INFORMATION TO USERS

This reproduction was made from a copy of a document sent to us for microfilming. While the most advanced technology has been used to photograph and reproduce this document, the quality of the reproduction is heavily dependent upon the quality of the material submitted.

The following explanation of techniques is provided to help clarify markings or notations which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting through an image and duplicating adjacent pages to assure complete continuity.

2. When an image on the film is obliterated with a round black mark, it is an indication of either blurred copy because of movement during exposure, duplicate copy, or copyrighted materials that should not have been filmed. For blurred pages, a good image of the page can be found in the adjacent frame. If copyrighted materials were deleted, a target note will appear listing the pages in the adjacent frame.

3. When a map, drawing or chart, etc., is part of the material being photographed, a definite method of "sectioning" the material has been followed. It is customary to begin filming at the upper left hand corner of a large sheet and to continue from left to right in equal sections with small overlaps. If necessary, sectioning is continued again–beginning below the first row and continuing on until complete.

4. For illustrations that cannot be satisfactorily reproduced by xerographic means, photographic prints can be purchased at additional cost and inserted into your xerographic copy. These prints are available upon request from the Dissertations Customer Services Department.

5. Some pages in any document may have indistinct print. In all cases the best available copy has been filmed.

University Microfilms International
300 N. Zeeb Road
Ann Arbor, MI 48106

Order Number 1334852

Modern sedimentary dynamics and Quaternary glacial history of Marguerite Bay, Antarctic Peninsula

Kennedy, Douglas Stokes, M.A.

Rice University, 1988

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark __✓__.

1. Glossy photographs or pages _____
2. Colored illustrations, paper or print _____
3. Photographs with dark background _____
4. Illustrations are poor copy _____
5. Pages with black marks, not original copy _____
6. Print shows through as there is text on both sides of page _____
7. Indistinct, broken or small print on several pages __✓__
8. Print exceeds margin requirements _____
9. Tightly bound copy with print lost in spine _____
10. Computer printout pages with indistinct print _____
11. Page(s) _____ lacking when material received, and not available from school or author.
12. Page(s) _____ seem to be missing in numbering only as text follows.
13. Two pages numbered _____. Text follows.
14. Curling and wrinkled pages _____
15. Dissertation contains pages with print at a slant, filmed as received _____
16. Other _____

_____

_____

U·M·I

RICE UNIVERSITY

MODERN SEDIMENTARY DYNAMICS AND QUATERNARY GLACIAL HISTORY OF MARGUERITE BAY, ANTARCTIC PENINSULA

by

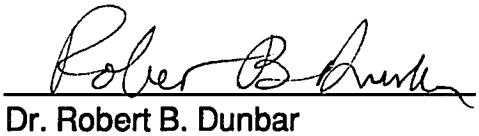
DOUGLAS STOKES KENNEDY

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

MASTERS OF ARTS

APPROVED, THESIS COMMITTEE:

Dr. John B. Anderson
Professor of Geology, Director



Dr. Robert B. Dunbar
Associate Professor of Geology

Dr. Howard C. Clark
Associate Professor of Geology

Houston, Texas
March, 1988

MODERN SEDIMENTARY DYNAMICS AND QUATERNARY GLACIAL HISTORY OF MARGUERITE BAY, ANTARCTIC PENINSULA

by

Douglas Stokes Kennedy

ABSTRACT

Piston cores and single-channel seismic data were acquired in Marguerite Bay, Antarctic Peninsula, to determine modern sedimentary conditions and recent glacial history of the area. Seismic data in the bay shows a rugged seafloor, having numerous deep troughs and a marked lack of sediment cover, with a thin layer of sediment over crystalline basement or older glacial deposits. Modern sedimentation consists predominantly of diatomaceous muds; ice-rafted debris is unimportant. These sediments show wind-driven or marine current influence. Piston cores are topped by diatomaceous muds, which are underlain by terrigenous muds and muddy gravels that were deposited beneath an ice shelf. Basal till sediments were recovered, reflecting deposition by a grounded marine ice sheet.

A reconstruction of the glacial history of Marguerite Bay since the last glacial maximum shows grounded ice filling the bay in late Wisconsin time; rising sea level caused slow ice margin retreat and existence of an ice shelf throughout the Holocene. An ice margin recessional facies model has been developed.

ACKNOWLEDGEMENTS

I know quite a number of people who have been to Antarctica, and so my perception of the uniqueness of the experience is skewed. In fact, of course, harldly anyone has gone, or will ever go, to the Antarctic, and I am slowly beginning to appreciate that idea and the light it puts on my journeys south.

For this experience, academic and otherwise, I can thank Dr John Anderson, advisor and friend, who made many extremely important contributions to the present work. His unflagging support and assistance, not to mention good humor, made this thesis truly a labor of love. Thanks go also to Dr H C Clark and Dr Rob Dunbar, who gave cheerfully of time and brainpower. I would also like to thank my fellow Antarctic Marine Geologists, the few, the proud, for making hard work, bitter cold, and nausea seem like a special kind of enjoyment. No study involving Antarctic cores can take place without the tireless diligence and assistance of Dennis Cassidy and his people at the Antarctic Core Facility at Florida State University, and for his help I am very thankful.

Most of all, I would like to thank Ingrid and my parents for their love and support -- they made what appeared to be an impossibility into reality.

TABLE OF CONTENTS

		page
1	**INTRODUCTION**	1
	Location	
	Present glaciological setting	
	Marguerite Bay glaciology	
	Oceanographic setting	
	Geologic history	
	Structural elements	
2	**PREVIOUS WORK**	30
	The continental shelf	
	Antarctic shelf sedimentation	
	Antarctic Peninsula glacial history	
3	**METHODS**	41
4	**SEISMIC DATA**	43
	Seismic lines	
	Origin of submarine troughs	
5	**SURFACE SEDIMENTS**	53
	Sediments	
	Discussion	
6	**STRATIGRAPHY**	73
	Northeastern/southeastern quarters	
	Northwestern quarter	
	Southwestern quarter	
	Basal tills	
	Bay-wide trends	
7	**RECONSTRUCTION**	117
	Glacial maximum (18,000 ybp)	
	Ice shelf period (10,000-12,000 ybp)	
	Retreat to present	

		page
8	**FACIES MODEL**	132
9	**CONCLUSIONS**	140
REFERENCES		144
APPENDIX 1	Core and bottom grab locations	153
APPENDIX 2	Coarse sand grain mineralogies	156
APPENDIX 3	Textural data	158
APPENDIX 4	Piston core lithologic logs	164

LIST OF FIGURES

		page
1.1	Location of piston cores, box cores, grab samples, and single-channel sparker seismic reflection lines used in this thesis	2
1.2	The Antarctic Peninsula, showing the location of George VI Sound and Marguerite Bay	6
1.3	Bathymetry of Marguerite Bay	8
1.4	Marguerite Bay and surrounding land areas	11
1.5	Present glacial drainage into Marguerite Bay	15
1.6	Flow-line map of George VI Ice Shelf	18
1.7	Faulting in the Marguerite Bay region	26
2.1	Reconstruction of ice caps and flowlines for George VI Sound, northwestern Palmer Land, and Alexander Island during the late Wisconsin glacial maximum	39
4.1	Detail of seismic line M1	45
4.2	Detail of seismic line MB-B, crossing Adelaide Trough	47
4.3	Seismic line MB-E, crossing George VI Trough	49
5.1	Division of Marguerite Bay into quarters	54
5.2	Distribution of surface sediments in Marguerite Bay	56

5.3	Size vs. frequency plots, surface samples in Marguerite Bay	59
5.4	Size vs. frequency plots, surface samples in Marguerite Bay	61
5.5	Proposed flow path of East Wind Drift and subsidiary spur into Marguerite Bay	69
6.1	Lithologic logs of cores recovered from the northeastern quarter of Marguerite Bay	75
6.2	Lithologic logs of cores recovered from the southeastern quarter of Marguerite Bay	77
6.3	Size vs. frequency plots, downcore samples in eastern Marguerite Bay	80
6.4	Lithologic logs of cores recovered from the northwestern quarter of Marguerite Bay	88
6.5	Size vs. frequency plots, downcore samples in western Marguerite Bay	90
6.6	Lithologic logs of cores recovered from the southwestern quarter	96
6.7	Size vs. frequency plots, downcore samples in the southwestern quarter of Marguerite Bay	99
6.8	Sand/silt/clay ratios downcore on selected cores from western Marguerite Bay	104
6.9	Roundness vs. sphericity plot of pebbles from basal till and transitional glacial-marine units	106
6.10	Roundness vs. sphericity plots of pebbles from compound and residual glacial-marine units	108

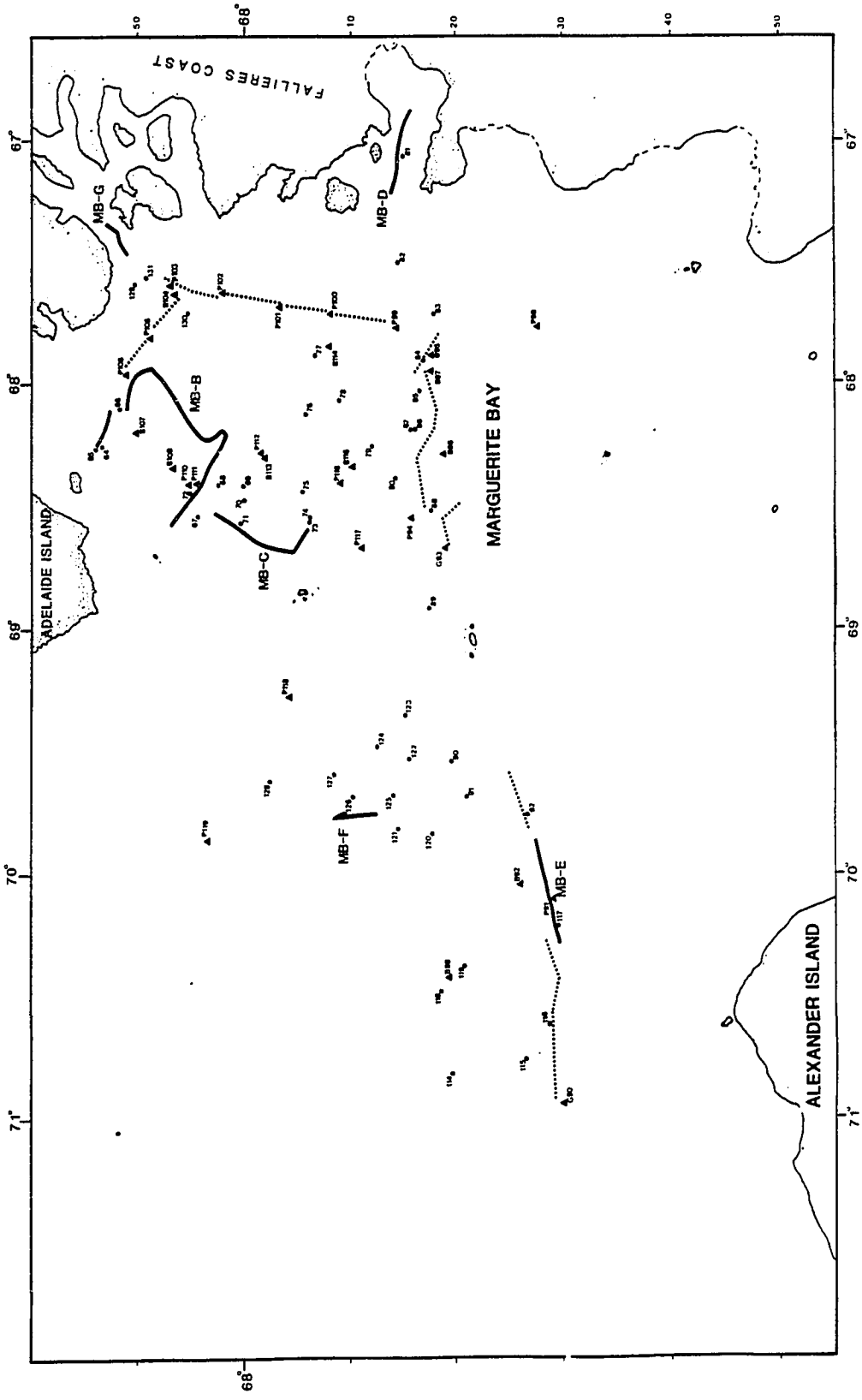
6.11	Pebble lithology abundances in selected compound glacial-marine, transitional glacial-marine, and diamicton units in Marguerite Bay	111
6.12	Location of quartz-mica schist/gneiss outcrops that are the likely source area for basal till units found in the southwestern quarter	115
7.1	A reconstruction of glacial drainage in the Marguerite Bay region during the late Wisconsin glacial maximum (18,000 ybp)	118
7.2	A reconstruction of glacial drainage in the Marguerite Bay region during the early Holocene (10,000-12,000 ybp)	123
7.3	Location of areas in Marguerite Bay with present water depth of less than 100m	125
8.1	Polar ice margin recessional facies model	133
8.2	Lithologic logs of cores in western Marguerite Bay, aligned roughly from west to east, with sedimentary units correlated	136

CHAPTER 1 INTRODUCTION

The Antarctic Peninsula, situated between longitude 55°W and 75°W, is the northernmost projection of the continent of Antarctica. The peninsula experiences the continent's most temperate climate and the glacial regime of the region can be expected to be more sensitive to changes in the environmental factors that influence the waxing and waning of ice sheets. This has led scientists to search for evidence of the Pleistocene ice advances, both on land and on the sea floor, and of climatic and eustatic changes since the last glacial maximum 18,000 years ago. During the USARP/Deep Freeze 85 and 86 expeditions to the Antarctic Peninsula, marine geologic and geophysical data were collected along the western continental margin and in the vicinity of the South Shetland and South Orkney Islands. Marguerite Bay (Fig. 1.1) was the site of a concentrated piston coring and seismic reflection survey, undertaken during both expeditions. A total of 73 piston core and box core stations were occupied, and more than 240 km of single channel seismic reflection data were acquired. This extensive data base was used in the present study to delineate modern sedimentary dynamics, and to postulate a possible Quaternary history for the area.

In the past ten years, Anderson et al (1980, 1983, 1984) have characterized sedimentation processes of the Antarctic continental shelf. A range of sediment types have been interpreted in terms of

Figure 1.1: Location of piston cores, box cores, and Shipek-LaFonde grab samples, and single-channel sparker seismic reflection lines used in this thesis. Marine geologic stations from Deep Freeze 85 are represented by solid circles; Deep Freeze 86 stations are represented by solid triangles, with a letter denoting the type of sample (G=Shipek-LaFonde grab; P=piston core; B=box core). Solid lines are seismic tracks from DF 85, and dotted lines are tracks from DF 86.


FALLIERES COAST
MB-G
MB-D
MB-B
MB-C
MB-F
MB-E
MARGUERITE BAY
ADELAIDE ISLAND
ALEXANDER ISLAND
67°
68°
69°
70°
71°
68°
-50
-10
-20
-30
-40
-50

amount and kind of glacial influence, in conjunction with marine processes. The recognition of basal till units, signifying deposition by a grounded ice sheet, has lent credence to theoretical models of an expanded Antarctic ice sheet grounded out to the edge of the continental shelf during past glacial maxima (Stuiver et al, 1981; Denton et al, 1986). Grounding of ice on the continental shelf in Marguerite Bay in late Wisconsin time has also been suggested by Nichols (1960) and Clapperton and Sugden (1982), on the basis of geomorphologic arguments. A primary goal of this thesis was to investigate piston cores for evidence that would confirm or invalidate these ideas, and to piece together a coherent sequence of events from the last glacial maximum through the present. The change from full glacial conditions to the present glacial marine setting most likely included a number of intermediary stages that may be reflected in the sediments.

Marguerite Bay is uniquely located with respect to the present glacial drainage of the Antarctic Peninsula. The bay receives ice from a number of different glacial regimes, including Antarctica's northernmost ice cap, the Palmer Land Ice Cap. Ice shelves, large outlet glaciers, and smaller valley glaciers all drain from the surrounding land areas into the bay. These various glacial elements, combined with high production of siliceous phytoplankton, contribute to the present sedimentary regime of the bay. Another primary objective of the study was to describe the characteristics and dynamics of the sedimentary setting, assessing the relative importance of each element.

The George VI Sound (Fig 1.2) has been proposed as a rift valley (Crabtree et al, 1985) and an extension of this feature is found in southwestern Marguerite Bay . The bay is cut by numerous deep (>700 m) troughs, whose origin as either tectonic features or products of glacial scouring, or a combination of both processes, has not been determined. The present research attempts to shed some light on this question, and offers the first detailed bathymetric map of the bay's extremely rugged seafloor (Fig. 1.3).

Situated between the temperate glacial regime of the northern Antarctic Peninsula and the polar glacial regime of West Antarctica, Marguerite Bay is strategically placed as a test area for various models of glacial and glacial marine sedimentation, the nature of ice sheet advance and retreat, and specific scenarios of the late Wisconsin ice sheet expansion. This thesis will address a number of these ideas, with the aim of further constraining our knowledge and conception of the Quaternary of the Antarctic Peninsula.

Location

The Antarctic Peninsula is located between 55°W and 75°W, and stretches from 62°S to about 76°S (Fig. 1.2). It is bounded to the west by the southern Pacific Ocean, to the north by the Drake Passage, and to the east by the Larsen Ice Shelf and the Weddell Sea. The peninsula is subdivided into Graham Land and Palmer Land along an east-west line running at roughly 69°S. Marguerite Bay lies between 67°45'S and 69°00'S along the western margin of the peninsula (Fig 1.4). The bay is bounded by Adelaide Island to the north, Alexander Island to the south,

Figure 1.2: The Antarctic Peninsula, showing the location of the George VI Sound, and of Marguerite Bay on the western margin, straddling the boundary between Graham Land and Palmer Land. Shaded areas are ice shelves. GS is the Gerlache Strait; GC is the Grandidier Channel.

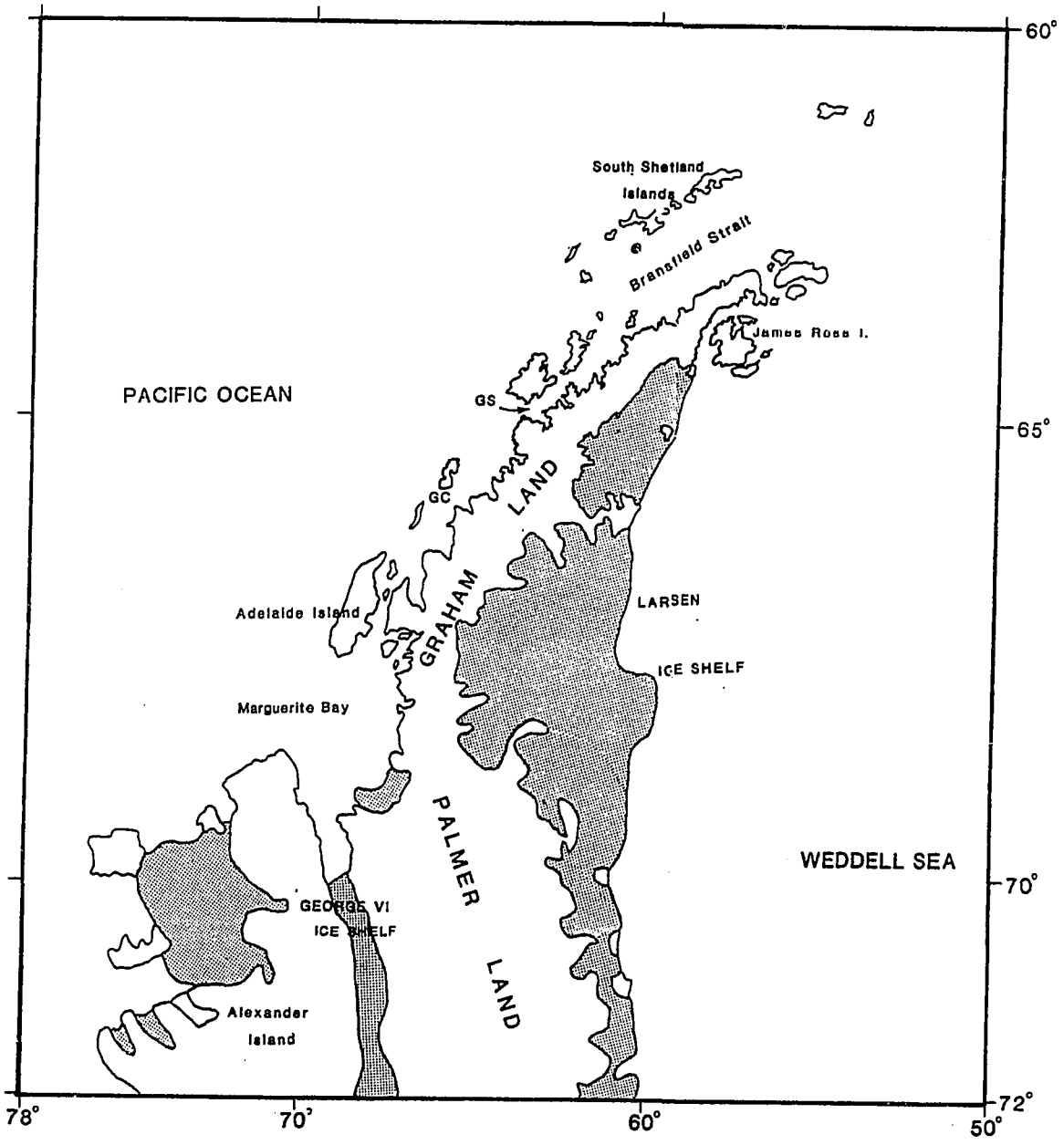
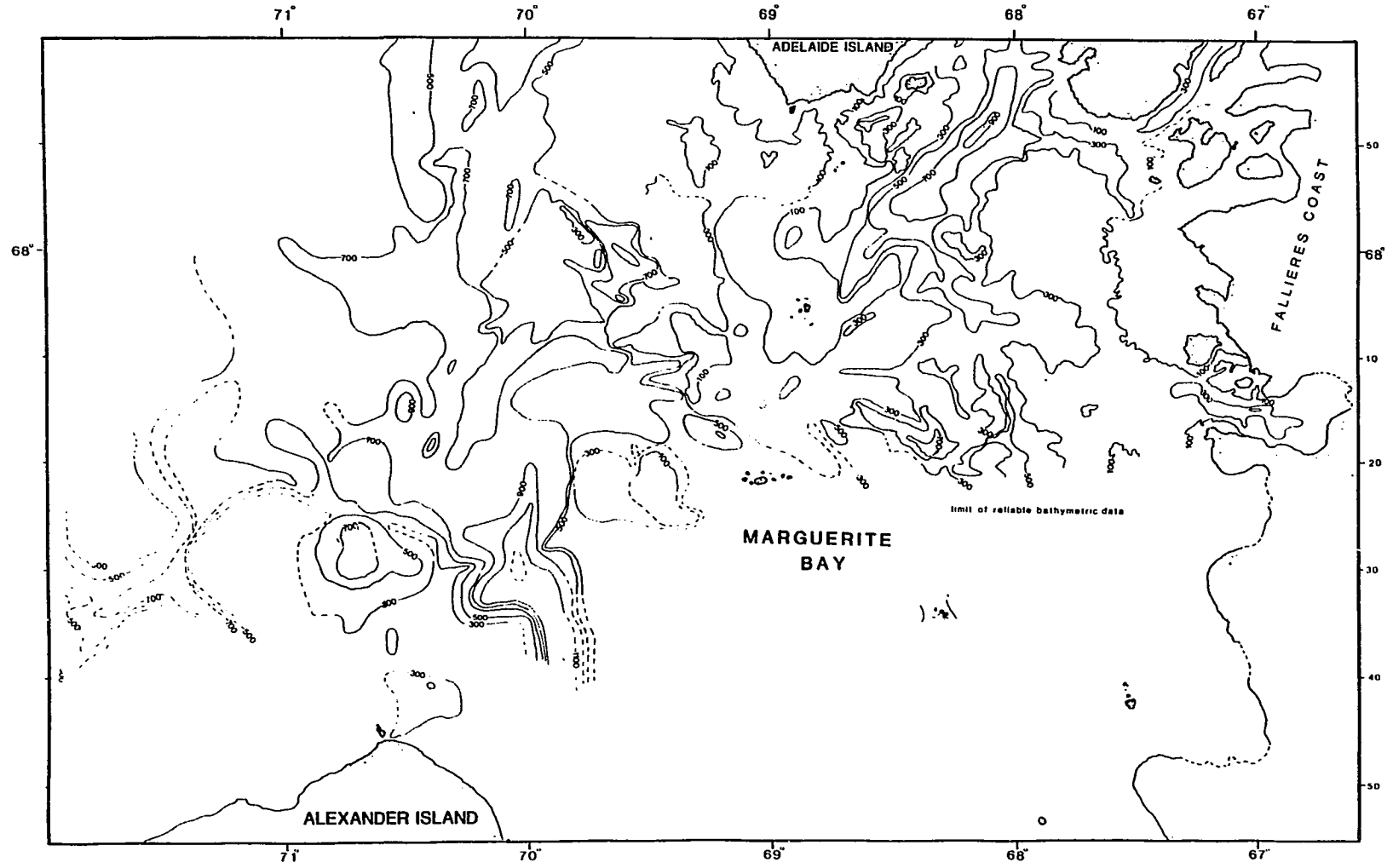

60°
65°
70°
72°
78°
70°
60°
50°
South Shetland Islands
Bransfield Strait
James Ross I.
PACIFIC OCEAN
GS
GC
LAND
GRAHAM
LARSEN
ICE SHELF
Adelaide Island
Marguerite Bay
PALMER
LAND
WEDDELL SEA
GEORGE VI
ICE SHELF
Alexander
Island

Figure 1.3: Bathymetry of Marguerite Bay, showing the extremely rugged seafloor and a number of deep troughs. Due to perennial pack ice cover, the southern half of the bay has only sparse bathymetric readings, and an accurate mapping of the seafloor is not possible. The extension of the George VI Trough reaches depths of greater than 1300m, and this feature is much deeper than the outer continental shelf to the west in the Bellingshausen Sea.


