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THE GLACIAL AND SEA LEVEL HISTORY OF DARLING PENINSULA, EASTERN ELLESMERE ISLAND, HIGH ARCTIC CANADA

BY

LYN GUALTIERI

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND
RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOGRAPHY
EDMONTON, ALBERTA
FALL 1994

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE GLACIAL AND SEA LEVEL HISTORY OF DARLING PENINSULA, EASTERN ELLESMERE ISLAND, HIGH ARCTIC CANADA submitted by Lyn Gualtieri in partial fulfillment of the requirements for the degree of Master of Science.

Dr. John England

Dr. Nat Rutter

Dr. Bruce Rains

September 30, 1994

ABSTRACT

The glacial and sea level history of Darling Peninsula was determined by studying three valleys and the intervening coastline. Meltwater channels, kettles and lateral moraines mark the last glacial maximum whereas shells in till, Greenland erratics and high-elevation Ellesmere Island erratics mark a more extensive, former glaciation. The chronology of deglaciation is based on surveying of raised marine deposits and ^{14}C dates from marine fauna. During the last glaciation, glaciers advanced up to 8 km beyond their present margins and calved into the sea. The North Water served as the principal moisture source for the glaciers on the peninsula. Deglaciation began at least 7.5 ka and the distribution of ice on the peninsula was similar to the present distribution by 6.0 ka or later. The Holocene marine limit ranges from 79-88 m asl and is principally marked by deltas and beaches. Approximately 35 m above the Holocene marine limit, older shorelines record the deglaciation from the former coalescence of Ellesmere Island and Greenland ice along the mouth of Gould Bay. The age of this glaciation remains uncertain, but it predates the late Wisconsinan. In other areas along this coastline Ellesmere Island ice blocked out Greenland ice, as shown by the widespread absence of Greenland erratics and shells >200 m above Holocene marine limit. The reconstruction of the glacial and sea level history of Darling Peninsula has aided in the mapping of the 80 and 90 m isobases on eastern Ellesmere Island which date ~ 7.5 ka.

ACKNOWLEDGEMENTS

Many people helped me to initiate, sustain and ultimately act upon my curiosity about Earth Science. I want to thank all of them for helping me to realize my potential, and hopefully this thesis is just the beginning of more to come. The first person who made me think about the Earth in a way that I had never done so before is Hoyt Taylor, from Groton School. I will never forget the day in 10th grade Earth Science class when he taught us about plate tectonics: that is when I realized that there was a lot more to the Earth than I could ever imagine. The most exciting part of the thesis was the field work, and without the strength, silence and cooperation of Darren Sjogren it may not have been so rewarding. If it wasn't for Darren I would have been washed down an arctic river, and never known how to make salami fried rice. I thank Darren for his patience with me, as I sometimes wandered and lingered for no apparent reason. I appreciate Nat Rutter and Bruce Rains for their thorough reading of the thesis and useful comments.

The thesis would not have been possible without the generous financial and intellectual support of my advisor, John England. Although I was a bit wary of my field area due to its name, it exceeded all my expectations, and the experience I had there only increased my desire to pursue work in the arctic. Whenever I left John's office I always felt better than when I had first walked in. His careful teaching, observations, and editing are very much appreciated. The most practical thing John ever taught me though was to not worry.

The biggest supporters of this thesis and its author are my parents, Domenic and Margery Gualtieri. My Dad's unfailing computer support and inquisitive comments kept me on top of things. My Mom got as excited as I did about my work and ended many emails, letters or telephone conversations with the concise direction to "Just do it"! I want to thank them especially for being a positive influence and not only encouraging me, but taking great interest in my studies. In addition to the people mentioned above, there are many other graduate students, friends, family members and one dog who made my graduate work at the University of Alberta memorable.

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CHAPTER 1

INTRODUCTION AND PREVIOUS RESEARCH

1.1 Introduction

The extent of ice during the last glaciation of eastern Ellesmere Island is still contested, and fundamentally different reconstructions have been proposed for the north and south (England 1976*b*, 1983, 1985, 1987; Blake 1977, 1992*a*). The relationship between the amount of ice cover and postglacial emergence is also interpreted differently, and tectonic factors, as well as the scale and chronology of deglaciation, must be considered for both areas (*cf.* Tushingham 1991; England *et al.* 1991).

Two hypotheses have been proposed for the last glaciation of the eastern Queen Elizabeth Islands (Fig. 1.1): 1) a thick, regional ice sheet (the Innuitian Ice Sheet) which coalesced with the Greenland and Laurentide ice sheets (Blake 1970, 1972, 1992); and 2) a discontinuous complex of glaciers and plateau ice caps (the Franklin Ice Complex) which left many fiords and channels ice-free, occupied by a full glacial Innuitian Sea (England 1976*b*, 1983, 1990, 1992; Dyke and Prest 1987). A regional database developed by several researchers has tended to favor the Franklin Ice Complex interpretation (England 1976*b*) based on fieldwork by Hodgson (1985); Bednarski (1986); Retelle (1986); Lemmen (1989); Evans (1990); Sloan (1990); and Bell (1992). Nonetheless, the east-central coast of Ellesmere Island (Fig. 1.2) has remained unstudied despite the fact that it borders the southeastern highlands from

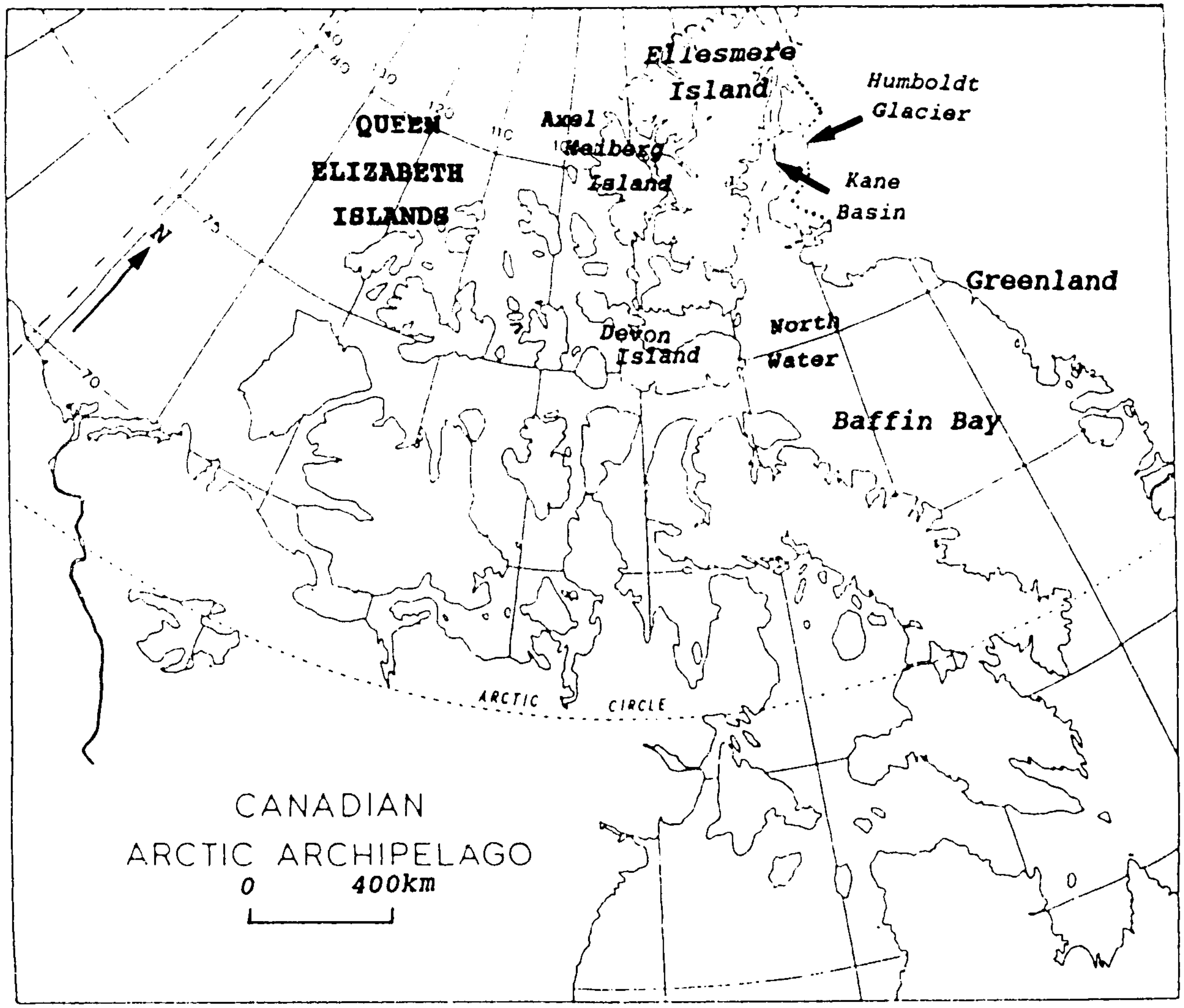

Fig. 1.1. Canadian Arctic Archipelago. Nares Strait is the body of water that separates Ellesmere Island and Greenland.

which part of the proposed Innuitian Ice Sheet dispersed (*cf.* Blake 1977, 1992*a*). Hence the east coast of Ellesmere Island is critical to this regional database. My field area is centered on Darling Peninsula, located along the western shore of Kane Basin, from which ice flowed north into Nares Strait and south into Smith Sound (Fig. 1.2). This study concerns the mapping of former ice margins and the associated postglacial emergence along this coastline in order to contribute a better understanding of the nature of the last glaciation and earlier events.

There is evidence for Greenland ice formerly extending onto much of the east coast of Ellesmere Island (*cf.* Christie 1967; Blake 1977; England *et al.* 1978, 1981; Lemmen and England 1992). The former divergence of ice from Kane Basin predominantly involved the Greenland Ice Sheet and particularly the large Humboldt Glacier that borders the east side of Kane Basin today (Figs. 1.1 and 1.2). The uncertain age of this glaciation has lead to disagreement among workers. Blake (1970, 1977, 1978, 1992) argues that the inundation of Kane Basin took place during the last glaciation, whereas England and Bradley (1978) propose a date of >35 000 years for the advance of Greenland ice onto northeast Ellesmere Island. More recently, Lemmen and England (1992) suggest an age of >400 000 years for the coalescence of Greenland and Ellesmere Island ice in Nares Strait and further propose, on glacioclimatic grounds, that it likely occurred during a period of reduced sea ice cover on the Arctic Ocean. To the north, along eastern Robeson Channel, Retelle (1986) dated the confluence of the Ellesmere Island and Greenland ice at >70 000 years based on amino acid ratios from marine shells collected from deglacial shorelines rising to

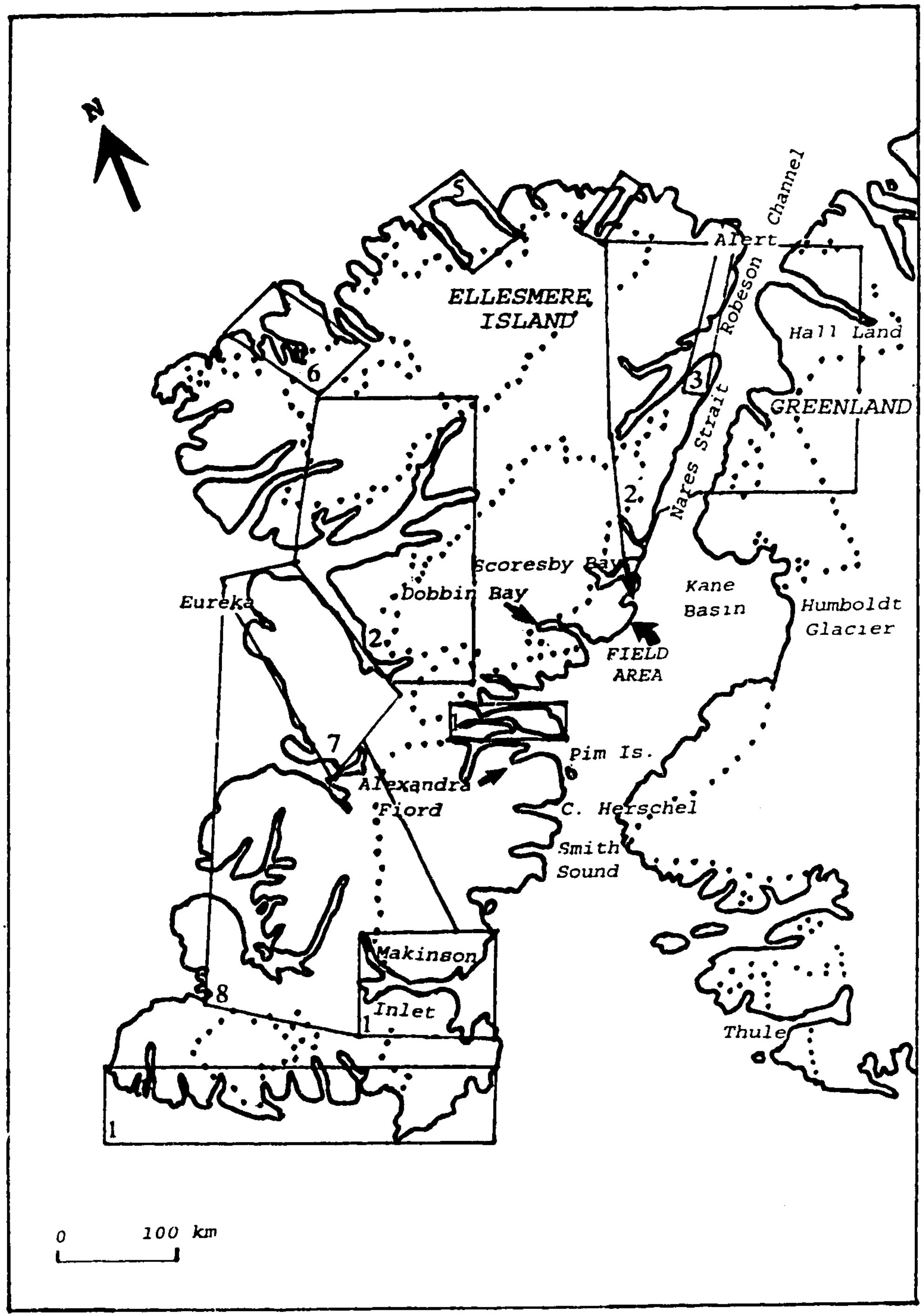

Fig. 1.2. Location of field area and place names in text. (1) Location of work by Blake (1970; 1972; 1977; 1992), (2) England (1976-1993), (3) Retelle (1986), (4) Bednarski (1986), (5) Lemmen (1989), (6) Evans (1990), (7) Bell (1992), (8) Hodgson (1985). Extent of present Ellesmere Island and Greenland ice • • • • • •

285 metres above sea-level (m asl). He referred to this marine event as the Robeson Aminozone.

England (1976*b*, 1983) proposed that the Hazen Moraines, on northeast Ellesmere Island, mark the limit of the last glacial maximum, (ca. 8.1 ka) indicating that a wide, Late Wisconsinan ice-free corridor separated the Ellesmere Island ice from the Greenland Ice Sheet. The Greenland ice terminated at prominent moraines surrounding Hall Land, northwest Greenland, on the opposite shore of Nares Strait (England 1985, 1987). However, this interpretation is contested by Bennike *et al.* (1987) who suggest that Greenland ice occupied northern Nares Strait well beyond England's (1985) proposed margin. Retelle (1986); however, found no evidence for such Greenland ice (during the last glacial maximum) on the adjacent Ellesmere Island coast. For the south end of Nares Strait, Blake (1977, 1992*a*) proposed that the last glaciation was characterized by pervasive ice infilling Kane Basin which flowed southward as the Smith Sound Ice Stream. This reconstruction is based on perched erratics, fresh striae; and the absence of differential weathering along the contacts of rocks of different grain size. At Cape Herschel and Pim Island (Fig. 1.2), Blake (1977) notes freshly polished and scoured bedrock at 280 and 500 m asl, respectively. Although it is useless to simply define the "freshness" of striae and scoured bedrock, he uses these features as evidence of former Ellesmere Island ice from the Innuitian Ice Sheet coalescing with the Humboldt Glacier which "funnelled" ice into Kane Basin to create an ice ridge (>1200 m thick) over Nares Strait during the last glaciation. This model has been recently reaffirmed by Blake (1992*a*) who suggests that the deglaciation from this extensive ice margin is recorded by an ice-contact delta of presumed Holocene age. Futhermore, Blake (1992*b*) contends that shelly tills deposited by the Smith Sound Ice Stream provide *finite* dates of 29-31 ka. Blake concludes that these provide reliable maximum ages for the last major ice advance following the Cape Storm Nonglacial Interval (35-50 ka). This conclusion is also based on presumed finite radiocarbon dates on terrestrial organic materials (20-43 ka) from Makinson Inlet (Fig. 1.2).

