. Paired valves of *Mya truncata* amongst lag gravels on the deflating surface of marine silts northeast of Camp 4 (GSC-4754).

Deposits of marine silt blanket valley floors north of Camp 4. These silt surfaces are being lowered by wind erosion, causing lags of angular pebbles and shells to accumulate. Interestingly, very few *in situ* shells were found in pits dug in the silt, although shells are abundant in the surface deflation lags. This suggests that considerable deflation lowering of the surface has occurred to produce the observed concentrations of shells. The possibility that the shells have been transported into the area by slopewash is considered unlikely because there are very few shells at higher elevations. The upper limit of marine silts is clearly discernible along valley sides in the upper reaches of drainage basins in this area, notably Jane's Creek and the slightly larger unnamed drainage to the west. This feature is at about 124 m and is almost certainly the Holocene marine limit.

Further east, in the vicinity of Camp 1, a date of 8210 ± 100 BP was obtained on a collection of *Mya truncata* fragments (GSC-4695). The shells were collected from a pebbly deflation lag on the surface of a deposit of marine silts adjacent to a large marine limit delta (Fig. 3-2, page 31). The collection is from an elevation of 92 m, 18 m below the flat delta surface measured at 110 m.

Two dates pertaining to marine limit were obtained for the south side of Bernier Bay. A sample of fragments of thick *Mya truncata* valves (GSC-4721) was collected from a pebbly deflation lag on marine silts about 1 km southeast of a large marine limit delta and approximately 25 km west of Camp 3. The sample is from an elevation of 118 m, only 7 m below the adjacent delta surface at 125 m, and had an age of 8440 ± 100 BP.

The second marine limit date is on a surface collection of fragments and whole valves of *Mya truncata* from a small deposit of grey stony clay on the south flank of the moraine about 10 km southeast of Camp 2 (GSC-4703). The shells were from an elevation of 91 m and gave an age of 8290 ± 100 BP, which should be considered a minimum age for marine limit in the Camp 2 area. There is no nearby marine limit delta. About 13 km east of this site, the height of a large marine limit delta was measured at 116 m. No shells were found on deposits flanking this feature. This delta is probably younger than the 125 m delta described above, judging by its elevation.

Two additional shell dates (not shown) are used in the discussion of the deglacial chronology of the area. The first is a date of 8800±90 BP (GSC-4704) on a sample of *Hiatella arctica* shells collected on the west coast of Brodeur Peninsula south of Fitzgerald Bay in 1988 by A.S. Dyke (pers. comm., 1989). The shells were collected at 77 m and and date deglaciation and marine limit, at 102 m, for the west coast of Brodeur Peninsula north of the study area. The second date used to frame the deglacial chronology of the area is a date of 8910±120 BP (GSC-4898), on a mixed collection of *Mya truncata* and *Hiatella arctica*, collected by myself at an elevation of 65 m atop a large kame northeast of Mathe

Point (west of Fury and Hecla Strait). The sample was not related to a measurable marine limit feature so the elevation of marine limit south of the study area is presently unknown.

The highest recorded occurrence of shells in the field area is an undated collection from an area south of the head of Bernier Bay. Numerous fragments of *Mya truncata* were found on the crest of a large moraine at 178 m asl. These are interpreted as glacially transported shells. The sample is probably beyond the range of radiocarbon dating.

Profile of the 8200 BP Shoreline

Four of the shell dates have been used to draw the approximate configuration of the 120 and 110 m isobases on the 8200 BP shoreline (Fig 4-3). Unfortunately, only one of the 8200 BP dates is clearly related to a former sea level feature, so only the 110 m isobase can be precisely located. The positioning of the 100 m isobase was made by assuming that the *in situ* shells dating 8120 BP from northeast of Morin Point grew in water less than 5 m deep and that sea level would have been slightly higher at this site at 8200 BP. Similarly the 120 m isobase was positioned east of the 125 m marine limit delta dated 8440 BP on the assumption that sea level at this site would have been about 10 m lower at 8200 BP. Other equally valid interpretations of the isobase pattern can be made by changing the assumptions regarding the height of former sea levels at the time the two westernmost shell samples were deposited. The preceding assumptions regarding the depth of water in which the shells grew are arbitrary since *Mya truncata* can grow in water up to 100 m deep (Andrews, 1985).

The trend of these tentative isobases accords well with the 8000 BP isobase map of the region (Miller and Dyke, 1974) although the total emergence in the field area is slightly greater than was previously thought. The isobase pattern suggests that the centre of the crustal loading was located east, and slightly south, of the field area. The observed pattern of emergence is probably a result of the pre-Late Wisconsin ice load, when the field area was inundated by grounded ice, rather than of more recent events. The effect of an ice shelf in Bernier Bay on the emergence history of the area is minor because floating ice produces crustal loading equivalent to that caused by open water given the same relative sea level. Thus, uncoupling of the ice from the seabed is isostatically equivalent to deglaciation.

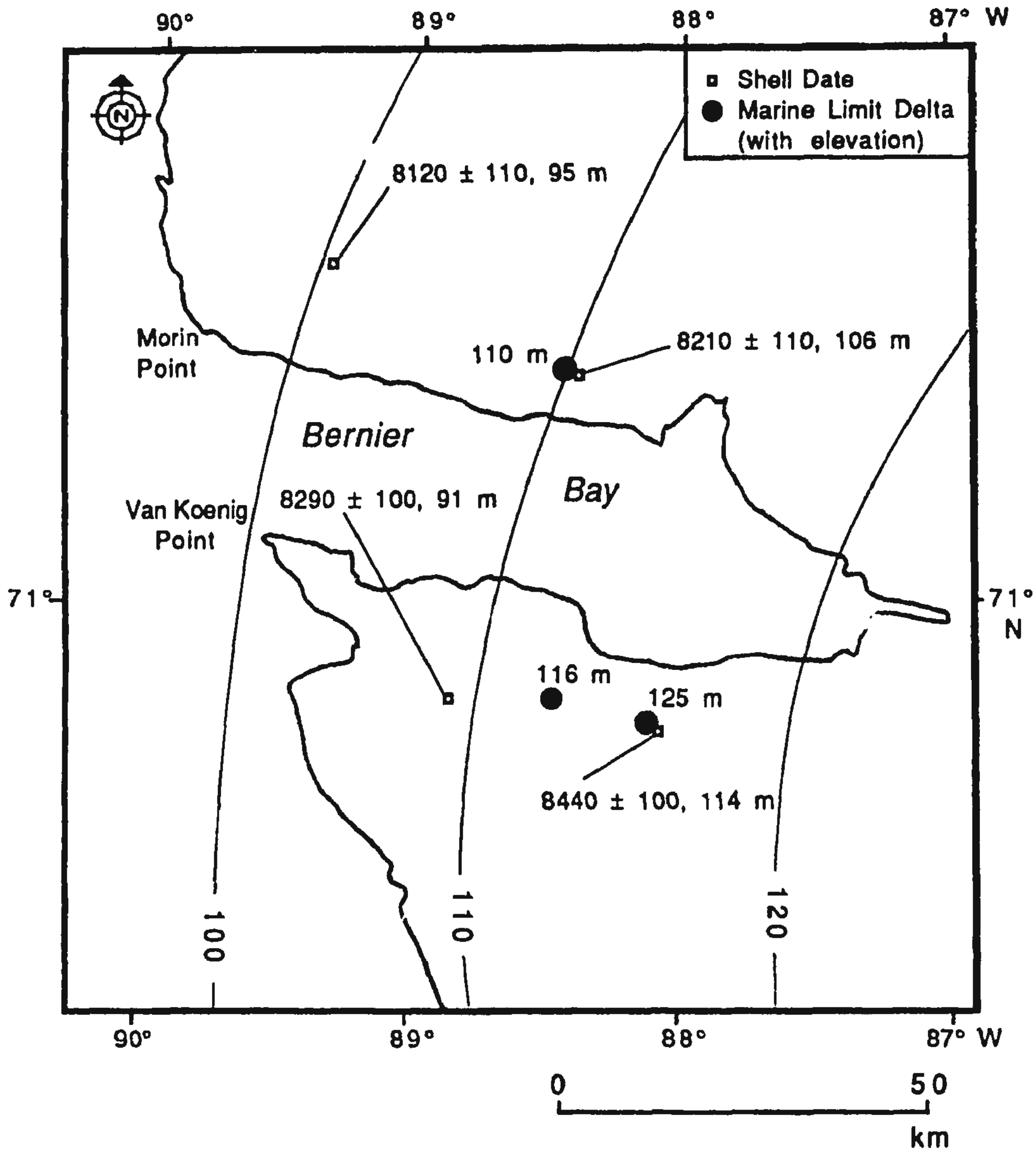


Figure 4-3. Proposed pattern of isobases for the 8200 BP shoreline in the study area.

