COASTAL ENVIRONMENTS AND PROCESSES
IN THE
CANADIAN ARCTIC ARCHIPELAGO

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CANADIAN ARCTIC ARCHIPELAGO

By

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ABSTRACT

The prime objective is to define and characterize the various coastal environments in the Canadian Arctic Archipelago. The research, which utilizes both secondary source information and actual field observations, takes into account coastal morphology, beach profile, sediment types, sea ice conditions, tidal range, depth of the frost table and wave energy. From a total of twelve coastal divisions based on the criteria of coastal morphology, tidal conditions and length of open water season, five have been chosen as the basic coastal environments of the Arctic Archipelago. They are as follows: the Arctic Coastal Plain, the Ice Shelf, the Fiord environment, the High Straight coastal environment, and the Ridge and Valley coastal environment. Field observations within the last three environments provided additional evidence for the divisions and observations on the beach and nearshore characteristics at five selected locations.

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TABLE OF CONTENTS

ABBREVIATIONS

km - kilometre
m - metre
cm - centimetre
mm - millimetre

HHWM - high high water mark
MHWM - mean high water mark
LWM - low water mark

E.S.T. - Eastern Standard Time
C.S.T. - Central Standard Time
A.S.L. - above sea level
B.P. - before present

M^2 - square metres

LIST OF FIGURES

LIST OF TABLES

Explorers say that harebells rise
from the cracks of Ellesmereland
and cod swim fat beneath the ice
that grinds its meagre sands
No man is settled on that coast
The harebells are alone
Nor is there talk of making man
from ice cod bell or stone

Earle Birney
Ellesmereland 1

CHAPTER 1

INTRODUCTION

INTRODUCTION

The prime objectives of this thesis are to define and characterize the coastal environments of the northern Arctic Archipelago, and to analyse the nearshore processes and their effects at five selected coastal locations. Previous attempts at mapping coastal types in the Arctic have either focused on the south-eastern Arctic (Bird 1967), or have been part of world classification (Valentin 1952, McGill 1958) and too general to achieve the present objectives. The present research involves the inventory and analysis of coastal morphology, tidal ranges and lengths of open water period, using secondary sources (aerial photographs, sea ice observations, published reports), in order to define the main coastal environments of the Canadian High Arctic. Five specific coastal locations were then selected, as representative of the basic coastal types, for detailed field studies. The study sites were also selected because of their location on or near proposed transmission "corridors" or their suitability as marine terminals.

The 1972 field season of almost three months, from June 22 to September 7, involved detailed field work at each of the five study areas (Table 1.1, Figure 1.1) for a period of thirteen to sixteen days, depending on weather and logistics. Four of the research areas were located on or north of Parry Channel, while the fifth area, Eclipse Sound-Pond Inlet, was further south on the NE coast of Baffin Island.

The field procedure involved the establishing of survey stations

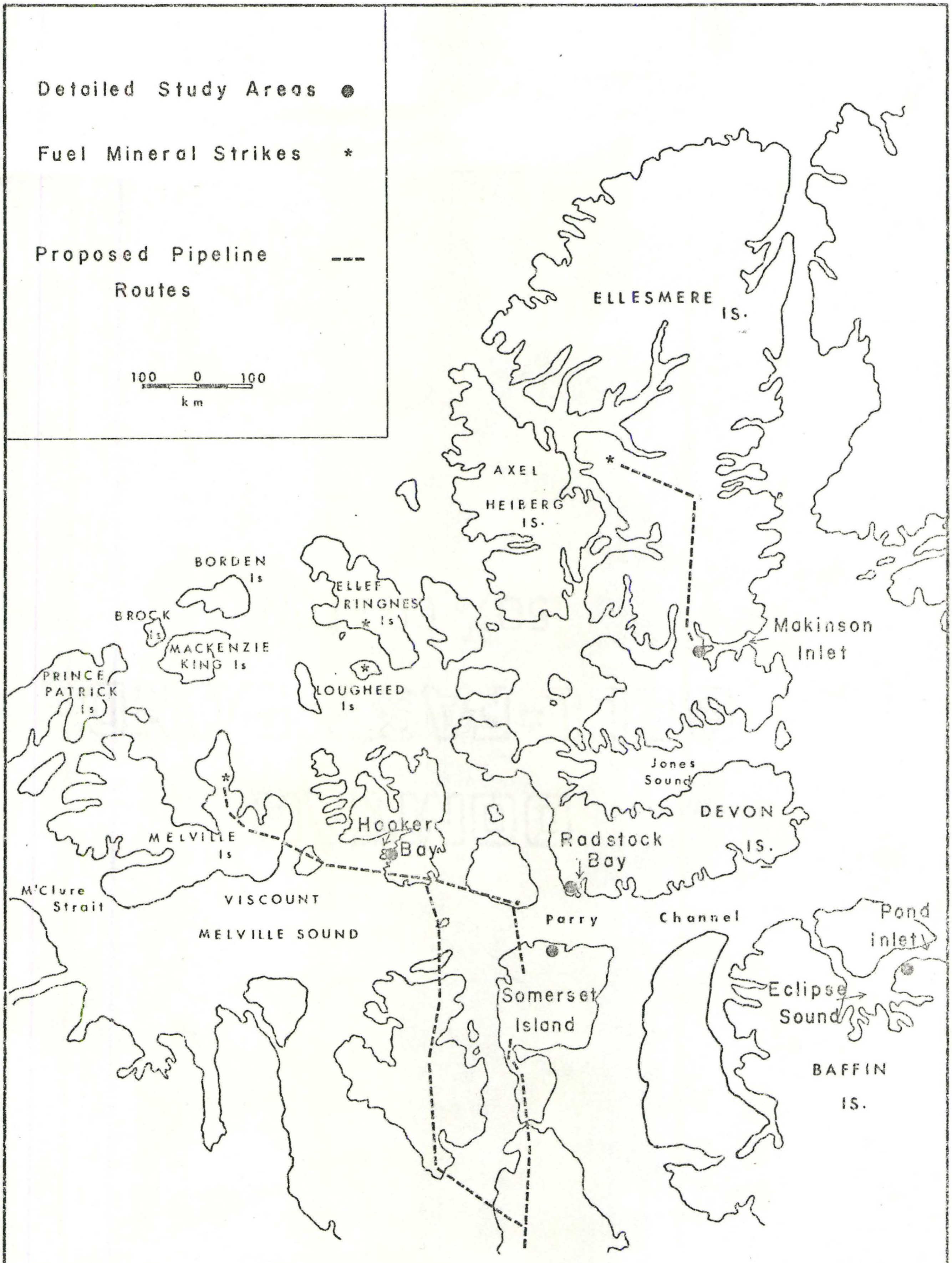

Detailed Study Areas ●
Fuel Mineral Strikes *
Proposed Pipeline Routes ---
100 0 100
km
ELLESMERE IS.
AXEL HEIBERG IS.
BORDEN Is
BROCK Is
MACKENZIE KING Is
ELLEF RINGNES Is
PRINCE PATRICK Is
LOUGHEED Is
Makinson Inlet
Jones Sound
DEVON IS.
Hooker Bay
Radstock Bay
MELVILLE Is
M'Clure Strait
VISCOUNT MELVILLE SOUND
Parry Channel
Pond Inlet
Eclipse Sound
Somerset Island
BAFFIN IS.

Figure 1·1

TABLE 1.1

LOCATION OF STUDY AREAS

Study Area	Latitude and Longitude	Date of Field Work
North shore of Somerset Island	74° 12' , 93° 15' W	July 1 - 14
Makinson Inlet (SE Ellesmere Island)	77° 15' N, 81° 31' W	July 16 - Aug. 1
Hooker Bay (W Bathurst Island)	75° 25' N, 100° 30' W	August 1 - 13
Radstock Bay (SW Devon Island)	74° 43' N, 91° 10' W	August 14 - 22
Pond Inlet-Eclipse Sound (NE Baffin Island)	72° 45' N, 77° 35' W	Aug. 25 - Sept. 7

for beach profiles, the monitoring of sea ice and climatic conditions, the systematic sampling of the beach sediments, observations of the effect of sea ice and rivers on the nearshore and beach zones, and the determining of the frost table depth across the beach. In addition, the littoral processes such as wave activity, currents and tides were examined, where possible. These basic geomorphic observations provide much of the information, about the beach zone, which is regarded as essential (Pathy and Garvie 1970) before complex marine facilities can be constructed or safely maintained. Thus, the study has practical applications which have been brought to the fore by the recent discovery of large quantities of natural resources in the High Arctic Islands and discussions concerning their transport to markets in southern Canada. The mode of transportation can be shipping or pipelines, but in either case, the beach and nearshore zones must be fully understood.

The present research is a development of the detailed work completed at Radstock Bay, Devon Island by the Geography Department of McMaster University (Owens 1969; McCann and Owens 1969, 1970; Carlisle 1972; McCann and Carlisle 1972; McCann 1972, 1973). This study, though broader in scope, has taken advantage of the field techniques devised by the authors mentioned above. This thesis begins with the division of the northern Arctic Islands into general coastal regions, followed by detailed observations at selected locations within the newly-defined regions.

As a summary of the former investigations at Radstock Bay, Devon Island and others, particularly those centred on Point Barrow, Alaska (Hume 1964, 1965; Rex 1964; Hume and Schalk 1964, 1967) a general model of the annual beach regime can be established.

Annual Beach Regime

The processes which occur in the beach and nearshore may vary in frequency or magnitude from year to year, but the following is a typical sequence of events. During the winter months, November to April, very little, if any, activity occurs; in fact, the only marine processes observed have been the creation of ice pressure ridges offshore, the grounding of ice in the nearshore and the possible movement of ice up the beach face. Sea ice break-up can occur any time between April (Smith Sound) and August (Jones Sound), or not at all (Peary Channel), but is believed to begin only after the mean daily temperatures are greater than 0° C. The snow cover on the land is transformed into puddles and then into raging meltwater streams which result in the destruction of the nearshore ice. Large amounts of fluvial debris are deposited on the sea ice during spring flood stage, but because the sediment hastens the melting of the underlying ice, it is not ice rafted far from shore. Rock debris is also found on the sea ice at the base of cliffs and talus slopes. There, the ice carries the debris beyond the littoral zone, which prevents the buildup of a protective beach (McCann and Owens 1970).

As spring break-up continues, a fracture zone of tidal cracks and 3
leads is created alongshore. The width of the fracture zone is regulated by the tidal range and nearshore bathymetry. In general, the final removal of sea ice within the small bays and inlets is dependent on the 4
rapidity with which the sea ice leaves the larger channels, which in turn is dependent on wind conditions. If favourable offshore winds do not

occur, the sea ice either begins to melt in situ and is removed later, or remains until the following fall when new ice is added to the old. Even after the offshore ice has left, a narrow band of beach fast ice normally remains. If the fast ice eventually floats out to sea, it usually carries beach sediments which have become frozen to the base of the ice during the previous winter.

During the open water season, processes similar to those found in temperate latitudes are observed. In fact, the locally derived waves attempt to produce an equilibrium beach profile, and transport sediment alongshore.

The beach sediments, e.g. shingle, are normally quite angular and poor to moderately sorted, which is due to the low energy coastal environment. When high onshore winds and open water occur together, widespread changes can occur to the beach; for example, at Barrow, Alaska in 1967, one storm moved the equivalent of twenty years normal longshore transport load (Hume and Schalk 1967). Net sediment drift alongshore is thought to occur in response to waves from the greatest fetch, but in many areas the changing wind systems result in an overlapping of sediment movement from two directions. Thus, the overall effect is less net sediment movement in the higher latitudes than in more temperate latitudes. In the fall, most of the low discharge streams in the eastern Arctic become blocked off at their outlets by a ridge of transported beach sediment from alongshore or offshore. Additional fine material is moved alongshore by flotation which depends on surface tension, and increases with increased salinity and decreased temperature. Although Hume (1963) found this process to be effective near Barrow, Alaska, flotation has not been given much importance in the gravel environments of the eastern Arctic.

One of the most striking features found in the coastal environments of the Arctic is the ice-push ridge or mound. It has been suggested by Hume and Schalk (1964) that only 1-2% of the local beach material is involved in the process of ice-push. In addition, McCann and Owens (1970), who found only small-scale ice-push ridges, suggested that these features do not affect the overall shape of the beach. The generally accepted hypothesis of formation is the movement of loose pack ice or solid winter ice shoreward against newly formed shore ice or remnant beach fast ice which buckles and leads to irregular mounds of beach material. Two other factors involved in the formation of ice-push ridges are the strength and direction of wind and the height of the tide. The push ridges will only be preserved if ice action ends far enough inland or in areas of continual pack ice where wave action is non-existant.

Permafrost, a characteristic of the polar beaches (Nichols 1961), can prevent the reworking of large amounts of beach material during storms, and reduces the permeability of the beach face slope. As a result, the swash and backwash velocities are nearly equal (Kirk 1966). The depth of the active layer is, as would be expected, least in the spring and greatest in the fall. McCann and Hannell (1971) found that there was no appreciable increase in frost table depth seaward on the intertidal zone.

Freeze-up generally begins when the sea temperatures approach -2.2° C and the spray from the waves begins to freeze on the snow-covered beach. Initially, a slushfoot is created, followed by a more substantial icefoot as the air and water temperatures decrease. There are different types of icefoot created under different conditions in the Arctic and Antarctic, but all have been well documented (Wright and Priestly 1922; Koch 1928; Bentham 1937; Joyce 1950; Feyling-Hanssen 1953; Rex 1964; Kirk 1966; Moore 1968; McCann and Carlisle 1972).

During some years, freeze-up can be initiated with the blowing inshore of large pieces of multi-year ice which ground in the nearshore zone and dampen the effect of waves, thereby allowing the calm nearshore waters to freeze. The method of freeze-up is important, because it dictates the composition and configuration of the nearshore ice which is observed in the following spring.

Although this is a valid sequence of events, these observations are based on investigations carried out over a long period of time at only a few locations within the Arctic. The present observations at several coastal areas, on a short term basis, add to the number of coastal types examined, and strengthen the validity of the suggested annual sequence of events.

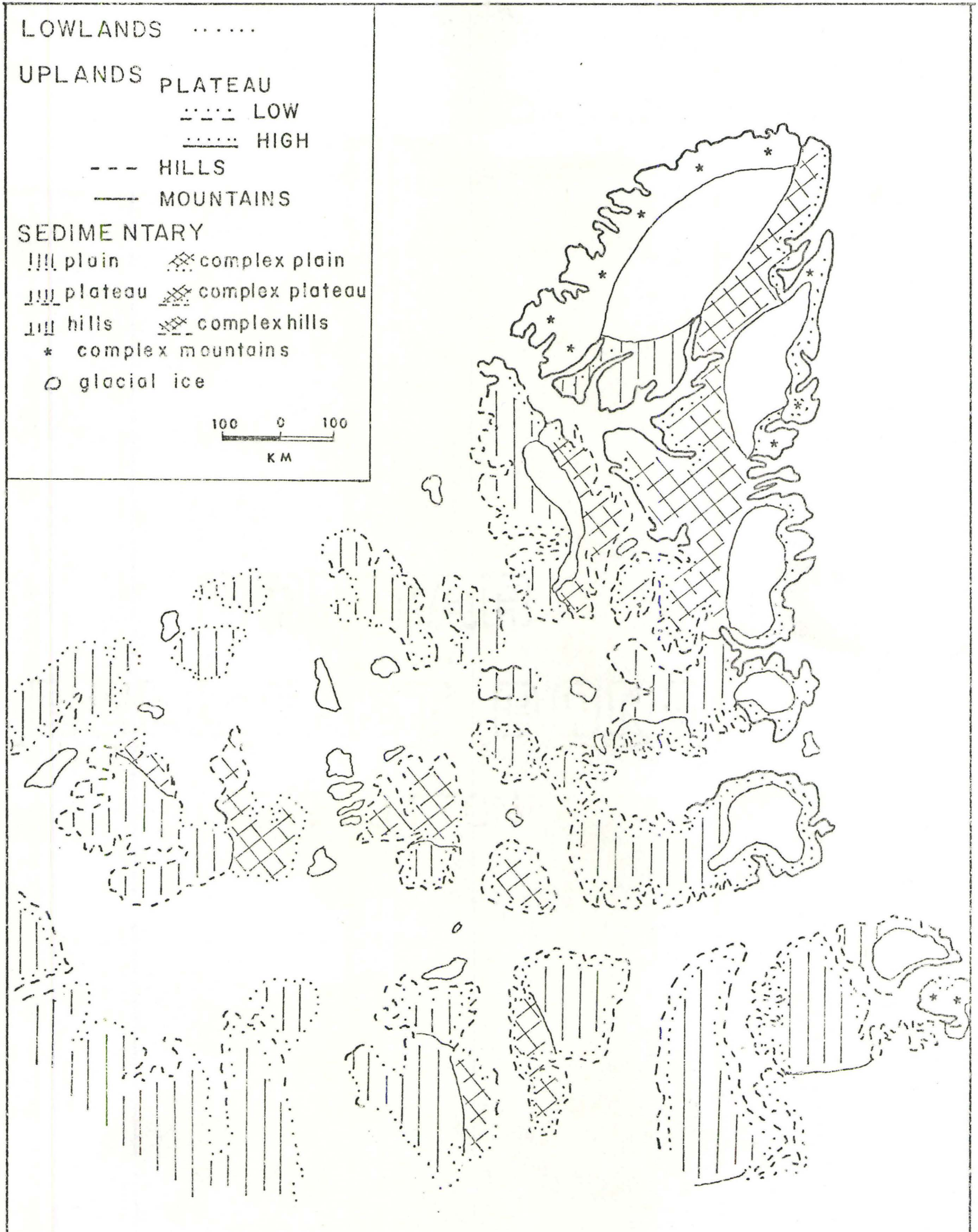
CHAPTER 11

ARCTIC COASTAL ENVIRONMENTS

2.1 INTRODUCTION

A study of Arctic coastal environments requires an understanding of the underlying geology and major landforms that together constitute the physical framework of the coasts. In addition, the factors which influence the magnitude and type of coastal processes should be examined; for example, the daily tidal range and the length of the open water season. General research on the coasts of the Queen Elizabeth Islands has only been completed by three authors; J.L.Jenness (1951), A.Taylor (1956) and J.T.McGill (1958). Taylor (1956) dealt with the physiography of the Queen Elizabeth Islands, based on explorers' records and the recent aerial photographic coverage of the early 1950's. His work was not specifically on coasts; it dealt with the physiography according to island, not to any chosen criteria or classification. McGill (1958) completed a map of coastal landforms of the world based primarily on geology, major landforms and marine transgression. His appraisal of the coasts in the Arctic was accurate but because of the very small scale to which he was confined, his division of coasts was very general (fig.2.1). Jenness (1951) studied the oceanography and physiography of the western islands of the archipelago and his report was very detailed, but lacked a good discussion of nearshore coastal processes and beach characteristics.

In the present study, information on the physical framework of the coasts was accomplished using aerial photography, historic records



COASTAL LANDFORMS - J.T. McGILL 1958

FIGURE 2·1

and recent literature. From the accumulated data the Queen Elizabeth Islands were divided into a number of regions, based on three criteria: (i) general morphology and coastal relief (ii) tidal conditions and (iii) length of open water season. Detailed maps showing the coastal morphology of the Queen Elizabeth Islands are included in Appendix A.

2.2 COASTAL ENVIRONMENTS - PHYSIOGRAPHY

> " The physical characteristics of the coasts in the Arctic Archipelago are greatly influenced by the underlying rock type and structure, each specific conbination produces its own distinctive landscape."(Arctic Pilot, vol.1 p.1).

The Queen Elizabeth Islands and those islands along the south side of the Parry Channel can be divided into four main physiographic regions (Thorsteinsson and Tozer 1970): (i) The Precambrian Shield is a belt of deeply dissected crystalline rocks which extends along the eastern side of the Arctic Archipelago as far north as the Bache Peninsula, Ellesmere Island (Figure 2.2). (ii) The Arctic Lowlands are composed of flat lying Paleozoic sedimentary rocks and extend along the eastern and western sector of Parry Channel and in Jones Sound. Cenozoic normal faults are expressed in this physiographic region as high linear stretches of coast. (iii) The Inniutian Region can be subdivided into the Greenland-Ellesmere and Parry fold belts, which include much of Ellesmere, Axel Heiberg, Cornwallis, Bathurst and Melville Islands. The land varies from high spectacular fold mountains on Ellesmere Island to strongly ridged terrain of less than 250 m relief on Bathurst Island. (iv) The Arctic Coastal Plain and Sverdrup Basin, which include the

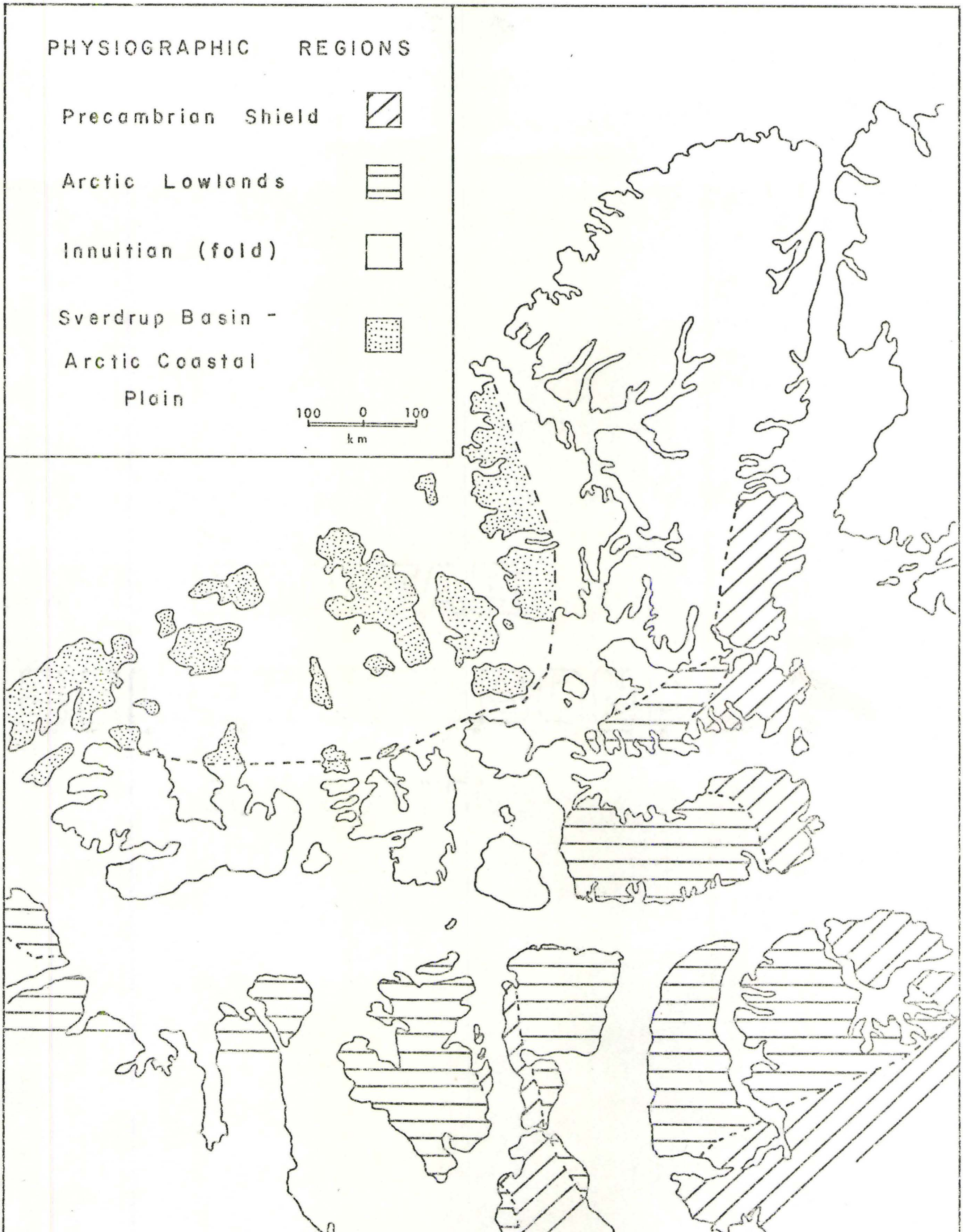


FIGURE 2·2 PHYSIOGRAPHIC REGIONS

(from Pilot of Arctic Canada)

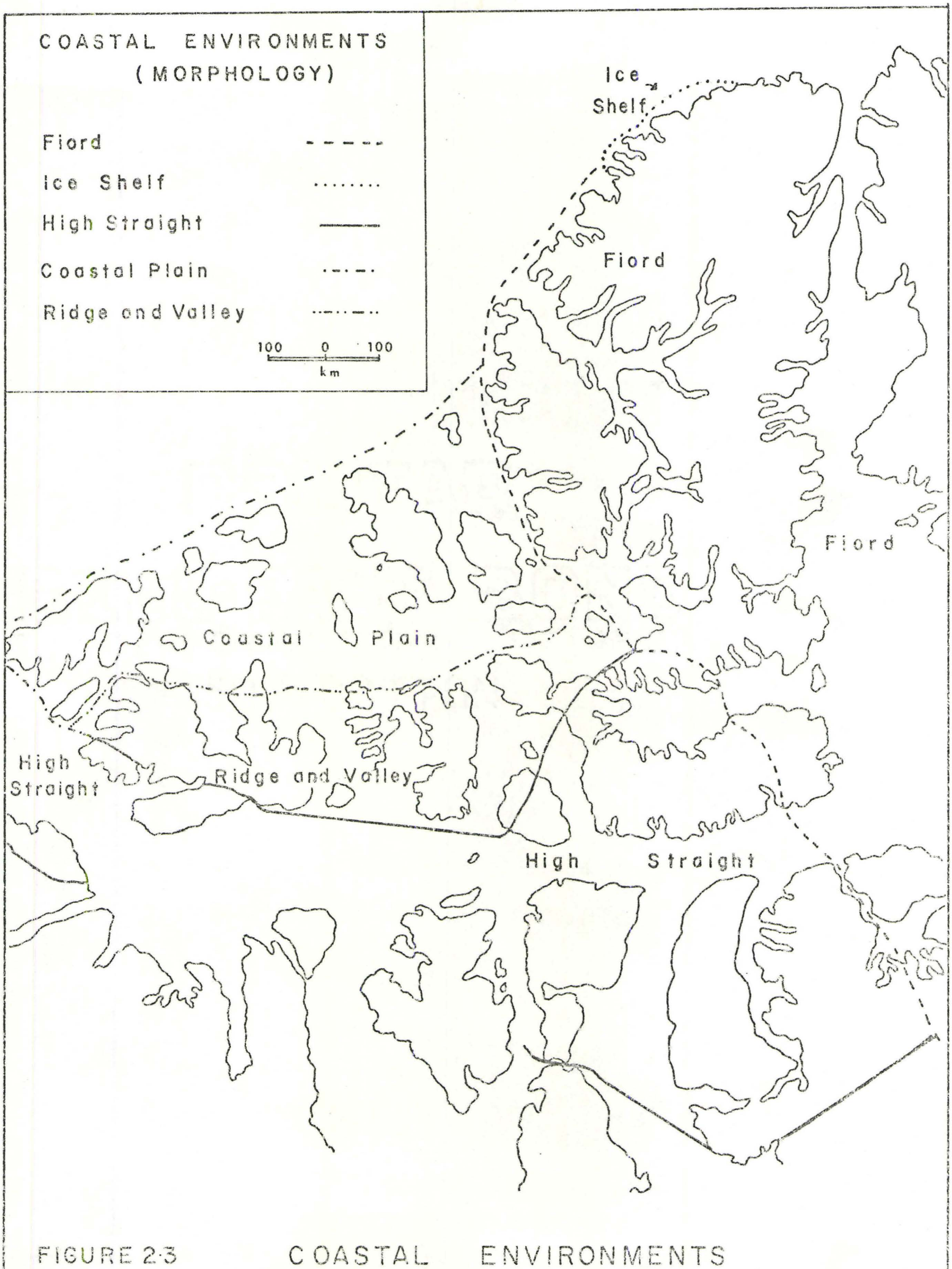


FIGURE 2·3 COASTAL ENVIRONMENTS

northwestern islands, are underlain by the Beaufort formation of unconsolidated Tertiary or early Pleistocene sands and gravels, and soft Mesozoic rocks, respectively. Although some areas contain dissected plateau up to 370 m., much of the coast is extensive plain only a few metres above sea level.

Using the recognized physiographic units (fig.2.2) of the archipelago, the coastal environments have been divided into four general divisions: (i) The Fiord Coast (ii) The High Straight Coast (iii) The Ridge and Valley Coast and (iv) The Coastal Plain. In addition, the ice shelf along the northern coast of Ellesmere Island has been given special attention (fig. 2.3).

The Fiord Coastal Environment

The fiord environment includes two physiographic regions: the Precambrian Shield and the Ellesmere-Greenland fold belt. The characteristic features of the first region are the high 180 to 925 m. resistant rock cliffs, the large proportion of tidewater glaciers and the numerous short, deep fiords. The fiords of the fold belt are much better developed (i.e.longer) and have been structurally controlled. The direction of folding is NE-SW, with the best examples of control being Vendom, Canon and Archer fiords on Ellesmere Island (plate 1). In these fiords, the coastal relief is very high, ranging from 615 m (near Vendom Fiord) to 1970 m (near Judge Daly Promontory); however, the steep sides are frequently broken by valley glaciers (plate 2). The terrain around Baumann and Slidre Fiords, although rugged, is much lower, with raised beach terraces and a wider beach zone.

The eastern coast of Ellesmere Island, between Makinson Inlet and Buchanan Bay, is almost continuous ice cliff. In fact, Wright (1939) estimated that only 20 of the 200 miles of coastline were not covered by ice, and even then the coast was composed of steep scree-banked cliffs. Whereas the Ellesmere coast has, at best, only a very narrow foreshore (backed by cliff), the coastal zone on Devon Island contains a much wider beach and more raised beach terraces and strandlines. In addition, the general coastal morphology of Devon Island is quite rounded and lower, as well as containing fewer tidewater glaciers (plate 3). With respect to tidewater glaciers, it is at the edges of the "Expanded Foot" variety that glacial deposition has been observed. The debris can take the form of terminal or lateral moraines (e.g. base of ice cliffs, east of Cape Warrender, Devon Island) which enclose the tongues of ice (Bentham 1941, Taylor 1956). Although many of these glaciers are actively discharging icebergs, the majority of icebergs found in Baffin Bay originate from Melville Bay, Greenland (Dunbar 1967) An interesting phenomenon observed on air photos was the movement of suspended sediment offshore from several of the glaciers along Clarence Head, Ellesmere Island . However, it is also possible that what was observed were the "...hot springs flowing into the sea beside one of the glaciers...", that was mentioned to Bentham (1941 p.40) by natives. If this was true, it could partially explain the "North Water" a large, nearly permanent body of open water in northern Baffin Bay.

The coast of Axel Heiberg is generally low and broken occasionally by cliffs or rocky bluffs, particularly on the southeastern coast. There, the fiords run across the strike. Taylor (1956) suggested that these (Strand, Middle and Li fiords) belong to the "Coastal Plain" environment and therefore, were cut along drainage channels in softer post-Silurian sediments.

In accordance with the rest of Ellesmere Island, its northern coast is bold and high, and is topped by tongues of the inland ice cap, and fringed by wide shelf ice e.g. up to 16 km wide

Ice Shelf Coastal Environment

Peary (1907) first reported that "a 'glacial fringe' extended all along the north coast, even to Nansen Sound..." At present, the Ellesmere ice shelf stretches from Yelverton Inlet to Markam Bay, with some isolated patches of ice further east and west (plate 4). Bird (1967) believed the ice shelf environment to be the only coastal type unique to polar areas. The ice has a distinctive 'ridge and valley' topography, with a relief of 1 to 8 metres and a general thickness ranging from 40 to 85 metres (Hattersley-Smith 1952, Keys et al 1968). Open water, found along the valleys of the shelf ice and at the mouth of rivers, gives the appearance of many discontinuous moats. Also, at several locations (e.g. McClintock Inlet), the ice is covered by debris from adjacent glaciers. Below the ice shelf, Keyes et al (1968) have found tidal currents with semidiurnal and diurnal periods and a tidal range of ten to fifteen cm. In addition, they found that fresh water from snow melt flowed downward through the ice, supercooled and refroze to the base of the shelf ice, thereby causing the shelf to grow from beneath. Hattersley-Smith (1952) believed that ice shelf disintegration was then at a maximum, and Koenig (1952) had reported "ice islands", or tabular bergs of up to 17 by 18 miles in dimension, which had broken away from the coast. In the winter of 1961 nearly half of the Ward-Hunt Ice Shelf broke away into five ice islands (Holdsworth 1970). The causes of this massive calving event are reported to be tidal and seismic - two major disturbances that occurred in close succession. In the past, two theories of the effect of ice shelf on the form of the coastline have been recorded. Nares (1876) and Taylor (1956) suggested that the large ice floes, as they moved westward, had filed away the headland, thereby creating a curved coastline. Hattersley-Smith (1952), on the other hand, believed that the ice shelf had acted as a buffer preventing the wearing down of the headlands. In any case, it is the belief of the author that coastal processes, in their normal sense, are non-existant in the areas of substantial ice shelf.

High Straight Coastal Environment

Included in the High Straight coastal environment are the shorelines of Lancaster and Jones Sound and McClure Strait. The coast, for the most part, is typified by straight stretches of steep scree-banked cliffs, 125 to 615 m high, with frequent indentations of short narrow inlets (plate 5). The shorelines of less relief (e.g.Western Devon Island) are composed of raised beach terraces, strandlines and lowland plains. The last is particularly characteristic at the head of the inlets. The beaches fronting the cliffs have been observed to be narrow "...rarely more than a few metres wide and often do not extend above high water mark", (McCann and Owens 1970), whereas those fringing the lowland areas are much wider. Simple shingle spits are usually found within inlets containing suitable current systems, e.g. Baad Fiord, Ellesmere Island, and larger, more complex offshore "barrier ridges" have been observed in front of the larger deltas of the shallower bays, e.g. Erebus Bay, Devon Island. The primary reason for the abundant source of shingle for beach and talus development, and additional offshore features, is the nature of the underlying bedrock. The uplands and plateau are composed of easily erodable sedimentary rocks, predominantly of a limestone and shale composition, with some sandstone.

Tidewater glaciers are few in number in this environment, and are restricted to the fiords of northern Jones and Lancaster sounds. In McClure Strait, the sea ice has been observed to play an important role in the erosion of the cliff faces along Dundas Peninsula, Melville Island (Arctic Pilot vol.111).

Several of the inlets along the Devon and southern Ellesmere coasts can be considered fiords, but have been placed in the High Straight coastal environment because of the straightness of the overall coastline and the nature of the underlying bedrock. The main differences between the Fiord and High Straight coastal environments are the relief, bathymetry, bedrock and the proportion of tidewater glaciers. The fiords of the former environment are also usually longer and narrower, thus of a more enclosed nature than the inlets (fiords) found in the High Straight coastal environment.

Ridge and Valley Coastal Environment

This region includes all of Bathurst and the surrounding islands, as well as parts of Cornwallis and Melville Islands. Geologically, the region is part of the Parry fold belt, and along many parts of the coast it resembles the High Straight coastal environment. Despite this resemblance, however, a separate coastal environment is proposed because of the characteristic ridge and valley topography which is best developed on northern Bathurst and southern Melville Islands. Taylor (1956) referred to these coasts as "strike coasts" because, here, the differential erosion of hard and soft strata in the folds has given rise to an intricate coastline which expresses the strike of the folding. The more resistant rocks create the long peninsulas and strings of offshore islands, while the embayments are, in many cases, the expression of the softer strata, e.g. Graham Moore Bay, Bathurst Island and Bridport Inlet, Melville Island (Plate 6). The orientation of the folds does change, just as the configuration of the coast, but on northern Bathurst, Erskine and May Inlets run at right angles to the folds. It has been suggested that they were drowned estuaries of rivers from the south, and were less affected by the folding processes (Arctic Pilot, vol. 1, p.18). Two additional marine features, created as a direct result of the resistant bedrock, are the structural terraces found along the north and south shores of Pearse Strait and Pell Channel by Jenness (1951), and the deltaic coastal promontories (Taylor 1956) created by streams which cross the resistant rock structures and do not terminate in coastal embayments, e.g. Northwest Bathurst Island.

In areas where the folds are less pronounced or have been severely eroded, e.g. Cornwallis Island, a much lower and more regular coastline exists. These coasts are normally lined with raised beach terraces and strandlines, and resemble those of the High Straight coastal environment.

Coastal Plain Environment

The coastal plain includes those islands of the northwestern and north central part of the Archipelago. These islands, which are characterized by their low relief, rarely exceed 150 m and are usually drained by short, consequent streams which flow parallel to each other and normal to the coast. The bedrock is young, sedimentary rocks; mud, sand and some gravel constitute the beach sediments.

Sea ice and fluvial processes play a much more important role in the altering of the nearshore zone than in other parts of the Archipelago. The large number of streams which line the shores have created vast lowland plains, mud flats and many deltas (Plate 7). Roots (1963), Taylor (1956) and Jenness (1951) all believe that the presence of the numerous deltas within the Coastal Plain indicate the inability of waves to remove fluvial sediments from the mouth of rivers. Deltas have been observed to either extend straight offshore, giving the coast a spatulate appearance, or become curved, e.g. Eglinton Island - deltas curve south where strong currents exist. The general lack of marine processes is a direct result of the semi-permanent to permanent ice cover found in the north central Queen Elizabeth Islands.

The islands skirting the Arctic Ocean are those most affected by the shifting or moving arctic pack ice. There, the low relief and the fine coastal sediments enable the ice to easily scour the shore and travel large distances inland. The most distinctive feature created by the sea ice is the "pingok" or ice push ridge. "Pingoks" have been reported by several of the explorers of the western Arctic, but are best described by Stefansson (1917, p.278) who stated:

> 'the biggest "pingoks" near the beach are not much over ten feet high, if that, and there are some equally large a quarter of a mile inland. There are hundreds of them (on Lougheed Island)...between one quarter and one half mile inland and their bases are some twenty feet above sea level.'

In a later article (1922, p.248) he wrote of the magnitude of the ice movements on the Isachsen Peninsula (Ellef Ringnes Island):

> '...the ice heaps upon the land and thousands of tons of it are shoved hundreds of feet inland and 20 or 30 feet above the level of high tide.'

Another feature thought to have been the result of ice movement are the "islets" which are found just offshore of many of the islands, e.g. Brock Island (Plate 8). The islets which were 1 to 4 miles offshore of Brock Island were reported by Stefansson (1915, p.99) as:

> 'Gravel ridges eight to fifteen feet high along the coast with lower land immediately behind them rising inland.'

On the northern coast of Prince Patrick Island, McClintock (1858, p.228) reported seeing ridges "40 to 60 feet high" which had a steeper seaward side.

Ice rafting of beach sediments has also been observed to be a common occurrence, e.g. Southern Mackenzie King Island, the reason being that the fine coastal sediments are easily blown off the land onto the offshore ice floes.

Accumulation (marine) features formed in this enclosed environment are generally of a simple form; however, on the east coast of Borden Island, bay bars have attached themselves to headlands which have created enclosed littoral swamps and saline lakes (Taylor 1956). On the other hand, to the south, on the Beaufort Sea, large complex systems of barrier islands and spits have been produced, e.g. Banks Island. Theoretically, this southern region is part of the Arctic Coastal Plain; however, it was not included in the area of study.

2.3 COASTAL ENVIRONMENTS - TIDAL RANGE

The type of tide, tidal period and tidal range are important controls of coastal processes because they determine the degree to which wave attack is concentrated on a particular sector of the beach. On a tideless coast the area of beach face under wave attack depends primarily on the size of the waves. On a coast where a large tidal range exists, the breakpoint of the waves is never fixed in position for long, and the effect of swash can operate across a wide intertidal zone if the coastal slope is gentle. On steep coasts, the usual wide, horizontal displacement of water is restricted to a narrow zone, and appears as only a rise and fall in the water level.

In their examinations of world coastlines, Davies (1964), McGill (1958) and King (1972) all differentiated between coasts of different tidal ranges. They observed that on coasts with little or no tidal range a single beach berm was usually formed, but on coasts with a large tidal range and substantial amounts of available material, a multiple 'ridge and runnel' type of berm was produced. Tides also give rise to currents, flood and ebb, the efficiency and strength of which is affected by the tidal range. The tidal currents are best developed on coasts with a large semidiurnal tidal range, and very weak on coasts with a small tidal range. The tidal currents are less effective in moving beach material because of their change in direction with each tide. However, since the currents flow at different levels on the beach, they affect the movement of material differently across the beach face (King 1972).

The tidal environments of the Queen Elizabeth Islands were defined on the basis of tidal range, using the classes proposed by Davies (1964): Macrotidal (greater than 3.96m), Mesotidal (2.13 to 3.96m) and Microtidal (less than 2.13m), (figure 2.4). Difficulties arose because of the general lack of tidal observations, and the fact that differences in tidal conditions occur between the inlets and the major sea channels, but a successful attempt was made using the tidal range values for large tides given in the Tide and Current Tables published by the Canadian Hydrographic Service. Supplemental mean tidal range values were collected from Arctic Pilot (Vols. 1, 11, 111).

The regular heights of the tides are often altered by winds. Winds which blow onshore raise the water level, while those which blow offshore lower the level. A combination of high onshore winds and high tidal conditions can result in tidal surges, which cause catastrophic


COASTAL ENVIRONMENTS
(TIDAL)
Macrotidal
Mesotidal
Microtidal
currents
lg· tidal range
2·2 m
Microtidal
·9
2·4
·55
4·7
·37
Macro-
Tidal
Microtidal
Meso-
Tidal
1·55
2·86
2·8
Microtidal
Mesotidal
100 0 100
km

FIGURE 2·4

changes in the beach environment. The tides within the inlets, with only one restricted opening to the sea, can oscillate in sympathy with the external ocean tide and become quite large, or can be independent and be governed by the characteristic period of the inlet or basin. The period of the basin is dependent on the depth and length of the particular basin (Defant 1958).

In the Queen Elizabeth Islands, the tides increase both west to east and north to south. The only area of macrotides is northern Baffin Bay and Smith Sound where tidal ranges of 4.7m or greater are experienced. The size of the tides tend to vary with channel width and location. For example, along Parry Channel the greater width of Viscount Melville Sound only produces a mean tide of 0.61m ; then, as the water passes quickly through the narrow Barrow Strait, a mean tide of 1.28m is found. Additional water from Wellington Channel into Lancaster Sound increases the amount of water which must funnel into Baffin Bay; hence, the mean tide increases from 1.71m at Beechy Island to 1.8m (mean tide) at Dundas Harbour. The near tideless conditions of the northern and northwestern portion of the Queen Elizabeth Islands would limit the part of the beach face subjected to wave action. It would also reduce the effect of the water level variations in the formation of the shore leads and cracks, and the formation of currents and the resultant removal of sea ice from the inlets and channels.

The suggested tidal environments within the High Actic, although not precisely defined, do help in the interpretation of the variety of beach characteristics observed throughout the Queen Elizabeth Islands.

2.4 COASTAL ENVIRONMENTS - OPEN WATER SEASON

The presence of ice at sea or along the shore (icefoot) for much of the year prohibits substantial wave action, and means that the beaches are, in a general sense, low energy beaches. There is a relatively low degree of reworking of beach sediments, and the annual changes in the beach plan or profile are minor (King 1972, McCann 1972). The principal feature of ice disintegration is the steady, outward progression of open water from several well defined areas of weakness (Schule and Wittmann1958). Nevertheless, considerable variability in sea ice removal occurs from season to season with some areas open every year, others severely congested, and a transition area where the annual differences in sea ice cover is greatest. Ice drift and disintegration are responsive to several factors: wind, currents, air temperature and, in some measure, bathymetry and tides (Collin 1962). In general, a narrow waterway, or one studded with numerous islets, is one where melting of the ice depends on air temperature and solar radiation. On the other hand, in wide unrestricted waterways, e.g. Parry Channel, wind is the main determinant of ice break-up.

An interpretation of the differences in annual beach regime throughout the Queen Elizabeth Islands can be more easily achieved if the coasts are divided according to the duration of ice free waters. Four categories were selected, based on ice observations from 1964 to 1969 by the Canadian Meteorological Service and ice data from previous

years, summarized in other literature (Arctic Pilot, vol.1). The categories are as follows: (i) Permanent - predominantly old ice which is solid and unmoving most years. Arctic pack ice, although permanent, is slowly moving throughout the year. (ii) Enclosed - less than four weeks of restrictive ice movement, with 8 to 9/10ths ice cover with extensive shore leads. (iii) Navigable - 4 to 12 weeks of open water or very young ice; at most, 3/10ths ice cover.
(iv) Open - over 12 weeks of open water, centre of sea ice breakup, and the ice is in motion during the winter under the influence of wind and currents (Figure 2.5).

The number of ice-free or open water days was computed for each waterway in the northern Archipelago, using open water to 7 to 9/10ths new ice as the limits of the ice free season. Waves can form long before open water exists in the whole channel; however, the presence of an ice foot or a narrow band of fast ice along shore would prohibit the altering of the beach by waves. Similarly, wave action can be effectively eliminated before a waterway contains 7 to 9/10ths new ice, but since a storm could destroy a smaller concentration of new ice, the higher limit was used.

The waterways designated as OPEN consist of north Baffin Bay, Smith and Lancaster Sounds, Prince Regent Inlet and Hell Gate-Cardigan Strait, each of which has constantly moving ice during the winter months. Three of the four centres of ice breakup in the Archipelago are found in the OPEN category - the North Water, the Barrow Polynya and the Cardigan Strait Polynya. The fourth centre is found in the Penny Strait-Queens Channel region. The North Water is by far the most

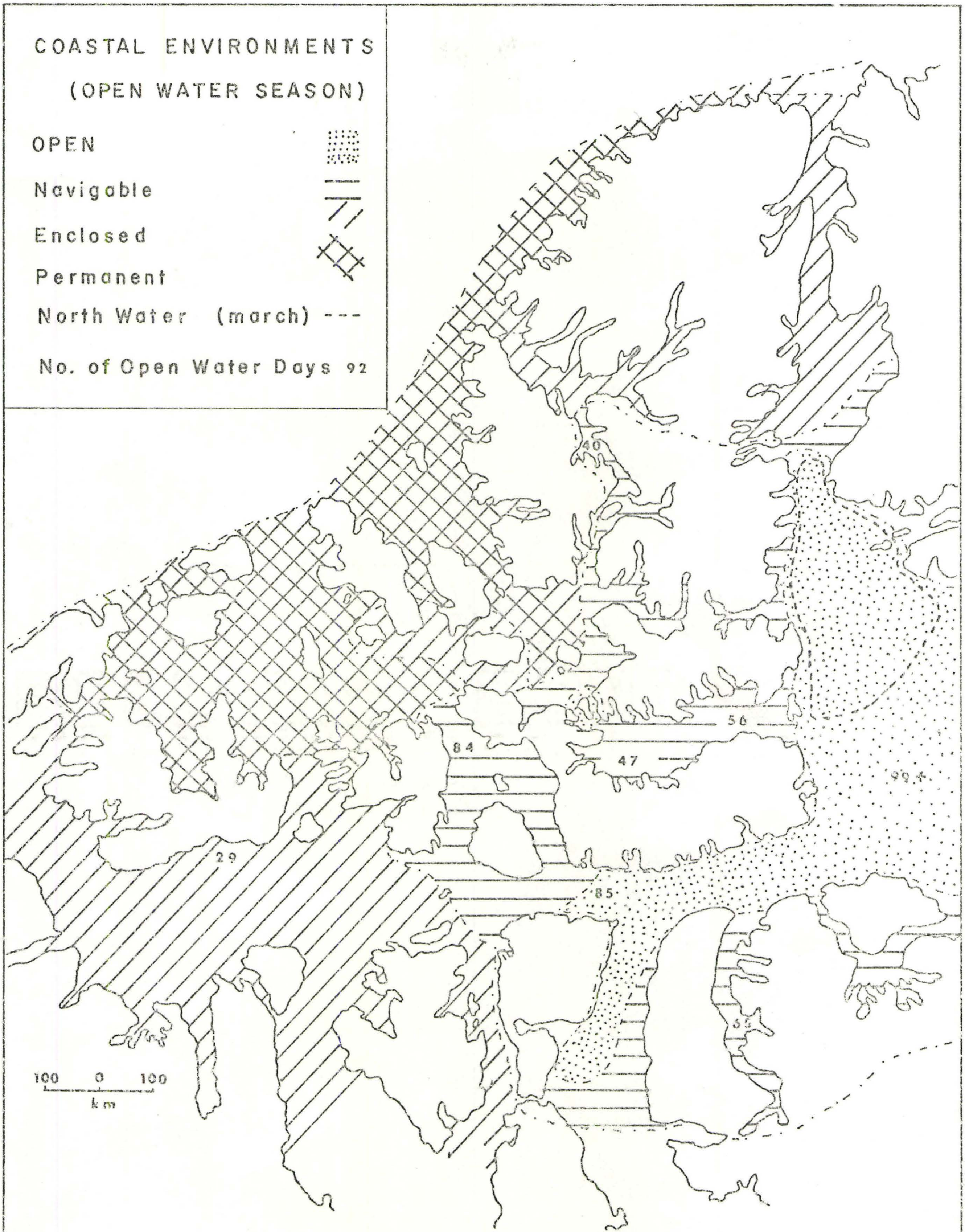


FIGURE 2·5 LENGTH of OPEN WATER SEASON

important and largest of the centres of sea ice breakup. During the winter, open water may be found in Smith Sound because of the strong winds and currents, large tidal oscillations and the formation of an ice bridge across the northern entrance to the Sound (M.Dunbar 1969). By May or June, the polynya has spread south along the west side of Baffin Bayinto the entrance of Jones and Lancaster Sounds. The time of ice removal in these waters is very important to the sequence of breakup in the rest of the Archipelago, because the former acts as a route for ice dispersal to the east and south. In the OPEN water area, the rule is for the inlets to become ice free after the main sea channels.

Sea ice removal in the NAVIGABLE region depends on favourable north and west winds which blow the ice to the already ice free waters further east. The narrow channels and numerous islands, found in this category, limit the possible wave fetch, as does the remnant ice floes usually found in the centre of the channels until late summer. The channels are usually navigable by mid-August or early September, and are covered by new ice by mid to late October.

A considerable amount of second or multi-year ice is found in the ENCLOSED waters, and, to some degree, the extent of ice break-up governed by the amount of old ice which enters from McClure and Byam Martin Channels the previous summer. Fractures and leads are observed radiating outward from headlands, and a considerable shore lead is usually developed along the coasts by early September. Contrary to the OPEN region, the inlets generally become ice free before the larger sea channels because of the effect of rivers and the presence of younger, thinner ice. Viscount Melville Sound can be considered a transition zone between NAVIGABLE and ENCLOSED ice conditions because of the great year to year variation in ice cover; however, for the sake of simplicity, it was grouped under the latter category.

The region designated as PERMANENT ice cover was difficult to delimit because of the lack of sea ice data for the northwestern part of the Archipelago. It is thought that the ice cover remains solid, although excessive puddling and ice fractures occur. Ice may be set in restricted motion once every three or four years, but even in the most favourable conditions which occur once every fifteen to twenty years, the ice cover rarely becomes less than 7/10ths (Arctic Pilot vol. 1, 1970)

From the foregoing statements, it can be summarized that the ice free conditions vary both with year and location, with comparable variations resulting in the annual beach regime.

2.5 CONCLUSIONS

Five distinct coastal environments are found in the Arctic Archipelago: the Fiord Coast, the Ice Shelf Coast, the High Straight Coast, the Ridge and Valley Coast, and the Coastal Plain. Furthermore, three divisions based on tidal ranges, and four based on the length of the open water season can be delineated. Many observations have been made, and considerable overlap was found with the resultant divisions; thus, some general statements are now in order.

The underlying bedrock, or geology, is important to the characteristics of the coastal environment because it determines the rate of erosion, consequently, the relief and form of the coast and the availability of sediment for beach development.

In very general terms, each of the coastal environments can be associated with one or two agents of formation. For example, the Fiords are associated with glacial erosion, the Ridge and Valley with the geologic evolution (folds), the Coastal Plain with bedrock, easily eroded, and the High Straight Coasts with isostatic uplift, e.g. raised beaches, and the bedrock, easily eroded. Since the initial shaping, conventional marine processes have modified the shoreline in each of the environments, but to different degrees because of sea ice and tidal conditions and the resultant amount of wave action.

The areas of the largest tidal range and swiftest currents were also the same as the OPEN ice cover region. However, the coastline of these areas was usually very high and steep which almost negates the great possibilities for beach development and coastal processes. Moreover, a large proportion of the ice coasts, excluding the Ice Shelf, were found there. At the other extreme, the ENCLOSED and PERMANENT ice cover regions contained near tideless conditions and very low coasts consisting of fine sediment. The result is very little, if any, wave action, but the swash zone is concentrated in a narrow band and the beach sediment is quite fine, thus more easily reworked and transported. Therefore, conventional marine processes, although restricted, are still possible, particularly with the presence of the numerous streams which line the shores. In the transition zone which is characterized by steep plateau or raised beach shorelines, the length of open water season varies considerably from year to year but is sufficient, along with the mesotidal ranges, to produce simple accumulation forms and substantial shingle beaches.

CHAPTER 111

THE FIORD COASTAL ENVIRONMENT

3.1 INTRODUCTION

A very high, rugged coastline extends along the eastern shores of the Canadian Arctic Archipelago, from Davis Strait north to Smith Sound. The eastern edge of the highlands, composed of Precambrian rocks, granites and gneisses, has been dissected by steep walled Norwegian-type fiords which, in many places, are intersected by glacial tongues. The mountainous terrain usually only extends inland to the head of the fiords where a lower plateau or upland topography exists.

Detailed investigations of the Fiord environment were centred on Makinson Inlet (77° 15' N, 80° 15' W), in southeastern Ellesmere Island, and on Pond Inlet-Eclipse Sound (72° 46' N, 72° 30' W), in northeastern Baffin Island. Research at Makinson Inlet took place between July 17th and 31st from a base camp situated on the south side of Swinnerton Peninsula. The investigations at Pond Inlet-Eclipse Sound were less detailed than those at Makinson Inlet, but were to reinforce the data already collected at the former location. The base camp was located at the settlement of Pond Inlet and the research was conducted between August 26th and September 8th.

MAKINSON INLET, ELLESMERE ISLAND

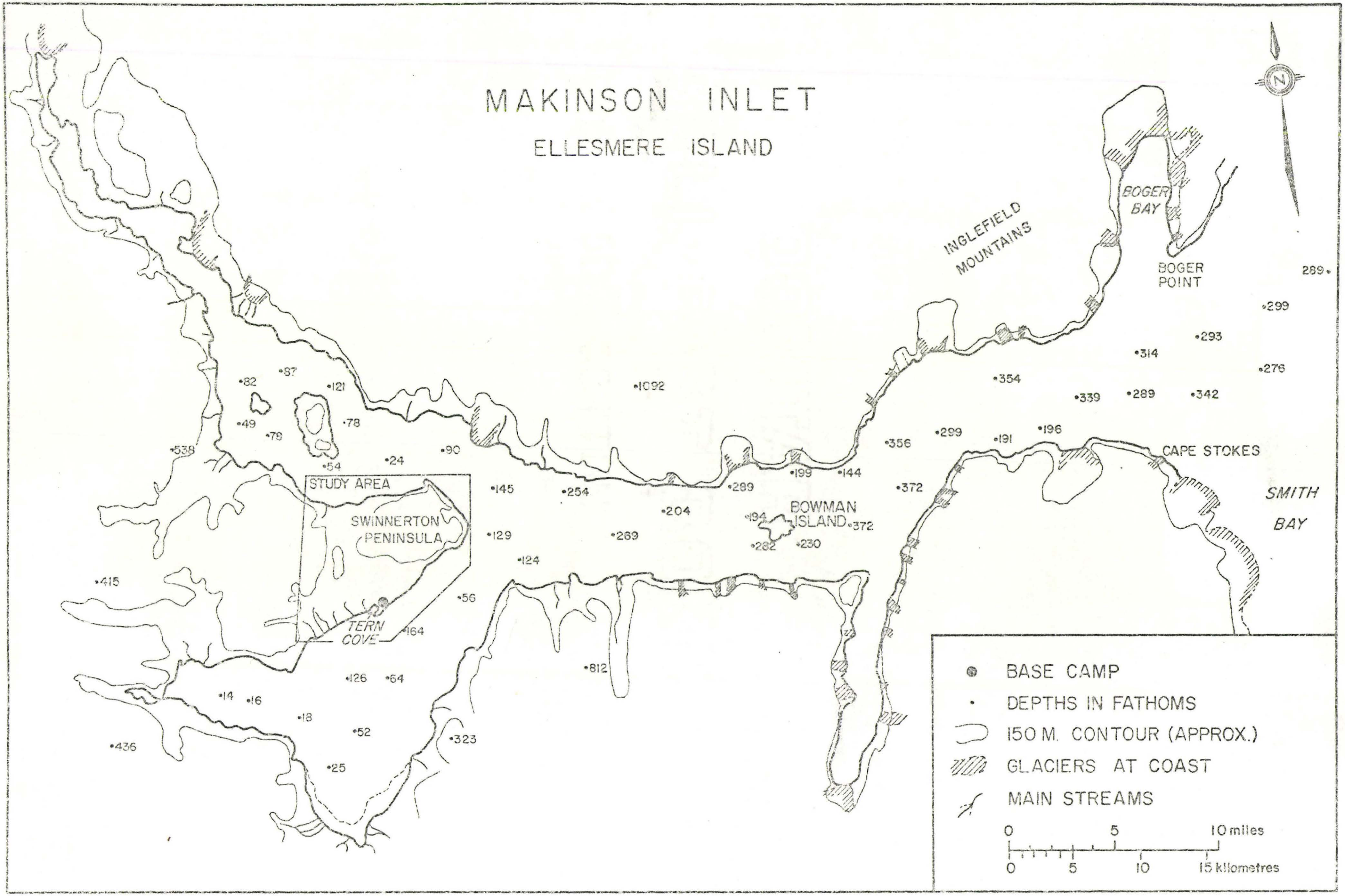
3.2 COASTAL MORPHOLOGY AND BATHYMETRY

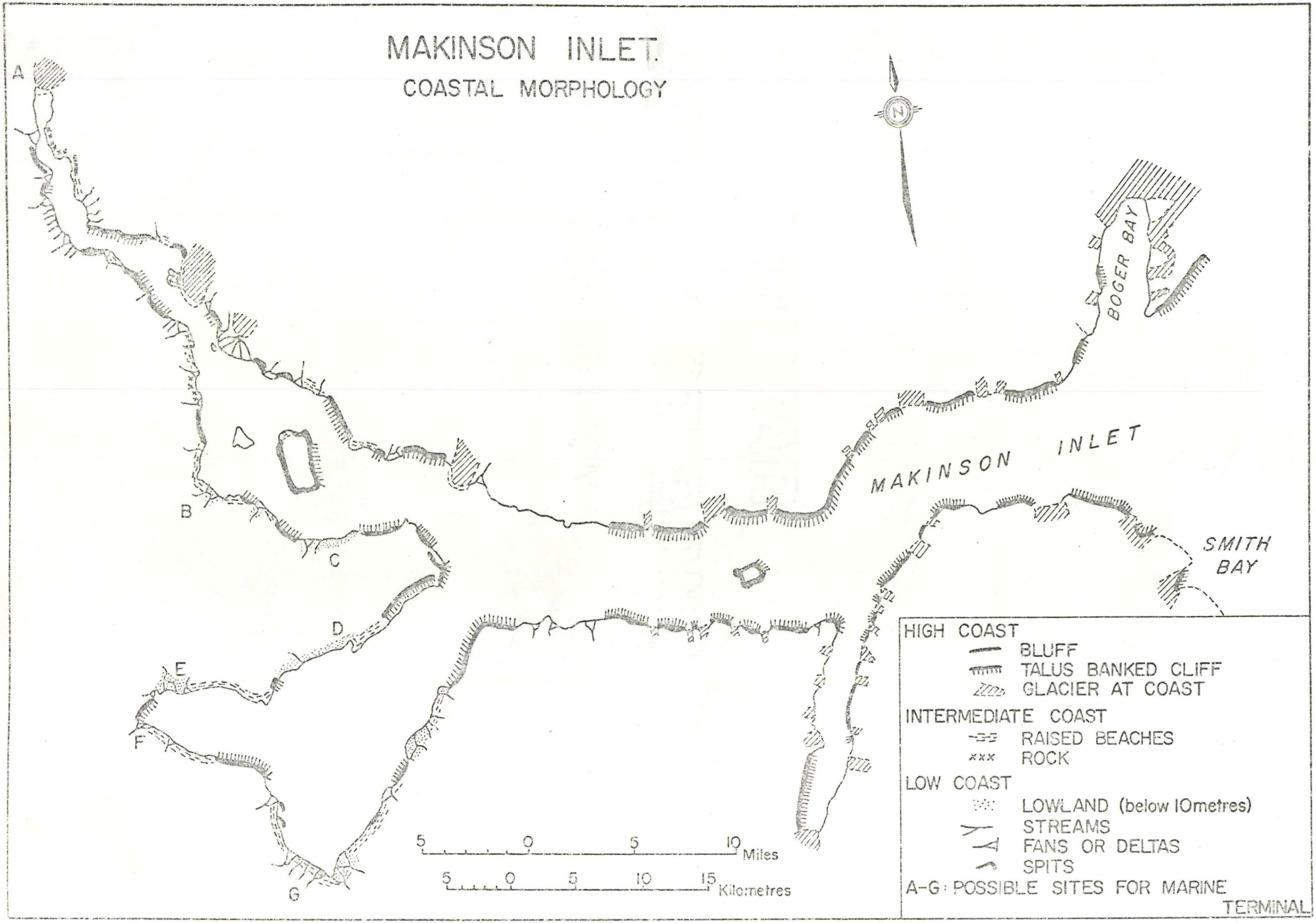
The inlet is very deep throughout its entire length, and especially so at the entrance where depths of over 300 fathoms are recorded. Off the tip of Swinnerton Peninsula, depths of up to 129 fathoms are sounded, but in both of the arms of the inlet lesser depths are encountered. In fact, there is shoaling to less than 20 fathoms at the head of the arms (Figure 3.1).