Evidence that the last ice inundation of Nares Strait is considerably older than the last glaciation is based on the age of ice-transported shells deposited by the Greenland Ice Sheet on Ellesmere Island, as well as by deglacial shorelines at 175-285 m asl which are clearly unrelated to Holocene sea levels that fall below 125 m asl along eastern Ellesmere Island (England *et al.* 1978, 1981; Retelle 1986). Furthermore, ice-shelf moraines deposited by Ellesmere Island ice remain undisturbed by any subsequent ice advances along Nares Strait since their deposition >35 000 ka (England 1978, 1981). Recent work by Bell (1992) suggests that the last regional inundation by glaciers in Eureka Sound and northern Nares Strait could be as old as late Tertiary (>2 Ma) based on amino acid ratios on shells in till which are similar to the ratios from the late Tertiary Kap København Formation on northern Greenland (Funder *et al.* 1985).

1.2 Climate

Koerner (1977) recognized the modern asymmetry in ice thickness and ice volume on the east and west sides of the central Ellesmere Island ice cap. This asymmetry is controlled by greater snow accumulation on the east side of the ice cap. The greater ice thickness has been linked to an influential polynya (the North Water) which serves as a local moisture source (Koerner 1977). The North Water presently occupies northern Baffin Bay (400 km south of Darling Peninsula), and it is responsible for more vigorous glacial activity on eastern Ellesmere Island. Hence, it may have played a similar role during the last glaciation. For example, along the east-central coast of Ellesmere Island, glaciers appear to have been more vigorous during the last glaciation than they were to the north, and they may have persisted close to the last ice limit until the mid- Holocene (J. England pers. comm. 1992). Koerner (1977) attributes the higher accumulation and ablation rates on the east side of Ellesmere Island to the warm Climatic Optimum (8-5 ka) when major bodies of water remained open for an unusually long period of time. The open water in Baffin Bay, coupled with cyclonic activity, brings higher accumulation to the slopes facing the water.

In order to place Darling Peninsula in a regional climatic setting, thirty year (1961-1990) mean annual climate data is presented (Table 1.1) for two weather stations (Eureka and Alert; Environment Canada 1990). Ten and twelve year data are presented for Alexandra Fiord, (Labine 1994) and Thule, Greenland, respectively (Fig. 1.2).

	Mean Annual Temperature, °C.	Total Annual Precipitation, mm.
Eureka	-19.9	68
Alert	-18	154
Alexandra Fiord	-16.5	62
Thule	-11.3	122

Table 1.1 Mean Annual Climate Data for Ellesmere Island and Thule, Greenland.

Eureka and Alexandra Fiord experience similar amounts of precipitation and both areas are considered to constitute a polar oasis (*cf.* Labine 1994). The noticeable difference (54 mm) in precipitation between Eureka and Thule exemplifies Koerner's (1977) observation of greater accumulation in areas exposed to the North Water. The North Water not only affects the precipitation, but also temperature on a regional scale. Warmer annual temperatures in Thule and Alexandra Fiord, compared to Eureka and Alert, may be a result of the prevailing air flow from the North Water (Labine 1994). The low precipitation rates in Alexandra Fiord compared with Thule may be attributed to the mean flow of air travelling from the polar ocean onto Ellesmere Island which is adiabatically dried as it crosses the 900 m asl uplands that separate Eureka from Alexandra Fiord (Labine 1994).

1.3 Research Objectives

The primary objectives of this study are:

1) To map and interpret the glacial geomorphology and marine deposits on Darling Peninsula with an emphasis on determining the extent of ice during the last glaciation.

2) To establish the pattern and chronology of postglacial emergence on the peninsula, based on ^{14}C dating of raised marine fauna.

3) To investigate the nature and chronology of older glaciations, especially evidence for the coalescence of Greenland and Ellesmere Island ice along this coastline.

1.4 Location of Field Area

Darling Peninsula is located on east-central Ellesmere Island at approximately 79°N, 72°W (Fig. 1.2). Scoresby Bay defines the northern extent of the peninsula whereas outer Dobbin Bay and Kane Basin define the southern and eastern limits, respectively. The peninsula is oriented northeast/southwest, and is 45 km long and 20 km wide. The area is characterized by mountains reaching 980 m asl which support small ice caps and valley glaciers. Three valleys extending inland from Maury Bay, Gould Bay and Cape Louis Napolean (Fig. 1.3), were studied extensively with additional investigations of their intervening coastlines. These ice-free lowlands contain diverse Quaternary landforms and sediments extending 5-10 km inland from the sea. Kane Basin is relatively shallow, varying in depth from 380 m off the west

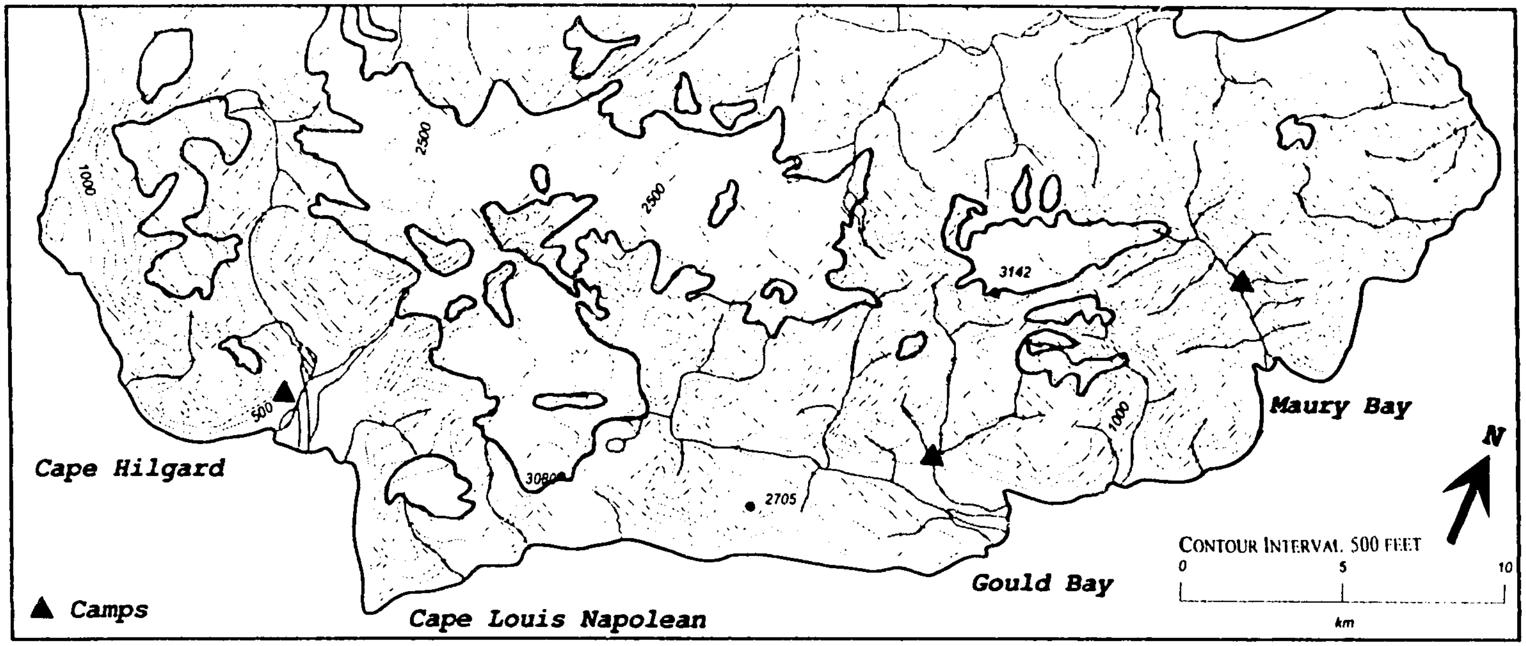

Fig.1.3. Darling Peninsula, western Kane Basin. Ice is enclosed in solid black lines.

coast of Greenland to 145 m in its centre. Depths increase to 250 m off Darling Peninsula (Canadian Hydrographic Service 1978). Nonetheless, this shallow body of water would have deepened due to glacioisostatic depression during past glaciations and any fluctuation of the Greenland ice would cause vertical adjustments on the Ellesmere Island coast. The Humboldt Glacier, the largest outlet glacier on northwest Greenland, lies 130 km east of the field area; hence it lies within the peripheral depression (~150 km, Walcott 1970) of the present Greenland Ice Cap.

1.5 Research Methods

Field Methods

The field methods used include surficial mapping, using Geological Survey of Canada criteria, airphoto interpretation, altimetry, and stratigraphic interpretation and collection of dateable organics.

The map of glaciated North America by Dyke and Prest (1987) shows the ice margin located off the coast of the Darling Peninsula at 9.8 ka, whereas the area is shown to be ice-free by 7 ka. The surficial geology of this peninsula was mapped in order to test the provisional ice margin proposed by Dyke and Prest (1987). The three valleys were chosen on the basis of their abundant glacial and marine deposits, as well as their distribution and accessibility. Preliminary reconnaissance of the field area using air photographs was conducted prior to the field season. Detailed mapping began during the field season (early July, 1993). Former ice margins are marked by moraines and meltwater channels as well as ice-contact deltas and related marine deposits. Standard mapping procedures were used in all areas visited on foot and by helicopter. Between the main valleys. the coast was accessible by travelling along the ice foot, whereas transects across the peninsula were made possible by helicopter. The helicopter was especially useful for altimeter surveys. minimizing the time taken between readings; thereby reducing errors caused by changes in atmospheric pressure. Elevations of significant landforms were always verified by repeated surveys. The helicopter surveys aided in the recognition of Greenland and Ellesmere Island erratics on summits and intervening passes as well as establishing a perspective on the landscape.

Surveying of raised marine deposits is closely linked with the mapping of former ice margins along coastlines. For example, massive marine sediments are commonly found where ice terminated in the sea (Stewart 1991) and such deposits commonly constitute mappable ice margins. Marine deltas, beaches, washing limits and marine silt were surveyed, mapped and sampled for datable marine fauna. The uppermost elevation of these deposits constitutes marine limit which provides a minimum measure of the amount of glacioisostatic unloading in the area. Andrews (1970) identified marine limit on Baffin Island based on: 1) the lowest altitude of undisturbed ground moraine 2) the lowest altitude of perched boulders, above the limit of former wave action 3) the highest elevation of beach ridges or deltaic deposits, and 4) the highest elevation of marine shells, algae or marine mammal remains. Marine limit on most of Darling Peninsula was marked by the highest elevation of beach ridges, deltaic deposits or whole valves of marine shells in marine sediment. Elevations were determined by microaltimeter (Paulin) corrected for both temperature and atmospheric pressure and are assumed to be accurate within ± 2 m (to elevations of ca. 100 m asl) and within ± 5 m for upland sites (ca. 1000 m asl). A reference position for sea level was taken at the same location in each valley and was measured by the highest visible water line, fresh ice-pushed ridges, or stranded sea ice (including the ice foot). Where possible, marine molluscs suitable for ^{14}C dating were collected from growth position in sediments. Establishing the stratigraphic context of these samples is essential for establishing a postglacial emergence curve.

In order to document the former coalescence of Greenland and Ellesmere Island ice, the distribution of Greenland erratics on the peninsula was mapped. These are represented by distinctive crystalline erratics (granite and gneiss) resting on sedimentary bedrock. The highest elevation of erratics above the marine limit was recorded in order to establish a general profile of the Greenland ice when it inundated Darling Peninsula. Ice-transported shells from glacial deposits, which also constitute erratics, were also mapped.

Laboratory Methods

Seven samples of *Hiatella arctica* and *Mya truncata* were dated at IsoTrace Laboratory, University of Toronto, by the AMS (Accelerator Mass Spectrometry) method. This technique is different from conventional ^{14}C dating in that ^{14}C atoms are counted directly after being separated by mass, as compared to conventional beta counting which depends on the radioactivity of the sample (Pilcher 1991). Both techniques show similar age assessments for Holocene samples. All samples were washed in an ultrasonic bath and were hand scraped and inspected visually to ensure the removal of surface contaminants that had accumulated on the shells. The outer 20% of all shells was subsequently removed by HCl leaching at IsoTrace prior to dating. The dates have been corrected for fractionation to a base of $\delta^{13}C = -25‰$ resulting in an added age adjustment of approximately 450 years (Bradley 1985). However, the dates have also been corrected for a reservoir effect which reduces the age by 410 years; thereby cancelling out the fractionation effect. Hence all of the Ellesmere Island dates are readily comparable whether they were calculated using a $\delta^{13}C$ base of 0‰ or -25‰ (with the reservoir effect subtracted).

1.6 Pre-Quaternary Geology

Darling Peninsula lies in the central Ellesmere Island fold belt (Trettin 1989). The bedrock of Darling Peninsula ranges in age from Proterozoic to Paleocene. Lithologies include dolomite, quartzose sandstone, conglomerate, fossiliferous limestone and shale, (Thorsteinsson and Tozer 1970; Thorsteinsson 1974) some of which have been disturbed by thin-skinned thrust faulting and folding during the late Devonian Ellesmerian Orogeny (Thorsteinsson 1974). There are two major northeast-southwest trending reverse faults cutting Darling Peninsula, (Fig. 1.4) as well as many other fold axes and smaller thrusts (Trettin 1989). Mayr and de Vries (1982) also report convergent wrenching, strike-slip faults of Miocene age or older, on Darling Peninsula.

The Pre-Quaternary geology of eastern Greenland, directly across Kane Basin,

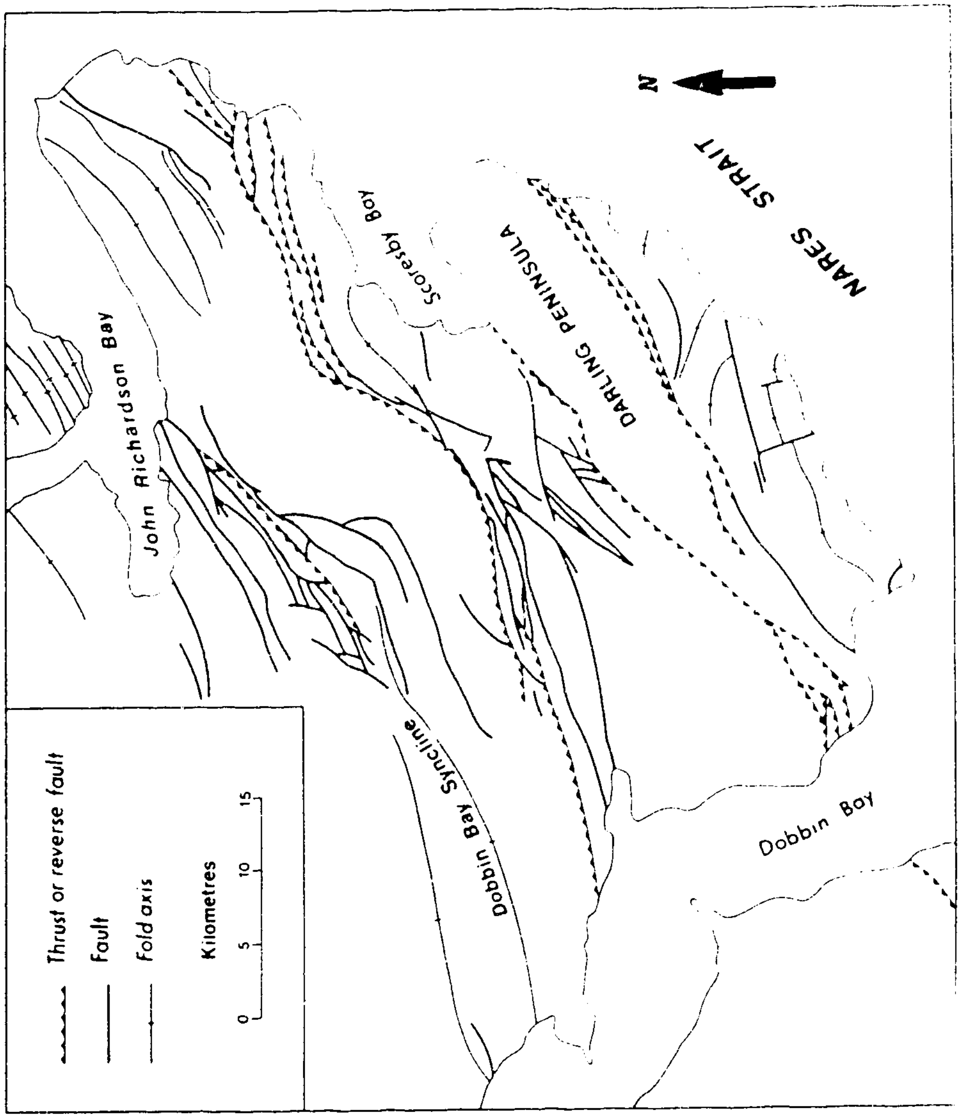

Fig. 1.4. Geologic structure of Darling Peninsula (from Mayr and de Vries 1982).

is useful in terms of erratic indicators. The bedrock consists of Precambrian crystalline and metamorphic rocks as well as granitic intrusions (Funder 1989). The Canadian Shield outcrops 100 km to the south of Darling Peninsula and younger sedimentary rocks of the Sverdrup Basin lie to the west (Thorsteinsson and Tozer 1970).