Dates on Postglacial Emergence

Three shell dates were obtained for elevations below marine limit. Two of these dates, discussed below, were used in conjunction with whalebone and walrus tusk dates for constructing emergence curves. A third date (GSC-4777) is on a sample of *in situ* paired whole valves of *Mya truncata* excavated from laminar sands in a small section near Camp 1. The sample was from 15 m asl and yielded an age of 6580 ± 80 BP. This is far older than one would expect for material at this elevation and it is likely that the shells grew in some depth of water. The date could not be related to a paleo sea level feature, and was not used as a control point for an emergence curve. Figure 4-4 is a map showing the location of dated bone and tusk samples used to construct the three emergence curves. The curves shown in the figures which follow were drawn subjectively, such that a minimum of points would fall above a smooth curve. Regression analysis, or other statistical methods, are not particularly well suited to this data because the elevation errors are not evenly distributed, i.e. the most frequent source of error is samples that are too old for their elevations.

The emergence curve for the fourth camp area (Fig. 4-5) is based on four whalebone dates and the two high-elevation shell samples described in the previous section. The lowest point on this curve is a date obtained from a small bowhead vertebra excavated from barren beach gravels at 5 m (S-3041). This was the only vertebra found in the field area which was sufficiently clean to date. This is because of its relatively young age and the sterility of the enclosing gravels. The sample had an age of 2176 ± 130 years.

A date of 3950 ± 70 BP was obtained on a large sample of bowhead earbone at 21 m (S-3043). At 24 m another sample of earbone (S-3074) dated 4350 ± 70 BP. A third sample of earbone (S-3042) was collected at an elevation of 33 m. This sample had an age of 5600 ± 90 years. This was the highest elevation bone date from the fourth camp. There are no control points on the emergence curve between this date and the two high-elevation shell dates discussed above at 95 m and 118 m.

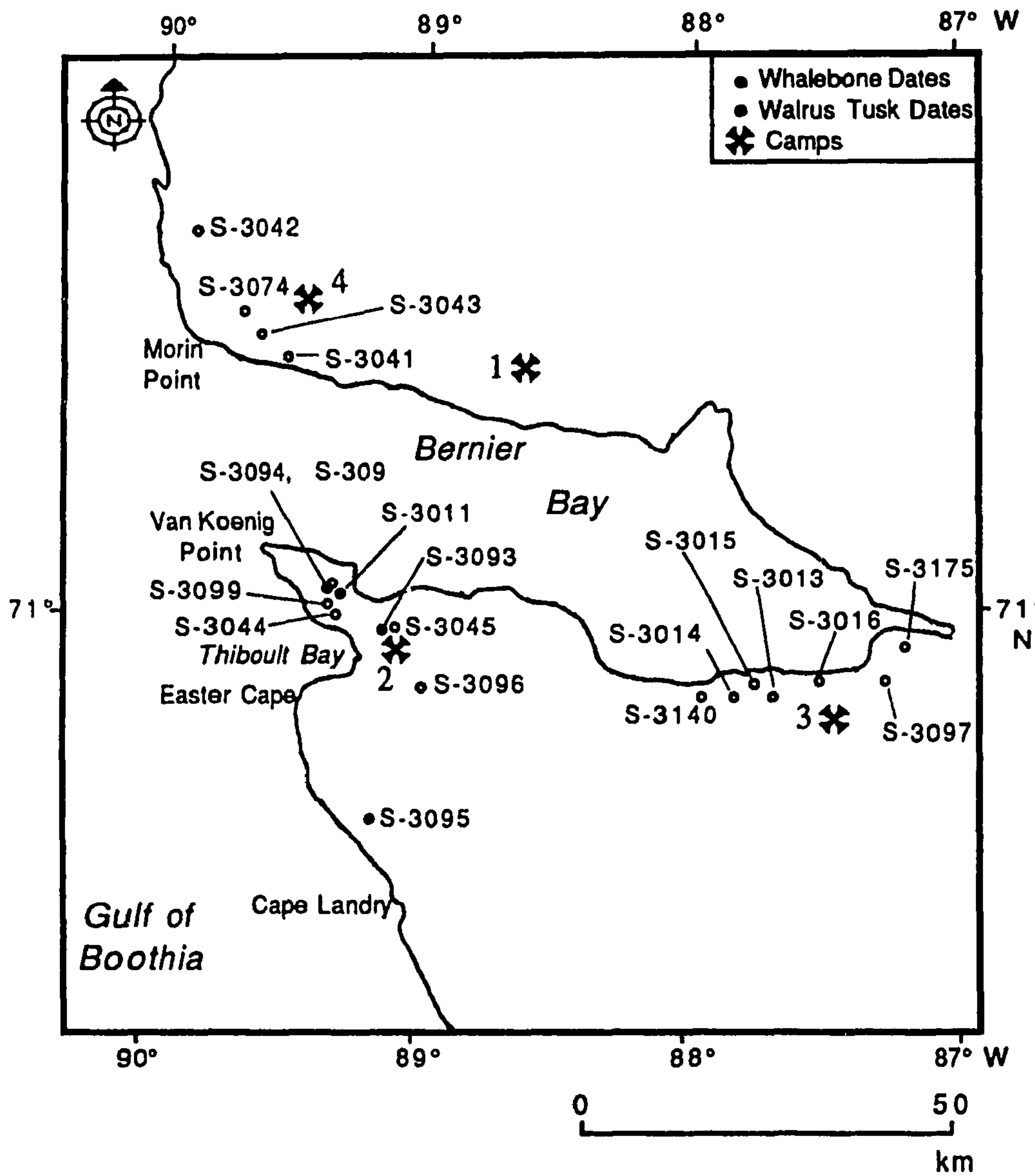


Figure 4-4. Locations of dated samples of whalebone and walrus tusk.

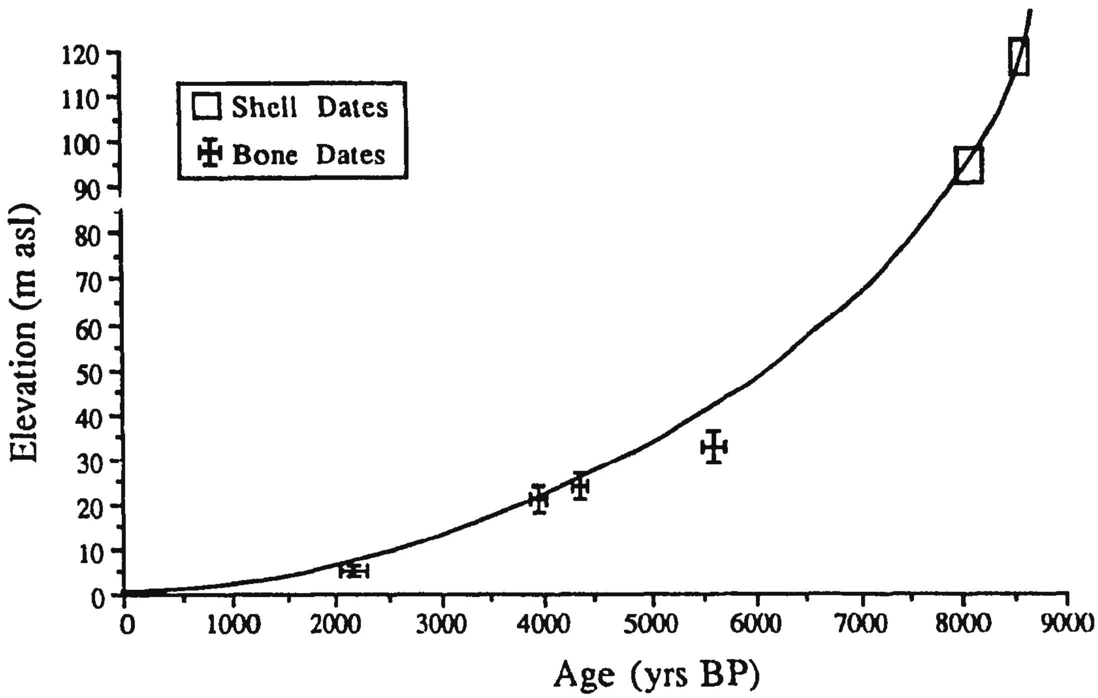


Figure 4-5. Emergence Curve for the Morin Point (Camp 4) area.

Five whalebone dates, four walrus tusk dates and two shell dates form the basis of the Camp 2 emergence curve (Fig. 4-6). The lowest point on the curve (S-3099) is a date of 1110 ± 60 BP on a bowhead earbone removed from a fragmented skull. Decomposing ribs and vertebrae were found at the same site. This material was scattered on the surface along the length of the beach and partly covered in clumps of moss.