71°
70°
69°
68°
67°
ADELAIDE ISLAND
FALLIERES COAST
MARGUERITE
BAY
limit of reliable bathymetric data
ALEXANDER ISLAND
68°

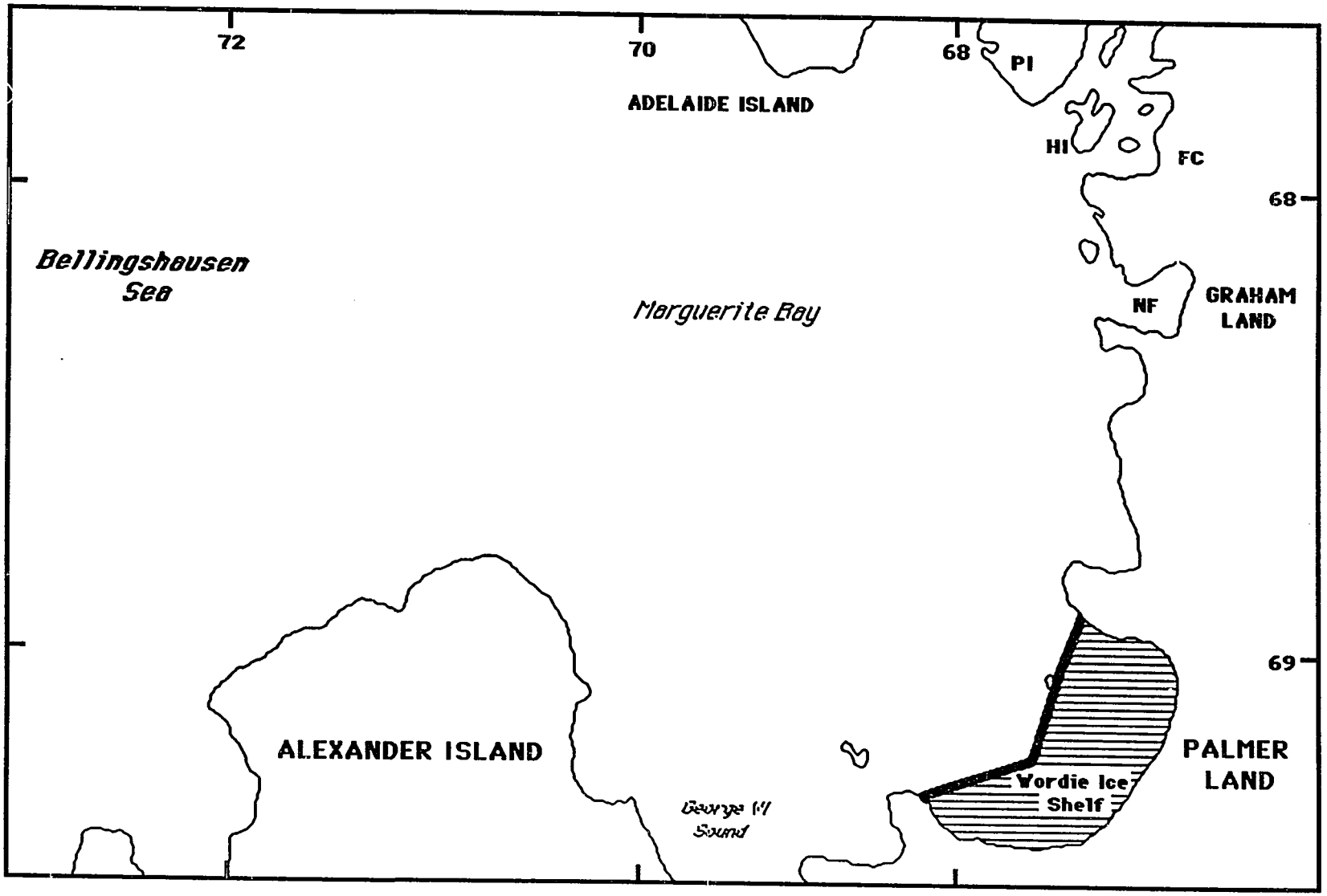
and the Graham Land and Palmer Land coasts to the east. The bay opens to the west into the Bellingshausen Sea.

Present glaciological setting

The northern Antarctic Peninsula is covered by ice domes that have a drainage distinct from that of the large West Antarctic Ice Sheet. Ice from the Graham Land plateau drains west into the Bellingshausen Sea and Bransfield Strait and east into the Weddell Sea, principally through the Larsen Ice Shelf. A small ice cap covers Palmer Land; this is the northernmost ice cap in Antarctica. Glacial drainage from this feature is to the west into the George VI Sound and southern Marguerite Bay, and to the east into the Weddell Sea.

Ice shelves buttress the draining of these ice caps on both margins of the peninsula. The Larsen Ice Shelf, ranging in width from 10 to 150 km, extends down the eastern side of the peninsula from south of James Ross Island to almost 75°S, ranging in width from 10 to 150 km. The ice shelf exhibits easterly flow, with icebergs calving into the Weddell Sea. The western drainage from the Palmer Land Ice Cap flows into the Wordie and George VI ice shelves; the former debouches directly into southern Marguerite Bay, while the latter has calving fronts at both its northern and southwestern termini. Reynolds (1981) discussed the distribution of mean annual temperatures in the Antarctic Peninsula, and noted that ice shelves are found only in areas having conditions colder than the -4°C isotherm. There is a marked difference in mean annual temperature between stations at similar latitudes on opposite sides of the peninsula; the eastern margin is on

Figure 1.4: Marguerite Bay and surrounding land areas (PI=Pourquoi-Pas Island; HI=Horseshoe Island; FC=Fallières Coast; NF=Neny Fjord).


72
70
68
PI
ADELAIDE ISLAND
HI
FC
68
Bellingshausen Sea
Marguerite Bay
NF
GRAHAM LAND
69
ALEXANDER ISLAND
George VI Sound
Wordie Ice Shelf
PALMER LAND

average nearly 6°C colder. This has been attributed to separate climatic influences on the region, the western margin being dominated by depressions moving east from the Bellingshausen Sea, and the eastern margin by westward flowing air masses from the Weddell Sea (Reynolds, 1981). Scientific stations on the Antarctic Peninsula record mean annual temperatures 10-15°C higher than stations on the continent (Schwertdfeger, 1984).

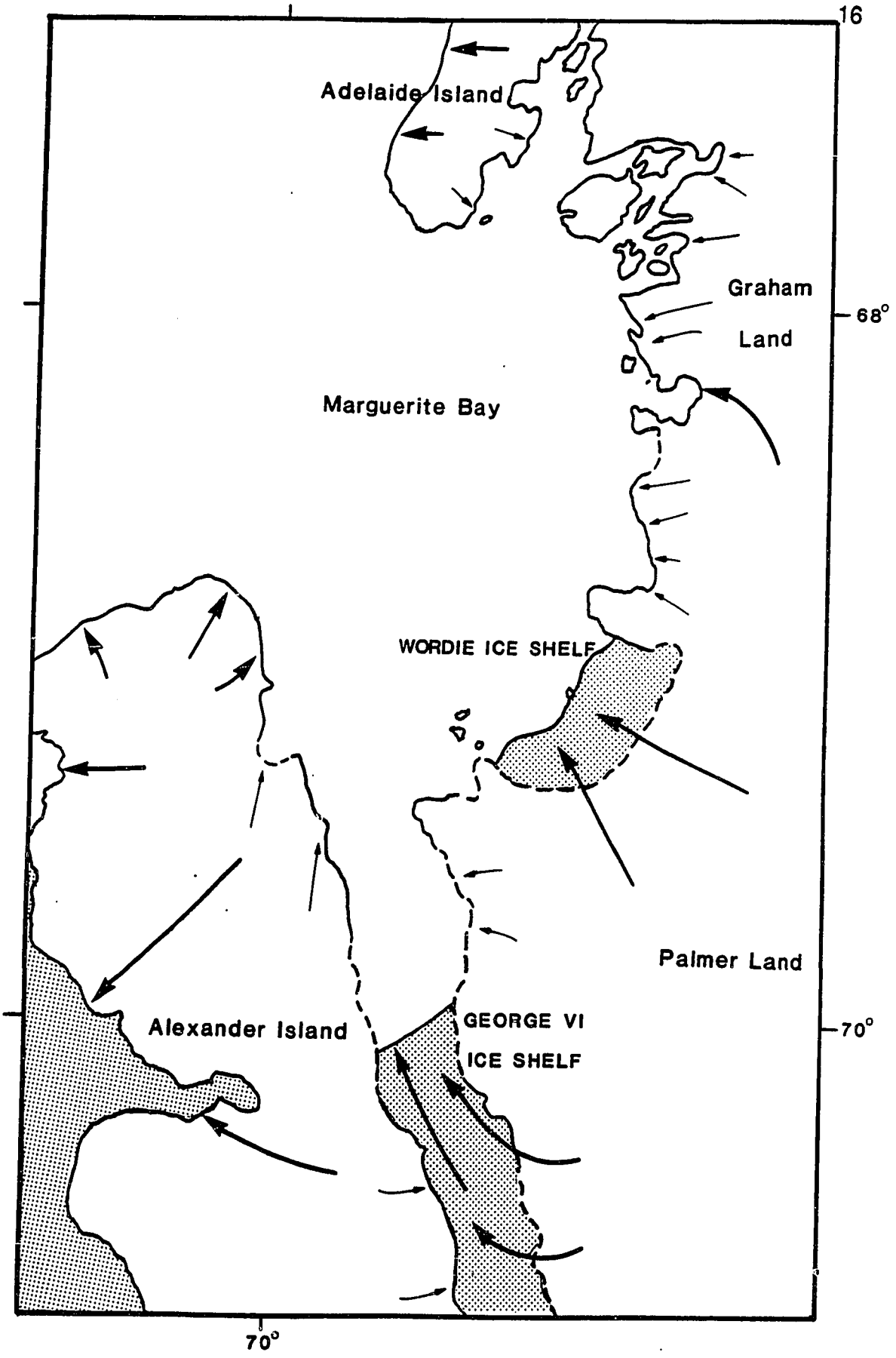
Snow accumulation in the Antarctic Peninsula appears to be high in comparison to most areas of Antarctica. Since 1983, Palmer Station on Anvers Island has received more than twice as much snowfall as McMurdo Station in the Ross Sea (Antarctic Journal of the U.S., 1983; 1984; 1985). The western side of the peninsula, in particular, receives very large amounts of snowfall, reflecting the movement of climatic depressions to the east from the Bellingshausen Sea, and to the south from South America (Potter et al, 1984). Dewar (1967) discusses very high accumulation rates on Adelaide Isand and in the Melchior Islands (64°20'S), although this high rate is restricted to the western-facing windward slopes of the north-south trending mountains. The existence of a precipitation shadow is also postulated for west central Palmer Land, where accumulation is much lower due to the presence of the Douglas and LeMay ranges of Alexander Island (>2500m elevation) to the west (Bishop and Walton, 1981). Ablation in the peninsula region occurs mainly through calving of icebergs, although melting is possibly as important as calving in northern areas. Melting under the George VI Ice Shelf appears to be a major ablation mechanism (Pearson and Rose, 1983), and considerable melting may occur under other ice shelves as

well (Robin, 1979). The ice fronts of the Larsen, George VI, and Wordie Ice shelves have retreated as much as 30 km in the last 30 years. This, coupled with a general increase in mean air temperature and a decrease in precipitation over the same time period, led Doake (1982) to propose that a general glacial recession is presently taking place. However, areas of the George VI Ice Shelf are thickening, probably in response to increased precipitation rates several hundred years ago, and thus the state of balance of the peninsula ice sheet is not known. It has been suggested that the ice sheet may never be in equilibrium with its external environment because of the very different time scales in which changes in average accumulation take place and subsequently affect the ice sheet (Doake, 1982).

Marguerite Bay glaciology

A number of glacial regimes drain into Marguerite Bay (Fig. 1.5). The northern and eastern areas of the bay receive ice from outlet glaciers draining from the high central plateau of Graham Land, and from smaller valley glaciers of the larger islands and the Fallières Coast. Several large glaciers draining the ice fields of northern Alexander Island flow into the southwestern quarter of the bay. The Wordie and George VI ice shelves, draining north from the Palmer Land ice cap, debouch into the southern reaches of the bay. The large outlet glaciers feeding the ice shelves are, in some places upstream of the grounding line, grounded at >500 m depth below sea level, and the troughs occupied by these glaciers show ample evidence of overdeepening, indicating that glacial erosion was, and most likely still is, active

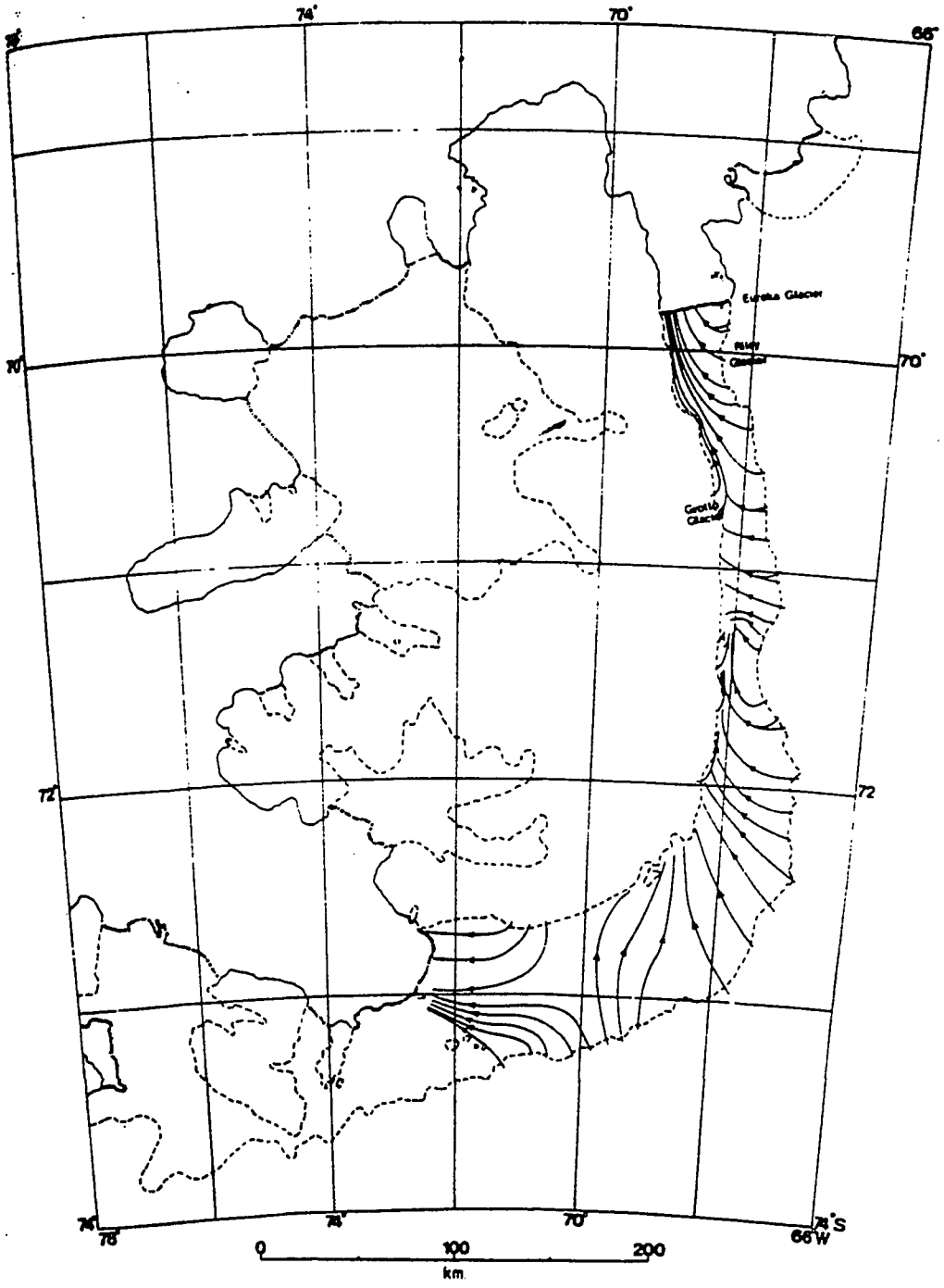
Figure 1.5: Present glacial drainage into Marguerite Bay. The majority of ice draining into the bay is from Palmer Land, entering through the George VI and Wordie ice shelves. Small outlet and valley glaciers of Graham Land and the large islands also contribute ice to the northern parts of the bay. Large arrows represent major drainage, small arrows represent minor drainage.


Adelaide Island
Graham
Land
68°
Marguerite Bay
WORDIE ICE SHELF
Palmer Land
Alexander Island
GEORGE VI
ICE SHELF
70°
70°

(Wyeth, 1977; Crabtree, 1981). It has been suggested that the larger western-flowing outlet glaciers occupy structurally formed troughs, which were subsequently greatly enlarged by glacial erosion (Wyeth, 1977; Crabtree et al,1985).

The George VI Ice Shelf has been extensively studied by scientists of the British Antarctic Survey over the last ten years. The ice shelf fills the George VI Sound and has calving fronts at both the northern and southwestern ends of the sound (Fig 1.6). The vast majority of ice draining into the ice shelf comes from Palmer Land, with Alexander Island glaciers supplying less than 8% of the total drainage (Potter et al, 1984). Flow lines in the northern section show an east to west track across the sound before turning north and flowing along the eastern coast of Alexander Island. In the central section, flow is also east to west directly onto the Alexander Island margin; it has been proposed that bottom melting is sufficient for removal of this ice (Pearson and Rose, 1983). Several studies have estimated bottom melting in the central and northern sections of the ice shelf to be ca. 2 m/year (Bishop and Walton, 1981; Potter et al, 1984), and this rate represents a very important contribution to the ice melt budget of Antarctica (Potter and Paren, 1985). Another indication of negative mass balance is the retreat of the northern ice front up to 30 km during the last 30 years, although the accuracy and significance of this is disputed (Doake, 1982).

Figure 1.6: Flow-line map of George VI Ice Shelf, from Pearson and Rose (1983). Ice from Palmer Land generally overwhelms the much lower volume of ice flowing off Alexander Island. In the central area of the ice shelf, ice flows directly across the sound onto the margin of Alexander Island; bottom melting is sufficient to maintain a rough balance (Pearson and Rose, 1983).



from Pearson and Rose (1983)

Oceanographic setting

There is no production of cold, saline bottom water in Marguerite Bay; Circumpolar Deep Water extends from the surface to the seafloor where it reaches a maximum in temperature and salinity (Lennon et al, 1982). No geostrophic currents have been recognized in the bay, although a clockwise gyre could exist without having been detected. The existence of a counterclockwise east-west current on the Antarctic continental shelf, known as the East Wind Drift, has been established by oceanographic study and by charting the drift tracks of large icebergs (Tchernia and Jeannin, 1980). This counterclockwise trend is opposite the main Antarctic clockwise marine current , the West Wind Drift, which lies farther offshore. Lennon et al (1982) concluded that non-tidal currents have velocities less than 1 cm/sec. Winds, however, are an important oceanographic agent in the bay. During Deep Freeze 85 and 86, wind velocities of 30 to 40 knots were not uncommon. Winter winds show a strong NNW to SSE orientation, which may tend to inhibit breakout of sea ice in the southern parts of the bay. Easterly winds off the Graham Land plateau are not common, occurring primarily during foehn storms, and katabatic winds are important only on the scale of a few days, due to the limited area of the plateau to generate these winds (Schwerdtfeger and Amaturo, 1979).

Extensive work has been done on the interrelationship between the George VI Ice Shelf and the surrounding oceanographic environment. A concentrated northerly "jet" of low density water has been observed at the northern ice front, hugging the western flank of the sound. This jet

the northern ice front, hugging the western flank of the sound. This jet rides buoyantly on denser water to a depth of 150 to 200 m, with flow velocities of 10-25 cm/sec (Potter and Paren, 1985). The flow has been linked to melting of ice at the base of the ice shelf, caused by heat advection from very slow southerly moving Warm Deep Water; this lower salinity water is diverted to the western side of the sound by Coriolis force (Potter and Paren, 1985).