1.7 Thesis Outline

The following chapters summarize the fieldwork of the thesis and its interpretation. Chapter 2 provides an introduction to the three valleys studied as well as their geomorphology, raised marine stratigraphy and distribution of Greenland erratics. The surficial geology map is presented and described in Chapter 2 as well. Chapter 3 presents the ice margins, chronology, sea level history, deglaciation and former glaciation of the peninsula. Darling Peninsula is then placed in a regional context in terms of postglacial emergence. A summary and suggestions for future research are included at the end of the chapter.

CHAPTER 2

SURFICIAL GEOLOGY AND GEOMORPHOLOGY

2.1 Introduction

Three valleys were studied in order to reconstruct the Quaternary history of Darling Peninsula: Maury Bay, Gould Bay and Cape Louis Napolean valley (Fig. 2.1). In this chapter, the surficial geology, raised marine stratigraphy and distribution of Greenland erratics is presented for each valley. The surficial geology of Darling Peninsula (Fig. 2.2) is included at the beginning of the chapter together with a description of its surficial units. A complete list and description of all marine surfaces measured on the peninsula is found in the Appendix.

2.2 Map Units

The following is a description of the map units found on the Surficial Geology Map of Darling Peninsula, found in the map pocket at the end of the thesis (Fig. 2.2). Units are broadly subdivided on the basis of their genesis. Commonly, deposits have been reworked by periglacial processes, but in most cases their mode of origin is identifiable, and they were mapped accordingly. Areas that were not investigated on foot or by helicopter were mapped from air photographs (1:72 000).

Pre-Quaternary

The Pre-Quaternary geology consists of weathered bedrock. Lithologies include dolomite, quartzose sandstone, conglomerate, limestone and shale. This sedimentary

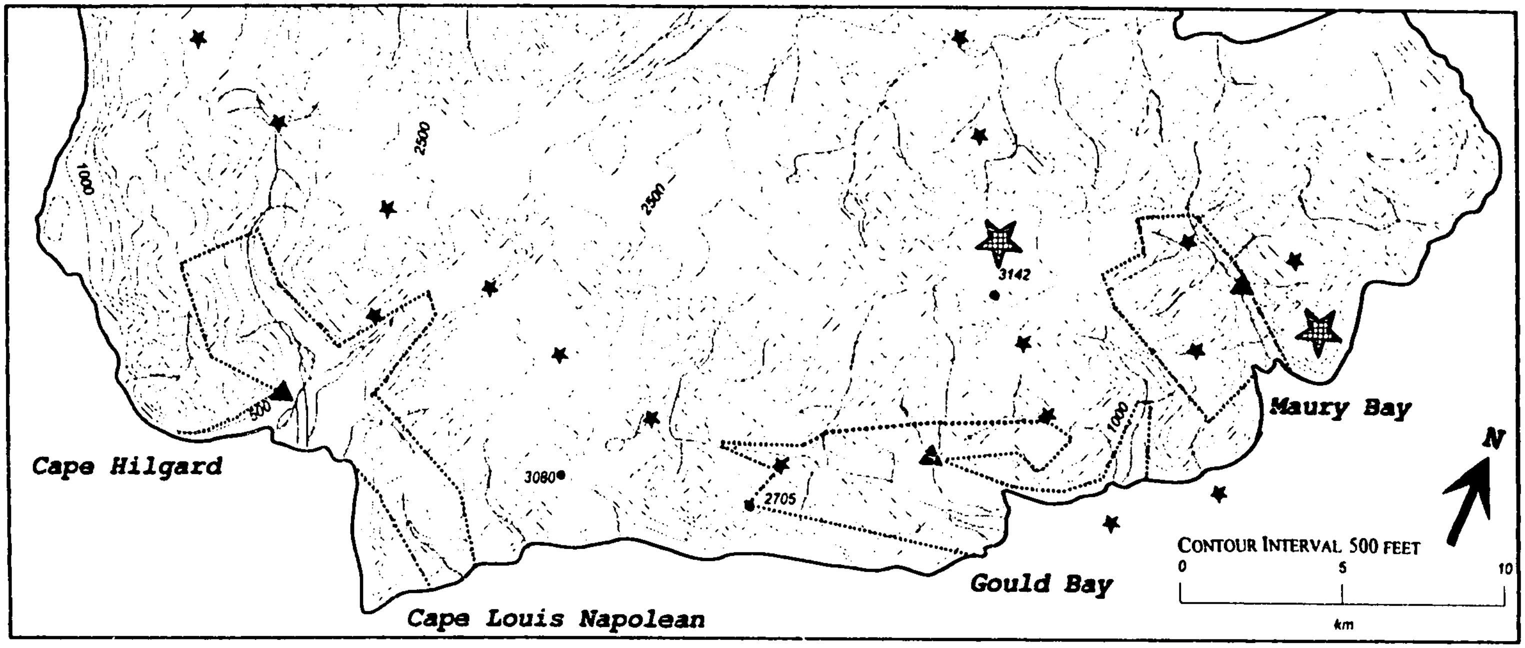

Fig. 2.1. Darling Peninsula camp locations (triangles), place names in text, and foot and helicopter transects. Black stars represent helicopter transects, dashed lines represent area covered on foot and larger stars mark sites visited by helicopter.

bedrock contrasts sharply with the Precambrian erratics from Greenland.

Bedrock (red stipple): This includes any of the above lithologies usually found in the form of cliffs, ridges, isolated outcrops or as recognizable remnant outcrops that have been substantially altered by frost action to produce felsenmeer and tors. A fine textured residuum also exists and was mapped as bedrock.

Glacial

The most common and ubiquitous glacial deposit on Darling Peninsula is till. Till frequently consists of unsorted and unstratified quartzose sandstone or limestone blocks in a sand or silt matrix. Erratics are often found in association with the till; however, they are not mapped as a separate unit. Occasionally, shells also constitute erratics within till. Mapping of till on air photos was done primarily by identifying areas where the bedrock was mantled by coarse material.

Till veneer (green): Till veneer is discontinuous and < 0.5 m thick. The surface of the till veneer mimics the shape of the underlying rock surface or structure (Dyke 1983). Till on Darling Peninsula rarely reaches thicknesses > 0.5 m; therefore, no till blanket was mapped.

Marine

Marine deposits consist of gravel, sand, silt, and clay commonly containing whole shells or fragments. These sediments record nearshore, deltaic and beach environments and are particularly important because they provide key information on the history of deglaciation, postglacial emergence and paleoenvironmental change (*cf.* Andrews 1970; Bednarski 1988; Stewart 1991).

Nearshore sediment (dark blue): These deposits include silt and fine sand up to 1.5 m thick. Deposits are found as isolated, sometimes reworked sections, slightly below marine limit. Sediments frequently contain *in situ* whole valves of *Mya truncata* and *Hiatella arctica*.

Deltaic sediment (royal blue): These deposits include ice-contact deltas displaying topset, foreset or bottomset beds typical of a Gilbert-type delta. These are often well exposed and dissected due to postglacial emergence. Some deltas on Darling Peninsula have well preserved ice-pushed ridges on their coastal margins whereas others display flat, terraced or dissected surfaces. Sand and gravel are the dominant sediments within the deltas. Due to the high energy environment represented by such deltas, shells are sparse and commonly fragmented.

Beach sediment (royal blue stipple): This includes gravel and shingle surfaces forming ridges 1.5 m thick. Beaches often contain shell fragments.

Fluvial

Fluvial sediments on the peninsula are divided into active and inactive types.

Proglacial outwash (yellow): This includes alluvial fans as well as sediment mantling valley bottoms, deposited principally as sandar from modern glaciers. Downvalley, braided channels are depositing contemporary deltas into the sea.

Terrace (yellow stipple): Throughout the field area fluvial terraces border modern sandar and rise above them by as much as 5 m. These terraces consist of poorly sorted gravel and sand.

Colluvium

Colluvium represents a significant part of the surficial geology of Darling Peninsula and commonly obscures raised beaches and nearshore marine sediment.

Colluvium (purple): This includes talus mantling valley slopes, predominantly as scree aprons below cliffs.

Rock glacier (black): This includes rock-glacierized moraines and detrital rock with interstitial ice (meteoric). Evidence of downslope movement is mostly in the form of arcuate ridges and troughs leading to a massive and steep lobate front.

Ice (*white*)

Ice is widespread on the uplands of Darling Peninsula and includes plateau ice caps and outlet glaciers as well as smaller cirque glaciers. The regional Equilibrium Line Altitude (ELA) ranges from about 600 m asl on the coast to approximately 700 m asl in the interior, whereas the Glaciation Level (GL) ranges from > 845 m asl on the coast to 900 m asl inland (Miller *et al.* 1975). The ELA was approximated by the elevation of the contour dividing the lowest small cirque glacier in the map area into an accumulation area roughly twice the size of the ablation area.

In addition to the units described above, symbols are used to indicate ice marginal landforms. These include:

→ Meltwater channels These are usually incised in bedrock and commonly form ravines, some of which are > 20 m deep.

∼ Moraines On Darling Peninsula, like most of the high arctic, moraines are rare. Most are lateral moraines and tend to be discontinuous occurring where talus has been impounded along a former ice margin. Such moraines are often ice-cored and become rock glacierized after ice retreat.

K Kettles Closed depressions often occur in the vicinity of ice-contact deltas and may or may not contain water. Former water lines can be seen in kettles in Cape Louis Napolean valley.

L Lakes A few proglacial lakes in the interior of the peninsula are dammed by ice. These lakes are up to 2.5 km in length and have a thin ice pan on the surface. The lakes appear to be stable.

2.3 Maury Bay - Physiography and Geology

The valley inland from Maury Bay (Fig. 2.1) is the northernmost area studied on the peninsula. The valley is < 0.7 km wide and extends 6 km beyond the outlet glacier occupying its upper catchment. Deeply-incised tributary valleys intercept the main valley at right angles, trending NE-SW. The physiography is rugged with coastal cliffs rising to small plateau remnants at 780 m asl on the south side and 680 m asl to the north. Five kilometres from the coast, the valley splits into two prominent tributaries. The main valley is occupied by an outlet glacier from a small icefield. Several undated river terraces extend to former relative sea levels associated with ongoing late Holocene emergence. The geology of Maury Bay is dominated by horizontal to northwest-dipping Ordovician limestone strata. Small ice-free cirques surround Maury Bay, and the next valley to the south supports a small valley glacier (Fig. 2.3).

2.3.1 Maury Bay - Geomorphology

Outcrops of weathered bedrock and colluvium surround the glacier at the head of the main valley. Where the two tributary valleys converge to form the main valley, unsorted fine-grained sediment and boulders mantle the bedrock. Based on its texture and position, this diamicton is interpreted as a till veneer, which does not mask the underlying geologic structure. Further downvalley, at its narrowest point, lateral moraines are found at elevations >180 m asl (Fig. 2.3). Meltwater channels have cut through till into bedrock and are most prominent on the north side of the valley (Fig. 2.4). Geliflucted bouldery till containing purple sandstone erratics, from the west of the peninsula, also dominate the north side of the valley. On the south side of the valley a lateral moraine extends for < 0.5 km at 185 m asl. The crest of this moraine lies above the most prominent meltwater channels. Towards the mouth of the valley, nearly horizontal landforms < 150 m asl in elevation, record impoundment of talus by former landfast sea ice. Isolated till veneers mantle slopes on the south side of the valley. Colluvium, frequently in the form of scree aprons or rock glaciers (Fig. 2.5), dominates the geomorphology of the southern coast. The northern coast of Maury Bay is characterized by bedrock cliffs descending to the sea.

2.3.2 Maury Bay - Marine Stratigraphy and ^{14}C Dates

Prest (1952), after taking a three hour trip to Maury Bay, described it mainly as stream-terraced outwash grading upwards into kames and talus. He did not observe any beach deposits. During 1993 a camp was established in the lower north side of

Fig. 2.3. Maury Bay valley showing ^{14}C dated sites and marine limit (ML). Camp is marked by ⊗. Barbed arrow outlines a meltwater channel and black arrows indicate moraines mentioned in text.

Fig. 2.4. Meltwater channels cut through till and into bedrock in Maury Bay.

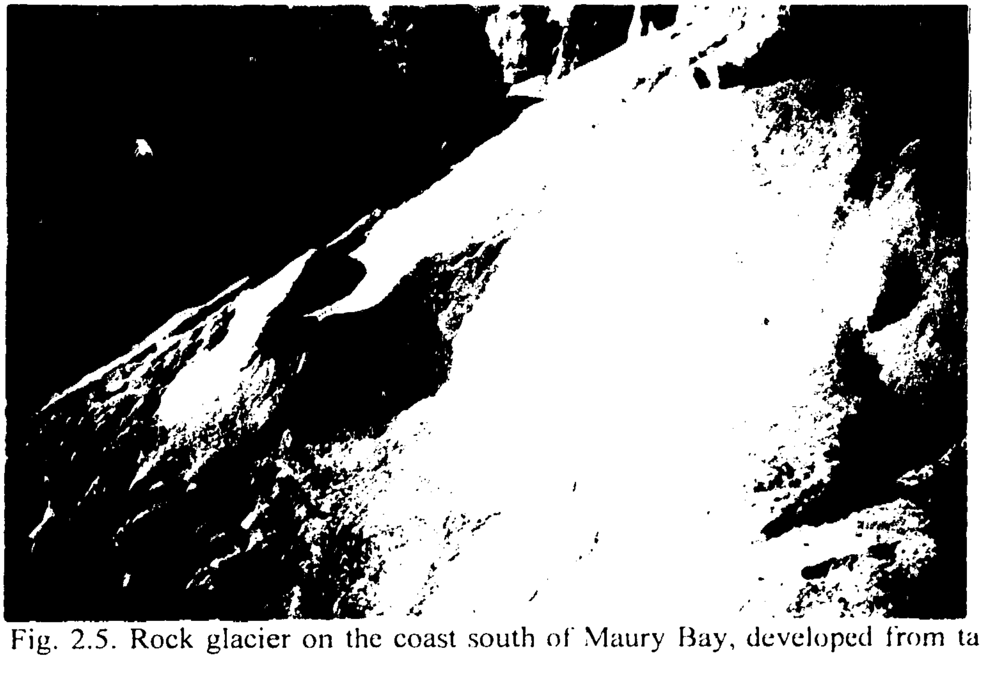

Fig. 2.5. Rock glacier on the coast south of Maury Bay, developed from talus.

the valley, ~ 2.5 km from the coast (Fig. 2.3). In this vicinity raised beaches. nearshore marine silt, deltas and shells were found. Shell samples were collected on the surface and in nearshore sediments at elevations between 65.5 and 71 m asl. Radiocarbon dated sample MB-4-93 was collected on the south side of the valley from nearshore marine silt (1 m thick) at 71 m asl. (Fig. 2.6). This sample dated 7430 ± 70 BP (TO-4214) and relates to marine limit at 83 m asl. The site of TO-4214 constituted the best sample in the valley in terms of shells in growth position related to marine limit. The highest beaches east of camp ranged from 65.5 to 83 m asl. (Table A.1) and beach ridges and abundant shell fragments are found along the north and south sides of the valley. Towards the coast, marine surfaces are difficult to distinguish due to widespread gelifluction and colluvium.

2.3.3 Maury Bay - Distribution of Greenland Erratics

Greenland erratics are found only at or below marine limit throughout Maury Bay. Consequently, sea-ice or iceberg rafting must have been responsible for their distribution (Fig. 2.7). For example, scattered Greenland erratics (red granite and gneiss) appear towards the south coast below marine limit and at the location of shell sample MB-4-93. West of camp, Greenland erratics were not found on either the north or south side of the valley. On the north side of the valley, the coastal upland (Site P1, Fig. 2.7) was visited by helicopter and Greenland erratics were absent. The second upland from the coast, (780 m asl) on the south side of the valley (Site P2, Fig. 2.7) is characterized by weathered fossiliferous limestone, colluvium and a few

Fig. 2.6. Collection of sample MB-4-93 from marine silt (71 m asl). Marine limit is behind the photographer.