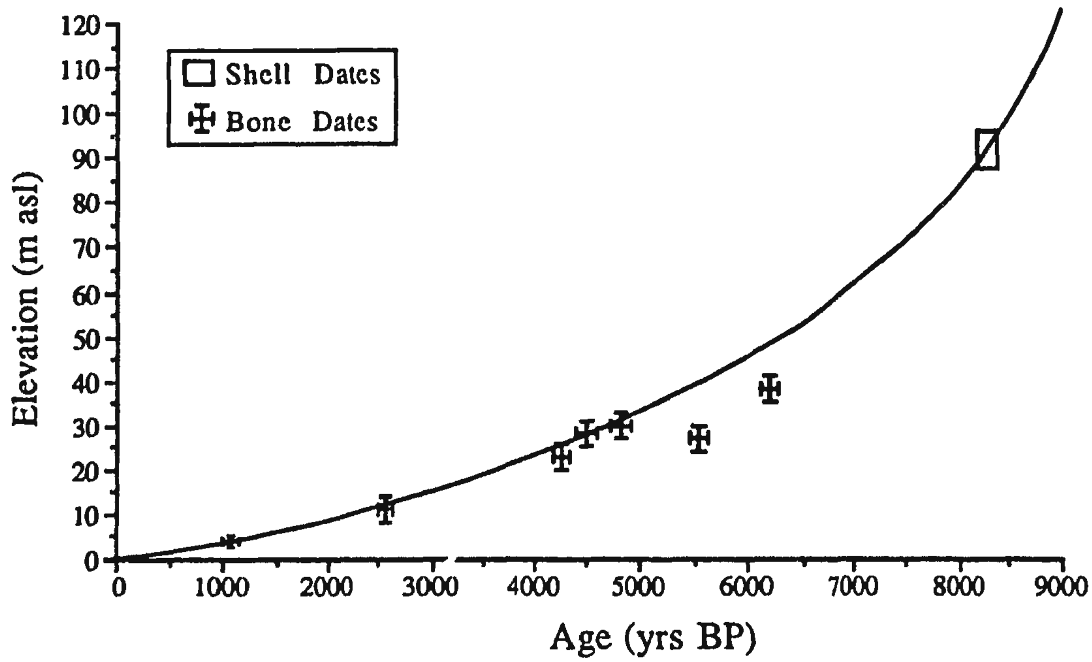


Figure 4-6. Emergence Curve for the Van Koenig Point (Camp 2) area.

A second whalebone date (S-3044) pertains to a skull collected from a gravelly sand beach at 11 m and less than 1 km south of the previous date. Both periotic bones were recovered and yielded a date of 2570 ± 60 BP.

A third whalebone date (S-3096) was obtained from a earbone collected at 23 m about 3 km south of Camp 2. The sample is from a raised gravel beach and yielded an age of 4250 ± 70 BP. Most of the skeleton of a large bowhead was found, much of it shallowly buried, at this locality.

The last whalebone date (S-3045) for Camp 2 pertains to a sample of earbone collected from a large bowhead skull embedded in gravelly sands about 1 km north of the camp. At 28 m asl, this was the highest whalebone sample found in this area and dated 4500 ± 80 BP. Figures 4-7 and 4-8 show two undated whalebone finds which typify conditions in this area.

Figure 4-7. Large bowhead rib unearthed southeast of Van Koenig Point.

Figure 4-8. Large bowhead mandible found on Van Koenig Point. Note that the bone has been previously excavated and the posterior end sawed off by Inuit who utilize the material for building komatiks.

All of the walrus tusk dates come from the Camp 2 area. Of these, three are from Van Koenig Point, and one is from a site about 20 km southeast of Easter Cape. The lowest two dates (S-3011 and S-3094) are from an area of prolific walrus finds on Van Koenig Point about 12 km northwest of Camp 2. These are from 23 m and 26 m, and dated 4320 ± 90 and 4440 ± 70 BP, respectively. The younger date is on a small tusk or piece of tusk found in association with several tusk fragments. Neither of the tusk fragments were embedded and appeared to have been gnawed by scavengers. Numerous walrus bones were found scattered along a beach about 200 m to the east and about 2 m below this site. The bones appeared to belong to more than one animal. No other material was found in association with the shallowly embedded 26 m tusk. These two dates have been omitted, for the sake of clarity, in the above plotting of the Van Koenig Point emergence curve.

A small walrus skull (S-3093) was found on Van Koenig Point about 1.5 km north of Camp 2 at an elevation of 38 m. A tusk from this skull dated 6200 ± 80 BP. The skull was collected from the surface of a sandy raised beach near the crest of the Van Koenig Point ridge. A second tusk was found a short distance away and apparently belonged to the same animal since it fitted the skull perfectly. No other bones were found in the vicinity.

The last walrus tusk date (S-3095) is also the farthest from the area of camp 2. The sample is a broken tusk removed from a large walrus skull. The skull was entirely embedded in beach gravels at 30 m and was discovered after the second tusk was seen on the surface. The tusk fragment which was dated had obviously broken off at the gumline while the animal was still alive as evidenced by the well worn, blunted end. The skull was approximately 45 cm long. The sample yielded a date of 4810 ± 90 BP. No other walrus bones were found in the immediate vicinity.

The final date used for the Van Koenig Point emergence curve is on a sample of *in situ* whole valves of *Hiatella arctica* collected east of Camp 2 (GSC-4776). The shells were excavated from a small section in gravelly mud at 24 m and dated 4310 ± 70 BP. The sample probably relates to an extensive level surface of gravelly marine sediment about 1 m above the collection site, interpreted as a former mud flat. This was the lowest elevation shell sample collected in the field area. For clarity, this point was omitted from Figure 4-6.

It is worth commenting here on the close agreement exhibited by whalebone and walrus tusk dates from Van Koenig Point where a date on a bowhead earbone (S-3096, 4250 BP) is. within one standard deviation of a date on a walrus tusk (S-3011, 4320 BP). In this case, the walrus tusk was found resting on the surface of beach sands and was not embedded. Both these dates were collected at 23 m asl. A shell sample collected several kilometres to the east (GSC-4776, 4310 BP) is from 24 m asl. This type of corroboration of dates on different materials lends credence to the fundamental assumption of the research technique that the carcasses of marine mammals usually ground at the current sea level, or in very shallow water.

Seven samples of whalebone and two shell samples form the basis of an emergence curve for the Camp 3 area (Fig. 4-9). Five of the dates are on bowhead earbones, the remainder are on collections of dense bone broken from the skulls. The youngest bone sample for this area (S-3016) is an earbone collected from a small skull embedded in bouldery beach gravels about 4 km north of Camp 3. The sample had a radiocarbon age of 2220 ± 75 years.

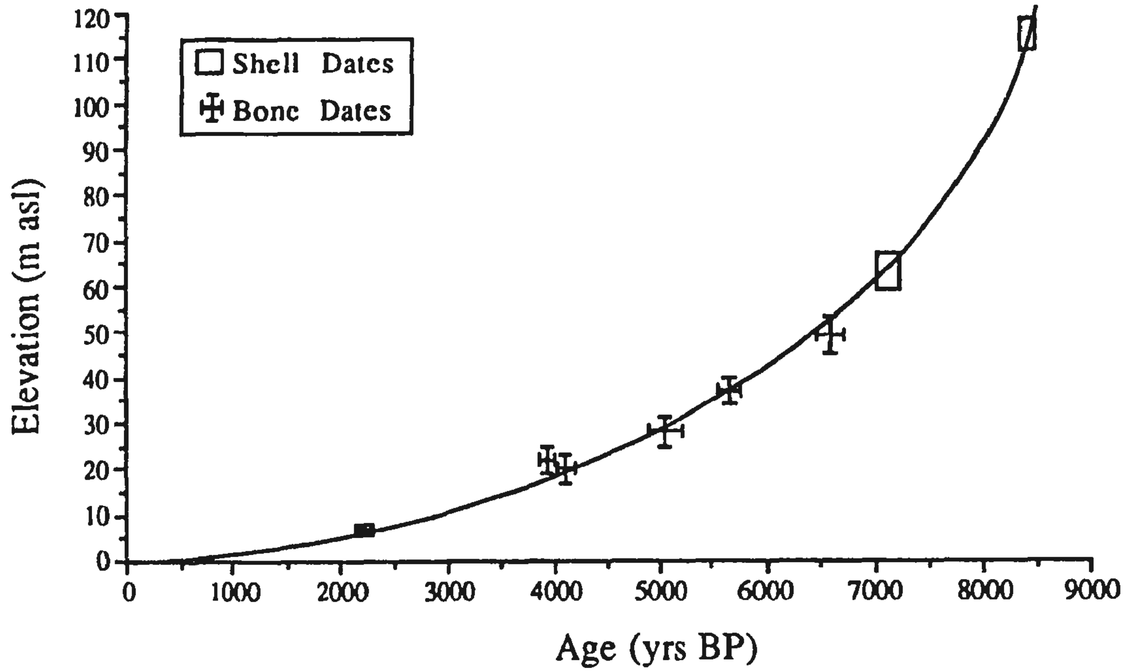


Figure 4-9. Emergence curve for southeastern Bernier Bay (Camp 3).

The next youngest bone sample (S-3015) is an earbone collected from a bouldery raised beach about 7 km northwest of Camp 3. The piece of periotic bone was collected from a fragmented bowhead skull at an elevation of 20 m, and dated 4115 ± 85 BP.