Sea ice is another important component of the modern oceanography and dynamics of Marguerite Bay. The bay is covered with sea ice for an average of eight to nine months a year, usually from late April to January. One-year ice will reach a thickness of a meter and a half (Heap, 1964). About one in five or six years the sea ice does not break out during the summer due to an especially severe winter or weakened offshore winds, and the ice thickens with another year of snow and ice accumulation (Heap,1964). During the six year period 1973-78, Marguerite Bay was free of sea ice each summer, although several times for only four to six weeks (United States Navy, 1974; 1976; 1978). The northwestern quarter of the bay, south and southwest of Adelaide Island, was most frequently the first area to become ice-free in the summer, and the last area to be covered by ice in the autumn. The bay fills with sea ice in the autumn as ice expands out of the bays and fjords of the Fallières Coast, and north from the southern reaches of the bay. Heap (1964) has linked the failure of the annual ice to break out with large masses of multiyear ice moving north from the Amundsen Sea and lying off the west coast of the peninsula. Semi-permanent pack ice fills the southern half of the bay, south of a

line due east from the northern end of Alexander Island. The ice chart data show that this permanent pack ice may expand or contract, contingent on the severity of the year's climate.

Geologic history

The oldest rocks exposed on the Antarctic Peninsula are metasediments and gneisses of the so-called "Basement Complex", originally presumed by Adie (1954) to be Precambrian-early Paleozoic in age. Subsequent geochemical dating has discounted this idea (Gledhill et al, 1982), and the Basement Complex is now presumed to be late Paleozoic-early Mesozoic in age. Upper Paleozoic sedimentary rocks are abundant on the peninsula, the most widespread stratigraphic unit being the Trinity Peninsula Formation (TPF). TPF rocks outcrop in the northern part of the peninsula, with stratigraphic equivalents found farther south. Smellie (1981) has proposed a complete arc-trench system for the Antarctic Peninsula in late Paleozoic time, with Pacific Ocean crust being subducted along the western margin. TPF rocks have been characterized as forearc basin deposits (Smellie, 1981) and as an accretionary wedge sequence (Storey and Garrett, 1985). Similar sedimentary rocks found in northern and central Alexander Island have been grouped together as the LeMay Group (Burn, 1983). Although presumed to be time-correlative with TPF, the LeMay Group contains a Triassic fossil assemblage, indicating that large parts of this extensive sequence may be early Mesozoic in age (Edwards, 1982). Both the TPF and the LeMay Group underwent metamorphism during the early Mesozoic, perhaps as part of the Gondwanide orogeny (Dalziel and

Elliot, 1971).

Beginning in early Jurassic time, the Antarctic Peninsula became the site of intense volcanic activity, generated by subduction of Pacific Ocean crust. This subduction continued throughout the Mesozoic and Tertiary, and produced vast amounts of volcanic material throughout the peninsula. These rocks are grouped together under the name Antarctic Peninsula Volcanic Group (APVG), and consist of a calc-alkaline suite of predominantly intermediate lavas, agglomerates, and tuffs (Thomson and Pankhurst, 1983). A related suite of plutonic rocks has been emplaced along the axis of the peninsula during roughly the same time period. These rocks are divided into an older (Jurassic) group on the eastern coast, a younger (Tertiary) group on the northwestern coast and adjacent islands, and intermediate aged (late Jurassic-Cretaceous) rocks throughout the region. The plutonic rocks also follow a calc-alkaline trend, with granite and granodiorite predominating (Saunders et al, 1982).

By early Tertiary time, subduction was declining along the western margin progressively to the north, as the spreading center reached the trench (Barker, 1982). At the southern end of the peninsula, where the initial ridge-trench collision occurred, volcanic activity ceased at about 50 Ma ago, whereas subduction-related volcanicity at the northern end stopped only in the last 4 Ma. Cenozoic subduction appears to be responsible for extensional tectonics in the peninsula, the Bransfield Strait being the most striking feature of this activity. The Recent volcanic centers Deception and Bridgeman islands show geochemistries consistent with back-arc spreading and diapirism. A

great amount of basaltic lava was deposited on James Ross Island during Miocene time; this volcanism has also been related to an extensional regime (Weaver et al, 1982).

In the Marguerite Bay region, gneisses, schists, and amphibolites of the Basement Complex outcrop along the Fallières Coast in the vicinity of Neny Fjord (Adie, 1954), on Horseshoe Island (Matthews, 1983a), and in northern Palmer Land (Skinner, 1973; Rowe, 1973). These rocks have been extensively intruded by Mesozoic plutons, principally of granitic composition. These plutonic rocks are found in most areas of the bay, including Adelaide Island (Dewar, 1970), Pourquoi-Pas and Horseshoe islands (Matthews, 1983a,b), and throughout the Fallières Coast (Adie, 1955) and in northern Palmer Land (Skinner, 1973). A number of intrusions show a gabbro to granite compositional progression (Dewar, 1970) but mafic plutonic rocks are minor in the region. Volcanic and volcaniclastic rocks of the APVG are found throughout the bay, including northern Alexander Island (Bell, 1974). Over 3 km thickness of andesitic lavas and agglomerates are found on Adelaide Island (Dewar, 1970). The youngest extensive outcrop in the bay is the Rouen Mountains batholith of northern Alexander Island, a large granodiorite body of early Tertiary age (Care, 1983; Pankhurst, 1982). Middle and late Tertiary dikes are found throughout the region, probably emplaced in conjunction with late Cenozoic extensional tectonics.

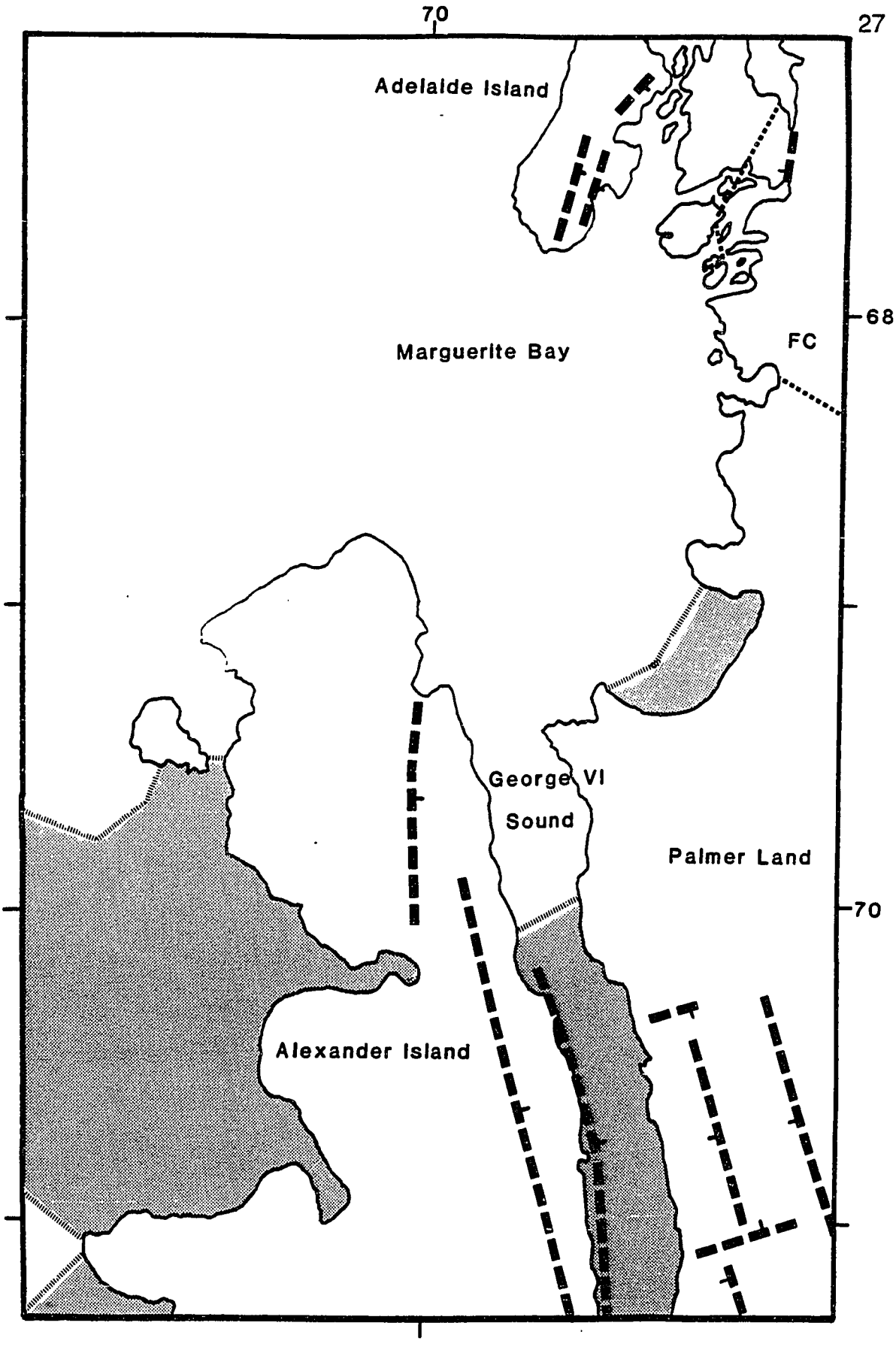
Structural elements

The Antarctic Peninsula has been subject to tectonic activity for most of its existence, including a late Cenozoic extensional phase.

This last phase of tectonism, commencing in Tertiary time, has greatly modified the continental margin of the peninsula. Bransfield Strait, Gerlache Strait, the Grandidier Channel, Marguerite Bay, and George VI Sound have all been tentatively interpreted as graben features (Fig. 1.2)(Storey and Garrett, 1985).

The most striking structural feature in the Marguerite Bay area is George VI Sound. The parallel flanks of the sound and parallel mountain ranges to the east and west led many early workers to propose that the sound was a rift valley (Fleming et al, 1938; King, 1964). This feature reaches 900 meters in depth near the northern ice front. Radio-echo and seismic sounding has demonstrated that the sound has a "W" shape in cross-section; this shape is continuous for at least 150 km to the south (Crabtree et al, 1985). Both glacial erosion (Crabtree, 1981) and normal faulting (Crabtree et al, 1985) have been suggested as the origin of these parallel troughs. Faulting parallel to the trend of the sound has been found both in Palmer Land (Crabtree, 1981) and on Alexander Island (Bell, 1975; Edwards, 1979)(Fig. 1.7). Crabtree et al (1985) have postulated that the rift actually extends from the LeMay Range fault on Alexander Island to a parallel fault 60 km east of the sound in Palmer Land. Transverse block faulting of this eastern flank of the rift is considered responsible for the formation of oversized valleys through which the outlet glaciers of Palmer Land flow into the George VI Ice Shelf. The rift feature extends to the north across Marguerite Bay, where it reaches >1300 meters in depth, and possibly continues to the continental shelf break. North-south trending faults are also found in the northern part of the bay on Adelaide Island

Figure 1.7: Faulting in the Marguerite Bay region. The roughly north-south trend of most faults may also be seen in submarine features; this normal faulting is due to a late Cenozoic episode of extension (Storey and Garrett, 1985). Heavy dashed lines are normal faults, with the tick on the downthrown side. Light dashed lines are strike-slip faults or faults of unknown sense of movement. Shaded areas are ice shelves. FC= Fallières Coast.


70
27
Adelaide Island
68
Marguerite Bay
FC
George VI
Sound
Palmer Land
70
Alexander Island

(Dewar, 1970), Horseshoe Island (Matthews, 1983a), Pourquoi-Pas Island (Matthews, 1983b), and Arrowsmith Peninsula (Moyes and Hamer, 1984)(Fig. 1.7). In these cases, the tectonism uplifts the eastern peninsula block; thus deeper structural levels are exposed to the east (Basement Complex).

Geophysical data supports the theory of rifting and block faulting in the Antarctic Peninsula. Aeromagnetic surveys conducted by the British Antarctic Survey have delineated a major change in magnetic intensity along a transect west from the central plateau of the peninsula across the western continental margin. The strongly magnetic signature of the metamorphic and igneous rocks of Graham Land and Palmer Land abruptly gives way to quiet magnetic conditions across the eastern margin of the George VI Sound and its northward submarine extension (Renner et al, 1982). This magnetic anomaly has been interpreted both as downfaulted sedimentary material in the George VI Sound and as a continuous batholithic feature underlying the west coast of the peninsula for at least 1200 km (Renner et al, 1982). A gravity survey across the George VI Sound has demonstrated crustal thinning beneath this feature, which may be associated with faulting (Renner et al, 1985).

Physiographic evidence of east-west trending faults across the peninsula has been extensively documented by Hawkes (1981), who proposed tectonic segmentation of the peninsula along trends of oceanic fracture zones in the southeast Pacific Ocean. However, positive geologic evidence of faulting is lacking (Barker, 1982; Storey and Garrett, 1985). Wyeth (1977) outlines the striking physiographic

changes that occur across a 150 km wide transition zone between Graham Land and Palmer Land. At least five major differences are evident: 1) width of Palmer Land is three times that of Graham Land; 2) large differences occur along the western side of the peninsula north and south of the transition zone; 3) sinistral curvature of Palmer Land changes to dextral curvature of Graham Land; 4) Graham Land glaciers are much narrower and steeper than Palmer Land glaciers; 5) the Palmer Land plateau is much more rugged than the Graham Land plateau. Although the trend of glaciers across the transition zone suggests transverse faulting, there is no discernible geologic discontinuity or change across the zone (Wyeth, 1977).

CHAPTER 2 PREVIOUS WORK

The continental shelf

The continental shelf of Antarctica is a vastly different sedimentary environment than shelves of lower latitiudes. The great depth of the Antarctic shelf is reflected in the average shelf break depth of 500 meters, compared with the world average of 60 meters. The bathymetry of the shelf is often very rugged, and deep submarine troughs, running both parallel and perpendicular to the coastline, are common. These troughs are generally interpreted as being glacially scoured, but origins as tectonic features subsequently filled with eroding ice cannot be ruled out, especially along the western margin of the Antarctic Peninsula (Vanney and Johnson, 1976). Sediment deposited in shelf basins is thus often below the reach of wind-driven currents. Along many margins, the shelf deepens toward the continent, further trapping sediments landward of the shelf break. The severe climate effectively eliminates most fluvial input, although ice-free areas of the Antarctic Peninsula may be the site of relatively large meltwater streams during the summer. The climate is also responsible for seasonal and perennial sea ice, which limits biological production to a few months a year and dampens wind-driven reworking of sediment. Most shelf deposits consist, in varying degrees, of four components: biogenic silica and/or carbonate, meltwater silts and

clays, volcanic ash and other aeolian debris, and ice-rafted debris (IRD). The importance of meltwater as an agent of sediment supply has not been accurately gauged; presumably meltwater processes are more prevalent in the northern regions of the peninsula. During Deep Freeze 86 (February), a large number of meltwater plumes were identified seaward of glaciers grounded at sea level in the vicinity of the South Shetland Islands and in the fjords of the Gerlache Strait area, but only one plume was sighted in Marguerite Bay. At the present time volcanic activity is restricted to the Bransfield Strait region, and therefore does not affect sediments in the southern part of the peninsula. Aeolian debris may comprise a significant component of marine sediments, especially in the Antarctic Peninsula, where there is a relatively large area of exposed rock. Katabatic winds often exceed 100 knots, and storms along the western margin regularly generate winds of 50 knots.

The origin of IRD has been a subject of much interest, chiefly because very few debris-laden icebergs have been sighted in Antarctic waters (Anderson et al, 1980b). The ice flowing off the Antarctic continent entrains debris at its base, as well as along its sides, and this debris-charged ice reaches the marine environment in three modes: ice cliffs, outlet glaciers/ice streams, and ice shelves. Ice shelves are by volume the most important mode of debouchment, but most ice shelves exhibit basal melting, and therefore any basal debris entrained in the base of the ice shelf will have melted out within a few tens of kilometers of the grounding line (Drewry and Cooper,1981). Flow paths of supraglacial and englacial debris will be down toward the base of

the ice shelf, due to surface snow accumulation and basal melting, and this material also will be deposited beneath the ice shelf seaward of the grounding line. Thus, icebergs calved from ice shelves are not thought to be significant contributors of IRD to the open marine environment. Ice cliffs are characterized by slow rate of advance, and wave action will cause virtually all basal debris to be deposited at the calving line. Outlet glaciers and ice streams exhibit rapid flow rates and often show basal freezing (Gill, 1973) which may allow basal debris to reach the calving line and be incorporated into icebergs. Outlet and valley glaciers also have higher amounts of englacial and supraglacial debris, eroded from nunataks and the confining walls of the glacial valley. Drewry and Cooper (1981) and Anderson et al (1983) conclude that outlet glaciers and ice tongues are responsible for the great majority of IRD reaching the ocean around Antarctica, although they represent less than a quarter of total ice drainage. Another important source of coarse material is aeolian debris blown onto fast ice, which is subsequently rafted into the open marine environment and melted out.

Icebergs melt quickly in the vicinity of the Antarctic Peninsula, due to the relative warmth of the seawater (Drewry and Cooper, 1981). Anderson (1972) found greater quantities of IRD on the continental slope of the Weddell Sea versus the adjacent continental shelf, due to faster melt rates of icebergs by upwelling warm water at the shelf-slope break.

Antarctic shelf sedimentation

The study of glacial-marine sedimentation has only recently been taken up in detail (e.g., Carey and Ahmad, 1961; Chriss and Frakes, 1972). Concentrating on the Antarctic continental shelf, scientists from Rice University have greatly expanded the understanding and recognition of glacial-marine sediments (Anderson et al, 1980a; Domack et al, 1980; Domack, 1982; Myers, 1982; Anderson et al, 1983b; Anderson et al, 1984). These studies have characterized shelf sedimentation in terms of the supply rates of the different types of sediment, and the subsequent reworking, both in the water column and on the seafloor, of these sediments.

Table 1 shows the four types of glacial/glacial-marine sediments distinguished by Anderson et al (1980a, 1983a): compound glacial-marine, residual glacial-marine, transitional glacial-marine, and basal till. Compound glacial-marine sediments are found in abundance on the continental shelf of Antarctica, including the western margin of the Antarctic Peninsula (Anderson et al, 1983b; Singer, 1987), and reflect the present low energy sedimentary environment found in most areas of >400 meters water depth. Terrigenous silts and clays predominate, and siliceous microfossils are an important constituent of these sediments, with a minor IRD component, indicating the low sediment input by debris-laden icebergs. Residual glacial-marine sediments reflect the influence of marine currents on the water column and seafloor, with the fine sediment component being winnowed, leaving behind unsorted IRD sand and gravel. This sediment type is most often restricted to shallow (< 300m) banks and to the

TABLE 1

CHARACTERISTICS OF GLACIAL/GLACIAL-MARINE SEDIMENT
(modified from Anderson et al, 1980b)

	BASAL TILL	TRANSITIONAL GLACIAL MARINE	COMPOUND GLACIAL MARINE	RESIDUAL GLACIAL MARINE
STRATI-FICATION	None	Subtle if present; generally absent	Crudely to well-stratified	None
CONTACTS	Sharp	Sharp to gradational	Usually gradational	Sharp to gradational
PHYSICAL PROPERTIES	Overcompacted	Loosely compacted	Water saturated	Loosely compacted
SEDIMENT TEXTURE	Polymodal; poorly sorted	Polymodal; poorly sorted	Often unimodal or bimodal, with strong very fine sand mode	Usually poorly sorted; sometimes sand mode is present
DOWNCORE TEXTURE	Strongly homogeneous	Homogeneous	Hetergeneous	Heterogeneous
MINERALOGY	Homogeneous	Homogeneous	Hetergeneous	Heterogeneous
PEBBLE FABRIC	None	Elongate pebbles sometimes parallel to bedding	Elongate pebbles parallel to bedding	Elongate pebbles crudely parallel to bedding
PEBBLE SHAPE	Medial roundness and sphericity	Medial roundness and sphericity	Low to medial roundness and sphericity	Low to medial roundness and sphericity
MARINE FOSSILS	Only reworked	Very low diversity	Variable diversities and abundances	Abundant
DISTRIBUTION	Continental shelf	Continental shelf	Continental shelf to abyssal floor	Continental shelf
ORIGIN	Deposition by grounded ice	Deposition beneath ice shelf	Deposition from floating ice in low energy environment	Deposition from floating ice in high energy environment

shelf break, where impinging marine currents are responsible for winnowing. Transitional glacial-marine sediments are derived from the basal debris zone of an ice shelf near the grounding line. This sub-ice shelf deposition has been recognized in the James Ross Island region, where the Larsen Ice Shelf has retreated substantially in the recent past (Smith, 1985). Basal tills reflect deposition from an ice sheet grounded on the seafloor. These sediments have only recently been recognized in Antarctica (Anderson et al, 1980a) and represent a very important source of information on past ice conditions.

Grounded ice entrains debris along its flow path, and deposits the debris downstream as lodgement till or subglacial meltout till. Boulton (1978) recognized that clasts carried in basal debris zones differ in shape from englacially or supraglacially transported clasts. Using the sphericity-roundness values of Krumbein (1941), Boulton defined three fields representing high-level transport, basal transport, and lodgement till. These criteria have been used identify basal till units on the George V continental shelf (Domack et al, 1980) and in the Weddell Sea (Andrews, 1984). The most diagnostic feature of basal till units is lithologic and textural homogeneity, reflecting the limited source area and lack of any sorting mechanism (Anderson et al,1980a). Overcompaction and lack of any stratification distinguish till units from other pebbly muds in the marine environment.

In addition to glacial/glacial-marine sediments, sediment gravity flow deposits are also found on the Antarctic margin (Anderson et al, 1983a). Due to the rugged nature of the inner shelf, slopes of >10° are not uncommon, and sediment gravity flows have been identified in the

George V Basin (Domack, 1982), Ross Sea shelf (Myers, 1982), and the Weddell Sea shelf (Wright and Anderson, 1982).

A number of models describing deposition in the Antarctic marine environment have been proposed (Drewry and Cooper, 1981; Orheim and Elverhøi, 1981; Anderson et al, 1983a). Drewry and Cooper (1981) stress four factors that control sedimentation of IRD: 1) nature of sediments as the ice reaches the grounding line; 2) nature of the transition from grounded to floating ice (ice shelf vs. ice cliff, etc.); 3) processes operating at the ice/water interface (melting vs. freezing); 4) processes governing movement and subsequent fate of icebergs carrying debris. The importance of ice shelves in sedimentation on the continental shelf is stressed by Orheim and Elverhøi (1981), although it is pointed out that the ice shelves have very little effect on ice-free areas. Anderson et al (1983a) constructed a comprehensive model of sedimentation in a polar glacial setting, emphasizing the nature of the ice/water transition, and including the effects of marine currents and the isostatic and bathymetric features of the continental shelf. The difference between polar and temperate glacial settings (e.g., presence/absence of meltwater) has a profound influence on sedimentation, and the northern Antarctic Peninsula has a much more temperate glacial regime than the rest of the continent.