The entrance to Makinson Inlet is bordered by high, steep, talus-banked mountains, frequently separated by glacial tongues, many of which extend into the sea (Arctic Pilot Vol. 11). The inlet divides 46.6 km from the entrance to Swinnerton Peninsula, into a southwestern arm 28.3 km long and a northwestern arm 43.4 km long. The southwestern arm is basically bordered by dissected plateau country fringed by raised beach terraces and large deltas; but the coast of the northwestern arm, particularly the eastern side, remains steep, though there are numerous deltas and alluvial fans present (Figure 3.2).

Swinnerton Peninsula, upon which the base camp was located, was the site of the most detailed field investigations. Here, the relief was less than 300 m, and the topography was that of dissected limestone plateau. The coastal morphology varied from sheer cliff at the tip of the peninsula to a lowland of deltas and alluvial fans at either end of 'Black Band' Valley. In general, the modern beach is very narrow and is backed by a series of raised beach terraces and talus-banked, plateau slopes. At the seaward edges of the raised beach terraces, frost cracks appeared to be centres of thermal erosion (melting of ground ice), a process which had led to severe gully erosion on the terrace slopes.

No curve can, as yet, be drawn to represent the rate of isostatic


MAKINSON INLET
ELLESMERE ISLAND
N
INGLEFIELD MOUNTAINS
BOGER BAY
BOGER POINT
CAPE STOKES
SMITH BAY
BOWMAN ISLAND
STUDY AREA
SWINNERTON PENINSULA
TERN COVE
289
299
293
314
276
354
339
289
342
1092
82
87
121
49
79
78
538
54
24
90
356
299
191
196
199
144
372
145
254
289
204
194
372
282
230
129
269
124
415
56
164
812
126
64
14
16
18
52
436
323
25
BASE CAMP
DEPTHS IN FATHOMS
150 M. CONTOUR (APPROX.)
GLACIERS AT COAST
MAIN STREAMS
0 5 10 miles
0 5 10 15 kilometres



MAKINSON INLET.
COASTAL MORPHOLOGY

rebound from the last glaciation for Makinson Inlet area; however, the limit of marine transgression seems to have been between 100 and 140 metres A.S.L., at about 8,500 to 9,000 years B.P. The only shoreline sample that has been radiocarbon dated, from Makinson Inlet, was found at approximately 73 metres and dated as 8,200 ± 220 years B.P. (Dyck and Fyles 1964). In addition, wood samples found by the author at 4.27 and 33.2 metres have been sent to the Geological Survey of Canada for radiocarbon dating.

Although the geology of the area has not been completed, field observations indicate that 'Black Band Valley' is primarily composed of the mid-Cenozoic, Eureka Sound Formation, while the plateau is composed of Paleozoic rock. The plateau, the talus and the beach sediments which lie beneath consist primarily of limestone shingle which vary from approximately -8 ∅ to -1 ∅ in size. On the other hand, the beach sediments fronting 'Black Band Valley' consist of a larger proportion of fine sediments. These finer sediments are the result of the underlying bedrock of the Eureka Sound Formation which consist mainly of sandstone and shale with numerous coal seams. The source and type of sediments are important to know, especially when analysing the size and shape of the sediments found along the coast.

3.3 TIDAL CONDITIONS

Tidal observations within the Arctic Archipelago are very limited, and it is doubtful if any measurements have been made in Makinson Inlet. Accordingly, a brief examination of daily tidal

TABLE 3.1

TIDAL CHARACTERISTICS

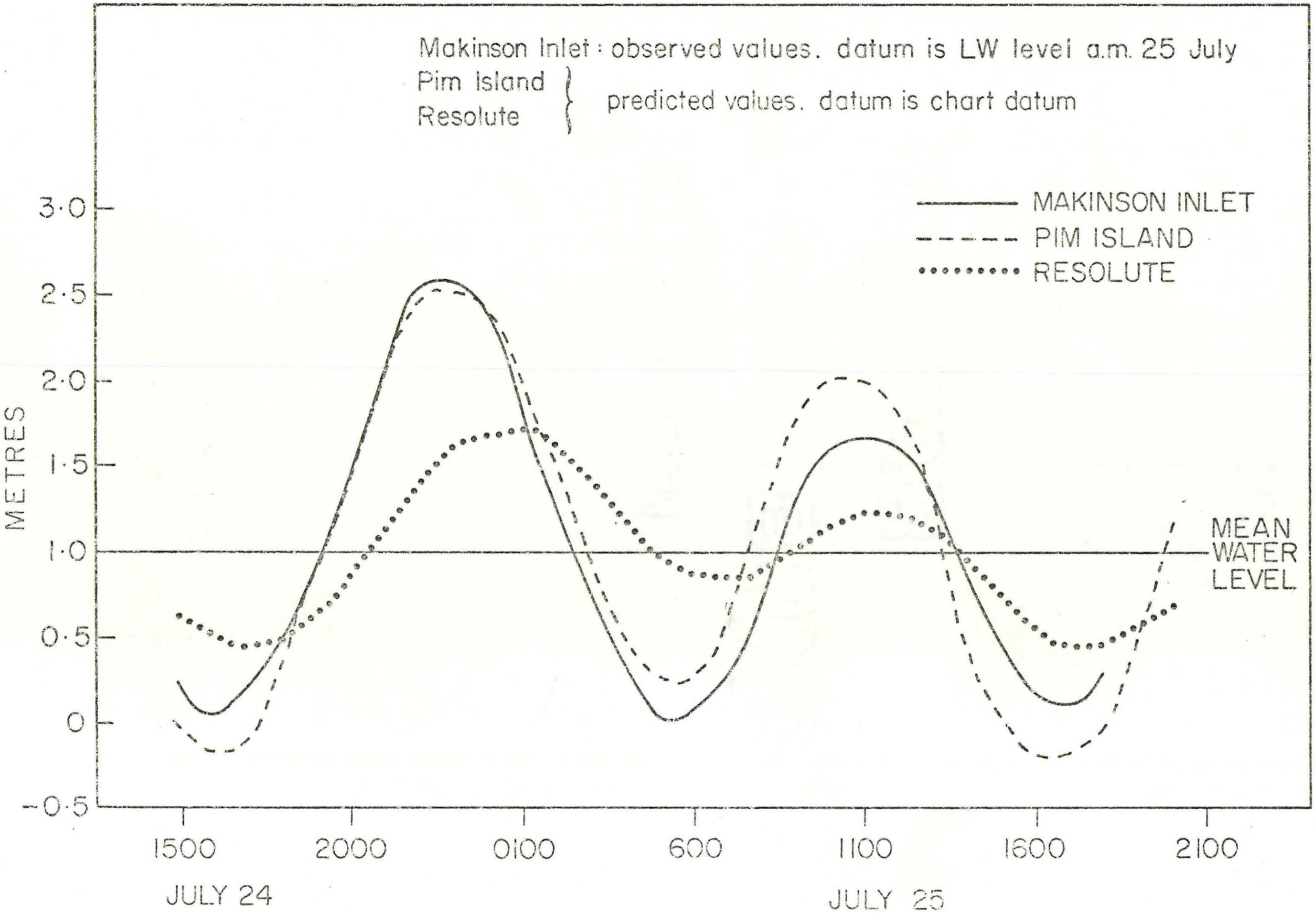
Comparisons of Makinson Inlet with Resolute and Pim Island

Location	Higher High Water		Lower Low Water		Mean Water Level	Range Mean Tide
	Mean Tide	Large Tide	Mean Tide	Large Tide		
Resolute Bay*	1.60	2.00	0.30	-0.10	1.00	1.30
Pim Island*	2.19	2.80	0.61	0.12	2.19	2.86
Makinson Inlet (proposed values based on observations)	2.02	-	0.47	-	-	2.46

*published values

Location	Mean High Tide +	Mean Low Tide +	Mean Water Level	Range Mean Tide	Period (in hours)
Resolute Bay°	1.46	0.59	0.97	0.82	10
Pim Island°	2.28	-0.06	2.30	2.22	12
Makinson Inlet (observed values)	2.11	0.04	0.98	1.90	12 1/2

° predicted values
+ level of average tide above or below mean water level
All heights given in metres.


Makinson Inlet : observed values. datum is LW level a.m. 25 July
Pim Island
Resolute
predicted values. datum is chart datum
MAKINSON INLET
PIM ISLAND
RESOLUTE
METRES
3·0
2·5
2·0
1·5
1·0
0·5
0
−0·5
MEAN WATER LEVEL
1500
2000
0100
600
1100
1600
2100
JULY 24
JULY 25

changes was carried out at 'Tern Cove', from 1500 EST, July 24th to 1730 EST, July 25th, with measurements of water level every half hour (full moon occurred on July 26th). For purposes of analysis, the Makinson data was compared with predicted values of tidal height and times for Pim Island (Smith Sound), the closest secondary port, and Resolute Bay, the tidal reference port (Figure 3.3).

It is apparent that the mixed, mainly semi-diurnal type of tide occurs at all three localities, and that the range at Makinson is greater than at Resolute but less than at Pim Island (Table 3.1). The estimated range at mean tide for the Makinson site is 2.46 metres. Makinson Inlet and Pim Island are quite close, but the local situations are different. Pim Island is situated on a major sea channel, Smith Sound, while the study site lies within a fiord linked to the sea by a narrow channel. It is considered that phase differences may exist between northern Baffin Bay and inner Makinson Inlet, and also that there may be independent oscillations within the inlet governed by the period of the basin.

3.4 SEA ICE CONDITIONS

Ice cover data for Makinson Inlet is very meagre, as the aerial reconnaisance flights in the past have concentrated on major shipping channels, such as Lancaster Sound - Barrow Strait, or areas of high priority research projects. The account which follows consists of a compilation from several sources of ice conditions in previous years.

PRIOR TO 1965

Ice data for the years 1946 to 1958 is summarized in

Swithinbank's Ice Atlas (1960); however, the nearest station to Makinson Inlet was east of Smith Bay. As part of the 'North Water', the open water season was long, generally lasting from the end of June to mid-September, a period of 75-77 days.

In the summer of 1959, much of the Arctic Archipelago, including Makinson Inlet, was photographed. From these photos, a detailed analysis of ice conditions within the inlet is possible for one instant in time. From figures 3.5, 3.6 and 3.7, it is evident that the northern arm becomes ice free before either the southwestern arm or the entrance to Makinson Inlet. Nevertheless, floating glacial ice occurred in considerable quantities, especially opposite the large calving glaciers halfway along the northwestern arm. Remnant ice of first and second year age was located along the east facing shoreline. In the southern portion of the inlet, open water existed at the head, but nearly complete cover of first year ice existed elsewhere. Photography flown on August 17th, 1959, indicated complete open water conditions for the areas described above.

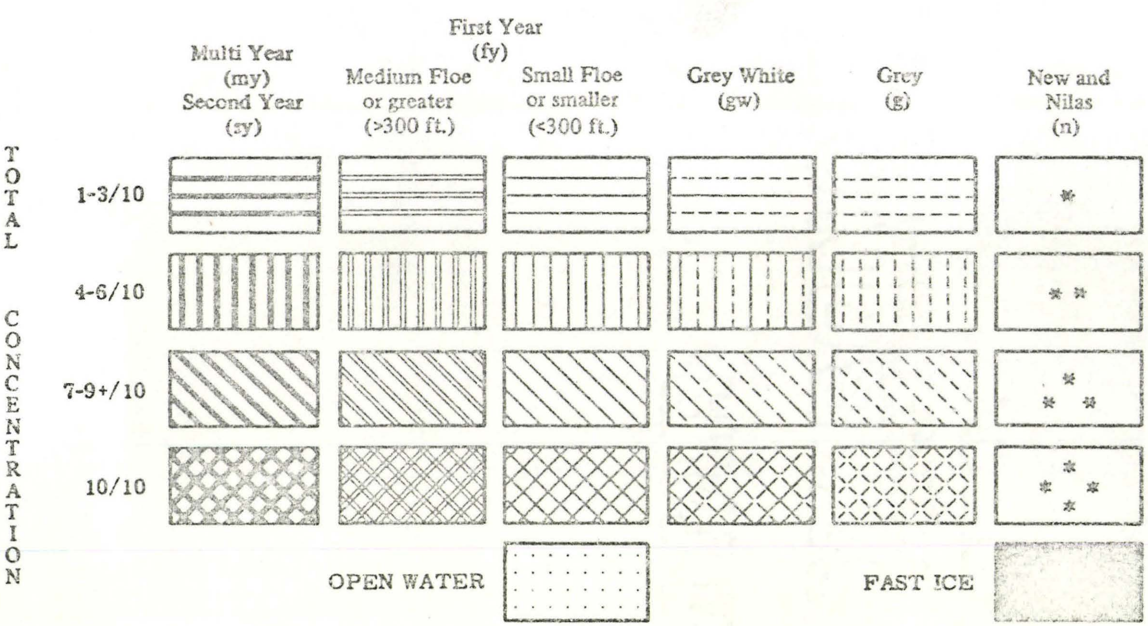
1965 - 1972

The ice observations of the Ice Division of the Atmospheric Environmental Service and of the Polar Continental Shelf Project provide a useful, though incomplete, record of ice conditions during this period. The data for the eight years is summarized in Figures 3.8, 3.9 and 3.10, a series of maps which indicate sea ice content and type in the third week of each of the three months of July, August and September. The approaches to Smith Bay in the area of the 'North Water' (Dunbar, 1969) are usually open by late June or early July, but Smith Bay - Makinson

ATMOSPHERIC ENVIRONMENT SERVICE

KEY TO ICE SYMBOLS

PREDOMINANT AGE



CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or Greater}}$$

$$\frac{C_{my}}{N_{my}}\frac{C_{sy}}{N_{sy}} . \frac{C_{fy}}{N_{fy}}\frac{C_{gw}}{N_{gw}}\frac{C_{g}}{N_{g}}\frac{C_{n}}{N_{n}}$$

Example $\frac{20.3410}{1\ \ \ 23}$

$\frac{2}{1}$ -- 2/10's Multi Year of which 1/10 is Medium Floe or greater

0 -- No Second Year

. -- Decimal Point

$\frac{3}{2}$ -- 3/10's First Year of which 2/10 is Medium Floe or greater

$\frac{4}{3}$ -- 4/10's Grey White of which 3/10's is Medium Floe or greater

1 -- 1/10 Grey, no Medium Floe or greater

0 -- No New

SNOW COVER

$\frac{Sn}{(n)}$

(n) tenths on ice

TOPOGRAPHY

$\frac{ΛΛ}{(n)}$ Rafted Ice

$\frac{ΛΛΛ}{(n)}$ Ridged Ice

SURFACE FEATURES

Sn/Ra Rd Hy Pd Th + F

$\frac{ΩΩ}{(n)}$ Hummocks

(n) number of tenths

"e.g. 6/1201"
6 -- 6/10 Snow Cover
/ -- Slant
1 -- 1/10 Rafting
2 -- 2/10 Ridging
0 -- No Hummocks
1 -- 1/10 Puddling

STAGE OF MELTING

$\frac{Pd}{(n)\ (n)\ Th + (n)\ F}$

(n) = tenths on ice
(n)th = tenths thaw holes
(n)F = tenths frozen

ICE OF LAND ORIGIN

△ -- (n) Icebergs

⏢ -- (n) Bergy Bits and growlers

Optional:
(n) -- number in area

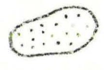
THICKNESS OF ICE AND SNOW

$\frac{T\ \ S}{n\ \ n}$ (n) -- nearest inch

WATER FEATURES


Crack


Lead


Polynya

UNDERCAST


Limits

BOUNDARY

——— Observed visually

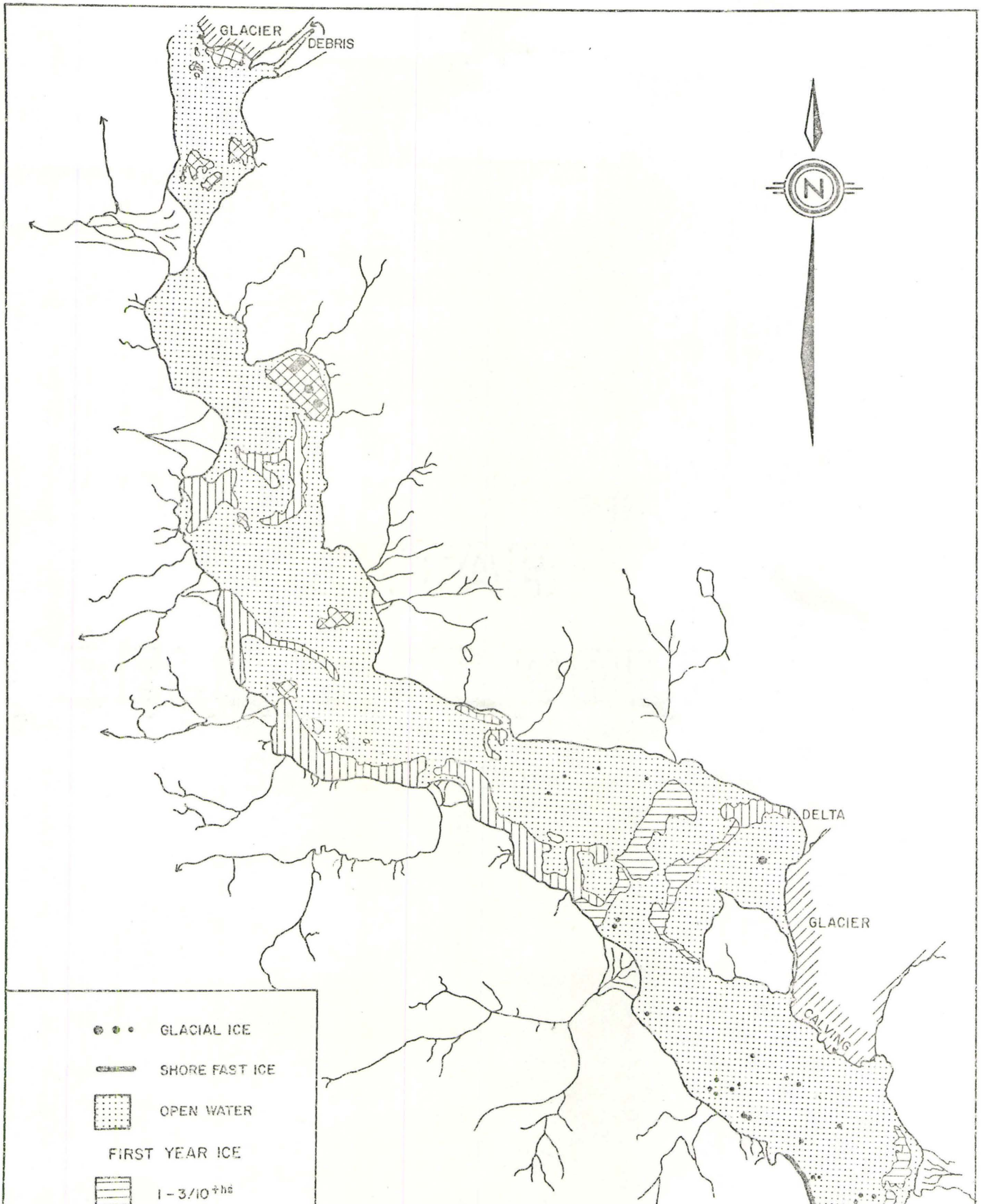
-✕-✕-✕- Observed by radar

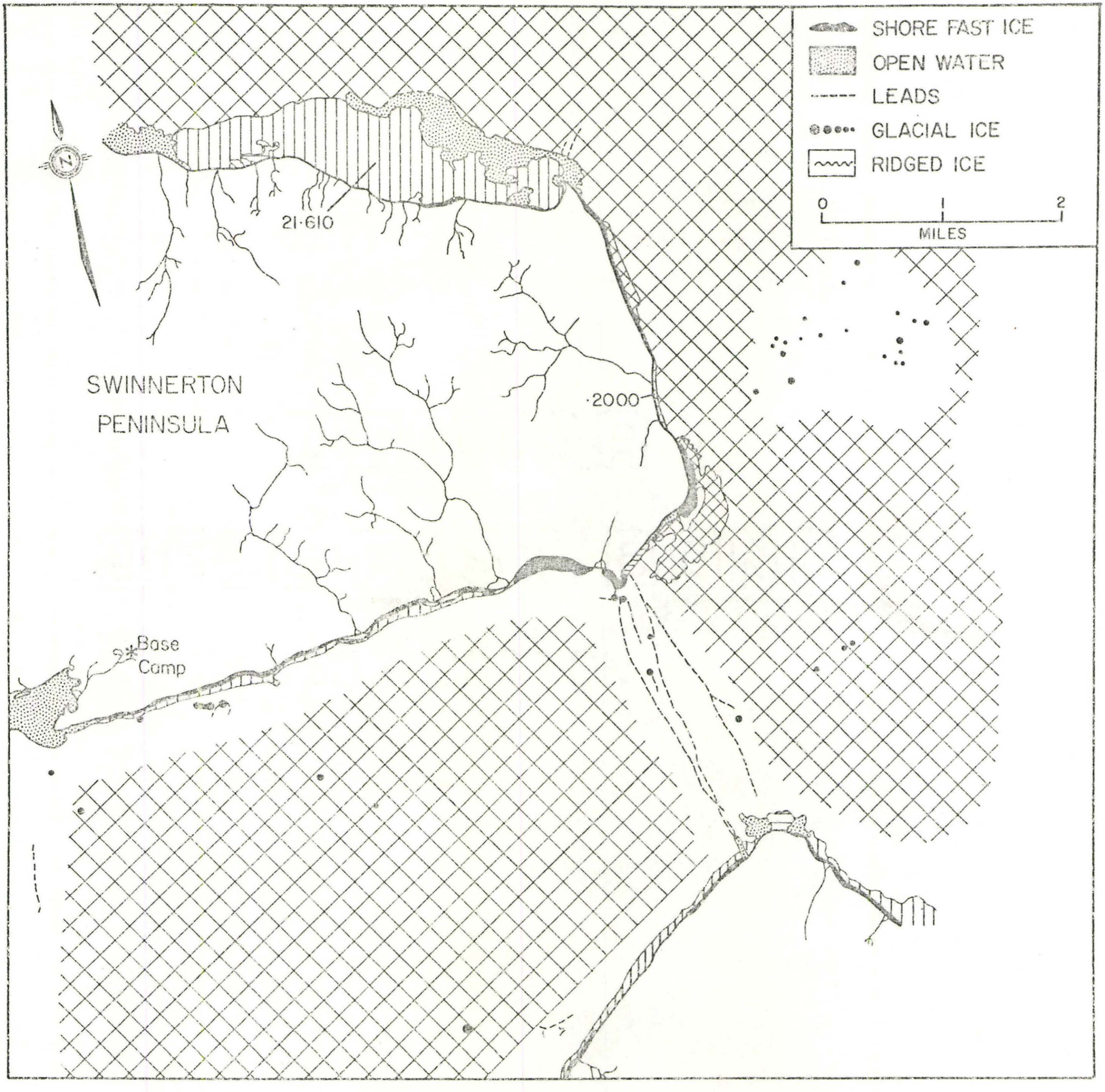
— — — Assumed

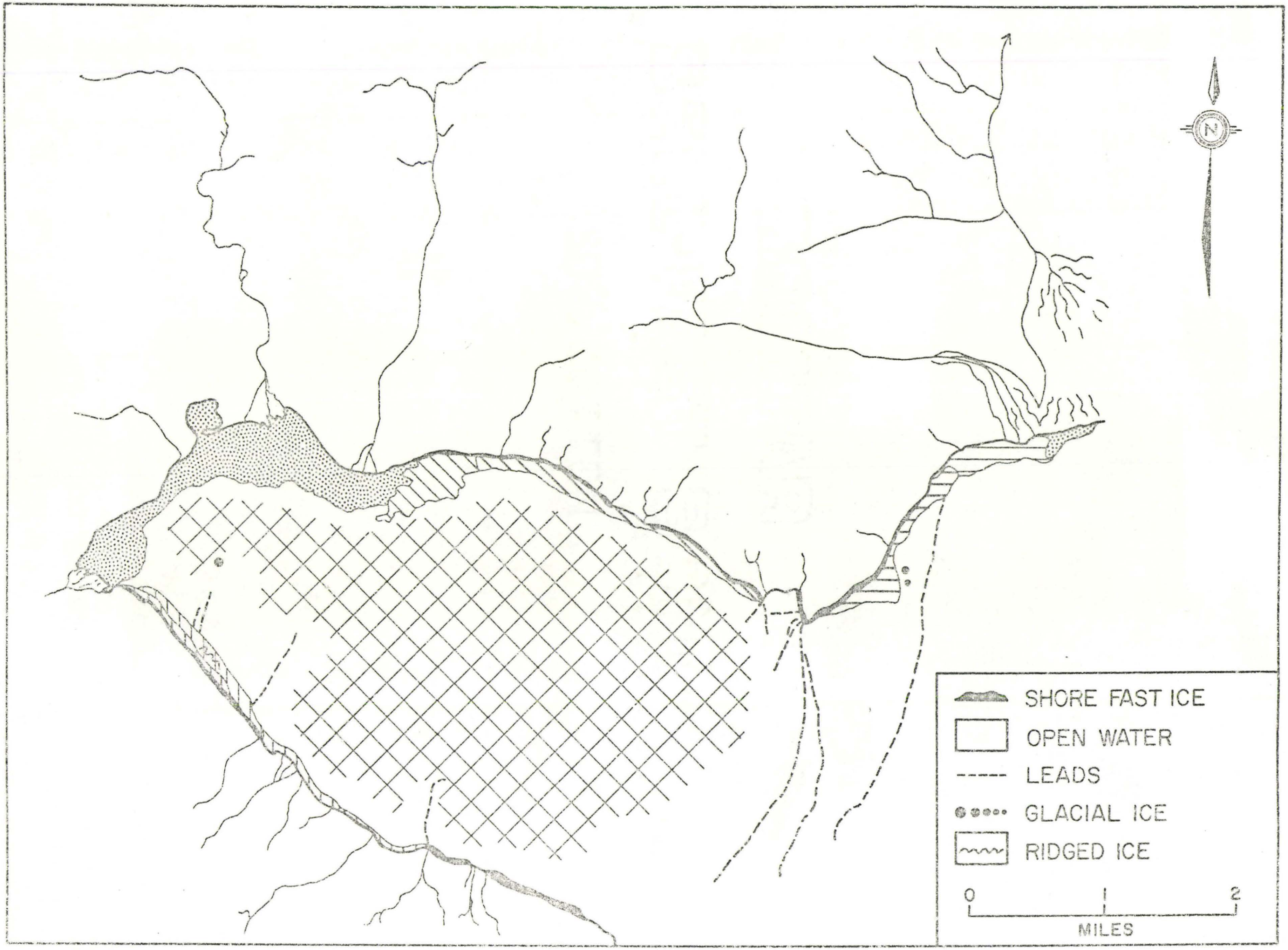
○○○ Limit of Observed data

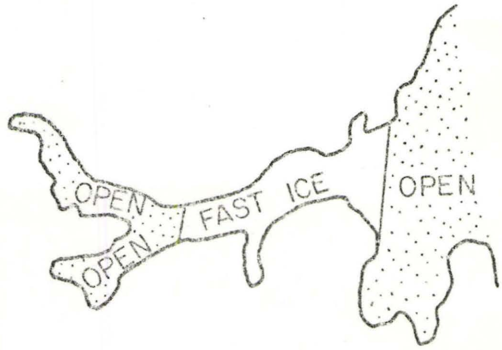
○✕○✕○ Limit of radar data

Symbols used for Recording the Various Ice, Snow, and Water Features

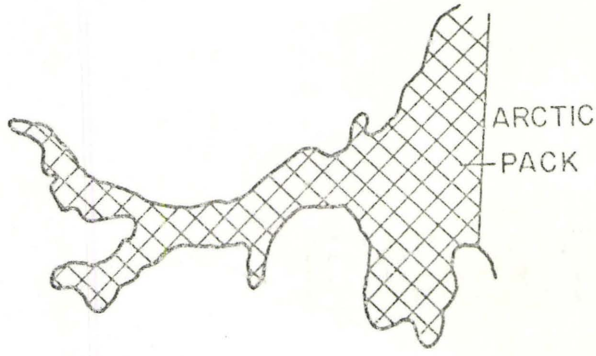

GLACIER
DEBRIS
DELTA
GLACIER
CALVING
N
● ● • GLACIAL ICE
SHORE FAST ICE
OPEN WATER
FIRST YEAR ICE
1 - 3/10ths
6 - 9/10ths
10/10ths
0
1
2
MILES


SHORE FAST ICE
OPEN WATER
LEADS
GLACIAL ICE
RIDGED ICE
0
1
2
MILES
N
21·610
SWINNERTON
PENINSULA
·2000
Base
Camp


N
SHORE FAST ICE
OPEN WATER
LEADS
GLACIAL ICE
RIDGED ICE
0
1
2
MILES

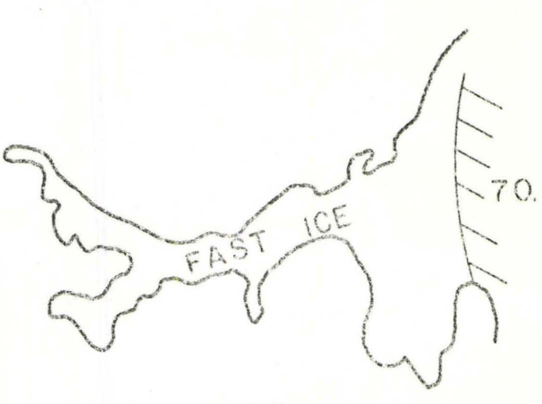


1965

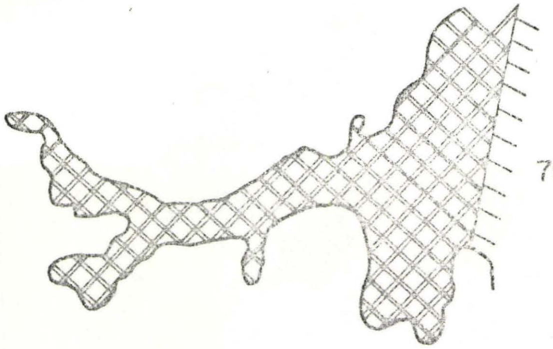


1966

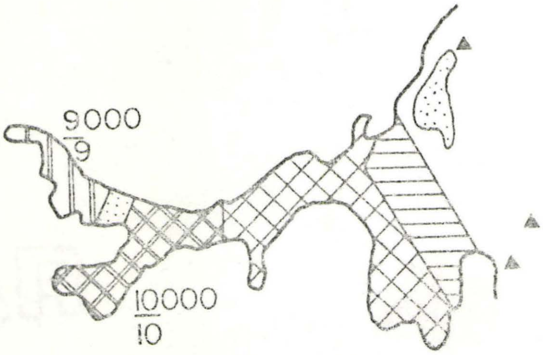
1967



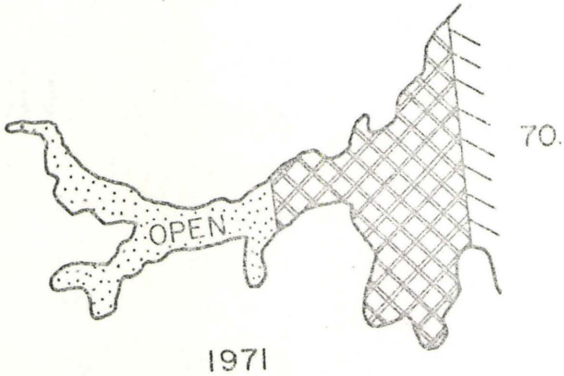
1968



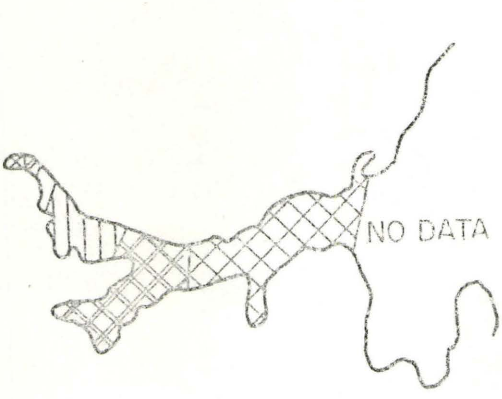
1969



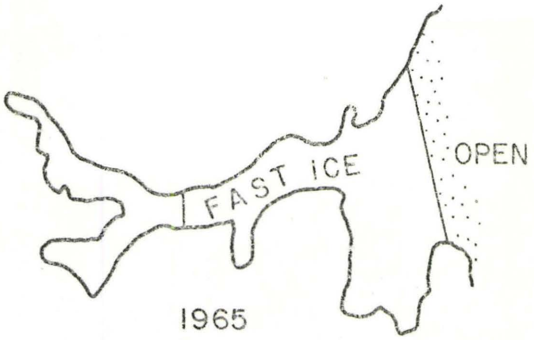
1970



1971

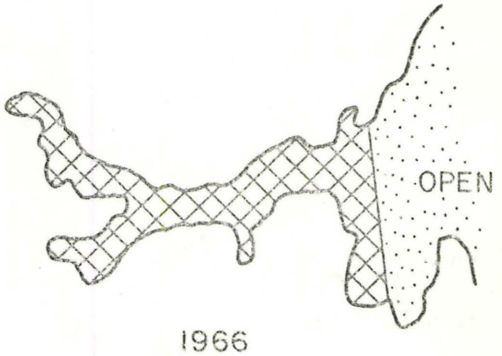


1972

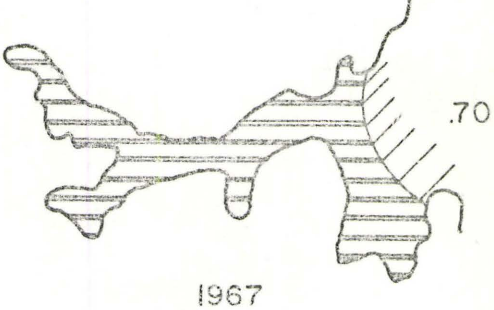


1965

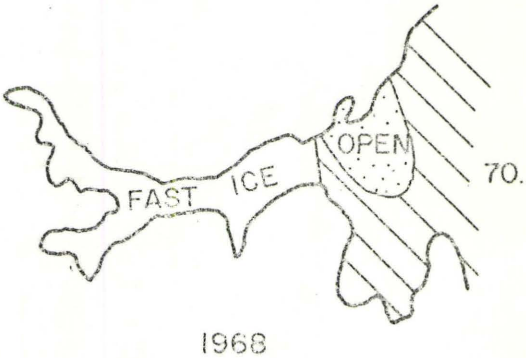
OPEN THROUGHOUT BY AUG. 20



1966

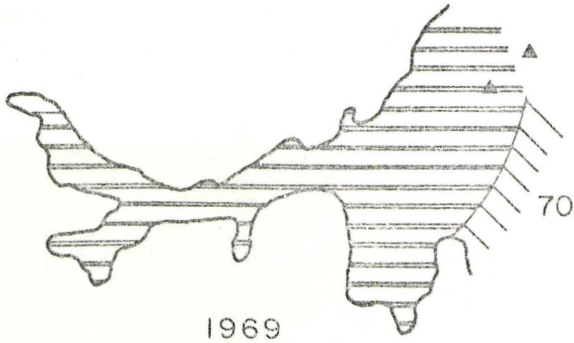


1967

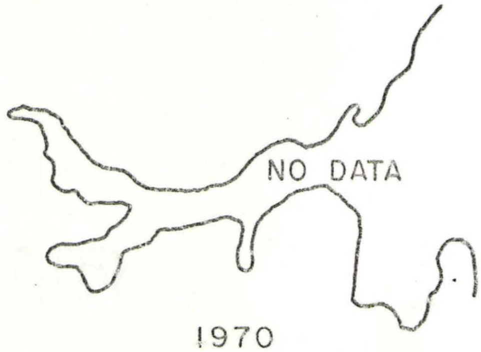


1968

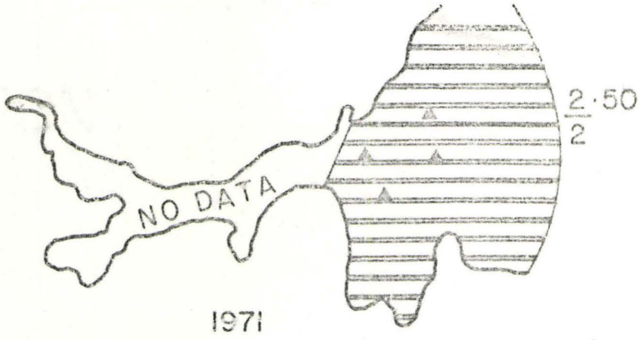
OPEN WATER BY AUG. 27
(within inlet only)



1969

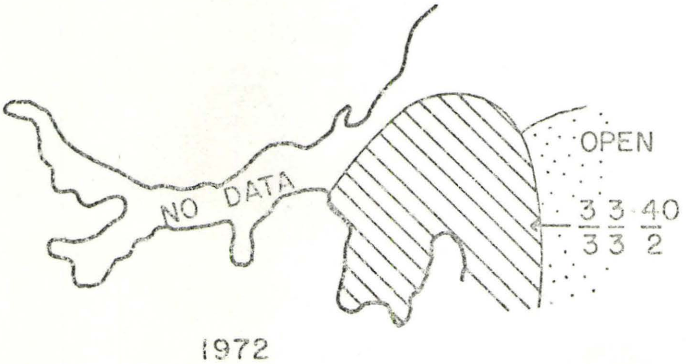


1970

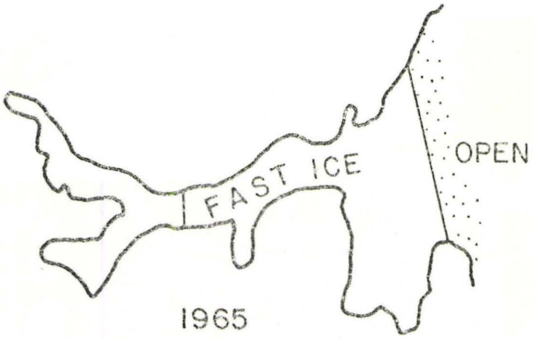


1971

(Only one reading)

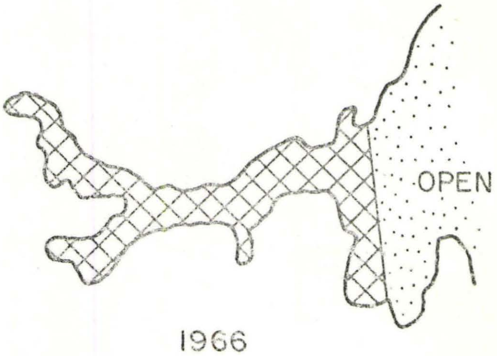


1972

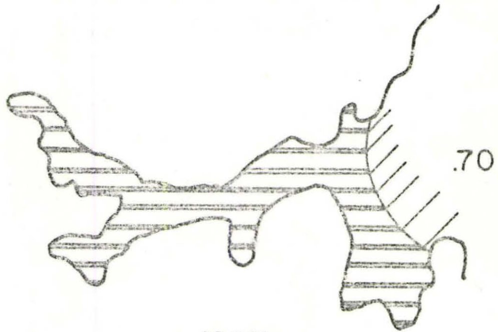


1965

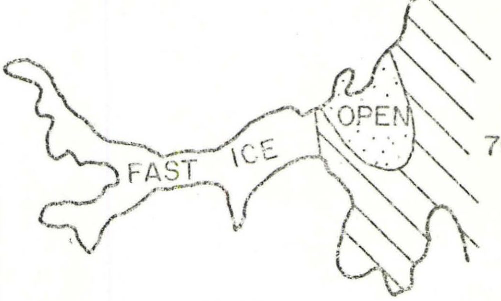
OPEN THROUGHOUT BY AUG. 20



1966

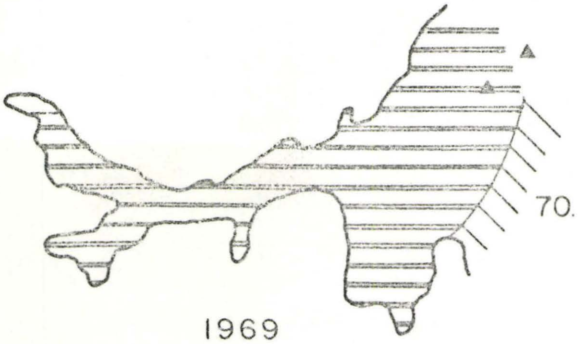


1967

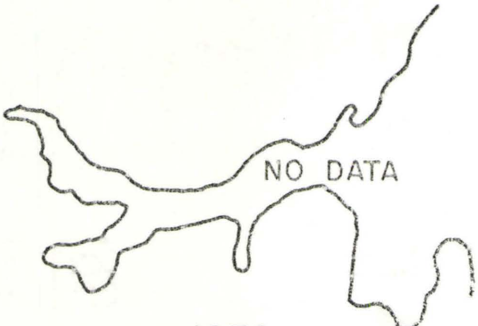


1968

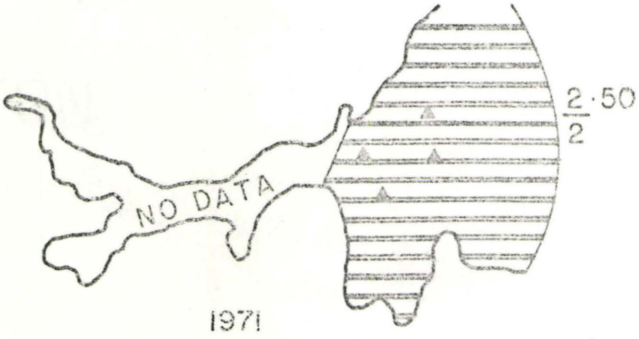
OPEN WATER BY AUG. 27
(within inlet only)



1969



1970



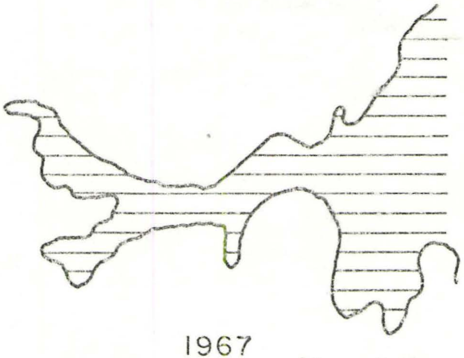
1971
(Only one reading)

1972

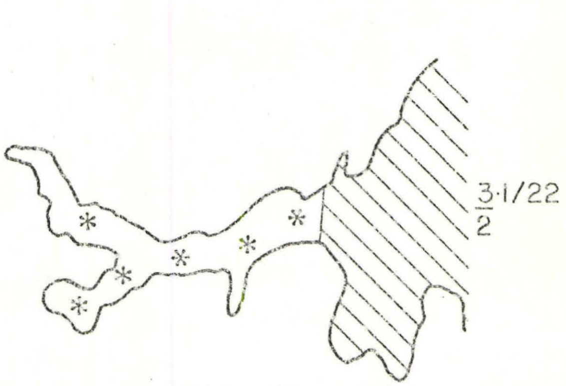
1965

(Open until Sept. 24)

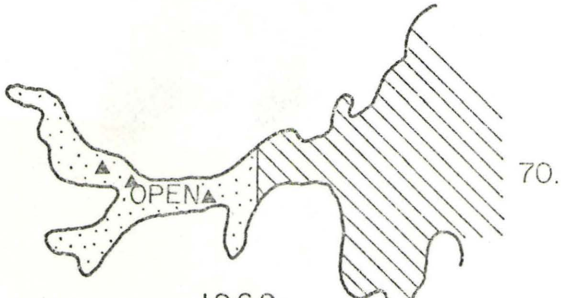
1966 (Sept. 24)



1967 (Sept. 24)

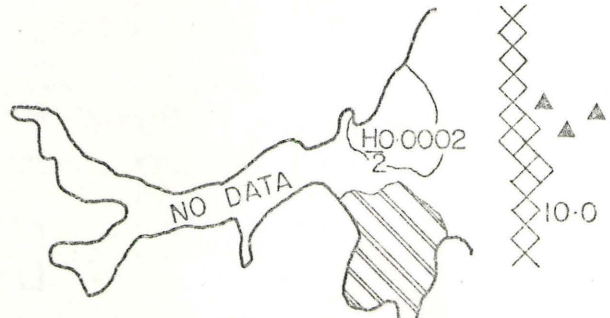


1968 (Sept. 24)

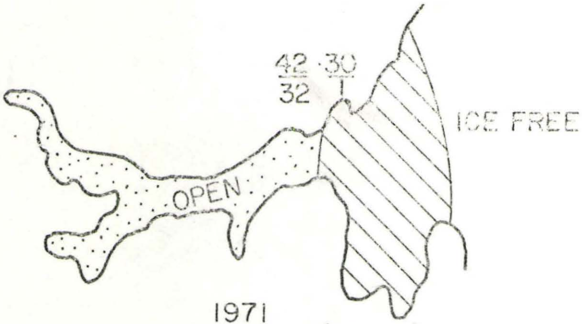


1969

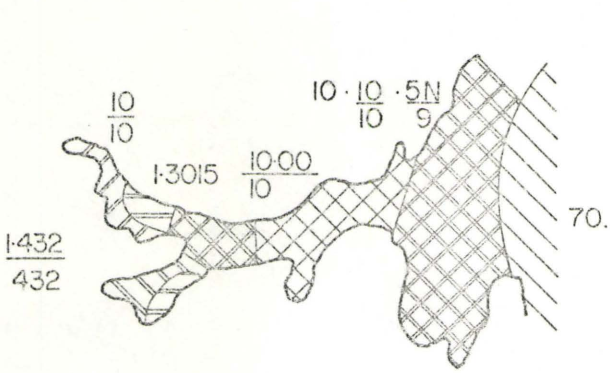
(Open until Sept. 24)



1970 (from PCSP)



1971 (Sept. 5)

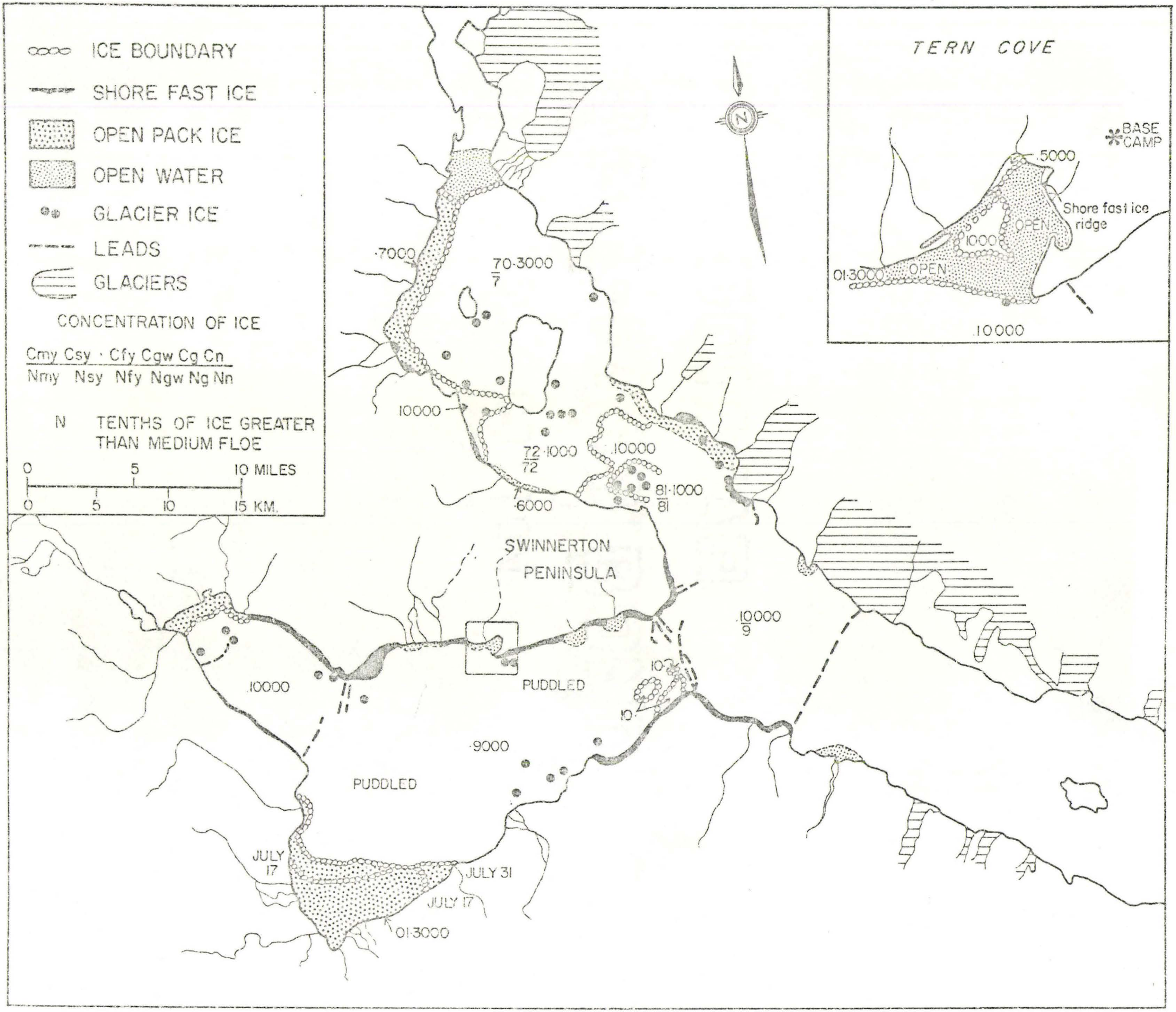


1972 (Sept. 20)

TABLE 3.2

LENGTH OF OPEN WATER SEASON

Year	Break-Up	Freeze-Up	No. of days
1965	Smith Bay = July 30	Smith Bay = Sept 24	25
	Makinson = Aug 20	Makinson = Oct 8	49
1966	Smith Bay = Aug 27	Smith Bay = Oct 8	42
	Makinson = Sept 24	Makinson = Oct 22	28
1967	Smith Bay = Aug 13	Sept 24 - Oct 8	48
	Makinson = Aug 20		41
1968	Smith Bay = Aug 20	Smith Bay = Aug 30	10
	Makinson = Aug 27	Makinson = Sept 24	28
1969	Smith Bay = Aug 27	Smith Bay Makinson = Sept 24	28
	Makinson = Sept 10		14
1970	Insufficient Data		
1971	Smith Bay - Aug 11	Insufficient Data	20
	Makinson = July 25	Sept 1 - Hard to pass through Smith Bay	--
1972	Break-Up Not Sufficient for Navigation		


ICE BOUNDARY
SHORE FAST ICE
OPEN PACK ICE
OPEN WATER
GLACIER ICE
LEADS
GLACIERS
CONCENTRATION OF ICE
Cmy Csy · Cfy Cgw Cg Cn
Nmy Nsy Nfy Ngw Ng Nn
N TENTHS OF ICE GREATER THAN MEDIUM FLOE
0 5 10 MILES
0 5 10 15 KM.
N
TERN COVE
BASE CAMP
.5000
Shore fast ice ridge
OPEN
1000
01·3000
OPEN
.10000
·7000
70·3000
7
10000
72·1000
72
.10000
81·1000
81
·6000
SWINNERTON PENINSULA
.10000
9
.10000
PUDDLED
10
10
·9000
PUDDLED
JULY 17
JULY 31
JULY 17
01·3000

Inlet remains blocked by solid fast ice until at least the end of July. The observable trend has been for Smith Bay to be open by August 20th and frozen over, or sealed off by pack ice, by September 24th. Arctic pack ice usually enters Smith Bay from Smith Sound-Kane Basin by mid-September, and in many cases has built a narrow but strong barrier across the entrance.

Inner Makinson Inlet, i.e. the northwest and southwest arms, is usually open, or partially open, by the end of July. The areas of open water, as observed in 1972, tend to occur near the mouths of streams (several) or near headlands or large tidewater glaciers (Figure 3.11). The normal open water season lasts from August 20th to late September, which results in an average open water period of 32 days. On many occasions, an accumulation of multi-year ice and glacial ice has occurred at the mouth of the entrance channel to the inlet. When a comparison of the ice conditions observed in July of 1972 was made with those of July, 1959, several similarities were noticed. The areas of glacial ice grounding, the width and configuration of beach fast ice, and areas of open water were formed in almost the same locations. Therefore, breakup may well follow a similar sequence each year, but with different timing.

3.5 BEACH AND NEARSHORE CHARACTERISTICS

BEACH PROFILES

A set of seven beach profiles, three on the south shore and four on the north, was surveyed along the shoreline of Swinnerton Peninsula. The profile sites were selected to represent the various beach conditions found in the area. Profiles A and F (Figures 3.12, 3.13) are typical of shorelines crossed by many small stream channels; both contain a tidal lagoon backed by low beach or dune ridges, and show low flat relief. The barrier beach ridges damming the main lagoons have been created by normal processes of longshore transport of beach material, and are usually reached by small inlets opposite the main stream channels. Former lagoons further inland have been infilled by alluvium which dries out in summer. Profiles B and C are located on the north and east shores of 'Tern Cove'; the former is characterized by a series of small ridges created by wave action due to refraction, and the latter has a steep, narrow, active beach zone and a narrow tidal lagoon. Profiles D and G are representative of the beaches near or beneath the plateau slopes; both are characterized by a narrow, active beach zone, backed by raised beach terraces. Profile E is representative of the wide, relatively flat shore at the northern end of 'Black Band Valley'. A feature, common to most profiles, is the steep slope section which occurs just above mean high tide level. This is, in part, a product of the coarse size of the beach material which is largely gravel, and represents a wave swash gradient steepened by the combing down of sediment by wave action (McCann and Owens 1970). Ice cored bars or ridges occur on some profiles in the intertidal zone.