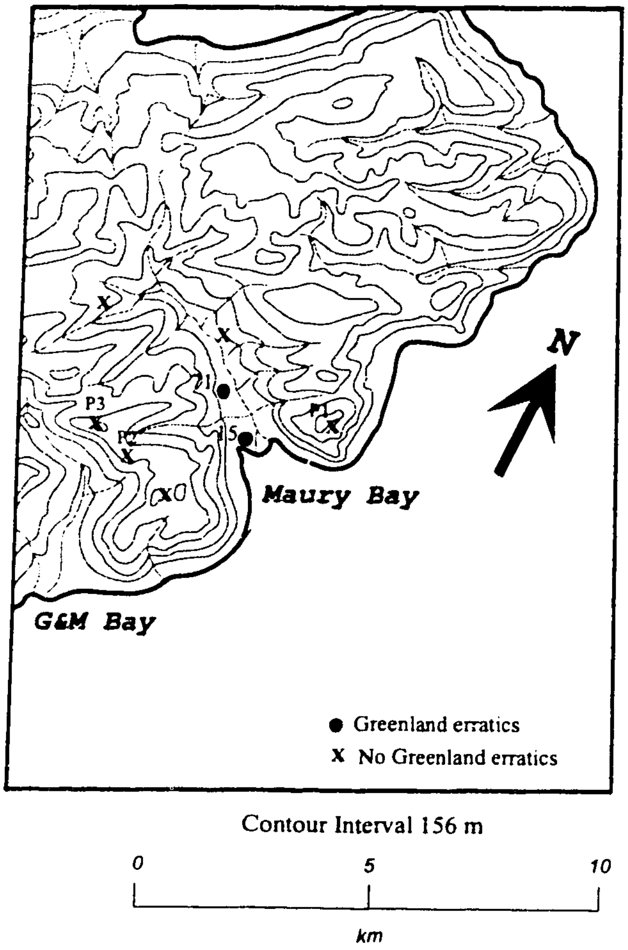

Fig. 2.7. Distribution of Greenland erratics in Maury Bay. Elevations are in m asl.

Ellesmere Island erratics. Just below the peak, opposite camp (Site P3, Fig. 2.7), are colluvium and abundant Ellesmere Island erratics, including pink and white quartzites, limestone and purple-banded sandstone. The absence of Greenland erratics on the uplands surrounding Maury Bay, however, is puzzling because Greenland erratics (above marine limit) were found inland of Scoresby Bay *ca.* 10 km to the northwest. Presumably these erratics were transported northwest across the divide on Darling Peninsula (J. England pers. comm. 1994). Alternatively, local Ellesmere Island ice precluded Greenland ice from crossing the peninsula but did not block it out of Scoresby Bay. A more widespread search of the uplands would be required to test these hypotheses.

2.4 G&M Valley - Geomorphology and Marine Stratigraphy

Along the coast between Gould Bay and Maury Bay is a delta unofficially named G&M valley (Fig. 2.3). The coast north of Gould Bay is characterized by shingle beaches, sea ice-pushed ridges and abundant shells. Greenland erratics are also common at or below marine limit along this section of the coastline. In G&M valley, the geologic structure is dominated by a NW-SE trending syncline. The valley is infilled with active proglacial outwash from the glacier ~ 4.5 km from the coast. On the south side of the valley, till mantles slopes above marine limit. Meltwater channels and remnants of moraines are also present. Weathered bedrock, cliffs and colluvium dominate the north side of the valley. There are prominent marine surfaces, but gelifluction has obscured the highest beaches. Sample GB-4-93 was collected on beach gravel at 79 m asl and relates to a minimum marine limit of 81 m asl. This sample was ^{14}C dated 6930 ± 90 BP (TO-4209).

2.5 Gould Bay - Physiography and Geology

Gould Bay borders an east-west trending valley 11 km long and 2 km wide (Fig. 2.1). The head of the valley is occupied by an outlet glacier from the central Darling Peninsula icefields. Gentle to moderate slopes rise to 780 m asl on the north and 845 m asl on the south side of the valley. Waterfalls and steep tributary streams feed into the braided river at the base of the valley. Cliffs with scree slopes occur to the north and south along the Gould Bay coast.

Mayr and de Vries (1982) map four fold axes in the Gould Bay valley (Fig. 1.4). The gently dipping syncline, composed of Ordovician limestone, on the north side of the valley is the most prominent geologic structure. Horizontal to westward-dipping limestone strata dominate the rest of the area.

2.5.1 Gould Bay - Geomorphology

Upper Valley

The geomorphology of Gould Bay is dominated by till and related glacial landforms. The mid to upper valley is predominantly characterized by till veneer containing quartzite and limestone boulders (Fig. 2.8). In this section of the valley till was observed up to 165 m asl. At lower elevations the till has been reworked fluvially. Meltwater channels cut in bedrock were recognized at several localities (Fig.

Fig. 2.8. Gould Bay showing ^{14}C dated sites, marine limit delta (*Md*), meltwater channels (barbed arrows), moraine (black arrow) and till veneer (*Tv*) mentioned in text. Camp is marked by ⊗.

2.2). On the south side of the valley are wide, lobate features resembling geliflucted till or protalus ramparts (*Tv*, Fig. 2.8). Lateral moraines from tributary valleys are commonly preserved whereas only remnants exist of main valley lateral moraines.

Mid-valley

In the central part of the valley, a fluvial terrace extends eastward towards the till boundary and eventually terminates at beaches (75 m asl). On the south side there is a well-preserved lateral moraine whose crest is 163 m asl (Figs. 2.8 and 2.9). The moraine is discontinuous and declines downvalley (Fig. 2.8). West of a prominent delta on the north side (*Md*, Fig. 2.8), meltwater channels incise bedrock and descend to marine limit (Fig. 2.10).

Lower valley

On the south side of the valley, colluvium obscures the highest beaches at the coast. Here, a local summit rises to 315 m asl below which shell fragments and Greenland erratics are common, particularly below 275 m asl where geliflucted till is widespread. In a col between the coastal uplands (U1 and U2, Fig. 2.8) meltwater channels with a NW to SE gradient are cut in bedrock (Fig. 2.11) indicating ice flow from the main Gould Bay valley. Shells or Greenland erratics were not found inland of the col. Upland U2 is dominated by cryoturbated and geliflucted residuum as well as frost-shattered bedrock. Ellesmere Island erratics (pink sandstone and white quartzite) are also found there.

On the gentle slope ascending the north side of the valley (U3, Fig. 2.8), parallel meltwater channels, with a northwest to southeast gradient, deeply incise till

Fig. 2.9. Lateral moraine in Gould Bay. Crest of moraine is 163 m asl.

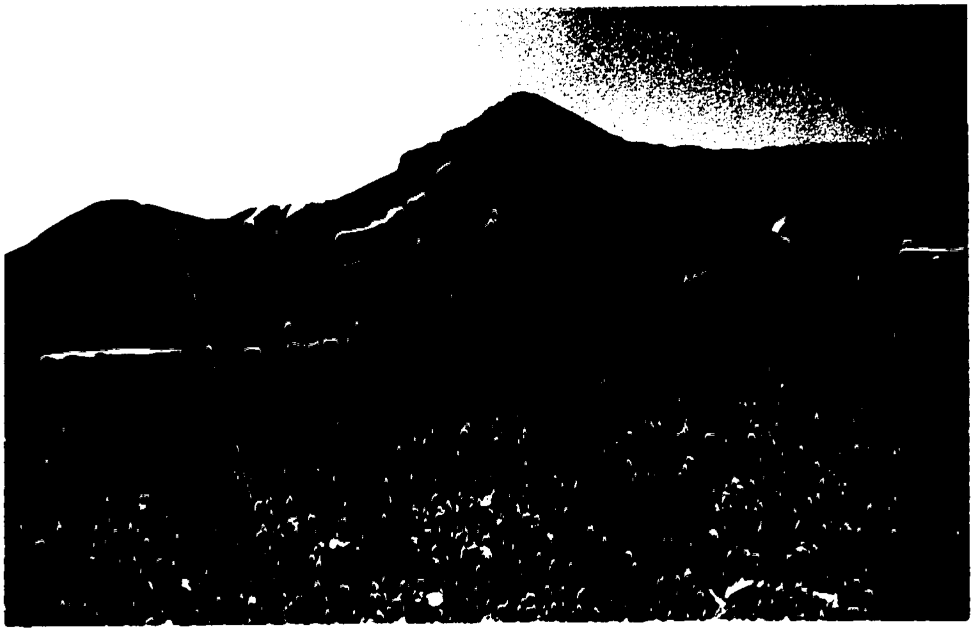

Fig. 2.10. Meltwater channels descend to marine limit (88 m asl) in Gould Bay. Arrow marks the 124 m surface. Note camp for scale (left centre) on lower delta (88 m asl).

Fig. 2.11. Meltwater channels on U1 with west to east (left to right) gradient.

Fig. 2.12. Meltwater channel on the north side of Gould Bay. The width of the channel is approximately 5 m. Ice flowed from upper right to left side of the photograph where the 88 m asl delta was built (not shown in photograph).

(Fig. 2.12). The top of U3 (625 m asl) is dominated by frost-shattered limestone and Ellesmere Island erratics of purple sandstone, conglomerate and white quartzite. The Ellesmere Island erratics indicate ice flow from the west of the peninsula.

2.5.2 Gould Bay - Marine Stratigraphy and ^{14}C Dates

South

On the south coast of Gould Bay the uppermost beaches are obscured by colluvium, but surface shells can be found up to 76 m asl. Nearshore marine sediment or deltaic deposits were not found on the south side, but a beach surface at 68 m asl can be followed for approximately 1 km (Fig. 2.13). Sample GB-7-93 was collected above this at 75 m asl on another prominent beach (Fig. 2.8). This sample dated 7480 ± 60 BP (TO-4210). Marine sediment was not observed upvalley from the moraine on the south side.

North

On the north side of Gould Bay the most striking feature is an ice-contact delta with an upper surface at 88 m asl (*Md*, Fig. 2.8). Ice-pushed ridges rising up to 87 m asl are clearly defined along the east and south sides of the delta. All meltwater channels in the vicinity of the delta terminate at this marine limit. The delta principally consists of coarse gravel; however, discernable topset, foreset or bottomset beds were not exposed. Shells are found on the west side of the delta front, on the surface, at 55 m asl; however, no shells were found on the eastern side of the delta (Fig. 2.10, surface from which picture was taken). A higher surface (124 m asl) above

Fig. 2.13. 68 m asl beach surface on the south side of Gould Bay.

Fig. 2.14. Marine limit delta in Gould Bay. Note higher surface on delta (arrow). Prominent meltwater channels cross-cut hillside to east (right) of marine limit delta.

the delta is easily seen from an aerial view (Figs. 2.10 and 2.14). This surface is covered with till, but its terrace-like morphology is indicative of a higher, older delta surface resulting from a more extensive glaciation of this valley. This older delta has subsequently been overrun by ice during the last glaciation. West of the delta, gelifluced till and marine silt are present; however, there is no counterpart to the prominent beaches on the south side of the valley. Reworked beach surfaces and marine silt range in elevation from 71 to 88 m asl (Table A.2). Sample GB-1-93 was found at 75 m asl in nearshore marine silt. This sample was dated at 7110 ± 70 BP (TO-4208) and provides a minimum age estimate for the 88 m asl delta. West of the sample location, there is a modern, low-elevation delta (< 10 m asl) with clearly defined foresets; however, it does not contain shells. East of the main delta marine surfaces become less distinguishable. The valley contains gelifluced sediment and occasional shells incorporated in colluvium.

2.5.3 Gould Bay - Distribution of Greenland Erratics

Evidence for former glaciation(s) of Darling Peninsula is most significant in Gould Bay. The distribution of Greenland erratics and the presence of shells above marine limit attest to this (Fig. 2.15). Greenland erratics consist of igneous and metamorphic rocks and are easily distinguishable from the local and regional bedrock (Fig. 2.16). Specifically on Darling Peninsula granite, gneiss and garnetiferous schist are found.

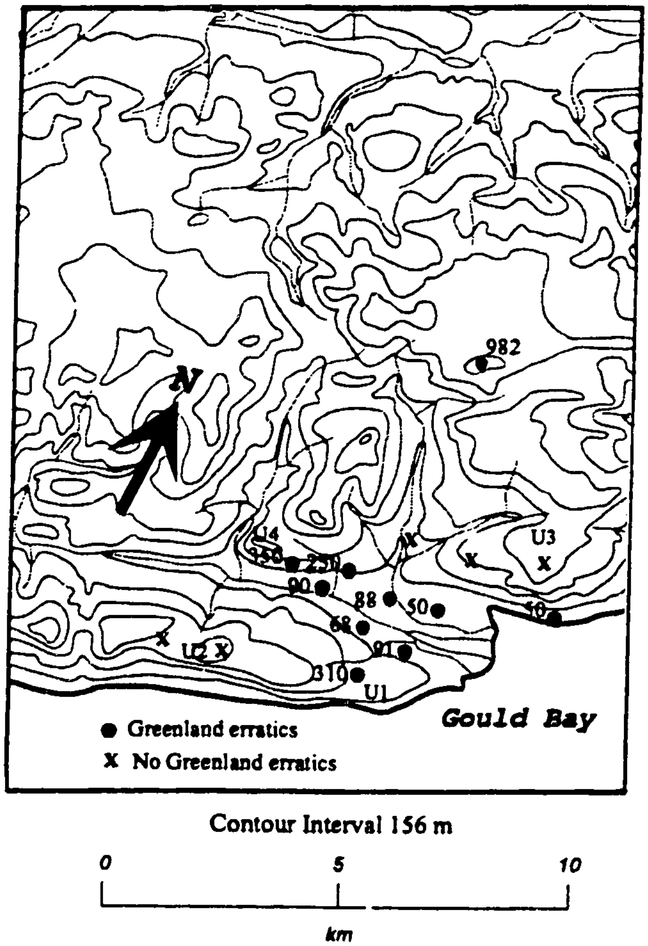

Fig. 2.15. Distribution of Greenland erratics in Gould Bay. Elevations are m asl. Shells of *Hiatella arctica* were found on U1. The 982 m point marks a spot height.

Fig. 2.16. Greenland erratics north of Gould Bay coast (50 m asl)

Fig. 2.17. Greenland erratics on U4 in Gould Bay (350 m asl).

West of main delta (north side)

Pink granite clasts, up to 10 cm. in diameter, are found on the surface of the main delta. West of the delta, at and below approximately 90 m asl, there is an increase in the number and variability of granite erratics. For example, where shells GB-1-93 were collected in nearshore marine silt, granites are abundant. Along the east flank of U4, highly oxidized Greenland erratics are found at 350 m asl (Fig. 2.17). The erratics exhibit oxidation and exfoliation suggesting considerable antiquity.

East of main delta (north side)

On the north side of the main delta two clasts of micaceous schist were found on the surface. Above the main delta a few erratics were found in geliflucted till up to 95 m asl; however, only Ellesmere Island erratics (purple sandstone, conglomerate and pink quartzite) occur on upland surface U3 (470 m asl, Fig. 2.8). Along the coast, north of Gould Bay, abundant gneiss and pink granite erratics are found above wave-washed beaches up to approximately 50 m asl.

South side

The largest Greenland erratic found on Darling Peninsula occurs at 91 m asl east of the first tributary valley from the coast (Fig. 2.18). West of the large moraine in the valley (Fig. 2.9) Greenland erratics are absent, suggesting that the associated glacier precluded entry of Greenland ice. Hence, this moraine corresponds to the breakup of coalescent Greenland and Ellesmere Island ice. East of the large erratic, along the 68 m beach, gneiss as well as red and pink granite are found, but these are attributed to sea ice rafting. Ascending U1, above the largest erratic, smaller erratics

Fig. 2.18. Largest Greenland erratic on Darling Peninsula (91 m asl).

are found. On top of U1. Greenland erratics and shell fragments of *Hiatella arctica* were found in till at 310 m asl. The Greenland erratics disappear in the col separating U1 from U2 and are absent on top of U2. again suggesting preclusion by local Ellesmere Island ice immediately inland from the coast.

The distribution of Greenland erratics indicates Greenland ice extended to 350 m asl. but was restricted to the lower part of the valley (3.5 km from the coast). Below marine limit. Greenland erratics are abundant but are likely rafted by sea-ice indicating relatively open water during the early Holocene when Greenland ice was calving in Kane Basin.

2.6 Cape Louis Napolean - Physiography and Geology

The valley between Cape Louis Napolean and Cape Hilgard constitutes the southernmost corner of Darling Peninsula (Fig. 2.1). It is oriented north-south and is the largest of the three valleys studied (3 km wide). Inland. the valley forks into eastern and western tributaries. The eastern tributary extends 2 km to an outlet glacier. and the western tributary valley supports many glaciers and extends to the northern boundary of the peninsula. Uplands in this area rise steeply to 780 m and support plateau ice caps and outlet glaciers. The valley contains a braided river which is fed by several glaciers.

The bedrock at Cape Louis Napolean includes purple sandstone. shale and limestone. Prest's (1952) preliminary map shows thickly bedded Ordovician limestone with minor black shale to the east. whereas Silurian or younger interbedded grey and buff limestone, red and white sandstone and conglomerate occur on the west side of the valley. There is a strong westward dip in all the units, resembling the geologic structure of Gould Bay. Mayr and de Vries (1982) map a fault cutting through the valley with a northeast-southwest trend (Fig. 1.4).