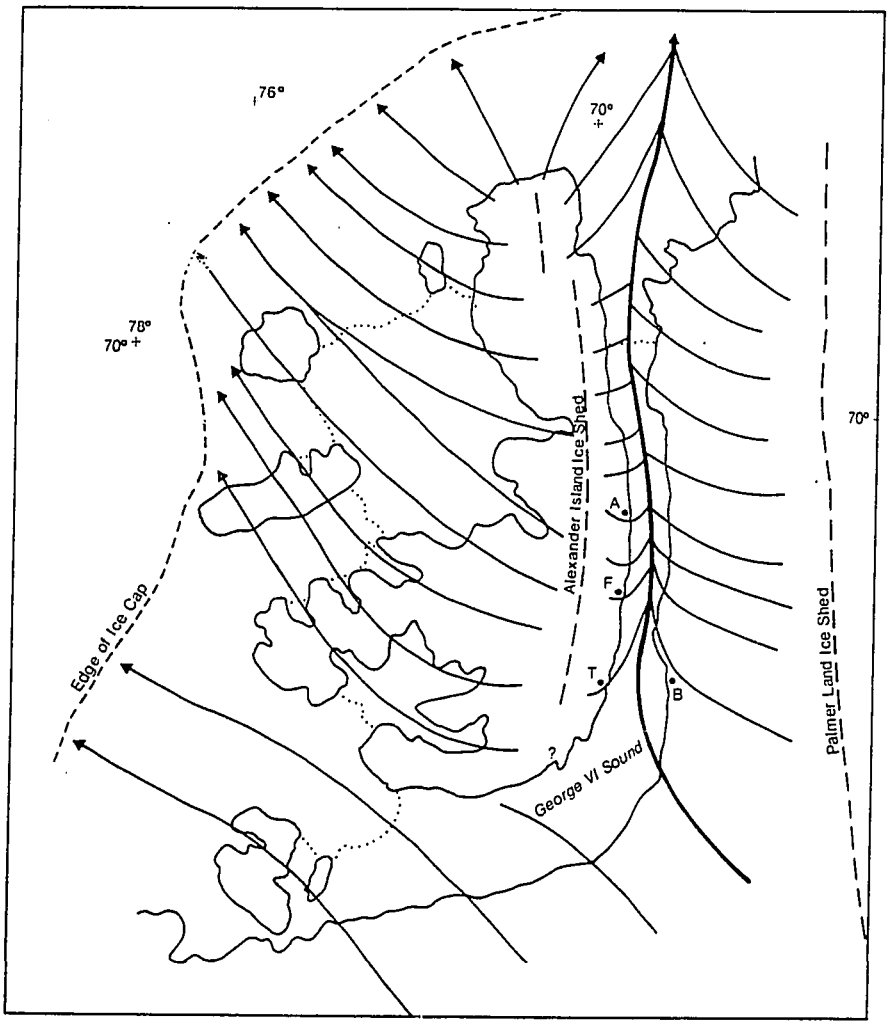
Antarctic Peninsula glacial history

The onset of glaciation in the Antarctic Peninsula is not definitely known, and it has been proposed that the West Antarctic Ice Sheet may have built up to approximately its present size in the last 4-5 Ma

(Mercer, 1973). Early Pliocene tillites have been identified on King George Island (Birkenmajer, 1984), and tillites interbedded with hyaloclastites in the northern mountains of Alexander Island have suggested at least an alpine glacial setting in this region 3-5 Ma ago (Burn and Thomson, 1981). However, Curl (1980) postulated glaciation in the South Shetland Islands no earlier than Illinoian time (400,000 ybp), based on well-preserved raised beaches and platforms. The Wisconsin glaciation has been extensively studied in the area, utilizing both theoretical and geomorphological data. Nichols (1960) estimated mainland ice at >900 meters thick in southern Graham Land during the last glaciation, based on the height of erratics and till, and proposed that ice was grounded offshore many miles westward into Marguerite Bay. A reconstruction of maximum ice conditions in the late Wisconsin by Stuiver et al (1981) showed a single large ice cap blanketing the southern Antarctic Peninsula, with separate ice domes in the north covering the South Shetland Islands and the northern end of the peninsula. However, geomorphological work on Alexander Island by Clapperton and Sugden (1982) has demonstrated that a separate dome existed over Alexander Island, with eastward-draining ice entering George VI Sound and flowing northward alongside ice from Palmer Land. This reconstruction shows the axis of the Alexander Island ice cap along the summits of the LeMay and Douglas ranges in the east-central part of the island, with major drainage to the west into the Bellingshausen Sea and north into Marguerite Bay, as well as to the east (Fig. 2.1). The discovery of shell fragments in a till on Alexander Island indicates that George VI Sound may have been ice-free during a

recent interglacial (Sangamon?) and also ca. 6500 years ago, perhaps reflecting a climate warmer than today (Sugden and Clapperton, 1980).

Figure 2.1: Reconstruction of ice caps and flowlines for George VI Sound, northwestern Palmer Land, and Alexander Island during the late Wisconsin glacial maximum, from Clapperton and Sugden (1982).



from Clapperton and Sugden (1982)

CHAPTER 3 METHODS

The samples used in this study were collected in Marguerite Bay during the Deep Freeze 85 and 86 cruises of the USCGC Glacier. Piston cores, trigger cores, and bottom grab samples were utilized in the study, and pebbles were sampled from a number of box cores (Fig. 1.1). The locations and other core information is contained in Appendix 1. In addition, 240 km of single channel seismic data were obtained using a 4.6 kilojoule sparker system.

All cores were split at the Antarctic Core Facility at Florida State University, and x-radiographed at Rice University to identify sedimentary contacts, laminated intervals, pebble fabrics, and pebbles larger than 1 cm. Cores were sampled at 50 cm intervals (sometimes at smaller intervals), and these samples were described by smear slide with respect to biogenic and organic content and rough gravel/sand/silt/clay classification. A 5 to 10 g sample was dried and weighed for settling tube analysis, and a small (.1 g) sample was placed in deionized water for hydrophotometer analysis. The large sample was washed through a 38 micron sieve to separate gravel, sand, and coarse silt from finer material. The sieved material was dried and passed through a -1 Φ sieve to separate gravel from sand and coarse silt. The latter component (-1 to 4.75 Φ) was analyzed using an

automated settling tube (RUASA). The small sample was analyzed using a hydrophotometer for medium and fine silt size distribution (Jordan et al, 1971). Weight percentages of gravel, sand, silt, and clay were calculated from these analyses.

Pebbles greater than 1 cm in diameter were extracted from the cores and grab samples and examined for lithology using a binocular microscope. Shape analysis was conducted on over 400 pebbles, using techniques outlined by Boulton (1978). Roundness values were determined by the comparison method of Krumbein (1941). Each pebble was measured using a caliper along three orthogonal axes, and sphericity was calculated from these measurements (Krumbein, 1941). The roundness vs. sphericity plots were utilized to ascertain mode of glacial transport (Boulton, 1978).

A number of samples were further analyzed for coarse sand mineralogy. For each sample, at least 300 grains were counted in a cuttings tray using the area method (Galehouse, 1971). These mineralogies were recorded as number percentages, and are tabulated in Appendix 2.

CHAPTER 4 SEISMIC DATA

Over 240 km of seismic data (1 kilojoule and 4.6 kilojoule sparker, single-channel) was collected in Marguerite Bay during Deep Freeze 85 and 86 (Fig. 1.1). The survey was undertaken to determine the existence and nature of structural evidence for tectonic influence on the formation of the deep submarine troughs. Late Cenozoic extensional features are found on land throughout the Marguerite Bay region, and it is possible that these structural features will extend onto the seafloor. Other objectives of the survey were to develop a seismic stratigraphy for the bay, and to investigate sediment distribution patterns in the bay.

Seismic lines

Seismic work was concentrated in the more protected eastern bay (170 km) and in the southwestern quarter (60 km). The survey was reconnaissance in nature, with the main objectives being the deep basins crisscrossing the seafloor, and the steep flanks of these troughs. Two lines (MB-D, MB-G) were acquired in Neny and Bourgeois fjords respectively, to contrast this environment with that of the open bay.

The most striking observation from virtually all lines is the virtual absence of sedimentary cover. A thin drape of sediment covers acoustic basement, which represents crystalline bedrock or older

glacial deposits (Fig. 4.1). The seafloor of the bay is extremely rugged, with steep slopes. The only spatially extensive area of relatively smooth seafloor surveyed was the broad deep basin west of the George VI Trough (line M1, first leg). Flat-lying sediments or ponding are found only in the deep basin and eastern flank of Adelaide Trough (line MB-B)(Fig. 4.2), a small basin in the vicinity of site P103 (350m depth), and in the larger basin east of site P94 (700m depth). The axis of the George VI Trough was crossed at a water depth of 1350m, and showed no pelagic sediment accumulation, and, as in most deep basins of the bay, the flanks are so precipitous that no seismic penetration occurred (Fig. 4.3). Sediment was ponded in the central basin of Bourgeois Fjord (line MB-G; 415m depth); morainal features were not found in either fjord surveyed.

The lack of seismic penetration hampered efforts to delineate structural features in the area. Possible evidence of normal faulting in the acoustic basement is seen in line MB-F in an arm of the expanded George VI Trough, and in the rough bathymetry of line M2. However, because no real sediment accumulation is present to accentuate faulting, these interpretations of normal faults are tentative.

Origin of submarine troughs

The origin of the deep troughs and fjords on the Antarctic continental shelf has been the subject of debate for many years. A number of workers have insisted that glacial processes of marine ice sheets are solely responsible for the formation of these features (Crary, 1966; Grosval'd and Glazoskiy, 1983). Vanney and Johnson

Figure 4.1: Detail of seismic line M1, showing the location of piston core DF85-92 (348m). Each vertical line represents 100 milliseconds. The horizontal scale is approximate. This line demonstrates the rugged bathymetry, steep slopes, and complete lack of seismic penetration that characterizes most of Marguerite Bay. Core 92 is a sandy gravel.

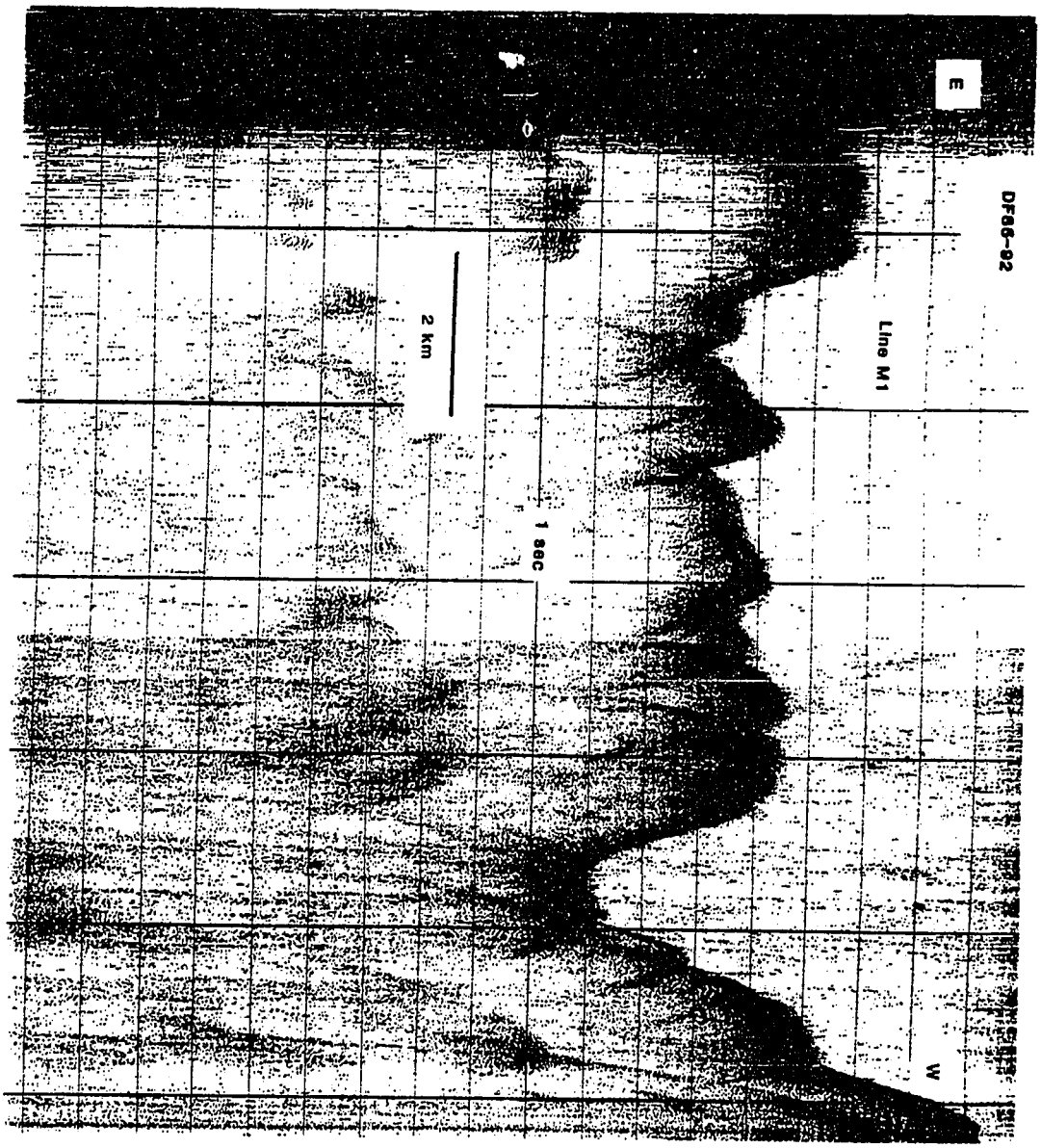

E
DF86-82
Line M1
2 km
1 sec
W

Figure 4.2: Detail of seismic line MB-B, showing the location of piston core DF85-72 (808m). Each vertical line represents 100 milliseconds. The horizontal scale is approximate. This segment crosses Adelaide Trough from southeast to northwest, and shows the very steep and rugged flanks of the trough. Ponded sediment (p) is found only in the deep central basin and on the southeastern flank. Core 72 recovered a thick diatomaceous mud unit atop terrigenous mud and sediment gravity flow deposits.

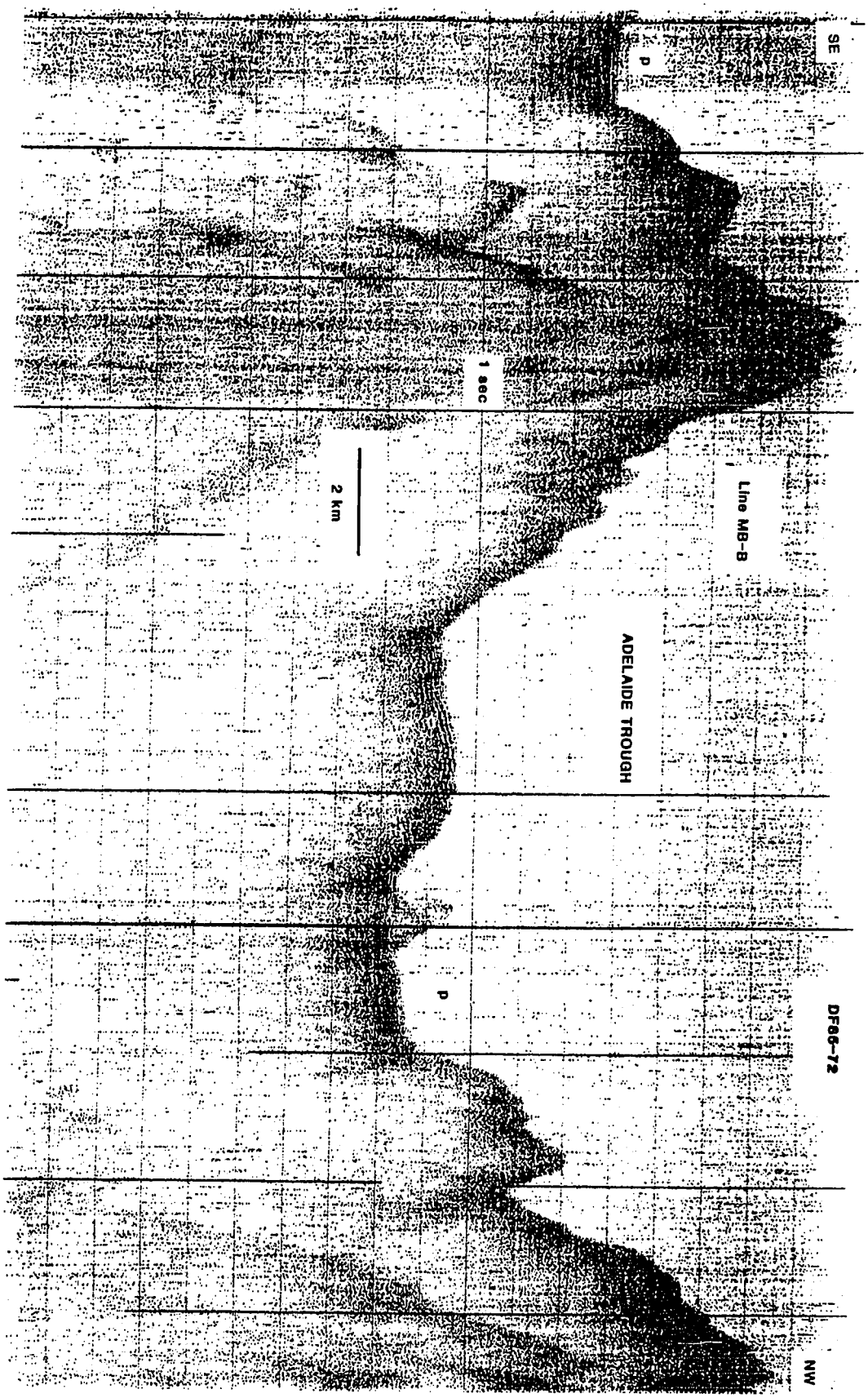
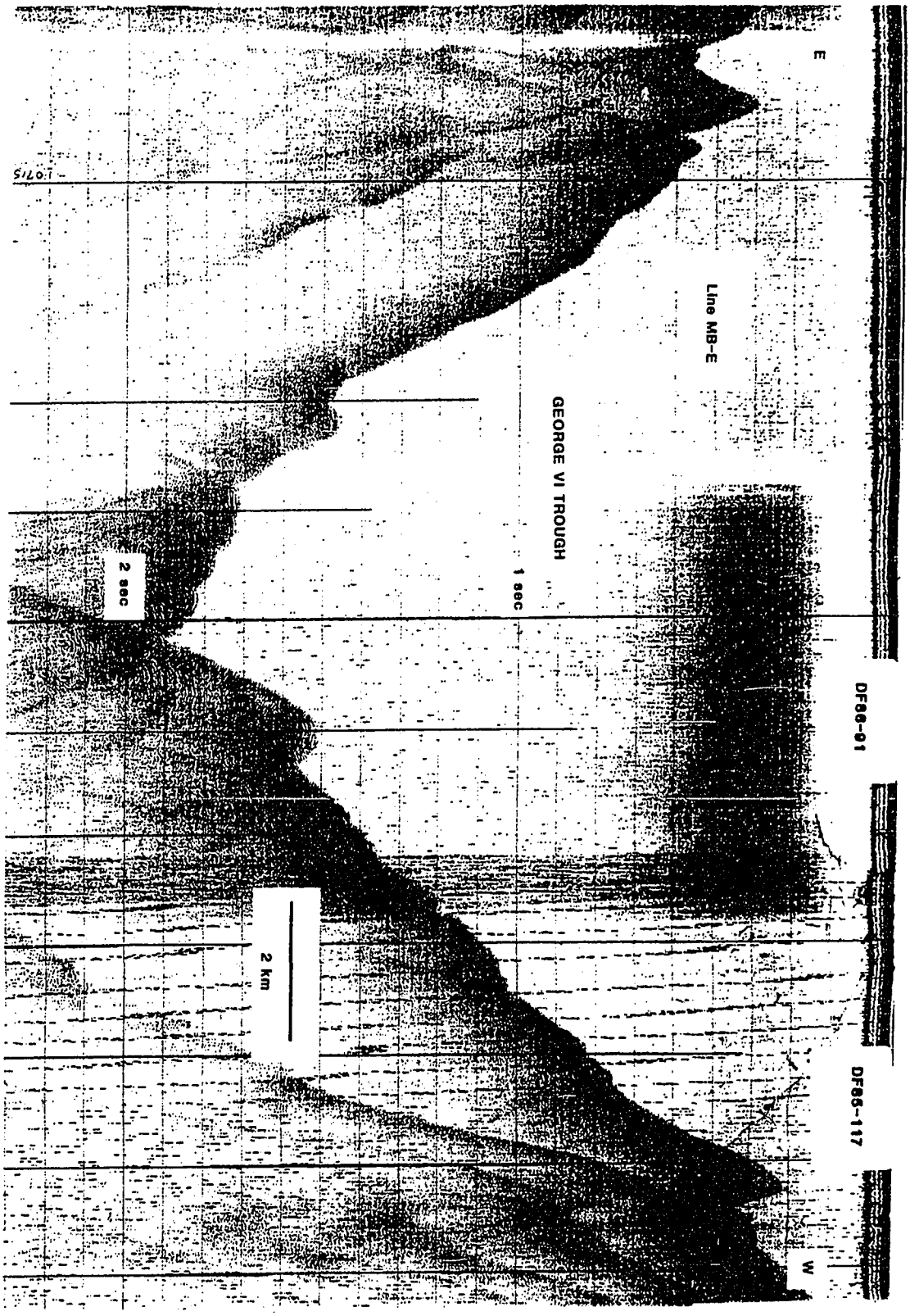

SE
P
1 sec
2 km
Line MB-B
ADELAIDE TROUGH
P
DF66-72
NW

Figure 4.3: Seismic line MB-E, showing the location of piston cores DF85-117 (503m) and DF86-91 (1079m). Each vertical line represents 100 milliseconds. The horizontal scale is approximate. This line crosses George VI Trough from east to west, showing flanks steeper than 9°. Slumps appear to be found at the base of the steeper (10.5°) eastern slope. No evidence of pelagic sedimentation is seen in this line. Core 117 recovered terrigenous mud overlying terrigenous muddy gravel. Core P91 penetrated a terrigenous mud unit with little IRD or biogenic material.


E
W
Line MB-E
GEORGE VI TROUGH
DF86-91
DF86-117
1 sec
2 sec
2 km

(1976) proposed that the troughs were primarily glacial in origin, but with geographical limits determined by fault control. The deep troughs and fjords of Marguerite Bay have not previously been ascribed to glacial and/or tectonic origin.

The George VI Trough is an obvious northward continuation of George VI Sound, which has been interpreted as a rift (Crabtree et al, 1985). However, to the north of an east-west line at roughly 68°20'S, the feature shallows and greatly expands, and the exact nature of its formation is no longer clear (Fig. 1.3). The tentatively identified normal faults in this area indicate that this northern continuation is most likely also structurally formed. The broad basin west of the George VI Trough is oriented roughly north-south, but no solid evidence of faulting exists in the seismic data.