Two samples of skull fragments (S-3097 and S-3075) were collected from bowhead skulls at 22 m. The first was from a skull found embedded in sandy beach gravel about 6 km northeast of camp 3 which dated 4010 ± 80 BP. This date is not shown on Figure 4-9, for the sake of clarity. Several other bones including a the posterior end of a large mandible were found at the site. The site had obviously been visited by Inuit who had sawed the long part of the mandible off and removed it. This practice is common in the area as the mandibles are used for making sled runners (Dyke, pers. comm., 1988, see Fig. 4-8). The skull appeared not to have been disturbed. The second skull fragment sample was collected from a boulder-strewn raised beach about 10 km northeast of Camp 3. This very large bowhead skull was well embedded in coarse gravels and dated 3930 ± 80 BP. No other bones were found in the vicinity.

A sample of bowhead earbone (S-3040) was collected from a large skull well embedded in coarse beach gravels about 15 km northwest of Camp 3. The skull was at an elevation of 28 m and dated 5050 ± 165 BP. No other bones were found at the site.

Another earbone sample (S-3014) was collected at from a skull well embedded in coarse beach gravels about 12 km northwest of Camp 3. The sample is from an elevation of 37 m and yielded a radiocarbon age of 5670 ± 100 BP.

The highest bone sample dated is a sample of earbone collected from a site about 10 km northeast of Camp 3 (S-3013). It was found at 49 m on a sandy raised beach, shallowly embedded about 7 m away from a large bowhead skull. This sample of otic capsule was the only earbone which was not found attached or immediately adjacent to the skull. Several vertebrae were also found in the vicinity. The latter two bone samples (S-3014 and S-3013) are the highest bone samples dated and help close the gap in the emergence curve between the lower elevation bone dates and shell dates approaching marine limit, making the Camp 3 emergence curve the best-controlled of the three curves.

The last point on the Camp 3 curve, below the marine limit date, is a date on a collection of *in situ* whole valves of *Hiatella arctica* from a site about 4 km northeast of Camp 3 (GSC-4775). The shells were excavated from laminar marine silts at 63 m and yielded an age of 7130 ± 90 years. Although the shells are not related to a specific shoreline feature, their age agrees well with marine limit dates for the area and also whalebone dates at lower elevations. This provides reasonable grounds for assuming that the shells grew in shallow water.

Raised Beach Surveys

Results of the raised beach surveys cannot be used to establish the direction or amount of tilting since measurement errors are of the same magnitude as the expected tilting. The beach surveyed on Van Koenig Point tilted up towards the southeast with an increase in elevation of 43.3 cm over the 1605 m length of the transect. This gives an average gradient of 27.0 cm/km.

The beach surveyed at Morin Point tilts up toward the east with an increase in elevation of 11.6 cm over the 761 m transect. This results in a slightly lower average gradient of 15.3 cm/km. The failure of the surveys to provide useful data is a result of the absence of recognizable strandlines of sufficient length. For the 20 m shoreline in the study area, obtaining unequivocal results would require surveying uninterrupted strandlines over a distance of at least 5 km.

Comparison of the Three Emergence Curves

The similarity of the emergence history of the various parts of the Bernier Bay coastline can be demonstrated by replotting all of the radiocarbon dates used above as a single curve (Fig. 4-10). Scattering of the points about the single line can be most conservatively interpreted as the result of small errors in the age and elevation measurements (see Figs. 4-5, 4-6 and 4-9). Differential emergence of the three areas is likely very small. If different parts of the area had experienced significantly different emergence histories, one would expect that points from each of the camps would, as a group, show a consistent departure from curves delimited by the other two sets of points.

That this is not the case does not detract from the arguments presented earlier regarding the slight gradients of the moraines and the 8200 BP shoreline. If the very low gradient of the moraines and the highest shorelines is correct, it is not at all surprising that the dates on whalebone and walrus tusks collected at lower elevations do not reveal measurable tilting, since the departure of shorelines from the horizontal is expected to decrease exponentially with decreasing elevation, reaching zero at modern sea level. Thus, the lack of measurable differential emergence at lower elevations tends to corroborate, rather than detract from, the interpretation of the low gradient of the moraines as an indirect measure of the tilt of the marine limit surface.

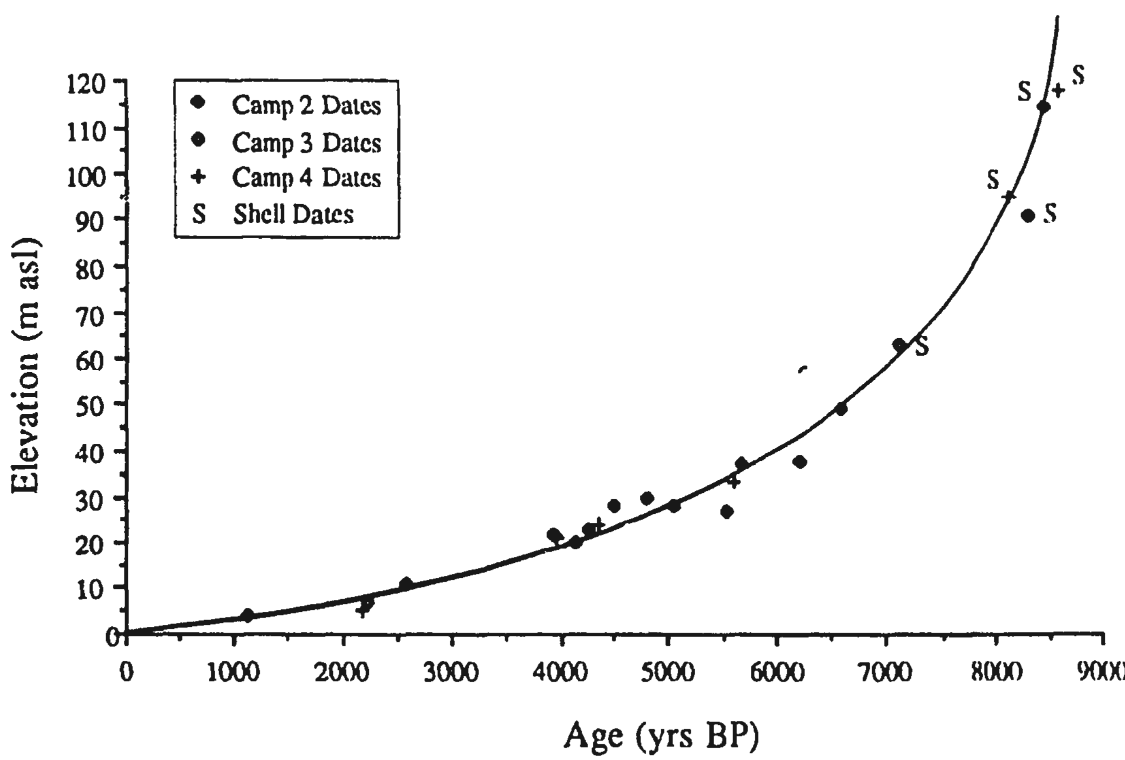


Figure 4-10. Composite emergence curve produced by plotting the points from the previous three curves on the same diagram. The uppermost five dates are all on shells.

Relative Abundance of Marine Mammal Bones

Figure 4-11 shows the relative abundance of finds of whalebone and walrus found during the 1988 field season according to their elevations. The histogram shows small numbers of bowhead and walrus finds between 0 and 20 m, many finds of both species between 20 and 30 m, and few bowhead and walrus between 30 and 66 m. No finds of either species were made between 66 m and marine limit. The most significant feature of the histogram is a major peak in the 20—30 m elevation range. This corresponds to the time interval 4000—5000 BP. The highest occurrence of whalebone is at about 64 m. This material, two undated collections, is estimated to be about 7000 years old. No bowhead bones were found above this elevation.