2.6.1 Cape Louis Napolean - Geomorphology

For purposes of field description, the Cape Louis Napolean field area is subdivided into three sections: west, central and east (Fig 2.19). The west section covers Cape Hilgard and the west side of the main valley up to the northwest tributary. The central section includes the convergence of the two tributary valleys, and the east section includes the east side of the main valley extending to Cape Louis Napolean.

West

The geomorphology of the west side of the valley is dominated by till, colluvium and bedrock. Wet and dry kettles are also present in the valley (Fig. 2.20). Former water margins are preserved in larger kettles, and dry kettles often contain ice-wedge polygons. The most prominent landform on the west side of the valley is a discontinuous moraine 25 m in height, with an upper surface of 88 m asl (Fig. 2.21). There are beaches, up to 63 m asl, containing shell fragments on the surface and leading up to this moraine, which is broken up by recent rockfalls. Weathered bedrock occupies the highest elevations around Cape Hilgard, and on some uplands Ellesmere Island erratics of purple sandstone and white quartzite are found. There is evidence for faulting in this area as indicated by slickensides on shattered bedrock of

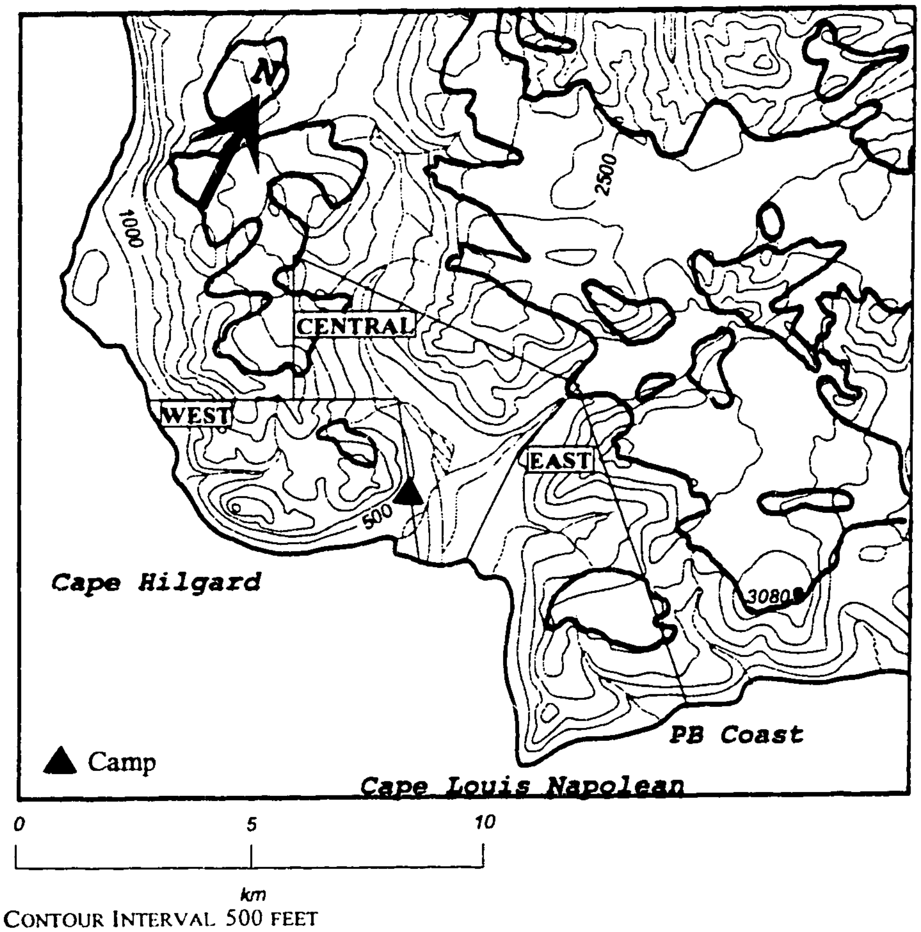

Fig. 2.19. The west, central and east sections of Cape Louis Napolean valley as defined in text. Solid black lines outline present ice.

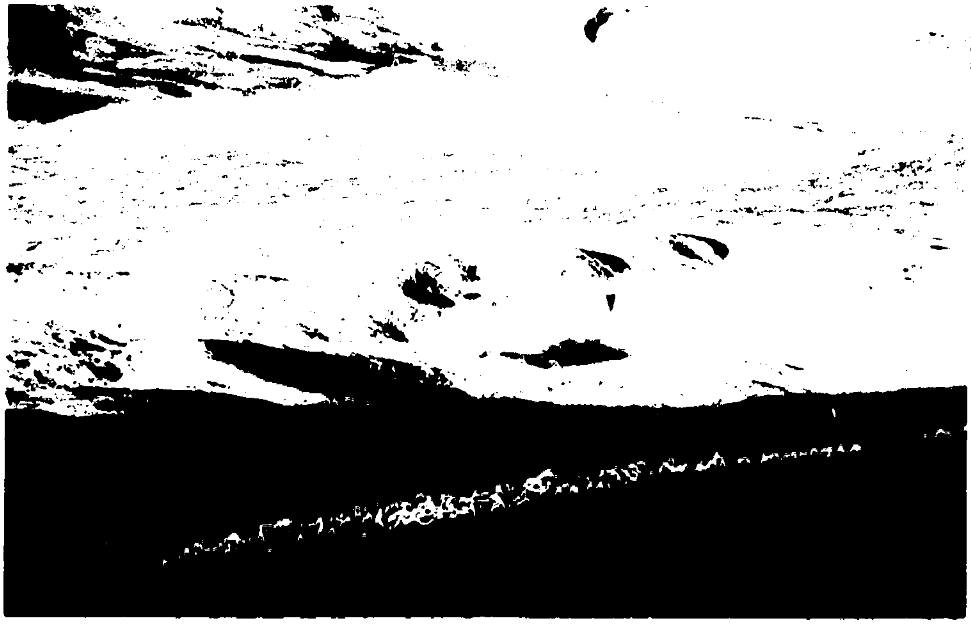

Fig. 2.20. Kettles in Cape Louis Napolean valley. Larger kettle is approximately 15 m across.

Fig. 2.21. Cape Louis Napolean showing ^{14}C dated sites, deltas (*d1*, *d2*), moraines (black arrows), fluvial terrace (*F*) and beach ridges (*Mr*). Camp is marked by ⊗.

P1 (Fig. 2.21).

Central

The relatively thick accumulations of marine deposits and till in the central part of the valley help to mark former ice margins as well as the inland extent of the sea following deglaciation. The mouth of the eastern tributary valley contains mostly colluvium and till with remnant lateral moraines (Fig. 2.21). There is a coarse gravel and sand surface which is interpreted as a fluvial terrace (*F*, Fig. 2.21). Although an altimeter elevation of this surface was not taken, it is estimated to be 5-8 m above a large delta (79 m asl) in the centre of the valley. It may be a higher surface of the main delta (*d1*, Fig. 2.21) or an ice marginal terrace to which former meltwater channels descended. Above this delta the slope is dominated by moraines, gelifluected till, colluvium and bedrock outcrops. At the mouth of the west tributary valley, end moraines and kames lie beyond an active glacier. Remnants of lateral moraines and meltwater channels dominate the valley side (Fig. 2.22).

East

The east section of the valley contains mostly till and moraines that have become rock glacierized (Fig. 2.21). Three horizontal moraines, approximately 60 m asl, extend to Cape Louis Napolean and are broken up by colluvium (Fig. 2.21). Till dominates the slope ascending to the plateau ice cap. On the summit above Cape Louis Napolean (P2, Fig. 2.21) there is shattered bedrock and gelifluected till.

Fig. 2.22. Moraine in west tributary valley.

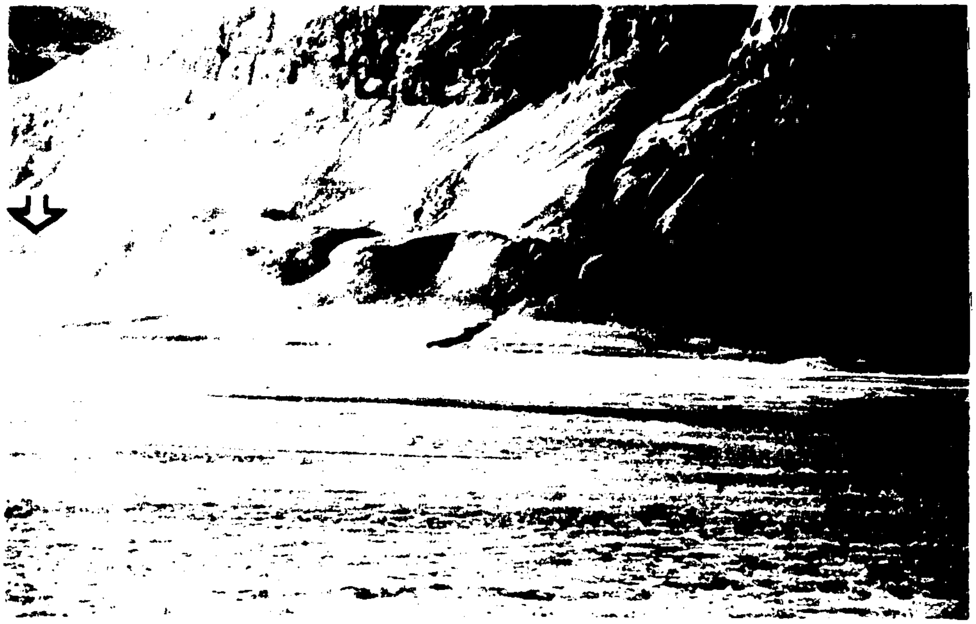

Fig. 2.23. Beaches extending to 63 m asl up to the prominent moraine which has an upper surface of 88 m asl. It does not appear that this moraine and the one shown in Fig. 2.22 are part of the same system.

2.6.2 Cape Louis Napolean - Marine Stratigraphy and ^{14}C Dates

West

The marine deposits on the west side of the valley consist mainly of fossiliferous beaches extending to 63 m asl below the prominent moraine on the valley side (Fig. 2.23). Nearshore marine deposits were not found on this side of the valley, and beaches there range between 52 and 63 m asl (Table A.3). Surface samples were taken from beaches, but none was dated. Near the waterfall at Cape Hilgard, large thick shells were found on a beach shingle surface at an elevation of 61 m asl. Two fragments were also found at 82 m asl in till on top of bedrock northwest of Cape Hilgard.

Central

The central section of the valley provides the highest marine surface measured in the valley (79 m asl). Sample LN-13-93 (collected at 61 m asl) relates to the highest delta surface at 79 m asl surface and dated 7040 ± 70 BP (TO-4212). The shells were the highest found on the surface of the dissected delta. Since the shells were found in a dissected part of the delta, it is assumed that they were transported from a higher elevation on the delta surface and relate to the 79 m asl surface (*dl*, Fig. 2.21). It is unlikely that the shells were deposited from a higher surface (> 79 m asl) since shells were not found above 61 m asl in this section of the valley in either till or marine deposits. The surface of the delta is highly dissected with small channels (Fig. 2.24). Foreset beds are recognizable (Fig. 2.25); however, topset beds were not observed. The rest of the delta is composed of coarse sand and gravel. West of the

Fig. 2.24. Surface of the 79 m asl main delta (*d1*, Fig. 2.21) with sample location LN-13-93 shown.

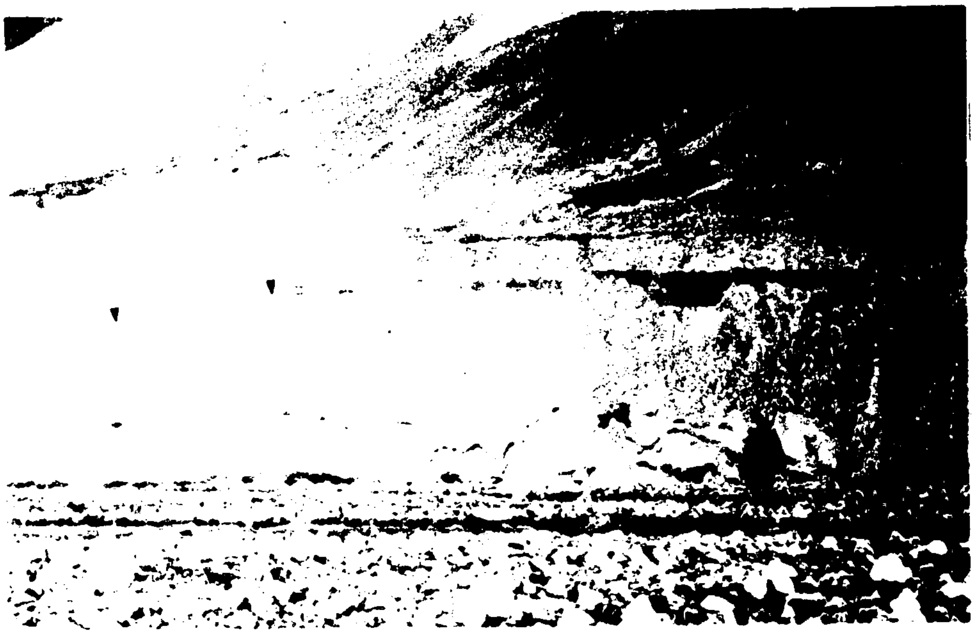

Fig. 2.25. Foresets in the main delta (*d1*).

central delta. in the tributary valley. there are nearshore marine sediments with shells. Most shells in this area were found between 58 and 62 m asl. Marine deposits are absent in both the west and east tributary valleys above and inland of the delta (Fig. 2.2).

East

The most prominent marine deposit on the east side of the main valley is a large delta (*d2*, Fig. 2.21) overlying bedrock exposed below a large ice-free cirque which forms a prominent tributary depression. A thin till veneer and deltaic sediment overlie the bedrock. The uppermost delta surface (> 100 m asl) is cryoturbated and weathered and is more boulder-rich than either the 79 m asl main delta (*d1*) or the main delta in Gould Bay. However, this highest surface is not easily discernable, as it is covered with till. This surface may also be the remnant of an older, larger delta that formed during deglaciation from a more extensive ice cover. Shells were not found on the surface of the delta (*d2*, Fig. 2.21), but fragments occur at lower elevations (78 m asl). Whole valves of *Hiatella arctica* and *Mya truncata* are found in clay, interpreted to be nearly horizontal bottomsets of the delta (*d2*, Fig. 2.21). Foresets can be traced upvalley from the bottomsets, and till lies on the surface upvalley from both foresets and bottomset beds. However, bottomset beds of the delta could not be easily traced. The shell samples relate to a relative sea level of at least 36 m asl and a lower delta surface. Separated valves were collected (3 cm apart) and highly oxidized barnacles were also found in the bottomset deposits. Beaches reaching up to 74 m asl are found southeast of the delta (Fig. 2.21). Sample LN-6-93 is a surface sample found on this highest beach and dated 7390 ± 70 BP (TO-4211).

Around Cape Louis Napolean to PB Coast (Fig. 2.19) the highest beach recognized is at 67 m asl. Shells are scarce on the upper beaches; however, sample LN-16-93 was obtained from this surface and dated at 6020 ± 60 BP (TO-4213).

2.6.3 Cape Louis Napolean - Distribution of Greenland Erratics

Greenland erratics were not found on any of the peaks visited in Cape Louis Napolean valley. Rather, Greenland clasts were found at or below marine limit (Fig. 2.26) and their distribution confirms that this valley was not inundated by Greenland ice during an earlier, more extensive glaciation due to exclusion by local Ellesmere Island ice. However, this absence of erratics is useful in reconstructing the pattern of the Greenland ice profile along Ellesmere Island. For example, areas where Greenland erratics were absent are areas where Greenland ice was precluded by Ellesmere Island ice.