The south shore profiles, A, B and C, show something of the nearshore bottom slope, which is very shallow at these locations. At Site A, depths of only 2 metres were recorded 75 metres from shore; at Site B, depths of 1 metre and 1.6 metres were recorded 20 and 25 metres from shore, respectively. Both were surveyed as the tide

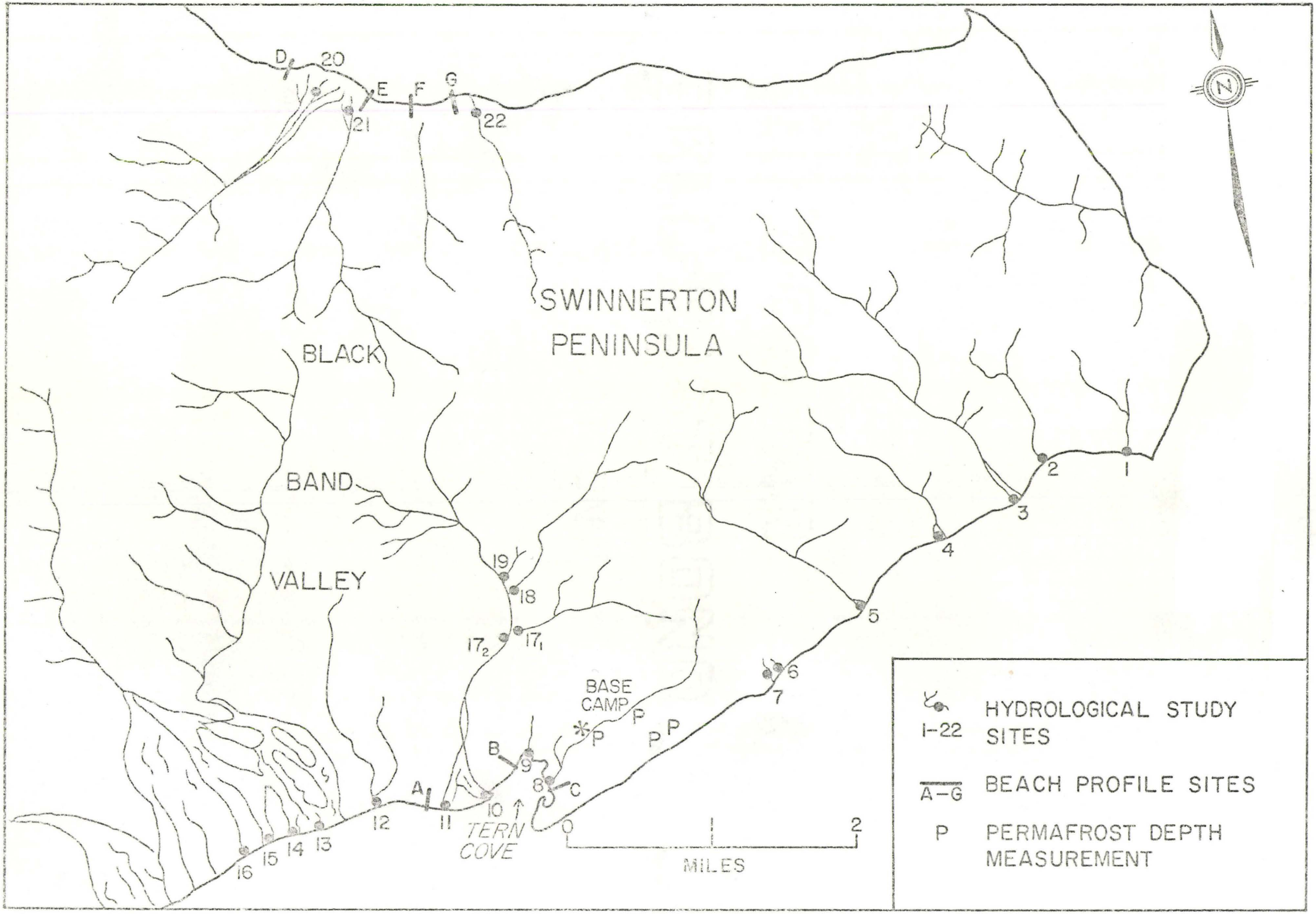
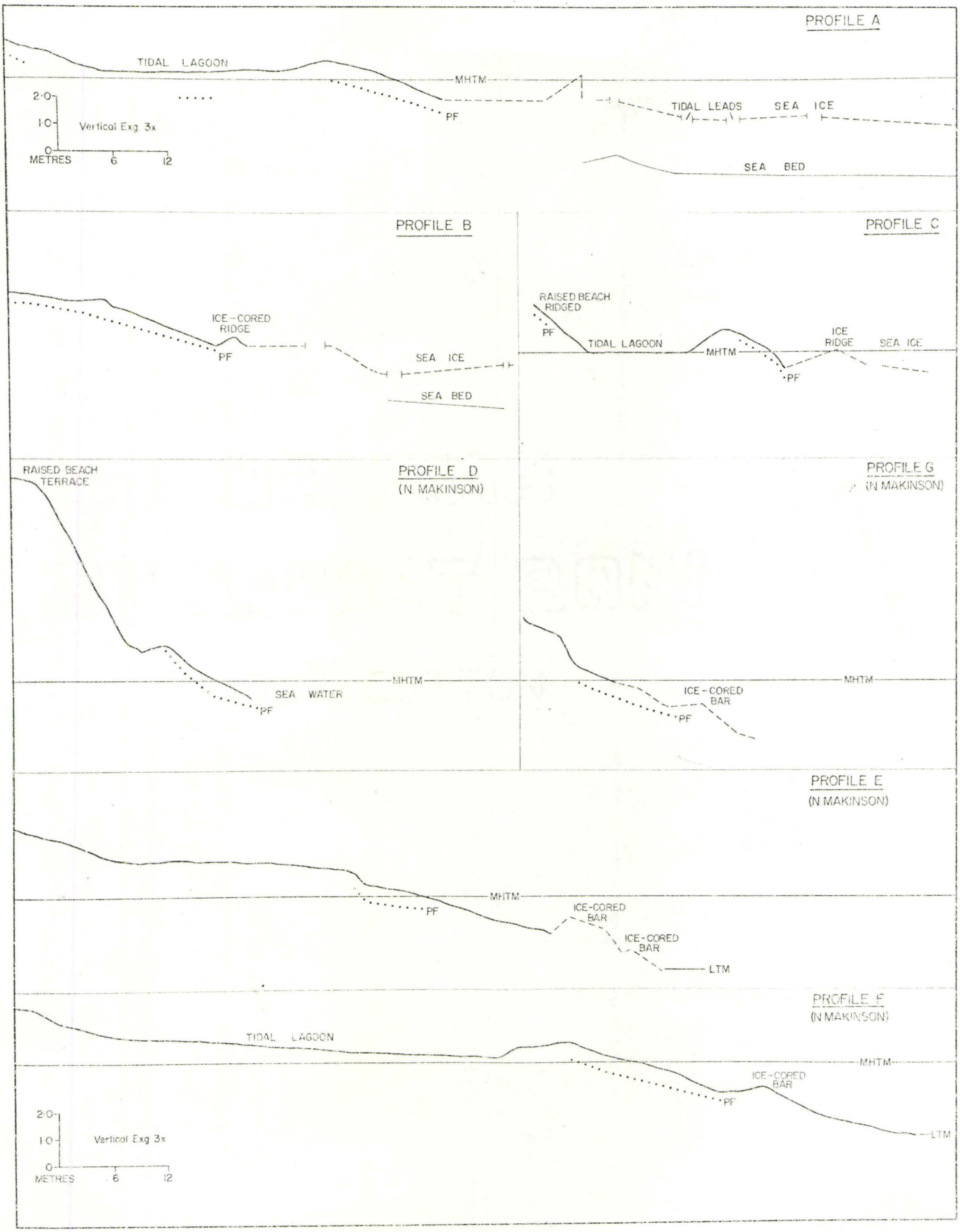

SWINNERTON PENINSULA
BLACK BAND VALLEY
BASE CAMP
TERN COVE
D
E
F
G
A
B
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17_1
17_2
18
19
20
21
22
P
N
0
2
MILES
HYDROLOGICAL STUDY SITES
1-22
A-G
BEACH PROFILE SITES
P
PERMAFROST DEPTH MEASUREMENT

FIGURE 3·12


PROFILE A
TIDAL LAGOON
MHTM
PF
TIDAL LEADS
SEA ICE
SEA BED
2·0
1·0
0
Vertical Exg. 3x
METRES
6
12
PROFILE B
ICE-CORED RIDGE
PF
SEA ICE
SEA BED
PROFILE C
RAISED BEACH RIDGED
PF
TIDAL LAGOON
MHTM
PF
ICE RIDGE
SEA ICE
PROFILE D
(N. MAKINSON)
RAISED BEACH TERRACE
MHTM
SEA WATER
PF
PROFILE G
(N MAKINSON)
MHTM
ICE-CORED BAR
PF
PROFILE E
(N MAKINSON)
MHTM
PF
ICE-CORED BAR
ICE-CORED BAR
LTM
PROFILE F
(N MAKINSON)
TIDAL LAGOON
MHTM
ICE-CORED BAR
PF
LTM
2·0
1·0
0
Vertical Exg. 3x
METRES
6
12

approached its low. Greatest overall slopes within the beach intertidal zone exist at sites C (20%), D (23%) and G (22%); smallest overall slopes occur at sites B (7%) and F (12%).

BEACH SEDIMENTS

Composite samples of beach material were collected at selected points along the beach profiles, at sites A,B,C and E, normally at the first raised beach ridge, at HHWM and at MHWM. Additional samples were taken of the material on top of the nearshore ice at sites A and B. The material was sieved, the various sieve fractions weighed, and the size distribution investigated, using standard moment measures. In addition, the a, b and c axes and the least radius of curvature r, of 25 pebbles, between 4 and 64 millimetres, were measured. The purpose was to analyse the shape, roundness and sphericity of the beach sediments. The method of measurement and formulae used in the determination of the shape indices are given in Appendix C.

(1) Grain Size Analysis: In general, the beach zone along the south shore of Swinnerton Peninsula is composed of poor to moderately sorted gravel. There is no apparent regular variation in sediment size along the shore which was profiled, but further east, toward the end of Swinnerton Peninsula, the beaches are built of fine gravels to very coarse material of cobble size (base of the stack). A pronounced across-beach sorting of different kinds occurs at profiles A and B. At A, the sediment becomes finer with distance seaward, while at B, it becomes coarser seawards. Site A is more exposed and likely to receive greater wave action, therefore this pattern is readily explained. Sand

size material makes up only a small proportion of the beach samples proper, but increases to 12 and 50% in the material collected on the surface of the ice, which fact substantiates the view that this material has been carried out by the streams during the spring flood period. The sediment on the floor of 'Tern Cove' (not sieved) was a compacted fine sandy silt. A majority of the sediment samples collected, especially those from the Eureka Formation, were positively skewed.

The range of sediment sizes along the north shore of the peninsula (Plate 16) is similar to that along the south shore, but there are no significant variations in sorting values or mean size values across the beach zone. This may indicate that the south shore is an area of greater wave action, i.e. more open water, longer fetches. Longshore movement of beach material occurs on both shores of the peninsula, but the main source of sediment in the wider beaches appears to be the input from rivers and streams during the flood stage.

(2) Shape Analysis: The principal measures of grain shape used in the analysis of the beach sediments were flatness and roundness ratios (Cailleux 1947, 1952) and sphericity and shape indices (Sneed and Folk 1958, Zingg 1935). An examination of the mean values of flatness, roundness and sphericity indicate several trends. The majority of beach sediments fell into the Zingg shape index of disc, except for profile C where a rod shape predominated. The Sneed and Folk shape index is more detailed; consequently, the results revealed sediment shapes ranging from bladed to very platy. Folk (1965) found that rivers tended to produce rod-like pebbles and beaches, disc-like pebbles; therefore, the presence of the rod shaped pebbles at profile C

can be explained by the proximity to the stream mouth. Sediment shape influences tractive movement in that round particles can roll but discs shuffle along, hence the large proportion of disc-like pebbles at Makinson indicate the latter mode of longshore transport (Bluck 1967).

Flatness ratios were slightly higher (303.2) on the southern side of Swinnerton Peninsula than on the northern shore (292.3); however, no conclusions can be drawn because only one profile was sampled on the north side. The mean flatness value for all sediment sampled was 299.2. The small number of sediment samples examined from along the shore prevented the detection of any trends in either direction, but the mean flatness ratios calculated for samples taken from across the beach indicated an expected trend. It was observed that the pebbles increased in flatness upslope from MHWM (253.4) to the raised beach ridge where the highest values (374.1) were recorded.

Opposite trends were found across the beach when sphericity and roundness parameters were calculated. The greatest sphericity values and roundness ratios (214.5) were discovered at MHWM, and progressively decreased upslope to the non-active beach. The higher values at MHWM are believed to be the result of the greater amount of wave action to which those pebbles are subjected.

Little difference in sphericity or roundness were observed between the northern and southern shores of Swinnerton Peninsula. The similarity in sediment characteristics on the two shores indicates that there is probably little difference in the wave regime or length of open water season between the two branches of Makinson Inlet. The mean roundness ratio and sphericity value, for all of the sediment sampled, was 185.3 and 0.561 respectively.

These results only represent a small portion of the coast, and before beach sediment characteristics in Makinson Inlet can be generalized, a considerably greater number of samples will be needed.

FROST TABLE DEPTHS

Measurements were made along profiles A,B and C , on July 20th, and along profiles D to G on July 27th (Table 3.3). The greatest depth to the frost table was usually found at high high water mark, and values decreased both landward and seaward of that point. The mean depth at all sites was 50.1 cm. On the first raised beach ridge, depths ranged from 34 to 45 cm, and at the seaward end of the profiles, from 15 to 46 cm. Aspect and sediment size appear to play only a minor role in determining the thickness of the active layer, though the greatest thicknesses were recorded at site A, which is south facing. Spot measurements through the silts and sands of the tidal lagoons gave active layer thicknesses of 90 cm or greater (Figure 3.13).

BEACH AND NEARSHORE ICE CONDITIONS

A variety of ice conditions was found within the nearshore of Makinson Inlet in 1972. The most common condition is that which occurred along the southern shore of Swinnerton Peninsula, excluding 'Tern Cove', where an ice foot of varying width with a maximum thickness of 2.5 m at low water mark, occurred (Plate 19). Since the ice foot is not disrupted by tidal fluctuations, it had only been appreciably altered by mid-July at the main stream outlets.

TABLE 3.3

DEPTH OF ACTIVE LAYER AT BEACH SITES, SWINNERTON PENINSULA

Beach Profile	Raised Beach Ridge	Top of Active Beach	HHWM	MHWM	Edge of ice or water	Mean Depth	Mean Grain Size (ø)	Aspect
A	45.0	70.0	67.0	--	46.0	57.0	-3.29	S
B	--	31.0	45.0	38.0	15.0	32.2	-3.52	SE
C	34.0	--	26.0	27.0	30.0	29.2	-3.27	W
D	--	25.0	46.0	52.0	23.0	36.5	-3.00	N
E	--	46.0	56.0	57.0	19.0	44.5	-3.63	N
F	--	60.0	61.0	55.0	23.0	49.7	-2.50	N
G	--	--	50.0	56.0	30.0	45.3	-3.10	NW
Mean Depth	39.5	46.4	50.1	47.5	26.6	--	--	-

Depths are in centimetres

The fracture zone, which exists further offshore, varied in width from 60 to 120 m, and contained from four to six major tidal cracks or leads. With a tidal range of 1.9 to 2.5 m, the fracture zone is well defined. The destruction of the ice proceeded rapidly within the fracture zone, as meltwater drained into the tidal cracks, which widened into leads; the ice separating the widening tidal leads broke into smaller pieces which eventually melted, leaving a band of open water. Circular pressure ridges of old ice were observed at many places, particularly between the fracture zone and the offshore sea ice. Cracks and leads were created, like spokes of a wheel, around these ridges, which became further centres of early ice destruction.

At a few locations around Swinnerton Peninsula, 'Tern Cove' and the north shore of 'Black Band Valley', a fringe of open water already existed by mid-July, and only a narrow strip of beach fast ice remained. The reason for the early melting of the nearshore ice at these locations was the discharge of numerous nearby streams. The fluvial debris, if not deposited too thickly on the ice, had accelerated surface ablation, and the large inputs of freshwater had melted the ice in situ. The beach fast ice remaining in these areas consisted of a series of ice-cored ridges located just above or below mean high tide level (Plate 24). The ridges were formed of ice attached to the beach slope, and were covered by beach gravels or fluvial debris, 20 cm or more thick. These ridges were probably formed by the build up of ice during the previous fall freezeup, and may well exist for more than one season, especially if little wave action occurs. Pieces of ice up to 30 m in diameter become grounded on the ridges, and produce an irregular barrier between the beach and the offshore zone (Plate 26). The ice cored gravel ridge protects the shore from wave action and ice push. In some cases, the grounding of ice floes, i.e. near the ridges, altered the lower beach face slope and moved very coarse sediment upslope.

EFFECT OF STREAMS ON NEARSHORE ICE

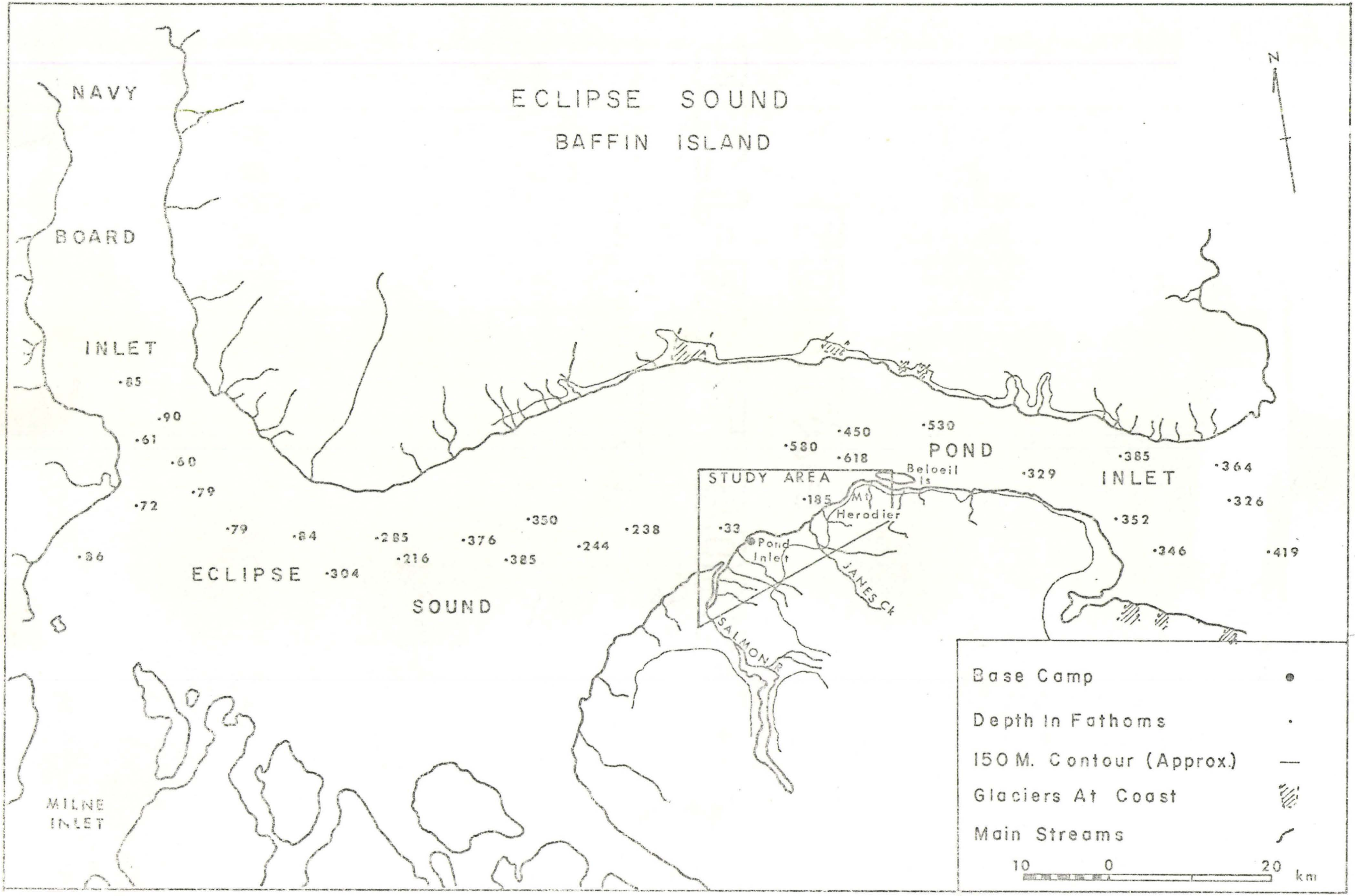
During the spring melt period, streams have a considerable effect on the melting of nearshore ice. At this time, flood-waters discharge across the surface of the ice, resulting in the removal of snow cover and in the expansion of the tidal leads. The streams entering the sea from the plateau area at the western end of Swinnerton Peninsula had small drainage basins, were very cold and carried very little suspended sediment; their effect was minimal (Figure 3.12). The streams entering the sea from 'Black Band Valley', on the other hand, appeared to have larger discharges and carried large amounts of both bed load and suspended sediment onto the nearshore ice. Even at the end of July, when discharges were very low, suspended sediment was still being deposited on sea ice. When piled in ridges on the ice, the sediment tends to protect it from melting, but more usually it was deposited as a thin layer and hastened the melting process. Each of the river mouths acted as a focal point for break up, and by the end of July, the isolated sections of open water joined to form a wide shore lead. The warmer waters of the latter streams also enhanced the break-up and melting process. Similar effects were observed at the northern end of 'Black Band Valley'.

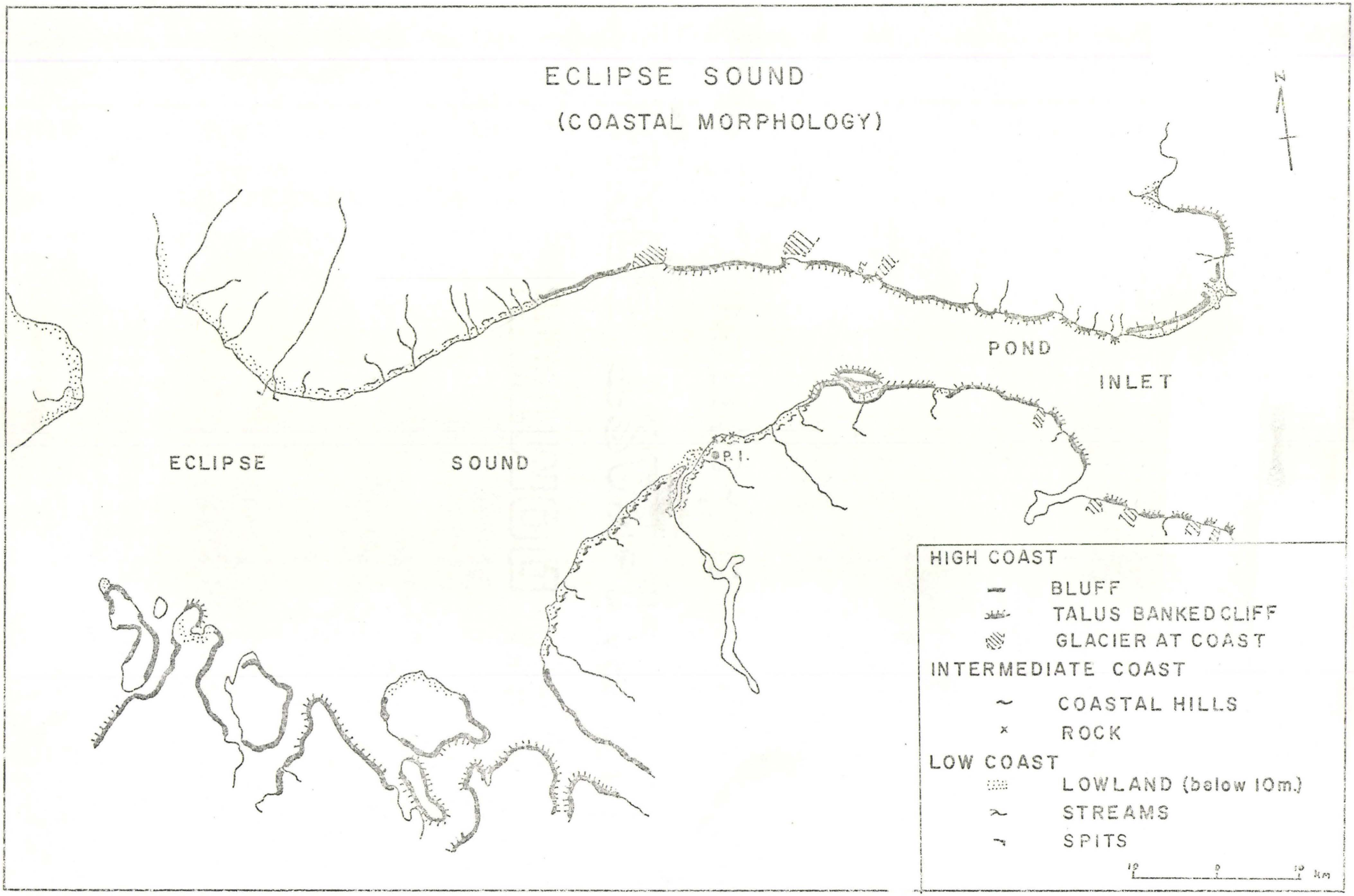
POND INLET - ECLIPSE SOUND, BAFFIN ISLAND

3.6 COASTAL MORPHOLOGY AND BATHYMETRY

Pond Inlet is the easternmost of the three inlets which extend from Baffin Bay to Lancaster Sound, separating Bylot Island from Baffin Island. The inlet, entered from the east between Cape Weld and Cape Graham Moore, is a deep and narrow fiord which widens into Eclipse Sound approximately 75 km from Baffin Bay. The depths charted within Pond Inlet vary from over 300 fathoms at the eastern entrance, to over 500 fathoms at its narrowest sector near Beloeil Island (Hydrographic chart 7055, 1969). Much shallower depths of less than 200 fathoms are recorded within Eclipse Sound which is also considerably wider than Pond Inlet (Figure 3.14).

The coastal morphology of Pond Inlet is similar to that of many other east coast fiords. The inlet is bordered by very high, steep mountains and there are several large glacial valleys containing glaciers which reach, or nearly reach, the sea (Figure 3.15). At the entrance to Pond Inlet, heights of 1,585 m are recorded within a few miles of the coast, while heights of 800 m are not uncommon at the shoreline. This straight steep coast continues along the north shore of Eclipse Sound, but on the south shore is replaced by a much lower (60-65 m) gravel plain. Here, the coast takes the form of a low cliff or bluff of unconsolidated deposits, fringed by a narrow gravel


ECLIPSE SOUND
BAFFIN ISLAND
N
NAVY
BOARD
INLET
·85
·90
·61
·60
·79
·72
·79
·86
·84
·285
·216
·376
·350
·385
·244
·238
·304
ECLIPSE
SOUND
·580
·450
·618
·530
POND
INLET
STUDY AREA
Beloeil Is
·185
Mt Herodier
·33
Pond Inlet
JANES Ck
SALMON R
·329
·385
·364
·326
·352
·346
·419
MILNE INLET
Base Camp ●
Depth In Fathoms ·
150 M. Contour (Approx.)
Glaciers At Coast
Main Streams
10
0
20
km



ECLIPSE SOUND

(COASTAL MORPHOLOGY)

foreshore. Long peninsulas of morainic material and boulders, together with the deltas of the larger rivers, e.g James River and Salmon River, give the south shore of Eclipse Sound an irregular configuration. The marine limit in the area is at 200 m on the highland adjacent to Mt. Herodier, and at least two marine terraces, 10 and 20 m A.S.L., have been recognized along the rock coast in the same vicinity (T. Mathiassen 1924).

A low coastal plain backed by low sandstone hills occurs on southwest Bylot Island. In addition, the large rivers which cross the area have provided the fine sand necessary for the formation of the many offshore spits and bars which may be observed. To the north, Navy Board Inlet is bordered at either end and on either side by a similar coastal plain; but near the middle of the inlet, the shores rise steeply from the sea to heights of up to 1,200 m.

The most detailed investigations of Pond Inlet-Eclipse Sound were carried out along the south shore between the Salmon River and Black Point, and a rapid reconnaissance was also completed of the coast between Black Point and Mt. Herodier. There are a series of bights, west of the settlement of Pond Inlet, which contain relatively wide, sandy beaches (Plate 14) backed by a series of low hills (70 m). At either end of the bights are low bluffs (Plate 13) composed of coarse gravel or boulder material. Shoals, boulders and offshore bars have been sighted in the shallow nearshore zone along this part of the coast. Just east of the settlement, and near Mt. Herodier, a relatively high rock coast exists. Considerable wave erosion has occurred at the joints near the base of the rock. The much larger bays and peninsulas found westward to Mt. Herodier contain a narrow beach, but gravel, rather than sand, is the prime constituent. The lowland along the south shore of Eclipse Sound is heavily covered by vegetation, such as hummocks of grasses and willows, which commonly break off as large masses of material when wave or thermal erosion occurs.

3.7 TIDAL CONDITIONS

The tidal range at the settlement of Pond Inlet is reported to be from 0.9 to 2.1 m, and at Tay Bay and on Bylot Island 1.7 m and 3 m, respectively (Arctic Pilot, Vol. 11, 1968). A tidal current of 2 knots has been recorded within Eclipse Sound. On a falling tide, the current flows to the east, while on a rising tide it flows to the west (Arctic Pilot, Vol. 11, 1968). Observations of the moving ice during the present study only indicated a current of approximately 1 knot per hour.

A brief investigation of the daily tidal oscillations was conducted from 12:30 E.S.T., September 3rd, to 17:30 E.S.T., September 4th, using a staff (marked in metres) anchored just offshore of the RCMP office (Figure 3.16). Since a complete tidal curve was not obtained, a detailed analysis and comparison with a reference port was not carried out. It appears that a semi-diurnal tide occurs, with a mean range approximating 0.75 m, a height which is considerably smaller than that reported in the Arctic Pilot. The shallow curve is the result of neap tide conditions, because September 3rd was just after the last quarter (moon).

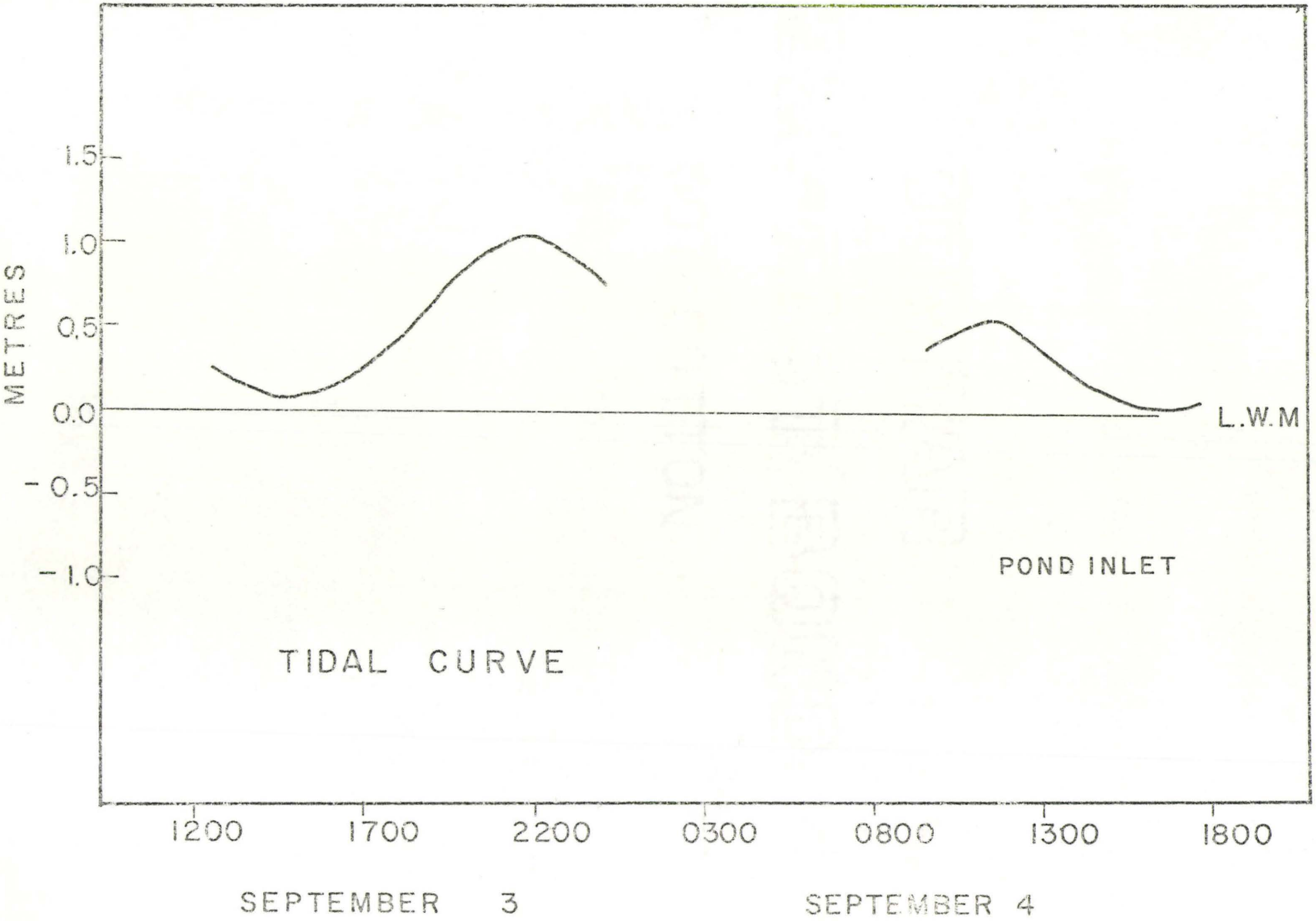

1.5
1.0
0.5
0.0
- 0.5
- 1.0
METRES
L.W.M
POND INLET
TIDAL CURVE
1200
1700
2200
0300
0800
1300
1800
SEPTEMBER 3
SEPTEMBER 4

FIGURE 3.16

3.8 SEA ICE CONDITIONS

Information on sea ice conditions in Pond Inlet-Eclipse Sound has been derived solely from the ice observations of the Ice Division of the Atmospheric Environment Service. The sea ice cover, from 1965-72, is summarized in figures 3.17, 3.18 and 3.19, for the months of July, August and October. Unless otherwise stated, the diagrams represent the last week of July, the second week of August, and the first week of October. September ice conditions were not included because the waterways were always ice free during that month, except in 1972.

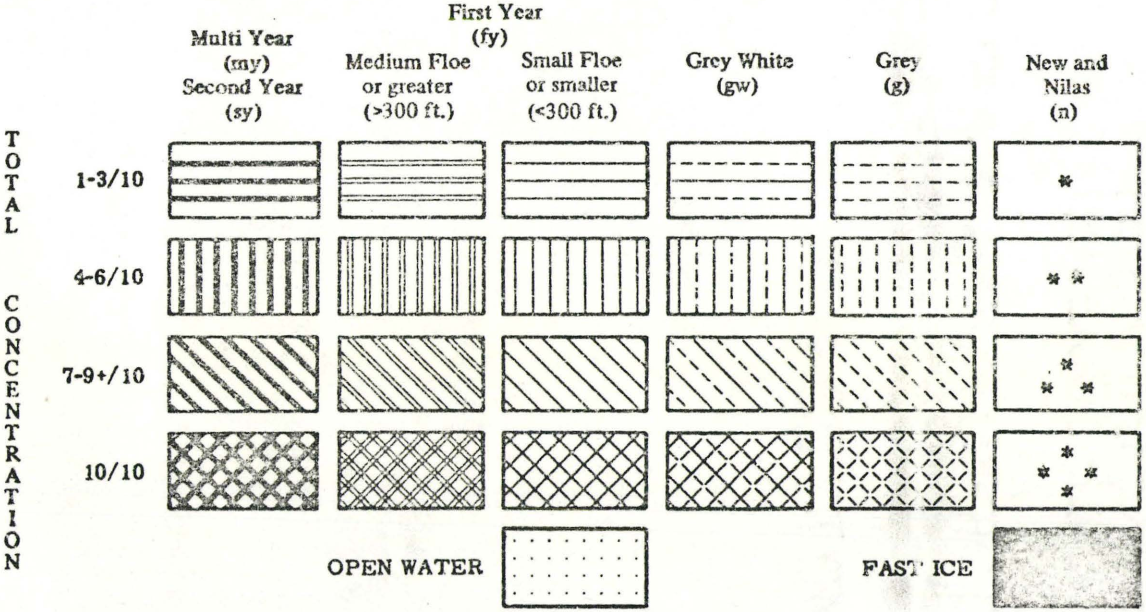
1965 to 1972

In early July, the sea ice consists of 10/10 cover of arctic pack or thick winter ice. By the end of July, the snow has been removed from the sea ice, substantial leads and cracks have been created radiating out from the glaciers and headlands, and some open water areas are observable. In most years, open water occurs at the northern entrance of Navy Board Inlet and at the eastern entrance of Pond Inlet by early August. This open water is an extension of the "North Water" which, by this time, has reached Bylot Island and extended into Lancaster Sound. Two other areas of early sea ice melting are the small inlets, i.e. Milne Inlet, south of Eclipse Sound and the southern entrance of Navy Board Inlet where a large glacial fed river reaches the coast. The last of the sea ice begins to move out of Eclipse Sound, under favourable winds, by mid-August, and ice free conditions then persist until early October. During the ice free period and under appropriate conditions, icebergs

ATMOSPHERIC ENVIRONMENT SERVICE

KEY TO ICE SYMBOLS

PREDOMINANT AGE



CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or Greater}}$$

$$\frac{C_{my}}{N_{my}}\frac{C_{sy}}{N_{sy}}\cdot\frac{C_{fy}}{N_{fy}}\frac{C_{gw}}{N_{gw}}\frac{C_g}{N_g}\frac{C_n}{N_n}$$

Example $\frac{2}{1}0.\frac{3}{2}\frac{4}{3}10$

$\frac{2}{1}$ – 2/10's Multi Year of which 1/10 is Medium Floe or greater

0 – No Second Year

. – Decimal Point

$\frac{3}{2}$ – 3/10's First Year of which 2/10 is Medium Floe or greater

$\frac{4}{3}$ – 4/10's Grey White of which 3/10's is Medium Floe or greater

1 – 1/10 Grey, no Medium Floe or greater

0 – No New

SNOW COVER

$\frac{Sn}{(n)}$

(n) tenths on ice

TOPOGRAPHY

$\frac{ΛΛ}{(n)}$ Rafted Ice

$\frac{ΛΛΛ}{(n)}$ Ridged Ice

SURFACE FEATURES

Sn/Ra Rd Hy Pd Th +F

$\frac{ΩΩ}{(n)}$ Hummocks

(n) number of tenths

STAGE OF MELTING

$$\frac{Pd}{(n)\ (n)\ Th + (n)\ F}$$

(n) = tenths on ice
(n)th = tenths thaw holes
(n)F = tenths frozen

"e.g. 6/1201"
6 – 6/10 Snow Cover
/ – Slant
1 – 1/10 Rafting
2 – 2/10 Ridging
0 – No Hummocks
1 – 1/10 Puddling

ICE OF LAND ORIGIN

△ – (n) Icebergs

⌂ – (n) Bergy Bits and growlers

Optional:
(n) – number in area

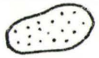
THICKNESS OF ICE AND SNOW

$\frac{T\ S}{n\ n}$ (n) – nearest inch

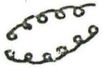
WATER FEATURES

+++++ Crack

═══ Lead


Polynya

UNDERCAST


Limits

BOUNDARY

——— Observed visually

—✕—✕—✕— Observed by radar

— — — Assumed

○○○ Limit of Observed data

○✕○✕○ Limit of radar data

Symbols used for Recording the Various Ice, Snow, and Water Features

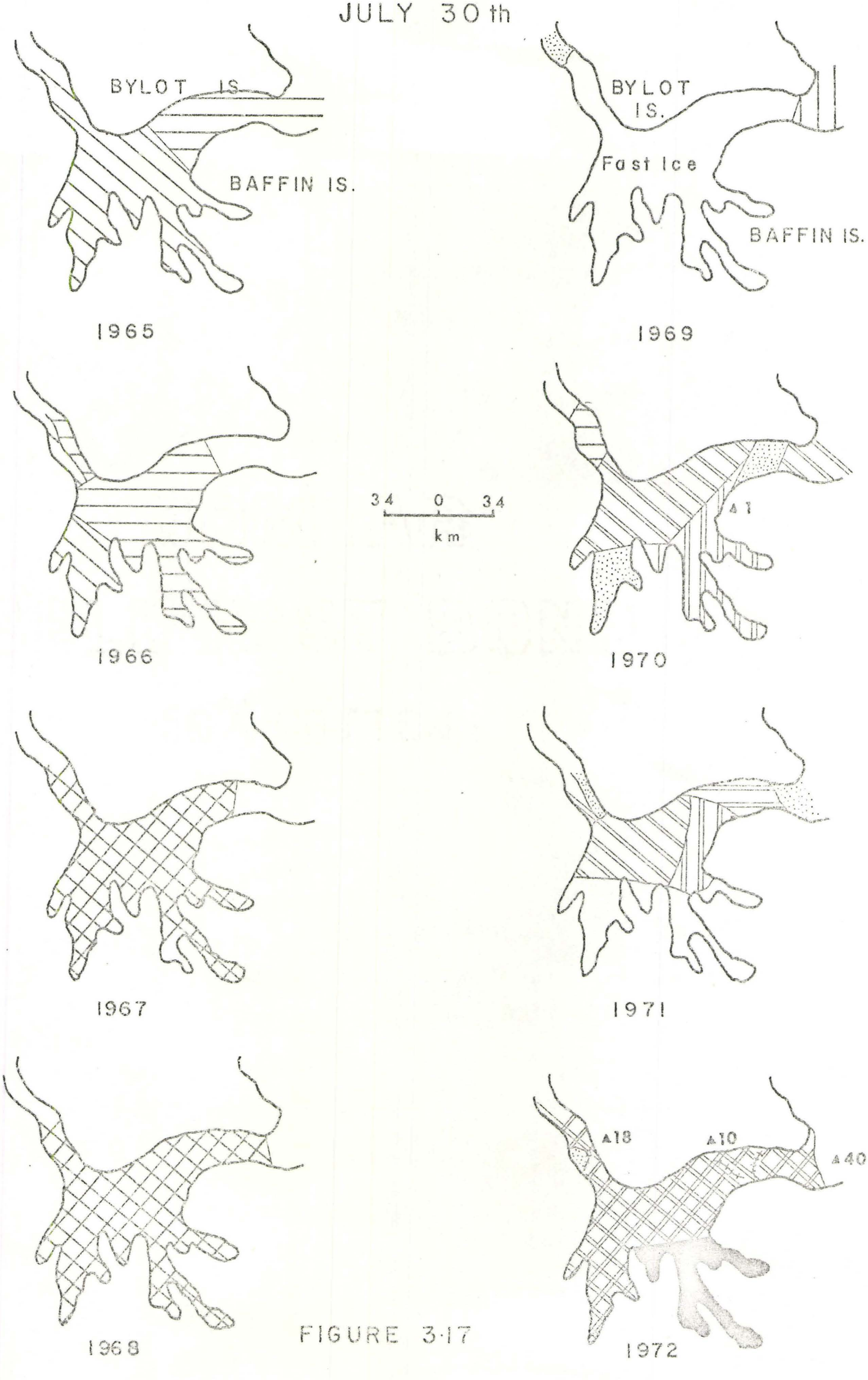

JULY 30th
BYLOT IS
BAFFIN IS.
1965
BYLOT IS.
Fast Ice
BAFFIN IS.
1969
1966
34 0 34
km
▲1
1970
1967
1971
1968
▲18
▲10
▲40
1972

FIGURE 3·17

AUGUST 13th

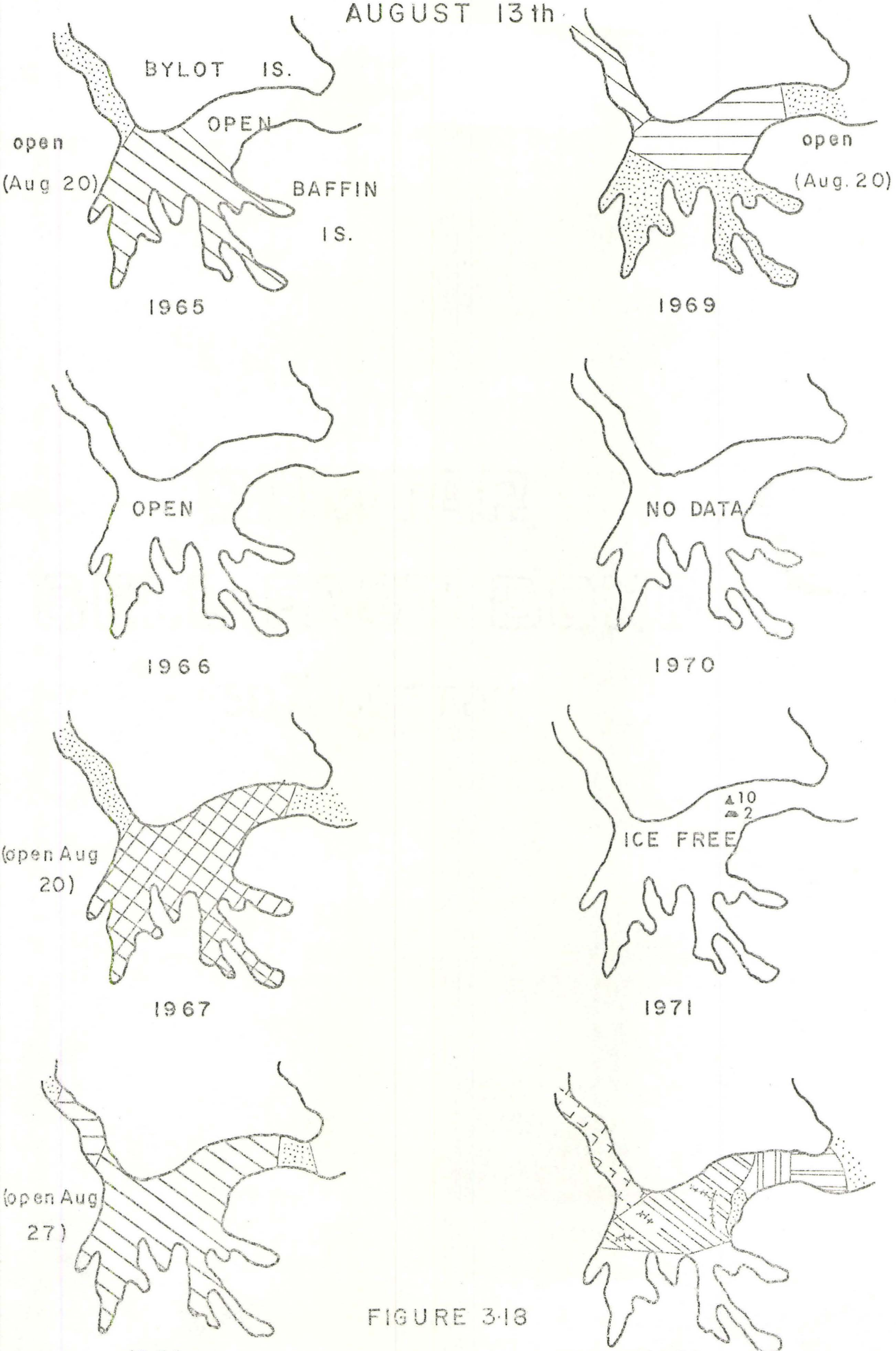


FIGURE 3·18

OCTOBER 8th

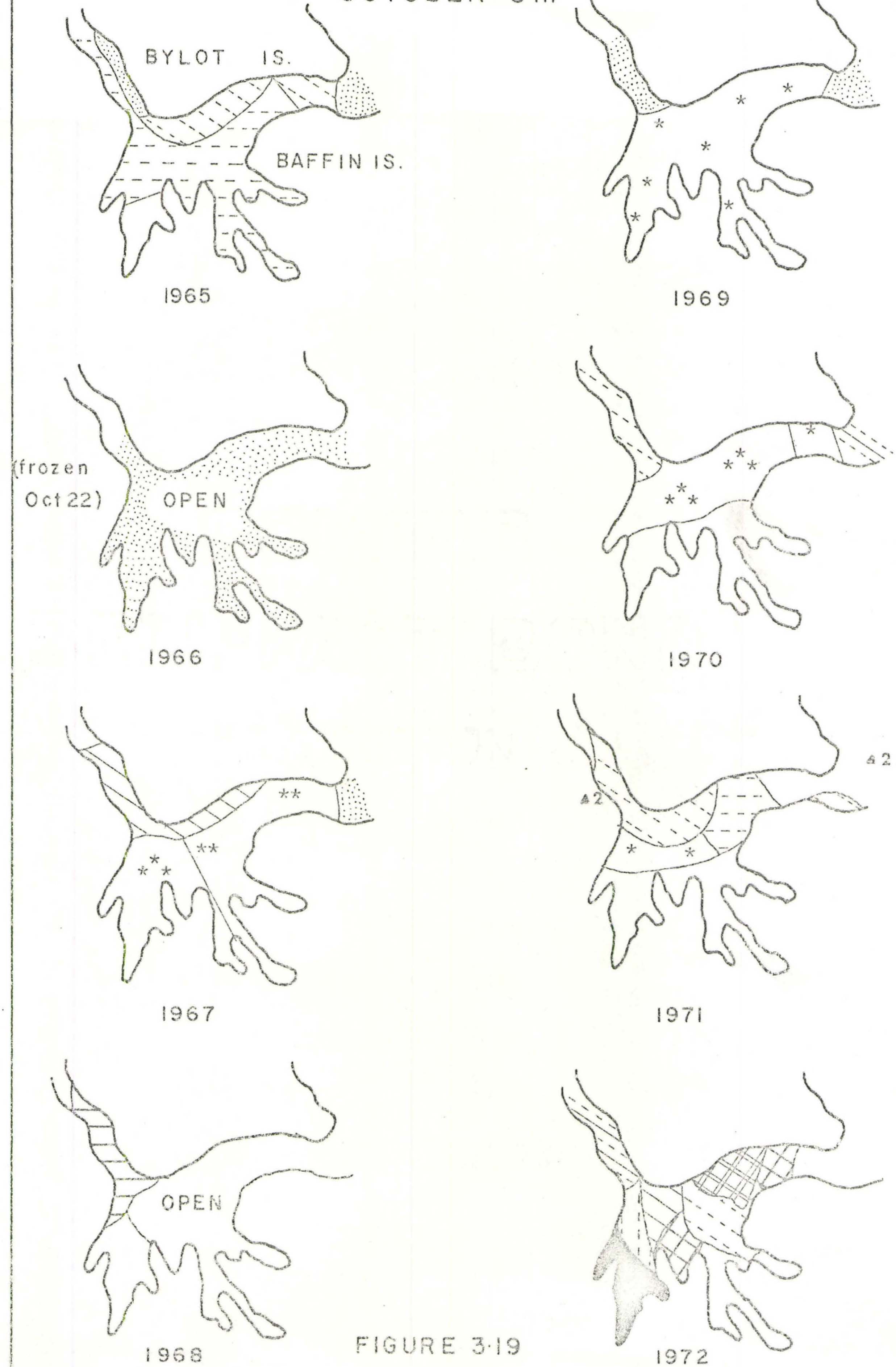


FIGURE 3·19

and bergybits, originating from Greenland or Ellesmere Island, enter Navy Board Inlet and drift south into Eclipse Sound and Pond Inlet. It appears that most of these icebergs become beset in Eclipse Sound during freeze-up and then are eroded and ablated during the following summer. In a typical year, 10 to 25 icebergs in Eclipse Sound-Pond Inlet are not uncommon. Freeze-up in early or late October progresses outward from the inlets south of Eclipse Sound, and ice is last to form at the eastern end of Pond Inlet.

Sea ice conditions in 1972 were reported by the natives of Pond Inlet to be the worst they could remember. Open water in early September was common along most of the shoreline, but the presence of grounded ice and an icefoot prevented effective wave action over a large part of that shoreline (Figure 3.20). The substantial sea ice cover, 7-9/10ths in Eclipse Sound, impeded wave development there; however, the open water conditions in Pond Inlet were more conducive to wave development. A study of the information on sea ice cover in Pond Inlet-Eclipse Sound, for the past eight years, indicates that the mean open water period is 60 days (Table 3.4). Complete open water and 7 - 9/10ths new ice were used as the limits of the open water season. Thus, Eclipse Sound-Pond Inlet would fall into the category of "Navigable" open water season in the classification devised in Chapter 2. The longest seasons were in 1971 (77 days) and 1966 (73 days), whereas the shortest periods of open water occurred in 1972 (29 days) and 1967 (56 days). As a general rule, a "poor ice year" usually follows an exceptionally "good year" because of the added quantities of old ice which are set free from the High Arctic. Another reason for "poor ice"

TABLE 3.4

LENGTH OF OPEN WATER SEASON
(Eclipse Sound - Pond Inlet)

Year	Break-Up	Freeze-Up	No. of Days
1965	Aug. 6	Oct. 8	63
1966	Aug. 6 - 13	Oct. 22	73
1967	Aug. 20	Oct. 15	56
1968	Aug. 27	After Oct. 22	56+
1969	Aug. 13 - 20	Oct. 22	62
1970	--	Oct. 15	--
1971	Aug. 6	Oct. 22	77
1972	Aug. 25 (not less than 3/10 cover)	Sept. 23	29

Mean Length = 60.1

SEA ICE CONDITIONS (AUGUST 31)

1972

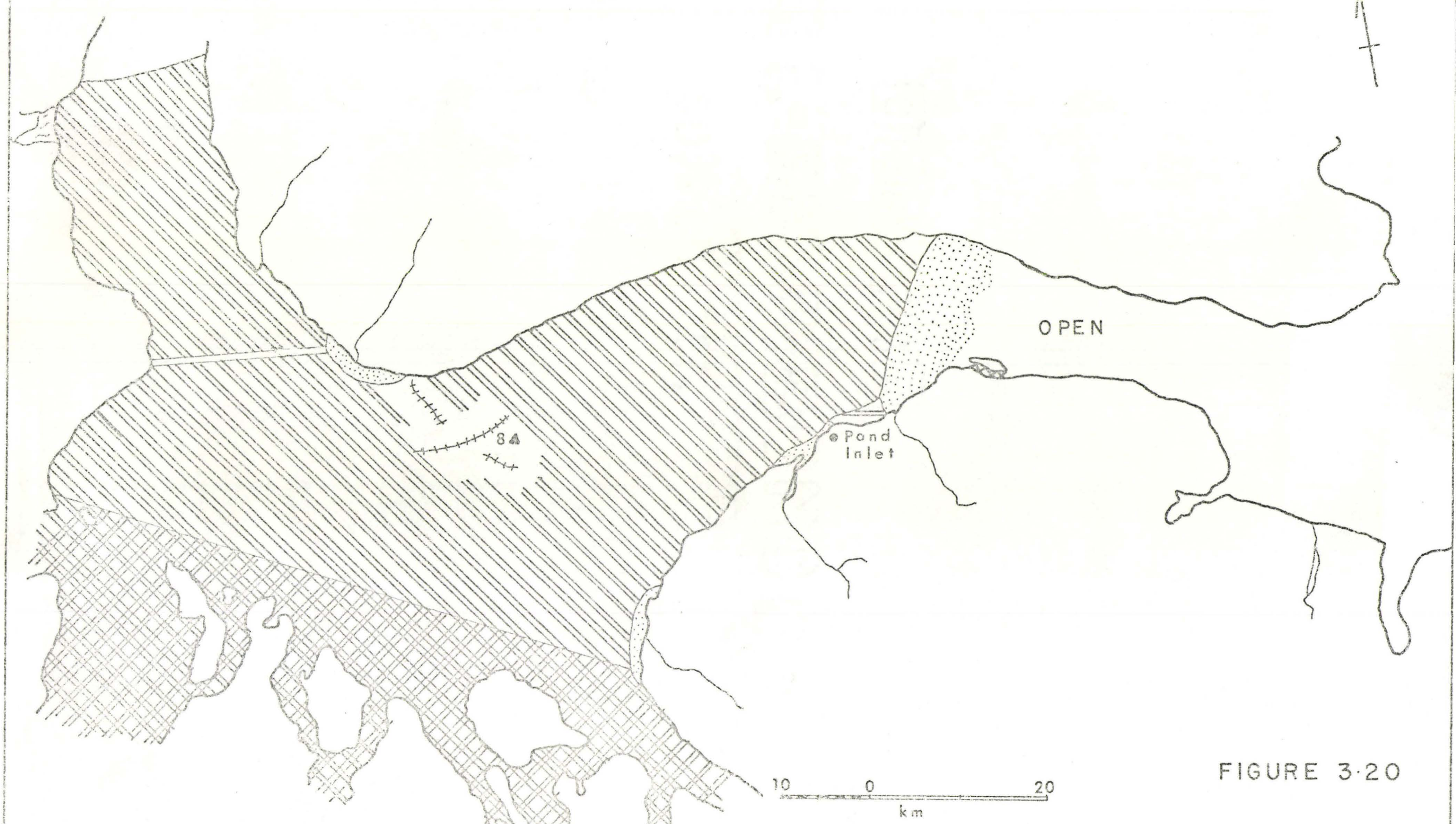


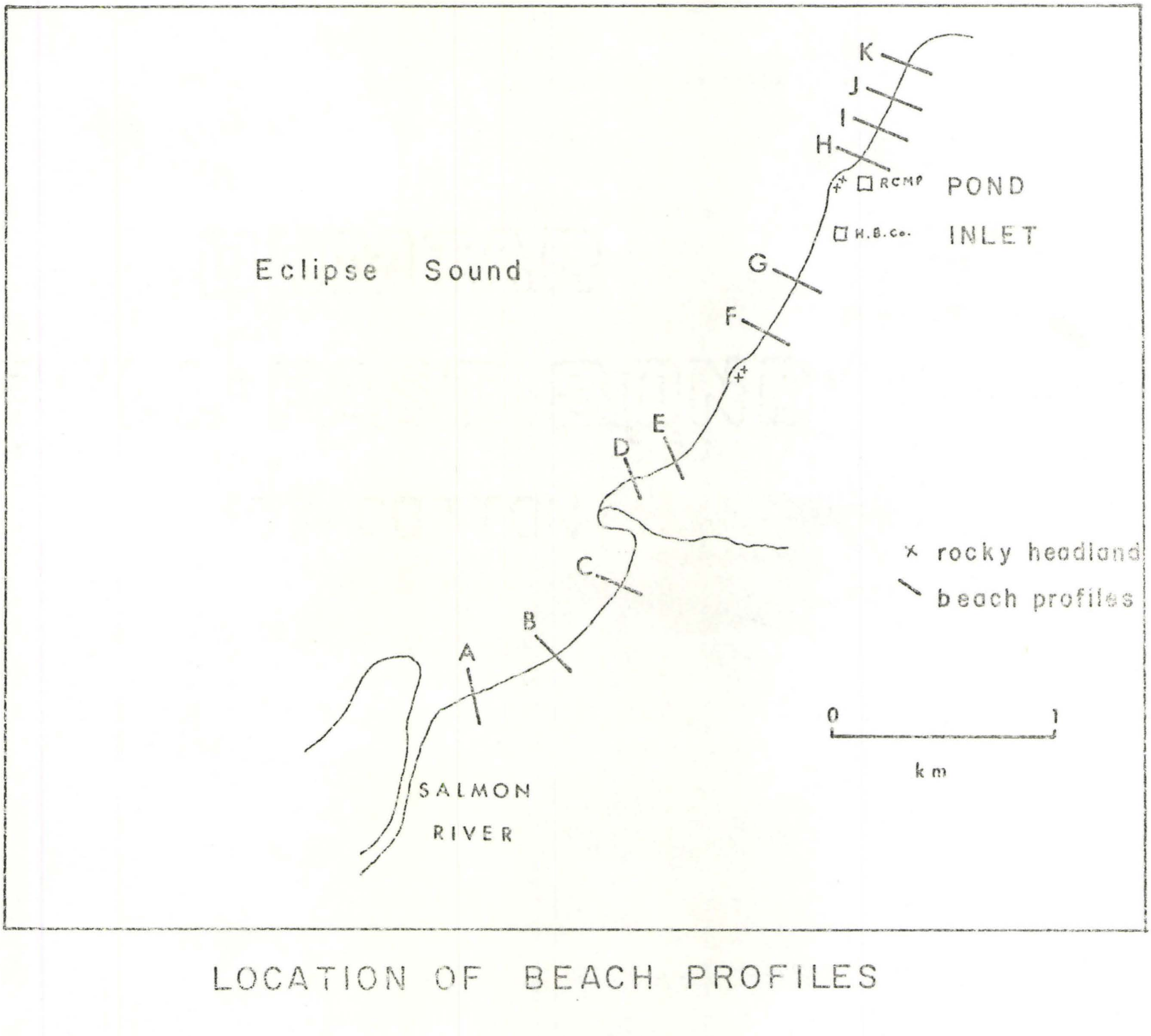
FIGURE 3·20

years is the lack of favourable winds. A combination of the two factors may have been the case at Pond Inlet in 1972 when an open water season, as such, was not experienced.