Adelaide Trough trends subparallel to late Cenozoic normal faults on Adelaide Island (Fig. 1.7)(Dewar, 1970). The trough also lies in the proposed path of ice flowing west and south from Graham Land during glacial maxima (Fig. 7.1), which will be discussed later. Neny Fjord has been suggested as a possible faulted basin that connects to a glacial trough stretching across the peninsula (Wyeth, 1977). The limited bathymetric and seismic data prohibit characterization of other smaller basins in the bay, although their orientations appear random with respect to structural elements found on the continent.

The accumulation of available information leads to the conclusion that the larger troughs in Marguerite Bay are structural features (their relationship to known structures on land) subsequently modified by glacial erosion (the notable lack of sediment in the basins and the occurence of basal till deposits at great water depth in the

southwestern quarter). During glacial maxima, glacial ice would flow down a pre-existing structural valley, deepening and widening the trough and stripping away any sediment cover. Both the George VI and Adelaide troughs are natural and obvious channels for drainage, and have probably undergone a large amount of glacial erosion. It is unknown whether the >1350m depth of the central basin of the George VI Trough is fault controlled or an example of overdeepening. The broad basin to the west was filled with grounded during the late Wisconsin (as evidenced by the basal till units, discussed later), and this may account for the smoother, rounded character of the basin. Neny Fjord and a number of smaller basins in the eastern bay also show signs of overdeepening. It is possible that these smaller features, without obvious structural orientation, have a strictly glacial origin.

There is an absence of moraines and other sediment accumulations in the bay, which would represent the sediment and bedrock excavated by flowing grounded ice from the troughs. This implies that the troughs were formed during earlier grounding events and later glacial ice expansion removed the detritus and further deepened the existing troughs. It is possible that grounded ice reached the continental shelf edge during past glacial maxima, including the late Wisconsin, and the products of earlier erosion would be remobilized and deposited over the shelf break.

CHAPTER 5 SURFACE SEDIMENTS

Sediments

For the sake of clarity, Marguerite Bay has been divided into four quarters (Fig. 5.1) and these divisions will be used throughout the study.

Bottom grab samples and piston core tops were analyzed in this study to characterize present sedimentary envirommment. Piston cores were sampled within 5 cm of the core top, and 5 to 10 g samples were taken from Shipek and Dietz-LaFonde bottom grabs. Comparison of x-radiographs of piston, trigger, and box core tops indicates that sampling of the top 5 cm of piston cores is a reasonable reflection of the surface sediment. These samples were utilized for textural analysis, and gravel/sand/silt/clay ratios were calculated from the analysis.

Three sediment types were found in the surface sediments of the study area: 1) siliceous (mainly diatomaceous) muds/oozes; 2) terrigenous muds; and 3) muddy sands and gravels (Fig. 5.2). By far the most widespread sediment types in the area are siliceous muds and oozes, especially in the northeastern and southeastern quarters of the bay. These sediments consist chiefly of diatom frustules and silt-sized quartz and feldspar, and typically have less than 10% sand. Organic carbon content is high, generally >1% (Dunbar, pers. comm.).

Figure 5.1: Division of Marguerite Bay into quarters (NE= northeastern, SE=southeastern, NW=northwestern, SW=southwestern).

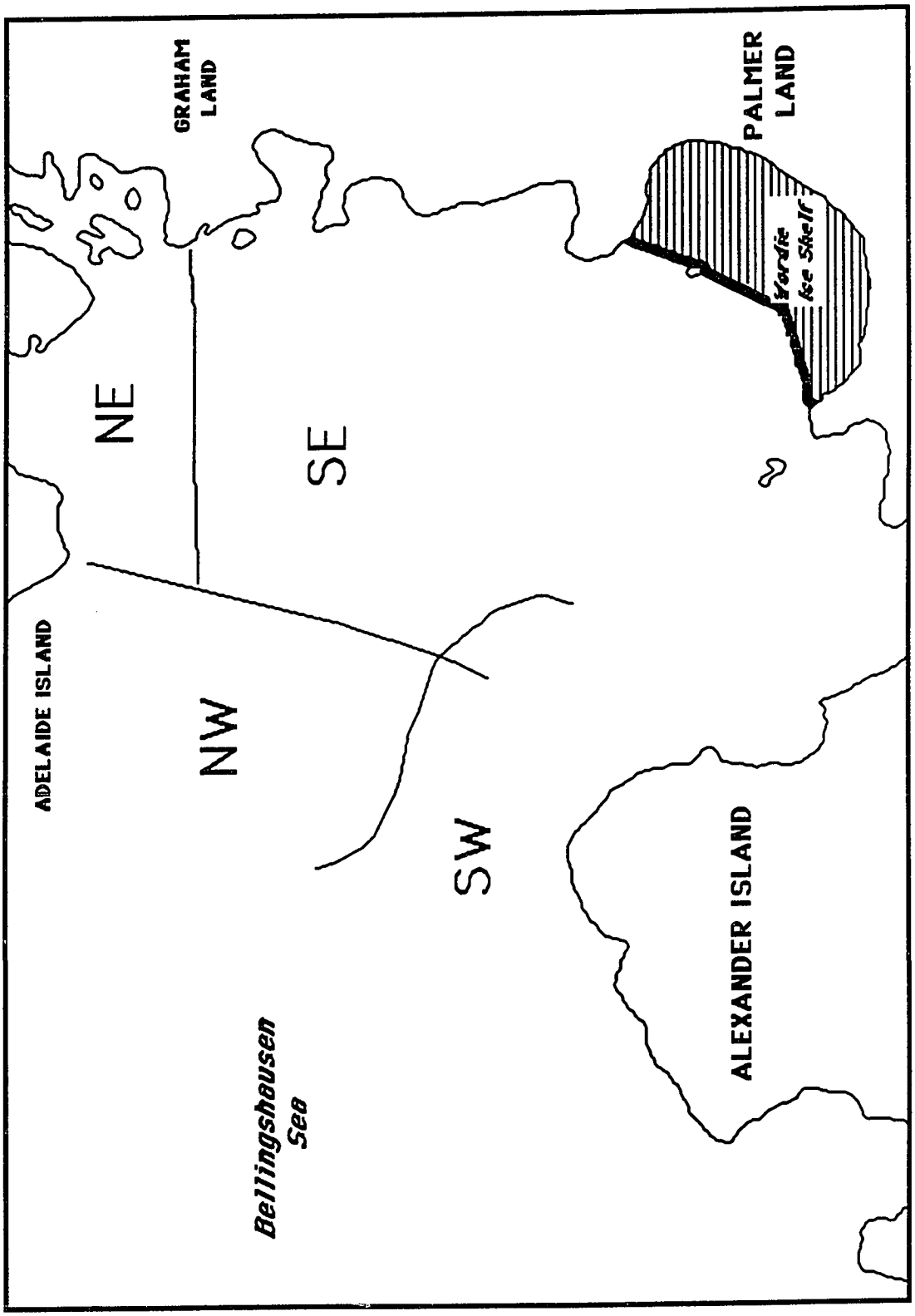
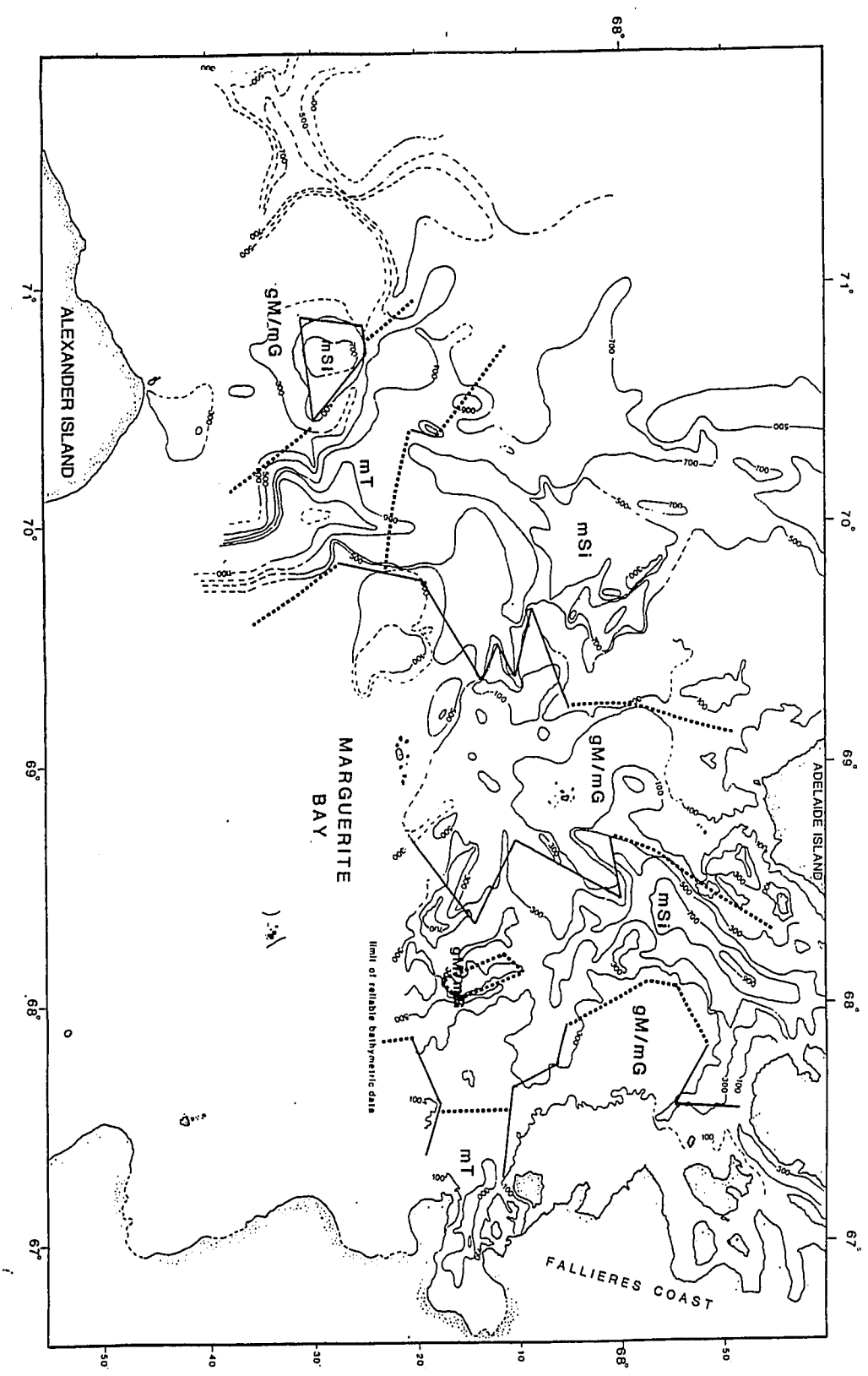

GRAHAM LAND
PALMER LAND
NE
SE
NW
SW
ADELAIDE ISLAND
Bellingshausen Sea
ALEXANDER ISLAND
Wordie Ice Shelf

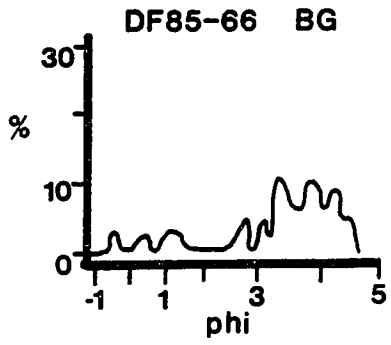
Figure 5.2: Distribution of surface sediments in Marguerite Bay. Three sediment types were found: siliceous mud (mSi), terrigenous mud (mT), and gravelly mud/muddy gravel (gM/mG). Siliceous mud is found in most areas of the bay at depths greater than 300m. Terrigenous mud is found only at the mouth of Neny Fjord and in the deep George VI Trough in the southwest part of the bay. Muddy gravels and gravelly muds are found predominantly in areas shallower than 300m depth.

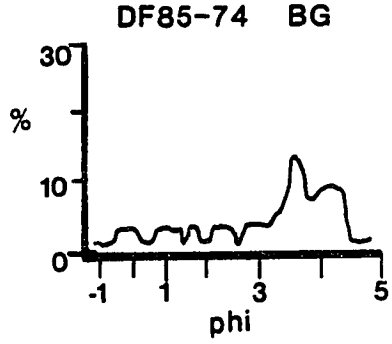

ALEXANDER ISLAND
MARGUERITE BAY
ADELAIDE ISLAND
FALLIERES COAST
gM/mG
mSi
mT
limit of reliable bathymetric data
68°
71°
70°
69°
68°
67°

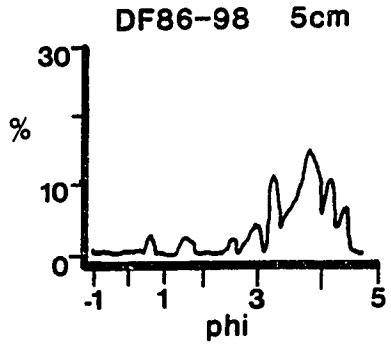
Sand content is generally related to depth, with deeper sites having lower percentages of sand. The sand component of these muds is most often a fairly well-sorted fine sand with a broad frequency mode centered about 3.50-4.00 Φ; usually less than one-quarter of the sand fraction is larger than 3.00 Φ (Fig. 5.3). Microscopic inspection reveals that the fine sand fraction consists almost entirely of quartz and feldspar grains, with very little biogenic material. The only siliceous muds that do not exhibit this mode are from cores 116 and 128. As icebergs deliver unsorted material to the marine environment, this mode reflects an additional sedimentation mechanism, possibly marine current and/or aeolian activity. The low sand contents also indicate that IRD is a very minor constituent in modern sediments. Siliceous muds/oozes are found in most of the eastern half of the bay at depths > 275-300 m, and at depths >350 m in the southwestern quarter.

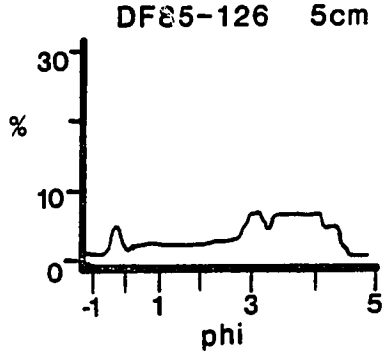
Terrigenous muds are found chiefly in the southwestern quarter, and at a few sites in the southeastern quarter (81,82). The sediments contain less than 10% opaline microfossils, and consist mainly of silt-sized quartz and feldspar. Sand content ranges from 3 to 30%, and the sand fractions of most surface samples (cores 118 and 122 excepted) exhibit a 3.50-4.00 Φ frequency mode similar to the siliceous muds/oozes (Fig. 5.4). Core 81 was recovered within Neny Fjord, which may be the locus of sediment-laden meltwater plumes produced from surrounding valley and outlet glaciers; this could account for the increased terrigenous component in the surface sample at this site.

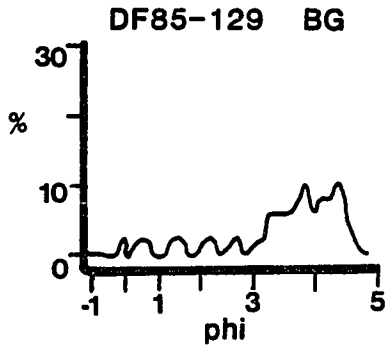
Figure 5.3: Size (-1.00 to 4.75 Φ) vs. frequency plots, surface samples in Marguerite Bay. Samples throughout the bay show a similar very fine sand to coarse silt mode at 3.50-4.75 Φ, with less than 25% of the sand fraction larger than 3.00 Φ. Terrigenous muds (81) also show this sand mode. BG= Dietz-LaFonde grab.


DF85-66 BG
30
%
10
0
-1
1
3
5
phi


DF85-74 BG
30
%
10
0
-1
1
3
5
phi


DF86-98 5cm
30
%
10
0
-1
1
3
5
phi


DF85-126 5cm
30
%
10
0
-1
1
3
5
phi


DF85-129 BG
30
%
10
0
-1
1
3
5
phi

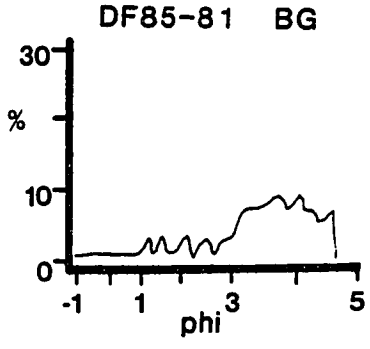
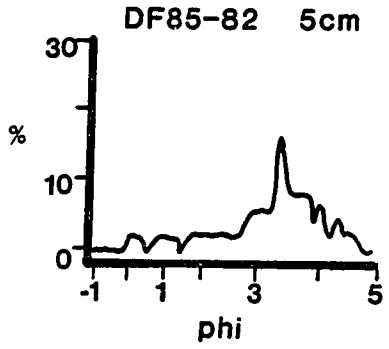
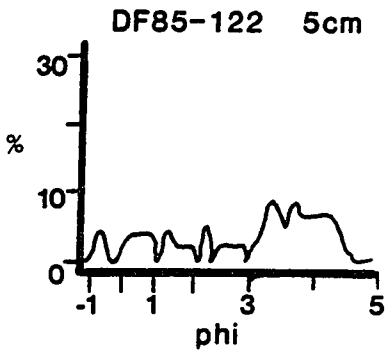
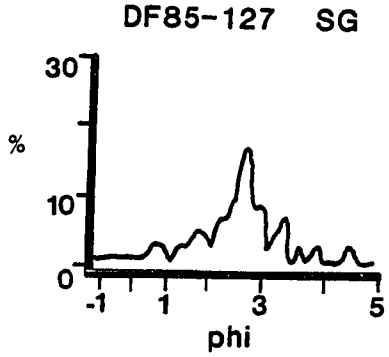
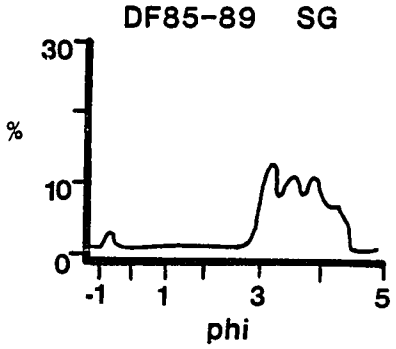

DF85-81 BG
30
%
10
0
-1
1
3
5
phi

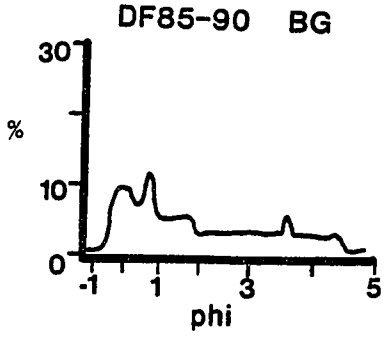
Figure 5.4: Size (-1.00 to 4.75 Φ) vs. frequency plots for surface samples in Marguerite Bay. Sample 122 exhibits an unsorted sand fraction, which is rare in surface samples from the bay. Samples 127 and 89 show evidence of current activity; both sites lie at water depths shallower than 250m. Samples 90 and P117 have curves reflecting water-column winnowing of fine material. BG= Dietz-LaFonde grab; SG= Shipek grab; PC= bagged piston core.

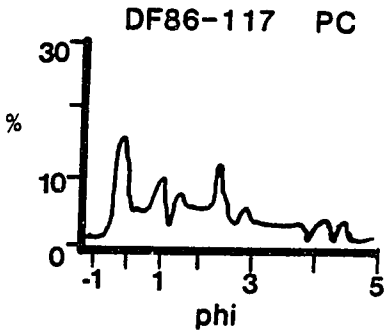

DF85-82 5cm
30
%
10
0
-1
1
3
5
phi


DF85-122 5cm
30
%
10
0
-1
1
3
5
phi


DF85-127 SG
30
%
10
0
-1
1
3
5
phi


DF85-89 SG
30
%
10
0
-1
1
3
5
phi


DF85-90 BG
30
%
10
0
-1
1
3
5
phi


DF86-117 PC
30
%
10
0
-1
1
3
5
phi

Likewise, core 82 may be influenced by a sediment-laden bottom layer flowing west out of the fjord, thereby increasing the terrigenous component with respect to opaline material. Cores 118 and 122 have sand components lacking the fine sand frequency mode, implying either lack of current energy at these sites or significantly greater IRD input.

Muddy sands and gravels are found at the surface exclusively on shallow banks and in nearshore areas. In the eastern half of the bay these sediments are found at depths shallower than 320 m, and in the western half at depths shallower than 350 m. Most of the surface samples are unsorted or very poorly sorted, with sand and/or gravel predominating over diatomaceous and terrigenous mud. A number of interesting textural features of these bank sediments have been uncovered. Sample 127, taken at 249 m from the western margin of a small bank, is 92% sand and coarse silt, and exhibits a pronounced frequency mode at 3.00 Φ, implying marine current activity. Sample 89, recovered from the northern edge of the Kirkwood Bank at 201 m, also shows a pronounced sand mode at 3.50 Φ (Fig. 5.4). Presumably, these sites are receiving sediment via a marine current, and the volume of this material is great enough to mask the IRD textural signature. Sites 90, 92, and P117 have poorly sorted gravelly sands that contain sparse material finer than 3.50 Φ (Fig. 5.4). These sites appear to be affected by currents in the water column that prohibit the settling and deposition of particles of very fine sand or smaller material.

Core 77, recovered in a very rugged area at 316 m, may represent a sediment gravity flow. An x-radiograph of the core shows crude grading in the top 15 cm of the core. Similarly, piston core P101 also

shows crude grading in the uppermost 60 cm, as does the trigger core from the same site (20 cm).

Discussion

The preponderance of siliceous muds/oozes in the surface sediments reflects the present open marine environment of Marguerite Bay. The sea is ice-free upwards of five months per year, allowing siliceous phytoplankton to flourish. Presently, IRD input is very low, and is masked by biogenic and current-derived sediments. These compound glacial-marine sediments generally have decreasing sand content with increasing water depth. This trend is compatible with the scenario of currents sweeping the upper 300 meters of the water column and carrying finer material to greater depths. Winnowing in the water column is preferred to bottom scouring for two reasons: winnowing takes considerably less energy, and the bank sands and gravels often have >25% mud content, possibly deposited during a weakened current episode; thereafter sufficient energy to resuspend the fine material is unavailable. For a particle to remain in suspension, shear velocity must exceed settling velocity of a particle (Middleton and Southard, 1977). In terms of current velocity, the mean velocity must be approximately twelve times the settling velocity (Blatt et al, 1980) for suspension to occur. The settling velocity of particles 3.00 Φ and 4.00 Φ size are 1.10 cm/s and 0.32 cm/s, respectively; the corresponding values of shear velocity for suspension are 13.20 cm/s and 3.85 cm/s (Anderson and Kurtz, 1985). Therefore, the current energy reflected by the modes found in the surface sediments of the

bay is in the range of 4-10 cm/s. The 3.50-4.00 Φ mode represents the coarsest material winnowed in the water column by the current, and this is dropped during any wane in current energy.