2.7 Summary

Prominent moraines and meltwater channels occupy all three valleys and contact marine limits ranging from 79 (Cape Louis Napolean) to 88 m asl (Gould Bay). The ^{14}C dates on these former sea levels indicate minimum ages of ~ 6.0 to 7.4 ka. High-elevation erratics of Greenland and Ellesmere Island origin occur to 350 m asl; however, Greenland erratics are absent, above marine limit, along stretches of the

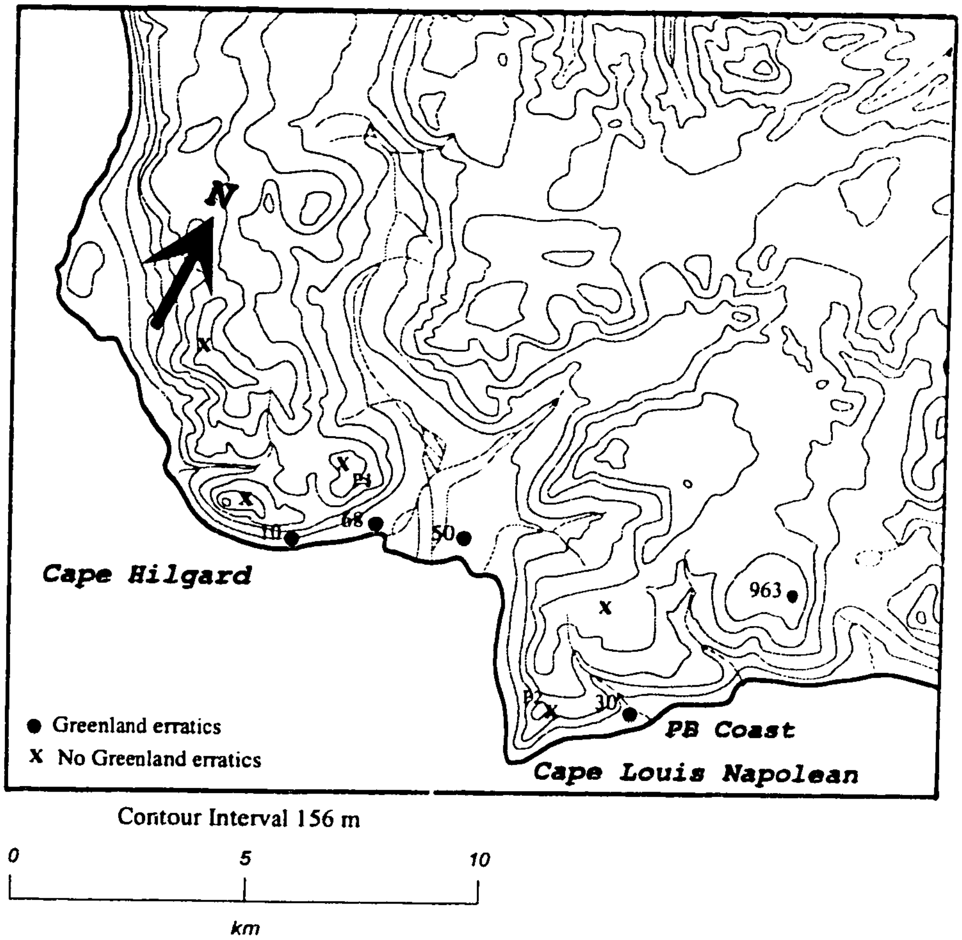

Fig. 2.26. Distribution of Greenland erratics in Cape Louis Napolean valley. Elevations are in m asl. The 963 m point marks a spot height.

coast. The next chapter provides a discussion of these field data.

CHAPTER 3

INTERPRETATIONS AND CONCLUSIONS

3.1 Introduction

This chapter covers former ice extent, geochronology and sea level changes on Darling Peninsula. The maximum extent of glaciation, based on the distribution of Greenland erratics and high shells, is also presented. Darling Peninsula is also placed in a regional context in terms of the pattern of postglacial emergence on eastern Ellesmere Island. A final summary and possibilities for future research are presented at the end of the chapter.

3.2 The Last Glaciation - Ice Margins

Ice margins and thickness for the last glaciation are based on the morphological evidence presented in Chapter 2 in conjunction with the modern ice configuration. In most cases, the ice marginal landforms provide a minimum limit for the last glacial maximum. Each valley is discussed in detail in the following sections, and a summary of the ice limit is shown (Fig. 3.1).

3.2.1 Maury Bay

Ice thickness in Maury Bay, and elsewhere along this coastline, was accentuated by the narrowness of its valley (< 0.7 km). The highest Ellesmere Island erratics in Maury Bay occur at 350 m asl in the col between P2 and P3, indicating that

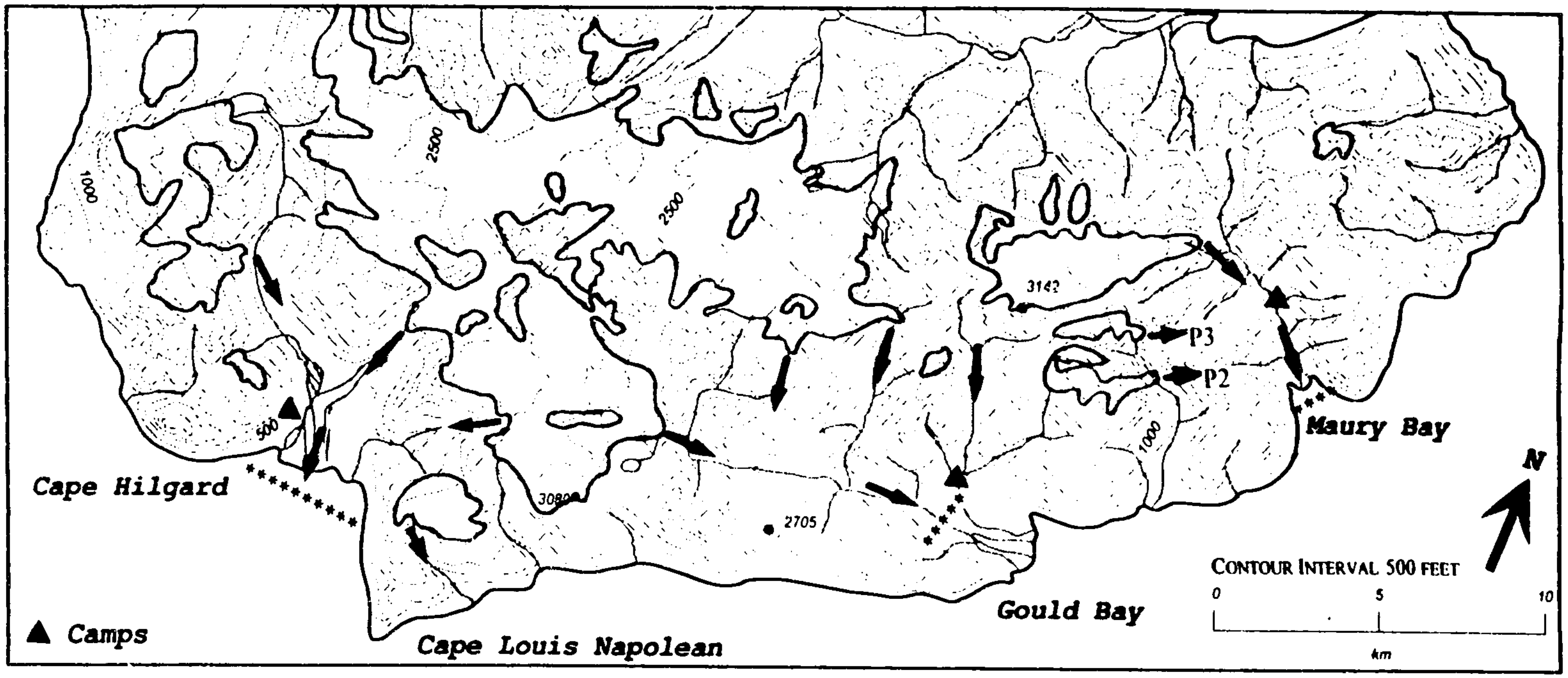

Fig. 3.1. The extent of ice during the last glaciation in major valleys on Darling Peninsula. The terminus of the last glaciation is shown (****). Arrows represent former ice flow directions. The solid lines represent present ice.

ice overtopped the passes leading from an unnamed valley (to the west) and entered Maury Bay (Fig. 3.1). The till that mantles the tributary valleys further west is evidence for ice extending from cirques in these valleys and coalescing with the main valley glacier in Maury Bay. In the narrowest part of the valley, a prominent moraine marks a former ice margin at 185 m asl.

3.2.2 Gould Bay

During the last glacial maximum, the ice surface in Gould Bay reached down to elevations of at least 165 m asl, as indicated by till in the upper valley and by the 163 m crest of the prominent lateral moraine in the mid-valley. The steep gradient on this lateral moraine suggests an ice margin in this vicinity. Marine deposits also terminate along this moraine which suggests that it corresponds to the last ice limit which contacted the sea at this position, 2-3 km inland from the present coastline (*cf.* Stewart 1991). The main valley ice also coalesced with valley glaciers which produced prominent meltwater channels (Fig. 2.8) that enter the main valley at similar elevations. Furthermore, glacier meltwater from the large tributary valley that entered Gould Bay from the north, formed a delta marking marine limit.

3.2.3 Cape Louis Napolean

The configuration of ice in the Cape Louis Napolean valley is marked by Ellesmere Island erratics, moraines and meltwater channels. The present ice configuration consists of two plateau ice caps and multiple outlet glaciers encircling the valley (Fig. 2.2). The widespread extent of prominent meltwater channels, till and lateral moraines provides a minimum estimate for the last ice limit. Ice around Cape Louis Napolean was apparently less extensive than that of the other two valleys. For example, the crest of the moraine on the west side of the valley is 78 m asl, below which is abundant kettled till. These landforms suggest that glaciers extended beyond their present margins and occupied the central valley where the ice became unstable and calved in the early Holocene sea (~ 90 m asl).

The present plateau ice cap on the west side of Cape Louis Napolean is a remnant of the ice that once flowed radially to the PB Coast (Fig. 2.19) and into the east tributary valley. Ice from this easternmost tributary extended from a cirque at the head of the valley and formed an ice-contact delta (*d2*) in a deglacial sea occupying part of the Cape Louis Napolean valley.

In summary, ice in the Maury Bay and Cape Louis Napolean valleys extended to the sea whereas the ice in Gould Bay probably extended at least 9 km beyond its present margin, but terminating 2-3 km inland from the coast. This ice configuration reflects the greater distance of ice from the sea in Gould Bay valley. If substantial deposition occurred during glaciation it must have been confined offshore as indicated by till veneer and the absence of till blankets within the main valleys. At most sites where ice contacted the sea, deltas and nearshore sediment were deposited during deglaciation and these constitute important ice margin indicators together with adjacent moraines and meltwater channels.

3.3 Radiocarbon Dates

The chronology of deglaciation and relative sea-level on Darling Peninsula is based exclusively on radiocarbon dating of marine shells. *Hiatella arctica* and *Mya truncata* were the most common species and their valves and fragments were collected from beach gravel and nearshore sediment. The depth of water in which these organisms presently live is variable: however, both are indicative of a modern intertidal, gravelly sand flat community (Dale *et al.* 1989) although *Mya truncata* can also extend into the upper sublittoral zone (5-50 m, Lubinsky 1980; Aitken 1990). The *Astarte* association, which includes *Hiatella arctica* and *Mya truncata*, is a nearshore association with modern species living at depths of 5-40 m (Aitken 1990). The *Astarte* association tends to be postglacial and ice-distal, coming in during mid-Holocene and is commonly not a deglacial fauna; however, the *Mya truncata* and *Hiatella arctica* association is more commonly deglacial. The dates are presented with associated information in Table 3.1 and in a geographical context on Fig. 3.2.

3.4 Sea-level history

The sea-level history of Darling Peninsula is included in the following section. An interpretation of the inland extent of the sea during deglaciation is followed by a discussion of marine limit for the peninsula in the following section. Darling Peninsula is placed in a regional context at the end of this chapter.

Lab. No	Field No.	Material	Stratigraphy	*Age (years BP)	Sample Elevation (m)	Relative sea level (m)	Lat. N	Long. W
TO-4208	GB-1-93	Shell fragment	Marine silt	7110±70	75	80	79°45'	71°30'
TO-4209	GB-4-93	Shell fragment	Beach	6930±90	81	>81-≤88	79°47'	71°09'
TO-4210	GB-7-93	Shell, *Hiatella arctica*	Beach	7480±60	75	>75-≤88	79°45'	71°22'
TO-4211	LN-6-93	Shell fragment	Beach	7390±70	74	>74-≤79	79°41'	72°17'
TO-4212	LN-13-93	Shell, *Mya truncata*	Delta surface	7040±70	61	79	79°43'	72°24'
TO-4213	LN-16-93	Shell, *Hiatella arctica*	Beach	6020±60	63	>63-≤79	79°40'	72°05'
TO-4214	MB-4-93	Shell fragment	Marine silt	7430±70	71	83	79°49'	71°07'

* Age corrected for a 410 year reservoir effect

Table 3.1 Radiocarbon dates and related sea-levels for Darling Peninsula

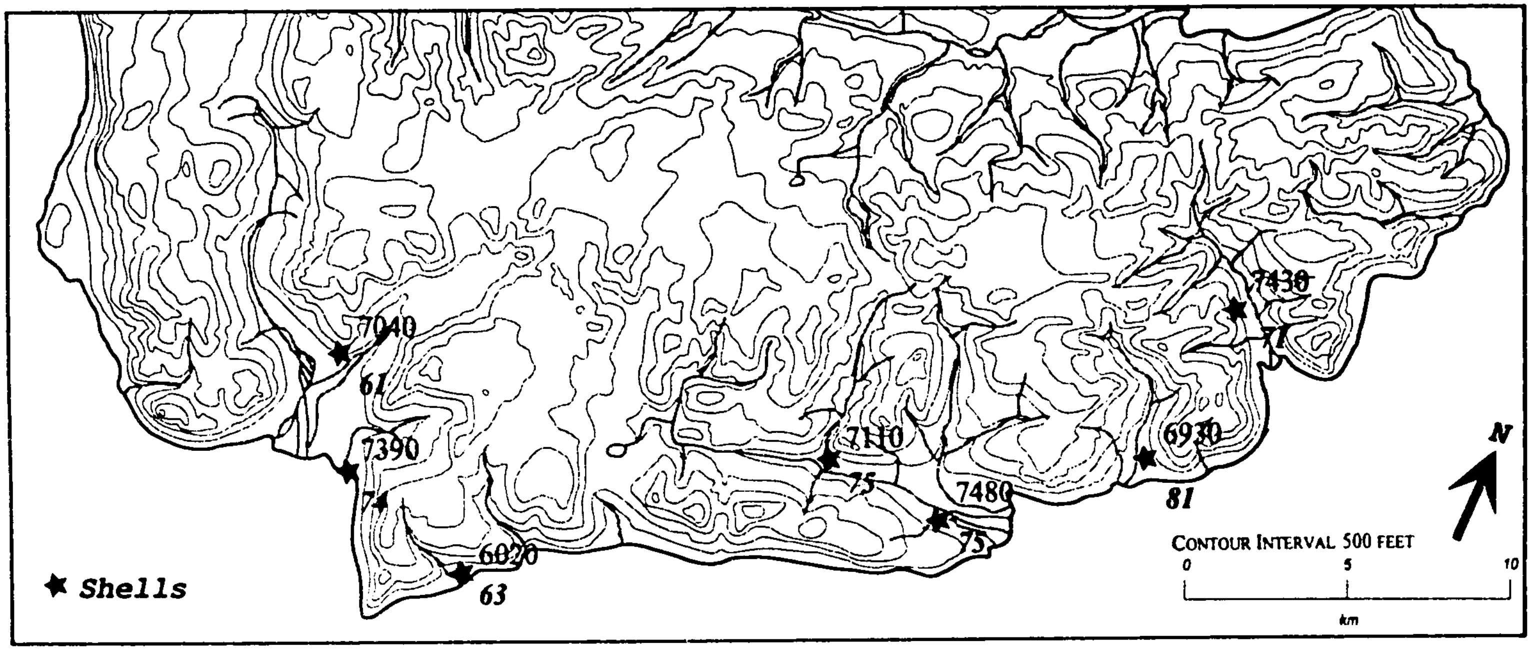

Fig. 3.2. Locations and elevations (m asl) of radiocarbon dated samples on Darling Peninsula. The corrected age (BP) of the sample in shown above the location. Note that elevations pertain to where shells were collected, their related relative sea levels are actually higher in most cases and, hence, collection sites do not necessarily indicate differential emergence for similar age samples.

3.4.1 Extent of sea

The inland extent of the sea on the peninsula (Fig. 3.3) is based on the distribution of raised marine deposits and ice-contact deltas. In Maury Bay, the limit of the sea is marked by extensive marine silts that extend 2.5 km inland where sample MB-4-93 was collected. Shells and recognizable marine deposits are absent west of this site. In Gould Bay, the sea reached ~ 3 km upvalley in the vicinity of sample GB-1-93 collected from marine silt on the north side of the valley. On the south side of Gould Bay, there is no evidence for the sea extending inland beyond the prominent moraine in the valley. At Cape Louis Napolean, the minimum extent of the sea is recorded by the prominent ice-contact delta in the central valley (79 m asl). There are few marine deposits at the mouth of the northwest tributary valley, extending < 0.25 km from the main delta (*d1*, Fig. 2.21). These deposits form the basis of the maximum extent of the sea at Cape Louis Napolean.