3.9 BEACH AND NEARSHORE CHARACTERISTICS

BEACH PROFILES

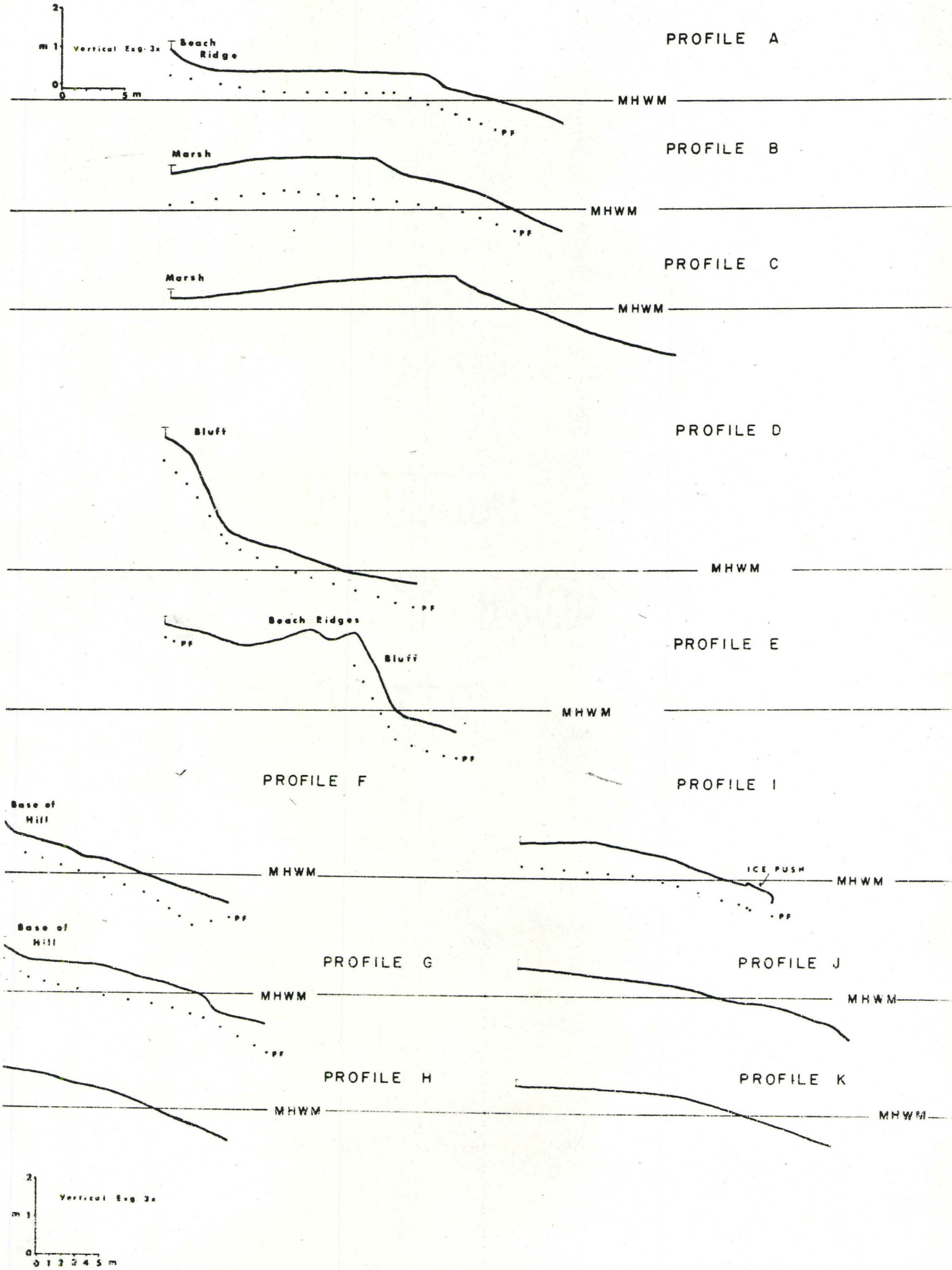
A set of eleven profiles were surveyed along the south shore of Pond Inlet-Eclipse Sound, from the Salmon River to the settlement of Pond Inlet (Figure 3.21). Bench marks (stakes or rocks) were generally placed at the back of the beach zone, either at the base of the series of hills lining the coast or at the edge of the lagoons. Each of the profiles represents the beach conditions in that particular area of the coast. Profiles A,B and C, which are located in the small bay east of the Salmon River, represent a wide, sandy beach environment with a lagoon and, in some cases, dunes further inland. Each of the profiles exhibits the break-in-slope at or near HHWM, which is characteristic of other arctic beach environments, e.g. Makinson Inlet. Profiles D and E represent the typical low, steep bluff topography found at the coastal promontories and further east toward Mt. Herodier. The bluff, which is usually 2.5 to 3.0 m high, is covered by a set of beach ridges or dunes which have been stabilized by vegetation cover. These are areas of rapid annual retreat by thermal and wave erosion; consequently, the base of the bluff is normally covered by masses of grass and soil which have fallen from above. The offshore zone is covered by coarse gravels and, in several locales, large boulders. Profiles F and G were surveyed immediately west of the settlement, while profiles H to K were located



LOCATION OF BEACH PROFILES

FIGURE 3·21a

BEACH PROFILES - ECLIPSE SOUND



in a small bay in front of the settlement. There is very little relief at any of these sites, and the gradient of the beach face slope is uniform, ranging from 9.7% at profile A and to 33.3% at profile E. The mean beach gradient was 15.2%. The low relief of the beach zone has permitted waves to cover most of the beach zone during storm activity, which has resulted in erosion in many places at the base of the hills and bluffs lining the coast. The plan of the coast, with its' many small inlets separated by rocky promontories, probably limits the longshore transport of sediment.

BEACH SEDIMENTS

(1) Grain Size and Shape Analysis: The nature and size of the beach sediments at HHWM and MHWM, at eight of the eleven profiles, were analysed by means of photographs taken at each of the sample sites. The method is satisfactory, but does not provide as much information as the sieving procedure used elsewhere. Mean grain size was calculated by measuring the three axial dimensions of twenty-five grains on each photograph. At the same time, the least radius of curvature and the inscribed and circumscribed circles of the maximum cross-sectional area of the same grains were measured. These measurements permitted the calculation of roundness (Cailleux 1947) and sphericity (Riley 1941) indices for each of the sand grains, using a computer program devised by the author.

The beach sediments varied from -1.5 to +1.0 ϕ and were primarily pebbles of shield rocks and quartz sand grains. The sediment, which was sampled over a distance of one to two km only, revealed few trends alongshore. Nevertheless, in nearly every case, the sediment at

MHWM was coarser and rounder than that found at HHWM. The mean sphericity values, on the other hand, were greater at MHWM (0.684) than at HHWM (0.665) but not by a large amount. Variations in grain size distribution alongshore indicated that the coarsest sediments occurred near the Salmon River (profiles A and B) and became finer toward the east, excluding profile D. Profile D is situated on a small headland fringed by a low vegetated bluff and containing a small stream outlet. The greatest sphericity values at HHWM were recorded at profiles A and D, but at MHWM they were found at profiles A and B. Roundness values revealed little information alongshore, except that the highest values at HHWM and MHWM were at profiles G and A, respectively. A measure of the degree of sediment sorting at each of the sample sites was limited to a visual impression; the results varied from poor near the Salmon River and at profile D, to well sorted at profiles F and G.

Conclusive statements cannot be made on wave regime or the source and mode of sediment transport, but field observations of the configuration of the coast and sediment analysis reveal some clues. The major sources of sediment are believed to be the large rivers, such as the Salmon River, and the wave and thermal erosion of the low bluffs which line parts of the coast. Evidence of this is the wide expanse of shoals and sand bars at the mouth of the Salmon River, and the masses of soil found at the base of the bluffs and on the nearby sea ice. In addition, the sediment analysis indicates a lag deposit of coarser sediment at the low bluffs (profile D) and the poorly sorted coarse sediments of profiles A and B reveal a proximity to a sediment source. The sandy beach fronting the settlement of Pond Inlet appears to be a zone of accretion, a fact shown by its' considerable width of well sorted and rounded sand grains (Plate 17).

FROST TABLE DEPTHS

Measurements of frost table depths for profiles A to H were completed on August 28th, and on September 4th for profile I (Table 3.5). The greatest mean depths recorded were at MHWM (mean depth=70.0 cm), but only slightly more so than those found elsewhere across the beach. The active layer depths observed at the first raised beach ridge and at the edge of the water were very similar, with mean depths of 65.6 and 65.7 cm. Depths recorded at profile C were greater (mean depth=83.8 cm) than those found elsewhere, particularly at profiles D to G, which were at the base of a large hill. Evidently, aspect must play some role in the resultant depths, just as the heavier vegetation cover is thought to be important at profiles D and E. There, depths of 32.0 and 37.0 cm were observed. The mean of all the recorded depths was 66.4 cm, with a maximum of 90.0+ cm at profiles C and H, and a minimum of 32.0 cm at profile D.

BEACH AND NEARSHORE ICE CONDITIONS

In most seasons, the sea ice and particularly the nearshore ice would have disappeared long before the author's arrival at Pond Inlet in late August. However, because of the extremely poor season with respect to ice removal and the nearness to freeze-up time, several nearshore ice features were observed.

At high tide, a wide zone of open water existed along the entire length of the coast, but at low tide much of the beach face once again became littered by pieces of grounded ice. Most of the ice, which

TABLE 3.5

DEPTH OF ACTIVE LAYER AT BEACH SITES, ECLIPSE SOUND

Beach Profile	Non-Active Beach	Top of Active Beach	HHWM	MHWM	Edge of Water	Mean Depth	Mean Grain Size (ø)	Aspect
A	72.0	62.0	71.0	78.0	78.0	72.2	-0.75	N
B	84.0	78.0	62.0	63.0	63.0	70.0	-0.50	N
C	90.+	77.0	78.0	87.0	87.0	83.8	+0.00	NW
D	68.0	32.0	53.0	--	66.0	54.7	-0.25	NE
E	37.0	71.0	90.0	81.0	75.0	70.8	+0.00	N
F	68.0	47.0	51.0	49.0	34.0	49.8	+0.25	N
G	40.0	76.0	60.0	57.0	73.0	61.2	+0.50	N
H	--	--	78.0	90.+	52.0	73.3	+0.00	N
I	--	66.0	62.0	55.0	63.0	61.5	--	N
Mean Depth	65.6	63.6	67.2	70.0	65.7	--	--	-

Depths are given in centimetres

varied from 0.25 to 2 m in thickness, was superficially rotten; the surface was composed of highly porous, brittle ice while the sides and bottom had been subjected to substantial water erosion. The only place where ice still remained 'fast' to the shore was at the base of the rock coast, where solar radiation was probably less effective. A ledge of ice had formed between high and low tide marks and ranged in width from 0.2 to 2.5 m (Plate 22). As water levels rose to high tide, gravels were sometimes washed up onto the ledge, but it is not known if the gravel hastens or hinders the destruction of the ice ledge. If the ice ledge is a permanent feature, and it very well could be, the ice could act as a focal point for further freezing in the fall, and could also have a stabilizing effect on the base of the exposed rocks.

A crack was observed in the beach sediments along the shoreline near low water mark, in front of the Hudson Bay Company store and also at profile G. Further investigation resulted in the discovery of an ice ridge buried beneath 18.0 to 30.0 cm of beach sediments (+1 ϕ to -2 ϕ). It is believed to be a similar feature, though smaller, to that found at Makinson Inlet.

Air temperatures during the first week of September were several degrees below freezing, and the sea water remained between -1° and 0° C near the shore. These low temperatures, plus the large amount of remnant ice in the inlet which prevented wave generation, resulted in the formation of new ice in the nearshore zone during most nights (Plate 34). Although the new ice was at times as thick as 1.0 cm, it was usually melted by the afternoon sun, or floated offshore at high tide. The newly formed coastal ice was quite flexible and took the shape of the underlying beach topography. The development of new ice was accompanied by the incorporation of the newly fallen snow. A similar process was recorded during the initial stages of freeze-up on Radstock Bay, Devon Island, in the fall of 1971.

The effect of sea ice on the plan and profile of the beach appears to be very slight, being limited to the erosion of some of the low bluffs and the formation of several small ice push mounds. The push mounds observed near profile G were oriented in a NNW direction, and were 2.0 m wide and 0.38 m in height, but all were found below HHWM, which means that when next subjected to wave action, they would probably be combed down and destroyed. The formation of several ice push mounds was documented on the morning of August 30th. An eastward flowing tidal current (0.2 m/second) was developed as the tide ebbed and the sea ice, which was drifting eastward, was forced landward. At the headland, the sea ice broke up on the rocks, but in the embayment to the east the ice scoured the nearshore bottom and created mounds of 0.35 to 0.45 m near MHWM (Plate 28). Along the more open sectors of the coast, the ice pressures were not significant enough to form similar features; hence, it is believed that the configuration of the coast has more importance in the formation of small scale push mounds than does the fetch or length of open water. The other factors which are needed for 'push mound' formation are a high water level, a deep active layer and the presence of sea ice offshore.

The effect of rivers on the nearshore ice destruction is not as important in Pond Inlet as in Eclipse Sound, because of the lack of rivers in the latter area. The rivers' flood discharge in the spring creates centres of ice breakup, and in 1972 the only ice free waters were those adjacent to the larger river outlets, e.g. Salmon and Ja~~m~~nes rivers.

3.10 SUMMARY

Makinson Inlet and Pond Inlet are typical of many of the east coast fiords found in the Arctic Archipelago. Both are lined by high, steep mountain slopes which are frequently broken by glacial tongues, many of which are tidewater. In the interior of the fiords a much lower relief is found, a dissected limestone plateau country less than 300 m in relief in Makinson Inlet, and a gravel plain of morainic material, less than 60 m in relief, in Eclipse Sound. The inlets are both very deep, particularly at their entrances where depths of 300 to 500 fathoms are sounded.

Location, tides, channel width and winds are all important factors in the removal of sea ice from the inlets. Makinson Inlet has narrow, sinuous channels and is normally characterized by a blockage of multi-year ice at its' entrance and/or S~~ou~~mith Bay; Pond Inlet-Eclipse Sound, on the other hand, is quite wide, and sea ice break-up is aided by the presence of open water, an extension of the 'North Water' at the eastern entrance of the Inlet. The large tidal range of 2.46 m within Makinson Inlet, which is over twice the range usually experienced in Eclipse Sound, should aid in the sea ice break-up, but the lack of an outlet for the ice impedes its removal in Makinson Inlet. As a result, Pond Inlet-Eclipse Sound experiences 60 open water days, twice that recorded at Makinson Inlet.

The longer open water season at Pond Inlet-Eclipse Sound is revealed in the beach sediment characteristics. The sediment along Eclipse Sound is a sand more spherical and rounded than the sediment along Swinnerton Peninsula, Makinson Inlet. The respective roundness and sphericity values for Pond and Makinson inlets were 349.8 and 185.2, and 0.673 and 0.561. Furthermore, the beach sediment was finer and better sorted at the former location.

Frost table depths were observed to be greatest at Eclipse Sound where the mean depth was 66.4 cm, a result of the different dates of measurement. The frost table on the beach face was greatest at HHWM at Makinson Inlet, but at MHWM at Eclipse Sound. This difference arises because the MHWM was still affected by the presence of sea ice and snow in mid-July at Makinson Inlet.

Nearshore ice conditions in these two locations are more difficult to compare because of the difference in time at which they were observed. Nevertheless, an ice foot and an ice-cored ridge at or below MHWM were found along the shores at both locales. The ice foot thickness (2.5 m) and the considerable size of the ice-cored ridges at Makinson Inlet is a function of the range in tide. The numerous small streams along Swinnerton Peninsula and the few large rivers emptying into Pond Inlet-Eclipse Sound play an important part in the melting of the nearshore ice, especially during the spring flood period.

Makinson and Pond inlets are similar in many respects, but latitude and situation create unique characteristics in each location. Makinson Inlet is representative of many of the Ellesmere Island fiords which experience more severe climatic conditions, and are more inaccessible than those fiords in more southerly latitudes. Pond Inlet-Eclipse Sound, on the other hand, is representative of the Baffin Island fiords which have a dense vegetation cover in the lowlands, and experience milder air temperatures.

Note: Wood sample found by author at 33.2 metres has been radio carbon dated as 6060 ± 90 years B.P.

CHAPTER 1V

THE HIGH STRAIGHT COASTAL ENVIRONMENT

4.1 INTRODUCTION

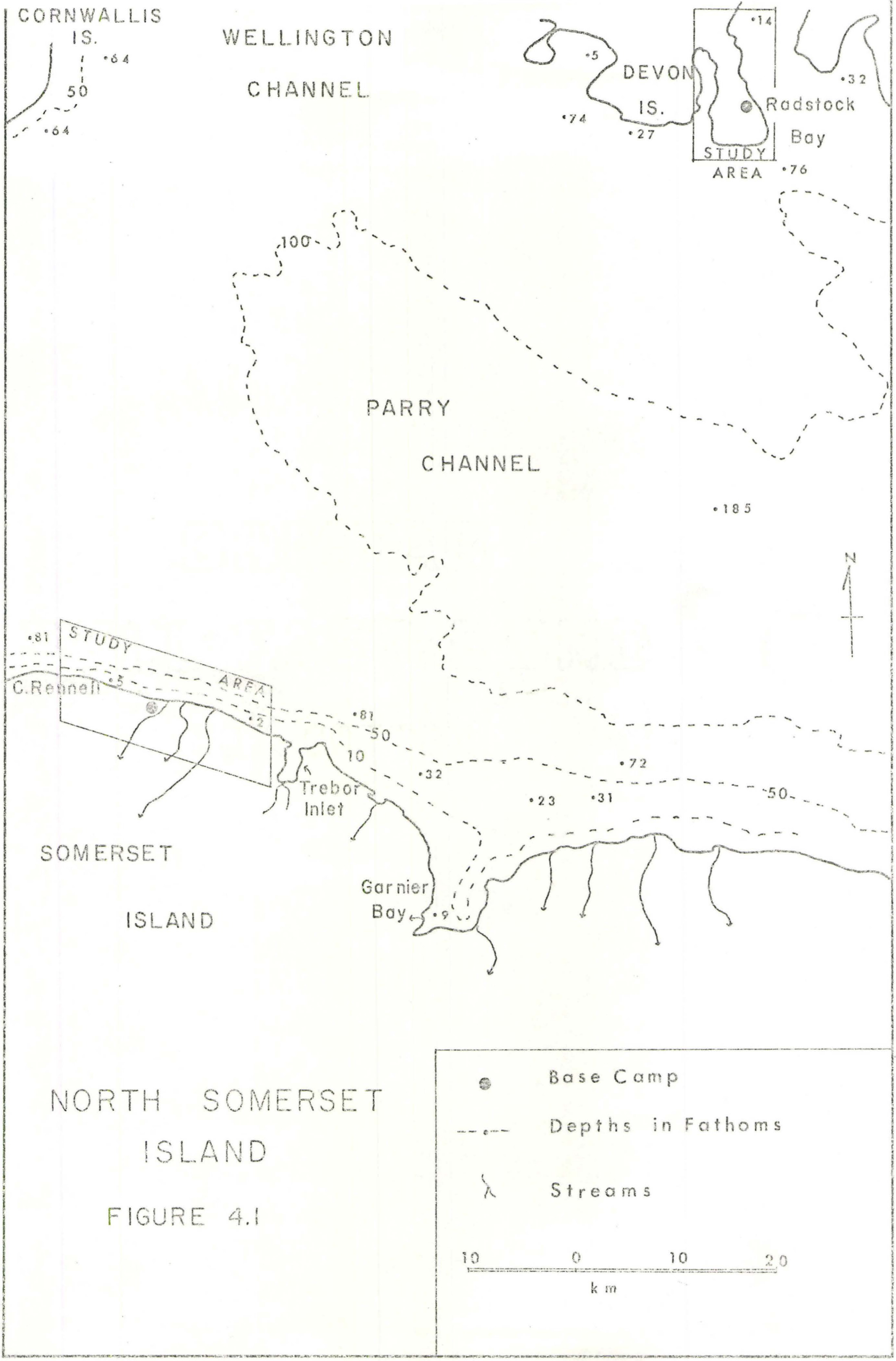
The High Straight Coastal Environment includes the coastlines of Lancaster and Jones sounds and McClure Strait, and is typified by long stretches of steep, scree-banked cliffs and raised beach terraces.

Detailed investigations were conducted during the first two weeks of July on the north shore of Somerset Island, between Cape Rennell and 'Trebor'Inlet. Radstock Bay, Devon Island, was visited on August 14th to 21st, after an earlier aerial reconnaissance on July 14th. The coastline just west of Garnier Bay was originally selected as the study area on Somerset Island because of the unique characteristic of numerous tundra ponds which lie between the raised beaches and the barrier beach ridges offshore. However, bad landing conditions, due to the lateness of the snowmelt, prohibited the occupation of this site, so the camp had to be located further west at 74° 08' N, 93° 08' W. There, a wide zone of open water presented a good location to study the spring break-up. Investigations at Radstock Bay have been conducted for several years by previous McMaster University field parties, and the 1972 work was a continuation of this.

NORTHERN SOMERSET ISLAND

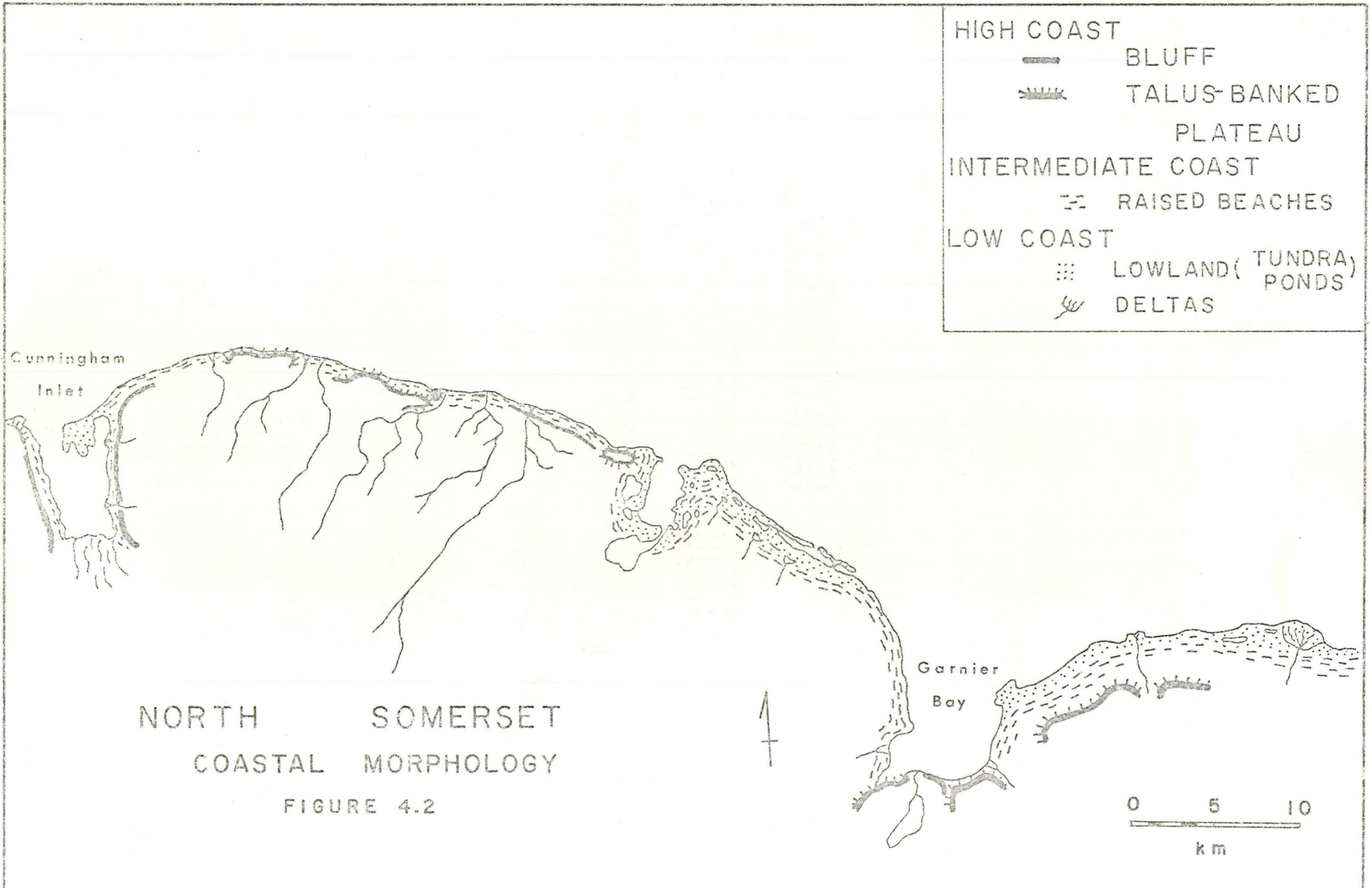
4.2 COASTAL MORPHOLOGY AND BATHYMETRY

The nearshore zone along the north coast of Somerset Island is very shallow, with depths of less than 10.0 fathoms occurring in places up to a kilometre from shore (Figure 4.1). Shoals and offshore barrier



NORTH SOMERSET ISLAND

FIGURE 4.1



NORTH SOMERSET
COASTAL MORPHOLOGY

FIGURE 4.2

ridges are common, and there is an almost continuous zone of lagoons and tundra ponds along the shore. The coastline is fairly regular in outline, containing only two major indentations, Garnier Bay and Cunningham Inlet. Except for a few isolated steep headlands such as Cape Rennell, the backshore is characterized by well-developed raised beach terraces (Figure 4.2). The Barrow Surface (Bird 1967), so well developed in the interior, only reaches the coast at the head of Garnier Bay and at the northeast end of the island. Along most of the coast, the raised beach zone is relatively narrow and culminates in a large terrace at approximately 35 m A.S.L. One dateable, a whalebone, was found at a height of 3.4 m A.S.L. and has been sent to the Geological Survey of Canada for radio carbon dating.

Several features observed along the upper active beach indicate that wave action during storm activity is important along this coast. For example, ice push ridges and numerous pits were found above HHWM, and a large amount of debris, such as driftwood and seaweed, had been swept up on shore in places beyond the normal active beach.

4.3 TIDAL CONDITIONS

The north coast of Somerset Island is part of the "Parry Channel" tidal region (Canadian Tide and Current Tables 1972), which contains several secondary ports with published tidal data, but only Port Leopold, which falls within the "Prince Regent Inlet" tidal region, is located on the south shore. A brief investigation of daily tidal changes was undertaken, therefore, in front of the base camp (Figure 4.1), between

TABLE 4.1

TIDAL CHARACTERISTICS

Comparison of Somerset Island (north coast) with Resolute Bay

Location	Higher High Water		Lower Low Water		Mean Water Level	Range Mean Tide
	Mean Tide	Large Tide	Mean Tide	Large Tide		
Resolute Bay*	1.60	2.00	0.30	-0.10	1.00	1.30
Somerset Island (north shore)	1.53	--	0.23	--	0.86	1.28
Radstock Bay*	0.58	0.73	0.12	0.00	1.28	1.74

*published values

Location	Mean High Tide	Mean Low Tide	Mean Water Level	Range Mean Tide	Period (in hours)
Resolute Bay°	1.50	0.16	0.85	1.33	11.0 to 14.0 Aug. = 12.1
Somerset Island	1.43	0.09	0.71	1.31	10.5 to 13.3 Aug. = 12.1

°predicted values
All heights are given in metres.

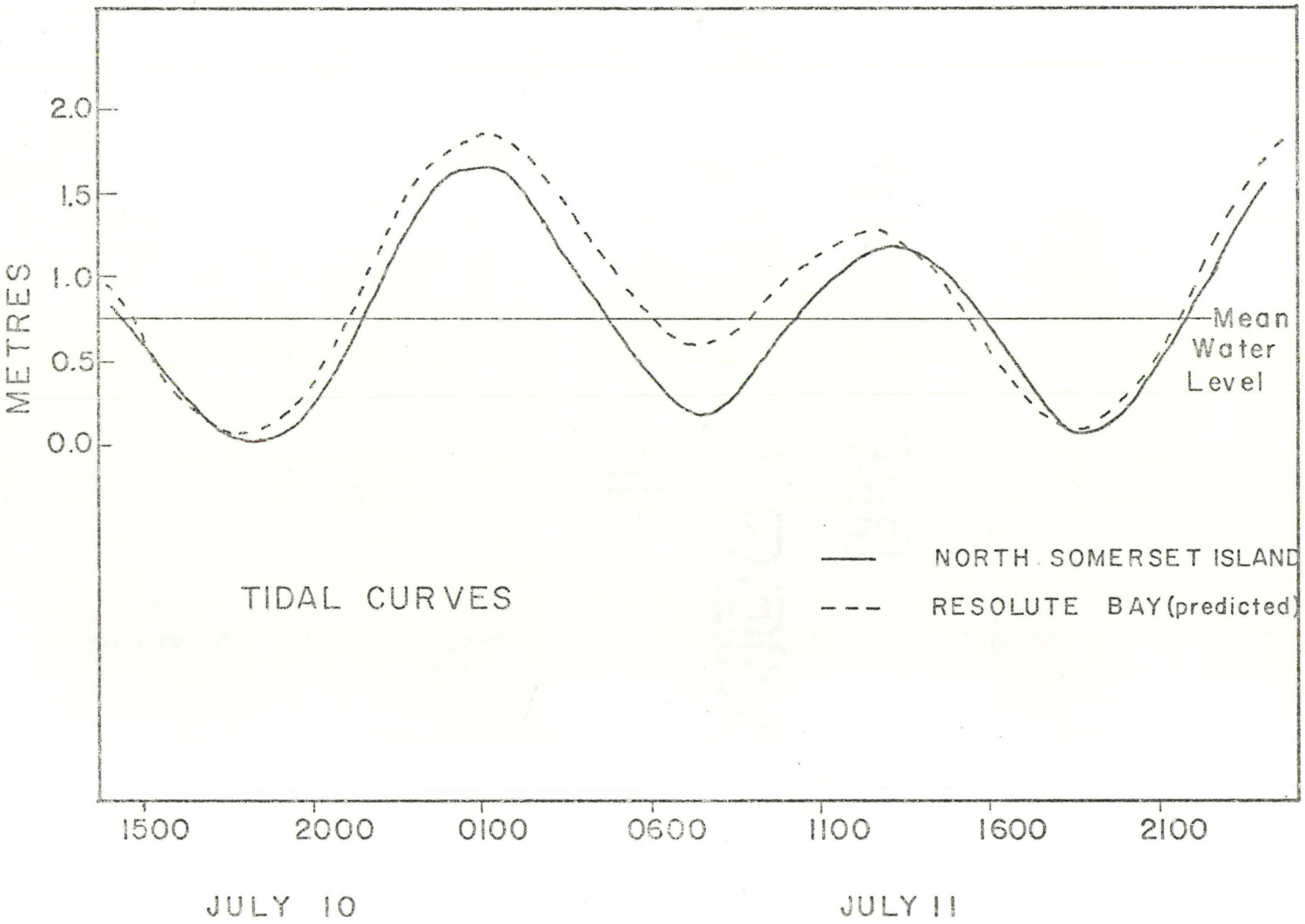

2.0
1.5
1.0
0.5
0.0
METRES
Mean
Water
Level
TIDAL CURVES
NORTH SOMERSET ISLAND
RESOLUTE BAY (predicted)
1500
2000
0100
0600
1100
1600
2100
JULY 10
JULY 11

FIGURE 4.3

1400 hours July 10th and 0100 hours C.S.T. July 12th. For purposes of analysis, the tidal values were compared to the predicted values for Resolute Bay for the same time period (Figure 4.3). The published tidal values for Radstock Bay are also included in Table 4.1. In each of the areas, a mixed semi-diurnal tide exists which, as usual, complicates the calculation of the tidal period; nevertheless, the average period was found to be 12.1 hours for both Resolute and North Somerset Island. The tidal data (new moon July 10th) calculated for Resolute and Somerset Island indicated very similar conditions, but Resolute had a slightly greater (0.02 m) mean tidal range and a slightly higher (0.07 m) mean high and low tide. The estimated mean tidal range for North Somerset Island is 1.28 m, while the value published for Resolute is 1.30 m. Hence, even though a small difference in tidal conditions exists between Resolute and northern Somerset Island, it is not sufficient to create a change in the coastal processes between the two sites.

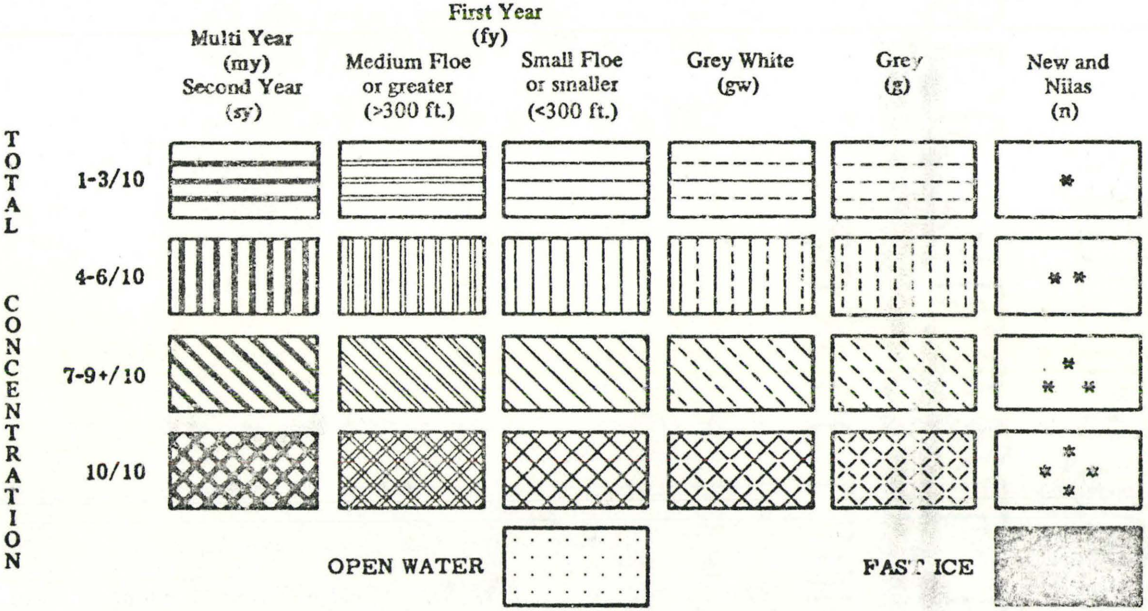
4.4 SEA ICE CONDITIONS

Information on sea ice conditions in Lancaster Sound, between Cornwallis and Somerset islands, is considerable because of the use of Resolute Bay as a base for sea ice reconnaissance flights. Despite this, many of the observations are limited to the central parts of Lancaster Sound, and the nearshore areas are ignored. Sea ice conditions for the summer of 1959 were examined, using aerial photography (Figure 4.4), and an investigation of sea ice conditions from 1965 - 1972 was completed, using the ice observations of the Ice Division of the Atmospheric Environment Service. A summary of the ice observations in the third week

ATMOSPHERIC ENVIRONMENT SERVICE

KEY TO ICE SYMBOLS

PREDOMINANT AGE



CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or Greater}}$$

$$\frac{C_{my}}{N_{my}}\frac{C_{sy}}{N_{sy}}\cdot\frac{C_{fy}}{N_{fy}}\frac{C_{gw}}{N_{gw}}\frac{C_{g}}{N_{g}}\frac{C_{n}}{N_{n}}$$

Example $\frac{2}{1}\frac{0}{}.\frac{3}{2}\frac{4}{3}\frac{1}{}\frac{0}{}$

$\frac{2}{1}$ — 2/10's Multi Year of which 1/10 is Medium Floe or greater

0 – No Second Year

. – Decimal Point

$\frac{3}{2}$ – 3/10's First Year of which 2/10 is Medium Floe or greater

$\frac{4}{3}$ – 4/10's Grey White of which 3/10's is Medium Floe or greater

1 – 1/10 Grey, no Medium Floe or greater

0 – No New

SNOW COVER

$\frac{Sn}{(n)}$

(n) tenths on ice

TOPOGRAPHY

$\frac{ΛΛ}{(n)}$ Rafted Ice

$\frac{ΛΛΛ}{(n)}$ Ridged Ice

SURFACE FEATURES

Sn/Ra Rd Hy Pd Th + F

$\frac{ΩΩ}{(n)}$ Hummocks

(n) number of tenths

"e.g. 6/1201"
6 – 6/10 Snow Cover
/ – Slant
1 – 1/10 Rafting
2 – 2/10 Ridging
0 – No Hummocks
1 – 1/10 Puddling

STAGE OF MELTING

$\frac{\text{Pd}}{\text{(n) (n) Th + (n) F}}$

(n) = tenths on ice
(n)th = tenths thaw holes
(n)F = tenths frozen

ICE OF LAND ORIGIN

Δ – (n) Icebergs

⏢ – (n) Bergy Bits and growlers

Optional:
(n) – number in area

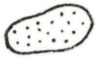
THICKNESS OF ICE AND SNOW

$\frac{T\ S}{n\ n}$ (n) – nearest inch

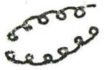
WATER FEATURES

+++++ Crack

═ Lead


Polynya

UNDERCAST


Limits

BOUNDARY

——— Observed visually

-×-×-×- Observed by radar

— — — — Assumed

○○○ Limit of Observed data

○×○×○ Limit of radar data

Symbols used for Recording the Various Ice, Snow, and Water Features

SEA ICE CONDITIONS

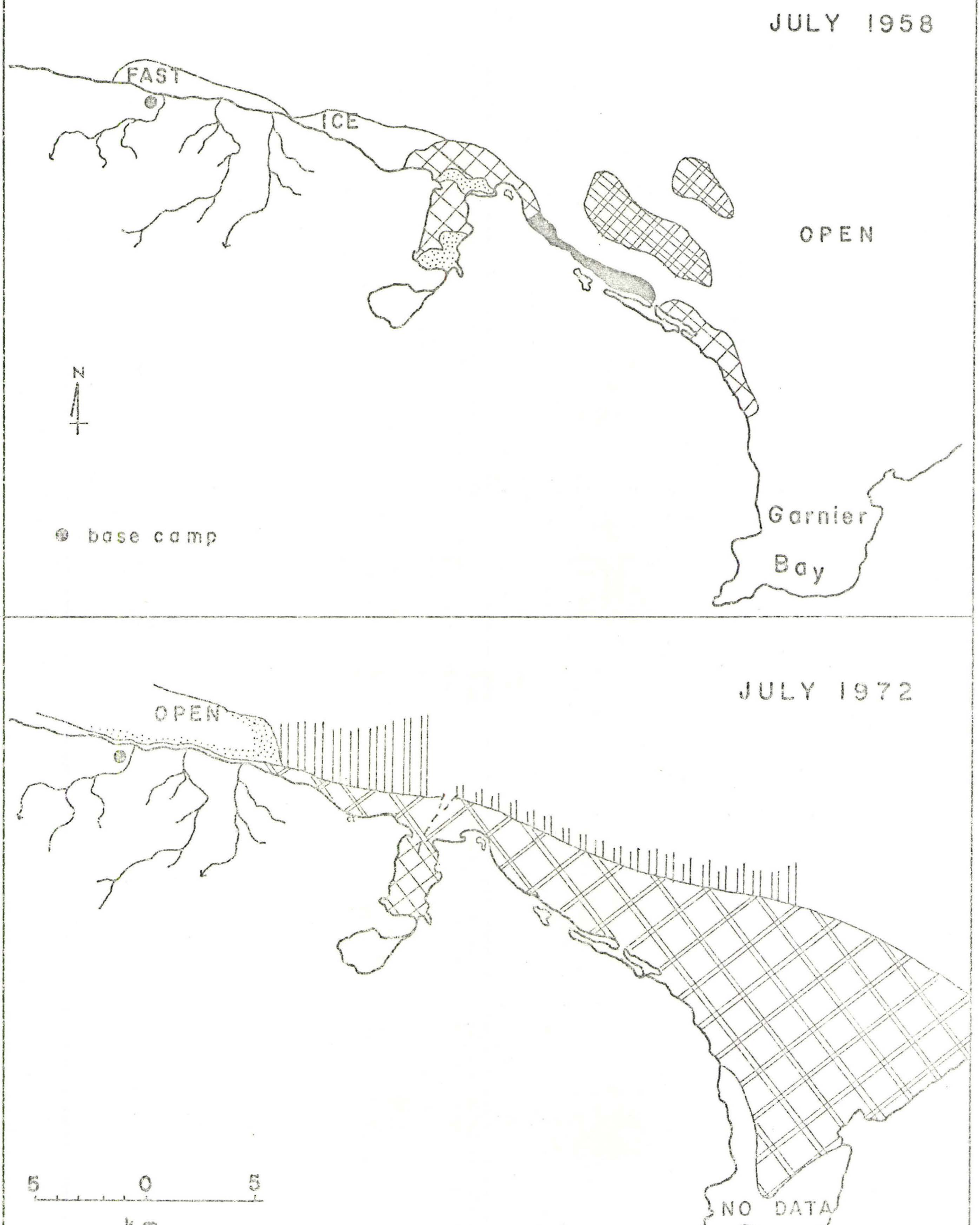


FIGURE 4.4

of July and August and first week of October is shown in Figures 4.5, 4.6 and 4.7.

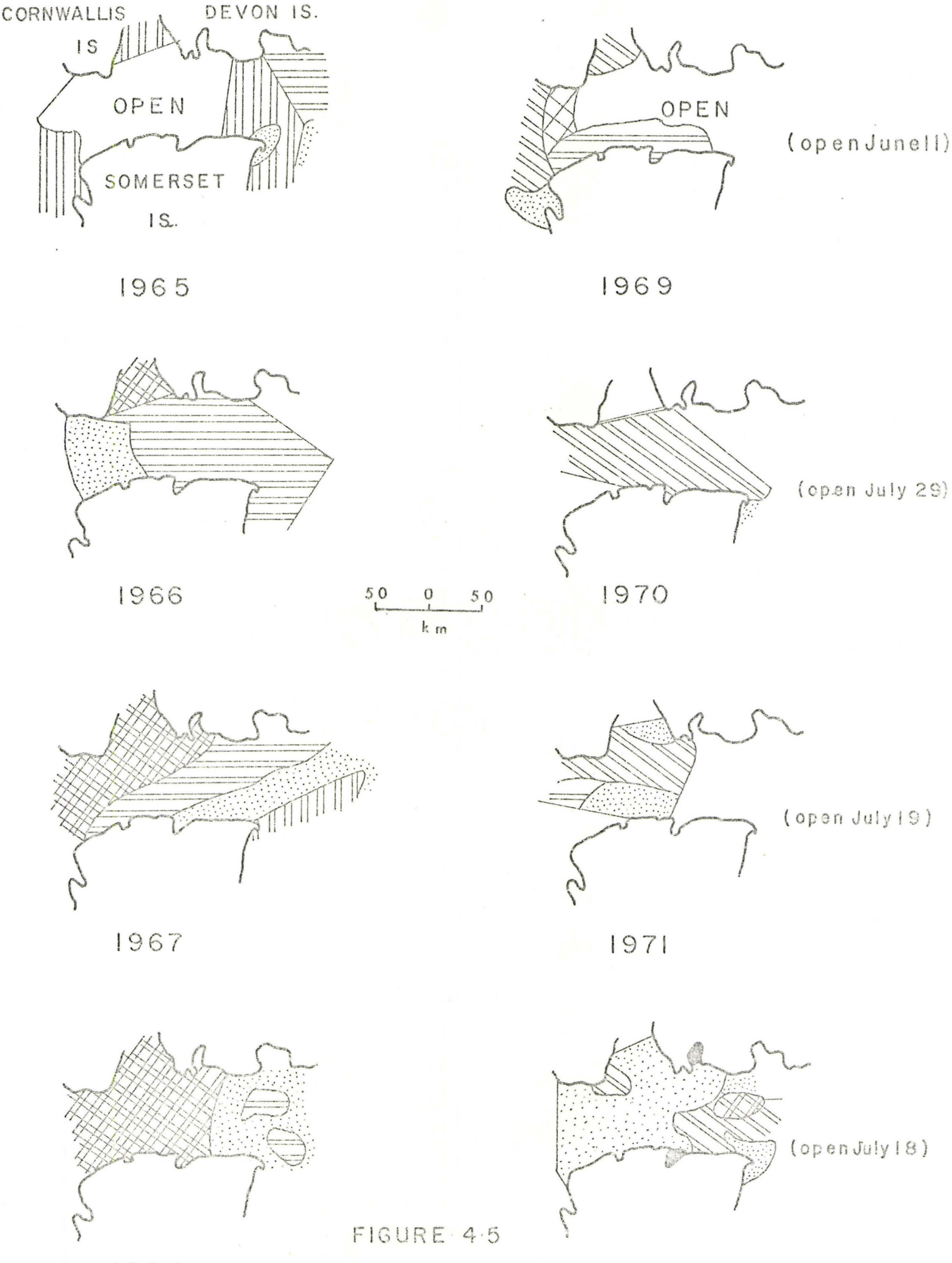
1965 - 1972

Except for a few abnormally good "ice" years, such as 1969 when open water existed in June, Lancaster Sound is usually completely covered by thick winter ice until mid-July. Leads are normally evident in early July, criss-crossing Lancaster Sound from major headlands or lines of ice weakness. Early melting or ice break-up is usually experienced near Prince Leopold Island and, in some years, offshore of Cunningham Inlet, Somerset Island. Open water occurs east of Prince Regent Inlet by mid-July, and in a major lead which forms between Cape Hotham, Cornwallis Island and the southwestern end of Devon Island.

Ice break-up usually proceeds from east to west in Lancaster Sound, in one of two ways, each of which affects the study area on Somerset Island. In some years, a strip of fast ice extending approximately from Cape Rennell to Garnier Bay was left along the north shore of Somerset Island, while further offshore, open water or near open water existed. In other years, including 1972, a wide shore lead formed along the north shore of Somerset Island from Cunningham Inlet to 'Trebor' Inlet. However, in 1966 this shore lead extended west of Cunningham Inlet instead of east. In any case, an ice foot was usually found along the major part of the coastline (1959 air photos, 1972 field observations). The presence of the ice foot, therefore, delays the date of initial wave action on the beach until the wave action can erode it.

Field observations in 1972 indicated that a W to SW wind is the

JULY 23rd



1965 1969

1966 1970

1967 1971

1968 1972

FIGURE 4.5

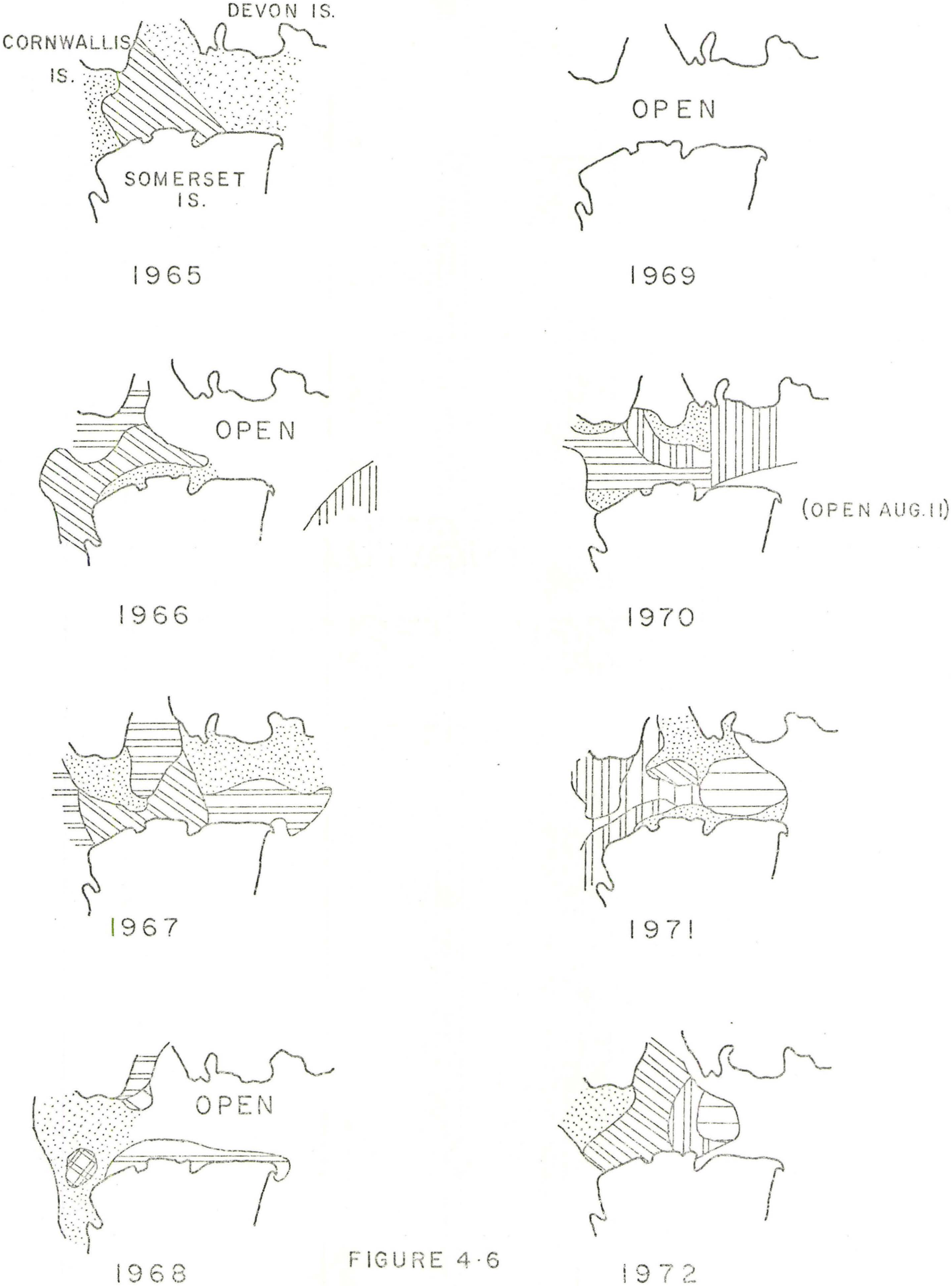

DEVON IS.
CORNWALLIS IS.
SOMERSET IS.
1965
OPEN
1969
OPEN
1966
(OPEN AUG. 11)
1970
1967
1971
OPEN
1968
1972

FIGURE 4·6

OCTOBER 8th

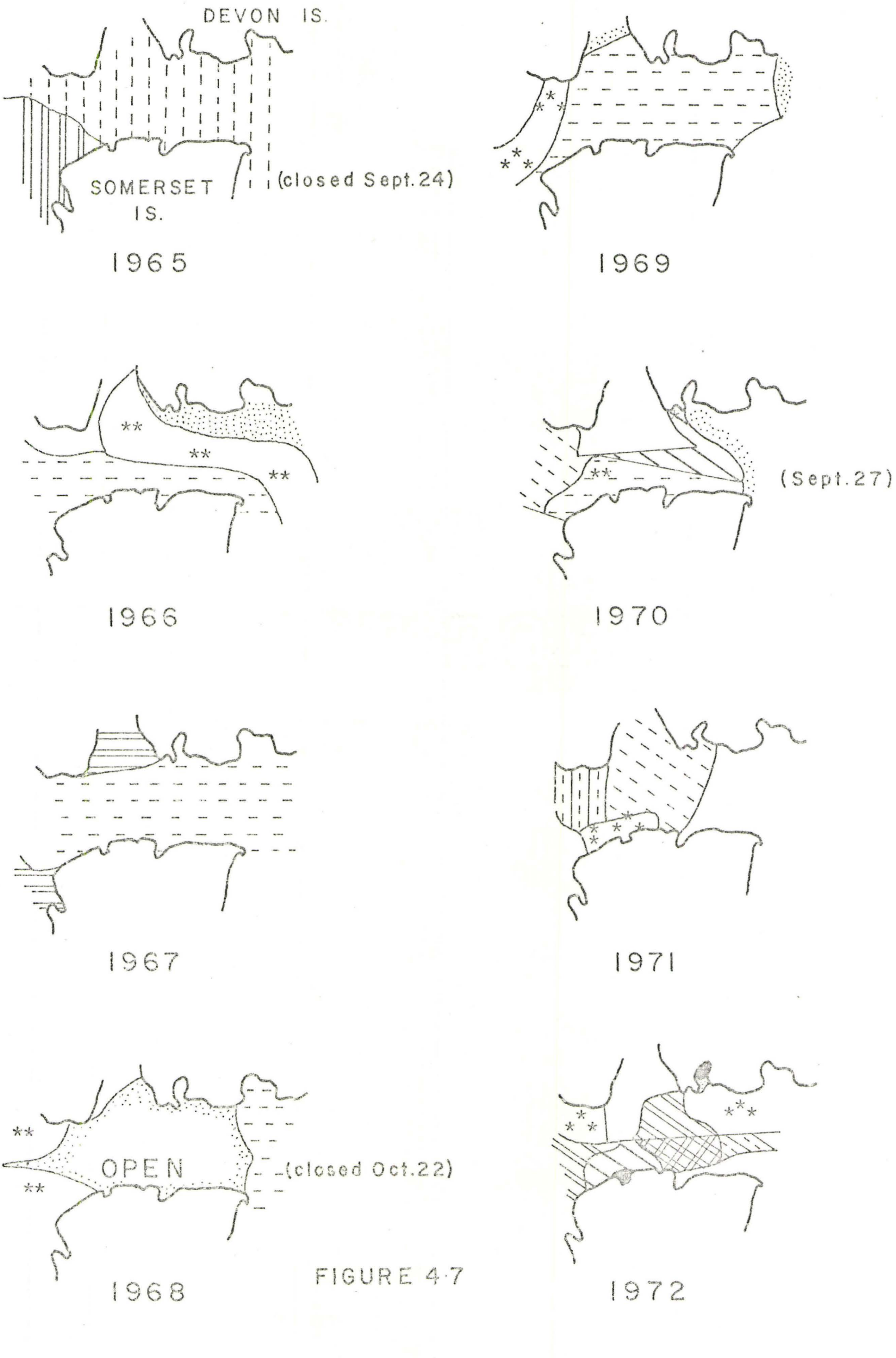


FIGURE 4·7

most influential in the removal of the nearshore ice, particularly if a wide shore lead exists offshore or to the east. A wide lead existed approximately 1/2 to 1 km offshore of the 1972 base camp on July 2nd and by July 9th, under the influence of NW to SW winds, all sea ice except a 15.0 m wide ice foot had drifted offshore and to the east. Later, on July 12th, winds from the NE returned a large proportion of the ice but it was very mobile and was easily removed eastward again by favourable winds.

Although Lancaster Sound is usually navigable by late July, large ice floes of first-year winter or multi-year ice are continually drifting east or south from Wellington Channel or Barrow Strait. As a result, the formation of long period waves is considerably hampered and probably rare until late August. The date of freeze-up varies from year to year, but appears to be initiated in late September, and well advanced by mid-October.

Using similar criteria to define the open water season as were utilized for the fiord coastal environment, it is apparent that the portion of the north Somerset coast under study has a mean length of 68 days (Table 4.2). In extreme years, the open water season can be as short as 47 days (1970), or as long as 90 days (1969). Open water conditions normally extend from July 18th - 20th to the last week in September or first week of October. Therefore, the coastline would fall into the category of "Navigable" open water season, as defined in Chapter 11.

TABLE 4.2

LENGTH OF OPEN WATER SEASON

(North Somerset Island)

Year	Break-Up	Freeze-Up	No. of Days
1965	July 23	Sept. 24	63
1966	July 30 - Aug.6	Oct. 8	66
1967	July 23	Sept. 24	63
1968	Aug. 20	Oct. 22	63
1969	June 11	Oct. 8	90
1970	Aug. 11	Sept. 27	47
1971	July 19	Oct. 3	76
1972	July 18	Sept. 29	73
		Mean Length = 67.6	

4.5 BEACH AND NEARSHORE CHARACTERISTICS

BEACH PROFILES

A group of ten profiles were surveyed on one to three occasions (July 4th, 8th or 13th) depending on the amount of change and accessibility of the particular profile (Figure 4.8). Each of the profiles was selected to represent conditions along 2.5 km of shoreline. Except to profiles A and H, which were backed by talus debris and a river respectively, each of the surveyed beach profiles was backed by a raised beach bluff. The width of the active beach ranges from 21.0 m at profile J to 2 or 3 m at profiles A and B; the beach slope also became greater toward the west, varying from 9.1% to 55.0% at profiles J and A respectively. The raised beach bluff mentioned above was from 0.3 to 0.9 m in height. Erosion, either by nearshore ice or wave action during the previous fall, was evident at the base of this ridge. Another trait of six of the ten profiles was a zone of pitting which occurred anywhere from 5.0 to 17.0 m from the estimated waterline, but on the average was 12.0 m in distance. The pitting zone was widest at profile E, and least developed at profile B (Table 4.3).