Proximity to the coast, and thus to a sediment source, also appears to have some control over sand content of the muds/oozes. Cores 64 and 129 have 19 and 10% sand respectively, and each lies within 5 km of land. Both cores exhibit a fine sand mode and have comparatively low sand mean grain size. Currents winnowing material from nearshore areas, where most IRD is probably being released, may be responsible for the higher sand contents. Site 129 is also within 5 km of the sole meltwater plume sighted in Marguerite Bay during Deep Freeze 86, off the southwestern coast of Pourquoi-Pas Island. It is reasonable to expect that subglacial and possibly subaerial meltwater processes are active in other parts of the bay but were not detected, although the development of a considerable number of meltwater plumes is not expected. The formation of higher density bottom currents is possible due to the presence of suspended sediment in the meltwater; however the very rugged bathymetry of the bay would limit the effectiveness of these currents to exert more than local influence. In addition, the relatively small size of the valley glaciers of Adelaide and Pourquoi-Pas islands would signal low volume meltwater production in this polar glacial environment. Sites 64 and 129 may reflect an increase in sediment supply due to influence of sediment-laden bottom layers much like site 81, but these layers are probably weak and short-lived and therefore do not exert influence at any appreciable distance from shore.

The terrigenous muds found in the southwestern quarter are also compound glacial-marine sediments. A number of factors may account for the low opal content at these sites. This area lies closest to the permanent pack ice line, and a recent retreat of this sea ice will be postulated elsewhere in this study. During climatically severe years, the southwestern quarter becomes free of sea ice very late in the summer, and will be covered with ice long before northern parts of the bay become iced over. The result may be reduced phytoplankton production, a lower sedimentation rate, and consequent increase in importance of terrigenous influx by currents and ice-rafting. Core 117, lying on the western flank of the George VI Trough, has 16% sand, and has a pronounced frequency mode centered arround 3.75 Φ. Greater input of terrigenous material from the George VI Sound, carried by the western jet moving north from the George VI Ice Shelf, may be the source for the higher sand contents at Site 117 and other sites in the southwestern quarter. The horizontal extent of the western jet has not been determined (Potter and Paren, 1985). Conversely, sites 118 and 122 show no fine sand mode, implying either lower current-derived sediment input or higher levels of IRD input. A similar pattern is found in the siliceous muds recovered at sites 116 and 128, and sites 125 and 126 show only weak fine sand modes. Glacial sedimentation should be more important nearshore, with IRD decreasing with increasing distance from the coast. Thus, the eastern part of the bay should show more evidence of IRD input than the outer, open marine western bay, although in fact the opposite is true. This leads to the conclusion that lower biogenic production, and possibly lower input of material from

marine currents, is responsible for the higher terrigenous and coarse sand content of the surface sediments in the western half of the bay.

The sands and gravels that cover the shallow banks and nearshore areas of the bay are residual glacial-marine sediments. Currents winnow fine material in the water column to a depth of 300-350 m, thus sites that lie above this depth will consist primarily of coarser IRD that cannot be eroded by current energy. Mud is deposited in these shallow areas only during periods of waning current flow. The lack of fine material in bank sediments reflects the velocity of the current winnowing the water column. Site 90 shows very little sediment finer than 2.00 Φ; site 92 has little finer than 2.50 Φ, and P117 has little finer than 3.50 Φ. This finer sediment is being deposited at greater depths by currents, and is responsible for the fine sand frequency mode found in muds throughout the bay. The well-sorted sands at sites 89 and 127 suggest currents of roughly the same velocity as found in the sand component of the compound glacial-marine sediments (4-10 cm/s). The source of the coarse sand and gravel at these sites is ice-rafting; given the very minor amount of IRD presently entering the marine environment of the bay, the sedimentation rate for the residual glacial-marine deposits must be very low, much lower than the compound glacial-marine sediments.

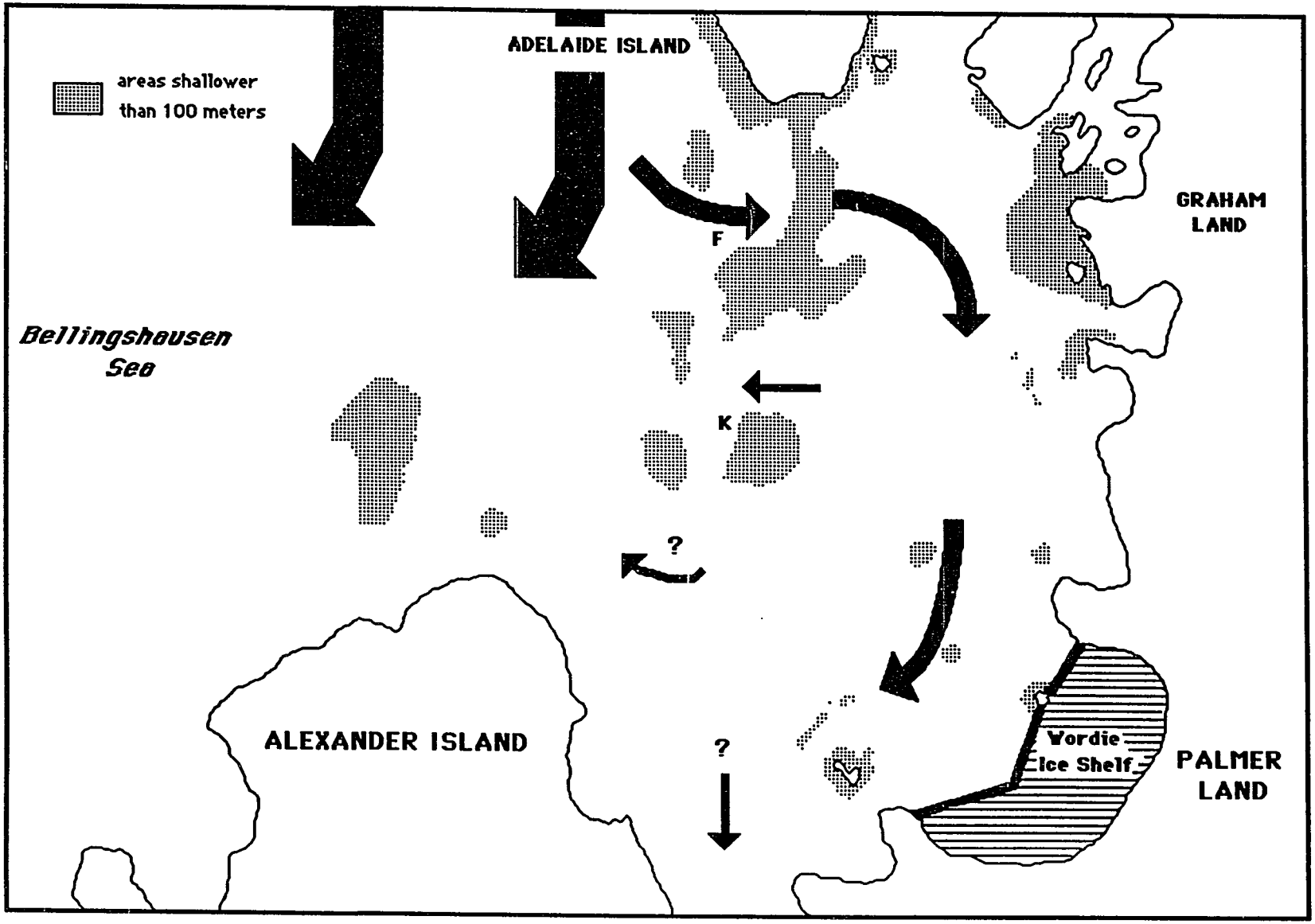
From the above discussion, two possible sources of current energy are proposed. One source may be the high winds of the region, which would generate periodical ephemeral wind-driven currents of variable energy in the bay. An alternative source is a spur of the East Wind Drift shelf current that enters the bay and is responsible for water

column winnowing in the upper 300 meters. Some evidence exists for each mechanism.

The main argument for periodical winnowing by storm-generated wind currents is the high mud content of many of the residual glacial-marine deposits. A number of shallow bank sites exhibit mud contents of greater than 30%, with site 89 (201m water depth) having 55% mud. Samples taken at similar depths in the Ross Sea (Myers, 1983; Anderson et al, 1984) and in the northwest Weddell Sea (Smith, 1985) show much lower mud contents (10-15%), indicating a more persistent current energy. These areas are subject to strong marine currents, which are less variable over time than wind-derived currents. As has been noted before, Marguerite Bay lies directly in the path of eastward moving storms from the Bellingshausen Sea, and also is subject to strong katabatic winds blowing westward off the Graham Land plateau (Schwerdtfeger and Amaturo, 1979). Periodical storms, for their duration, may winnow the water column of material finer than 3.00 Φ, but as conditions calm, fine material will resume its slow descent. Once deposited, this mud cannot be eroded by subsequent storms, which lack sufficient energy for resuspension.

A spur of the East Wind Drift entering Marguerite Bay may be responsible for the remarkable similarity in the sand mode found in the majority of the siliceous muds. A possible flow path for currents in the area has been developed (Fig. 5.5), with a spur of the main southwesterly-moving water mass breaking away and moving east into the bay, assisted by the Coriolis effect. This spur passes between Adelaide Island and Faure Bank and flows clockwise along the Fallières

Figure 5.5: Proposed flow path of East Wind Drift and subsidiary spur into Marguerite Bay. The spur breaks off the main current south of Adelaide Island under the influence of the Coriolis effect, and moves southward along the Graham Land coast into the southern parts of the bay. Minor flow may continue south at very low velocity into the George VI Sound, or west to rejoin the main current in the Bellingshausen Sea. Sediments reflect slightly higher current energy along the flanks of Faure (F) and Kirkwood (K) banks. Large arrows represent main body of the current; intermediate arrows represent main flow of spur; small arrows represent minor or possible flow directions.


areas shallower
than 100 meters
ADELAIDE ISLAND
GRAHAM
LAND
F
Bellingshausen
Sea
K
?
ALEXANDER ISLAND
?
Wordie
Ice Shelf
PALMER
LAND

Coast and into the southern half of the bay, where it becomes sufficiently weakened that it no longer is detectable. It has been noted earlier that a clockwise gyre in Marguerite Bay would not have been detected during previous oceanographic work (Lennon et al, 1980). Flow back to the west through bathymetric gaps may also be possible. The main body of the East Wind Drift would continue to the southwest, across the western part of the bay and the outer continental shelf.

The eastern spur would exhibit weaker flow velocities than the main current, and would become further weakened during its clockwise path through the eastern bay. This is reflected in the shallower depth at which residual glacial-marine deposits are found in the eastern bay as compared to the western bay. A lowering of velocity is expected at the edges of the current, in protected areas close to the coast and near banks.

Potter and Paren (1985) estimated that southward advective flow of Circumpolar Deep Water under the George VI Ice Shelf at <1 cm/sec would be sufficient to account for both ice shelf bottom melting and the western margin jet current. The eastern spur may be responsible for some southward-directed flow in the top 250 m, but it is doubtful that any significant current velocities exist in the southern reaches of the bay. The introduction of Circumpolar Deep Water into the south accelerates the basal melt rate of icebergs calving off the ice shelves (which are not free drifting, but remain trapped in the permanent pack ice for years), further limiting IRD available for deposition in the open-water parts of the bay to the north.

Although the possibility of influence from the East Wind Drift exists, it is proposed that the principal winnowing agents in the bay

are ephemeral wind-derived currents. The term ephemeral refers to storm-related events, as opposed to a persistent wind influence. The high mud content poses important problems to the marine current model, indicating periods of waning energy that are more easily explained by wind-derived currents. It is probable that there is a depth control on winnowing within the affected upper 300m, but the data in this study is too limited to determine a trend. Based on the surface sample analysis, Marguerite Bay appears to be a much more quiescent environment than that of other areas studied in the Ross and Weddell seas, particularly open marine areas. This lower energy setting is most likely due to the protected nature of the bay, sheltered from impinging marine influences by a broad continental shelf, and bounded on three sides by high land masses.

CHAPTER 6 STRATIGRAPHY

The piston cores recovered from Marguerite Bay show considerable variation downcore, giving a glimpse at a past environment very different from that of the present. The discussion of the stratigraphy of these cores will address the general, compositional, and textural characteristics of the sediment, and the implications of the changes from one sediment type to another. Three geographic areas will be separately treated: northeastern/southeastern quarters, northwestern quarter, and southwestern quarter. Stratigraphic trends from these areas will then be combined to delineate bay-wide correlations. Textural data of cores referred to in this chapter and others is found in Appendix 3. More detailed lithologic logs of the piston cores used in the study can be found in Appendix 4.

Northeastern/southeastern quarters

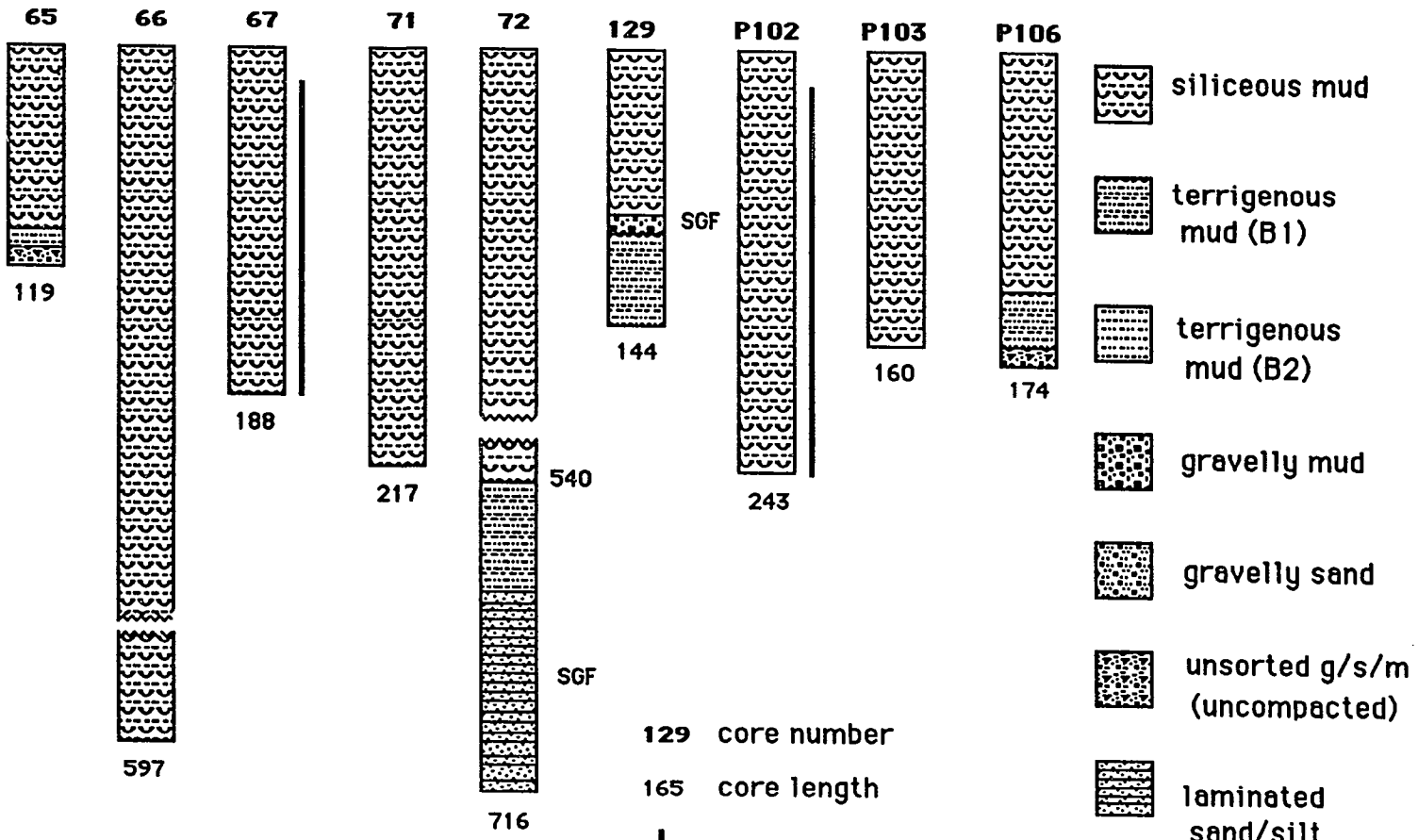
Seismic data in this part of the bay (the "eastern" bay) shows a very rugged seafloor, with extremely shallow penetration in most areas . A thin veneer of sediments covers acoustic basement, which may be earlier glacial deposits or bedrock. Sediment ponding is rare, found only below 500m, chiefly in the Adelaide Trough where ponding occurs in the deep central basin and along the eastern flank.

All cores recovered at depths greater than 350m are capped by a

unit of siliceous mud/ooze, of varying thickness around the eastern bay (Figs. 6.1, 6.2). The thickness of this unit is strongly related to water depth, with thicker intervals at greater depths. The muds are moderate olive brown or light olive gray, and are composed predominantly of diatom frustules, sponge spicules, and silt-sized quartz and feldspar; pebbles are very rare. Organic matter is well-preserved, often in the form of stringers or sheets of organic material, and also as decomposing chloroplasts within whole diatoms. Although the muds are most often massive, thin intervals of laminations are found in most cores, usually corresponding to intervals of high organic content. Preservation of biogenic carbonate is rare, but the siliceous mud unit in core 72 contains a number of complete scaphopod tests and other shell fragments. Cores 66, 79, 87, and P116 also contain scaphopod fragments at depth in the siliceous mud/ooze unit. Sand content is less than 10%, and much lower in most deep cores. The sand fraction of these siliceous mud/oozes shows the same 3.50 Φ frequency mode found in surface samples in the bay. This mode is found throughout the 600 cm of core 66, indicating that at this site, in the deepest part of the Adelaide Trough, the same sedimentation factors have been constant for a substantial length of time. The lower contacts of the siliceous muds generally are gradational, although a small number show sharp contacts (76, 84).

Terrigenous muds lie below the siliceous mud units in most cores of the eastern bay. Thicknesses of terrigenous mud units vary from 10 to 175 cm, but generally are less than that of the overlying siliceous mud. These muds are grayish olive to olive gray, consisting mainly of

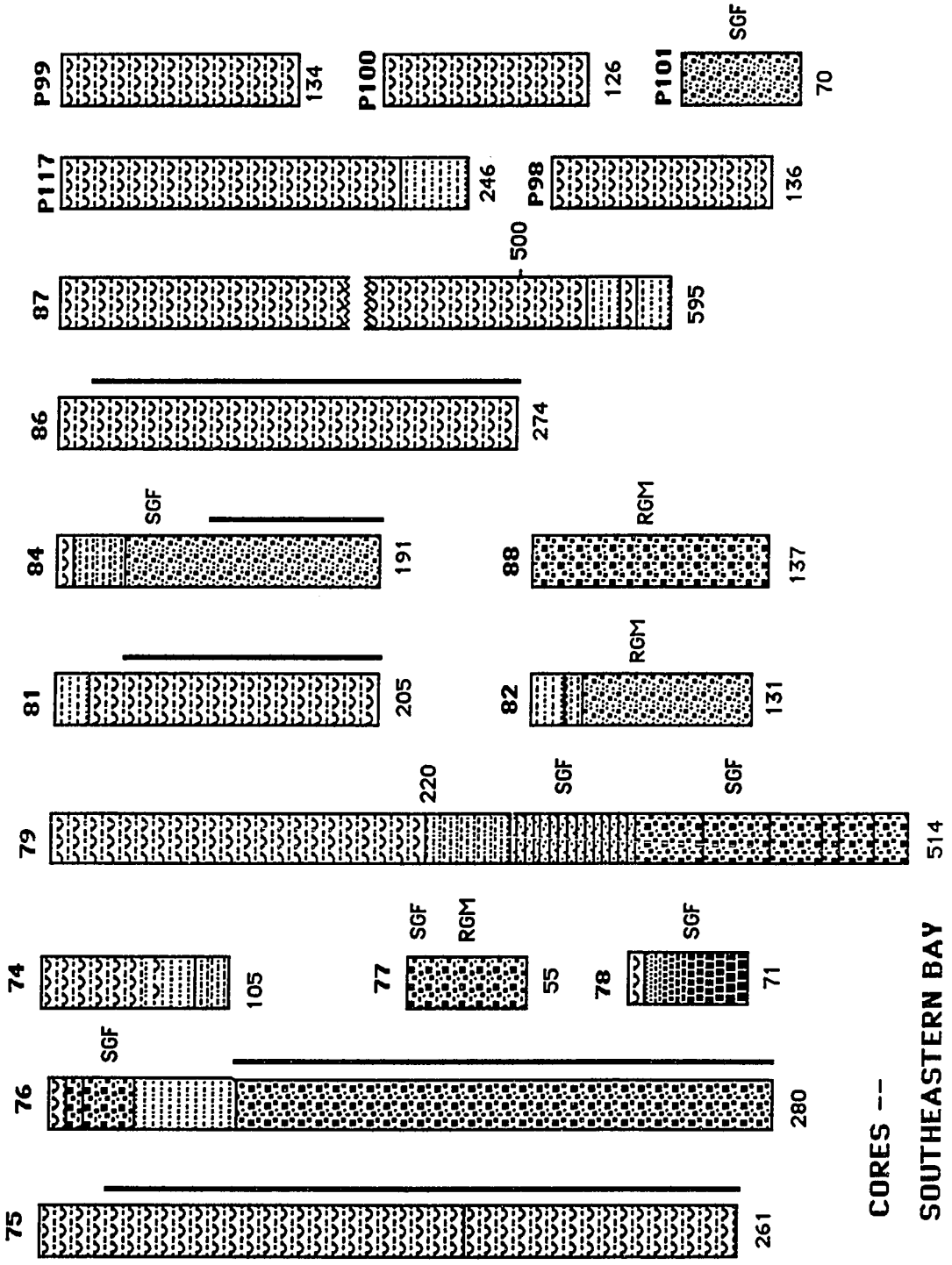
Figure 6.1: Lithologic logs of cores recovered from the northeastern quarter of Marguerite Bay. For core locations, see Figure 1. For more detailed core descriptions, see Appendix 4.



CORES --

NORTHEASTERN BAY

Figure 6.2: Lithologic logs of cores recovered from the southeastern quarter of Marguerite Bay. Symbols and abbreviations the same as those found on Figure 6.1. For core locations, see Figure 1.1. For more detailed core descriptions, see Appendix 4.