3.4.2 Marine Limit

The highest ice-contact delta in the valley, or the highest recognizable shoreline with shells (Maury Bay), was considered to mark marine limit. Marine limit on Darling Peninsula is deglacial and ranges from 79 m (Cape Louis Napolean) to 88 m asl (Gould Bay). Marine limit is either horizontal in the valleys or inclined gently inland, indicating an approximate balance between the rate of glacial retreat and crustal rebound (Andrews 1970). Because 6 out of the 7 radiocarbon dates fall within 500 years of each other, and relative sea levels range between 74-83 m asl, it is concluded

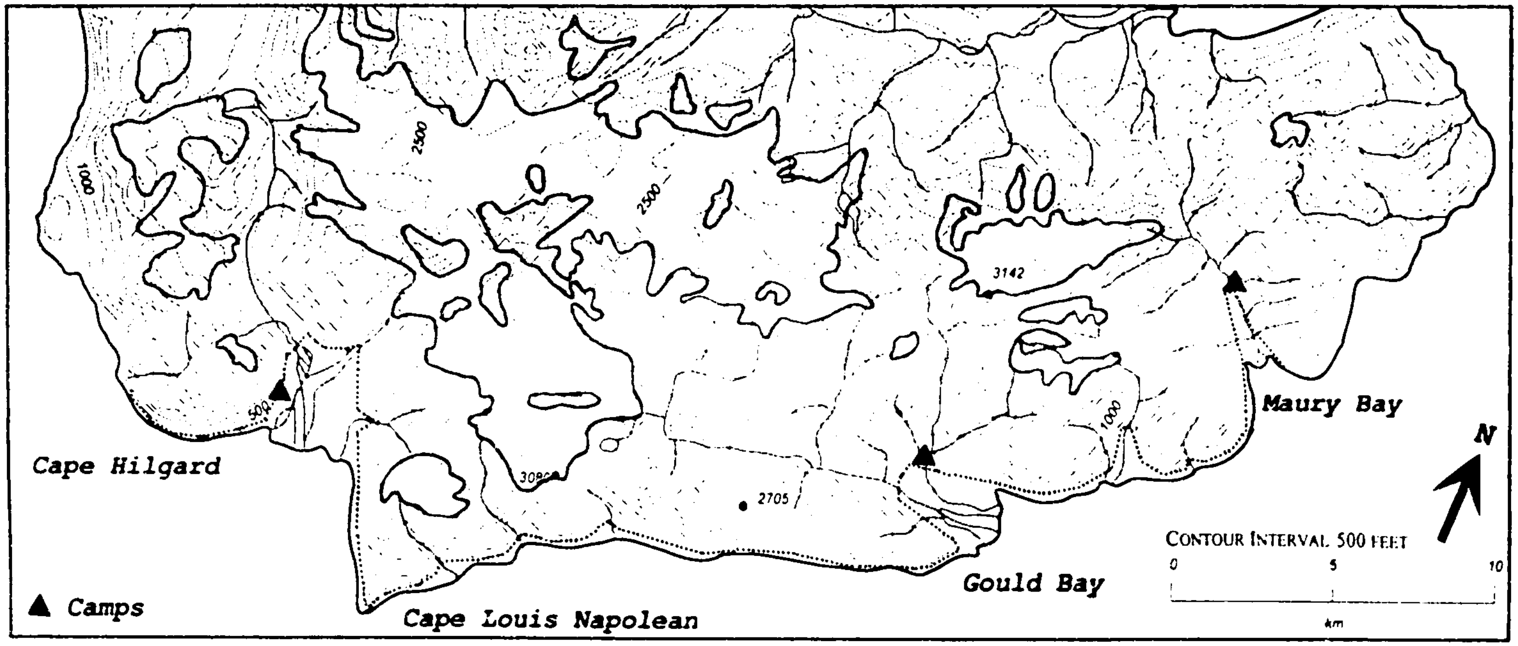

Fig. 3.3. The extent of the sea inland on Darling Peninsula (dashed line). This former sea level constituted an important barrier to small outlet glaciers descending from local plateau ice caps. Solid lines represent present ice.

that the sea was relatively stable (± 5 m) during this interval. Between 6.9 and 6.0 ka sea level dropped from 86 (maximum) to 63 m asl as postglacial emergence proceeded rapidly.

A summary of other reported marine limits on Ellesmere Island is shown by Fig. 3.4. Marine limit on the east coast of Ellesmere Island, to the north of Darling Peninsula, ranges from 98 m asl in Archer Fiord (England 1977) to 127 m asl on Judge Daly Promontory (J. England pers. comm. 1994). Marine limit in Scoresby Bay, which borders Darling Peninsula to the north, is 83 m asl (England unpublished). Blake *et al.* (1992) reported marine limits of 87.5 - 90 m asl at Cape Herschel, ~ 100 km south of the peninsula, and up to 110 m at Rice Strait (Blake 1992*a*). On the Greenland coast, at Kap Inglefield Sø, the marine limit is 83 m asl (Blake *et al.* 1992). On the northwestern and western parts of Ellesmere Island marine limits range from 117 m asl at the head of Phillips Inlet (Evans 1990) to 150 m asl on the Fosheim Peninsula (Bell 1992).

Emergence patterns on Ellesmere Island include a ridge of uplift extending from Eureka (Fig. 1.2) to the northeast, running parallel to the geologic structure, suggesting the possibility of a tectonic component to postglacial uplift (England 1992). Isobases decrease in elevation to the east coast; however, they rise again from there towards Greenland (England 1976, 1983, 1985). Since the marine limit is 83 m on the east central Ellesmere Island and west central Greenland coasts, the 80 m isobase must lie somewhere in Kane Basin. The 90 m isobase most likely lies to the west of Darling Peninsula, as well as on Greenland. This corresponds to the regional uplift

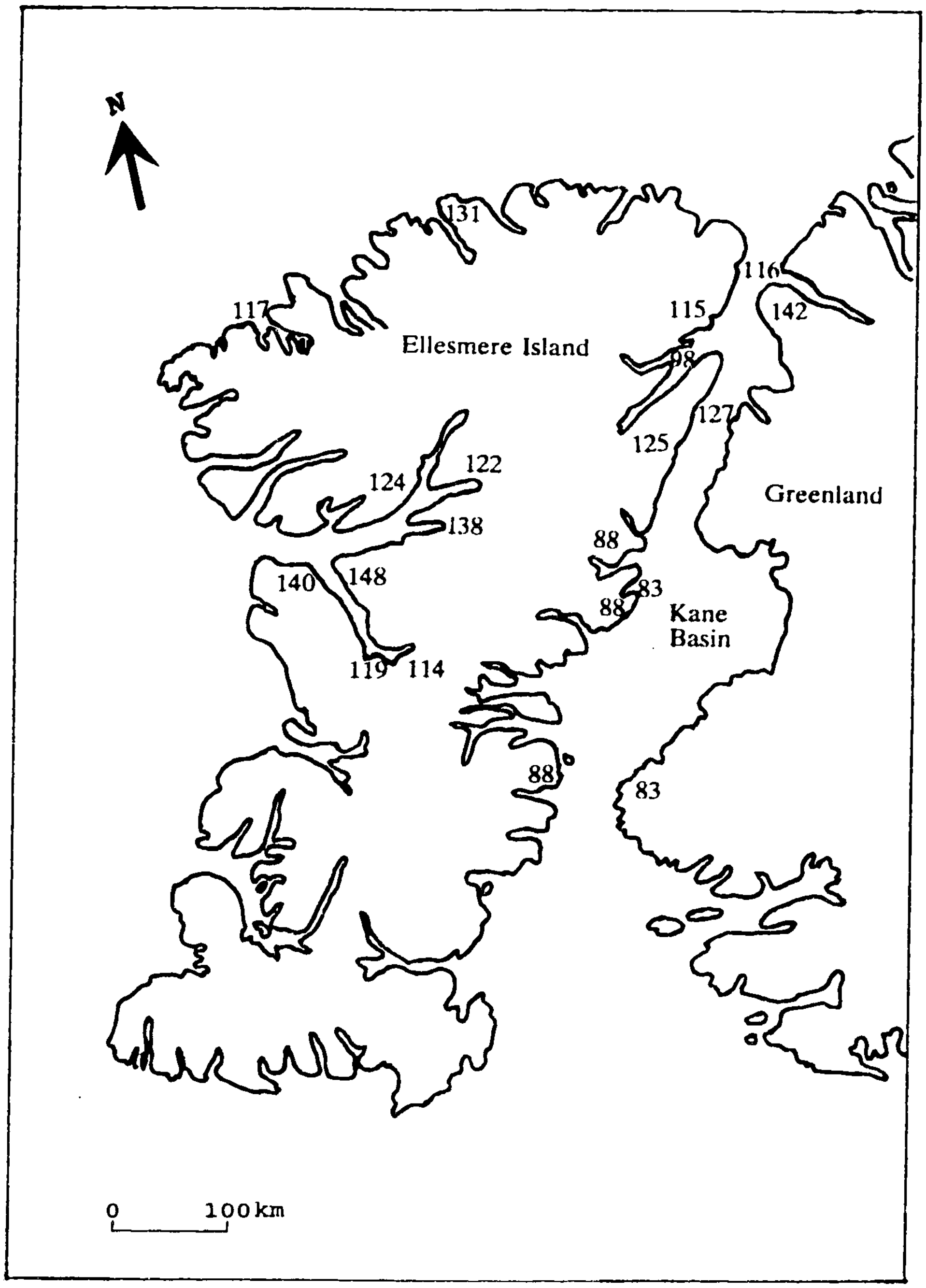

Fig. 3.4. Marine limits (m asl) for 7-8.5 ka on eastern Ellesmere Island and western Greenland, as discussed in text.

pattern currently being interpreted by England (pers. comm. 1994). The relatively low marine limit on Darling Peninsula, compared with others in the region, may be a combination of late deglaciation on the central east coast of Ellesmere Island as well as other factors discussed in the next section.

3.5 Deglaciation and Postglacial Emergence

The available ^{14}C dates provide a minimum date for deglaciation on Darling Peninsula of 7.5 ka. Because the dates are so close in age (Fig. 3.5) differences in timing of deglaciation between the three valleys cannot be distinguished. However, based on marine deposits and geomorphology, the style of deglaciation can be described. In all three valleys the last glacial maximum terminated in the sea and was constrained by calving. The lack of ice contact deltas in the lower parts of the main valleys also suggests that calving was an important process during deglaciation. Other evidence for a calving ice margin include the lack of sediment and end moraines in the lower valleys. Based on the elevation of the lateral moraines, ice thickness approximated water depth along the ice margins. The occurrence of ice-contact deltas at the mouths of tributary valleys argues for more stable ice margins above the influence of the sea.

Compared with other dates on deglaciation for Ellesmere Island, Darling Peninsula fits into the regional pattern. For example, initial emergence of Robeson Channel began between 8.6-8.0 ka (England 1985; Retelle 1986), and after 8.0 ka in Archer Fiord (England 1983). In general, deglaciation was later ($\leq$ 8.0 ka) on the

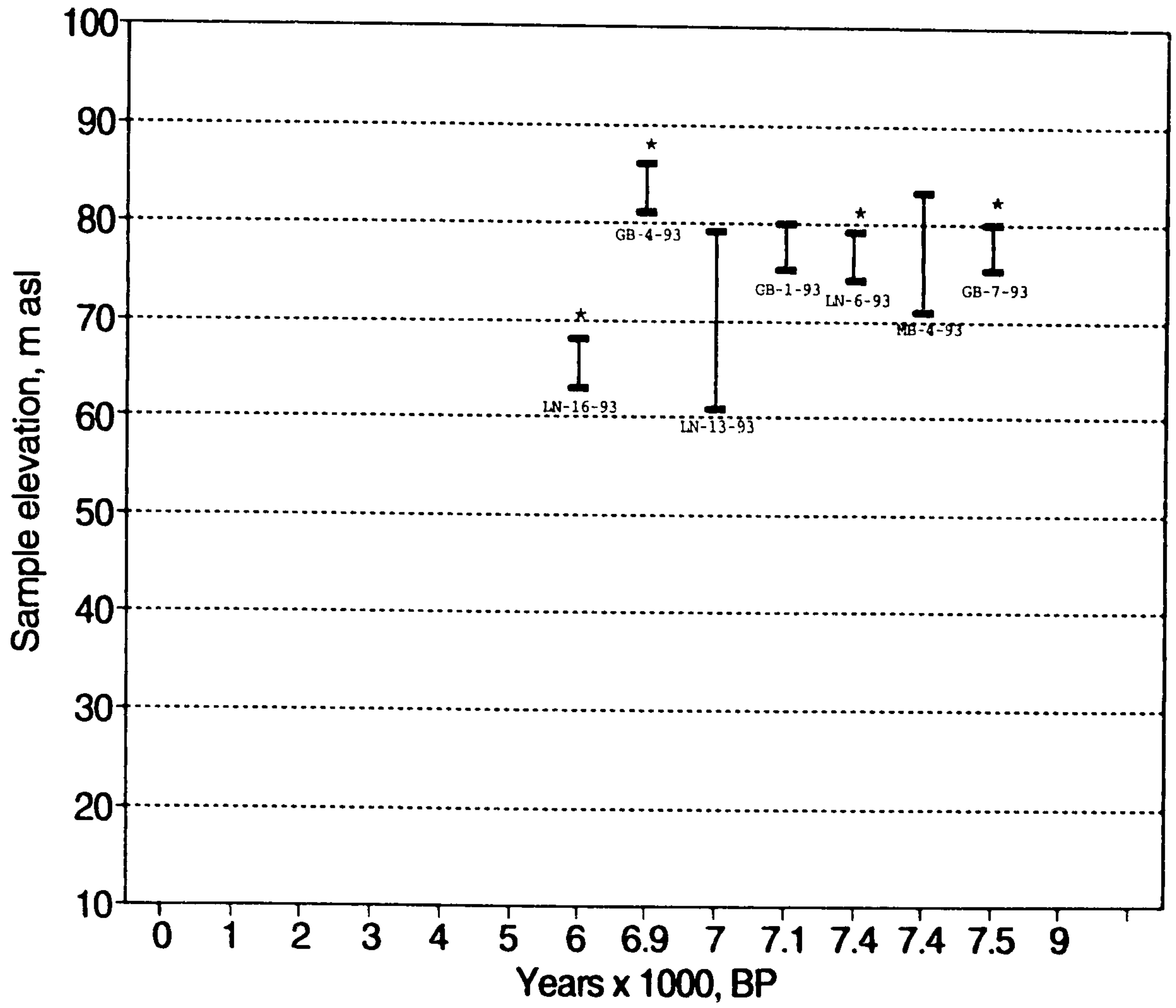

Fig. 3.5 Elevations and associated relative sea levels for ^{14}C dated samples. Samples are plotted at the elevations where they were found and their corresponding relative sea levels are shown. In cases where an exact relative sea level was not determined samples were plotted five metres above the elevation where they were collected and are indicated by *.

south side of the Grant Land Mountains than on the north side (≤ 10.0 ka, England 1982; Bednarski 1988; Lemmen 1988): this was likely due to topoclimatic factors and glacier dynamics. Dyke and Prest (1987) show Darling Peninsula to have the present ice cover by 7.0 ka; however, it is most likely that the peninsula more closely resembled its present ice configuration around 6.0 ka or later, due to late unloading.

The amount of postglacial emergence is indicated by marine limit, which provides only a minimum estimate on the amount of glacioisostatic unloading following the last glaciation. The actual amount of unloading to date has been countered by approximately 20 m of glacioeustatic sea level rise since 7.5 ka (Fairbanks 1989) whereas an unknown amount of restrained rebound occurred prior to the entry of the sea during deglaciation (*cf.* Andrews 1970; England 1992). Hence, a minimum of 108 m of postglacial uplift has occurred on Darling Peninsula since 7.5 ka (88 m marine limit + 20 m of eustatic sea level rise). Because of the similarity in age of the dated samples and their close association with marine limit, a postglacial emergence curve for Darling Peninsula cannot be established. However, the dates can be used in a regional context to establish uplift patterns on eastern Ellesmere Island which are tied directly to the history of deglaciation and the rate of glacial unloading. The lower isobases around northern Kane Basin may be due to tectonic or structurally influenced adjustments in Eureka Sound (J. England, pers. comm. 1994).

For Cape Herschel and southeast Ellesmere Island, Blake (1992*a*, 1992*b*) concludes the entire area was covered during the last glacial maximum and that there has been a total of 140 m of emergence since 9 ka, of which 40 m took place between

8-7 ka. What does seem clear; however, is that the significant emergence reported by Blake (1992; 40 m between 8-7 ka) did not occur on Darling Peninsula where a shoreline, dated 6 ka, is still within 25 m of marine limit (≥ 7.5 ka, Fig. 3.5). Because Darling Peninsula is closer to the proposed source of Greenland ice (the Humboldt Glacier, Blake 1977) which presumably reached Cape Herschel during the last glaciation, it remains unclear why so much emergence is reported there between 8-7 ka while relative sea level was far more stable to the north. Although there are recorded faults on Darling Peninsula and other areas along the east coast of Ellesmere Island (Mayr and deVries 1984), it is unclear whether tectonics played a role in the uplift pattern across the island during any glaciation. If the age of the tectonic events could be determined, a better understanding of how they might have effected uplift patterns could be achieved.

Blake (1992*a*) also attributes an extensive ice cover to the magnitude of emergence at Cape Herschel (140 m, which does not include an additional 30 m eustatic sea level rise since 8.5 ka). However, the 140 m delta at Cape Herschel is dated indirectly whereas the highest shells of Holocene age occur at only 108 m asl (Blake 1992*a*). Hence, the 140 m delta, attributed to the Holocene, could be much older, like the higher pre-Holocene shorelines on Darling Peninsula.