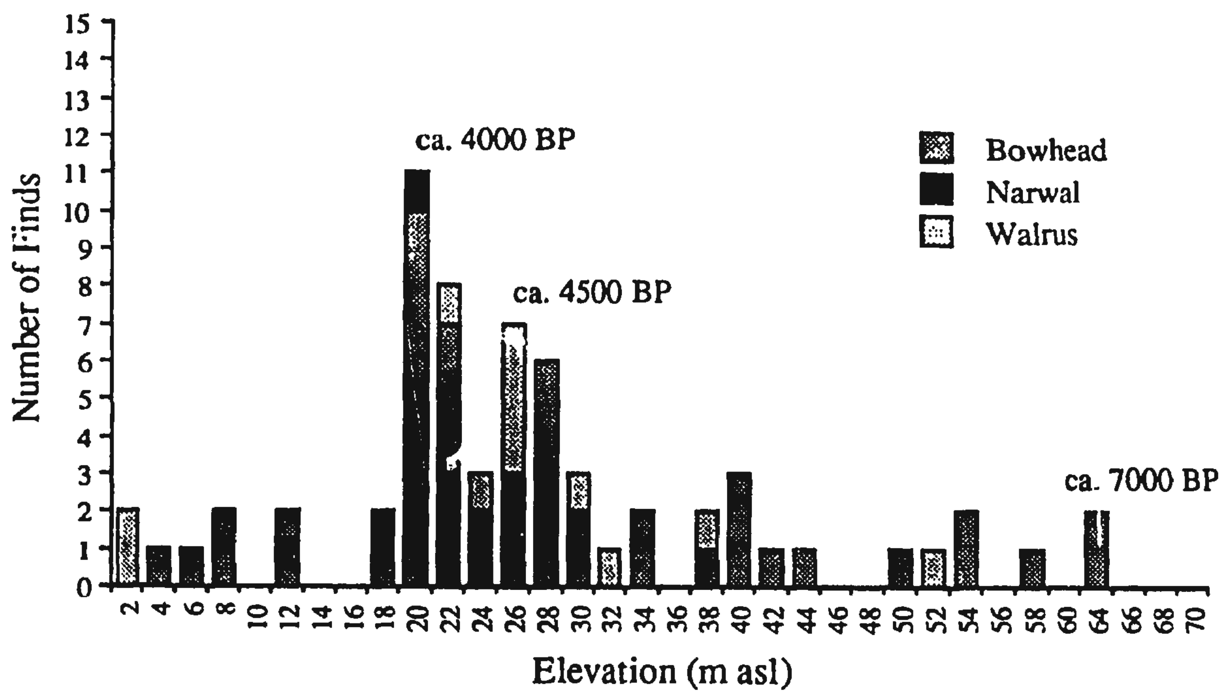


Figure 4-11. Relative frequency histogram of bowhead, walrus and narwal finds with elevation.

Chapter 5. Discussion

This discussion is confined to the Late Wisconsin and deglacial history of the study area. Evidence for earlier glacial events was not found; it is likely that the majority of preexisting sediments were reworked by subsequent ice advances. Reconstructions of the Laurentide Ice Sheet, including those which argue for minimal ice coverage of North America, show the field area entirely ice covered during the last glaciation. Because of the present lack of evidence, attempts to reconstruct the early history of the area are speculative, although future research may uncover stratigraphic evidence for pre Late Wisconsin events.

Westward flow of Late Wisconsin ice in the Bernier Bay trough is evidenced by a field of large east-west trending drumlins east of the head of Bernier Bay and along the south side of Berlinguet Inlet. These were deposited by an ice stream in the Bernier Bay-Berlinguet Inlet trough. The ice stream drained the Foxe Dome since 18,000 BP or earlier (Dyke and Prest, 1987). Unlike other areas which experienced altered flow regimes during the waning stages of glaciation due to calving and marine downdraw, the direction of ice flow in the study area remained largely unaltered throughout late glacial time.

The main departure from previous reconstructions resulting from this research is the proposed existence of an extensive ice shelf in Bernier Bay. The existence of the ice shelf is supported by geomorphic evidence and indirectly by the observed pattern of postglacial emergence which reflects loading of the crust by regional ice during the height of the last glaciation rather than loading by an ice tongue grounded in the Bernier Bay trough.

Deglacial Chronology

Following the disintegration of the ice shelf in Lancaster Sound and Prince Regent Inlet, ice in the Bernier Bay trough retreated towards the east. This retreat is documented by three shell dates associated with marine limit. Deglaciation of the field area proceeded from the west beginning prior to 8600 BP with the head of Bernier Bay becoming ice free by 8200 BP. The date of 8600 BP on shells collected northeast of Morin Point is the oldest date obtained in the field area, however dates from northern Brodeur Peninsula and the south coast of Baffin Island indicate that the ice shelf in Prince Regent Inlet and the Gulf of Boothia had disintegrated by 8900 BP. The west coast of Brodeur Peninsula was ice free by 8800 BP (Dyke, pers. comm., 1989). An additional date (GSC-4898, on shells collected by the author) from south of the study area, west of Fury and Hecla Strait, indicates that the south coast of Baffin Island in the Gulf of Boothia was ice free by 8900 BP also.

Regional thinning of Foxe ice prior to the Cockburn Phase probably led to the uncoupling of the ice over Bernier Bay from the seabed and the establishment of an ice shelf in Bernier Bay. The timing of uncoupling is uncertain but it must have happened prior to the major moraine building episode, or before about 9000 BP. Based on the measured elevations of the postglacial marine limit, the depth of the bay at this time would have been about 180 m, sufficient to float a tongue of ice up to 200 m thick. An important consideration in the initial development of an ice shelf in the bay is the lowering of basal shear stress which would have caused the ice to undergo rapid extending flow and to assume a near horizontal surface profile.

Deposition of Moraines and Related Features

The moraines and associated glaciofluvial features were deposited, during Cockburn time, prior to about 8200 BP, after which ice retreated beyond the eastern margin of the study area. The initiation of the moraine-building event has not been dated in the field area but it is probably correlative with the deposition of Cockburn age moraines on the eastern part of the island which began about 9000 BP.

The most convincing evidence that the large moraines were deposited by an ice shelf is the very low gradient of the moraines. Buckley (1969) measured the gradients of present day outlet glaciers entering fiords in Alaska, Greenland, Antarctica and Arctic Canada by reference to the available topographic maps. None of these glaciers had average gradients of less than 1:120 (about 8 m/km). The gradient of the Bernier Bay Moraines is about a quarter of this minimum value.

In addition, no evidence was found of any moraines crossing the mouth of Bernier Bay. It was initially thought that such moraines were absent due to rapid retreat of ice, perhaps as a calving bay progressed eastward towards the head of Bernier Bay, or that they had subsequently been obliterated by beach-forming processes. However, an ice shelf flowing out of Bernier Bay and calving into Prince Regent Inlet would probably not deposit moraines across the trough. The increasing separation between the moraines along the north and south of the bay toward the west can also be explained by the spreading of the ice shelf over the outer part of the bay. With a grounded ice tongue, one would generally expect the size of lateral and terminal moraines to increase down-ice (west). The moraines around Bernier Bay are largest in the eastern part of the area and become smaller and less distinct in the west. This pattern can be explained by deposition along an ice shelf which thinned westward due to lateral spreading and basal melting.

The amount of sediment available for deposition by an ice shelf is controlled by the sediment content of the ice, the thermal regime at the base of the ice, which could allow freezing on of saturated sediments, and by the presence of erodible materials along the coastlines against which it impinges. In modern ice shelves most of the debris entrained in basal ice is deposited in a narrow zone proximal to the grounding line as basal melting occurs at the ice/water interface, so that only minimal amounts of englacial debris remain entrained in the ice shelf. Thus, the main source of material incorporated in the Bernier Bay moraines was probably the local rocks and preexisting unconsolidated sediments along the gently sloping valley sides. These materials were eroded and redeposited by the ice shelf as it grounded onshore.

The location of the main grounding line for the ice shelf is not known with certainty. The topographic constriction that occurs in the main valley at the head of Bernier Bay may have led to stabilization of the grounding line over the area of the isthmus separating Bernier Bay and Berlinguet Inlet. The anomalous surficial deposits in this area, consisting of large numbers of granite and gneiss boulders, could have been produced by the melting of basal ice in the vicinity together with the effluence of large volumes of subglacial meltwater which flushed out finer materials from the sediment. Other potential locations for the grounding line can be found to the east of the study area along Berlinguet Inlet.

The presence of shells in many of the local tills, including some above marine limit, is indicative of considerable reworking of sediments formerly below marine limit, together with the transport of this material inland. The flow of ice onshore is also supported by N-S trending striations southwest of the head of the bay. This pattern of reworking is more likely under an ice shelf than under a grounded ice tongue where the major conduit for throughput of debris rich basal ice would lie along the bottom of the trough, with minor amounts of basal debris being carried away from the main axis of flow to be deposited in lateral moraines.

Sugden and Clapperton (1981) note that the horizontal moraines formed by the George VI Ice Shelf in Antarctica consist predominantly of locally derived material. Loops and embayments southeast of the head of Bernier Bay reflect the movement of ice in an onshore direction. The above authors also describe embayments in the moraines and the presence of multiple moraine ridges where the valley sides bounding the George VI Ice Shelf are gently sloping.

Evidence for local ice north of the bay includes the distribution of erratics, the presence of numerous subglacial and ice-marginal channels in the northwest part of the study area, the relatively linear form of the main moraine along the north side of the trough and the field of small north—south trending drumlins northwest of the head of the bay. The quantity of Precambrian erratics in drift samples is markedly lower in the area formerly influenced by local ice. There is no source of Precambrian or other distinctive rocks on southern Brodeur Peninsula. Large numbers of lateral meltwater channels occur above marine limit on the plateau north of the bay and especially on southwestern Brodeur Peninsula. The drumlins formed when ice draining from the local ice cap underwent extending flow as it drained into the Bernier Bay trough to the south. A long N—S trending moraine occurs north of the large unnamed lake and marks the likely late glacial western margin of the local ice cap. The local ice cap probably persisted hundreds of years after Bernier Bay was deglaciated. Similar evidence for the existence of local ice on the plateau south of Bernier Bay is lacking.