The presence of sea ice along the shoreline permitted the extension of the profiles out onto the ice and the sounding of the nearshore bathymetry at the numerous shore leads. At profiles A to D, it appears that a shore platform extends on the average 11.0 m offshore, whereas a considerable increase in water depth occurs (Figure 4.9). It was also observed that the seaward edge of the ice foot on July 14th

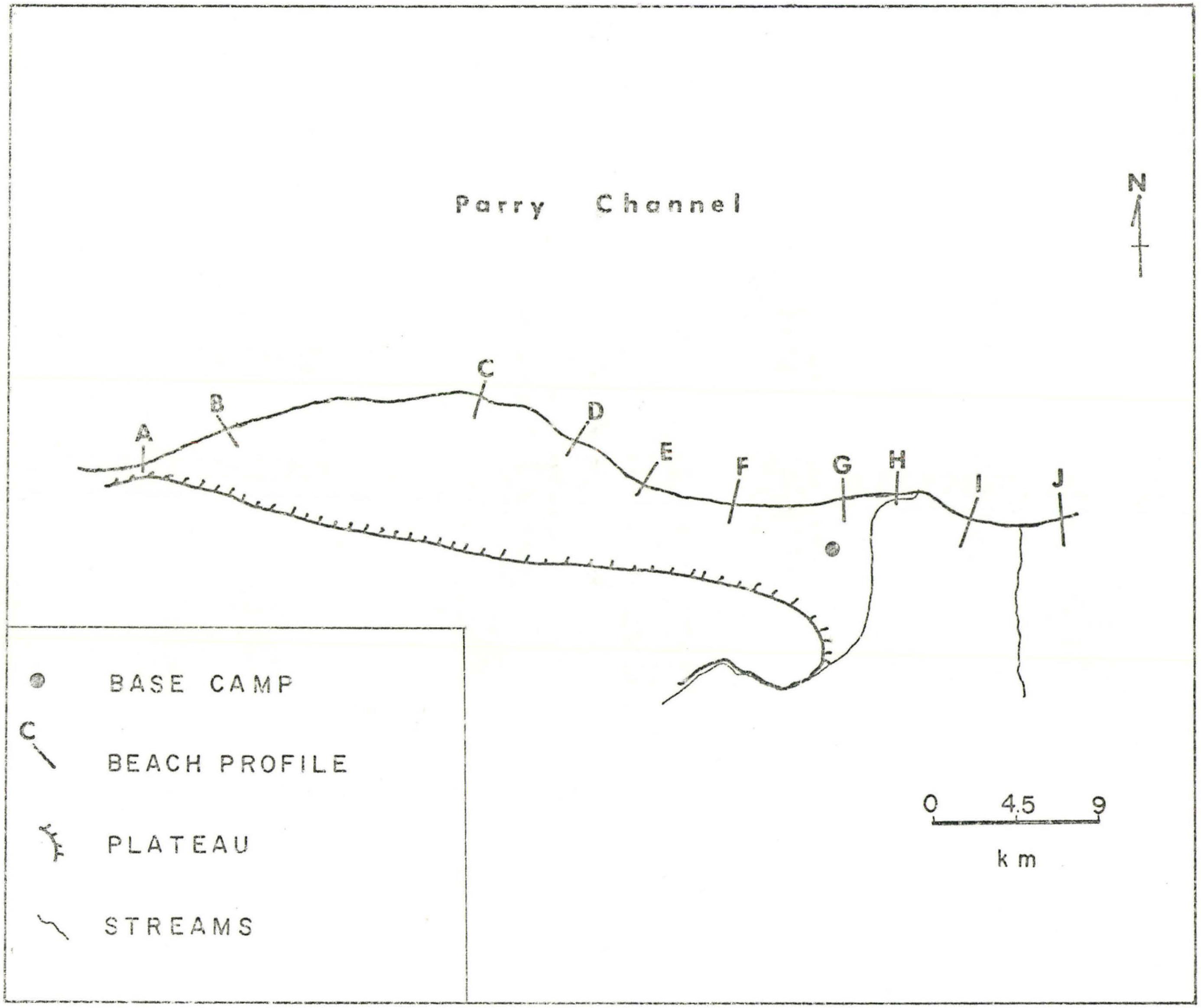
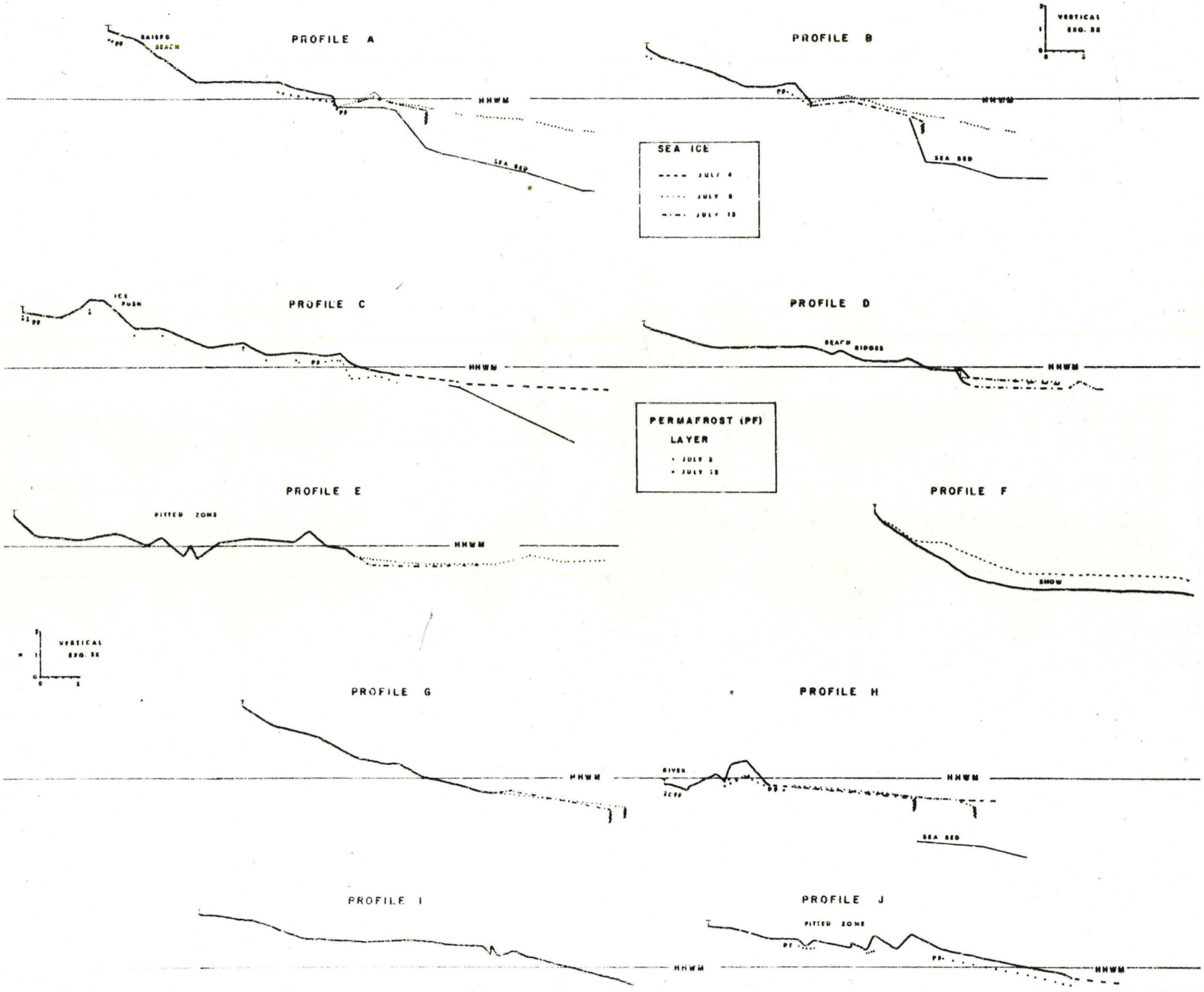

Parry Channel
N
A
B
C
D
E
F
G
H
I
J
BASE CAMP
C
BEACH PROFILE
PLATEAU
STREAMS
0
4.5
9
km

FIGURE 4·8

BEACH PROFILES – SOMERSET ISLAND

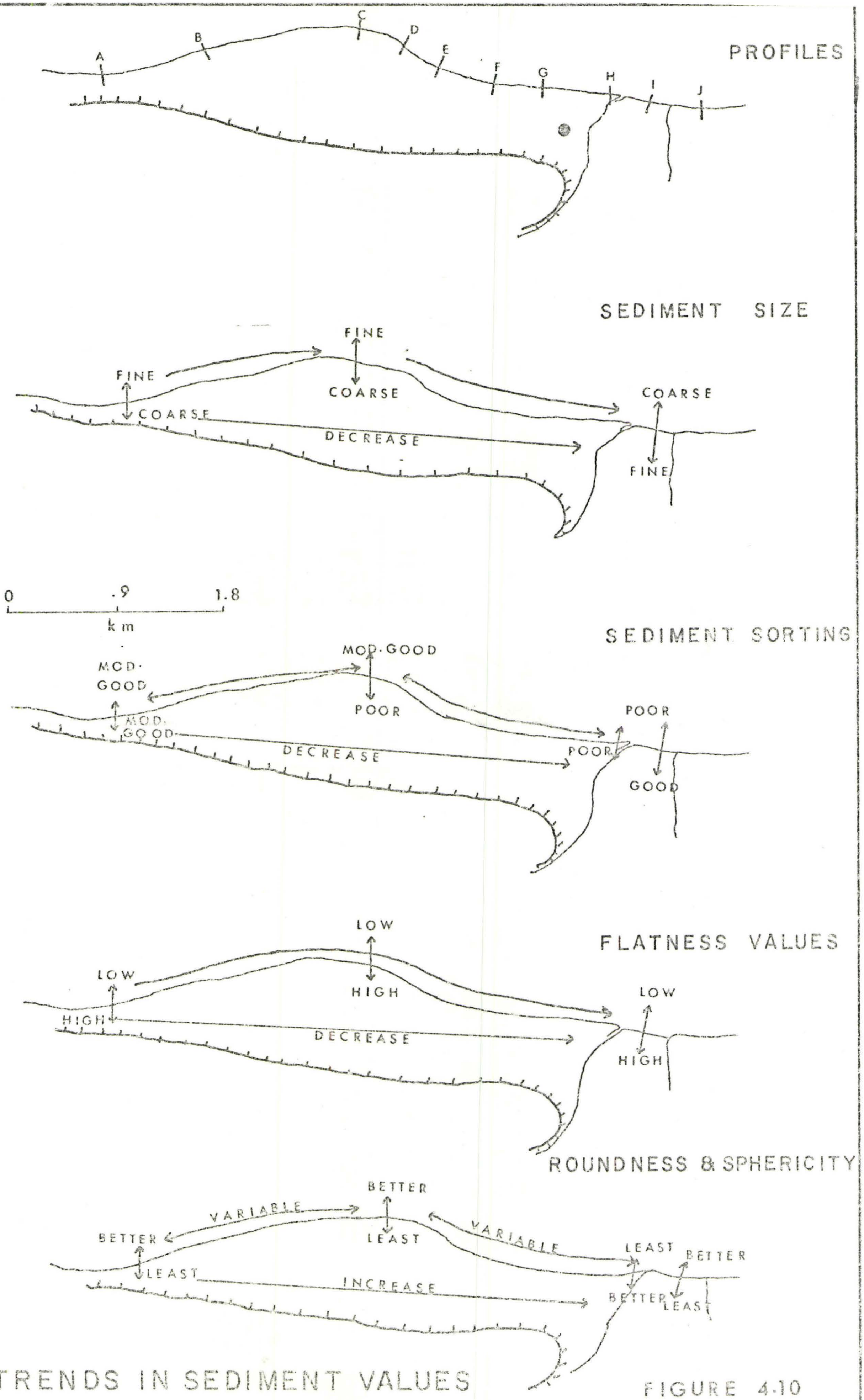


coincided with this break in slope. In general, the shallow depths offshore, indicated on bathymetric chart 7056, 1968, were confirmed in the present study. At a distance of 50.0 m, offshore depths of 3.0 m or less were recorded. The floor of the nearshore zone was usually covered by coarse gravels, but at profile B bedrock was found.

BEACH SEDIMENTS

(1) Grain Size Analysis: Sediment samples were collected from preselected sites across the beach at eight of the ten profiles. The beach sediment was shingle of -2.0 ∅ to -5.0 ∅ size, with very little sand. In general, the beach sediments were moderately sorted, but were found to vary from moderately well sorted to poorly sorted. If it is assumed that the talus-banked plateau slope adjacent to profile A (Figure 4.2) is the primary source of sediment for beach development, then sediment size should decrease with distance eastward. An examination of the beach sediment on the non-active beach provided evidence to substantiate this assumption, because mean grain size decreased eastward from profile A to J. On the other hand, a reverse trend of increasing sediment size from west to east was detected on the active beach (Figure 4.10). Regular changes in grain size were also evident across the beach. At the five western profiles, A to E, the grain size increased upslope, but in the remaining three profiles, F to H, the grain size became finer with distance upslope.

The tendancy for the coarser material to occur at the top of the beach results from the sorting action of breaking waves which move the larger grains to the upper part of the beach, especially if storm waves occur (McCann and Owens 1969). Using standard deviation as an indicator



TRENDS IN SEDIMENT VALUES

FIGURE 4·10

TABLE 4.3

EXTENT OF PITTING ZONE

Profile No.	Distance from Water Line	Width of Pitting Zone	Mean Diameter	Mean Depth
B	7.0	6.0	-	-
E	16.0	23.0	4.0	0.48
H	5.0	10.0	2.0	0.36
I	14.0	6.0	2.7	0.30
J	17.0	19.0	3.0	0.38

All measurements in metres.

TABLE 4.5

NEARSHORE SEA ICE ATTENUATION

Profile No.	Width of Ice July 8	Width of Ice July 13	Surface Ablation	Reduction in Width
A	over 52.0	12.0	0.10	over 40.0
B	" 31.0	15.0	0.25	--
C	" 32.0	22.0	0.25	--
D	" 35.0	over 35.0	0.30	--
E	85.0	56.0	0.05	29.0
G	17.0	14.0	0.10	3.0
H	23.0	15.0	0.05	(July 4-8) 7.0 (July 8-13) 8.0

All measurements in metres.

of sediment sorting (Folk and Ward 1957), it was observed that the best sorting occurred at HHWM but the difference in sorting across the beach slope was small. There was no regular variation in sorting along the beach; however, the best sorted sediments of the active beach were observed at profiles A and B.

The proportion of sand in each sample was usually less than 4%, but at profile I the sediment samples consisted of up to 17% sand. This higher proportion of sand is assumed to be the function of the proximity to the two streams - one on either side of profile I. Skewness values show that the sediment of the highest and lowest portion of the beach zone is positively skewed, while negatively skewed values were true of the sediment at HHWM. These skewness values appear to reinforce the idea of cross-beach sorting.

(2) Shape Analysis: Similar parameters to those used at Makinson Inlet were used to analyse the beach pebble shapes on North Somerset Island. The three axes and least radius of curvature were measured for 25 pebbles selected from each of the samples used in the grain size investigation. The actual procedure and list of formulae used are given in Appendix C.

The majority of pebbles fell into the Zingg (1935) shape class of disc and bladed, or bladed to very bladed if the Sneed and Folk (1958) classification was used. Moreover, a considerable number of spherical and rod-like pebbles were found at HHWM and MHWM. The variety of pebble shapes across the beach, and the even distribution of pebble shapes at HHWM, appear to indicate across beach sorting and greater sediment transport at that level of the beach.

The mean flatness values across the beach decreased downslope, as would be expected, from 317.56 at the raised beach to 251.42 at the mean high water level. Along the beach, flatness values remained relatively uniform on the active beach, but on the non-active beach the flatness values decreased with distance eastward from profiles A to G, and then increased again. The mean flatness value for all the pebbles measured was 280.71.

Regular changes in the sphericity and roundness of the pebbles were observed across the beach. The least rounded and spherical pebbles were found on the non-active beach, the best at MHWM. Nevertheless, the differences in values of sphericity and roundness were small for the pebbles measured from the different locations across the beach. The across-beach trend in flatness, sphericity and roundness was not found to apply for profiles G and H. The mean sphericity and roundness for all the pebbles measured was 0.570 and 199.10, respectively. The only trend alongshore was once again on the non-active beach where roundness increased eastward. The smallest sphericity values were found in the west at profiles A and B, and sphericity generally increased from profiles A to F, then again from profiles G to I, at the mean high water level.

Shape influences the mode of transport of the beach pebbles. Bluck (1967) found that disc and blade-like pebbles move in the same way - by shuffling along - while round particles were more apt to roll in bottom transport. The predominance of the first two shapes on north Somerset Island indicates a shuffling form of bottom transport.

An examination of all the parameters which describe sediment size and shape indicates a difference in deposition and source of sediment for the beach zone between profile G and J. There, storm wave activity in the previous fall was particularly intense, as is revealed by the large pittings found above HHWM, and the reverse trends in sediment size and shape across the beach. The better-sorted and rounder pebbles found between the two profiles, and the observance of a "river burst" in 1972 implies that the two streams nearby are the predominant source of sediment, especially the finer sediment found on the non-active beach.

FROST TABLE DEPTHS

A survey of the frost table depths at the established profiles was conducted on the 3rd and 13th of July, but only measurements at profiles C and H were obtained on both occasions. With respect to the individual profiles, very uniform active layer depths were recorded; the lowest, 24.3 cm was measured at profile A on July 13th, the deepest, 36.0 cm at profile H also on July 13th. The mean frost table depth recorded during the period of study at Somerset Island was 32.2 cm, (Table 4.4). The top of the raised beach bluff had the greatest mean depths (47.3 cm), and there was a decrease both landward and seaward from this position. The shallowest mean depths were recorded at the edge of the sea ice (19.9 cm), and the depths found at HHWM were, on the average, 10.0 cm greater than those noted at MHWM; however, only a few measurements were possible because of the deep snow cover.

When the general frost table was drafted on the cross-profiles, it was interesting to note that even though near zero depths were recorded within the centre of the (ice) pits, these depths were usually

TABLE 4.4

DEPTH OF ACTIVE LAYER AT BEACH SITES, SOMERSET ISLAND

Beach Profile	Raised Beach Ridge	Top of Active Beach	HHWM	MHWM	Edge of Ice or Water	Mean Depth	Mean Grain Size (ø)	Aspect
A								
(July 13)	43.0	48.0	27.0	29.0	9.5	29.3	-3.81	N
B								
(July 13)	36.0	37.0	--	--	0.0	24.3	-3.88	NW
C								
(July 3)	23.0	33.0	37.0	22.0	39.0	32.5	-3.93	NNE
(July 13)	28.0	38.0	45.0	25.0	--	35.3	-3.93	NNE
H								
(July 3)	43.0	75.0	--	--	16.0	34.0	-4.27	N
(July 13)	33.0	64.0	--	19.0	--	36.0	--	N
J								
(July 3)	29.0	36.0	40.0	30.0	38.0	34.0	--	N
Mean Depth	33.6	47.3	35.2	25.0	19.1	32.2	--	-

Depths are in centimetres

similar or just slightly deeper than the much greater ones found at the edge of the pits. Consequently, it appears that the frost table is at a nearly uniform level, irrespective of the micro-topography of the beach. The mean daily lowering of the frost table at profiles C and H, from July 3rd to the 13th, was 0.20 to 0.30 cm. Since all the sites are north facing, and there is less than a 0.5 Ø difference in sediment grain size (excluding profiles I and J), the effect of aspect and sediment seems to be slight.

BEACH AND NEARSHORE ICE CONDITIONS

On the first of July the shorefast ice, which existed for a distance of 0.5 to 1.5 km offshore, was covered by 0.3 to 0.65 m of snow and slush, especially at the edge of the active beach. By July 13th most of the nearshore ice had drifted offshore, but at profiles D and E the larger multi-year ice still remained for a distance of 64.0 m offshore. It is believed that the larger pieces of ice had grounded; thus, final removal from the shore was more difficult. A fracture zone was well established along the coast and, during the first two weeks of July, the tidal cracks and leads continued to widen, lengthen, and even at times close up and later re-establish themselves. The mean daily reduction in the width of the nearshore ice between July 8th and 13th was 2.1 m (Table 4.5); but the usual case was a breaking away of large pieces of ice on few occasions. The mean surface ablation of the snow and ice was 0.15 m over the period from July 4th to the 13th. The net result was an icefoot along a greater proportion of the shoreline, with a width of 15.0 m and thickness of 2.0 m at the seaward edge. The ice foot, which protected the active beach from wave action, was eroded by the salt waters and the continual washing of gravel into the base of the ice foot. Erosion of 10.0 cm or more occurred at the surface of the ice foot on July 11th, when high tide coincided with storm waves of 0.2 m height, from the northeast.

Ice push ridges were observed along the whole shoreline, the most common location being just above HHWM. The mean diameter and height of the ridges measured were 3.7 m and 0.47 m and, as was expected, the largest ridges had the greatest width of scour and were located the furthest inland (Table 4.6). The direction from which the sea ice was driven up on shore to produce the push ridges varied from NW to NE.

Pitting, created by the melting of sea ice deposited on the beach, was common and best developed near the larger stream outlets. At the stream outlets, the greater proportion of fine gravels and the presence of a recently formed barrier beach, which is formed by wave action in the fall, provide an area of less compacted, thus more easily shifted, beach sediments. The mean diameter and depth of ten pits measured was 3.09 and 0.63 m, respectively (Table 4.6).

It is concluded that the beach profile, within the bounds of the study area on north Somerset Island, is substantially affected by the action of sea ice, especially since this coast is opposite the southern end of Wellington Channel which is one of the principal routes for the removal of pack ice from the inner sea areas of the archipelago.

EFFECT OF STREAMS ON THE NEARSHORE ICE

The north coast of Somerset Island contains few large rivers, and

TABLE 4.6

ICE PUSH RIDGE AND ICE PITTING DIMENSIONS
(in metres)

1)ICE PUSH RIDGES

Location	Diameter (D)	Width of Ridge (W)	Height of Ridge (H)
9.0 metres from edge of shore-fast sea ice	5.0	2.9	0.50
	2.5	(behind 1st ridge)	0.40
	6.5	2.9	0.70
	3.0	0.5	0.45
Range of 10 samples - same location	1.4 to 4.0	0.3 to 3.0	0.20 to 0.55

Others in profiles			

2) ICE PITTINGS

Location	Diameter	Depth	Ratio
All were from area adjacent to river east of camp	1.4	0.50	2.8:1
	2.2	0.60	3.7:1
	2.0	0.50	4.0:1
	1.6	0.30	5.3:1
	7.3	1.40	5.2:1
	7.2	1.50	4.8:1
	4.4	0.50	8.8:1
	1.9	0.40	4.7:1
	0.9	0.20	4.5:1
	2.0	0.45	4.4:1

these enter into the head of Garnier Bay and Cunningham Inlet. The general case is for streams to flow only a few miles to the sea, from lakes and/or large snow accumulations found further inland. Most of the streams are narrow, and are only deeply entrenched where they cut through the series of raised beaches separating the sea from the low inland areas.

The streams, which had not begun to flow by July 1st, 1972, can not be credited with the creation of the wide shore lead found further offshore, but were certainly instrumental in the removal of the remaining shorefast ice. On July 6th, one of the small streams adjacent to beach profile J burst open, "bulldozing" huge amounts of snow and gravel to either side of the stream channel and onto the nearshore sea ice. The cause of the tremendous discharge of water was the blockage of meltwater by a large accumulation of snow in the stream valley where the stream cuts through the raised beach zone. The resultant discharge of water created numerous large channels in the shorefast ice, and within a few hours had pushed all of the nearshore ice fronting the outlet offshore, where it drifted east under the influence of NW winds. The widened shore cracks and leads on either side of the stream outlet made it easier for the winds to remove additional ice when, two days later, they blew from the south and southwest. The other streams near camp did not begin actively flowing until July 7th; the streams near Cape Rennell had not reached any sizeable discharge by July 9th. As a result, a wide zone of shorefast ice remained near Cape Rennell, but near base camp only a narrow ice foot existed. Another observation was that a stream, which bursts open suddenly, pushes the nearshore ice in front straight offshore; but a stream which gradually reaches flood discharge creates wide leads to either side of its outlet, but leaves the ice in front practically unaltered.

The streams definitely have a great effect on the destruction and removal of the nearshore ice on north Somerset Island, but the magnitude of the effect would depend on the number, if any, of streams which burst open, similar to the one witnessed, in any one year.

RADSTOCK BAY, DEVON ISLAND

4.6 COASTAL CHARACTERISTICS

Field investigations of coastal conditions at Radstock Bay and vicinity have been conducted under the supervision of Dr. S.B.McCann since the summer of 1968. However, a brief outline of the coastal characteristics is required, so that a comparison can be made with the other coastal environments currently being studied. It is also now possible to summarize the net beach profile change for the period 1970-72.

The coastline of southwest Devon Island is characterized by vertical cliffs, 200 - 300 m high (Figure 4.11), which have been a primary source of sediment for the development of the adjacent modern and raised beaches in the major bays and inlets. The modern marine accumulation features are few and simple in form; offshore ridges and spits have formed in Union and Erebus bays, while a tombolo connects Beechy Island to Devon Island.

The semi-diurnal tides at Radstock Bay have a maximum range of 2.8 m, and a mean range of 1.74 m. Tides further west at Beechy Island are slightly less, with a maximum range of 2.7 m. Over an eleven-year span (1960-71), Carlisle (1971) using the ice reconnaissance data, found that the open water season varied from 26 to 50+ days and that the average season lasted 44 days. Break-up usually occurred in late July or early August, and freeze-up by early October.

McCann and Owens (1969) documented the shape and size of the

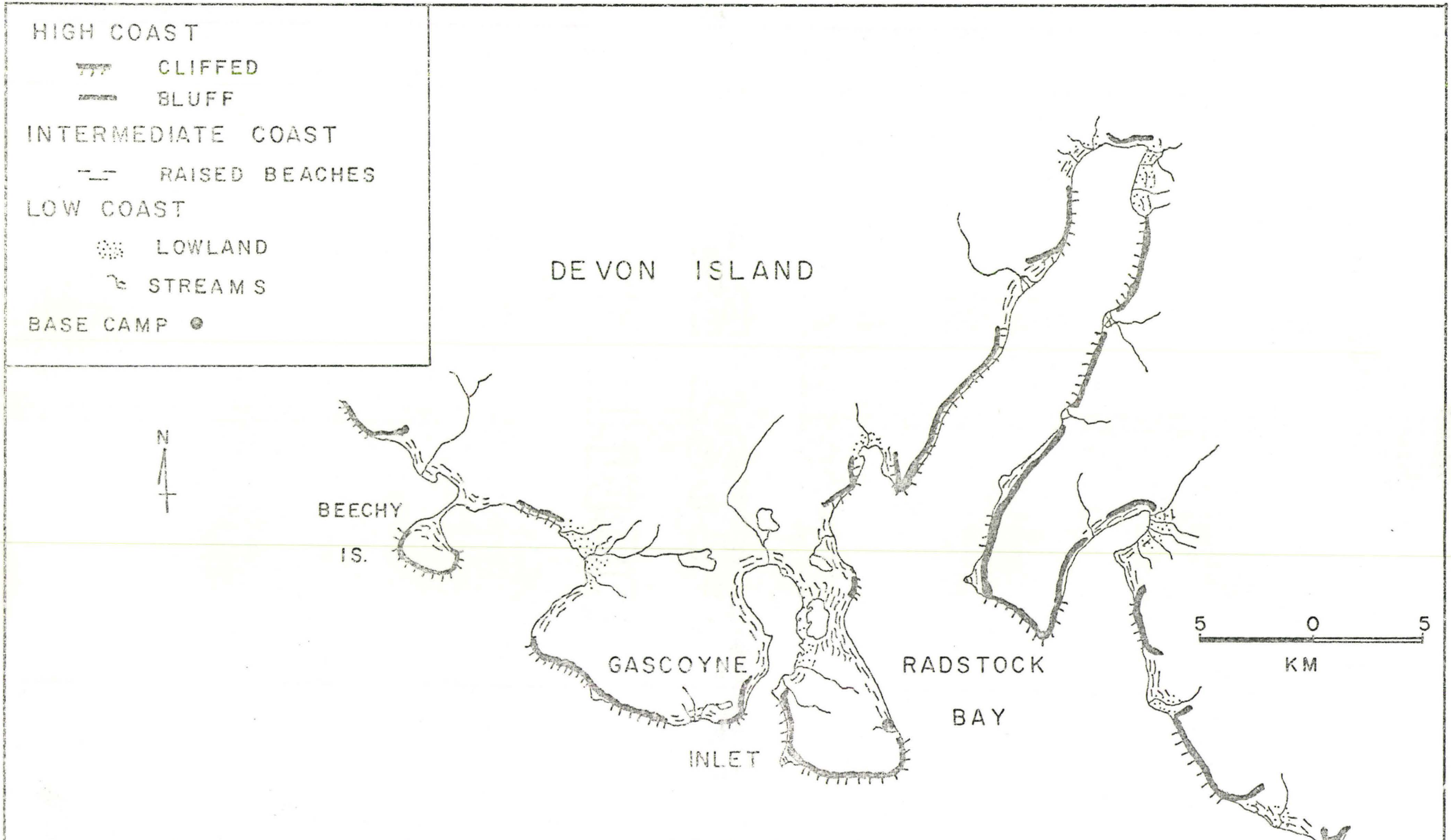


figure 4.11 COASTAL MORPHOLOGY

beach material at Walrus Bay, Cape Ricketts and Radstock Bay. Very little sand was observed, and the beach gravels varied from -3.0 ϕ to -5.0 ϕ . Cailleux roundness values for the modern beach sediments were very low, varying from 25 to 267, with a mean of 184.

Along the nearshore, an ice foot has been observed during each of the summers since 1968. The size and extent of the ice foot has varied from year to year, but was best developed in 1970 when the average width and thickness was 16.2 m and 2.2 m respectively (McCann and Carlisle 1972). Streams have played a very minor role in the destruction of the nearshore ice; however, meltwaters draining from the major frost-wedge cracks have been observed to erode channels across the ice foot, and to remove sediment from the active beach (Taylor 1971).

Small-scale pitting was quite common along the western shore of Radstock Bay, but the only shores containing a high concentration of ice-push scars and ridges were those at Cape Ricketts. In 1969, a series of ice cored mounds covered by 0.3 m of gravel, and having a height of up to 7.0 m above mean sea level were surveyed by Owens at Cape Ricketts (Owens and McCann 1970).

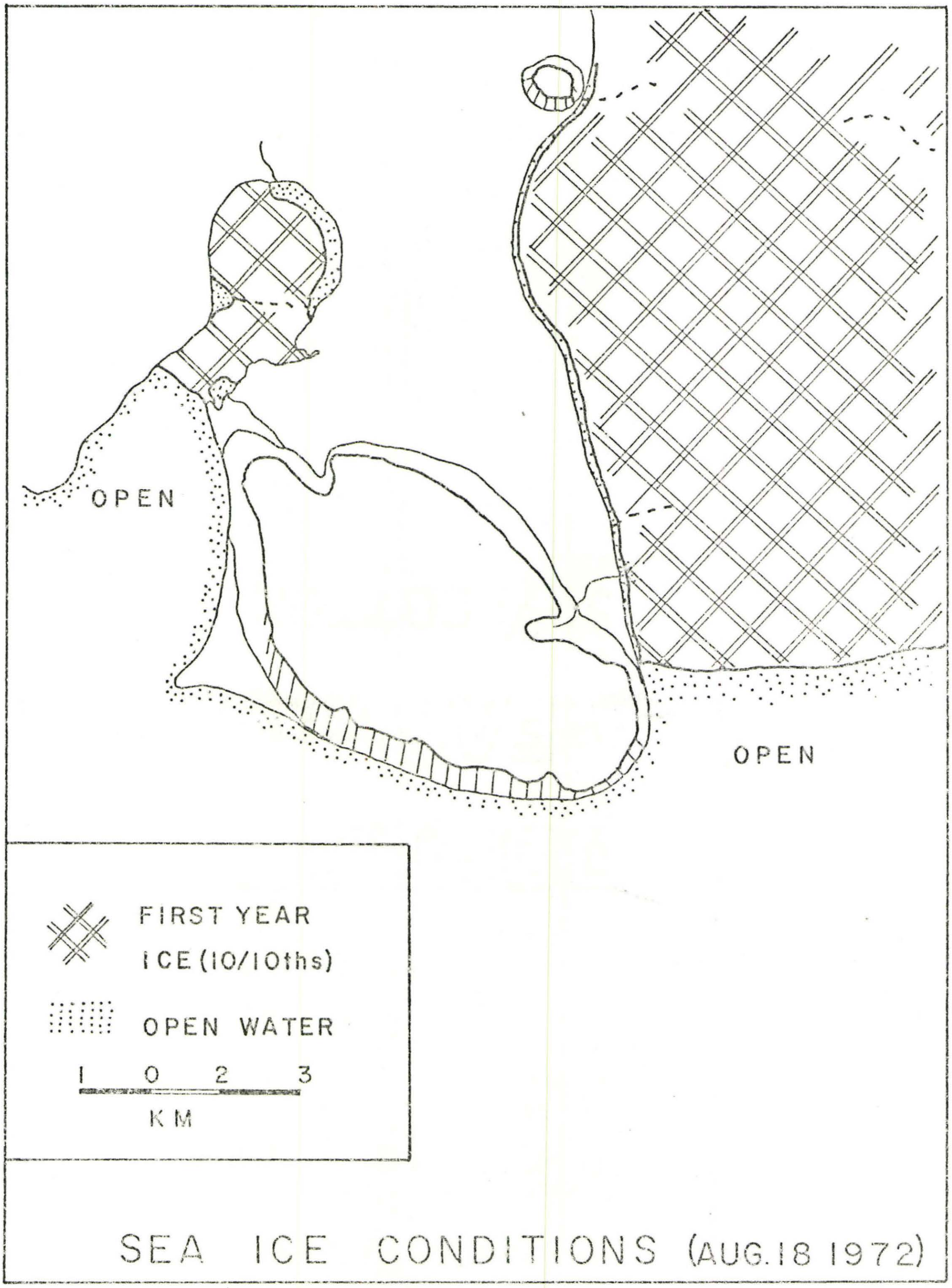
4.7 SEA ICE CONDITIONS

1971 - 1972

During the fall of 1971, the freeze-up sequence was monitored by R.J. Carlisle and the author. On several occasions, a small slush or "false" ice foot was formed, but in every case wave action during the following high tide destroyed it. Permanent freeze-up did not begin until after a storm on September 29th which carried large pieces of old ice, i.e. bergy bits and growlers, into Radstock Bay from Lancaster Sound. This ice became grounded along the western shore of the bay, creating a protective barrier (10 - 50 m wide) for the beach against further wave action. A subsequent drop in air temperature and the calm condition of the nearshore waters resulted in the formation of "grease", "pancake" and finally, "young coastal" ice. By October 6th, approximately 95% of Radstock Bay was frozen (Plate 36).

Radstock Bay was revisited briefly, on July 14th, 1972, at which time very little melting of the nearshore ice had occurred (Plate 37). In front of the base camp the multi-year ice, which had grounded in the nearshore the previous fall, protruded above the general ice surface and was very dirty in appearance. There was some puddling on the offshore ice but the snow cover was still quite thick along the shore. Evidence of ice foot development was absent along the western shore of the bay except just south of Caswall Tower, where a characteristic narrow rampart of ice extended out from the shore.

A month later, August 14th, a detailed investigation of sea ice and beach conditions was resumed. At that time, both Radstock Bay and Gascoyne Inlet remained virtually ice covered north of Cape Liddon and Walrus Point, respectively. Further south, within Lancaster Sound, nearly complete open water existed. Large leads existed across Radstock Bay at the usual locations (Figure 4.12), and a narrow stretch of open water existed along both shores. The main body of first year ice within Radstock Bay was in a very advanced stage of melting but, according to the observations of the Ice Division of the Atmospheric Environment Service, very little change in the concentration of ice occurred for the



SEA ICE CONDITIONS (AUG.18 1972)

Figure 4.12

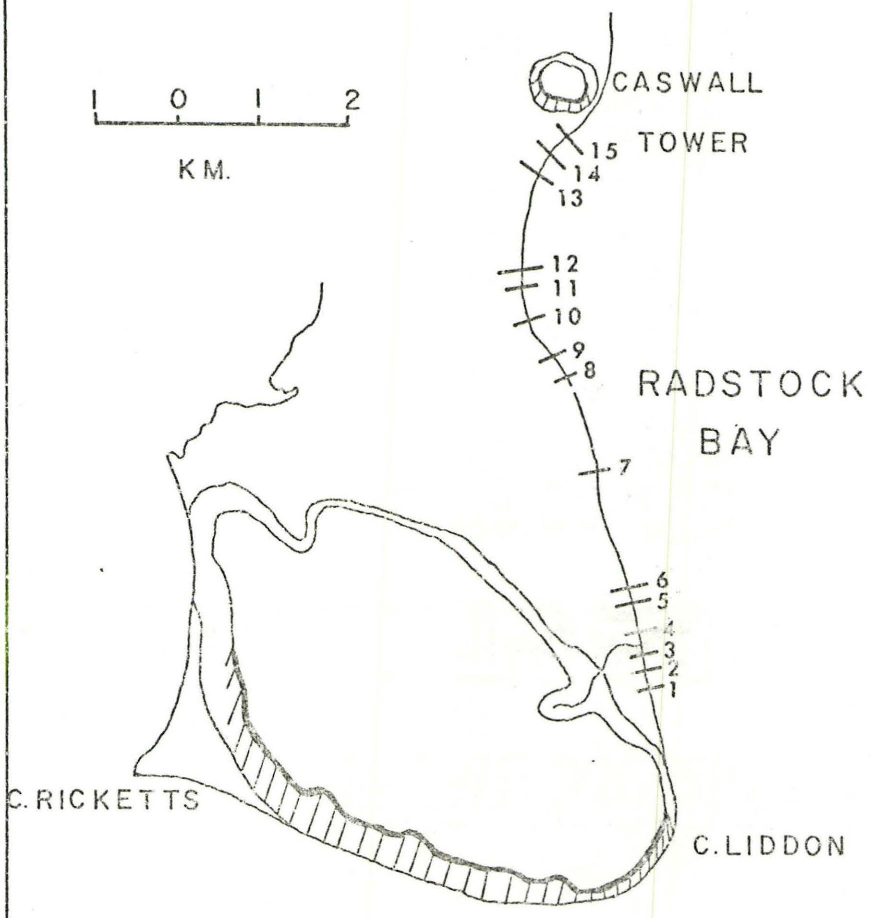
remainder of 1972. Therefore, there was no open water season in Radstock Bay and Gascoyne Inlet during 1972.

4.8 BEACH CHARACTERISTICS

BEACH PROFILES

A series of 15 profiles were surveyed on August 19th, between Caswall Tower and Cape Liddon at the south end of the beach (Figure 4.13). The survey lines, set up by R.J. Carlisle in 1970 and 1971, extend from the bench marks on the raised beach to the waterline. The use of similar profile stations allows an examination to be made of the net beach profile changes over various periods of time between 1970 and 1972. In this examination, the characteristics of the beach profiles at each of the time periods will be discussed, but first it is proposed to outline the general beach conditions found along the five mile stretch of coast.

At the north end of the beach near Caswall Tower, there is a wide, gradual sloping beach (11.7%), which in August 1972 was characterized by a rampart of shore-fast ice at the land-sea interface, and a shingle ridge just above HHWM (Plate 12). Further south along the shore, the active beach is much narrower and is usually backed by a steep bluff cut in raised beach deposits. At profiles 11 and 12 the active beach is usually lined with numerous small beach ridges caused by waves refracting at the small headland further south. In 1972, the same area exhibited some beach pitting. Ice push mounds and a steep backshore are the main features found at profiles 9 and 10 and, to a lesser degree, at profile 8. The steepest active beach slope, 19.6%, was observed at profile 9. Profiles 1 through 7 are all backed by a steep raised beach bluff, and



LOCATION of BEACH PROFILES

FIGURE 4.13

BEACH PROFILES - RADSTOCK BAY, DEVON ISLAND

in 1972 all possessed a ridge of at least 0.25 m in height at, or just above, HHWM. The slope of the active beach varies at the seven profiles but the mean slope in August 1972 was 17.1%. Bedrock is found at the back of profile 1, while till is found at the base of the backshore of profile 7; the remaining profiles consist entirely of gravel. Two small stream outlets, entering the sea between profiles 3 and 4, and 11 and 12, are the only interruptions in the continuity of the shoreline.

FROST TABLE DEPTHS

Frost table depths were obtained on August 19th and 20th at pre-selected sites across nine beach profiles located along the western shore of Radstock Bay. The greatest depths found across the beach were at HHWM. Elsewhere across the beach the depths were similar except at the waterline, where a mean depth of 20.2 cm was found. Differences in the depth of the active layer were also observed along the beach; for example, on the south facing beach near Caswall Tower average depths of 43.6 cm were recorded, but on the east facing beach which is lined by a relatively high backshore, the depths were only 28.3 cm. It appears that local aspect and situation are the primary factors controlling the frost tables on this beach. Similar conclusions on the effect of aspect were also reached, after a study of ground temperatures on different facing slopes near the base camp.

4.9 CHANGES IN BEACH PROFILE

A regular part of the beach program at the Radstock Bay site has been to resurvey a set of thirteen to fifteen profiles over the three field seasons of 1970 to 1972 (Figure 4.13). A set of seven profiles

TABLE 4.7

DEPTH OF ACTIVE LAYER AT BEACH SITES, RADSTOCK BAY

Beach Profile	Raised Beach Ridge	Top of Active Beach	HHWM	MHWM	Edge of Ice or Water	Mean Depth	Mean Grain Size (ø)	Aspect
1								
2	26.0	26.0	32.0	23.0	21.0	25.1	-4.48	E
3								
4	33.0	29.0	26.0	28.0	13.0	28.0	-4.48	E
5								
6	31.0	23.0	39.0	31.0	31.0	31.0	-4.48	E
7	30.0	28.0	27.0	24.0	--	24.6	-4.46	ESE
8	31.0	33.0	44.0	31.0	18.0	30.8	-4.30	E
9	34.0	19.0	18.0	--	12.0	20.7	-4.30	ENE
10								
11								
12	--	30.0	46.0	29.0	19.0	30.2	-3.74	E
13	38.0	45.0	64.0	45.0	--	48.0	-4.21	S
14								
15	--	45.0	44.0	33.0	28.0	39.2	-4.21	S
Mean Depth	32.0	30.9	37.9	30.4	20.2	30.3	--	-

Depths are in centimetres

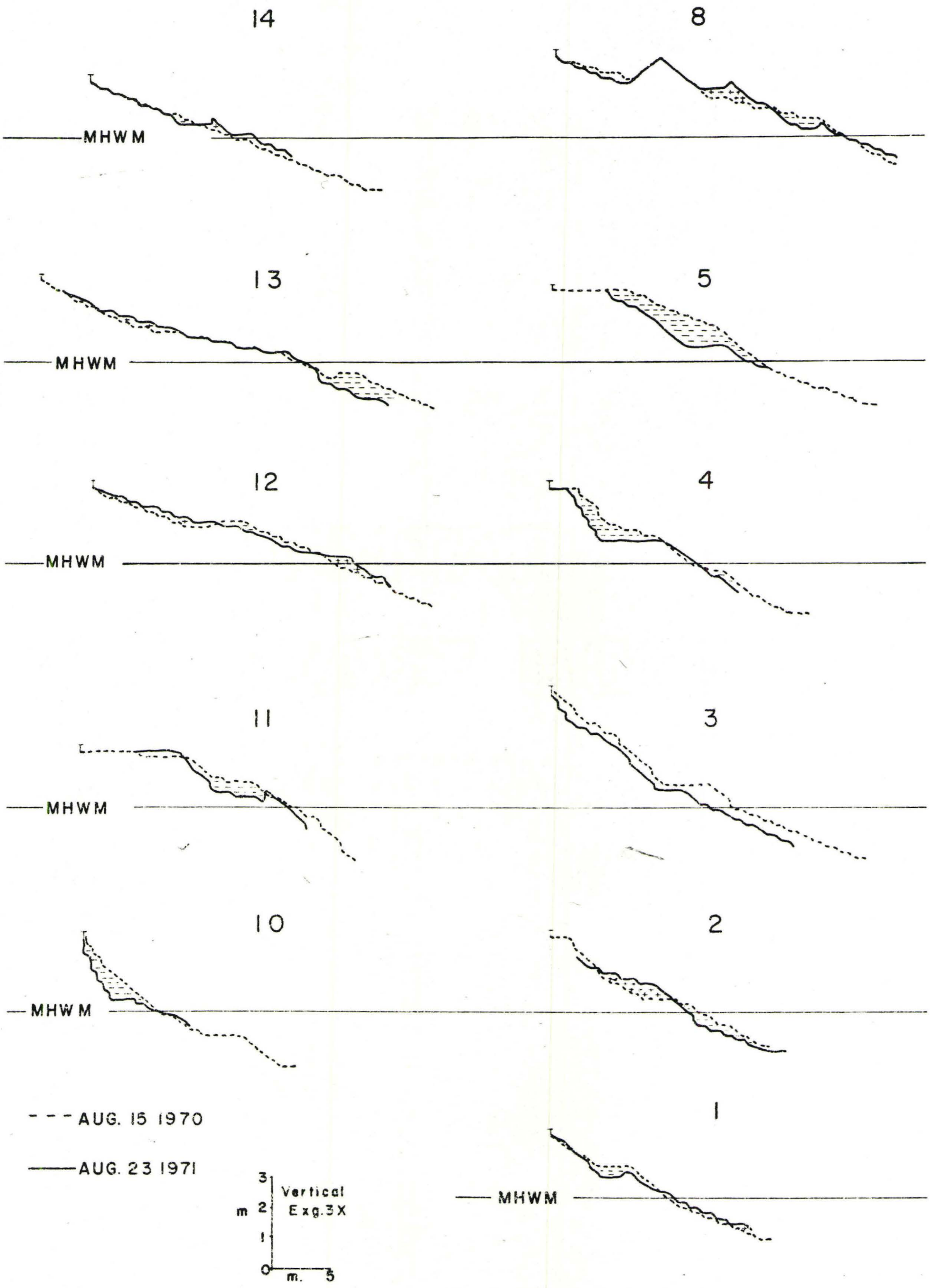
Mean grain size from Owens (1969)

were also surveyed in 1969, but are not included in the present analysis of beach changes. The 1970 and 1971 beach profiles surveyed by R.J. Carlisle, as part of his M. Sc. study, were used by McCann (1973) together with earlier data, to document the short term profile changes occurring as the result of three individual storms, one in 1969 and two in 1970. Changes in beach profile over a whole season, however, were not examined, nor has there been any discussion of changes over an average winter season. It is these longer term changes, plus the change in beach profile over the two-year period of 1970 - 1972 which are examined below.

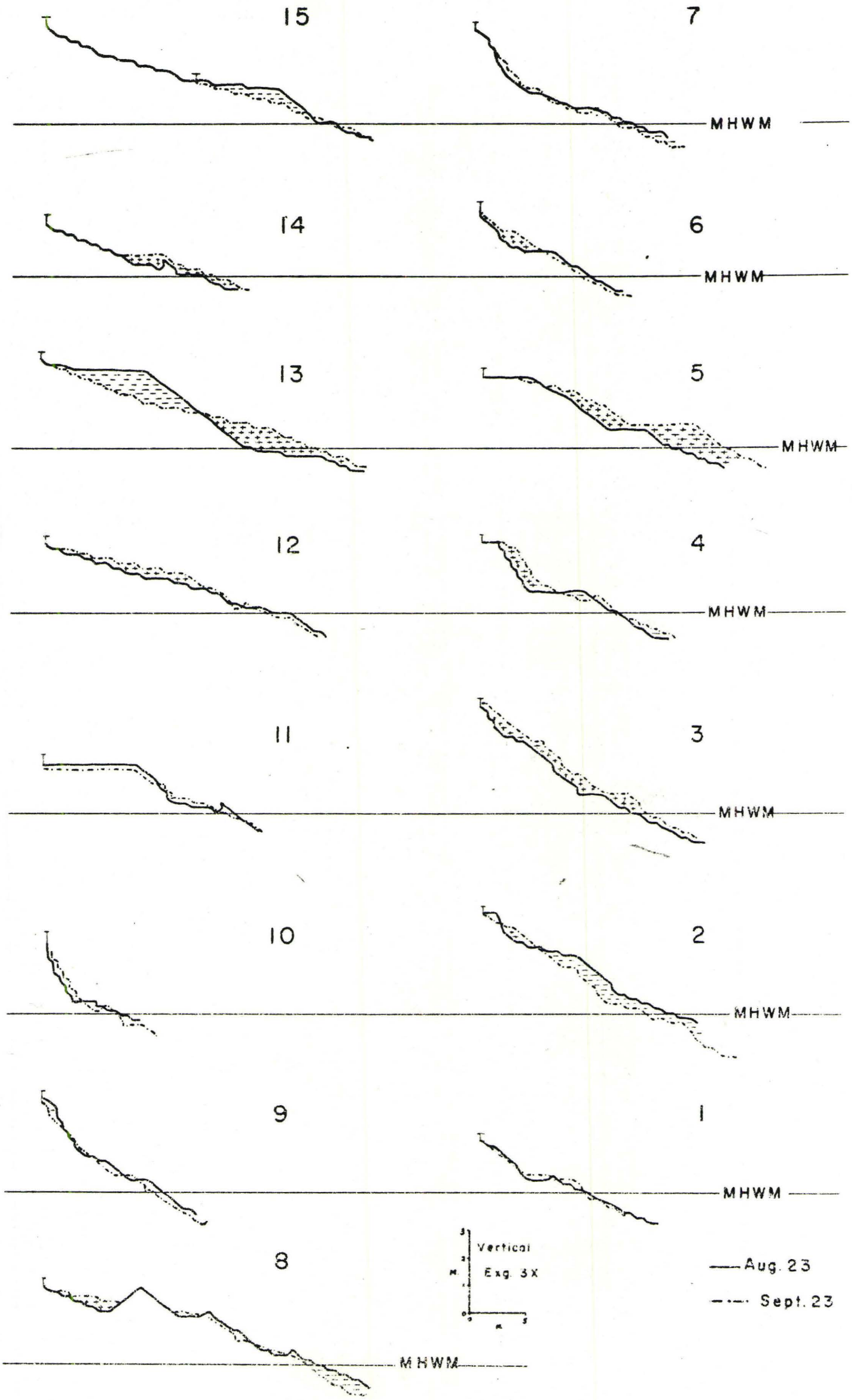
A comparison of the individual profiles over selected periods of time was facilitated by the use of a computer program devised by E. Bryant (1972). The results are expressed as an areal measure (M^2) representing the change in area between successive profile curves. Negative values indicate a loss in beach material from the foreshore zone, and positive values an addition. A cumulative value of change for the series of profiles may be used to provide a mean value for the beach as a whole. Although the individual profiles were carefully surveyed on each occasion, difficulties arise in comparing successive profiles because of changes in beach terminology or reference points by different observers over the two year period. Any set of profiles which were thought to be inaccurately aligned and likely to give inaccurate results have been rejected in the current analysis. The resultant profile changes are shown in Figures 4.14 to 4.17.

(1) Annual Change: Annual changes in beach profile result from

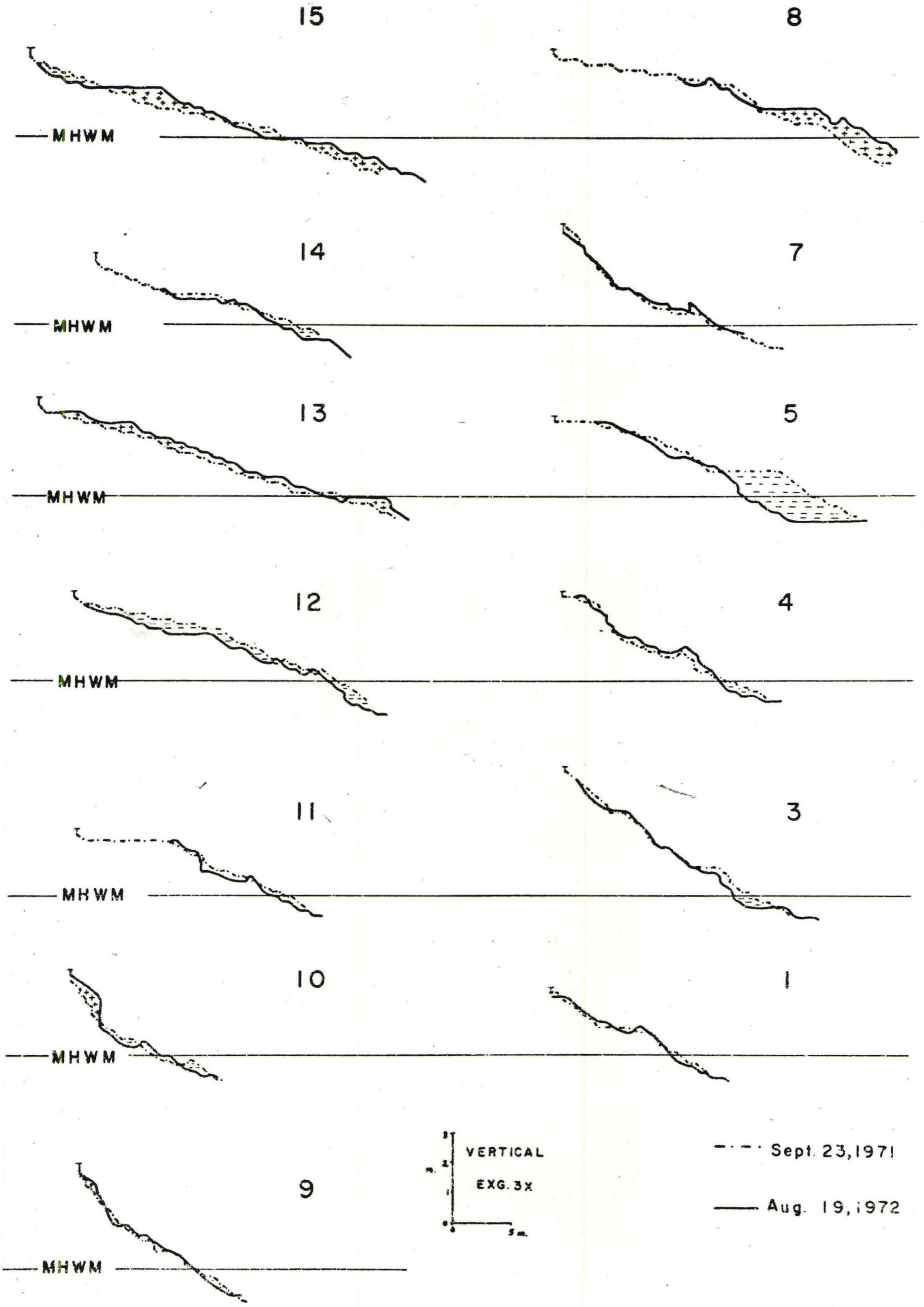
BEACH PROFILES - RADSTOCK BAY (AUG.15 1970 - AUG.23 1971)

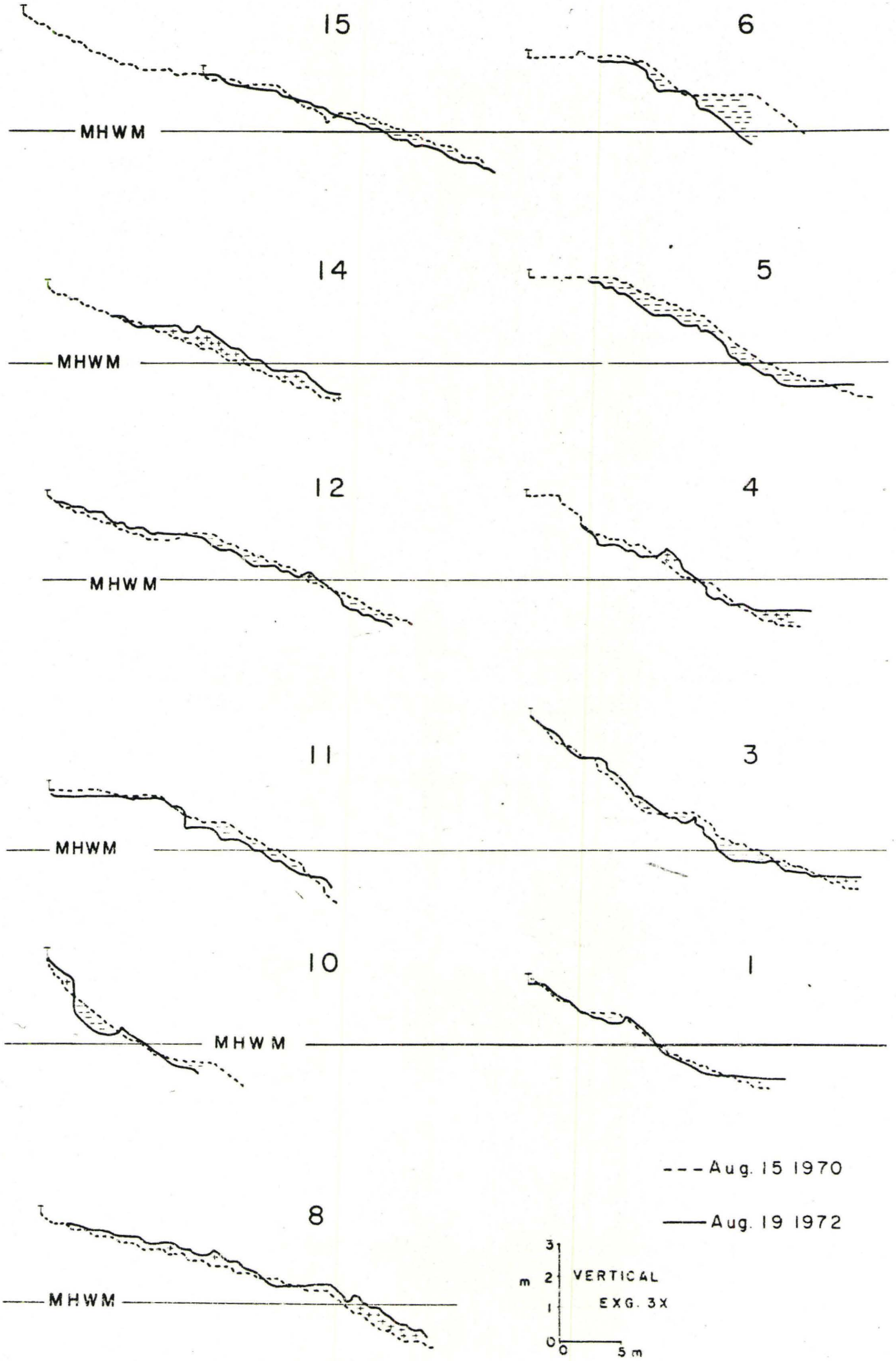


BEACH PROFILES - RADSTOCK BAY (AUG. 23-SEPT. 23 1971)



BEACH PROFILES - RADSTOCK BAY (SEPT. 23, 1971 - AUG. 19, 1972)




15
6
MHWM
14
5
MHWM
12
4
MHWM
11
3
MHWM
10
1
MHWM
8
MHWM
Aug. 15 1970
Aug. 19 1972
m
3
2
1
0
VERTICAL
EXG. 3X
0
5 m

wave action during the open water season, sea ice action during the fall and the effects of springmelt runoff. Net annual change for each profile was calculated for 1970 - 1971 and 1971 - 1972 by comparing a set of profiles surveyed at the beginning of open water season in the first year, and a second set at a comparable time the following year.

Between August 15th, 1970 and August 23rd, 1971, the net beach profile change over the 8.0 km long, 25.0 m wide active beach was -18.96 M^2 (Table 4.8). In general, the ~~sou~~north end of the beach experienced the greatest positive change. This trend appears to substantiate the claim by all previous writers that the net longshore sediment movement is from south to north; however, the source of sediment for the build-up of the northern part of the beach could have been from offshore. An examination of the individual profiles indicates that the wave action of 1970 was destructive; eight of the thirteen profiles experiences erosion in the upper part of the beach zone, particularly of the steep raised beach bluff which occurs at several of these profiles. Two profiles experienced general erosion across the whole foreshore and three others had erosion in the lower foreshore, and accretion in the upper foreshore. The observations of beach conditions in 1970-71 indicate a general combing down of the intertidal beach zone, with most profiles experiencing a steepening of the backshore. Further evidence of the magnitude of the storm wave activity in 1970 was the presence of new ice push at profiles 6 to 8, and buried br~~u~~ash ice near profile 3.

The annual beach profile change in 1971-72 was slightly less than in the previous twelve months , and there had been a buildup of 16.88 M^2 . For the 1971-72 period, it is more instructive to break down the twelve

TABLE 4.8

NET PROFILE CHANGE - RADSTOCK BAY

Profile No.	1970-1971 (1 year)	1971-1971 (Aug.-Sept.)	1971-1972 (Sept.-Aug.)	1970-1972 (2 years)
1	+0.625	-0.208	+0.312	-0.311
2	+0.625	-7.083	--	--
3	-7.604	+6.250	-1.458	-2.083
4	-3.437	+1.979	+1.042	-0.099
5	-7.708	+9.167	-10.521	-6.040
6	--	+1.146	--	-5.937
7	--	-1.771	+1.354	--
8	+1.849	-0.921	+6.354	+7.604
9	--	-0.521	+0.833	--
10	-2.187	+0.417	+1.042	-1.042
11	-1.875	-0.937	-0.521	-2.812
12	+2.500	+3.229	-6.042	-0.937
13	--	+0.000	+4.479	--
14	+1.562	+3.021	-1.562	+5.939
15	-1.458	-2.919	+6.562	-2.502
+ change	7.161	25.209	21.978	13.543
- change	24.269	14.360	20.104	21.763
Net change	-17.108	+10.849	+1.874	-8.220

months into two shorter time periods, so that the effect of wave action and sea ice on the beach profile can be isolated and better understood.

(2) Seasonal Change - Wave Action: In 1971, beach and sea ice conditions were monitored from August 20th to October 8th, a period which included all but the first three weeks of the open water season which began in the last week of July (Carlisle 1971). The last set of profiles was surveyed on September 24th, when freeze-up of the beach had been initiated. Two medium-sized storms occurred during the season, one on August 23rd to 26th, the other on September 10th to 11th. Associated with both storms were winds of 35 mph, from the south or southeast, waves of 4 to 6 second period, and sea ice which drifted into Radstock Bay from Lancaster Sound. The sea ice, which drifted to the west shore of the bay, acted initially as a protective barrier for the active beach against the storm waves. Eventually, the ice was eroded and the remnants thrown up onto the upper beach and buried by shingle. The beach profile changes after each of the storms has been summarized by Carlisle (1971) and McCann (1973), and an examination of the changes over the open water season (August 23rd to September 24th) substantiate their observations. There was a net accretion of 10.85 M^2 in this period; the principal areas of accretion were at profiles 12 to 14, and 3 to 6 (Figure 4.13). At nine of the fifteen profiles there was deposition in the upper part of the beach, and at eight of those profiles erosion occurred in the lower beach. The beach profiles adjacent to Caswall Tower showed an opposite trend of buildup in the lower beach, with some erosion in the upper beach.

(3) Seasonal Change - Non-wave Action: The return visit to Radstock Bay in August 1972 provided an opportunity to see what changes,

if any, occur in the beach profile during the winter and spring.. In 1972, open water was not experienced within inner Radstock Bay, except for a narrow band of open water along the shore.

The net beach profile change was as expected, very small, with a net increase of only 1.87 m for the entire beach. In spite of the small overall change to the beach, there were considerable changes recorded at the individual profiles. For example, the changes varied from a decrease of 10.0 m at profile 5 to an increase of 6.3 m at profile 8. At ten of the fifteen profiles, the lower part of the beach had been eroded and at nine of those same profiles, a substantial shingle ridge had been formed at the top of the intertidal zone. The ridge was probably the result of pressures exerted on the shore fast ice by the sea ice during the winter months. The erosion of the lower beach slope could have been a result of the formation of the high tide ridge and/or the springmelt waters which have been observed to carry sediment from the land out onto the nearshore ice. Accretion at the base of the raised beach bluff and erosion near HHWM, with deposition to either side, were additional features observed along the beach. The former feature is thought to be the result of sediment slumping from the raised beach slope as the permafrost melts, and the second feature may be due to a melting in the spring of the brash ice which was thrown up on shore and buried during the previous fall.

It is not possible to state whether similar variations in individual beach profiles occur each winter, but it is believed that the general lack of a well-developed ice foot in the winter of 1971-72 may have facilitated an increased sea ice movement on the beach face at the beginning and end of the winter period. Overall, the changes are small and of no great significance in the general beach process.

(4) Two Year Change: The beach between Caswall Tower and Cape Liddon has suffered a net loss of sediment of 8.22 M^2 over the two-year period. A general net decrease in beach profile occurred along the beach, except at profiles 8 and 14 where a net increase was found. Areas of erosion in the beach profile were found at the steep, raised beach bluff at the back of the active beach and in the lower beach.

It can be concluded from the foregoing analysis that a considerable change in a given beach profile can occur in any one year, but which, depending on circumstances, may be a net positive change or a net negative change such that, when the results are averaged for the whole beach, less change is observed. In the case of the beach at Radstock Bay, the input of sediment appears to be insufficient to offset the losses of sediment; hence, it has been slightly eroded over the two-year period of 1970-72.

4.10 SUMMARY

The coasts of north Somerset Island and southwest Devon Island are good examples of the High Straight coastal environment; each has a regular coastline consisting of raised beach terraces along the major portion of the shore, and high steep plateau slopes at the headlands. The two study areas are located across Lancaster Sound from each other, but they differ in situation. The beach studied on north Somerset Island lies on a major sea channel, whereas the beach examined on southwest Devon Island is within Radstock Bay; consequently, the open water season is longer at the former location. North Somerset Island experiences a mean open water season of 68 days, whereas Radstock Bay is only open an average of 44 days. A semidiurnal tide is experienced at both places, but because of location Radstock Bay has a 0.5 m greater mean tidal range than north Somerset Island.