3.6 Former Glaciation(s)

Evidence for a more extensive glaciation on the peninsula is marked by the distribution of Greenland erratics, uppermost Ellesmere Island erratics, and the presence of shells found > 200 m above Holocene marine limit. Since Greenland erratics on Darling Peninsula are only found *above* marine limit in Gould Bay, it is concluded that Greenland ice inundated only this part of the Peninsula (Fig. 3.6). In areas where Greenland ice did not deposit erratics on the peninsula it is assumed that the Ellesmere Island ice blocked out and interfingered with the Greenland ice as it flowed north into Nares Strait and south into Smith Sound (J. England pers. comm. 1994). Where Greenland erratics were found at 315 m asl shell fragments are also common and, if dated, would provide a maximum age for this glaciation. So far, shells dated by amino acid analyses from similar Greenland tills along this coast are assigned to the Robeson Aminozone (40 - 70 ka, Retelle 1986; Lemmen and England 1992). Meltwater channels found on uplands surrounding Gould Bay (Fig. 2.11) probably resulted from this earlier, more extensive glaciation. After the Greenland ice retreated from Gould Bay, the local ice apparently then overtopped upland U1 (Fig. 2.8). This may have been facilitated by the previous buttressing of Ellesmere Island ice by Greenland ice which allowed oversteepening of the Ellesmere Island ice profile (Lemmen and England 1992).

Shorelines formed during deglaciation from older glaciations have been found in several areas to the north of Darling Peninsula (England *et al.* 1978, 1981; Retelle 1986; Lemmen and England 1992) and record one or more discrete intervals of glacioisostatic loading attributed to the breakup of Ellesmere Island and Greenland ice. Although no such surfaces were clearly defined on Darling Peninsula, the higher delta surfaces in Gould Bay (above the main Holocene delta) and at Cape Louis Napolean

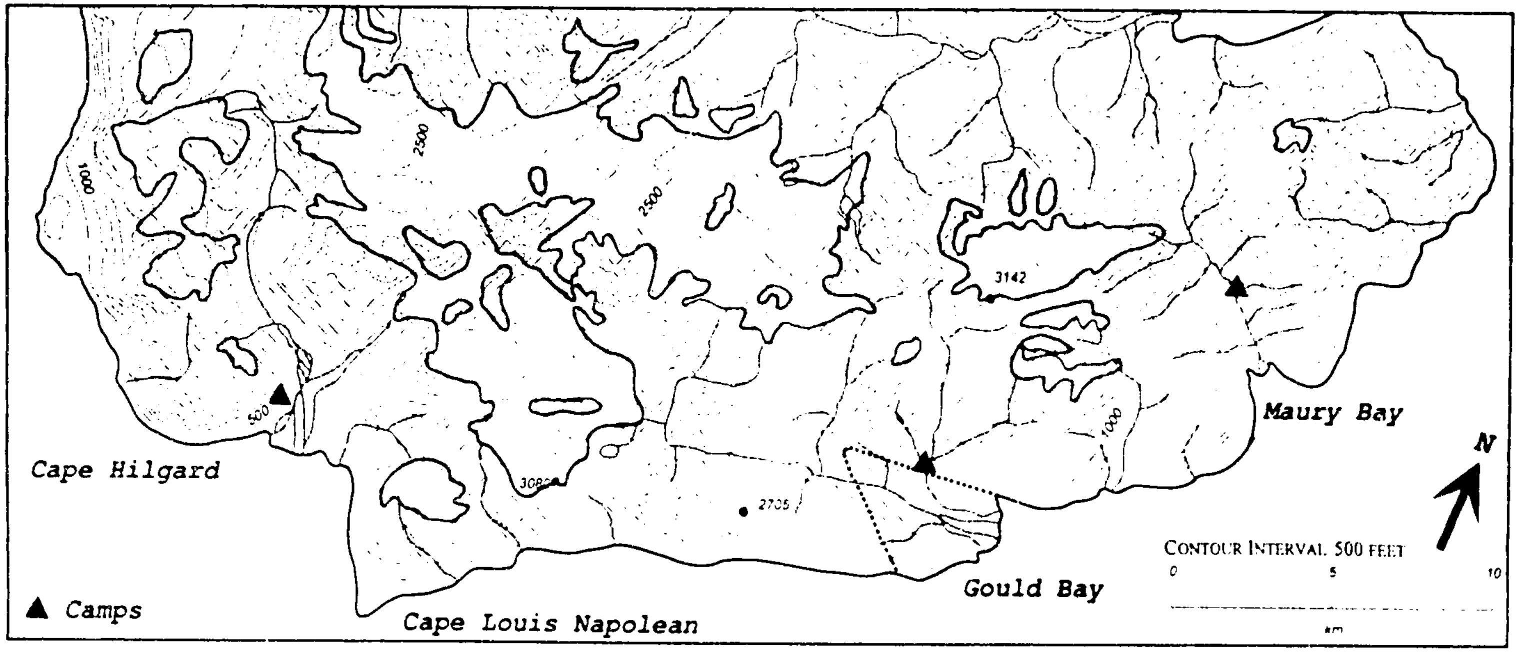

Fig. 3.6. The extent of Greenland ice on Darling Peninsula (dashed lines) based on the distribution of Greenland erratics and shells found 315 and 350 m asl. Solid lines represent present ice.

above the eastern delta) are considered to be remnants of such pre-Holocene deltas. These higher surfaces are 31-36 m above the Holocene marine limits, but are nonetheless lower than the previously reported old shorelines elsewhere. These lower elevations are likely due to their occurrence directly across from the Humboldt Glacier. They are sites likely to have been deglaciated last. An alternative interpretation for the higher shorelines found in Gould Bay and Cape Louis Napolean is that these are Holocene marine limits. This possibility; however, seems unlikely because despite extensive surveying, shorelines at similar elevations are rare and those with Holocene shells consistently occur at 85 ± 5 m asl. Furthermore, these older surfaces are covered with till. Consequently, these surfaces are interpreted to be remnants of ice-contact deltas deposited during an older glaciation that have subsequently been overridden during the last glaciation.

3.7 Summary

During the last glaciation of Darling Peninsula, cirque and outlet glaciers occupied valleys and cols extending to the coast in some areas where they calved into the sea. Average ice thickness during the last glaciation for the lower valleys was 140 m. A paleoglaciation level for the peninsula is estimated at 470 m asl based on the elevation of ice-free uplands on the north side of Gould Bay that were likely ice covered during the last glaciation. The North Water was the main precipitation source for these glaciers prior to 7.5 ka. Meltwater channels, kettles and lateral moraines mark former ice margins whereas ice-contact deltas and beaches record former high sea levels. Marine limit was attained at least by 7.5-7.0 ka after which emergence was slow until 6.0. It is difficult to separate some of the factors that may affect postglacial emergence (uplift resulting from more than one ice mass, structural influences etc...); however, the data from Darling Peninsula contribute to the regional pattern of emergence, specifically defining the occurrence of an 80 and 90 m isobase along this coastline. These isobases (for ~ 7.5 ka) constitute regional lows and they are consistent with the highest Holocene shells reported by Blake (1992*a*) at 108 m to the south versus the undated delta at 140 m. The 140 m delta, together with the delta in Gould Bay, may relate to an older more extensive glaciation. During an earlier glaciation only a small part of the peninsula was inundated by Greenland ice, as pervasive Ellesmere Island ice kept the Greenland ice out of other valleys.

3.8 Future research

The origin, chronology and distribution of what appear to be older deltas needs to be investigated on the peninsula and elsewhere along this coastline. Dating and collecting samples from these deltas would provide a critical test on the age of the ice streams diverging north and south from Kane Basin (Blake 1977, 1992*a*; England *et al.* 1978, 1981). The difference in timing of rapid emergence on the north and south parts of Ellesmere Island needs to be better understood. The possibility that the rapid emergence pattern for the southern part of the island is influenced by its underlying bedrock (Canadian shield) in a structurally unstable area, independent of the Franklinian mobile belt, needs to be further investigated. Aside from obtaining more data on marine limit and former ice margins along the coast, the tectonic and geophysical factors affecting postglacial emergence must also be studied more closely. There is evidence for large scale tectonic movement on Ellesmere Island (Dawes and Kerr 1982 pp. 159-252), but in order to test whether Tertiary or younger faulting may be influencing postglacial emergence needs to be clarified.

The investigation of whether or not the fiords were ice-free during the last glaciation could be clarified by coring the sediments. The geophysical modelling of uplift also needs to be better integrated with the late Quaternary geology and pattern of postglacial emergence.

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APPENDIX

Table A.1 Maury Bay Marine Surfaces and Shell Samples

North/South	Location	Site Description	Elevation, m asl	Shells	Shell Elevation, m asl
S1	1st fan from coast	moraine above, bouldery washed sediment above	30.3	yes	no collection
S2	1st valley from coast	ice-pushed ridge	50.4	yes	50.4
S3	opposite 1st fan on north side	geliflucted marine silt	82.6	no	------
S4	opposite 2nd fan from coast on north side	geliflucted marine silt; Greenland erratics	59.1	yes	59.1
S5	< .5 km east of camp	nearshore marine sediment; Greenland erratics	83.2	yes	71.1
N1	2nd fan from north side coast	beach shingle	69	yes	69
N2	< .5 km east of N1	beach shingle above ice-pushed ridges	77.5	yes	77.5
N3	opposite S4	beach surface, whole valves of *Mya truncata*	65.5	yes	65.5
N4	west of 1st waterfall on north side	geliflucted marine silt	69.6	yes	69.6
N5	east of 1st waterfall on north side	discontinuous and gelifluccted beach surface	70.9	yes	70.9

Table A.2 Gould Bay Marine Surfaces and Shell Samples

North/South	Location	Site Description	Elevation, m asl	Shells	Shell Elevation, m asl
S1	Hayes Point	base of scree; above geliflucted beaches	78.4	yes	75.9
S2	west of S1; east of camp	prominent surface; marine sediment above; Greenland erratics	66.4	yes	66.4
S3	west of S2; east of large Greenland erratic	most prominent beach shingle	75.4	yes	75.4
S4	west of large Greenland erratic	geliflucted marine (?) sediment	86.9	no	------
N1	.5 km west of camp	not distinct surface, steep drop to horizontal surface	91.9	no	------
N2	1.3 km west of camp	marine silt	------	yes	70.9
N3	SE of 1st valley north of Gould Bay	wave cut benches; Greenland erratics	•47.5	yes	•50
N4	north side of ▪G&M Valley	minimum marine limit, below geliflucted surface	•79	yes	•79
N5	camp delta	ice-pushed ridge on outer lip of delta	83.1	no	------

N6	camp delta	continuous ice-pushed ridge farther up on delta than N5	86.5	no	------
N7	proximal side of camp delta	lower delta surface	------	yes	54.9
N8	.5 km from coast	gelifluctéd surface obscured by talus	48.7	yes	no collection
N9	below 1st waterfall from coast; opposite large erratic on south side	base of scree; no prominent surface	97.9	no	------
N10	< 1 km west of camp	best "beach" surface west of camp, no prominent surface; meltwater channels level to this surface; break in slope here	93.5	no	------
N11	2nd waterfall west of camp	marine silt	79.9	yes	74.9

* Elevations uncorrected for atmospheric pressure.

▪G&M Valley is the unofficial name of the valley between Gould and Maury Bay along the coast.

Table A.3 Cape Louis Napolean Marine Surfaces and Shell Samples

North/East /West	Location	Site Description	Elevation, m asl	Shells	Shell Elevation, m asl
W1	below waterfall at Cape Hilgard	beach shingle	61.2	yes	61.2
W2	on top of bedrock outcrop at Cape Hilgard	weathered surface; till	82	yes	82
W3	< .5 km from coast	minimum marine limit	59.9	yes	59.9
W4	north of W3	marine silt	56.3	yes	56.3
W5	between camp and moraine	gelifluctea beach	62	yes	62
W6	below break in moraine	gelifluctea beach	51.8	yes	no collection
*PB1	west side of river	highest beach	67.1	yes	52.9
*PB2	east side of river	shells above and below gelifluctea surface	62.8	yes	62.8
N1	main delta	minimum marine limit; lip of delta	79	no	------
N2	main delta	whole shell fragments in dissected delta surface	60.8	yes	60.8
N3	NW tributary valley; <.5 km from main delta	marine silt	43.3	yes	43.3

N4	west of N3 in NW tributary valley	marine silt	61	yes	61
N5	west of N4 in NW tributary valley	shells in till(?) boulders, marine sediment below	58.6	yes	58.6
E1	north side of east delta	beach shingle, minimum marine limit	60.4	yes	60.4
E2	NW of E1 on north side of east delta	beach shingle surface, consistent with main delta surface	78.2	no	------
E3	north of E2, below kettle	beach shingle surface	73.8	no	------
E4	east delta	ice-pushed ridges	40.4	no	------
E5	east delta	bottomsets; black mud; abundant shells	35.5	yes	35.5
E6	below syncline	gelifluected beach shingle	73.5	yes	73.5
E7	south of E6 approaching moraine	beach shingle, abundant whole valves	62.3	yes	62.3
E8	below moraine	beach shingle obscured by talus	41.3	yes	41.3

*PB is the unofficial name for the first valley northeast of Cape Louis Napolean along the coast.

SURFICIAL GEOLOGY OF DARLING PENINSULA, ELLESMERE ISLAND

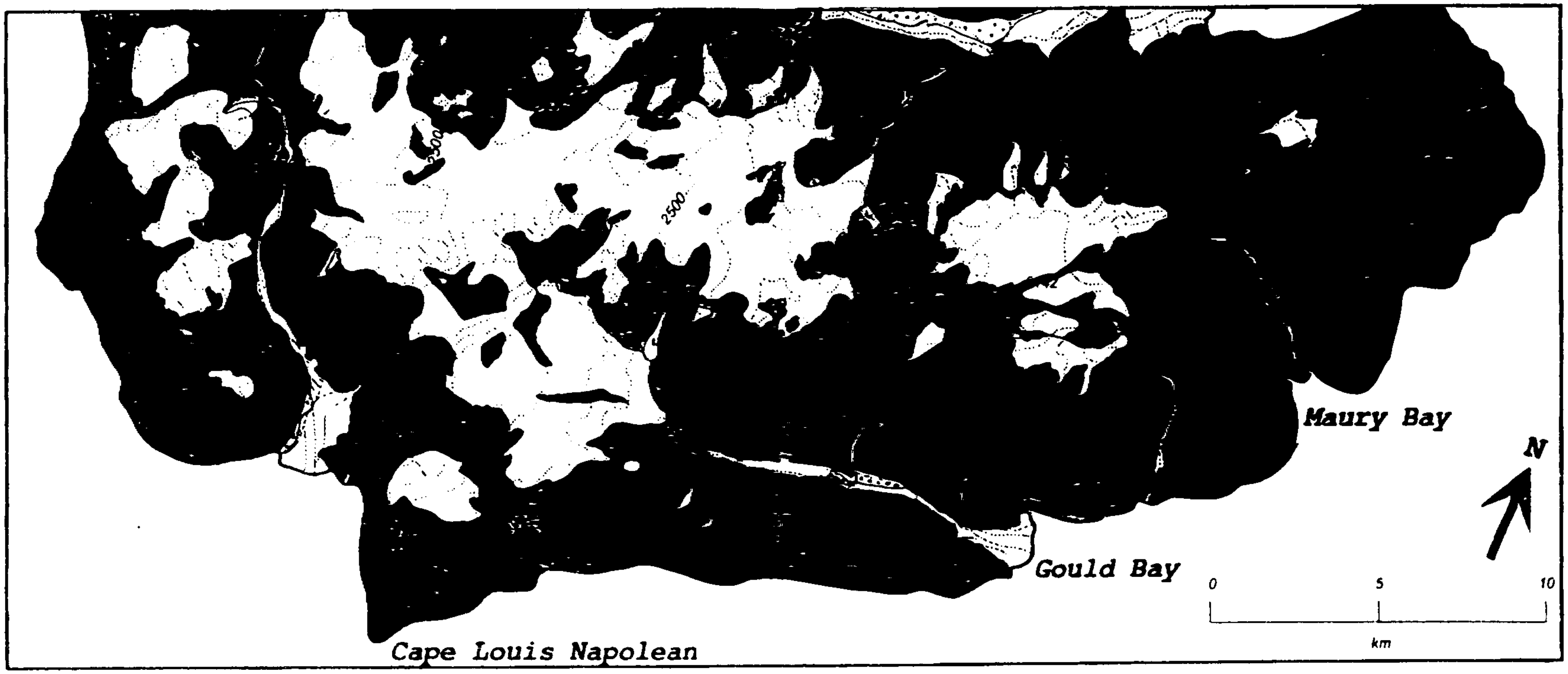

Fig. 2.2 Surficial geology of Darling Peninsula, eastern Ellesmere Island