Rates of Holocene Emergence

The three independently-controlled emergence curves reveal a pattern of spatially uniform postglacial emergence in the study area. In fact, taking elevation and age errors into account, all of the radiocarbon dates can be adequately accommodated on a single curve. The form of the curves is similar to those obtained for adjacent Somerset Island (Dyke, 1979) and other deglaciated areas of Canada which experienced continual emergence throughout the postglacial. Following deglaciation initial emergence occurred at an average rate of 4.9 m per century over the first 1000 years with 42% of the total emergence being accomplished during this interval. Emergence during the last 1000 years was approximately an order of magnitude slower at 40 cm per century with only 3% of the total postglacial emergence being accomplished during this interval. The average rate of emergence over the entire postglacial period is about 1.4 m per century.

Results of surveys conducted along the 20 m (ca. 4000 BP) shoreline in two localities must be considered equivocal because of measurement errors. The results obtained do not contradict the direction of tilting as indicated by the gradient of the moraines or the results of comparing the elevation ranges of shell dates on the 8200 BP shoreline.

Three phases of rebound are proposed for the area. The first is a period of restrained rebound following the thinning of grounded continental ice from its Maximum Wisconsin thickness. There is no evidence for this phase but it is a likely response to the thinning of continental ice provided that isostatic equilibrium had been attained during the Wisconsin Maximum. The second is a period following uncoupling of the ice from the seabed in Bernier Bay and the establishment of an ice shelf when rebound may have been partially restrained by the existence of residual local ice north of the bay and by the mass of ice-cored moraines adjacent to the grounded margin of the ice shelf. The third phase is the time following deglaciation and the only phase for which radiocarbon information is available.

Profile of Marine Limit

Of the four measurements available on marine limit in the study area, three are on raised deltas and one is the height of the upper limit of marine silts northeast of Morin Point. Shell dates related to two of the deltas indicate that the age of marine limit decreases, by approximately 600 years, towards the east (Figure 4-1, page 52). The elevation of the uppermost limit of silts in the northwest part of the area is estimated at about 124 m. This is slightly lower than the height of the highest marine limit delta, measured in the southeast part of the study area at 125 m. The two lower deltas, which occur approximately between these points, are at 110 m north of the bay and 116 m on the south side of the bay. No date is available for the 116 m delta.

This pattern of elevations can be explained if the lower deltas formed at sea level along the margins of an ice shelf which was growing progressively narrower during the initial period of isostatic recovery. The date of 8210 BP on the 110 m delta north of the bay supports this contention. Thus, the uppermost shell dates from the study area, although not particularly useful for reconstructing the profile of marine limit at a given time, accurately reflect the elevation of marine limit and time of deglaciation for each locality.

If the moraines are indeed ice shelf moraines, then the present gradient should be close to the gradient of tilting on the marine limit shoreline. In this regard it is probably unfortunate that the gradient of the moraines was not measured more carefully during fieldwork. The gradient measured from topographic maps is within the expected range of values for marine limit gradients measured elsewhere.(eg. Dyke, 1979). From the gradient of the moraines, the average elevation of marine limit declines in a northwesterly direction at about 2.4 m/km. Given the initial assumption of an ice shelf in the bay, the departure of the moraines from horizontal can be explained by tilting of the marine limit surface.

Paleoenvironmental Inferences

New radiocarbon dates from the moraines around Bernier Bay clearly demonstrate that the moraines are correlatives of the Cockburn Moraines of eastern Baffin Island. Deglaciation of the entire west coast of Baffin Island was essentially complete by 9000 BP, the beginning of the Cockburn substage. This was due to the rapid collapse of the ice shelf in Prince Regent Inlet and the Gulf of Boothia by calving. The ice shelf in Bernier Bay may have originally been part of this larger ice shelf which was preserved after the outer coast was deglaciated due to the more confined nature of the bay as well as enhanced inputs of ice flowing westward from the Foxe Dome, which was, at that time, experiencing a period of renewed positive mass balance. Alternatively, grounded ice in the bay would have been buttressed by an ice shelf in Prince Regent Inlet. Removal of this buttressing ice shelf at the beginning of the Cockburn substage is a possible triggering mechanism for uncoupling of grounded ice in Bernier Bay from the seabed.

Following deglaciation of the outer coast, penetration of the sea into the interior of the Bernier Bay trough was delayed for an additional 800 years, i.e. over virtually the entire Cockburn substage. During this period, discharge of ice into the head of the bay from the Foxe Dome would have to have been sufficiently large to deposit the large moraines flanking the bay and also to maintain a calving margin at the bay mouth. Additional ice drained southward from the local ice cap on southern Brodeur Peninsula. This flow probably took the form of an outlet glacier which flowed down a broad but shallow depression in the side of the Bernier Bay trough northwest of the head of the bay.

In discussing the age distribution of radiocarbon dated bowhead bones from Prince of Wales Island, Dyke and Morris (in prep.) suggest that the climatic event which occurred during the Cockburn substage was either a shift to cooler summer conditions or a shift to wetter conditions due to increased areas of open water in the Arctic Islands. Increased open water in the channels allowed a large population of bowheads to range freely during this interval, possibly exploiting larger amounts of plankton present in waters enriched by melting glaciers. On the basis of the abundance of bowhead bones dating between 11,000 and 8500 BP from the raised beaches of Prince of Wales Island, the latter climatic interpretation is favoured. The oldest bones from Somerset Island (Dyke, 1979) also date from this interval.

The 800 year delay in deglaciation of Bernier Bay accounts for the absence of whalebone during a time when bowheads were known to be abundant in other parts of the arctic. A gap of approximately 1600 years exists between the time that the field area was deglaciated, as evidenced by dates on shells, and the earliest appearance of bowhead bones on raised beaches. This can be explained by severe sea ice cover in the bay during the interval 8200 to 6500 BP.

Between about 6500 and 5000 BP the numbers of bowheads and walrus entering Bernier Bay appear to have remained at relatively constant low levels. This was followed by steadily increasing numbers of these animals during the interval 5000 to 4000 BP. After 4000 BP the number of bone finds drops abruptly and remains low from 4000 BP to the present. These age ranges are only approximate since they are based on 65 bone finds, twenty of which have been dated. These variations can be explained by changing sea ice conditions which, due to the confined nature of the bay, have probably been more severe than ice conditions along more exposed coastlines throughout the Holocene. Despite the limitations of the data base, the peak in the numbers of marine mammal finds between about 5000 and 4000 BP is a possible correlative of the 5000 to 3500 BP peak in the numbers of bowheads in the channels around Prince of Wales Island (Dyke and Morris, in prep.).

The unexpected absence of driftwood in the study area can also be explained by sea ice conditions in Bernier Bay which were more restricted than in other areas throughout the Holocene. That no driftwood entered the area during the peak of bowhead penetration, between 5000 and 4000 BP, when sea ice cover presumably reached its Holocene minimum, can perhaps be attributed to patterns of marine currents which prevented the entry of driftwood into Prince Regent Inlet. Alternatively, driftwood passing south along Prince Regent Inlet would have a high probability of grounding along the long coastlines of this narrow channel before reaching the field area. The preceding discussion of its absence must be considered largely speculative since it is based solely on a lack of evidence.

Chapter 6: Summary and Conclusions

Much new information has been gathered on the characteristics of surficial deposits in the field area. These are interpreted as mainly tills and washed tills with significant deposits of glaciofluvial gravel. The deposits are thickest within the belts of morainic deposition paralleling the north and south coasts of Bernier Bay. The drift cover on plateau areas north and south of the bay is thin and probably contains a significant component of reworked bedrock residuum. Precambrian erratics occur throughout the area, but are most abundant south of the bay. Beach sediments cover a large portion of the area below marine limit with the best development of beach morphology at elevations approaching modern sea level. All of the the surficial deposits have been reworked by cryoturbation and have experienced alteration by frost shattering and solution weathering during postglacial time.

The large moraines flanking the bay are reinterpreted, on the basis of their estimated gradient and morphology, as ice shelf moraines. The elevation of the moraines declines toward the northwest with an average gradient of 2.4 m/km. This is much less than the lowest gradients measured on contemporary outlet glaciers. The low gradient of the moraines is indicative of deposition by an ice shelf and can, therefore, also be used as a approximation of the amount and direction of tilt on the marine limit surface. The configuration of the moraines, with the diminishing size and increasing separation of the ridges flanking Bernier Bay towards the west as well as the lack of moraines crossing the valley, lends additional support to the ice shelf model. The moraines were deposited during the Cockburn substage by ice flowing westward from the Foxe Dome and are correlatives of the Cockburn Moraines of eastern Baffin Island. Positive mass balance conditions experienced by the ice over eastern Baffin Island and Foxe Basin would have had to be sufficient to supply the large volumes of ice required to sustain a thick, actively depositing ice shelf and a seaward calving margin in Bernier Bay during this period.