The nearshore ice characteristics are similar along both coasts; each exhibits a substantial ice foot, with dimensions of 15 to 16 m wide and 2 to 2.2 m thick, in most years. Ice pitting and ice push are common on either shore, but are best developed on the more exposed coast of north Somerset Island. The push mounds observed in Radstock Bay were generally of a small scale, while similar features found on Cape Ricketts were of a more comparable size to those on north Somerset Island. The mean diameter and depth of the ice formed pits were 3.09 m and 0.63 m, respectively, on north Somerset Island.

The characteristic beach profile was a narrow, relatively steep active beach, backed by a low, steep, raised beach bluff. The mean active beach slope at Radstock Bay was 17.1%; the width of the beach varied, but it was less than 25.0 m. Trends of decreasing grain size and increasing roundness of pebbles, with distance northward from the plateau on the beach at Radstock Bay, have indicated the direction of net longshore drift (McCann and Owens 1970). On the other hand, at north Somerset Island opposing trends in grain size and shape were found on the active and non-active beach with distance from the plateau slopes. The sediment of the non-active beach indicated a movement of sediment from west to east, whereas the analysis of sediment on the active beach indicated a longshore drift from east to west. The Cailleux (1947) roundness value for the sediments from north Somerset Island was 199.1, and from Radstock Bay, 184.0. The beach sediments samples at Somerset Island also contained a larger proportion of sand than the sediment examined at Radstock Bay.

Frost table depths were recorded in early July on Somerset Island and mid-August at Radstock Bay, yet the mean values for each beach were very similar. The mean frost table depth on the beach of north Somerset Island was 32.2 cm, whereas a mean depth of 30.3 cm was recorded on the west shore of Radstock Bay. Aspect is believed the greatest factor affecting the depth of the active layer at Radstock Bay, because the greatest depths of 48.0 cm were found on the south facing beach, while depths of only 20.1 cm were recorded on the east and north-east facing beaches.

Beach profile change over a two-year period at Radstock Bay shows a net loss of 8.22 M^2, which indicates that either the input of sediment was not sufficient over that period to maintain an equilibrium, or the waves were of a destructive rather than a constructive nature. In 1971-72 the beach was built up, but in the previous year it had been combed down by an even greater amount; therefore, a change in beach profile one year can cancel out, or possibly even enhance, the change created in the previous year. It can be concluded that, in the short time period, variation in beach profile at one site is usually much greater than that for the whole of the beach.

CHAPTER V

RIDGE AND VALLEY COASTAL ENVIRONMENT

HOOKER BAY, BATHURST ISLAND

5.1 INTRODUCTION

The "Ridge and Valley" coastal environment, which is part of the Innuition physiographic region, is characterized by an irregular coastline of long, fingerlike peninsulas and intervening inlets. The peninsulas are representative of the most resistant fold rocks; the valleys, of the least resistant. A detailed investigation of a short stretch of coast within this coastal environment was completed during the first two weeks of August, on the west coast of Bathurst Island. Hooker Bay (75° 23'N, 100° 30'W), the site of the detailed study, is situated at the southern entrance to Graham Moore Bay where the ridge and valley topography is particularly well developed. To the south of Hooker Bay, the coast is more characteristic of the Arctic Coastal Plain, with low relief and numerous consequent streams. It was originally planned to extend the investigations to this low, sandy coastline, but landing difficulties and poor weather curtailed operations. Consequently, this chapter on the Ridge and Valley coastal environment is restricted to the information obtained within Hooker Bay and the immediate surroundings.

5.2 COASTAL MORPHOLOGY AND BATHYMETRY

Graham Moore Bay and northeastern Viscount Melville Sound are both relatively shallow, with maximum soundings of only 125 fathoms, and more common depths of 80 to 100 fathoms (Hydrographic chart No. 7078). There are no actual depths given within Hooker Bay but it is presumed to be shallower than 17 fathoms (Figure 5.1). Foreshore flats or shallow waters are also indicated along the entire shoreline of the bay, on the Graham Moore topographic map (68G). The two large shoal areas within Viscount Melville Sound (Figure 5.1) are too distant to really affect coastal processes within Hooker Bay, but they could promote the grounding of sea ice and delay its final removal from the Sound, thus decreasing the amount of possible wave action.

The coastal environment of southwestern Bathurst Island is part of a low marine plain which extends from Allison Inlet on the southern Bathurst shore to Cape Cockburn and north to the head of Hooker Bay . The coast is low, flat and featureless, with numerous small streams crossing the area at right angles to the shoreline. The majority of these streams are intermittent, and have usually dried up by early August. In the vicinity of De la Beche and Peddie Bays, the broad sandy beaches rise gently and slowly to the low, vegetated plain further inland (Figure 5.2). Raised beach terraces are also very prominent along these shores, but particularly so at the headlands of the bays and inlets. At the sides of the inlets, the vegetation and solifluction activity have covered the raised beach terraces and

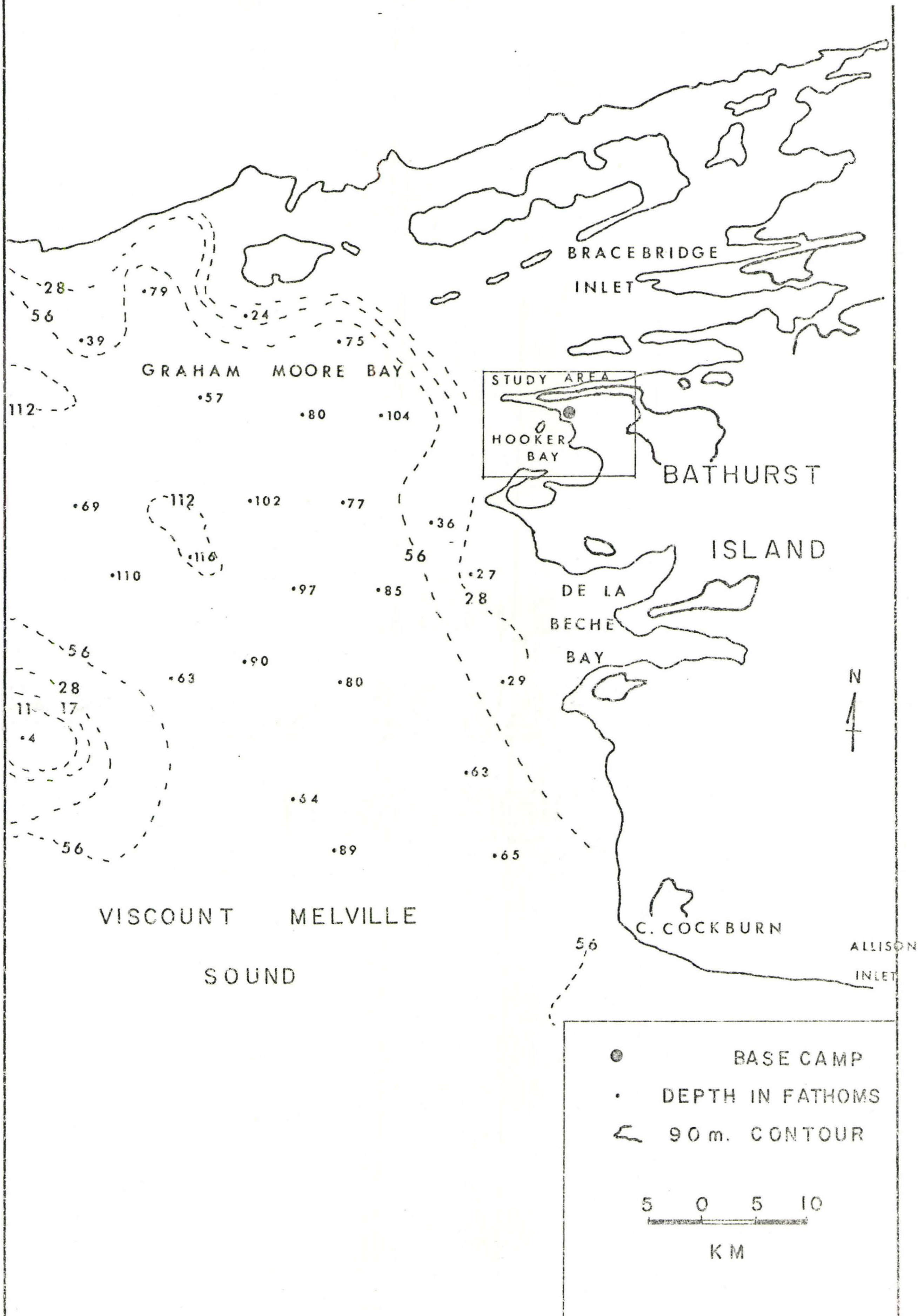

BRACEBRIDGE
INLET
GRAHAM MOORE BAY
STUDY AREA
HOOKER BAY
BATHURST
ISLAND
DE LA BECHE BAY
C. COCKBURN
ALLISON INLET
VISCOUNT MELVILLE SOUND
N
28
56
•79
•24
•39
•75
112
•57
•80
•104
•69
112
•102
•77
•36
•116
56
•110
•97
•85
•27
28
56
•90
•63
•80
•29
28
11
17
•4
•63
•64
56
•89
•65
56
BASE CAMP
DEPTH IN FATHOMS
90 m. CONTOUR
5 0 5 10
KM

FIGURE 5.1

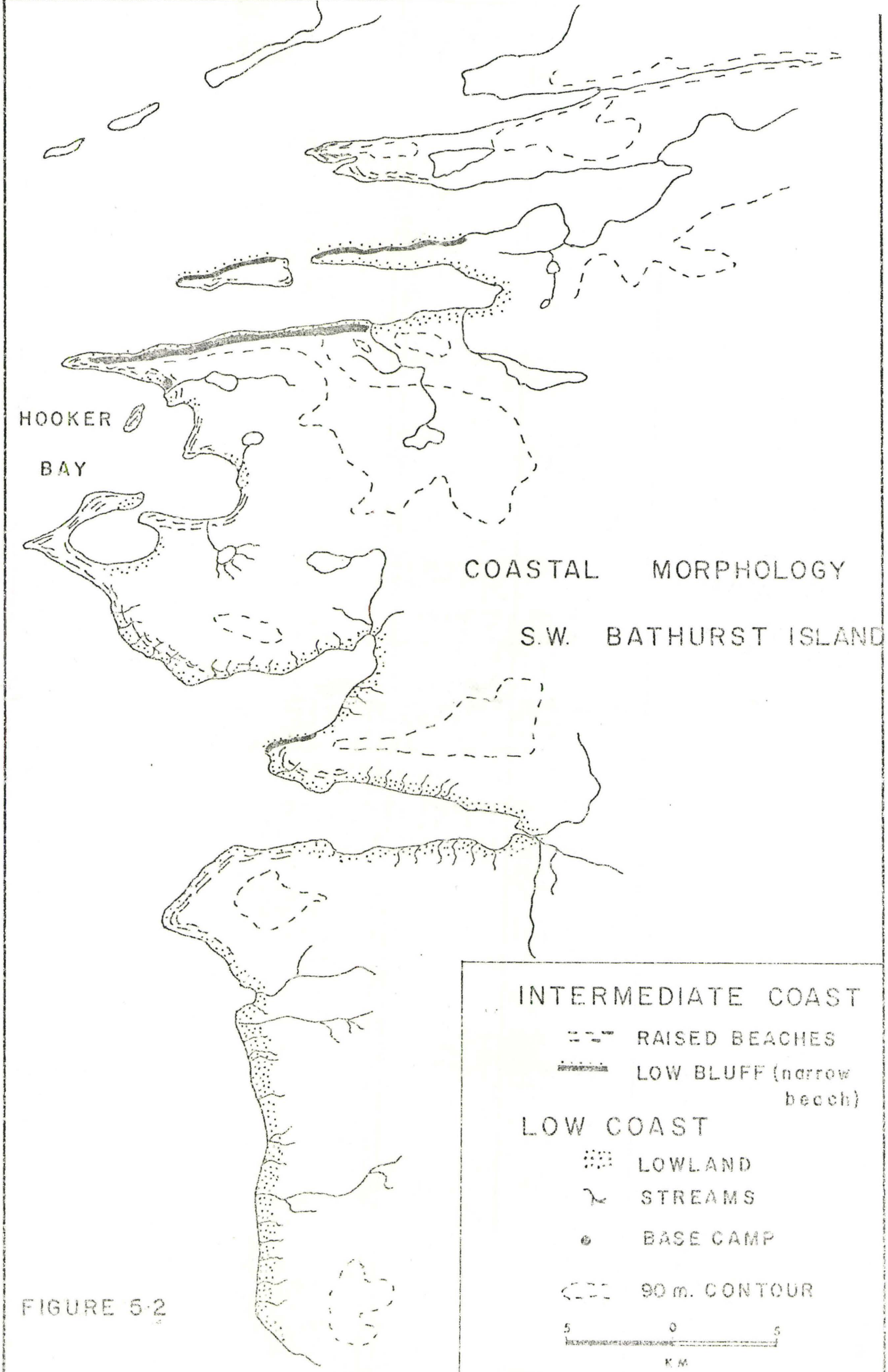


FIGURE 5·2

COASTAL MORPHOLOGY

S.W. BATHURST ISLAND

bedrock to form a gradual rising slope. Although the relief of the land only rises to 90 or 125 metres,several kilometres from the coast three very prominant hills occur; at Cape Cockburn, south of De la Beche Bay and just south of Hooker Bay.

From Hooker Bay northward to the north shore of Bracebridge Inlet, the beaches become narrower and the coast steeper and much higher (60 to 150 m). It is here that the resistant fold rocks oriented in a SSW-ENE direction have created the long peninsulas and strings of islands. These islands, which appear void of vegetation, have a core of solid limestone or sandstone bedrock, covered and fringed by shattered rock debris.

The area of detailed nearshore and beach investigations extended from the south shore of Bracebridge Inlet along the irregular coastline of bays and peninsulas to the south shore of Hooker Bay. Diagnostic characteristics were observed for each of the north, south and west shorelines of the several peninsulas and bays. The northern shoreline is characterized by narrow , steep, active beaches of gravel, backed by a low, steep bluff and a relatively steep slope of coarse gravels and boulders. In many cases, the lower slope is covered by solifluction debris and remnant snow patches which represent the upper limit of solifluction. Raised beach terraces are very prominant on the northern slopes, particularly at or near the western end of the peninsulas. In the latter area, the active beach is once again very narrow, backed by a steep ice push ridge and wide raised beach terraces with intermediate small ponds. Outcrops of sandstone and/or limestone are also very common. On the southern shores, the active beach becomes progressively wider toward the head of the bay, and is composed of fine gravels and sand. Further inland, a much shallower slope of soliflucted debris and vegetation, frequently cut by short streams, exists. At the head of the bays, wide, sandy-gravel beaches, cut by numerous small intermittent streams and usually one larger stream, are the general case. Wide mud flats with some boulder or rock outcrop (Plate 14) are exposed at low tide, particularly adjacent to the major stream outlets.

A small spit occurs at the end of some of the peninsulas, probably as the result of wave action.

5.3 TIDAL CONDITIONS

A brief examination of the daily tidal oscillations was carried out in front of the base camp at Hooker Bay, between the hours of 10:00 C.S.T. August 6th to 03:00 C.S.T. August 7th. Measurements of the water level were obtained every half hour, using an abney level and surveying staff. The data from Hooker Bay was, for purposes of analysis, compared to the predicted tidal heights and times for Winter Harbour(Viscount Melville Sound), the closest appropriate secondary port, and Tuktoyaktuk, the tidal reference port (Table 5.1).

A semi-diurnal tide occurs at all three locations and the mean range in tide is small - less than 1.0 m - on August 8th, approaching new moon. Values for mean tidal range on August 6-7 were greatest at Winter Harbour (0.97 m) and least at Tuktoyaktuk (0.18 m); Hooker Bay had a range of 0.65 m (Figure 5.3). Difficulties arose in the attempt to develop general tidal values for Hooker Bay because of the

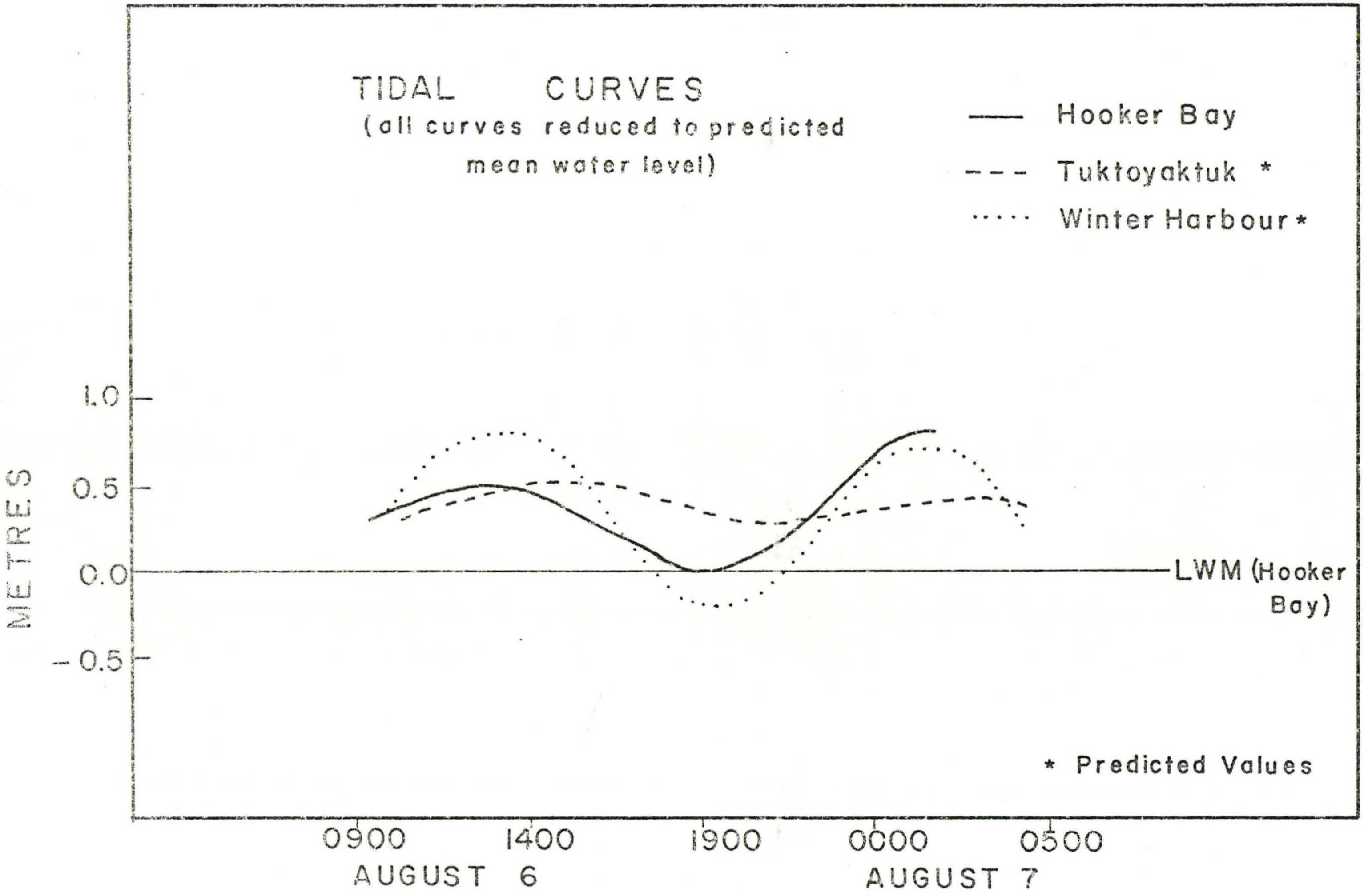

TIDAL CURVES
(all curves reduced to predicted mean water level)
Hooker Bay
Tuktoyaktuk *
Winter Harbour *
METRES
1.0
0.5
0.0
- 0.5
LWM (Hooker Bay)
* Predicted Values
0900
1400
1900
0000
0500
AUGUST 6
AUGUST 7

FIGURE 5·3

TABLE 5.1

Comparisons of Hooker Bay with Tuktoyaktuk and Winter Harbour

Location	Higher High Water		Lower Low Water		Mean water level	Range mean tide
	Mean tide	Large tide	Mean tide	Large tide		
Tuktoyaktuk*	0.60	0.70	0.30	0.20	0.40	0.30
Winter Harbour*	0.37	0.64	-0.24	.40	0.49	0.91
Hooker Bay (proposed values)	0.39	-	0.15	-	-	0.68

*published values

	Mean High tide	Mean Low Tide	Mean water level	Range Mean tide	Period (in hours)
Tuktoyaktuk #	0.06	0.12	0.54	0.18	11.5
Winter Harbour #	0.34	0.60	0.83	0.97	12.0
Hooker Bay°	0.25	0.39	0.39	0.65	13.0

predicted values

° observed values

All heights given in metres

inconsistencies found between the published and predicted values for the other two locations. Nevertheless, it is believed that the mean tidal range of Hooker Bay would approximate 0.68 m. The tidal period, a function of geographical position, was longest at Hooker Bay (13 hours) and shortest at Tuktoyaktuk (11.5 hours).

5.4 SEA ICE CONDITIONS

Information, in detail, on sea ice conditions within Hooker Bay is nearly non-existent because of its location and lack of importance for ship navigability. Nevertheless, data of sea ice cover offshore of the western side of Bathurst Island is sufficient to draw inferences about the ice conditions in Hooker Bay.

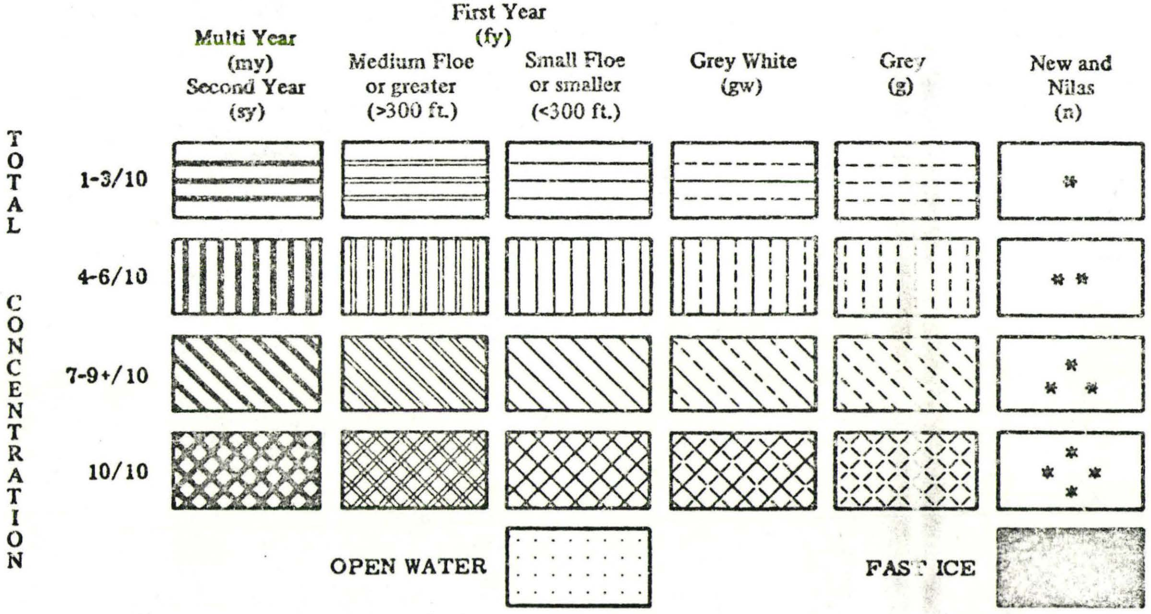
SUMMER OF 1958

Aerial photographic coverage of Hooker Bay taken in mid-August of 1958 permits an appraisal to be made of sea ice conditions within the bay during one particular year, and also provides an insight into the relationship between sea ice cover in Viscount Melville Sound and Hooker Bay (Figure 5.4). There was no evidence of fast ice of any type along the shores; in fact, open water existed at the head of Hooker Bay, De la Beche Bay and Bathurst Inlet. A narrow strip of open water could be observed along the entire shoreline, even where solid ice cover still existed offshore. Leads and fractures radiated outward from the headlands and islands, which acted as centres of sea ice breakup. The ice in northern Melville Sound was, however, still complete. The centres of sea ice disintegration within Hooker Bay appear to have been at the

ATMOSPHERIC ENVIRONMENT SERVICE

KEY TO ICE SYMBOLS

PREDOMINANT AGE



CONCENTRATION AND SIZE BY AGE

$$\frac{\text{Tenths of each Age}}{\text{Tenths of Medium Floe or Greater}}$$

$$\frac{C_{my}}{N_{my}}\frac{C_{sy}}{N_{sy}}\cdot\frac{C_{fy}}{N_{fy}}\frac{C_{gw}}{N_{gw}}\frac{C_{g}}{N_{g}}\frac{C_{n}}{N_{n}}$$

Example $\frac{2}{1}\frac{0}{}.\frac{3}{2}\frac{4}{3}\frac{1}{}\frac{0}{}$

$\frac{2}{1}$ – 2/10's Multi Year of which
1/10 is Medium Floe or greater

0 – No Second Year

. – Decimal Point

$\frac{3}{2}$ – 3/10's First Year of which
2/10 is Medium Floe or greater

$\frac{4}{3}$ – 4/10's Grey White of which
3/10's is Medium Floe or greater

1 – 1/10 Grey, no Medium Floe or greater

0 – No New

SNOW COVER

$\frac{Sn}{(n)}$

(n) tenths on ice

TOPOGRAPHY

$\frac{\text{ΛΛ}}{(n)}$ Rafted Ice

$\frac{\text{ΛΛΛ}}{(n)}$ Ridged Ice

SURFACE FEATURES

Sn/Ra Rd Hy Pd Th + F

$\frac{\text{ΩΩ}}{(n)}$ Hummocks

(n) number of tenths

"e.g. 6/1201"
6 – 6/10 Snow Cover
/ – Slant
1 – 1/10 Rafting
2 – 2/10 Ridging
0 – No Hummocks
1 – 1/10 Puddling

STAGE OF MELTING

$\frac{Pd}{(n)\ (n)\ Th + (n)\ F}$

(n) = tenths on ice
(n)th = tenths thaw holes
(n)F = tenths frozen

ICE OF LAND ORIGIN

Δ – (n) Icebergs

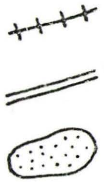
⏢ – (n) Bergy Bits and growlers

Optional:
(n) – number in area

THICKNESS OF ICE AND SNOW

$\frac{T\ \ S}{n\ \ n}$ (n) – nearest inch

WATER FEATURES



Crack

Lead

Polynya

UNDERCAST

Limits

BOUNDARY

——— Observed visually

—✕—✕—✕— Observed by radar

— — — Assumed

○ ○ ○ Limit of Observed data

○✕○✕○ Limit of radar data

Symbols used for Recording the Various Ice, Snow, and Water Features

SEA ICE CONDITIONS (AUG.10 1958)

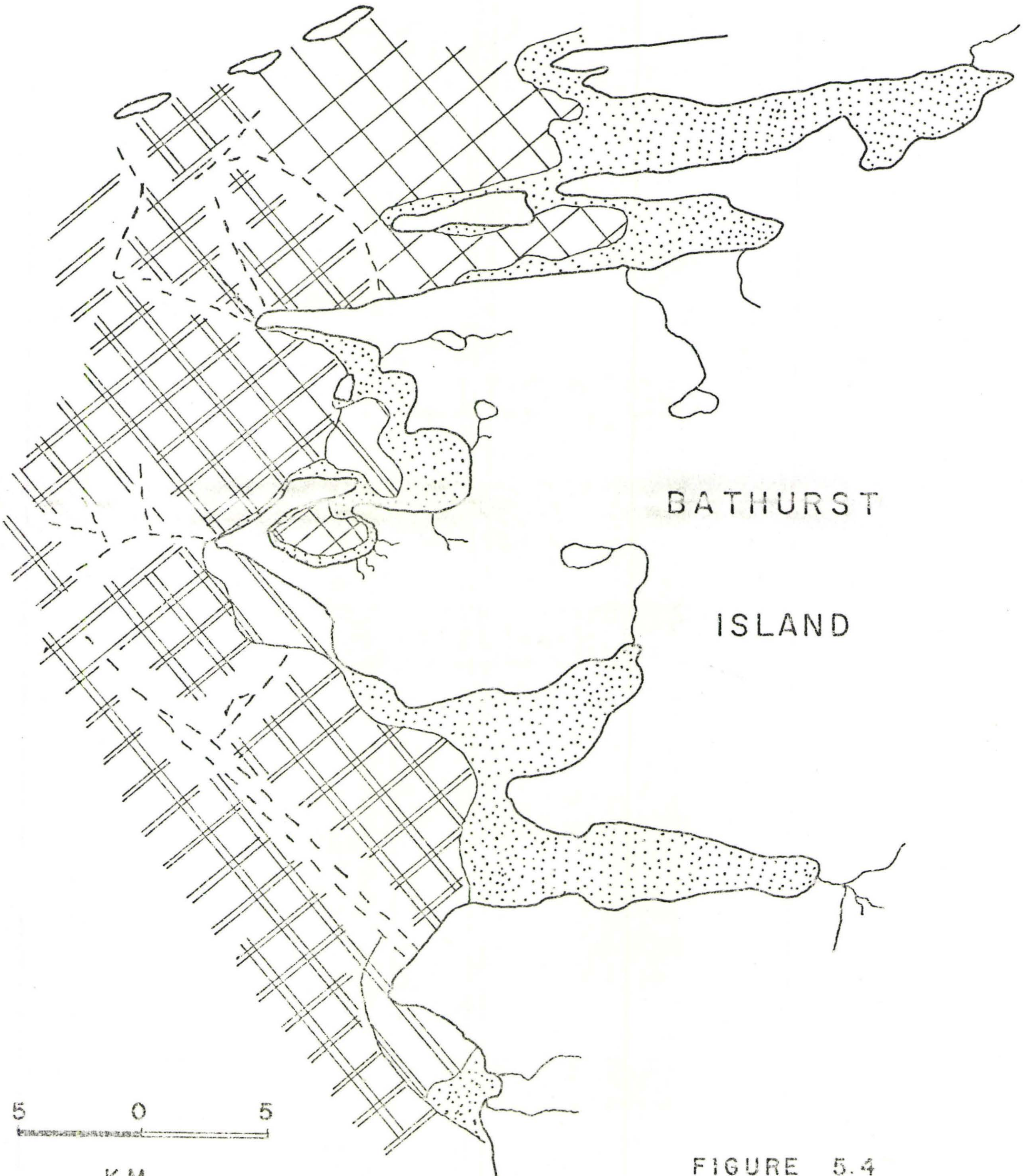


FIGURE 5.4

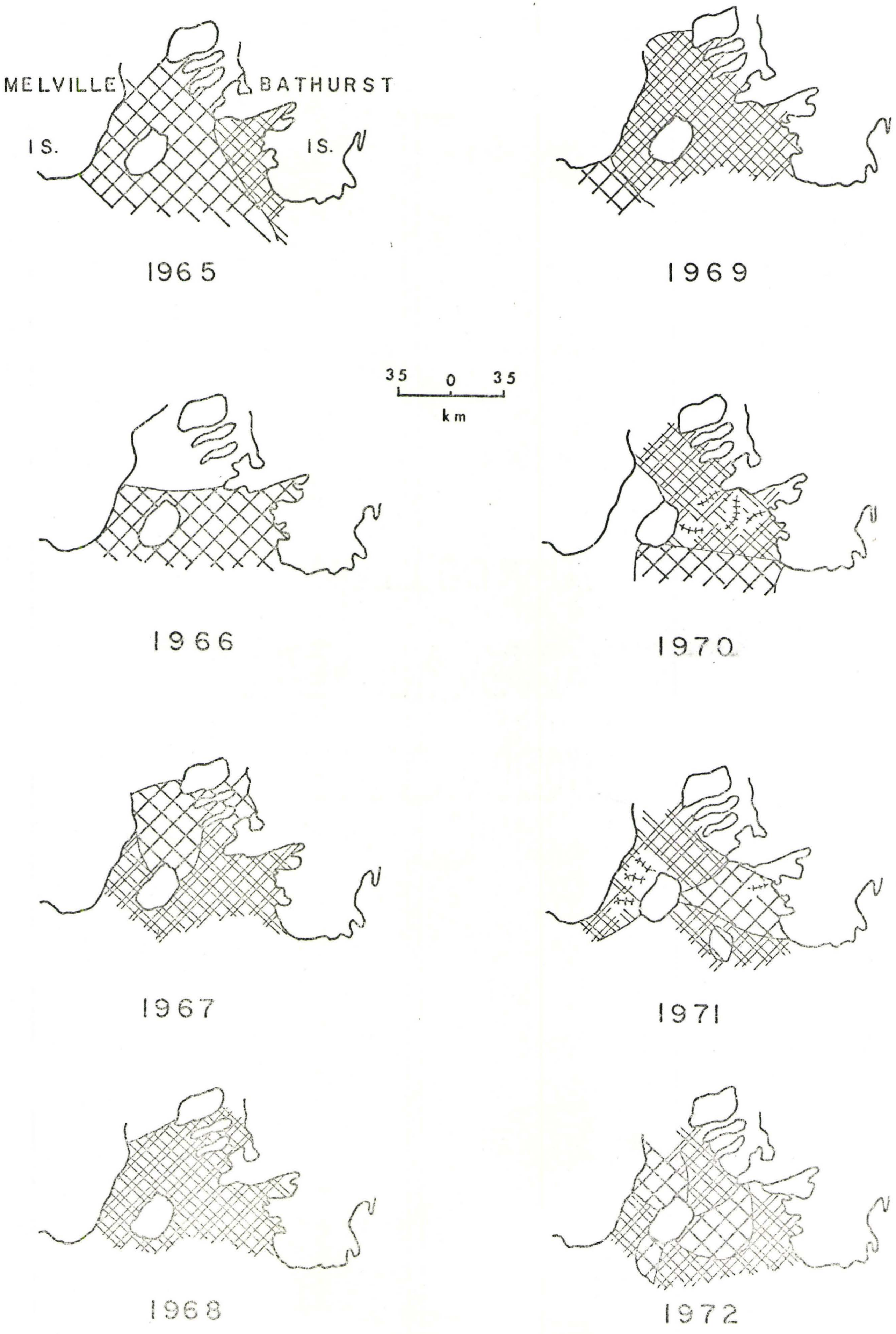
mouth of the large streams or wherever substantial fluvial discharge occurred during the spring melt. Melting in situ and wind action were probably two important factors in the final removal of ice from the bay. If the 1958 ice conditions are indicative of other years at the same time period, then one can assume that wave action is limited, since a fetch of open water of less than 6.0 km is possible.

1965 - 1972

The ice observations of the Ice Division of the Atmospheric Environment Service provide the only available record of ice conditions during this period. Sea ice cover for each of the eight years has been summarized in Figures 5.5, 5.6 and 5.7. Each indicates the ice conditions in the third week of the three months of July, August and September, unless otherwise stated.

In July, the inlets and channels are completely covered with multi year or thick winter (first year) ice, and, except for the initial formation of tidal cracks and leads and the melting of surface smow, little happens. By mid-August, open water areas have been created in one or all three of the following locations: Byam Martin Channel, Byam Martin Island and the south shore of Bathurst Island. In addition, many of the bays and inlets may contain substantial open water by this time. In the most favourable years, e.g. 1970, wind action creats a linkage of the centres of ice breakup, resulting in nearly complete open water conditions between Bathurst and Melville Islands. On the other hand, under less favourable conditions the open water areas will only expand slightly or not at all. It would

JULY 23rd (Figure 5·5)



1965

1969

1966

1970

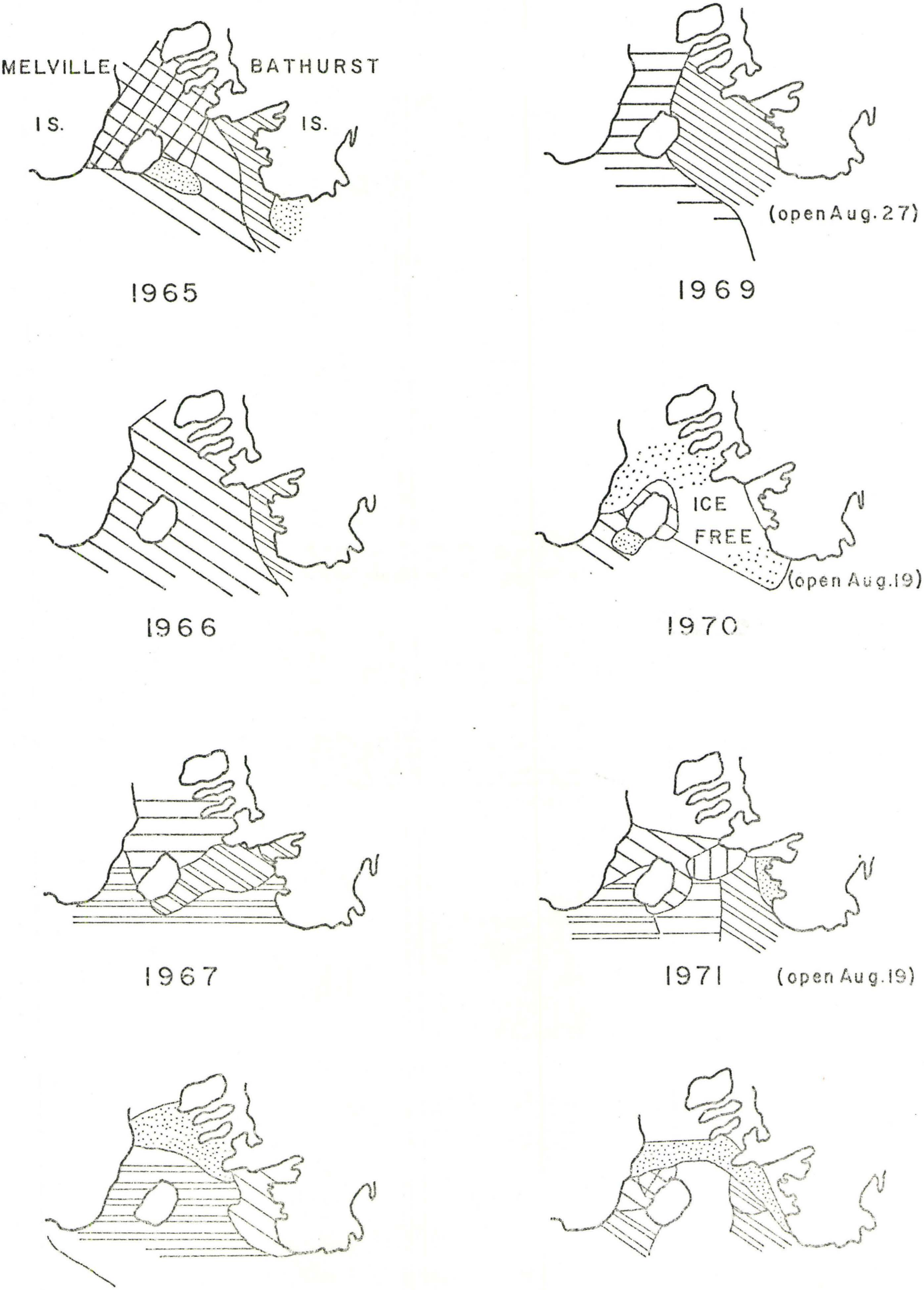
1967

1971

1968

1972

AUGUST 20th (Figure 5·6)



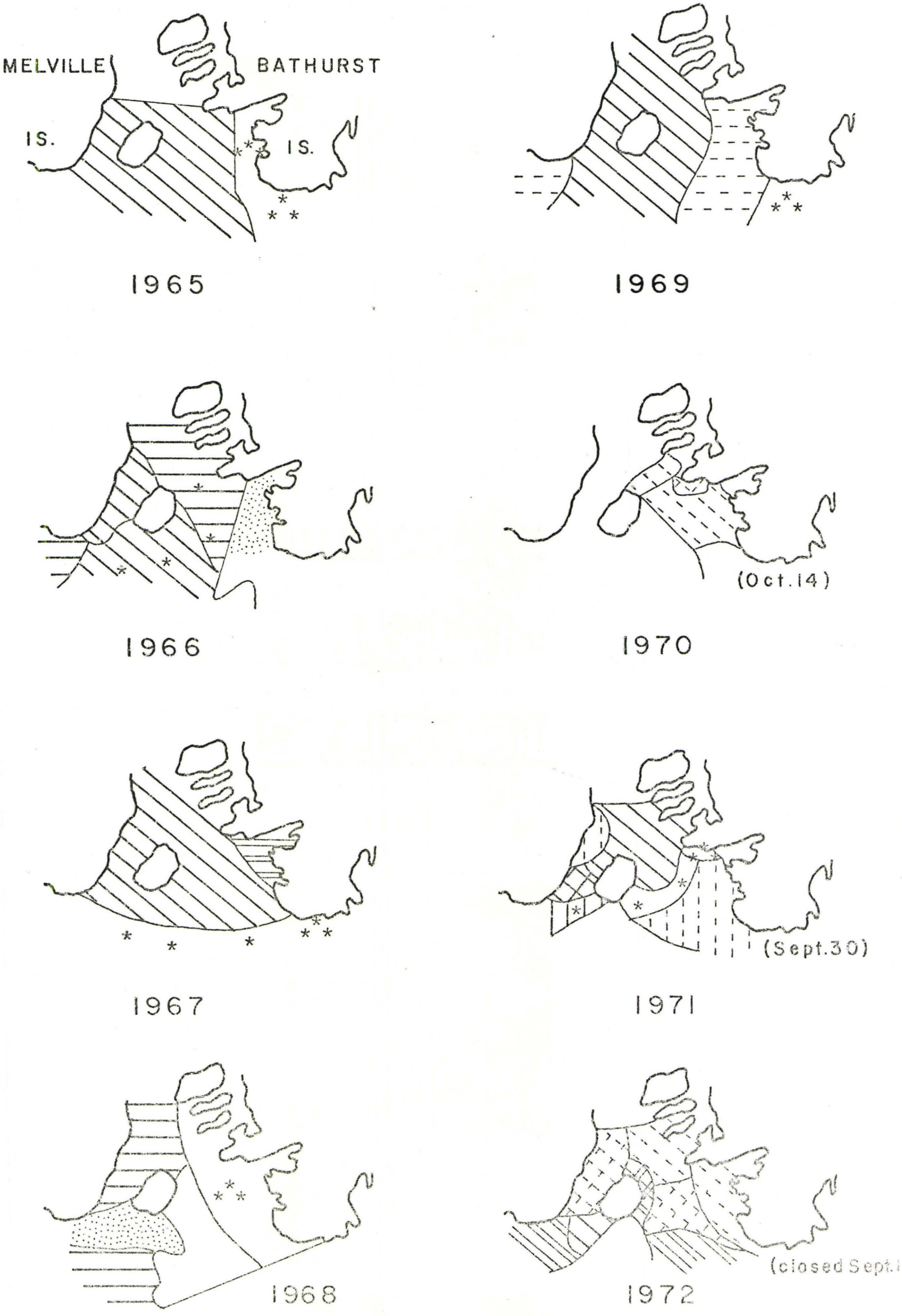
1965 1969

1966 1970

1967 1971

1968 1972

SEPTEMBER 24th (Figure 5·7)



1965

1969

1966

1970 (Oct.14)

1967

1971 (Sept.30)

1968

1972 (closed Sept.

appear that maximum open water conditions occur in the first two weeks of September.

The length of open water season in Hooker Bay was calculated using complete open water as the beginning of the season, and at least 7-9/10ths new ice at the end (Table 5.2). The basic data is derived from information relating to the western coast of Bathurst Island, particularly near Hooker Bay. Assuming that there was no open water in the bay during 1967 and 1968, the mean length of open water season for the eight year period was only 25 days. The longest open seasons were recorded in 1970 (46 days) and 1966 and 1971 (42 days). In an average year, Hooker Bay is open by August 30, and frozen over again by September 24. Wave action in Hooker Bay is possible before the dates given in Table 5.2; however, wave action is probably prohibited in the bay at an earlier date than in Viscount Melville Sound. Freeze-up probably occurs very easily within Hooker Bay, given appropriate temperatures, because of its shallow bathymetry and sheltered location. Sea ice conditions on August 10th are shown in Figure 5.8, and the ice cronicle for the first two weeks of August 1972 is given in Appendix E.

Larger ice floes and multi-year ice were observed to linger in the north-central portion of Viscount Melville Sound, a fact which substantiates the earlier remark that the shoals, present there, hinder the removal of ice.

TABLE 5.2

OPEN WATER SEASON
(Western Shore of Bathurst Island)

Year	Break-Up	Freeze-Up	No. of Days
1965	Sept. 10	Sept. 24	14
1966	Sept. 10	Oct. 22	42
1967	9/10 thick winter ice (Aug. 20)	Sept. 24	0
1968	7-9/10 thick winter ice (Aug. 20)	Sept. 24	0
1969	Aug. 27	Sept. 24	28
1970	Aug. 19	Sept. 24 - Oct. 14	(36 - 56) 46
1971	Aug. 19	Sept. 30	42
1972	Aug. 20 (approximately)	Sept. 13	24

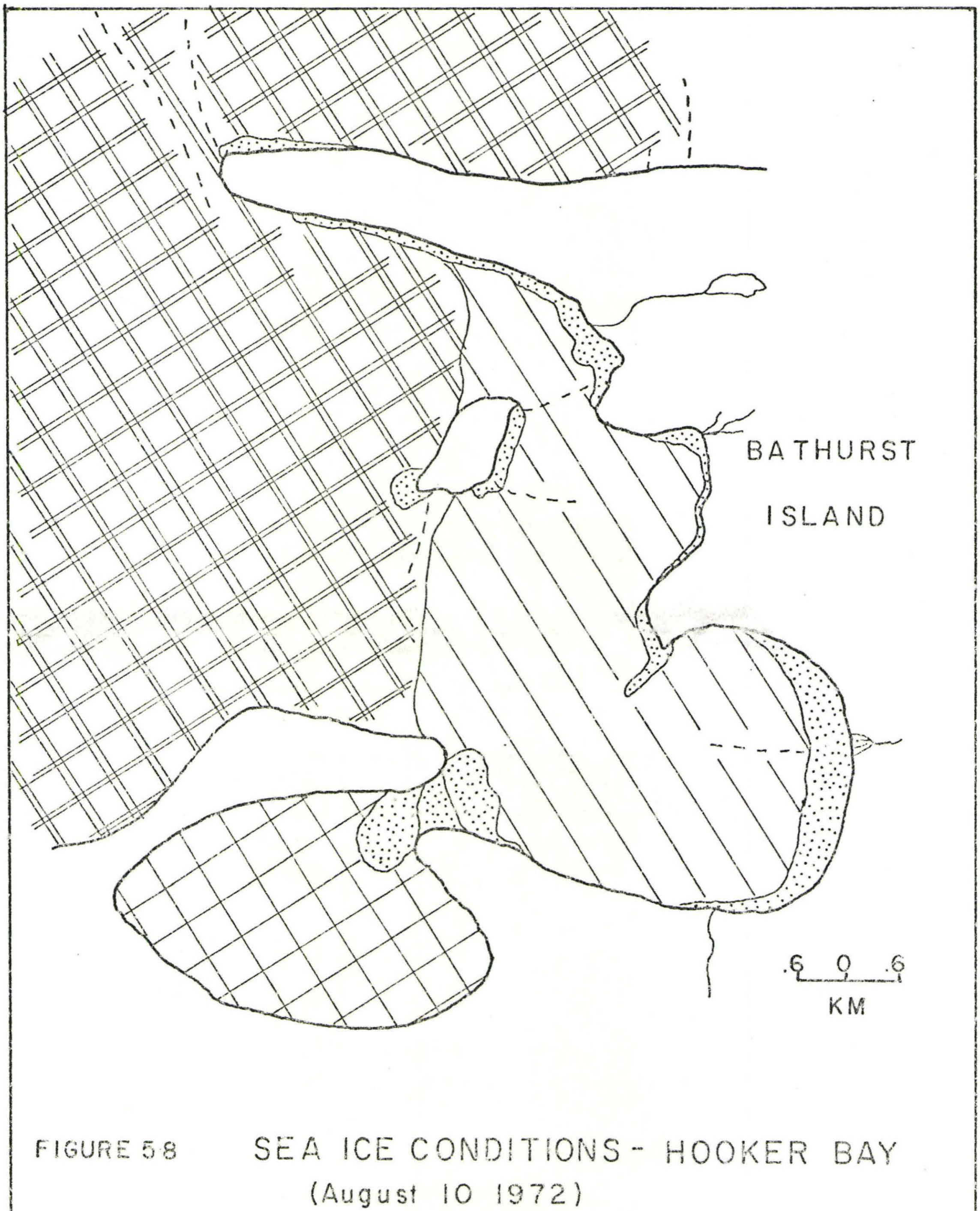


FIGURE 58 SEA ICE CONDITIONS - HOOKER BAY
(August 10 1972)

5.5 BEACH AND NEARSHORE CHARACTERISTICS

BEACH PROFILES

A set of 10 profiles were surveyed along the shoreline of Hooker Bay (Figures 5.9, 5.10). The location of the profiles was selected so that comparable sites along the shoreline of the peninsulas and small bays could be examined. Bench marks (of stakes) were usually placed at the base or top of the low bluff found at the rear of the beach zone. In situations where the beach was very wide, the bench marks were fixed on one of the small, raised beach ridges.

Profiles C and I, which are located at the end of peninsulas, and profiles A and ~~O~~ D which have similar characteristics, can be discussed together. The active beach at profiles A,C and D are backed by a low bluff, 0.5 to 1.5 metres high, and have a narrow, steep beach face, 2-4 metres. Slope gradients of 19.2% and 18.2 % were obtained at profiles A and C, and 13.3 % at profile I. Although these gradients were the steepest of the ten profiles surveyed, profile I, which had the shallower gradient and wider beach face (11 m), was more comparable to the rest of the profiles. The width of the active beach varies from 7.0 to 12.0 m at profile B, E and H, and the steepness of the slope is nearly identical at all three locations (11.6 to 11.8 %). However, the latter two profiles differ from the first because there is a much wider and flatter backshore zone, up to 40 m wide. A depression once filled with water occurs in the backshore zone of profiles E and H. Beach development is greatest at or near the head of the bays where large rivers provide sediment for reworking by marine processes. Profiles

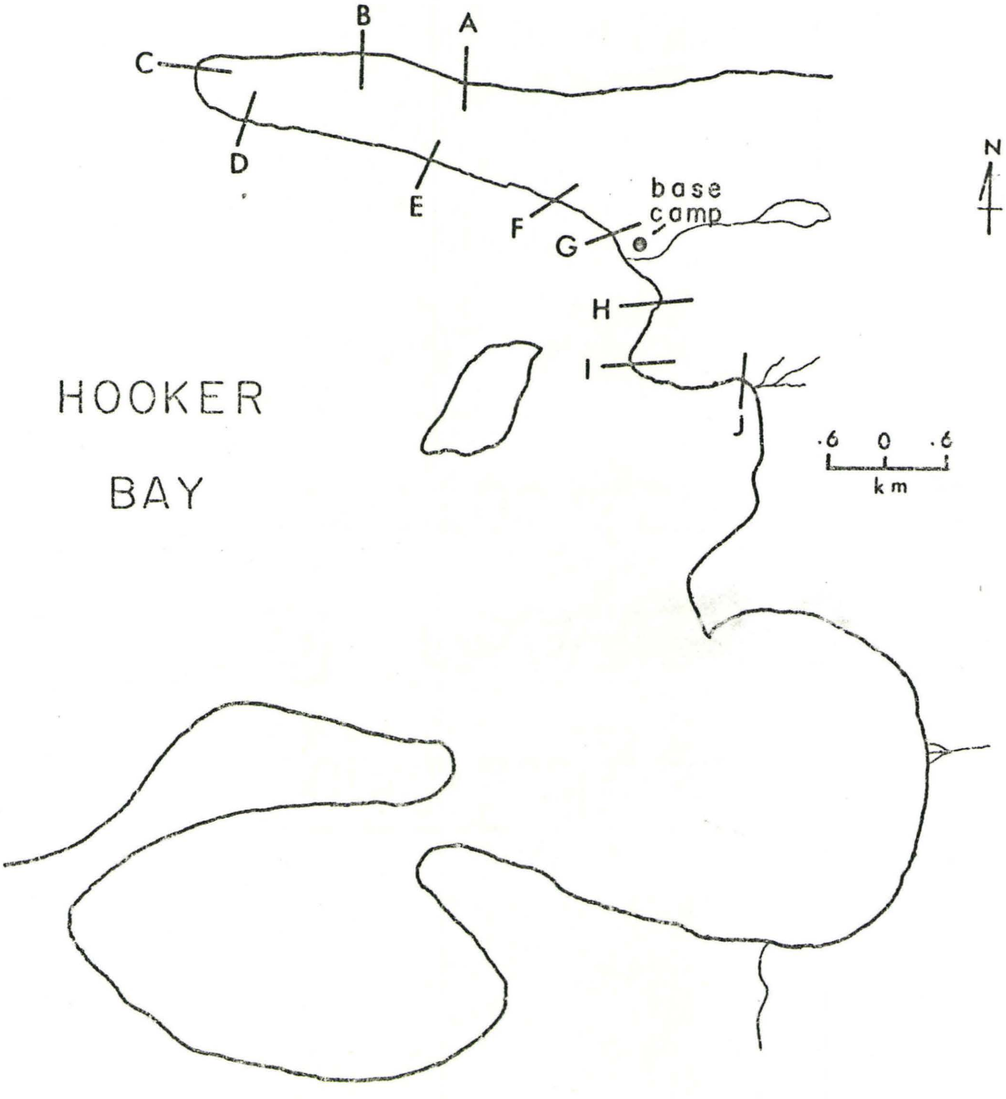
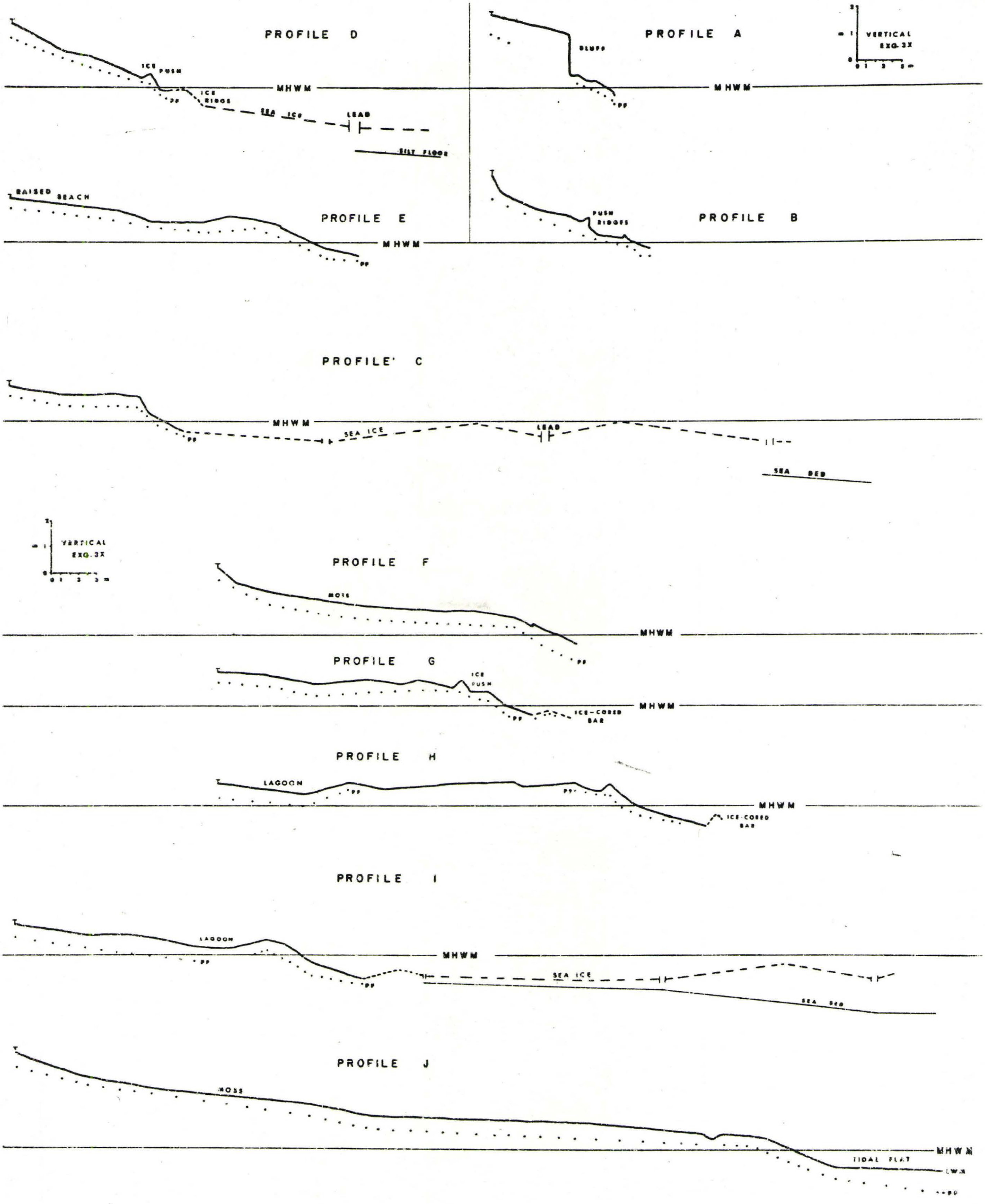


FIGURE 5·9 LOCATION OF BEACH PROFILES

BEACH PROFILES – HOOKER BAY, BATHURST ISLAND



F, G and J are representative of the bayhead beaches and have beach zones over 40 m wide which are backed by low moss covered bluff. This bluff marks the interior limit of the beach zone. These profiles are also characterized by the widest active beach, 11 - 12 m , and the shallowest beach face slope. The gradients calculated ranged from 8.5% (profile G) to 10.9 % (profile J). The offshore depths at the last three profiles are very shallow, with a nearshore topography of ice-cored mounds, boulders and sandy-mud flats being exposed at low tide. In fact, at profile J, it was possible to walk offshore for 12.0 m, on the exposed sand flats. Additional nearshore depths were recorded to profiles C,D and I where the measurements could be made from the sea ice which still existed alongshore. In each case, the nearshore is very shallow, but at the side of the peninsulas there appears to be a greater slope (at a comparable distance) than at the end of the peninsulas (Figure 5.9). Offshore at profile C (112 m) a depth of 1.7 m was found on a bedrock floor, where a shallow rock platform is believed to extend considerable distances offshore.