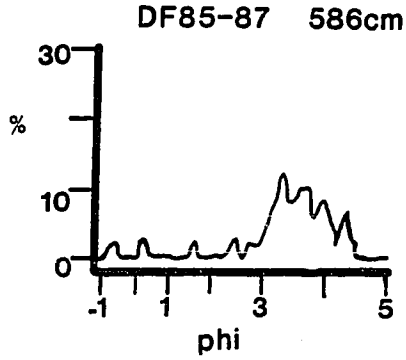

P99
134
P100
126
P101
SGF
70
P117
246
P98
136
500
87
595
86
274
84
SGF
191
88
RGM
137
81
205
82
RGM
131
220
SGF
SGF
79
514
74
SGF
105
77
SGF
RGM
55
78
SGF
71
76
SGF
280
75
261
CORES --
SOUTHEASTERN BAY

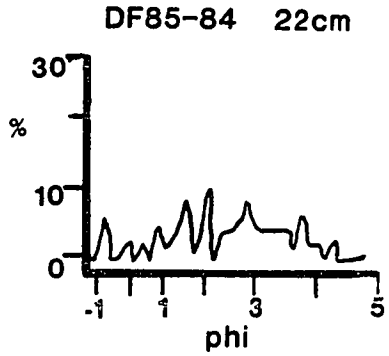
silt-sized quartz and feldspar grains, with rare siliceous biogenic material, and no preserved organic matter. Although often containing a higher sand content than the overlying siliceous muds, pebbles are rare.

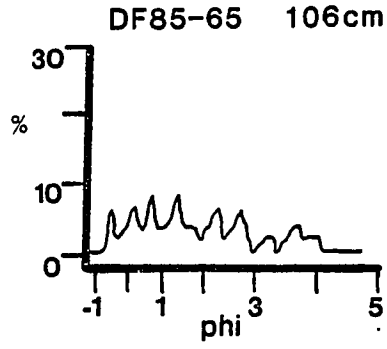
Two types of terrigenous mud are found in the eastern bay: a sandy/silty mud with unsorted sand fraction and higher sand content (B1), and a silty mud exhibiting the 3.50 Φ frequency mode, and having lower sand content, with very rare biogenic material (B2)(Fig. 6.3). B2 mud is found underlying siliceous mud only in core 87 at c. 550 cm, where it interfingers with siliceous mud. Core 82 has a 30cm terrigenous mud unit at the surface, which grades from B2 to B1. Both B2 and B1 muds are generally massive, but laminations are present in cores 72, 76, and 79. Cores 72 and 79 have laminated intervals of about 100cm, showing thin (1-5cm) normally graded silty to sandy mud layers. The laminae in core 76 are much finer, with alternating mud and silty mud layers, and with no sign of internal grading within individual layers. In all cases the upper contacts of these laminated intervals appear gradational. Where present, the lower contacts of the terrigenous mud units are sharp.

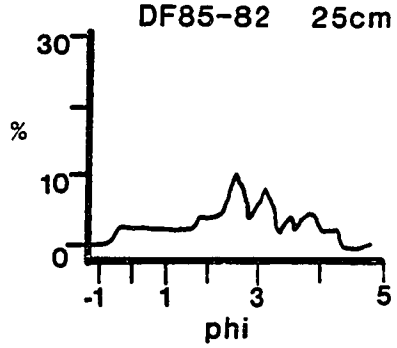
The next lowest stratigraphic unit consists of terrigenous gravelly mud or muddy gravel. Three types of terrigenous gravelly muds/muddy gravels are found in the eastern bay. The first is found in cores 65 and P106, and consists of medium gray sandy gravelly mud, which is very poorly sorted and lacks microfossils or organic matter. These sediments are differentiated from the B1 sandy muds lying directly above them by a sharp contact dividing the units, a much higher gravel content, and a distinctive gray color. A second type of muddy gravel

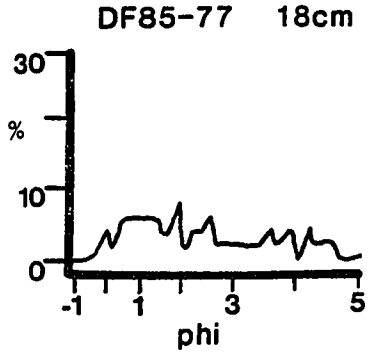
Figure 6.3: Size (-1.00 to 4.75 Φ) vs. frequency plots, downcore samples in eastern Marguerite Bay. The terrigenous mud (B2) in sample 87 (586cm) shows a similar very fine sand mode to that found in the siliceous mud units, whereas samples 84 (22cm), 65 (106cm), and 82 (25cm) are B1 muds, with unsorted sand fractions. Samples from core 77 show a marked decrease of material finer than 3.00 Φ.

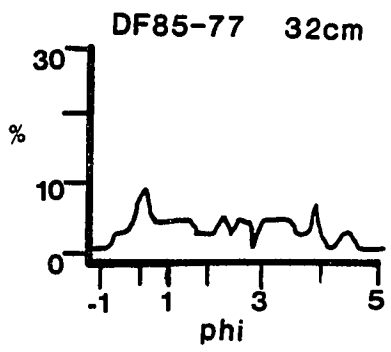

DF85-87 586cm
30
%
10
0
-1
1
3
5
phi


DF85-84 22cm
30
%
10
0
-1
1
3
5
phi


DF85-65 106cm
30
%
10
0
-1
1
3
5
phi


DF85-82 25cm
30
%
10
0
-1
1
3
5
phi


DF85-77 18cm
30
%
10
0
-1
1
3
5
phi


DF85-77 32cm
30
%
10
0
-1
1
3
5
phi

has very little fine material, consisting primarily of poorly sorted sand and gravel, with minor amounts of siliceous or terrigenous mud. These sediments are found in cores 77, 82, and 88, all at water depths of <325m. The sand fraction of core 77 shows a marked frequency decrease of material finer than 3.00 Φ, indicating at least periodic winnowing (Fig. 6.3). Crudely to perfectly graded units with sharp internal contacts make up a third type of gravelly muds. Core 78 exhibits a perfectly graded 60cm fine sand-to-gravel unit, with sedimentary clasts of siliceous mud included in the interval; the site lies on a slope of >4°. Other crudely graded units are found in cores 76, 79, 84, 129, and P101, most often underlying siliceous or terrigenous mud units. These units have sharp upper contacts, and often show internal contacts between crudely graded intervals.

A general downcore progression of sediment type, siliceous mud/ terrigenous mud/terrigenous gravelly mud, is found throughout most parts of the eastern bay. The thickness of the capping siliceous unit varies widely with depth; core 66 (859m) has a 597cm thick unit, whereas core 84 (329cm) has only 12cm of diatomaceous mud. Muds at these deeper sites also have lower sand contents, mirroring the trend found in the surface samples. The glacial maritime setting during deposition of the siliceous muds presumably resembled the present setting, with high biogenic production and low IRD input. If the transition to terrigenous mud took place synchronously across the eastern bay, the sedimentation rate for the siliceous mud at 800m would be five times the rate at 350m.

The gradational change to the sandy silty B1 muds implies a more

severe glacial setting, with production of phytoplankton virtually lacking, and ice rafting being a significant mode of deposition. These muds were deposited under a cover of floating ice, either in the form of permanent pack ice or an ice shelf. The distinct lack of pebbles indicates that icebergs were not free-floating through this area, and basal melting of an ice shelf was either not occurring or had already stripped the base of the ice of its debris content in areas closer to the coast. The interfingering of siliceous and terrigenous mud in core 87 may reflect an unstable time of transition in that area between open marine and more permanent sea ice conditions. The unsorted sand content of the mud can be accounted for by a combination of aeolian and supraglacial debris working its way downward through the ice, until it reaches the base where it melts out and is deposited. Meltwater input of fine material may also be important, and may be responsible for the B2 sand mode and the masking of any IRD signature. The thin laminated muds of core 76 are meltwater deposits, based on the very fine material found in the laminae and the lack of internal grading. The deposit may represent pulses of subglacial meltwater production, which may be seasonally controlled. The sedimentation rate of the terrigenous mud is probably much lower than that of the siliceous mud, due to the lack of input of the biogenic material, which is largely responsible for the great thickness of the siliceous units. Both the siliceous and terrigenous mud units can be classified as compound glacial-marine sediments.

The three types of gravelly muds represent three different modes of sedimentation. The first, the gray sandy gravelly muds of cores 65 and

P106, are compound glacial-marine deposits reflecting close proximity to a glacial source. The proximity of land makes the sites well-placed to receive large amounts of IRD deposited near the glacial calving line or directly seaward of the grounding line of an ice shelf, which is reflected in the unsorted nature of the sediment. The muddy gravels cored at sites 77, 82, and 88 are examples of residual glacial-marine sediments. These cores show that water column winnowing has been important at depths <300m for a considerable length of time. The lack of fine material at these sites is probably not source-related, as nearby sites (P100, 84, 87) show ample silt- and clay-sized material reaching the seafloor. A much lower sedimentation rate is expected for these units, at least during the time period in which conditions were similar to the present. During climatically colder periods, the supply of IRD to the bay may have been much greater, thereby increasing the sedimentation rate of the bank sands and gravels.

The sharply bounded graded units and the thin graded sandy laminations are examples of sediment gravity flows, which are to be expected in an area of such high bathymetric relief. The small debris flows found in cores 76 and 129 underlie siliceous mud units, eroding an unknown amount of sediment and clouding the time relationships of the units above and below the flow. The thin (12cm) cap of siliceous mud over the perfectly graded turbidite of core 78 and the debris flow of core 76 attest to the importance of sediment gravity flow processes in the modern sedimentary environment. The thin graded sands of cores 72 and 79 represent the successive deposition of waning turbidity currents; in core 79 these turbidites may be distal equivalents of the

debris flows found deeper in the core. The increasing occurence of sediment gravity flows downcore points to an earlier time when downslope flow was more widespread in time and space. During a more climatically severe period, when glaciers and/or ice shelves may have extended farther into the bay, much more coarse unsorted material would have been delivered to the bottom, and thus would be available for sediment gravity flow.

The preservation of biogenic carbonate takes place only in siliceous mud intervals having high organic matter contents. Scaphopod tests are found at two levels in the cores: shallow (100-150cm; cores 79 and P116) and deep (most fossils between 350-575cm; cores 66, 72, 87). Cores 79 and P116 lie in the same small basin, and the fossils may represent a basin-wide preservation event. The fossils are more widely scattered in the other cores, which lie at the bottom of large basins where sediment ponding has been observed. Again, the carbonate is associated with high organic matter preservation. Although the presence and decay of organic matter may accelerate the dissolution of carbonate in near-surface sediments, it is possible that burial was rapid enough for the fossils to be preserved. Periodic anoxic or near-anoxic events may be responsible for the laminated intervals in the siliceous muds, the high levels of organic matter, and the rare preservation of biogenic carbonate. Although these events may have affected the entire bay, it is more likely that the deeper basins were the principal sites of anoxic sedimentation. The presence of faint laminae in most siliceous mud units of the eastern bay points to low levels of activity by burrowing fauna, and, coupled with the high

organic carbon contents found in surface samples (Dunbar, pers. comm.), may indicate that near-anoxic to anoxic conditions are commonplace in Marguerite Bay. Circumpolar Deep Water, which extends from the surface to the seafloor in the bay, is a well-oxygenated water mass, and remains well-mixed. The onset of anoxia by depletion of oxygen in this water mass would be difficult. A mechanism for creating anoxic conditions in the bay is not readily apparent.

The downcore progression of transitional glacial-marine/compound glacial-marine/siliceous mud can be seen throughout the eastern bay, although the thicknesses of individual correlatable units are quite variable. It is therefore plausible that the entire eastern bay has undergone a similar history at least as far back in time as the deposition of the terrigenous muds, and possibly the gravelly muds. The fact that one of the deep basin cores (66) did not reach any unit below the siliceous mud may be accounted for by a very high sedimentation rate. The rough correlation of the organic-rich scaphopod-bearing intervals also points to a broadly similar progression of environments.

Northwestern quarter

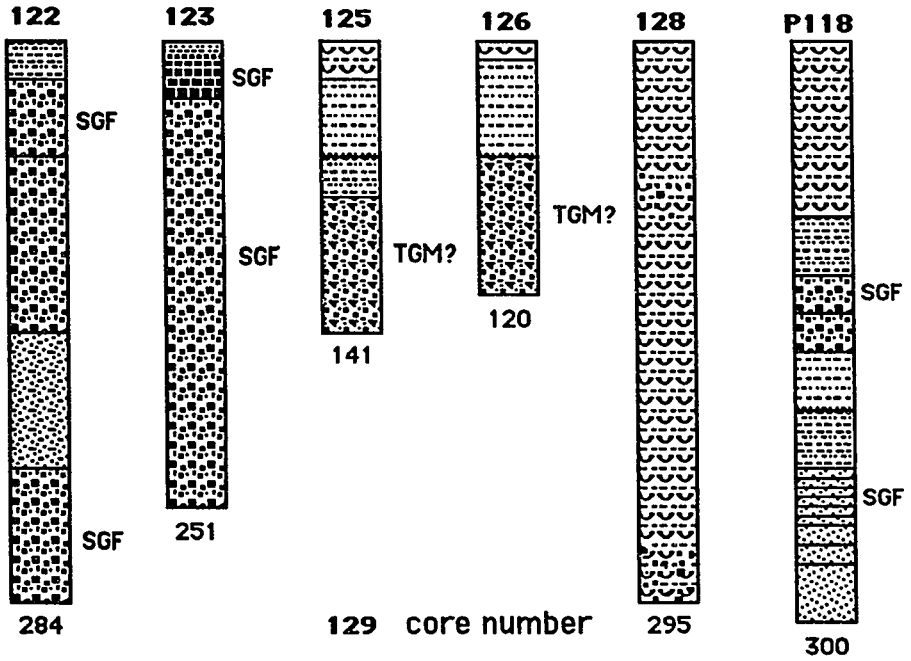
The northwestern quarter of Marguerite Bay is typified by rugged, possibly faulted basement covered by a thin drape of sediment. An extension of the George VI rift feature trends north-south through the quarter, and water depths of >900m are found in this trough. Only one seismic line (MB-F) was collected in this portion of the bay. This line shows evidence of slumping on the steep slopes of the small basin to

the west of site 126, and no sediment ponding.

As in the eastern bay, most basin cores in the northwestern quarter are capped by siliceous mud units (Fig. 6.4). The thicknesses of these units, however, are much less than those to the east, and sand contents are generally higher for cores at similar water depths. Core 126 is topped by a siliceous mud unit of 8cm, even though the core was recovered at 860m, comparable to core 66 at 859m, which has over 600cm of siliceous mud. Similarly, cores 125 and P118 show much thinner siliceous mud units than comparable cores in the eastern bay. Core 128, from 774m depth on a very steep slope, recovered almost 300cm of siliceous mud, with sand content ranging from 10-14%, and with two gravelly intervals. The higher sand/gravel content at these sites indicates that either IRD input is higher or production of biogenic material is lower. With the exception of P118, the sand fraction of the siliceous mud units lacks the strong current-derived size mode found in the eastern bay muds (Fig. 6.5). The near-absence of the siliceous mud in the southern half of the quarter, coupled with a similar downcore progression in the southwestern quarter, implies a dividing line running west-east in the area between sites 126 and 128, separating thick siliceous muds to the north from sites where siliceous muds are sparse to absent to the south.

Three cores (125, 126, P118) penetrated terrigenous mud and terrigenous muddy sandy gravels beneath the siliceous mud unit. The terrigenous mud unit in the two southern cores (125, 126) exhibits a gradational change from B2 to B1 mud (Fig. 6.5), with an accompanying increase in sand content, and terminating in a sharp lower contact. The

Figure 6.4: Lithologic logs of cores recovered from the northwestern quarter of Marguerite Bay. For core locations, see Figure 1.1. For more detailed core descriptions, see Appendix 4.



CORES --

NORTHWESTERN BAY

129 core number

165 core length

interval of highly disturbed core

SGF sediment gravity flow
TGM transitional glacial-marine
RGM residual glacial-marine

siliceous mud

terrigenous mud (B1)

terrigenous mud (B2)

muddy sand

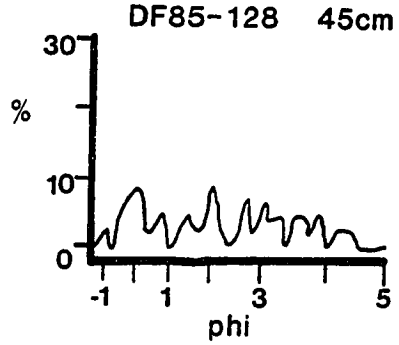
gravelly mud

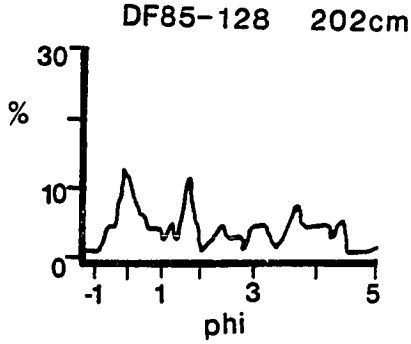
gravelly sand

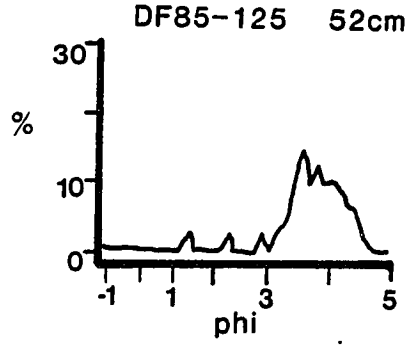
unsorted g/s/m (uncompacted)

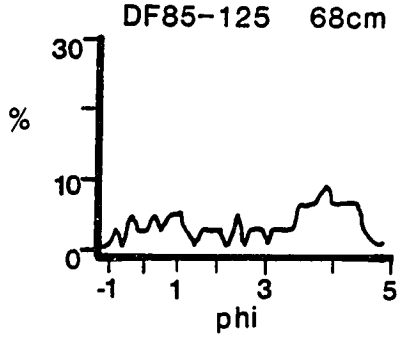
laminated sand/silt

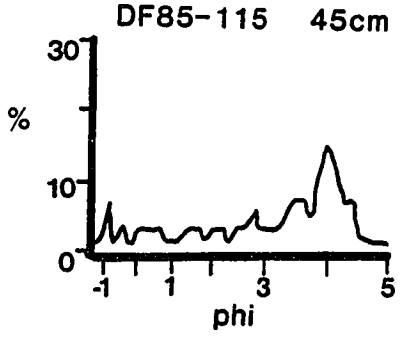
Figure 6.5: Size (-1.00 to 4.75 Φ) vs. frequency plots, downcore samples in western Marguerite Bay. The siliceous muds of the western bay (samples 128 (45cm, 202cm) and 116 (6cm)) generally lack the strong current-derived size mode found in the eastern bay muds, although the mode is found in a few cores (sample 115 (45cm)). Core 125 shows the gradational change from B2 to B1 mud, with an increase in sand content.

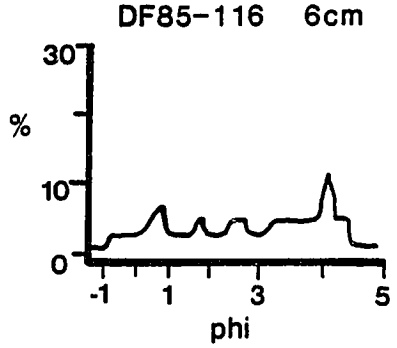

DF85-128 45cm
30
%
10
0
-1
1
3
5
phi


DF85-128 202cm
30
%
10
0
-1
1
3
5
phi


DF85-125 52cm
30
%
10
0
-1
1
3
5
phi


DF85-125 68cm
30
%
10
0
-1
1
3
5
phi


DF85-115 45cm
30
%
10
0
-1
1
3
5
phi


DF85-116 6cm
30
%
10
0
-1
1
3
5
phi

upper terrigenous mud in core P118 is a B1 unit, which is truncated by a debris flow. Below the flow, a sandy mud (up to 35% sand) shows the same B2 to B1 grading downcore, and terminates in a sandy laminated interval showing thin normally graded layers. These lamina are very similar to those found in cores 72 and 79, and are assumed to be thin turbidite layers. The close proximity to the west of Faure Bank may be partially responsible for the higher sand content found at this site. The muddy sandy gravels of cores 125 and 126 are unsorted, non-graded, and show no internal contacts. This unit in core 125 shows a marked textural homogeneity downcore.

Sediment gravity flows are also found in cores 122 and 123, which lie in areas of steep and very rugged bathymetry. Core 123 is topped with a perfectly graded fine sand to gravel unit, interpreted as a turbidite, which is underlain by number of debris flows showing crude grading.

Piston coring attempts at sites 121 and 124 resulted in bent core barrels, and the samples were bagged, with loss of downcore integrity. Muddy gravel was recovered at both sites, and in the case of site 124, at 215m water depth, the gravel contained >60% green metasedimentary pebbles. The shallow depth would suggest a residual glacial-marine deposit, although the predominance of one lithology in the gravel fraction may reflect earlier depostion by grounded ice.

The downcore progression from siliceous mud through terrigenous muddy gravel mirrors the pattern seen in the eastern bay, with a few important differences. The thin capping unit of siliceous mud implies that present environmental conditions have been in effect for a much

shorter length of time than in the eastern bay. If a greatly reduced sedimentation rate for the biogenic fraction is proposed, higher sand content due to ice rafting would be expected. This is observed in core 128, where intervals of coarse material are found, reflecting either higher IRD input rates or lower production and deposition of biogenic silica. Even under a much slower sedimentation rate, the thin layer of siliceous mud in cores 125 and 126 represents a considerably shorter time span than found in siliceous units to the east. The B2 mud directly underlying this unit shows evidence of heavy ice cover, having very low amounts of coarse IRD. Although the B2 muds could be a product of increased supply of terrigenous material, it is difficult to explain such an increase in conjunction with overlying and underlying sedimentary units. As the mud grades from B2 to B1 and IRD increases without introduction of any biogenic material, the nature of the overlying ice cover is changing. A reasonable mechanism for this gradual change is a shift from permanent pack ice/distal ice shelf to an area more proximal to the grounding line of an ice shelf. Supraglacial and englacial debris which has worked its way down through the glacier/ice shelf (and would be the only debris still being transported in this portion of the ice shelf) is melted out of the base of the ice shelf and deposited. This coarsening trend continues in the sediment as the terrigenous mud is underlain by muddy and sandy gravels.

It is often difficult to interpret the large number of unsorted gravel/and/mud units found in Marguerite Bay in terms of genetic origin. In this case, however, mineralogic homogeneity, lack of internal stratification or grading, and correlation with similar sequences in the

southwestern quarter suggest the possibility that the sandy gravels are transitional glacial-marine deposits. These sediments were melted out from the basal debris zone of an ice shelf near the grounding line, and the extremely poor sorting implies both an unsorted source and lack of subsequent reworking by marine or sediment gravity flow processes. However, the lack of downcore textural homogeneity is consistent with interpretation as a debris flow. The mineralogical homogeneity may be a reflection of a source in earlier glacial deposits, which show a limited source area. These units stand in contrast to cores 122 and 123 which show internal contacts and grading. In addition, the turbidite atop core 123 is evidence that sediment gravity flow is an important process at that site. Thus, the origin of the sandy gravels of cores 125 and 126 is uncertain.