A local ice cap which existed on southern Brodeur Peninsula during the main phase of moraine deposition probably coalesced with ice flowing down the Bernier Bay-Berlinguet Inlet trough, so that the parts of the main moraine north of the bay can be considered interlobate moraines. An outlet glacier draining ice from the southern part of this ice cap into the main trough deposited a field of NNE—SSW trending drumlins as it flowed down the side of the valley into the main trough. The local ice cap also left abundant marginal meltwater channels on the plateau in the northwest part of the area.

The area was deglaciated from the west beginning with deglaciation of the outer coast by about 9000 BP with the head of Bernier Bay becoming ice free by about 8200 BP. Uncoupling of grounded ice from the seabed and the establishment of the ice shelf probably occurred slightly before 9000 BP. The Bernier Bay-Berlinguet Inlet isthmus is suggested as a possible location of the grounding line of the ice shelf during the main period of moraine building. The timing of the melting of local ice on southern Brodeur Peninsula is uncertain. The local ice probably readvanced to coalesce with ice in the main trough during the Cockburn substage and persisted for several hundred years after the rest of the area had been deglaciated.

Four shell dates were used in conjunction with the elevation of marine limit deltas to draw isobases on the 8200 BP shoreline. The amount of emergence accomplished since 8200 BP increases from about 100 m in the northwest, near Morin Point, to about 120 m in the southeast part of the area (south of the head of Bernier Bay). Measurement of the amount of tilting on the marine limit shoreline is complicated by the strongly time transgressive nature of marine limit in this area.

Twenty radiocarbon dates on whalebone and walrus tusk were used to construct three independently-controlled emergence curves. The curves exhibit a typical pattern of postglacial emergence with the rate of emergence declining exponentially from its postglacial maximum. The similarity of the three curves reveals that the emergence of the Bernier Bay coast was relatively uniform. The average rate of emergence over the postglacial period was 1.4 m per century with 41% of the total emergence being accomplished in the first 1000 years following deglaciation. During this period the average rate of emergence was 4.9 m per century. Only 3% of the total emergence occurred during the last 1000 years at an average rate of 40 cm per century. A small amount of emergence probably remains to be accomplished before isostatic equilibrium is attained.

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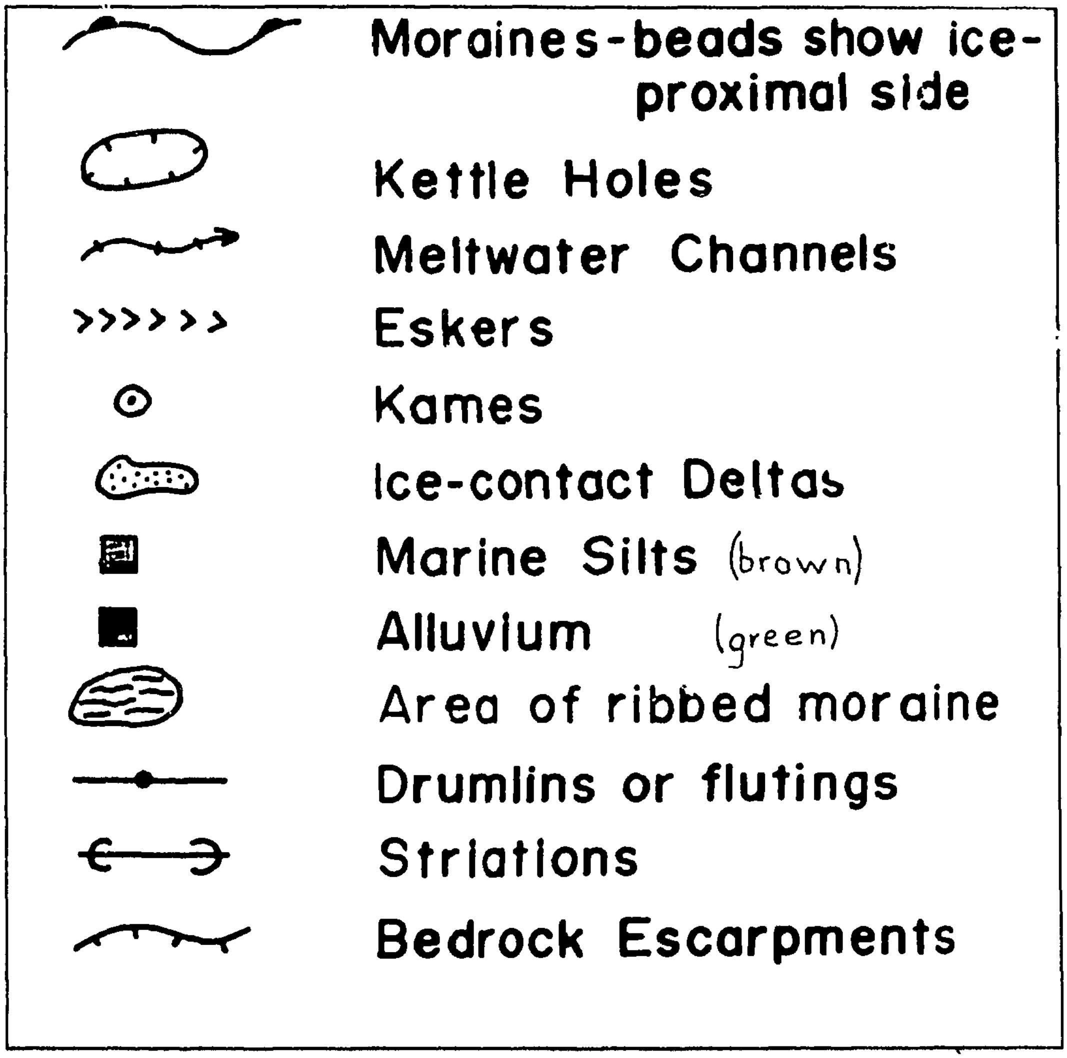
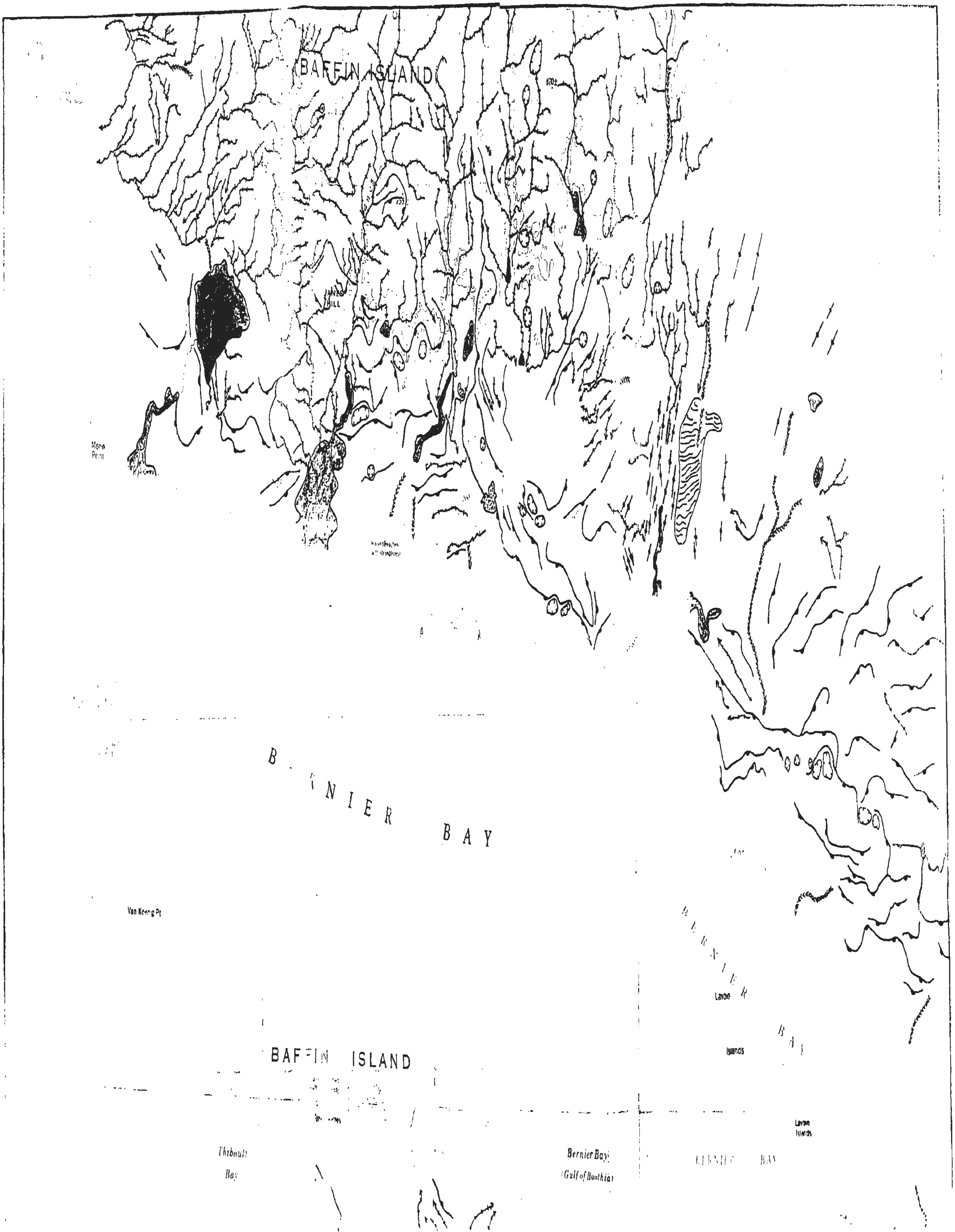
Appendix: Legend for Geomorphic Map (Fig. 3-1)



Scale 1:250,000
Contour Interval: 100 ft.