BEACH SEDIMENT

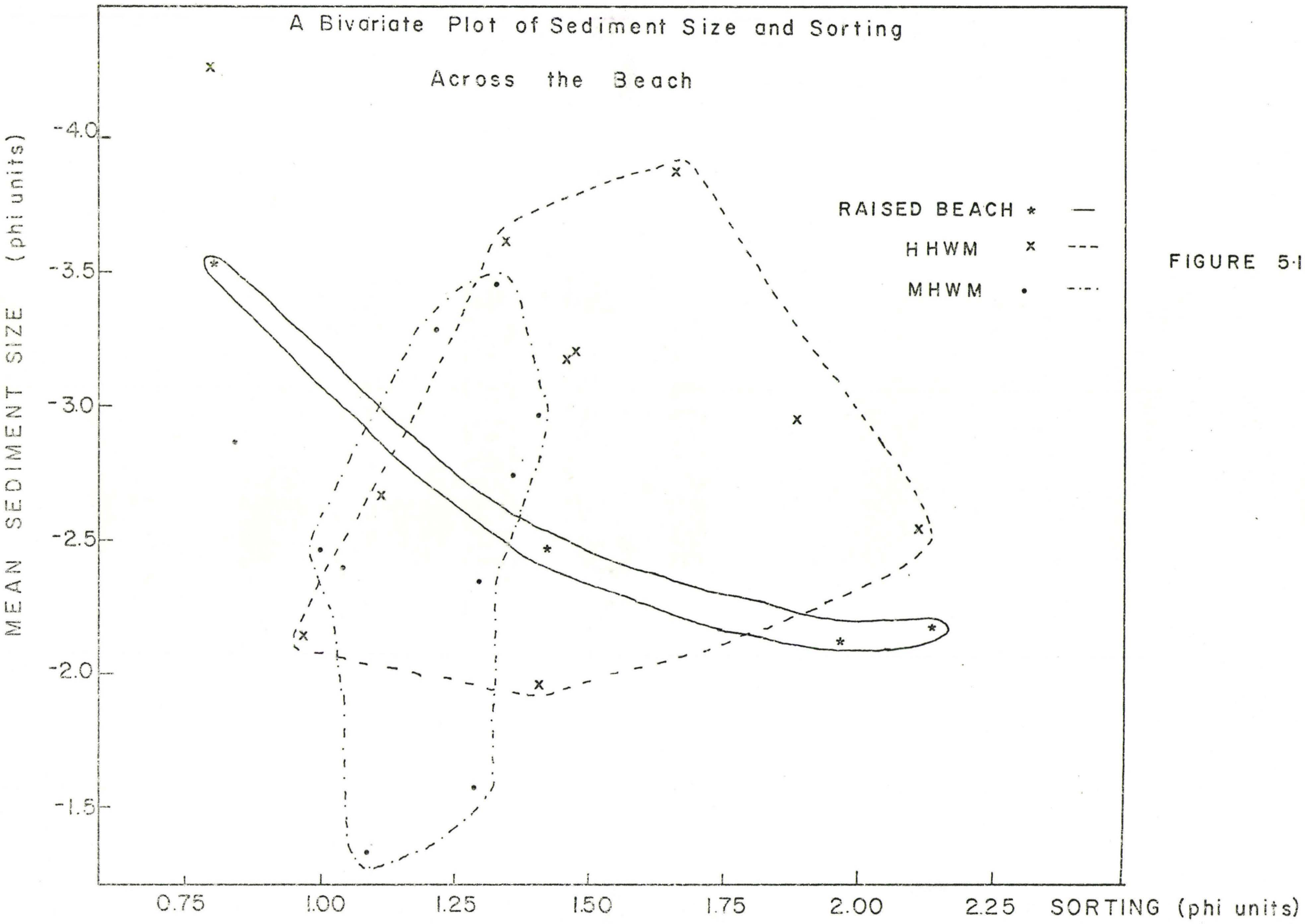
(1) *Grain Size Analysis:* Samples of beach sediment were collected at three locations across each of the surveyed beach profiles and on the exposed offshore flats at profile J.

The sorting in each of the samples was poor to very poor, except for two of the samples collected at profile I which were moderately sorted. Sorting, which provides an indirect measure of wave energy, testifies, in this case, to the "Enclosed" annual sea ice conditions (Chapter 11) and the fact that Hooker Bay is very sheltered from wave attack over a long fetch. A more detailed examination of the sorting values reveals that the best sorting occurs on the northwestern end of the headlands (profiles B and I), and the poorest on the sheltered southern side of the peninsulas.

The beach sediment is fine gravel (<-4 ∅) and contains varying amounts of sand. A trend in mean grain size occurs both along the beach and across it. The sediment becomes progressively coarser outward from the head of the bays to the end of the peninsulas or headlands where the coarsest sediment (-3.5 ∅) was observed (Appendix C,D). This is partially the result of the quantity of sand in the samples which decreases in proportion outward from the head of the bays. The largest proportion of sand occurs in the sample from the offshore flats, which consisted of 75% sand and had a mean grain size of +0.26 ∅. It is believed that there are two sources of sediment in Hooker Bay: the first is the erosion at the tip of the headlands and the second is the large streams at the head of the bays. A dual source of the beach sediment along the peninsulas is substantiated by the bimodal grain size distribution of those sediments as compared with the unimodal distribution for the rest of the samples. A bivariate plot, using mean grain size and standard deviation (sorting), further emphasizes differing sediment characteristics along the shore (Figure 5.11). Moreover, the sediments from the head of the bays and the side and end of the peninsulas may be differentiated.

A further trend in grain size distribution may be observed

FIGURE 5·11



A Bivariate Plot of Sediment Size and Sorting Across the Beach

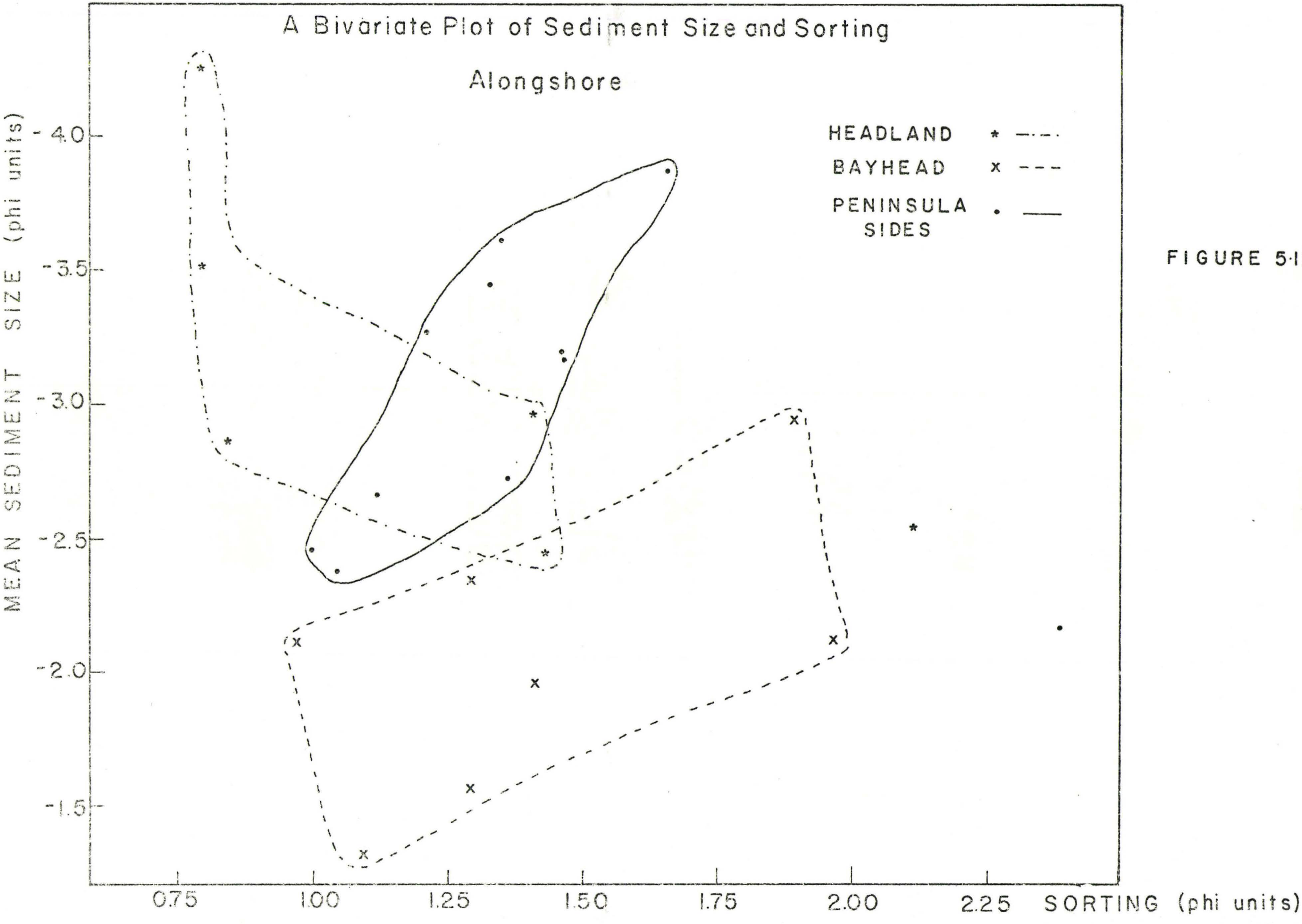

A Bivariate Plot of Sediment Size and Sorting
Alongshore
HEADLAND * —·—·
BAYHEAD x - - -
PENINSULA SIDES • ——
MEAN SEDIMENT SIZE (phi units)
-4.0
-3.5
-3.0
-2.5
-2.0
-1.5
0.75
1.00
1.25
1.50
1.75
2.00
2.25
SORTING (phi units)

FIGURE 5·I

across the beach. There, the sediment increases in size upslope from MHWM, and, as would be expected, the proportion of sand in each sample decreases upslope from MHWM. This clear demarcation of sediments across the beach is not so distinct when shown on a bivariate plot ($\overline{X}$ vs σ), where considerable overlap between the samples occurs (Figure 5.11). It is considered that the finer sediments are being combed down the beach face and deposited at MHWM where the increased wave action enables the finer sediments to move alongshore.

Little additional information was gained from an examination of skewness values, except that all the samples but those from profile B were positively skewed. Reasons for the finely skewed samples could be the presence of sandstone bedrock and the additional input of fine sediment from the large streams.

(2) Grain Shape Analysis : A study of grain shape along with the size distribution analysis enables a more comprehensive understanding of the coastal processes in Hooker Bay. Roundness values provide an indirect measure of wave energy and the shape and sphericity the agent of deposition and transport (Krumbein 1941, Sneed and Folk 1958),

Measures of flatness,sphericity and shape were calculated for each of the sediment samples used in the size analysis, and roundness values were obtained from five samples. The procedures followed were similar to those used at Makinson Inlet (p.50), and are outlined in Appendix C . The mean value of flatness, sphericity and roundness for all of the samples collected was 461.67, 0.448 and 188.06.

Use of Zingg (1935) and Sneed and Folk (1958) shape ratios reveals that the beach sediments of Hooker Bay are Disc to Bladed

(Zingg) or very bladed to very platy (Sneed and Folk) in shape. A three dimensional diagram of those shapes is shown in appendix C. Using the Cailleux (1947, 1952) flatness index as a measure of shape of the sediments of Hooker Bay allows a more detailed analysis of the spatial distribution of sediment shapes to be made. Flatness values of the sediment sampled alongshore indicated little or no trend. Nevertheless, the lowest values at HHWM were detected at the headlands, while the lowest values recorded at MHWM were observed adjacent to the two large streams. A very noticeable trend in flatness values was found across the beach. The mean flatness values decreased downslope from the non active beach (574.49) to MHWM (373.16). A mean flatness measure of 505.05 was recorded at HHWM.

The scarcity of data prevents a good analysis of roundness; however, the greatest values were found at MHWM (195.9) and became less further upslope, e.g. HHWM = 180.1 . Trends in sphericity values substantiate those of roundness. The most spherical grains were observed at MHWM (0.510 mean), and the least spherical above the active beach (0.391 mean). Alongshore the largest sphericity values found at HH and MHWM were discovered at the two headlands, and also at MHWM adjacent to the two large streams.

Logically, MHWM is the level at which longshore transport would be the greatest, and the low flatness and high sphericity values give added support to this view. The more rounded particles at MHWM also testify to a greater amount of reworking of sediment or abrasion at that level of the beach. The more spherical particles, which are observed at the headlands and adjacent to the rivers, are indicative of a higher energy environment, or the source of an already altered sediment, i.e. fluvial debris. Evidence of longshore transport to the south from the stream near the camp is provided by the presence of rod and elongate shaped pebbles at profiles H and I. Sneed and Folk (1958) found that rivers tended to produce rod-like pebbles, whereas beaches produce disc-like pebbles. Since spherical grains are more susceptible to traction, and flat particles to suspension transport, (Krumbein 1942, Wadell 1934), it seems that suspension is the main agent of sorting across the beach, and traction is the main agent alongshore.

FROST TABLE DEPTHS

The thickness of the active layer across 8 of the 10 beach profiles, C - J, was obtained on August 2nd and 3rd; the remaining two, A and B, were obtained on August 10th. By comparing the average depths for each of the profiles and each of the sites measured across the profiles (Table 5.3), it was found that the frost table was lowest (52.9 cm) at the Bench Mark, i.e. raised beach ridge or top of vegetated bluff and across profile F (55.1 cm). Active layer depths on the beach face slope were greatest at MHWM (44.3 cm) and decreased both further up and down slope. The active layer was, as usual, shallowest at the seaward edge of the profiles, with a mean depth of 29.7 cm being recorded. An examination of the mean depths for each of the profiles as a whole indicated very uniform results. Profiles C to H (excluding F) had mean depths ranging from 34.8 cm at C to 37.8 cm at H, whereas profiles A,B,I and J recorded depths of 44.4 to 49.5 cm. It is difficult to determine the effect of aspect on the frost table

TABLE 5.3

DEPTH OF ACTIVE LAYER AT BEACH SITES, HOOKER BAY

Beach Profile	Raised Beach Ridge	Top of Active Beach	HHWM HHWM	MHWM MHWM	Edge of Ice or Water	Mean Depth	Mean Grain Size (Ø)	Aspect
A (Aug 10)	75.0	37.0	35.0	38.0	40.0	49.5	-3.53	N
B (Aug 10)	82.0	35.0	31.0	40.0	34.0	44.4	-2.52	N
C (Aug 2)	43.0	43.0	28.0	--	15.0	34.8	-2.70	W
D	54.0	--	25.0	--	25.0	37.6	-3.58	SW
E	43.0	33.0	35.0	39.0	21.0	35.6	-3.01	SSW
F	47.0	37.0	66.0	71.0	68.0	55.1	-2.83	SSW
G (Aug 2)	44.0	--	34.0	33.5	12.0	35.4	-1.94	W
(Aug 10)	39.0	--	38.0	44.0	--	39.2	-1.94	W
H	54.0	34.0	49.0	32.0	14.0	37.8	-1.64	W
I	50.0	39.0	44.0	51.0	18.0	45.4	-3.19	WSW
J	51.0	37.0	45.0	50.0	50.0	47.9	-1.68	S
Mean Depth	52.9	36.9	39.1	44.3	29.7	--	--	-

Depths are in centimetres

depths, because all but two profiles were south or west facing and measurements at profiles A and B, which are north facing, were not obtained until August 10th, by which time considerable precipitation had occurred, altering the frost table by an average of 4 cm, as is shown at profile G. When the mean grain size of sediment and the mean frost table depth for each profile were compared, there appeared to be little or no correlation. The greatest depths measured at profile F were found in a medium of -2.83∅. A detailed analysis of sediment grain size and the individual depths measured at the back of the active beach at HHWM and MHWM showed the greatest depths to be associated with sediment of -2.57∅, and the shallower depths with sediment of -3.04∅. However, in spite of these results, very uniform frost table depths were observed over quite a wide range of sediment sizes. Therefore, the degree to which sediment size and aspect affect the frost table depth is still relatively unknown.

BEACH AND NEARSHORE ICE CONDITIONS

The absence of an ice foot, in the nearshore zone of Hooker Bay, contrasted greatly to the well developed ice foot previously observed on both Makinson Inlet, Ellesmere Island and on North Somerset Island. Instead, a zone of open water existed from 40 to 175 metres offshore along the bay, except within Graham Moore Bay and at the end of the peninsulas. There, the shore was lined by flat first year ice with a substantial fracture zone within the nearshore. The sea ice was found to cover much of the narrow active beach, and in several places reached the base of the low bluffs. As a result, the spring melt waters were transporting fine sediments onto the ice; furthermore, in some places, the ice had eroded the bluff, causing shore material to fall onto it. Ice rafting is believed to be of only minor importance because of the nature of the ice and coast; therefore, this material is deposited in the nearshore zone where the nearshore marine processes redistribute it, e.g. longshore drift.

An additional phenomena which contrasted with the other coastal environments visited, was the flatness of the sea ice and the lack of ridged ice within the fracture zone, especially in the bays and inlets. The more common large scale pressure ridges of sea ice were observed offshore at the western end of the long peninsula. The ice on either side of the tidal shore leads was found to be recessed and, at high tide, was usually filled with pools of water. The flatness of the sea ice surface within the inlets seems to be due to the protection of the offshore island, which prevents a long fetch of wind and shifting sea ice, and to the small tidal range (0.68m) which prevents large scale vertical movements of ice.

Despite the apparent lack of beach fast ice, a series of small, ice-cored, gravel ridges was discovered near low water mark at profiles D, G, H and I (Plate 26). Their characteristics were identical to the ridges found at Makinson Inlet, but their relief or height (.25 to 4 m) was considerably less. The sea ice, which appeared to be subsequently covered by gravels, was exposed at the seaward edge of the larger ridge; the thickness of surface gravels was 25-30 cm. On the much smaller ridge formed further upslope, the thickness of the gravels was 10-15 cm. The latter ridge could have been the result of the grounding of the sea ice which presently underlies the first gravel ridge. Sea ice was often observed grounded on these gravel ridges at low tide. Small, isolated, ice-cored mounds of sand or gravel (anchor ice) were also formed in the shallows near the head of the bays. These mounds were of a small scale (not measured) and observable only at low tide.

Ice push ridges or mounds of various sizes had been created all along the investigated shorelines. The push ridges found along the north and south shores of the peninsulas were small (0.5 m in height, 1-4 m wide), and usually occurred at HHWM. The alignment of the major axis of the push ridges was N or NE and S or SW respectively, on the north and south facing shores. In both cases, the distance of possible fetch was less than 2 km, but because of the size and location of the ridges they would easily be removed during open water conditions. Small push ridges of sand were also observed at the head of some of the bays. At the highly exposed end of the peninsula (south side Graham Moore Bay) large remnant push ridges existed. These ridges constituted, for the most part, the low bluff (1 m) found at the back of the active beach. The base of the ridges had been recently eroded, exposing bedrock and large boulders. The vegetation covering the upper portion of the ridges suggested that the ridges had existed for several years.

With only a small number of large scale ice push ridges and an absence of ice pitting, the major effect of sea ice on the plan or profile of the beach zone is that of its mere presence and the prevention of a long period of open water and resultant wave action.

EFFECT OF STREAMS ON THE NEARSHORE ICE

The coast of south-west Bathurst Island is literally covered by short stream channels, which drain the immediate interior of spring meltwater. These streams had stopped flowing by early August, but during the Spring, at maximum discharge, they are believed to be a tremendous agent of erosion of the nearshore ice. The wide, ice free zone along the shores, containing numerous stream channels, is evidence of this. The dried up stream channels become scars across or along the back of the beach face slope, and could be removed or filled in only if sufficient wave action occurred during the late summer season. If this did occur, it is felt that new channels of spring meltwater could easily be formed the following Spring. The largest open water areas were at the head of the bays where discharge from a much larger river melted the surrounding sea ice. The large amount of sediment which is deposited in the nearshore zone, creating large offshore flats and providing sediment for beach development on the adjacent shoreline, is an additional role. The few large rivers which were still flowing by August were also affected by the sea; the low relief of the interior and the coastal zones enabled the sea to flow upstream on a rising tide, and flow back to the sea on a falling tide. The direct results were to enlarge the discharge of the river and raise the level of the lake further inland during high tide. Other effects during high tide were to create brackish water and, on an excessively high tide, fill the surrounding beach lagoons with water and slightly alter (deepen or widen) the main outlet channel at the mouth.

The overall effect of the numerous streams was to clear the adjacent nearshore areas and the small bays and inlets of ice before the major channels became ice free. This contrasts with the Lancaster Sound area because there, the major sea channels become ice free before the smaller inlets which are connected to them.

5.6 SUMMARY

Hooker Bay is situated between two long peninsulas of resistant fold rocks which are very characteristic of the ridge and valley coastal environment. These peninsulas create a coastal environment, sheltered from long fetch waves, within Hooker Bay. Consequently, the pressure ridges of ice, which are common offshore of the long peninsulas, are non existent in Hooker Bay; in fact, the ice surface is very regular and nearly flat. The beach sediments varied from -1.0 to -3.5 ∅ in size, and were very bladed to very platy in shape. The increase in sediment size, sorting and flatness values upslope, and the decrease in roundness and sphericity values upslope from MHWM, indicates that the sediment at MHWM is subjected to the most reworking. The small tidal range (0.68 m), when considered with the sediment characteristics, suggests that longshore transport also may be greatest at MHWM. From the sediment characteristics, it is hypothesized that there are two source areas for sediment - the ends of the headland and the larger streams. The generally poor sorting of the beach sediments reflects the "enclosed" nature of the sea ice cover and the lack of wave action. Based on the ice observations available, Hooker Bay is usually ice free for an average of 25 days, but can be ice free for as long as 46 days, or less than 14.

Narrow, steep slopes (18 - 19%) characterize the active beaches near the end of the headlands, while much wider (11 - 12 m) and more gently sloping (8 - 10%) active beaches are found at the head of the bays. Frost table depths varied from 34 to 55 cm along the shoreline of Hooker Bay, and were observed to be deepest at the non-active beach (52.9 cm). On the active beach, the shallowest depths were found at the water's edge (29.7 cm) and deepest to MHWM (44.3 cm).

There was little or no fast ice within Hooker Bay, because of the "moat" of open water which fringed the entire shoreline. The numerous small streams and fewer large streams were the prime factors in the melting of the nearshore ice. Ice-cored ridges were observed near LWM at profiles F and G. These ridges were smaller in scale, (.4 m beachside), than those found at Makinson Inlet, but were covered by a similar depth of sediment 10 - 30 cm. In addition, small mounds of ice were observed at low tide on the offshore flats, near the head of the bays. It is not known if the ice has recently formed and just covered some boulders, or is multiyear ice which has increased in thickness over a period of time from the bottom of the bay. Ice push ridges, consisting either of sand or gravel, were common at HHWM throughout Hooker Bay. However, their location and small scale (1 - 4 m wide) makes them vulnerable to any substantial wave action that might occur. The greatest effect which the sea ice has had on the beach profile and coastal processes in Hooker Bay is its mere presence over much of the year.

CHAPTER V1

DIFFERENCES IN DESIGNATED COASTAL ENVIRONMENTS USING FIELD OBSERVATIONS

DIFFERENCES IN DESIGNATED COASTAL ENVIRONMENTS USING FIELD OBSERVATIONS

6.1 INTRODUCTION

In Chapter 11, twelve coastal regions for the Arctic Archipelago were defined, using morphology, tidal range and length of open water season as criteria for subdivision. It is appropriate now to summarize the information collected in the field, in 1972, to determine if further differences occur between each of the designated coastal environments. By considering the information on beach profile and beach sediments, it is possible to assess the differences in the magnitude of marine processes occurring between each of the study areas. Also, consideration of the characteristics of fast ice at each of the beaches examined allows a better understanding to be reached of where and how the various types of fast ice form.

6.2 BEACH PROFILE

A major characteristic of the beaches within the Arctic Archipelago is the steep beach face slope which was evident at each of the five beaches examined. The mean beach slope of all the profiles surveyed was 14%, and is representative of beach conditions of the previous fall, since wave action had not yet begun for 1972. The mean beach slope for each of the beaches varied from 13.0% at Hooker Bay, to 17.1% at Radstock Bay. The steep nature of the beach is a reflection of the short open water period, the resultant lack of constructive long period waves and the coarse beach material. Situation is also an important factor of beach profile because at the headlands, where the greatest wave energy is expended, the beach slope is quite steep and usually backed by a low, steep, raised beach bluff. In the embayments, on the other hand, a lower backshore morphology is found, and the beach slope is more gradual. For example, at Hooker Bay, Bathurst Island, the headland beach slopes were 18% and 19%, while only 8% to 10% slopes were observed on the bayhead beaches.

In terms of distinguishing the different coastal environments based on beach profile, only, general comments can be made, since the beach profile is dynamic and the 1972 profiles represent only one period of time. The best developed beaches, in relation to temperate beaches, were those at Eclipse Sound where the beach was wide, had a flat backshore and a gradual sloping foreshore (figure 3.22). The beach profile at Radstock Bay and north Somerset Island was characterized by a steep, step-like profile containing numerous beach ridges and was usually backed by a low, steep, raised beach bluff. The Radstock Bay beach was particularly characterized by a prominent high tide ridge, a function of storm conditions the previous fall, but at north Somerset Island, many large ice push ridges and large pittings were found above HHWM, which indicate a higher energy coast or one subject to considerable ice and storm wave activity. The higher energy beach environments observed at Eclipse Sound and north Somerset Island are a function of the long open water period of 60 to 67 days. The beach profile of the southeast shore of Swinnerton Peninsula, Makinson Inlet, resembles the profile found at Radstock Bay and north Somerset Island, but the shores of 'Black Band

Valley', Makinson Inlet, which are backed by lagoons, resemble the beach characteristics found at Hooker Bay. A very low relief and generally gradual foreshore slope backed by lagoons or, in some cases, a low bluff, represent the beach conditions at Hooker Bay. Many small ice push ridges were also present in the intertidal zone; however, because of their location, these ridges represent lower energy processes and will be vulnerable to future wave activity.

The lagoons observed at Hooker Bay and Makinson Inlet were generally found adjacent to stream outlets and were usually dried up by late summer. The lagoons only contained an appreciable amount of water when the tide level was very high, or during excessive stream discharge. The lagoon bed consisted of very fine sediments and mucks and had a very deep frost table.

The steep beach slope distinguishes the arctic beaches from many temperate beaches, and the minor differences in profile between the various beaches within the Arctic help to distinguish the different coastal environments, and to some degree reveal the magnitude of the processes at each.

6.3 BEACH SEDIMENT

An examination of the beach pebbles from each of the beaches visited reveal similar trends in size, sorting, shape and roundness, but differences in absolute value (table 6.1). The type of rock from which the beach sediments originate is the determining factor of the sediment shape and size, because it affects the pebbles' resistance to abrasion by littoral processes. The beach sediments sampled from Radstock Bay, north

TABLE 6.1

BEACH SEDIMENT CHARACTERISTICS

1) Sediment Grain Size (ø)

Location	Total No. of Samples	Raised Beach	HHWM	MHWM	Bedrock
N. Somerset	22	-3.95	-3.96	-3.57	Limestone
Radstock Bay	12	--	-4.08	-3.96	Limestone
Makinson Inlet	11	-3.64	-3.25	-3.69	Limestone
Eclipse Sound	12	--	0.00	-0.25	Shield rocks
Hooker Bay	24	-2.57	-3.04	-2.54	Limestone Sandstone

2) Degree of Sorting

Location	Total No. of Samples	Raised Beach	HHWM	MHWM	Mean Length of Open Water Season
N. Somerset	22	1.03	0.86	0.90	68
Radstock Bay	12	--	1.01	0.88	44
Makinson Inlet	11	1.29	0.98	0.97	32
Eclipse Sound	--	No data	--	---	60
Hooker Bay	24	1.65	1.42	1.18	25

3) Sediment Grain Shape (Sneed and Folk)

Location	Total No. of Samples	Raised Beach	HHWM	MHWM
N. Somerset	22	Very bladed	Bladed-platy	Bladed
Radstock Bay	No data	--	--	--
Makinson Inlet	11	Very bladed	Bladed	Bladed
Eclipse Sound	No data	--	--	--
Hooker Bay	24	Very bladed to very platy	Very bladed	Very bladed

4) Sediment Flatness Ratio (Cailleux)

Location	Total No. of Samples	Raised Beach	HHWM	MHWM	Bedrock
N. Somerset	22	317.56	273.16	251.42	Limestone
Radstock Bay	No data	--	--	--	Limestone
Makinson Inlet	11	374.11	302.29	253.44	
Eclipse Sound	No data	--	--	--	Shield rocks
Hooker Bay	24	574.49	505.05	373.16	Limestone Sandstone

5) Sediment Sphericity (Sneed and Folk)

Location	Total No. of Samples	Raised Beach	HHWM	MHWM
N. Somerset	22	0.530	0.570	0.600
Radstock Bay	No data	--	--	--
Makinson Inlet	11	0.500	0.558	0.598
Eclipse Sound	12	--	0.665	0.684
Hooker Bay	24	0.391	0.407	0.510

6) Sediment Roundness (Cailleux)

Location	Total No. of Samples	Raised Beach	HHWM	MHWM
N. Somerset	15	194.88	200.87	201.56
Radstock Bay	12	--	143.20	150.00
Makinson Inlet	11	159.30	186.24	214.53
Eclipse Sound	12	--	383.37	302.91
Hooker Bay	4	--	180.18	195.93

Somerset Island, Makinson Inlet and Hooker Bay were predominantly limestone; however, some sandstone pebbles may have been measured at Hooker Bay. Quartz sand and pebbles from shield rocks constitute the beach sediment found at Eclipse Sound-Pond Inlet, hence a meaningful comparison of sediment characteristics cannot be made between Eclipse Sound and the sediment from the other four beaches.

Mean grain size, which is a function rock type and the distance the sediment has travelled from its source, was finest at Eclipse Sound (0.0 ∅) and coarsest at Radstock Bay where the mean size was -4.02∅. A bivariate plot of mean grain size versus the degree of sorting reveals the similarity between the sediment of Radstock Bay and north Somerset Island, and the difference between them and the other beaches (Figure 6.1).

The degree of sorting and the roundness of the beach material provide an indirect measure of wave energy which is a function of the length of open water season. The degree of sorting varies from moderately well sorted sediment on north Somerset Island, to very poorly sorted sediments at Hooker Bay (Table 6.1). The mean value of sorting for all of the samples collected is 1.11 ∅ which, using the Folk and Ward (1957) sorting parameters, indicates poorly sorted sediment. This low degree of sorting is a function of the short ice free season found in the Arctic. The mean open water season for the five beaches is only 46 days, but has a maximum mean length of 68 days off north Somerset Island and a minimum mean length of 25 days at Hooker Bay. A simple linear regression of sorting values against mean open water season, at each location resulted in a correlation coefficient of -0.76 with a standard error of estimate of 0.10 (Figure 6.2). A graph of open water period against mean sorting

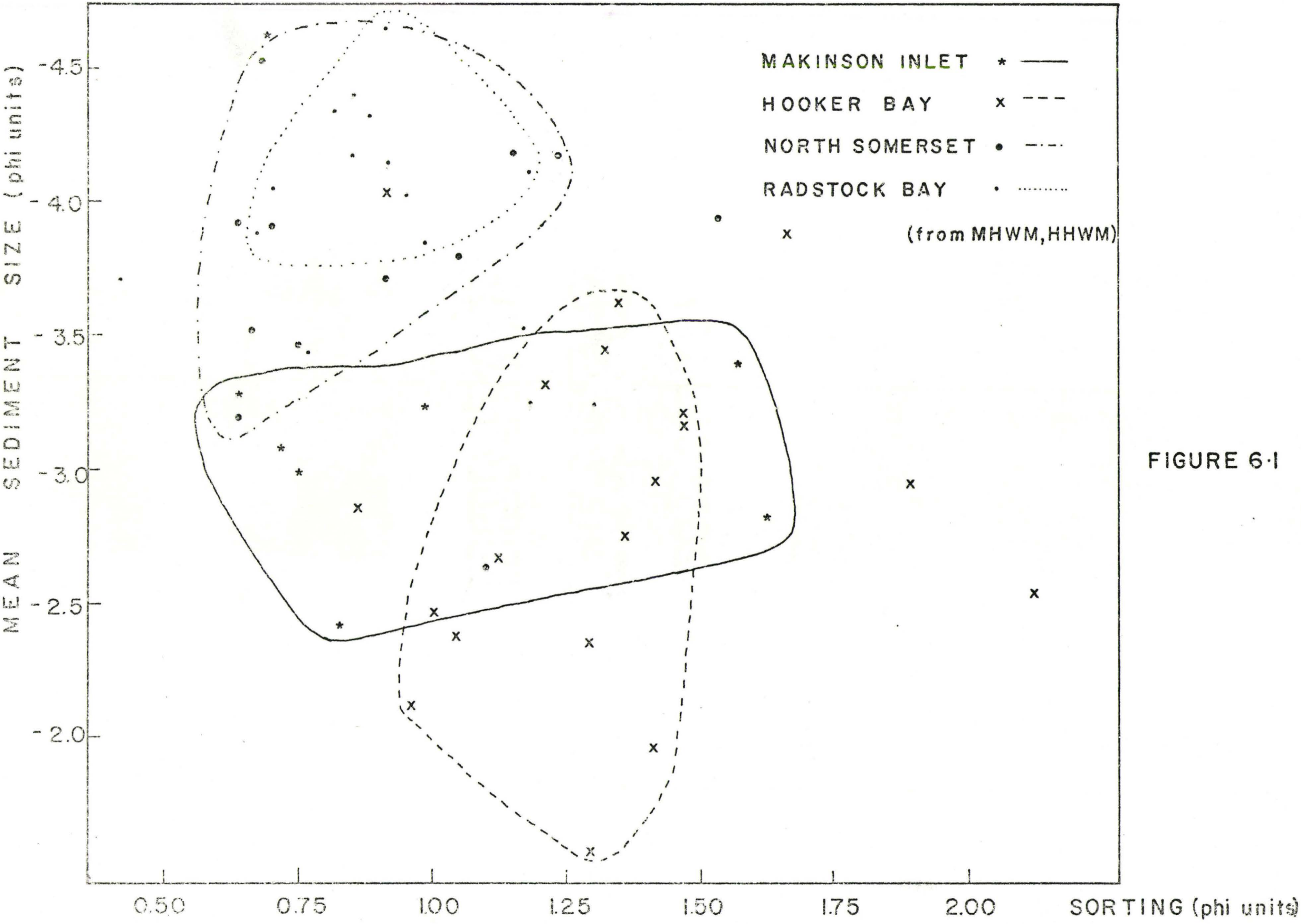
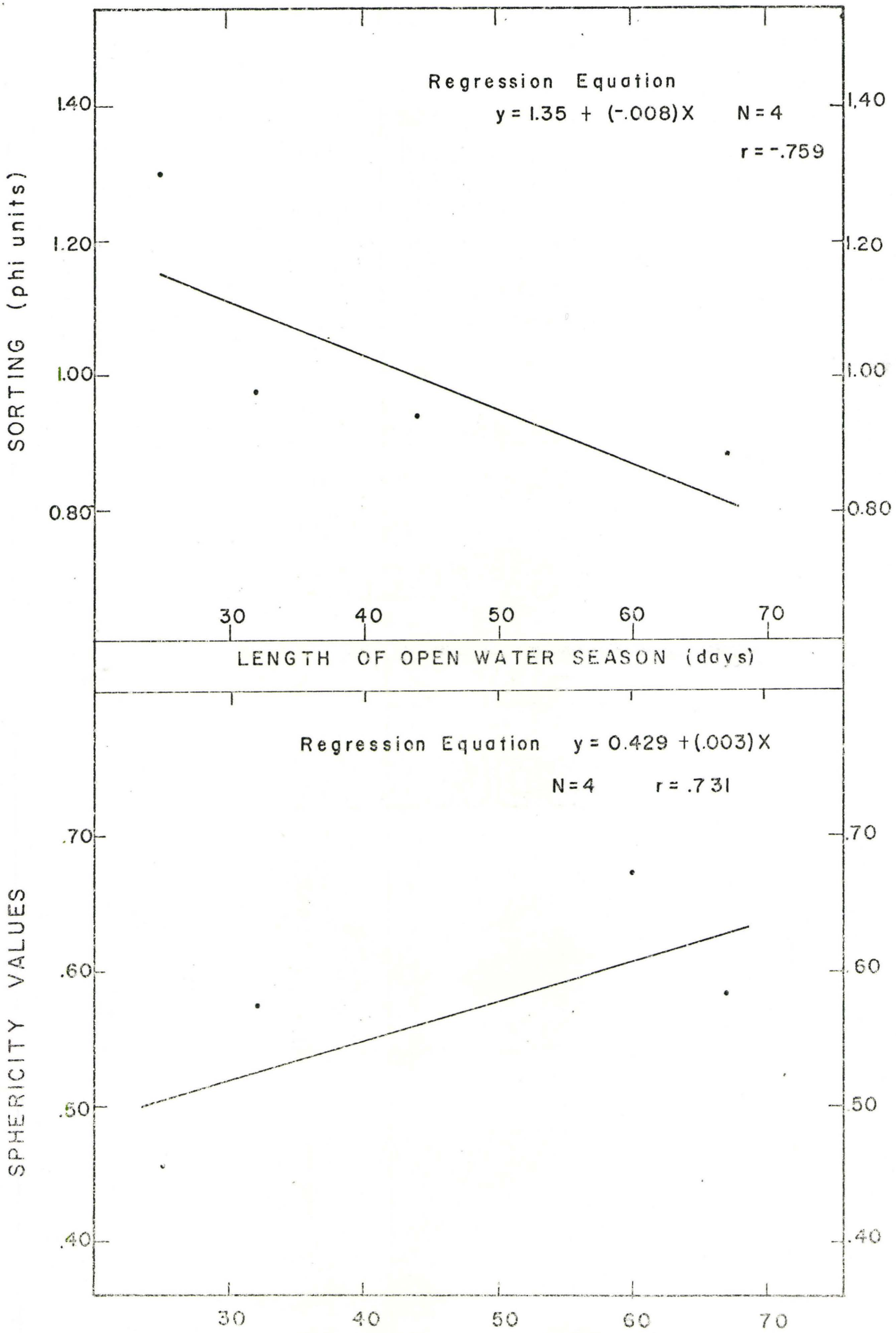

MEAN SEDIMENT SIZE (phi units)
-4.5
-4.0
-3.5
-3.0
-2.5
-2.0
0.50
0.75
1.00
1.25
1.50
1.75
2.00
SORTING (phi units)
MAKINSON INLET
HOOKER BAY
NORTH SOMERSET
RADSTOCK BAY
(from MHWM, HHWM)

FIGURE 6·1

of beach sediments revealed that when the period of open water became less than 30 days the degree of sorting dropped rapidly (Figure 6.2). D.R. Horn (1967) working in the Sverdrup Islands which never have an ice free season, and C.A.M. King (1969) working on the southeast coast of Baffin Island which has a very long season of open water, provide additional evidence for the good correlation between length of open water season and the degree of sediment sorting. In the first case, extremely poor sorting values of 2.38 ∅ were observed, whereas on east Baffin Island, well sorted (0.39 ∅) beach sediment was found. A very low correlation was found between the roundness of the beach sediments and the length of open water season. This is because relatively similar values of roundness, e.g. 188.1 to 201.2, were found for the beach sediments of north Somerset Island, Hooker Bay and Makinson Inlet, and the most angular pebbles occurred at Radstock Bay. Sphericity, like sorting, showed a strong relationship to the length of open water season, i.e. .073 correlation. The most spherical pebbles came from north Somerset Island (excluding Eclipse Sound) and the least spherical from Hooker Bay.

The beach sediments collected along Eclipse Sound were found to be considerably rounder and more spherical than the sediment sampled from the other beaches. This could be a result of the finer sediment which is present at Eclipse Sound and/or the fact that quartz grains generally exhibit higher sphericity values than limestone (Folk 1965). King (1969) also reported much rounder beach sediments on Baffin Island. For example, a mean roundness value of 591 was found for the sediments of east Baffin Island, but a roundness value of only 295 was observed for the west coast sediments. The beach sediment sampled by King (1969), and the sediment


Regression Equation
y = 1.35 + (-.008)X N = 4
r = -.759
SORTING (phi units)
1.40
1.20
1.00
0.80
30
40
50
60
70
LENGTH OF OPEN WATER SEASON (days)
Regression Equation y = 0.429 + (.003)X
N = 4 r = .731
SPHERICITY VALUES
.70
.60
.50
.40
30
40
50
60
70

sampled from Eclipse Sound in the present study, were sand size of -1.5 ∅ to +1.76 ∅ .

Very bladed to bladed pebbles predominated at each of the beaches sampled; however, some spherical elongated and platy shaped pebbles were observed, especially in the lower intertidal zone. The Cailleux (1947) flatness values were highest for the beach pebbles of Hooker Bay , and least on north Somerset Island.

The low sorting, sphericity and roundness values of the sediment from the beaches sampled, in relation to values for temperate beach sediments, indicate that the beaches of the northern Arctic Archipelago are characterized by low energy wave conditions (Table 6.1). Isostatic recovery in arctic regions has affected the resulting sediment characteristics because the rate of recovery determines the length of time the beach material is subject to wave action. The fact that the mid-latitude beach sediments have been in the beach zone for a long time, and that processes operate nearly year round, inhibit a comparison with arctic beaches (King 1969). Nevertheless, a few examples of shape values for temperate beaches of similar sediment have been included in Table 6.2.

From the previous statements on sediment characteristics, it can be concluded that the various coastal environments, based on the length of open water season, can be distinguished, but environments of different tidal range or morphology cannot be identified using only sediment shape and size.

Moore (1966) and Owens (1969) have both concluded that littoral processes similar to those found in temperate latitudes can be found in the Arctic, but of a different magnitude. The sediment characteristics found in the present study reinforce that conclusion. Changes in grain

TABLE 6.2

COMPARISON OF SEDIMENT SHAPES ON ARCTIC AND NON-ARCTIC BEACHES

Source	Location	Rock Type	Environment	No. of	Rd.	Sph.
Present study	North Somerset	Limestone	Arctic - sheltered	22	201.21 (mean)	0.585
-'-	Hooker Bay, Bathurst Island	Limestone - sandstone	Arctic - enclosed	24	188.05 (mean)	0.458
Cailleux (1948)	Mediterranean Sea	Limestone	Mid-latitude	--	320. to 510.	--
Van Andel et al (1954)	Netherlands	Limestone-crystalline	Mid-latitude	11	200. to 330.	0.678 to 0.747
Present study	Eclipse Sound, Baffin Island	Quartz sand grains	Arctic - sheltered	12	343.14 (mean)	0.674
Bryant (1972)	New Brunswick	Quartz sand grains	Mid-latitude	16 sets	--	0.755

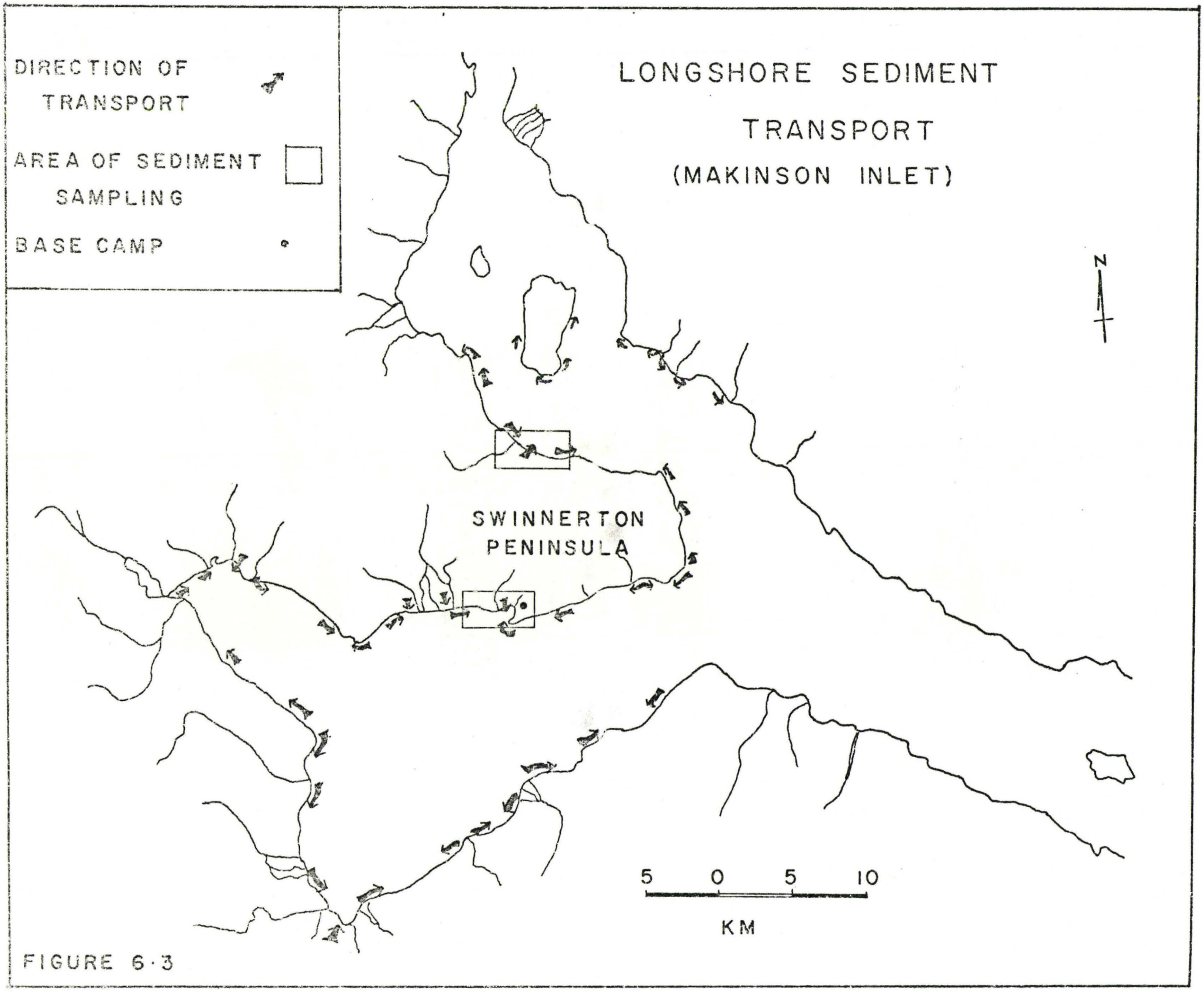
size, sorting and roundness alongshore indicate longshore transport, while the trends in sediment sorting and pebble shape across the beach indicate selective sediment transport by wave action (McCann and Owens 1969). Flatness values were observed to increase upslope, whereas sphericity sorting and roundness decreased upslope on all five beaches. Sediment size, although usually decreasing downslope, was also found to increase upslope at certain locations. These trends are a function of the effectiveness of the wave action and the length of time a particular portion of the beach is subject to wave action.

The probable direction of the longshore transport of sediment and the sources of sediment can be determined for the coastlines of each of the study areas, based on the sediment analysis and supplemental information gained from aerial photographs.

The primary source of the finer sediments found in the beach zone originate from the large streams or from areas containing numerous smaller streams. Plateau slopes which have an absence of a protective beach at their base or headlands of low bluffs tend to be areas of erosion hence, sources of sediment. Coarse lag deposits were usually found on the narrow beaches of the headlands e.g. Eclipse Sound and Hooker Bay, but much finer gravels or sands were observed on the wide bayhead beaches. Longshore movement of sediment could very easily change in direction from year to year, based on wind and wave conditions; however, the directions indicated on Figures 6.3-6.5 show the dominant direction of sediment movement based on features interpreted using aerial photography.

6.4 FAST ICE AND ASSOCIATED FEATURES

Fast ice is common to both polar coasts and some temperate coasts



LONGSHORE SEDIMENT TRANSPORT (MAKINSON INLET)

FIGURE 6·3

LONGSHORE SEDIMENT TRANSPORT

(NORTH SOMERSET ISLAND)

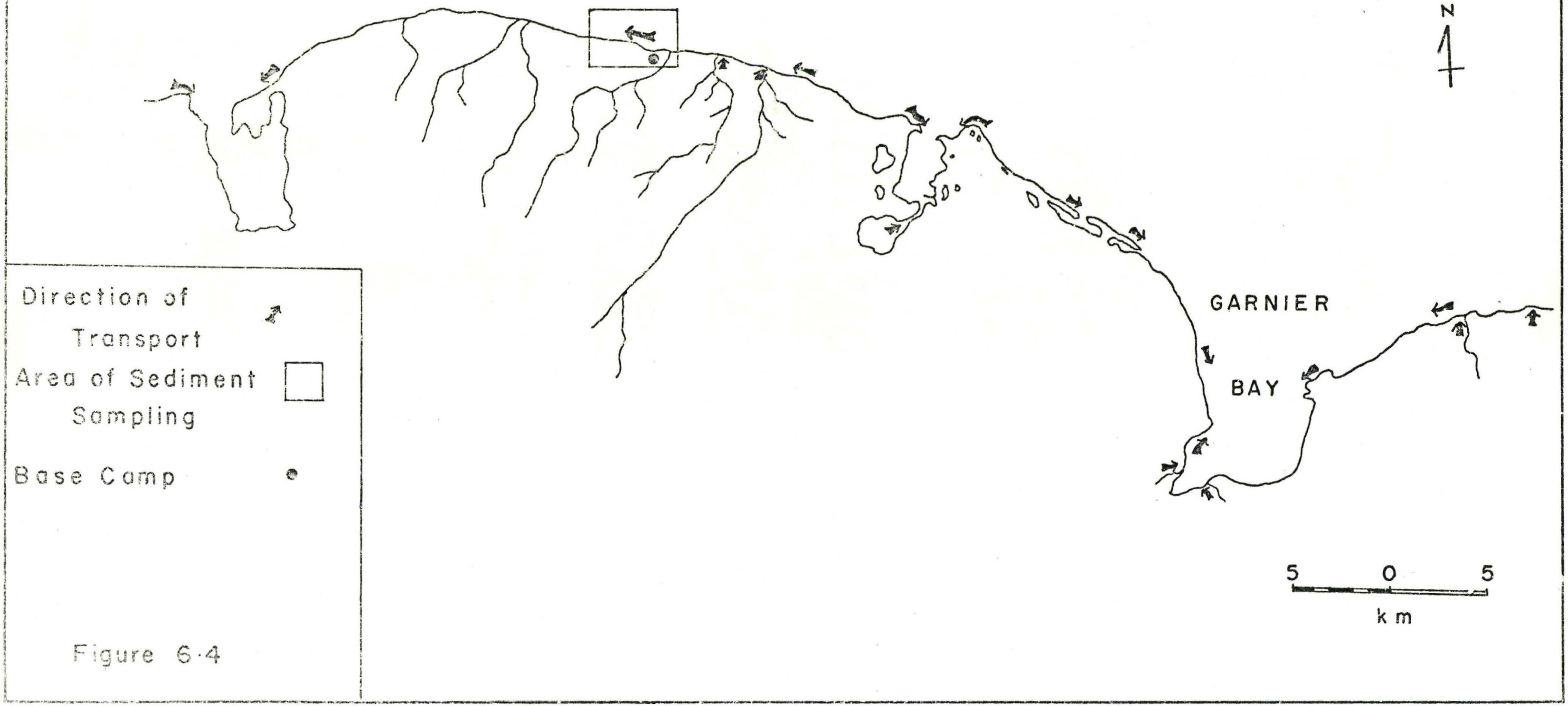
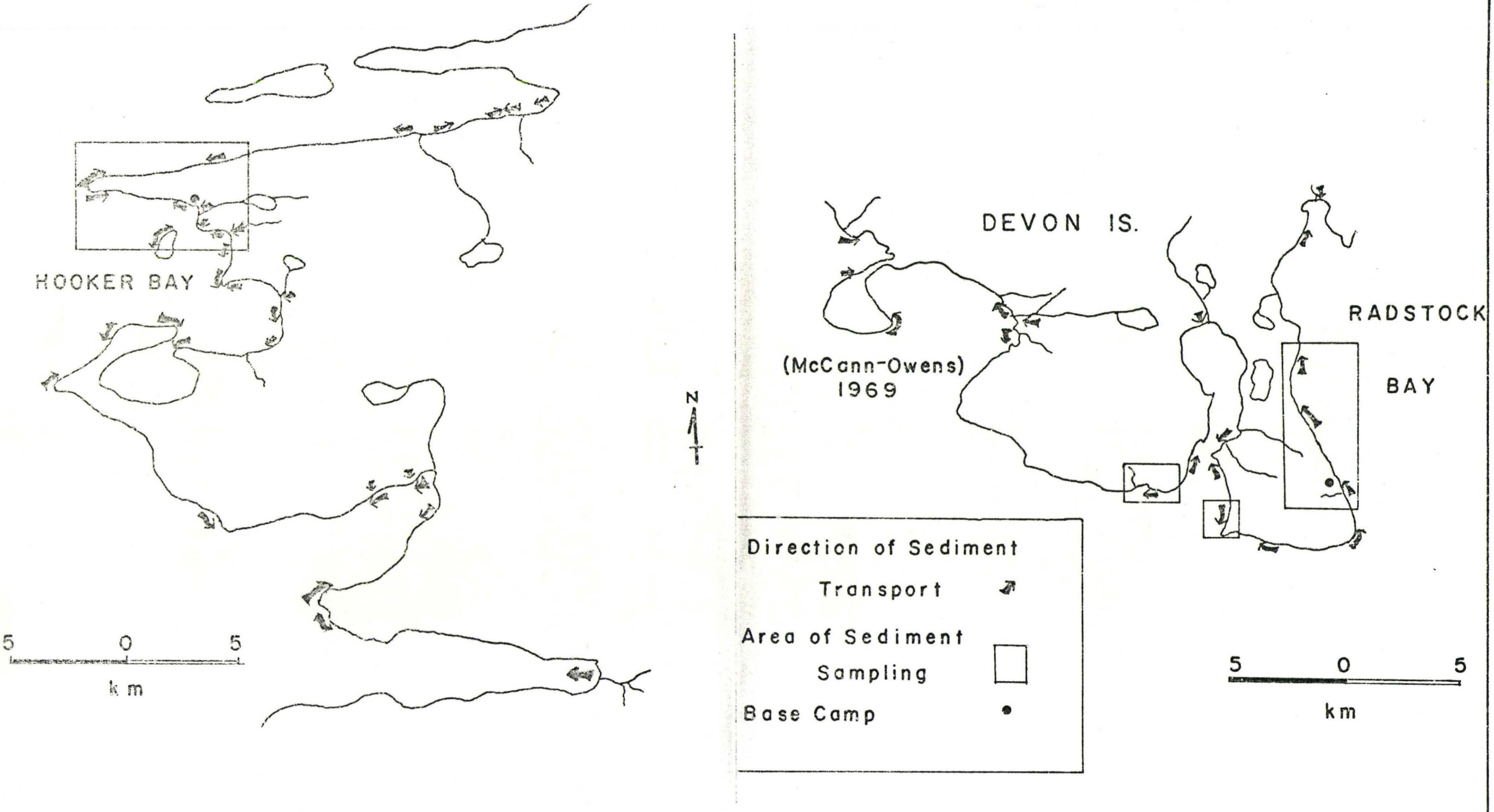


Figure 6·4



LONGSHORE SEDIMENT TRANSPORT

FIGURE 6·5

in the winter, but only to the former in the summer months. Fast ice is defined as:

> 'sea ice which forms and remains fast along the coast...may be formed <u>in situ</u> from sea water or by freezing of pack ice of any age to the shore. It may extend a few feet or several hundred kilometres from the coast. Vertical fluctuations may be observed during changes in sea level.' (Manice 1969, p.4).

It is the presence of this fast ice, particularly the icefoot, in polar regions which inhibits wave action and helps create the low energy beach characteristics revealed in the sediment analysis and beach profiles. Wright and Priestly (1922) and Joyce (1950) have suggested that there are as many as ten varieties of icefoot. Of those described, the "tidal platform" and the "storm" icefoot formed between high and low tide levels and above mean high tide, respectively, are the most common along the eastern Arctic coasts. The icefoot is best developed along coasts with a mesotidal range or greater. For example, a well developed icefoot was observed at each of the study beaches except Hooker Bay, Bathurst Island (Table 6.3). It usually occurred along steep gravel beaches, but in the case of Eclipse Sound it was attached to a rock coast (Plate 22). In macrotidal regions, the icefoot generally contains little sediment because of the ice cover which is also formed, at low tide, on the lower beach slope. Along coasts with microtidal ranges, the icefoot is absent or poorly developed and has large quantities of sand and gravel incorporated in it. The term 'Kaimoo' has been given by Moore (1966) to these less developed gravel-sand-ice features, and McCann and Carlisle (1972) have suggested that the term be restricted to microtidal regions. The narrow intertidal zone restricts the development of the icefoot, except

TABLE 6.3

ICE FOOT DIMENSIONS

(in metres)

Location	Mean Tidal Range	Width of Icefoot	Thickness of Icefoot	Ice-cored Gravel Ridge (thickness)
Radstock Bay (1970)	1.74	16.2	2.0	0.47
Makinson Inlet (1972)	2.46	15.0	2.5	0.18 to 1.29
North Somerset Island (1972)	1.28	15.0	2.2	None present
*Eclipse Sound-Pond Inlet (1972)	1.50	2.5	1.0	--
Hooker Bay		-	-	0.25 to 0.40

* Measured in late August

in storm wave conditions, consequently it is easily eroded by spring meltwaters, especially if the coast is lined by numerous stream outlets, as is the case in the Arctic Coastal Plain.

At three of the beaches visited in 1972, a fast ice ridge which was covered by a layer of gravels 0.10 to 0.30 m thick, was observed in the intertidal zone just above LWM. This ridge of ice was not continuous along the coast and was best developed in sheltered embayments and normally adjacent to one or more stream outlets. The streams, however, are not a prerequisite for the formation of the ridge. The shape of the ice ridge was similar to the icefoot with a steep seaward side and a more gradual sloping landward side, but its position on the beach slope differentiates it from the icefoot.

Two varieties of the fast ice ridge or ice-cored gravel ridge could be distinguished at Makinson Inlet, Ellesmere Island. The first, observed in 'Tern Cove', covered most of the intertidal zone and is believed to be an icefoot covered by a thick layer, 0.3 m, of beach gravels. Ice-cored gravel ridges were also found just offshore, on the other side of 'Tern Cove'; however, these were the vertically displaced ice of the fracture zone which had been covered by gravels either from the nearby streams or from the bottom of the cove (Figure 3.13, Profile B). The layers of sediment present in these ridges indicate a multi-year feature.

The second type of ridge was found on the north shore of Swinnerton Peninsula, Makinson Inlet, where a ridge of 0.18 to 1.29 m in height occurred just above LWM (Plate 27). A similar but less well developed ice ridge was observed at Eclipse Sound, Hooker Bay and

Radstock Bay. Multiple ice ridges were observed at Makinson Inlet and Hooker Bay, but in the first area the smaller ridge was on the seaward side of the larger ridge, but in the latter area the smaller ridge was on the landward side. The size of the ice ridge at Hooker Bay varied from 0.25 to 0.40 m. A similar ice ridge, 0.47 m high, was also observed at LWM, along parts of Radstock Bay.

These ice ridges are a protective barrier for most of the beach slope against sea ice scour, except at high tide when smaller pieces of ice can float over the ridge and strike the upper beach slope.

Joyce (1950) and Kirk (1965-66) have both referred to the presence of bottom ice in the Antarctic at or below LWM. They believe that the ice is formed from spicular crystals which, in time, create a layer of ice in shallow waters, extending only some yards below LWM. The ice-cored gravel ridge observed at LWM, during the present research, is hypothesized to have formed in one of two ways. During the fall freeze-up, a layer of ice is usually formed on the beach slope, but an additional core of ice e.g. anchor ice, could be created at the base of the intertidal zone over one or more seasons. Gravels are washed up onto the ice ridge by regular wave action, or may originate from nearby streams during maximum discharge, in the spring. Erosion of the fast ice ridge would probably occur during storm wave conditions, or if the cover of gravels was not sufficient to protect the ridge from solar radiation or regular wave action. Alternatively, the fast ice ridge could be a remnant icefoot or a small scale icefoot created during unfavourable conditions. In the spring, melt-waters from the nearby streams or ice rafted sediments are deposited on the ice core. The latter may have been the case at Radstock Bay in 1972, when a well developed icefoot was absent and the fast ice ridge was observed for the first time in three years.

The ice-cored ridge was found on beaches with either micro or mesotidal conditions; however, the largest ridges were observed at Makinson Inlet and the smallest at Hooker Bay, which had a 2.46 m and 0.68 m tidal range, respectively.

Beach Features Created by Sea Ice

Ice pitted beaches and beaches with marine ice-pushed mounds are characteristic of polar areas (Nichols 1961). In the northern arctic islands, the pitted beaches are primarily the result of the differential melting of large and small pieces of sea ice which have been thrown up on shore during storms and later buried by gravels also thrown up on shore by the storm waves. The only beaches with well developed zones of pitting were on Radstock Bay and north Somerset Island; however, in the latter area much larger pits of 3.09 m in diameter and 0.63 m in depth were found.

Ice push ridges were observed at each of the study areas except Makinson Inlet, but only on north Somerset Island and Radstock Bay were there large relict push ridges above HHWM. The ridges found at Hooker Bay and Eclipse Sound-Pond Inlet were below HHWM, and would be vulnerable to later wave action. The large ice push features and beach pittings found on north Somerset Island and west Radstock Bay indicate higher energy wave conditions and a greater frequency of storms. The small features at the other beaches, on the other hand, indicate a lower energy wave environment, or a coast not subject to massive ice movements, as is reported for the Coastal Plain.

6.5 SUMMARY

The arctic beach profile is characterized by a steep foreshore slope which is a function of the short open water season and the coarse beach sediment. Sufficient differences can be observed in the beach profiles surveyed at each of the study areas to make a distinction between the different coastal environments. For example, the north Somerset and Radstock Bay beaches are characterized by a steep step-like profile, whereas the beaches on Eclipse Sound-Pond Inlet are wide and flat with a more gradual foreshore slope.

The differences between the designated coastal environments and the similarity between Radstock Bay and north Somerset Island are evident when using a bivariate plot of mean grain size against the degree of sediment sorting. Significant correlations, -.76 and .73, between both sediment sorting and sediment sphericity, respectively, and the length of open water season, emphasize the coastal regions which have been defined by using the length of open water season. In addition, the trends in sediment size and shape reveal the direction of longshore sediment movement.

The tidal coastal divisions (Chapter 11) can be identified by examining the differences in icefoot development along a beach. The thickness is directly related to tidal range; for example, a well developed icefoot is restricted to meso and macrotidal regions, whereas the less developed kaimoo is restricted to microtidal regions.

In 1972, an ice-cored gravel ridge was observed near LWM at all of the study areas except north Somerset Island. The ridge of ice appears to be a small scale icefoot formed in unfavourable conditions or, possibly, an accumulation of anchor ice over several seasons.

The number and size of the ice push mounds, and extent of pitting on a shoreline are a rough indicator of the magnitude of storm wave activity which can occur on that particular beach. The largest features were observed on the north Somerset shoreline - the smallest at Hooker Bay, Bathurst Island. In the former area, the presence of mobile pack ice from Wellington Channel, and the exposed nature of the Somerset coastline, create favourable conditions for the formation of ice push mounds and beach pitting. On the other hand, the almost solid cover of sea ice offshore, and the protected shoreline of Hooker Bay, prohibit any large scale storm wave activity from reaching that beach.

CHAPTER V11

CONCLUSION

CONCLUSION

Using secondary source information, the coasts of the Canadian Arctic Archipelago have been effectively divided into five morphological divisions, three tidal zones, and four regions based on the length of open water season. The five morphological regions comprise the basic coastal environments. The suggested coastal regions give order to the wide variations in coastal characteristics found in the Arctic, and provide a useful base from which future coastal research in the Arctic can begin.

The use of secondary sources to obtain information on coastal types has revealed the adequacy of panchromatic aerial photography in analysing general coastal characteristics, and also the lack of nearshore bathymetry in the Arctic and the limitations of the sea ice observations in coastal research. Until recently, the primary purpose of collecting information on sea ice cover has been for the shipping activity during the summer months. Consequently, the sea ice data presently available is not really suitable for the coastal researcher because of the general lack of nearshore observations. Nevertheless, an examination of the ice cover data over a period of several years allows one to make generalizations about the characteristics of sea ice break-up and the types of ice usually present. In addition, using carefully selected criteria, the length of open water season or the period in which effective wave activity occurs can be determined. By summarizing the sea ice data and delimiting the open water season, in a similar way to that used in the present research, the researcher is able to make a good assessment of the possibility of long fetch waves reaching a particular beach.

The detailed field investigations, at seclected locations within the different coastal environments, provides additional evidence of the differences that can be found within the Arctic, both in terms of the magnitude of the processes and of the beach and nearshore characteristics. The trends in the size and sorting of the beach sediment provide a good indication of the length of open water season and amount of wave activity. The beach profiles and the presence or absence of beach features created by sea ice movement also provide useful comparisons between coastal areas. The individual studies of Makinson Inlet, Hooker Bay and north Somerset Island, presented in this thesis, provide the first and only substantial documentation of coastal characteristics of, and processes in, those areas. Previously, just a short note on coastal conditions there had been written by geologists (Fortier et al 1963). Each segment of the information collected is vital in planning the construction of marine facilities or pipelines. Continuing research at Radstock Bay has provided a longer term monitoring of beach profile change, and has shown that open water conditions do not exist every year in the bay.

Field investigations over a short period, at five locations within the archipelago, indicate that the basic annual sequence of events suggested in Chapter 1 is correct. Slight modifications, however, must be made for each beach because of differences in tidal range, length of open water season, overall coastal morphology, and number of stream outlets along the coast.

It has been mentioned that considerable attention is now focussed on means of transporting the natural resources of the Arctic to southern markets. Although none of the beaches studied in detail may become the site of a new marine terminal or be part of the transmission "corridor", the research should provide a good base for future coastal studies. In addition, the observations recorded in this thesis will add to the meagre knowledge of the nearshore and beach processes occurring in the Canadian Arctic Archipelago.

It is recommended that future research deal with the nearshore zone, below LWM, in more detail than the present study, so that beach changes and characteristics may be better explained. Further research should be conducted at an appropriate location in the Arctic Coastal Plain, in order to allow the actual documentation of the effects of sea ice movements and stream activity, which is indicated in previous accounts (Stefansson 1917) to be so important in that coastal environment.

APPENDIX A

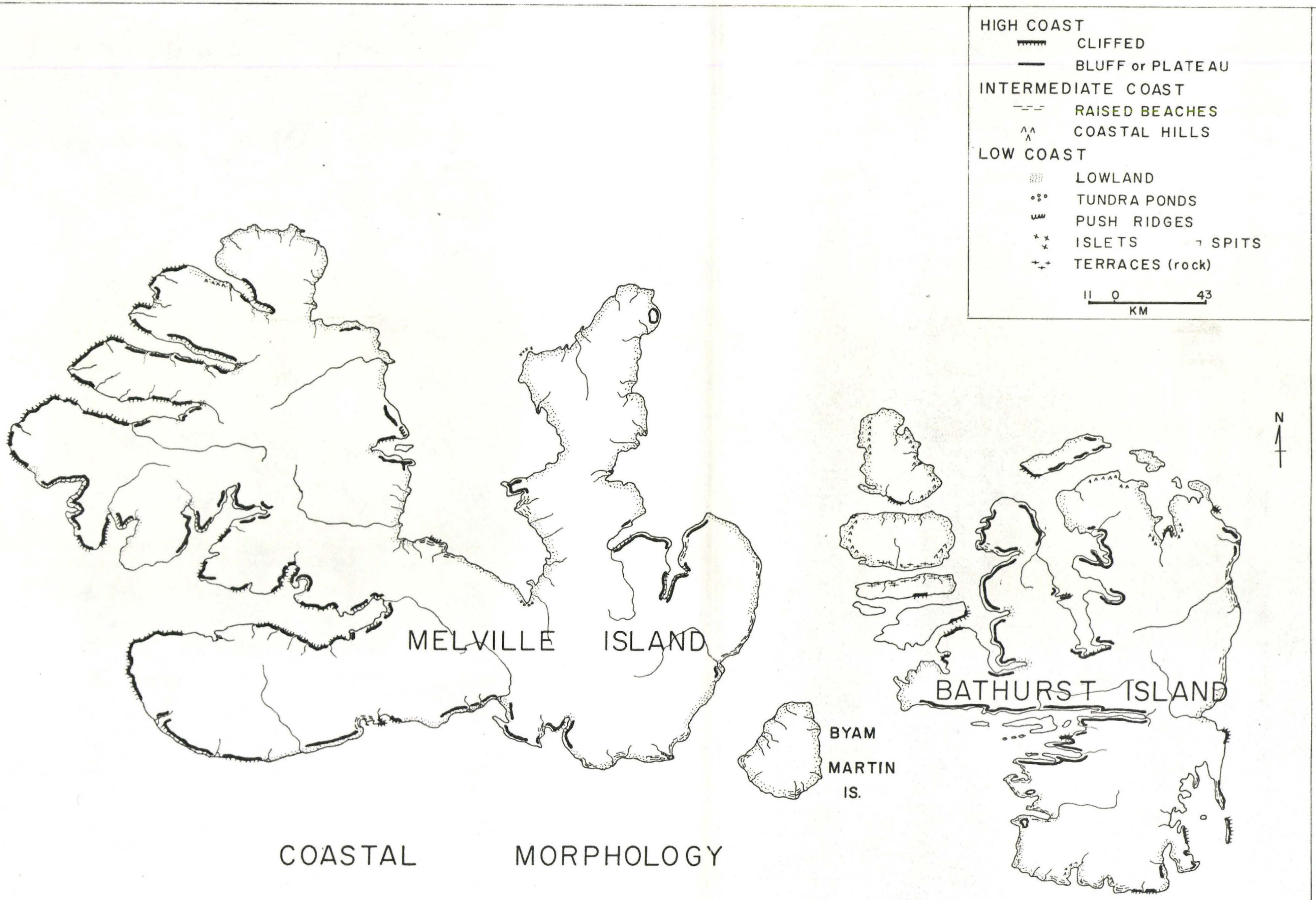
THE COMPILATION OF COASTAL LANDFORM MAPS

A division of the northern arctic islands into coastal environments was initiated by compiling a series of maps on the coastal landforms which constitute the physical framework of the coasts.

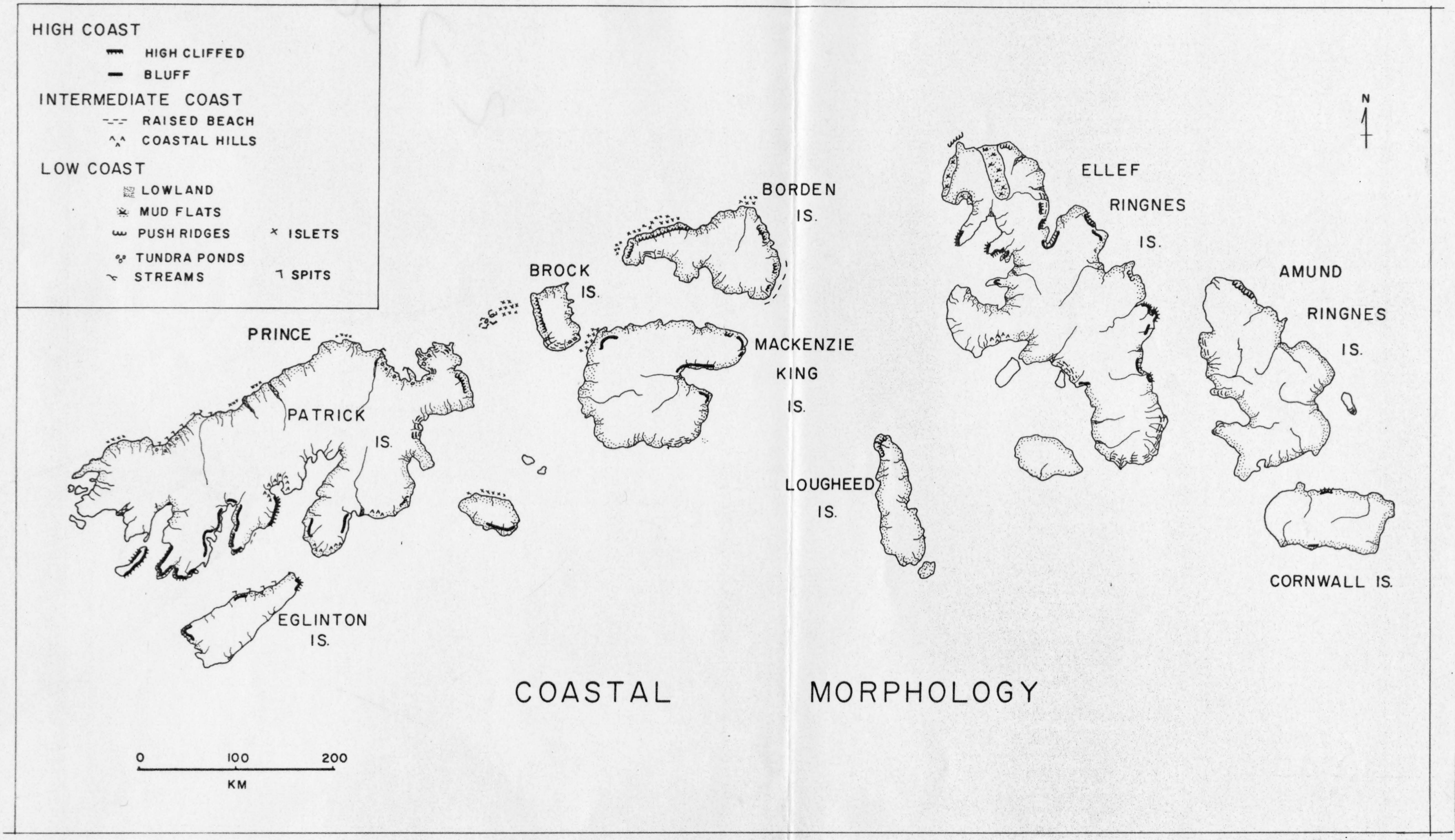
Extensive use of available aerial photography kept at the National Air Photo Library in Ottawa, and general navigational publications such as Arctic Pilot, Vols. 1 and 11, and Arctic Canada From the Air by Dunbar and Greenaway (1957), provided information on the coastal landforms of each island. Additional information was acquired from recent government publications, i.e. Geological Survey of Canada Memoirs, university theses e.g. A. Taylor (1956), and the topographic maps at 1:250,000 scale. Suggestions for the use of symbols in the finished maps were gained from other authors, e.g. Bird (1967) and McGill (1958), who have made similar maps of coastal landforms.

The symbols shown on Canadian hydrographic charts and topographic maps were used, where possible, and only a few new symbols were required. The landforms depicted on the maps represent the characteristic features found within 0.8 km (0.5 miles) of the waterline. With regard to coastal areas on which little or no information was available, the map was left blank. A more detailed map of coastal landforms is provided for each of the coastal locations visited in the 1972 field season (Chapters 111, 1V, V). These maps were based primarily on information gained from aerial photography and field observations.

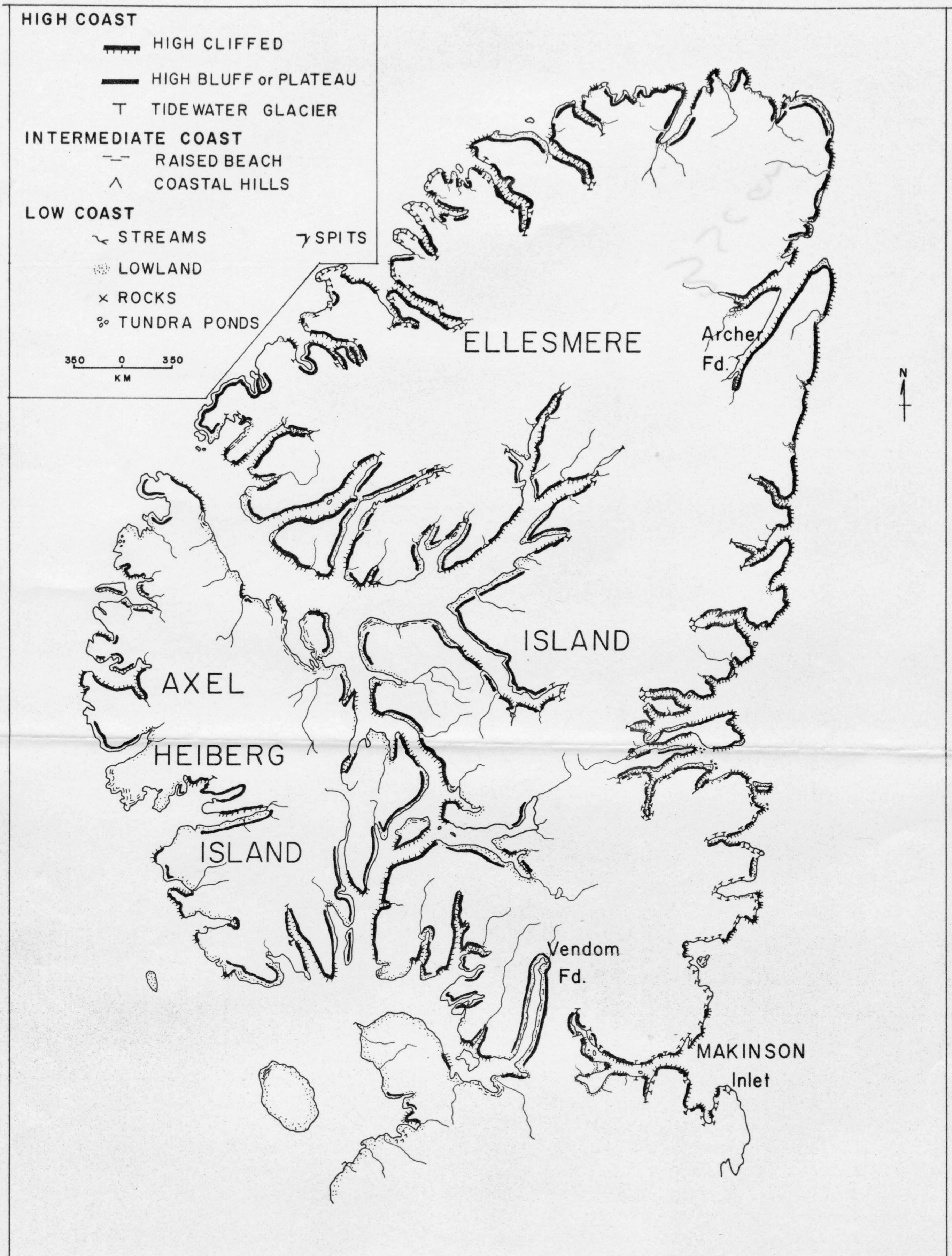
Limitations due to scale are present, but the maps do provide an inventory of coastal features which fringe the arctic islands. Parent rock types and relief determine the texture and composition of the beach sediment of the far northern islands (Horn 1967); consequently, the maps can provide a general insight into the nearshore characteristics which could be expected in any particular area. The maps also provide a useful starting point in the search for possible landing beaches which could be used by scientific parties or for future economic development.



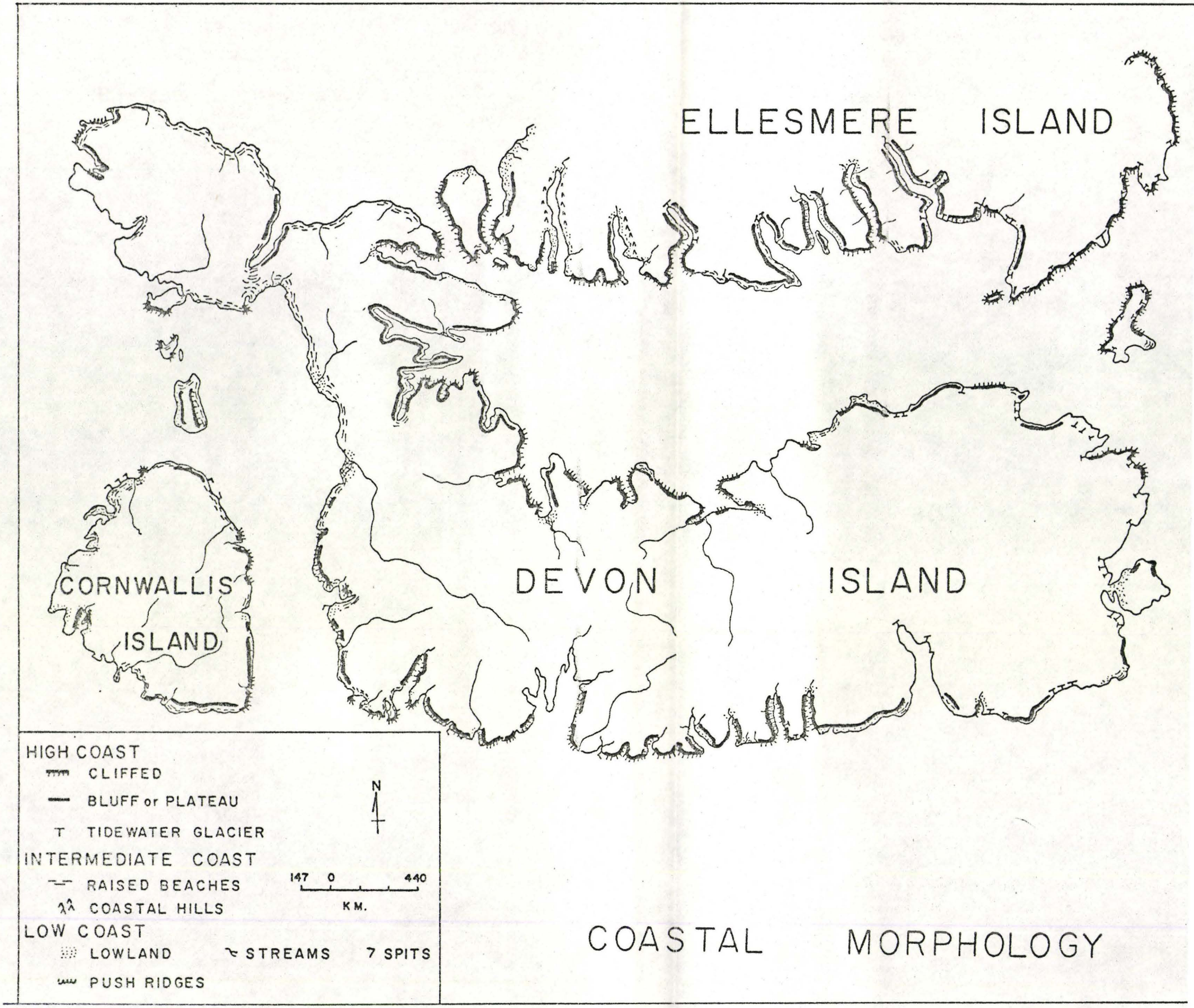
COASTAL MORPHOLOGY



COASTAL MORPHOLOGY



COASTAL MORPHOLOGY



COASTAL MORPHOLOGY

APPENDIX B

A STUDY OF ARCTIC COASTAL ENVIRONMENTS USING AERIAL PHOTOGRAPHY

Aerial photographs were used extensively in completing an inventory of coastal landforms for the arctic islands. An evaluation of their use in the identification of coastal features and processes was then possible.

INTERPRETATION

The coasts of the arctic islands usually consist of steep mountain or plateau slopes with very little beach, or a narrow active beach backed by a series of raised beach terraces. These terraces are observed as alternating light and dark lines, a result of the greater moisture and vegetation cover found between the beach ridges. The raised beaches can be distinguished from the active beach by the darker tone of the latter. The older higher raised beaches, however, do sometimes have a similar tone to the active beach. The type of beach sediment on the active beach is more difficult to distinguish, but usually gravels have a darker tone than sands because of the better light reflection capabilities of sand. Solifluction lobes and patterned ground on the raised beaches, also ice-push ridges and pittings on, or just above the active beach, are additional features that can be observed. The lobes are identified by their streaked appearance, the patterned ground by a regular network of circles or lines, and differential relief allows an identification of the push ridges and pittings. The tidal phase at the time of photographing can be approximated by the presence of a high tide ridge on the active beach slope and its distance from the water's edge.

The monitoring of coastal processes in the arctic is severely limited because of the lack of sequential photography and the presence of sea ice on the beach and nearshore. Truncated coastal features on the photos indicate fluvial or marine erosion, but accretion is revealed by accumulation forms such as spits or well-developed beaches. The direction of longshore sediment movement can be determined by examining the distal end of the spits.

Different tones on the photos help to distinguish between offshore zones and the presence of ice scour which produces a hummocky topography and is identified by light-toned markings on the sea floor. Any movement of sea ice, between exposures, results in a relief displacement of the water surface, which can be used to detect water movement, e.g. currents. The direction of currents can be approximated by contouring the water surface, but the current velocity cannot be calculated because the principal and conjugate principal points occur on a moving water surface.

Air photos provide a good plan view of the coasts and when the photos are used along with an electronic map digitizer, it is possible to compare a particular shoreline to an appropriate geometric form. Yasso (1965) found that the logarithmic spiral approximates the plan shape of headland beaches. A n^{th} order regression analysis was applied to the shoreline between Walrus Point and Cape Ricketts on Devon Island. The curve which best fitted this shoreline was when $n=3$; accretion and erosion were indicated on the curve by positive and negative residuals. Much more research is needed to test whether or not the quadratic function is the best fit curve for arctic headland beaches, but the method does provide an interesting study.

USE OF FILM TYPES

Aerial photography, using four types of film, was flown at Resolute Bay, N.W.T. and vicinity in 1971 (Howarth 1972), which allowed an assessment of the use of each type of film in studying coastal features. Unfortunately, the assessment is limited to the detection of terrestrial features because of the presence of fast ice. Raised beaches were easily identified on all films, but when the ridges became less distinct or more closely spaced, their detection was difficult when using colour infrared film. Colour infrared and colour film were best when distinguishing between water and vegetation or the raised beach lines. The distinction between sea ice and water was possible using any of the films, but when distinguishing between puddling on the sea and polynas, which had a much darker tone than the puddles, colour and colour infrared films were best.

Colour film was the most useful; however, since panchromatic film was found to be the second most useful, the advantages of the former may not outweigh its extra cost. The only real advantage of black and white infrared and colour infrared films was a better identification of the waterline.

APPENDIX C

GRAIN SHAPE ANALYSIS

METHOD OF FIELD MEASUREMENTS

Each of the parameters used in the present study to describe grain shape and roundness was chosen so that a minimum number of measures were required. The principal parameters used were: the Cailleux flatness and roundness ratios, the Sneed and Folk sphericity and shape index, the Riley projection sphericity, and the Zingg shape index.

A total of 25 grains of between 4 and 64 mm were chosen from each of the samples used in the size distribution analysis. An exception was the beach sediment from Pond Inlet which measured only 0.5 to 4 mm, and was not analyzed in the field, but rather in the laboratory with the use of photography which is not as satisfactory as actual field measurements because it allows only a two-dimensional view of the sediment.

In the field, the length of the three axes of each pebble was measured using a transparent ruler, while the radius of least curvature was determined by using the Cailleux roundness target which is made up of concentric circles of known diameter. Each pebble is fitted to an arc, thus providing an exact measure of angularity. The same set of circles was used to determine the inscribed and circumscribed circle used in Riley's sphericity formula. The basic measures of $\underline{a}$, $\underline{b}$, $\underline{c}$ and $\underline{r}$ were then punched onto IBM computer cards for the purpose of calculating the above-mentioned shape parameters. The mean and standard deviation for flatness, roundness and sphericity, and the division of each grain into the various shape classes was completed, using a computer program devised by the author.

METHODS OF GRAIN SHAPE ANALYSIS

There is extensive literature written by various authors on grain shape, its analysis and interpretation. Two principal grain-form parameters are in common usage today - shape and roundness. "Grain shape is defined in terms of the described spatial geometric form of grains, whereas grain roundness describes the relative sharpness (or lack of sharpness) of grain corners and edges." (Pryor 1971, p.131).

(1) Shape: The quantitative grain shape parameters most commonly used are the sphericity and flatness ratios. Sphericity states how nearly equal the three dimensions of an object are; a sphere has a sphericity of 1.0. A sphericity value which shows the behaviour of a particle during transport is the Maximum Projection Sphericity introduced by Sneed and Folk (1958). Particles tend to settle with the maximum projection area (plane of the a, b axes) perpendicular to the direction of motion, and hence resist the movement of a particle. This formula compares the maximum projection area of a given particle with a maximum projection area of a sphere of the same volume. For example, a particle with a sphericity of 0.600 means that a sphere of the same volume would have a projection area only 0.600 as large as that of the pebble. Therefore, the pebble settles 0.600 times as fast as the sphere because of the increased surface resisting downward motion (Folk 1965). Shape also influences tractive

movement. Round particles roll, whereas disc-shaped pebbles shuffle along, and some other shapes move as a type of surface creep.

Particles of a similar sphericity can be different shapes, therefore will behave in different ways during transport and deposition (Krumbein 1941a). To overcome this problem which resulted from earlier sphericity equations (Wadell 1935, Krumbein 1941), Zingg (1935) defined four shape classes according to the b/a, c/b axes ratios. Each combination of ratios indicates a part of the sphericity diagram. The four shape classes were Disc, Blade, Spheroid and Rod. More recently, Sneed and Folk (1958) combined sphericity with the intercept ratios of c/a and (a-b)/(a-c) into a form triangle with four major classes: Compact, Platy, Bladed and Elongated, which can be divided into a total of ten subclasses.

Sphericity can also be determined using visual comparators such as Power's (1953) and Krumbein and Sloss' (1955), but the resultant values are very subjective. A two-dimensional measure of sphericity was introduced by Riley (1941) who used a method of projection to determine the inscribed and circumscribed circle for each grain, with a set of circles of known diameter. This method is very useful when photography of sediment samples is available.

Cailleux (1947) adapted the roundness ratio originally proposed by Wentworth (1922) as his flatness ratio, but required that the three dimensions meet at right angles. Cailleux used the flatness ratio as his index of shape; it compares the <u>c</u> axis to the <u>a</u> and <u>b</u> axes.

(2) Roundness: The two methods which have found the greatest usage in determining the roundness ratio of grains have been Krumbein's (1941a) visual chart, and Cailleux' (1947) formula. Krumbein constructed a visual chart using pebbles of known a roundness value which he calculated using Wadell's (1933) method. Cailleux defined roundness as the ratio of the diameter of the sharpest corner r in the plane of maximum projection and the greatest length a. For a completely round pebble $2r=a$, therefore roundness=1000 (see formulae). Blenk (1960), Tonnard (1963) and King and Buckley (1968) have all found Cailleux' measure of roundness satisfactory;Van Andel, Wiggers and Maarleveld (1954) used both measures, and obtained similar results.

Krumbein (1941) found that roundness is sensitive to abrasion and that change in the particles, resulting from abrasion, may occur quite rapidly in the early stages of sedimentation, i.e. near the source area, then approach an equilibrium value. Krumbein also observed that the rate of rounding was greater for larger sized grains than smaller ones.

SHAPE AND ROUNDNESS FORMULAE

a	is the longest axis of a particle.
b	is the intermediate axis of a particle at right angles to a.
c	is the shortest axis of a particle at right angles to the a b plane.
r	is the least radius of curvature as determined using the Cailleux target.
di	is the diameter of the largest inscribing circle.
Dc	is the diameter of the smallest circumscribing circle.

Sphericity Formulae

ψ_i = Krumbein's Intercept Sphericity (Krumbein 1941)

$$\psi_i = \sqrt[3]{\frac{abc}{a^2}}$$

ψ_p = Maximum Projection Sphericity (Sneed and Folk 1958)

$$\psi_p = \sqrt[3]{\frac{c^2}{ab}}$$

ψ_r = Riley Projection Sphericity (Riley 1941)

$$\psi_r = \sqrt{\frac{di}{Dc}}$$

Zingg Shape Index (Zingg 1935)

$b/a \leq .667$ $c/b \leq .667$	blade
$b/a > .667$ $c/b \leq .667$	disc
$b/a \leq .667$ $c/b > .667$	rod
$b/a > .667$ $c/b > .667$	sphere

Sneed and Folk Shape Index (Sneed and Folk 1958)

$R_1 = c/a$

$R_2 = (a-b)/(a-c)$

$R1 > .7$		compact
$.7 \geq R1 > .5$	$R2 \leq .333$	compact platy
$.7 \geq R1 > .5$	$.333 < R2 \leq .667$	compact bladed
$.7 \geq R1 > .5$	$R2 > .667$	compact elongated
$.5 \geq R1 > .3$	$R2 \leq .333$	platy
$.5 \geq R1 > .3$	$.333 < R2 \leq .667$	bladed
$.5 \geq R1 > .3$	$R2 > .667$	elongated
$R1 \leq .3$	$R2 \leq .333$	very platy
$R1 \leq .3$	$.333 < R2 \leq .667$	very bladed
$R1 \leq .3$	$R2 > .667$	very elongated

Cailleux Flatness Ratio (Cailleux 1947)

$$F_c = [(a+b) / 2_c] \times 100$$

Roundness

Wentworth Roundness Ratio (Wentworth 1922)

$$Wr = (a+b) / 2c$$

Wadell Degree of Roundness (Wadell 1933)

$$Pd = \Sigma (r/R) / N$$

Cailleux Roundness Index (Cailleux 1947)

$$Rc = (2r/a) \times 1000$$

APPENDIX D

GRAIN SIZE DISTRIBUTION ANALYSIS

The size distribution analysis of beach sediments was completed by using a nest of sieves of one phi interval, and a spring balance. Each of the sediment samples which were sieved was collected, as a composite sample, from the surface layer of each beach zone. All sediment coarser than 0.0 Ø was hand sieved and weighed in the field, while the finer sediment was later resieved in the laboratory at McMaster University. Photography was used to sample the beach sediments of northern Makinson Inlet, Ellesmere Island, and Eclipse Sound, Baffin Island. From each photo, the b axis of 25 to 50 grains was measured in millimetres and then converted to phi units. The use of photography speeds up the actual field work, but prohibits a sound quantitative analysis of the size distribution, i.e. skewness and standard deviation.

The percentage weights of each sieve interval from each sediment sample was then fed into two computer programs which calculated the four moment measures of each sample. The Woods Hole SEDANL program was devised by Schlee and Webster (1965), and later modified by D.R. Ingram of McMaster University.

The SEDANL program provides a fequency curve which is very useful in giving a visual impression of the data, and it uses computation techniques rather than graphic methods such as those proposed by Inman (1952) and Folk and Ward (1957).

A supplemental computer program, devised by Greenwood (1971) and modified by E. Bryant, computed the moment measure statistics, the Folk statistics and the Inman statistics. The program also provided a cumulative frequency curve.

Either program is sufficient for most grain size studies, but together they provide a sound statistical base from which to interpret the resultant grain size distribution.

APPENDIX E

SEA ICE CHRONICLE 1972

1 SOMERSET ISLAND (July 1-13)

July 2: winds from the W at 15 mph: a wide shore lead existed 0.5 km offshore from Cunningham Inlet to Prince Leopold Island: ice was in advanced stage of puddling and tidal cracks and leads had formed along shore: a large quantity of the nearshore ice was multi-year.

July 3-5: rain and winds from W and NW at 10-20 mph: the ice had started to break away from landward side of the large lead and drifted to the east where ice rafting occurred offshore of the small inlet: further east near Garnier Bay the sea ice cover was still complete.

July 6: in the early morning, one of the streams burst wide open forcing sediment, water and ice out from the shore just east of base camp. Also, the adjacent shore leads were widened.

July 7: little change in sea ice under near calm conditions: Air temperature was 5° C.

July 8: only an icefoot was left along the shoreline directly in front of camp: to the west, little change to the sea ice: by 2300 hours, the sea ice further east had also left shore, leaving only an ice foot and some grounded large pieces of ice:

a SW wind of 5-10 mph greatly helped the ice removal.

July 10: during the past few days, light winds from the west, along with drizzle had ablated the ice surface, and under SW winds 10-20 mph, the sea ice to the west of camp was beginning to break away at the ice edge.

July 11: winds from SW 30-35 mph, and later SE, resulted in all but a narrow band of icefoot leaving the nearshore and drifting east.

July 12: Storm winds from the NE, along with rain, created waves of 0.4 m in height at high tide, resulting in great erosion of the icefoot surface, 10cm: the storm also returned the ice which had drifted east the previous day, to the nearshore zone: the width of the offshore lead seemed to be 4-6 km and an ice content of 7 - 8/10 existed at the seaward side of the lead.

July 13: winds of 5 mph from NE brought more ice shoreward, but there was still open water all along the shore from profile A (Chapter 1V) to 'Trebor Inlet'.

11 MAKINSON INLET, ELLESMERE ISLAND (July 18-31)

July 18: within the southwest arm, the shoreline was fringed by a fracture zone of both linear and circular pressure ridges and tidal leads: the zone was 50-60 m wide and the ice within the zone was second-year and multi-year ice: open water existed off each major stream outlet: no leads extended across the entrance to the southwest arm: Most of this arm was filled with first-year ice (10/10) in an advanced stage of puddling: several icebergs and bergy bits lined the shoreline.

(reported by J.G. Cogley): the ice at the head of the northwest arm showed moderate puddling and the shores were fringed by beach fast ice, which was covered by fluvial debris at the mouths of the various streams: icebergs and bergy bits were observed to the head of this arm.

July 20: extreme W end of southwest arm predominantly first year ice with a few bergy bits: shore fast ice, a fracture zone lining the shore: short leads now crossed the entrance to the arm and a small area of open water existed at the head: N shore of Swinnerton Peninsula fringed by shore fast ice ridge, rafted ice and a narrow strip of partially open water: nearshore ice covered by fluvial debris: icebergs numerous offshore.

July 23: channels of open water flowed out from circular pressure ridges near shore, acting as loci for formation of leads and areas of open water: at tip of Swinnerton Peninsula 1/10 - 3/10 ice cover up to 150 m offshore and leads prolonged outwards across entrances to both inner arms, from headlands and icebergs further offshore: towards the entrance to Makinson Inlet severely puddled 10/10 ice cover existed, with glacial ice located primarily along the north shore and in the immediate vicinity of the various tidewater glaciers: open water existed off the large glacier halfway up the northwest arm and to an unknown extent near or within Smith Bay.

July 24: open water areas on the S. coast of Swinnerton Peninsula at 'Tern Cove' and the large delta complex to the W.

July 27: (reported by G.S.C. helicopter pilot): 'very rotted ice within centre of southwest arm': N shore of Swinnerton Peninsula, rafted ice along shore (blocks 0.5-4 m thick) and 8/10 cover offshore.

July 28: the only beach fast ice remaining in 'Tern Cove' was an ice ridge at low tide level: blocks of ice floated and abandoned at high tide in lagoons at this location: open water in fracture zone W of 'Tern Cove'.

July 31: three days of variable winds resulted in the destruction of the remaining ice within 'Tern Cove' and along the shore to the west: widening of old leads and creation of new ones in southwest arm.

111 HOOKER BAY, BATHURST ISLAND (August 1-10)

August 1: broken cover of first-year ice at the head of Hooker and De la Beche bays: a narrow band of open water lined the shores of the bays until the entrance where complete ice cover occurred: multi-year ice was common offshore in Austin Channel: Bracebridge Inlet had 10/10 ice cover, but leads had formed across the entrance to the inlet and from the ends of the numerous islands.

August 7: little change in sea ice cover over the past week; broken ice existed throughout Hooker Bay, but 8-10/10 cover existed near the entrance to the bay and around the small island: a great deal of melting and candling of ice at the head of the bay, less than 7/10 cover.

August 10: open water surrounded the small island within Hooker Bay and open water occurred at the entrance to the "hook": leads were found across the inlets further south and all ice in each of the inlets was rotten.

Note: The presence of low clouds which created poor lighting, and very little contrast between ice and water prevented a detailed account of the sea ice cover. In addition, the low relief of Bathurst Island does not provide a good observation point for viewing the sea ice conditions.

1V RADSTOCK BAY, DEVON ISLAND (July 14, August 14-18)

July 14: in front of base camp there was a very irregular ice surface near shore composed of grounded multi-year ice covered by snow: snow was still thick on the surface of the nearshore ice and beach: further offshore, some small tidal cracks existed but no major leads: puddling was advanced on the offshore first-year ice: buried ice was still present on the beach above HHWM, having been buried during a storm the previous fall.

August 14: the ice edge existed across the mouth of Radstock Bay from Cape Liddon to the east shore of the bay: there was a narrow band of open water along both shores of the bay and open water existed just north of Caswall Tower at the mouth of the large stream: leads radiated across the bay at their usual places - Caswall Tower, the north side of Scallion Cove and a site in the north channel.

at Gascoyne Inlet, the ice edge occurred at Walrus Point and open water existed along the north shore and at the outlets of the major streams: the rest of the inlet contained rotten first-year ice: a partial lead with 8 -10/10 ice cover existed across the inlet about half way between Walrus Point and the north shore of the inlet.

August 15-16: there had been little change except for small quantities of ice breaking away from the ice edge, under the influence of 10 mph north winds: a narrow band of shore fast ice still existed on both sides of Cape Ricketts.

August 17: south winds had created ice rafting at the ice edge, and a couple of bergy bits or growlers had entered the mouth of Radstock Bay on the east side.

August 18: the only change in the ice at Radstock Bay was a new lead radiating from the west shore about 1 km north of base camp: Barrow Strait was generally ice free in the northern and central portions, but considerable ice was observed near Prince Leopold Island.

V POND INLET - ECLIPSE SOUND, BAFFIN ISLAND (August 25-September 3)

August 25: 8-9/10 sea ice cover in southern Navy Board Inlet and Eclipse Sound, but open water existed at the outlets of all major streams, and large leads radiated out from all headlands: open water was observed in Pond Inlet as far west as Mt. Herodier: Albert Harbour, adjacent to Beloeil Island was covered by 10/10 first-year ice: a considerable number of icebergs were present within Eclipse Sound.

: near the settlement of Pond Inlet a band of open water existed all along the shore, but the ice was continually shifting under the influence of tidal currents.

August 26: to the east of the settlement, a wide zone of open water existed along the shore; however, a narrow ledge of ice existed at the base of the rock coast: in the shallows, ice had grounded on the many boulders observed at low tide: open water offshore of the Salmon River.

August 28: below freezing night temperatures had resulted in a new layer of ice across the beach face, varying from 0.02 - 0.07 cm in thickness: the ice broke easily in one's hand. but still acted as a protective sheet for the beach: a thin layer of grease ice had formed between the nearshore ice floes: some sediment was contained in the new ice surface.

August 29-30: the offshore ice was continually shifting and was less than 5/10 in some places, but in general 8/10 ice cover existed: new snow on August 30th resulted in an added cover of ice to the beach: this cover, if exposed to the sun, melted rapidly, the old porous ice from the surface of the ice pieces had, in many cases, been incorporated into the new ice layer on the beach.

August 31: night temperatures of -5 to -7° C: new ice formed in calm waters and on shore appeared as a white opaque substance at low tide.

September 2: NE winds drove ice onto the south shore along Pond Inlet and parts of Eclipse Sound: the sea had a temperature of -1 to 0° C: the rivers had a +1 to 0° C temperature.

September 3: new ice was still forming on the beach face but the offshore sea ice conditions were getting less because of increased wave action which was possible in the larger open water areas.

APPENDIX F - PHOTOGRAPHS

COASTAL TYPES

PLATE 1 *

Archer Fiord, Ellesmere Island

PLATE 2 *

Radmore Harbour, Ellesmere Island

PLATE 3 *

Fiord Coastal Environment - Cape Warrender, Devon Island

PLATE 4 *

Ice Shelf - McClintock Bay, Ellesmere Island

PLATE 5 *

High Straight Coastal Environment - south coast of
Devon Island

PLATE 6 *

Ridge and Valley Coastal Environment - Bracebridge Inlet,
Bathurst Island

PLATE 7 *

Arctic Coastal Plain - north Borden Island
- note the numerous stream outlets along the coast

PLATE 8 *

Arctic Coastal Plain - south Ellef Ringnes Island - note the "islets" in the nearshore zone

BEACH TYPES

PLATE 9

Shingle Beach - north Swinnerton Peninsula, Makinson Inlet, Ellesmere Island (July 20, 1972)

PLATE 10

Shingle beach - north Somerset Island (July 6, 1972) - the ice-push ridges are oriented N.E.

PLATE 11

Shingle beach - Radstock Bay, Devon Island (August 19, 1972) -

- in the foreground is a pronounced high tide ridge
- further upslope, ridges of buried brash ice are found

PLATE 12

Beach bluff - Eclipse Sound, Baffin Island (August 28, 1972)

- an area of erosion, both thermal and wave

PLATE 13

Wide sandy-gravel beach - Eclipse Sound, Baffin Island (August 28, 1972)

- beach backed by ponds and coastal hills

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* photographs 1-8 are taken from A. Taylor's (1956) Ph.D. Thesis

PLATE 14

Coastal flats, at low tide, at the head of a small bay -
Hooker Bay, Bathurst Island (August 11, 1972)
- the foreground is the mouth of a large stream

BEACH SEDIMENT

PLATE 15

Beach sediment, (HHWM) profile F - north Swinnerton Peninsula, Makinson Inlet, Ellesmere Island

PLATE 16

Beach sediment, (HHWM) profile G - Eclipse Sound, Baffin Island

PLATE 17

Beach sediment from small headland spit - Hooker Bay, Bathurst Island

PLATE 18

Dirt cone on nearshore ice - north Somerset Island (July 13, 1972)

BEACH AND NEARSHORE ICE

PLATE 19

Icefoot - south Swinnerton Peninsula, Makinson Inlet, Ellesmere Island (July 23, 1972)

PLATE 20

Fast ice - north Somerset Island (July 3, 1972)

PLATE 21

Icefoot - same location as photo 20 (July 10, 1972)

PLATE 22

Icefoot, at base of rock coast, Eclipse Sound, Baffin Island (August 28, 1972)

PLATE 23

Meltwater channel, cut in fast ice - Radstock Bay, Devon Island (July 1970) - note the beach sediment in the channel

PLATE 24

Shorefast ice-cored ridge (icefoot)- 'Tern Cove', Makinson Inlet, Ellesmere Island (July 20, 1972)

PLATE 25

Sea ice of fracture zone covered by beach sediment - 'Tern Cove', Makinson Inlet, Ellesmere Island (July 19, 1972)
- survey staff is 3.5 m long

PLATE 26

Shorefast ice-cored ridge, at low tide - Hooker Bay, Bathurst Island (August 11, 1972)

PLATE 27

Shorefast ice-cored ridge - north Swinnerton Peninsula, Makinson Inlet, Ellesmere Island (July 20, 1972)

- large pieces of ice grounded in the ice ridge
- low tide, note the coarse nearshore sediments

BEACH FORMS CREATED BY ICE

PLATE 28

Formation of an ice-push mound - Pond Inlet (settlement), Baffin Island (August 30, 1972)

- newly fallen snow on shore

PLATE 29

Storm wave activity - Radstock Bay, Devon Island (August 23, 1971)

- brash ice thrown up on shore and buried
- 10 cm interval staff in foreground

PLATE 30

Close-up of Plate 29 - Radstock Bay, Devon Island

PLATE 31

Buried sea ice - Radstock Bay, Devon Island (August 1971)

PLATE 32

Pitted beach above HHWM - north Somerset Island (July 11, 1972)

PLATE 33

Freeze-up, young coastal ice - Pond Inlet (settlement), Baffin Island (August 28, 1972)

PLATE 34

Freeze-up, the formation of an icefoot - Radstock Bay, Devon Island (October 3, 1971)

PROCESS

PLATE 35

Open water conditions - Radstock Bay, Devon Island (August 24, 1971)

PLATE 36

Freeze-up - Radstock Bay, Devon Island (October 1, 1971)

PLATE 37

Spring melt conditions - Radstock Bay, Devon Island (July 14, 1972) - thick snow cover on beach and nearshore

PLATE 38

Summer ice conditions - Radstock Bay, Devon Island (August 26, 1972) - no open water occurred in 1972 at this site

FIGURE 11 T-397R-147

THE ELLESMERE-GREENLAND FOLD BELT, NORTHEAST GRINNELL LAND. The 60-mile length of Archer Fiord (3 to 5 miles in width) is seen in this westward view. This straight trench is deeply engorged along the strike of the folds of the Ellesmere-Greenland fold belt on the northwest margin of Judge Daly Promontory of northeast Grinnell Land. To the right are the steeply-dipping, more finely laminated beds forming the erosional surface of the Greely-Hazen Plateau, which also parallel the axis of Archer Fiord. (Photo by courtesy of Royal Canadian Air Force.)

1

FIGURE 10 T-398R-25

THE ELLESMERE-GREENLAND FOLD BELT, EAST GRINNELL LAND. An eastward view acros the head of Radmore Harbour near the northeastern extremity of the Ellesmere-Greenland fold belt. The deeply-dipping folds are clearly visible on both sid of the fiord, dipping almost vertically toward the left in this view and more gently a few miles to the south (right), with indications of faulting and perhaps thrusting visible. The summits of these beds form the sharp ridge crests of the Victoria and Albert Mountains. The intervening troughs between the ridges are largely ice-filled, the snowline rising to the crest of the ridge on the north-facing slopes, and descending on the southern slopes to much lowe altitudes. (Photo by courtesy of Royal Canadian Air Force.)

2

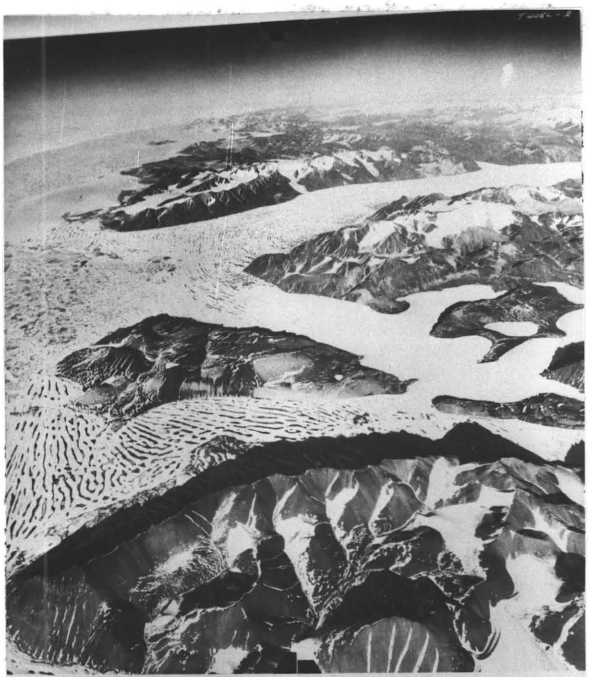

FIGURE 24 T-408L-2

MOUTH OF MCCLINTOCK BAY, LOOKING EASTWARD. Here is the principal trench of McClintock Bay, which runs for 50 miles inland. In the foreground is the isla intervening between the East and Middle Portal Inlets. On the far wall of McClintock Bay, 25 miles inland, a small inlet marks the outlet of a valley at the base of the Parr-Yelverton depression, at this point largely ice-free. No of this inlet, with a small ice field margining the bay, are the highest (4000 feet) peaks of the indiscriminately arranged peaks and ridges of the Challenge Mountains. Note the lineated pattern on the shelf ice. (Photo by courtesy of Royal Canadian Air Force.)

3

FIGURE 6 T-508R-12

CAPE WARRENDER, THE SOUTHEASTERN EXTREMITY OF DEVON ISLAND. An eastward view out of the mouth of Lancaster Sound across the rocky cape on which Dr. Neill, Parry's geologist, collected the first geological specimens from the Queen Elizabeth Islands in 1823. These coastal ridges of Precambrian crystalline formations are similar to those occurring on eastern Lincoln and Sverdrup Lands farther north. Here they rise steeply from a narrow coastal platform to altitudes of about 3000 feet, well below the 6000-foot summit of the island. The perimeter of the "Devon Ice Field" almost reaches the south coast at this point, though with no great activity. (Photo by courtesy of Royal Canadian Air Force.)

4

T-[illegible]-206

[illegible] 1. An eastward view along the high, cliffed, straight south [illegible], with the ice-free waters of Lancaster Sound to the right [illegible] cliffs characteristic of this coast also line the walls [illegible] deeply penetrate the 2000-foot-high sedimentary Paleozoic plat [illegible] are [illegible]. On the interfluve plateau remnants, small isola [illegible] exist, occasionally sufficiently productive to feed tidewater glaci [illegible] horizon to the left may be seen the broad extend of the "Devon I [illegible] the eastern highlands of the Island. (Photo by courtesy of Royal [illegible] Air Force.)

5

FIGURE 6 T-410R-164

BATHURST ISLAND. The Parry Island Fold Belt on southwestern Bathurst Island, where resistant strata of the folds have expressed their induration as extended peninsulas along this coast. These peninsulas, as well as the north side of Bracebridge Inlet as far west as Schomberg Point, parallel the strike of the folds as do the string of islets in the center background. This deeply indented coastline is completely controlled by the differential erosion of the parallel exposures of the folded strata. (Photo by courtesy of Royal Canadian Air Force.)

6

FIGURE 2 T-411R-163

BORDEN ISLAND. The north coast of Borden Island looking west, showing the remarkably uniform dendritic drainage pattern which has lightly inscribed itself along this gentle slope. At the shore the principal streams broaden in braided valley floors before depositing their load of eroded fines in coastal outwash plains. The pattern of the folds is accentuated here by the partly snow-filled valleys. Borden Island is one of several islands in this northwestern sector of the Queen Elizabeth Islands which are part of the Arctic Coastal Plain. (Photo by courtesy of Royal Canadian Air Force.)

7

FIGURE 21 T-411L-11

THE ARCTIC COASTAL PLAIN, SOUTH ELLEF RINGNES ISLAND. Westward view of the so coast of Ellef Ringnes Island on the Arctic Coastal Plain with the Beaufort Se to the west. This low, flat coast is typical of much of the land area in this plain. The light dusting of snow the land has received highlights remarkably intricate dendritic drainage system lightly inscribed as the outwash area. (Photo by courtesy of Royal Canadian Air Force.)

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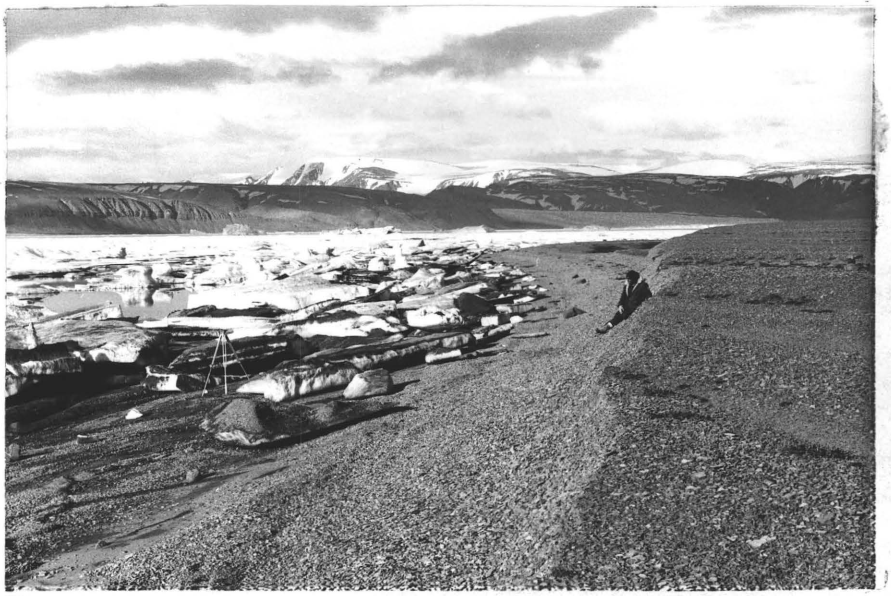

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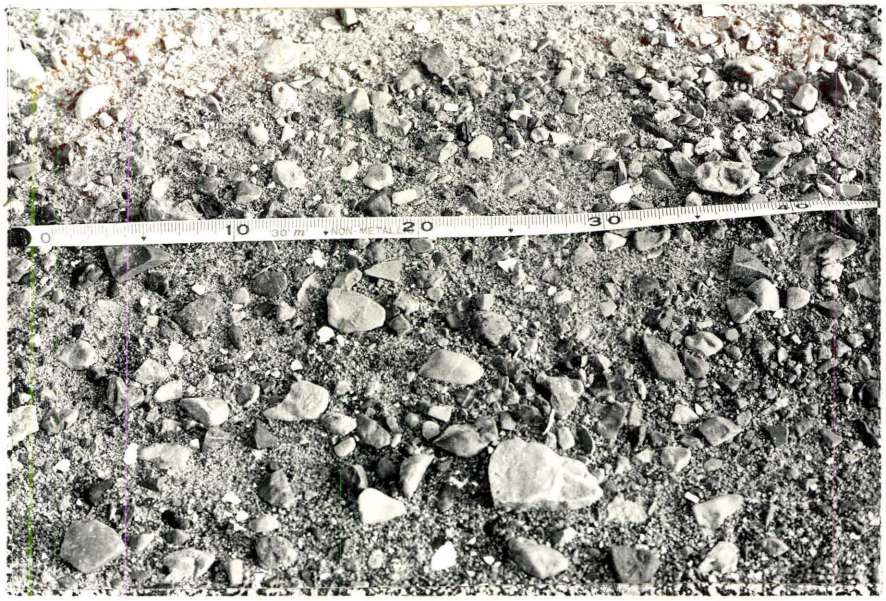

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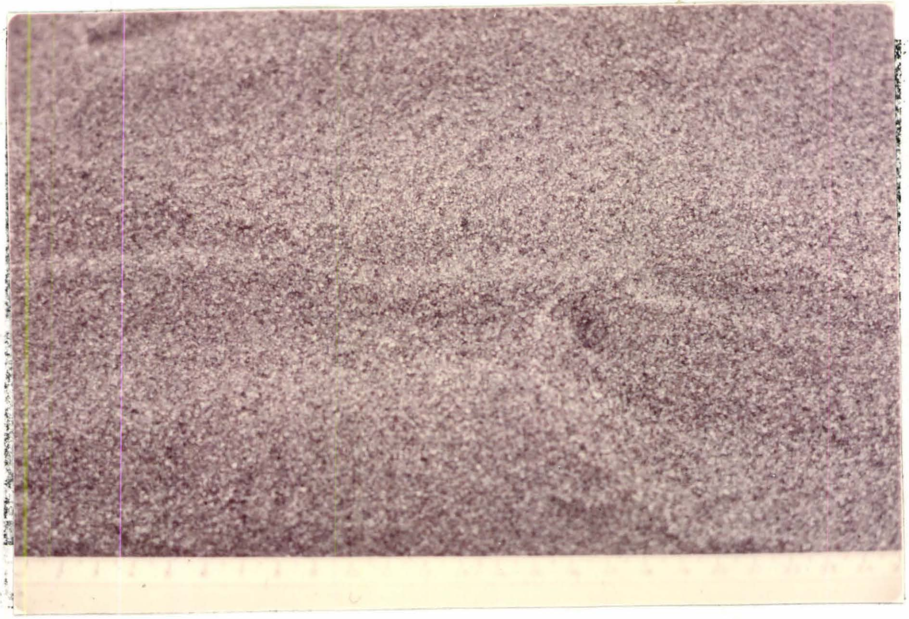

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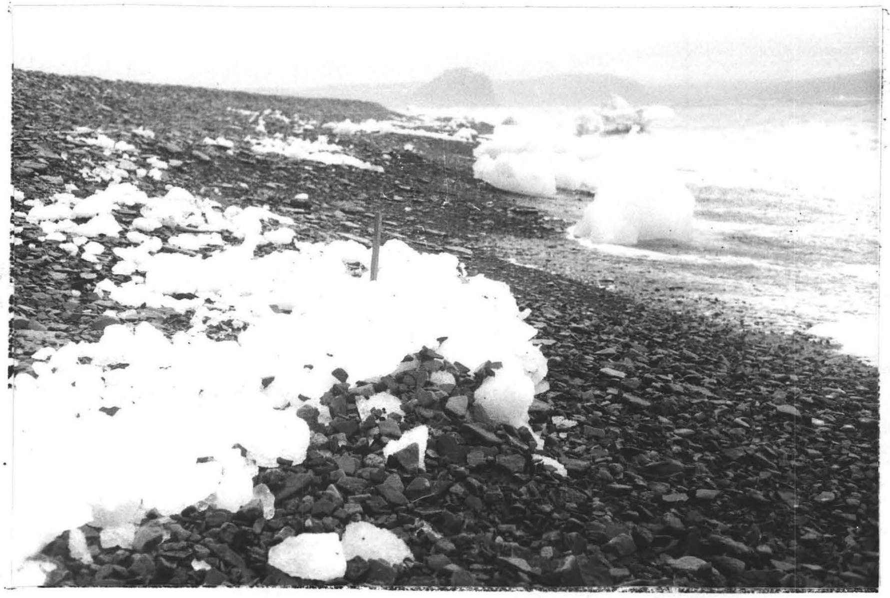

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