Compiled from portions of NTS sheets 47F, 47G, 57E and 57H.


BAFFIN ISLAND
Moro Point
BERNIER BAY
Van Koenig Pt
Lavoie
Islands
BAFFIN ISLAND
Thibault
Bay
Bernier Bay
(Gulf of Boothia)
Lavoie
Islands

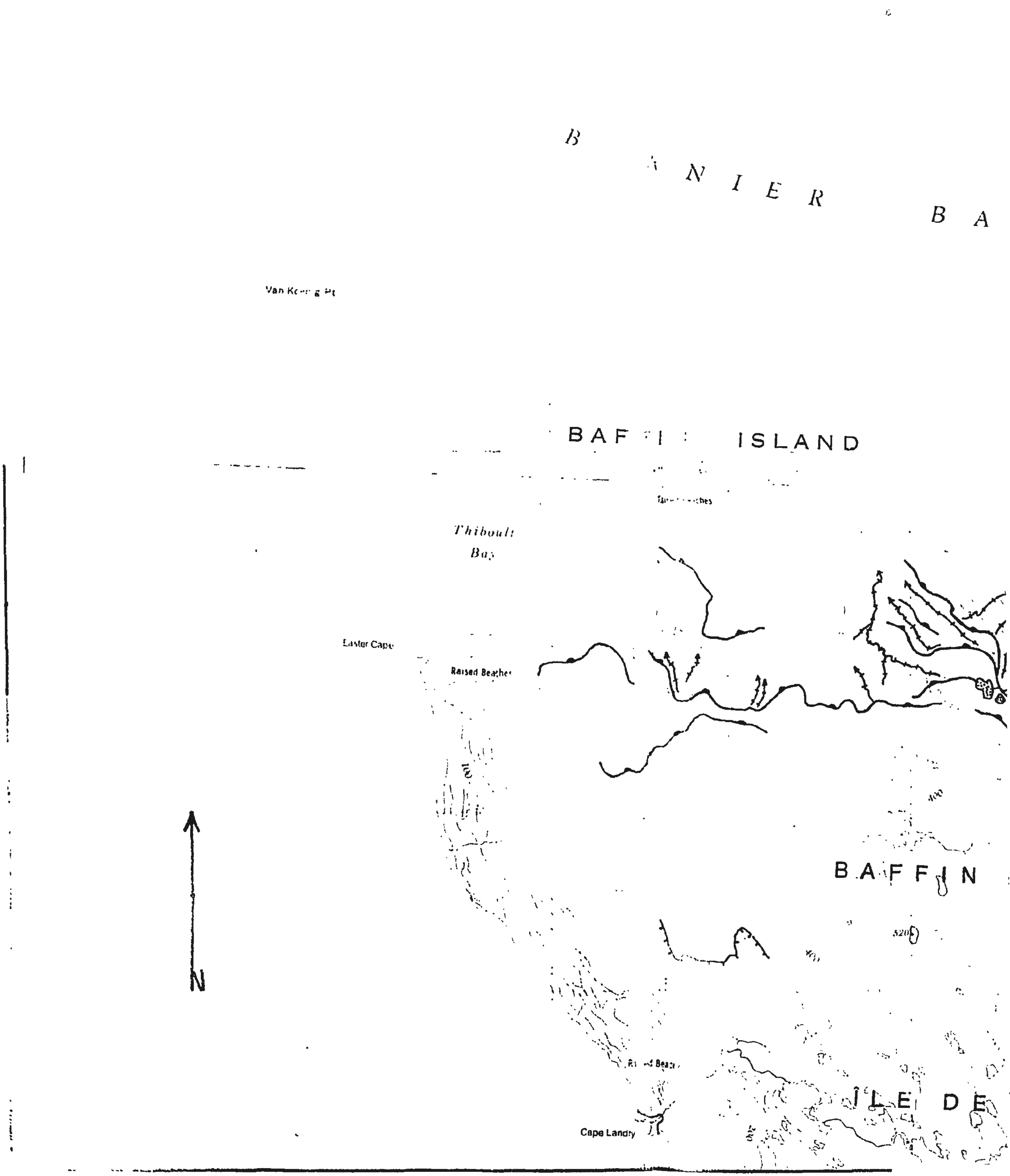
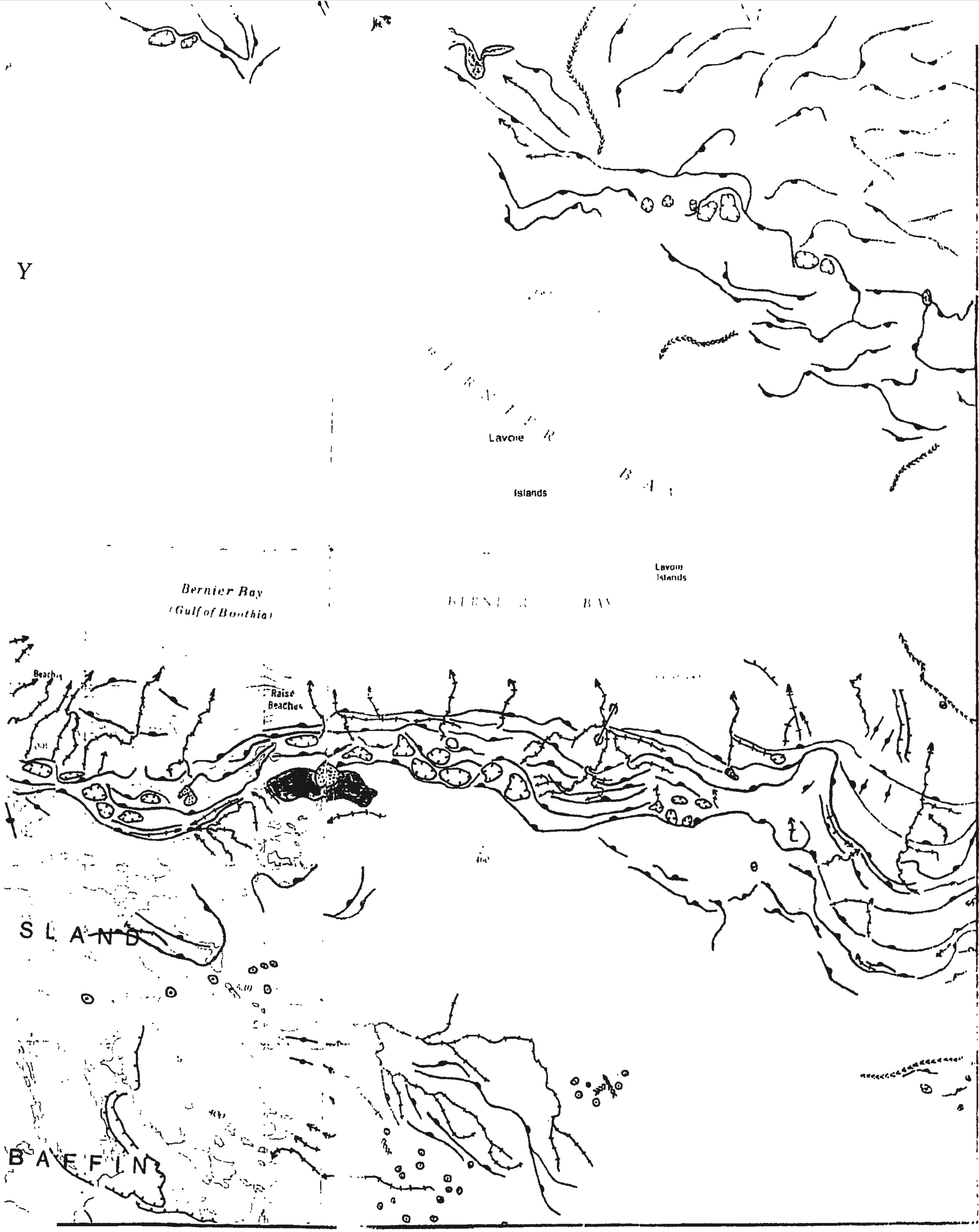


FIGURE 3-1. GEOMORPHOLOGY OF THE BERNIER BAY AREA



SCALE 1:250,000

LATE QUATERNARY GLACIAL AND SEA LEVEL HISTORY
OF THE
BERNIER BAY AREA, NORTHWESTERN BAFFIN ISLAND, N.W.T.

BY

© James Hooper, B.Sc.

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