The northwestern quarter can be roughly divided into two halves based on downcore sediment patterns. The northern area (cores 128 and P118) shows patterns much like that found in the eastern bay, albeit with possibly lower sedimentation rates and/or higher IRD input. To the south, cores 125 and 126 exhibit strikingly similar progressions downcore, which are also seen in cores of the southwestern quarter. The west-east line separating the two halves may be a significant boundary with respect to present and past ice conditions. Although detailed long term data is lacking, sea ice charts for Marguerite Bay have shown that the extreme northwestern part of the bay is consistently the first area to clear of sea ice each summer and the last to ice over in autumn. This would allow longer time for open water primary production, increasing the phytoplankton population and thus

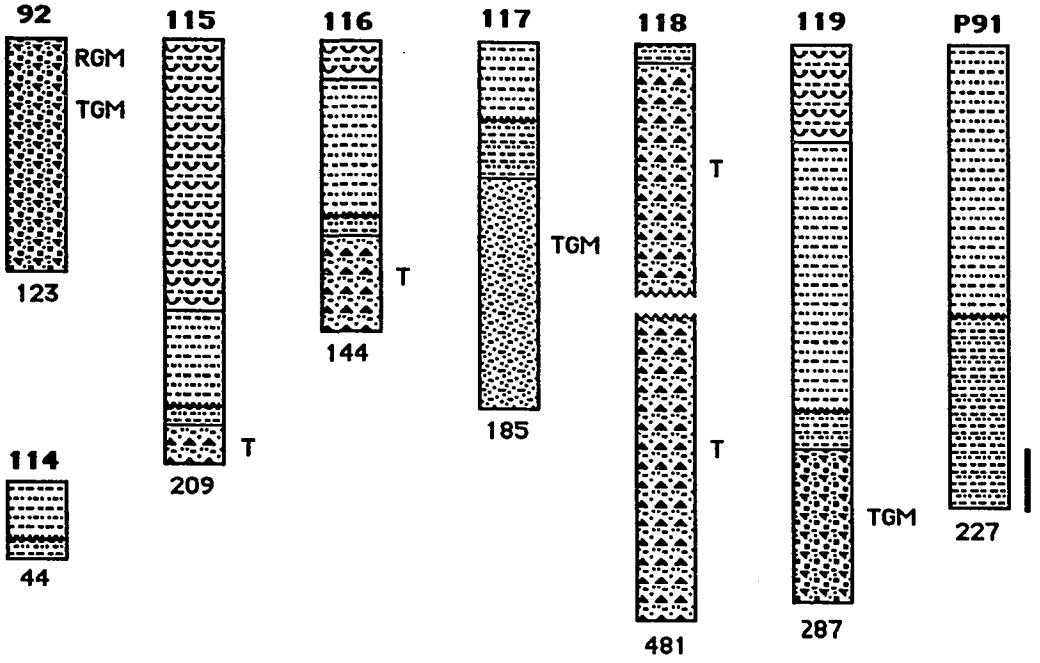
the sedimentation rate of the biogenic phases. It is evident that a significantly different history, much more dominated by ice, has taken place to the south and southwest of the boundary.

Southwestern quarter

The southwestern quarter is dominated by the George VI Trough, the rift feature running north from the George VI Sound. The trough reaches >1300m at its deepest, and is flanked by deep basins to the west and east. The quarter is bounded on the west by the Alejandro Rios Bank (which appears to be an effective barrier to icebergs from the south and west) and on the east by the Kirkwood Bank. The seismic lines running west to east show a very rugged seafloor, with evidence of normal faulting at and near the surface. No ponding of sediment is seen, even in the George VI Trough, and a very thin veneer covers acoustic basement. The trough has flanks with a gradient of 10°, and some slumping may be occuring near the base of the eastern flank.

Siliceous mud units are relatively rare in this part of the bay, found only in cores 115, 116, 119, and B89 (Fig. 6.6). As seen in the northwestern quarter, these units are thin, the thickest being 125cm, found at site 115 (726m water depth). The units in cores 116 and 119 have an unsorted sand fraction, whereas core 115 shows a very strong frequency mode centered around 4.00 Φ (Fig. 6.5). Terrigenous muds or gravels are found topping cores 92, 114, 117, 118, P91, and B92, and underlying the siliceous mud units mentioned above. The terrigenous mud units from the two cores taken in the George VI Trough (P91, B92) have a slightly increased biogenic component as compared to other

Figure 6.6: Lithologic logs of cores recovered from the southwestern quarter of Marguerite Bay. For core locations, see Figure 1.1. For more detailed core descriptions, see Appendix 4.



siliceous mud

terrigenous mud (B1)

terrigenous mud (B2)

gravelly mud

gravelly sand

muddy sand

unsorted g/s/m (uncompacted)

diamicton (compacted)

CORES --

SOUTHWESTERN BAY

129 core number
165 core length

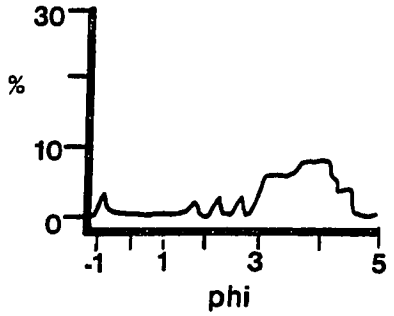
| interval of highly disturbed core

SGF sediment gravity flow
TGM transitional glacial-marine
RGM residual glacial-marine
T basal till

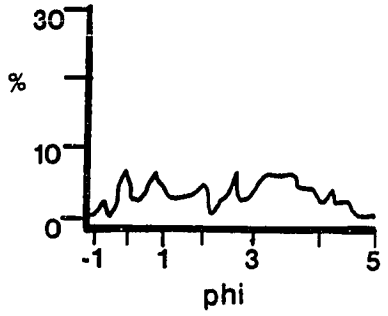
terrigenous units in the quarter. In virtually all cores in the area, this terrigenous mud unit grades from B2 to B1, with the former being two to three times thicker. The B2 units in cores 114, 115, 116, 119, and P91 have low sand contents, often less than 2%. The B2 unit in core 117 has 18-20% sand but shows the same 3.50-4.00 Φ frequency mode as the other finer mud units (Fig. 6.7). Core 118 is topped with a thin B1 unit that shows a striking similarity to the B1 unit in core 114 (Fig. 6.7). The B2/B1 gradation is typically accompanied by an increase in sand content, and the thin B1 mud has a sharp lower contact. A number of different gravelly mud/muddy gravel units are found in this area. The sandy muddy gravel at the base of core 119 shows no internal contacts or grading, and exhibits textural and mineralogic homogeneity downcore. This unit may be correlatable to the transitional glacial-marine unit found at site 125 (and possibly 126), which has an analogous downcore progression. Core 92, recovered from 348m on the eastern flank of the George VI Trough, is a compact gravelly sand showing textural and mineralogical homogeneity downcore. Textural analysis reveals a consistent frequency mode at 0.25 Φ throughout the core, presumably reflecting very strong current velocity (Fig. 6.7). It is possible that this core is a residual glacial-marine deposit, although the currents involved are much stronger than any found reflected in other sediments of the bay, present or past. This core may represent deposition by a subglacial meltwater stream immediately seaward of the grounding line, and subsequent grounded ice at the site (ice shelf pinning point?) compacted the sediments. Alternatively, the striking textural

Figure 6.7: Size (-1.00 to 4.75 Φ) vs. frequency plots, downcore samples in southwestern quarter, Marguerite Bay. The upper B2 terrigenous mud unit in core 117 (32cm) shows a strong 3.50-4.00 Φ size mode, and is underlain by a B1 terrigenous mud (42cm). Similar B1 units occur in cores 118 and 114. Samples from core 92 exhibit a consistent mode at 0.25 Φ, which would appear to indicate a very strong current velocity.

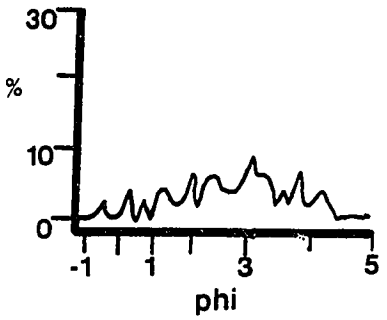
DF85-117 32cm



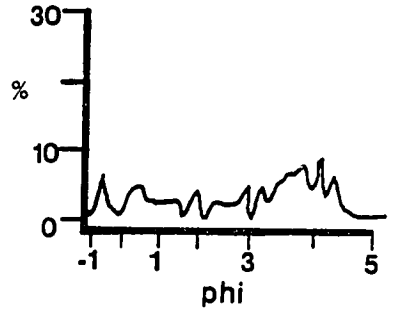
DF85-117 42cm



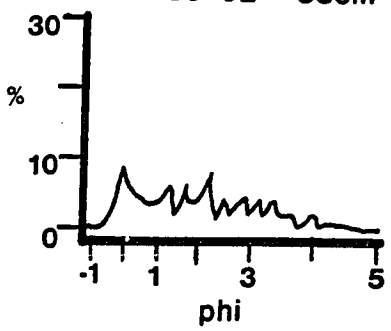
DF85-118 5cm



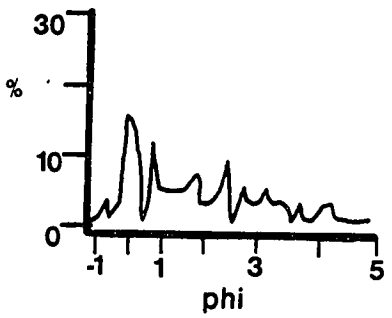
DF85-114 34cm



DF85-92 38cm



DF85-92 108cm



homogeneity in the lower 100cm of the core gives credence to an interpretation of the unit as a transitional glacial-marine deposit. The 0.25 Φ frequency mode may represent glacial source control, as opposed to the effect of a marine current. The occurrence of the 0.25 Φ mode in the surface sample at this site is problematic; it appears unlikely that a current of this strength would affect such a small area, or not be detected at nearby sites. The eastern flank of the George VI Trough has a slope of 10°, and it is possible that recent sediments have moved downslope, leaving older deposits exposed at the surface. This process may also have occurred at site 118, which is on a steep slope and appears to be missing a capping siliceous mud or B2 unit. Core 117 has a muddy gravelly sand at its base, showing textural and mineralogic homogeneity within the unit. The interval is virtually unsorted and has been interpreted as a transitional glacial-marine deposit.

An unsorted diamicton unit has been recovered in cores 115, 116, and 118. It is proposed that these are sediments deposited by grounded ice, and will be discussed in detail in the following section.

Basal tills

The sites where the diamicton units were found lie to the west and northwest of the deepest part of the George VI Trough. Cores 115 and 116 were recovered at 726m and 650m respectively, and the core bottoms out in a thin diamicton. Core 118, from 489m water depth, has an almost 500 cm thick diamicton, showing no internal structure. The units, for the most part sandy gravelly muds, are medium to dark gray, with no biogenic material present. Values of cohesive and compressive

strength are much greater than those of other gravel/sand/mud units in the study area (Table 2). Downcore textural analysis in core 118 reveals a remarkable homogeneity in sand/silt/clay ratio. No such homogeneity is found in compound glacial-marine or sediment gravity flow units in cores recovered from the same area (Fig. 6.8).

Boulton (1978) sampled supraglacial and englacial debris, and basal debris zones, and related the shape of the pebbles to their mode of transport. He found that debris carried englacially or supraglacially had generally lower roundness and sphericity values than material from basal debris zones, due to the relatively passive nature of englacial transport. The diamicton pebbles, as well as pebbles from compound, residual, and transitional glacial-marine units, were plotted on roundness versus sphericity diagrams as a comparison with mode of transport fields delineated by Boulton (1978) (Figs. 6.9, 6.10). The basal till and transitional and residual glacial-marine fields all plot in the same general area, on the boundary between high level and basal debris zone transport. The compound glacial-marine samples plot primarily in the high level transport field, showing lower roundness values than other sediment types. On the whole, the fields show lower roundness values than those of similar sediment type recorded by Domack et al (1980) and Smith (1985); this difference may be influenced both by glacial regime and pebble lithology. The large number of small outlet and valley glaciers, and the comparatively high percentage of exposed rock, may be responsible for higher levels of englacial and supraglacial debris reaching the seafloor of Marguerite Bay. The pebbles retrieved from the diamictons are predominantly

TABLE 2

COMPRESSIVE AND COHESIVE STRENGTHS OF SEDIMENT TYPES

	COMPRESSIVE STRENGTH (kg/cm^2)		COHESIVE STRENGTH (kg/cm^2)	
	avg	range	avg	range
BASAL TILL	3.2	0.6-4.5	3.9	1.4-6.6
TRANSITIONAL GLACIAL-MARINE	1.0	0.1-2.9	2.6	1.1-4.0
SEDIMENT GRAVITY FLOW	0.6	0.0-2.2	1.8	0.0-3.6
COMPOUND GLACIAL-MARINE	0.2	0.0-1.5	1.2	0.0-5.1

Figure 6.8: Sand/silt/clay (s/z/c) ratios downcore on selected cores from the western bay. The basal till and transitional glacial-marine units show a marked downcore homogeneity. Compound glacial-marine and sediment gravity flow units show textural heterogeneity downcore. Points along the left margin of the plots mark sample locations.

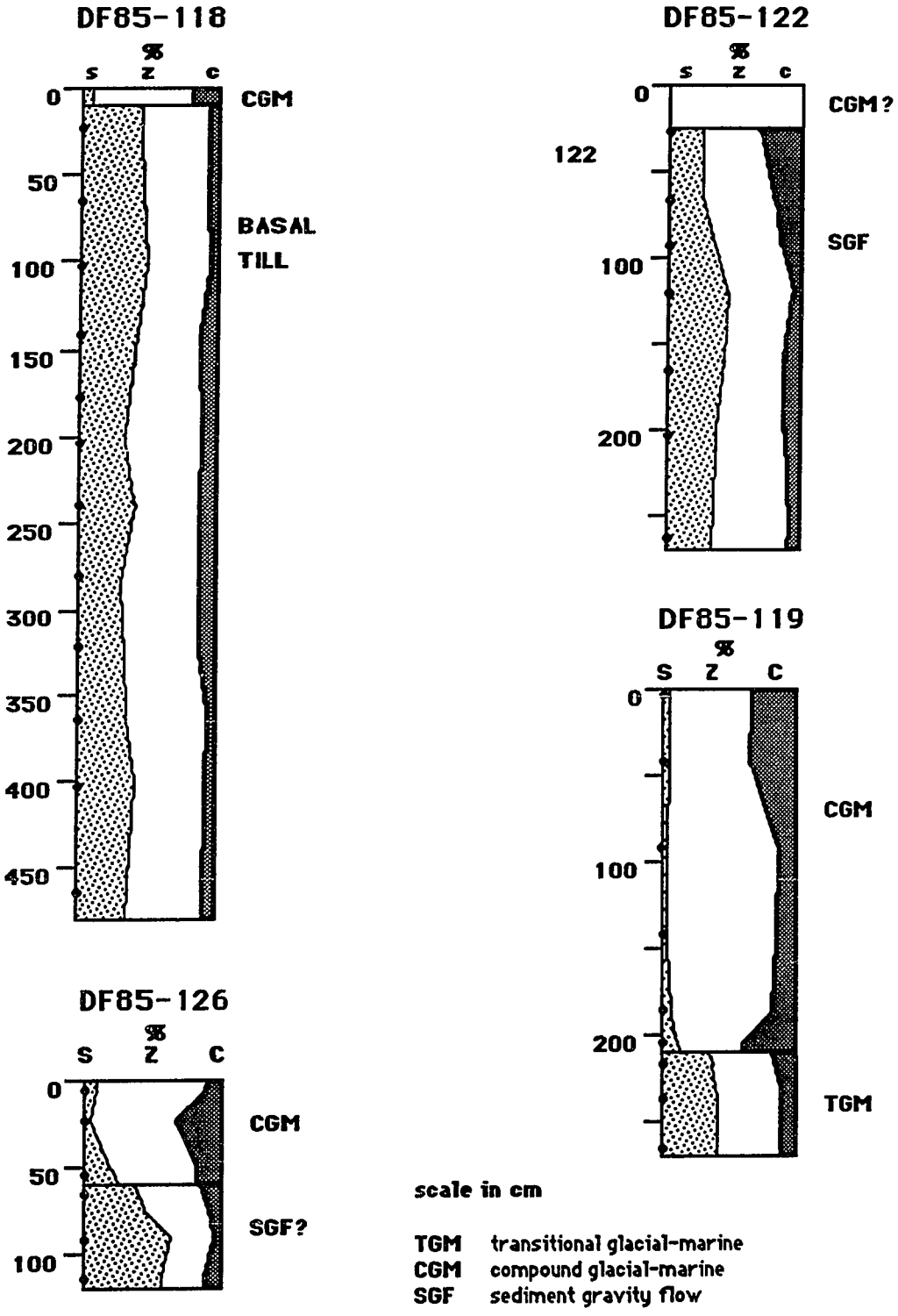
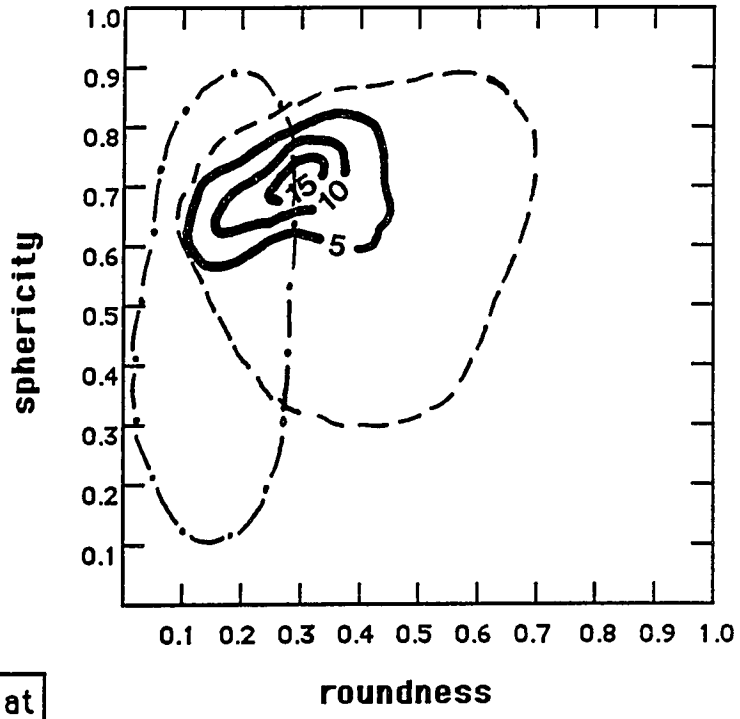

DF85-118
%
S Z C
0
50
100
150
200
250
300
350
400
450
CGM
BASAL TILL
DF85-122
%
S Z C
0
122
100
200
CGM?
SGF
DF85-119
%
S Z C
0
100
200
CGM
TGM
DF85-126
%
S Z C
0
50
100
CGM
SGF?
scale in cm
TGM transitional glacial-marine
CGM compound glacial-marine
SGF sediment gravity flow

Figure 6.9: Roundness vs. sphericity plots of pebbles from basal till and transitional glacial-marine units. The basal debris zone transport field (dashed line) and high level transport field (dashed dotted line) of Boulton (1978) are shown. Both these sediment types plot in the boundary area between high level and basal transport. Most of the basal till pebbles are of quartz mica schist/gneiss lithology, and this may account for the low roundness values.

basal till

n=38



contour intervals at 5, 10, and 15 % per 1% of total area

transitional glacial-marine

n=41

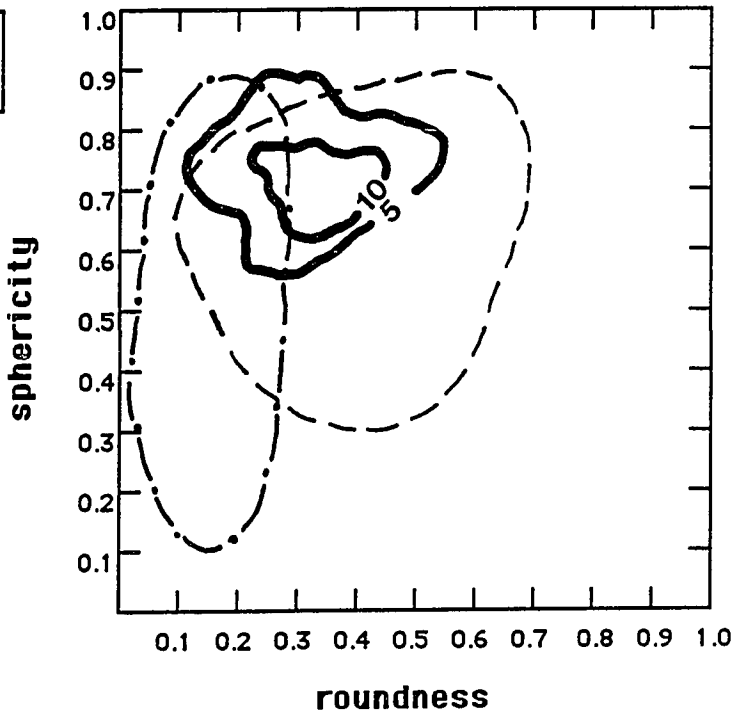
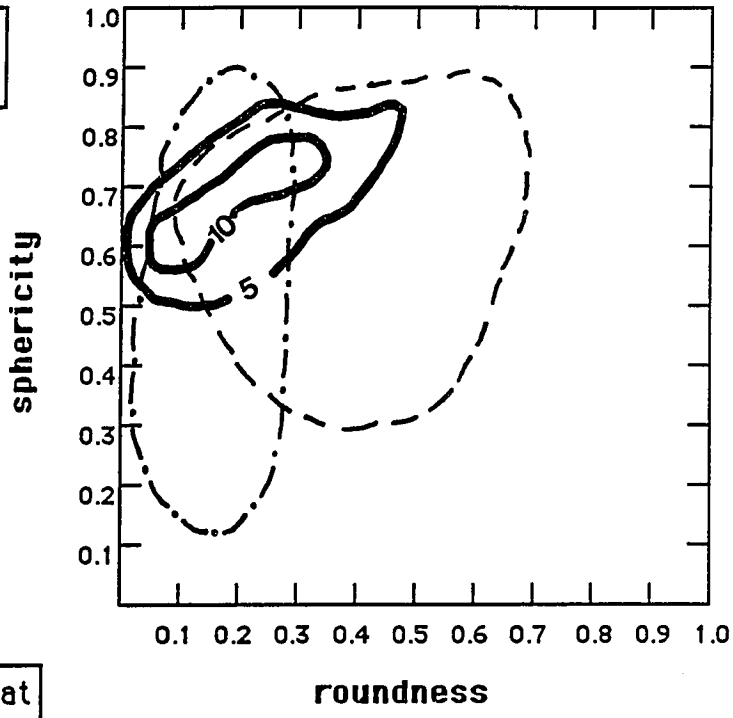


Figure 6.10: Roundness vs. sphericity plots of pebbles from compound and residual glacial-marine units. The basal debris zone transport field (dashed line) and high level transport field (dashed dotted line) of Boulton (1978) are shown. The compound glacial-marine pebbles plot primarily in the high level transport field, reflecting the importance of englacial and supraglacial debris in this setting. The residual glacial-marine pebbles plot on the boundary between high level and basal transport; this field may represent a mix of pebbles derived from the two different transport modes.

compound glacial-marine

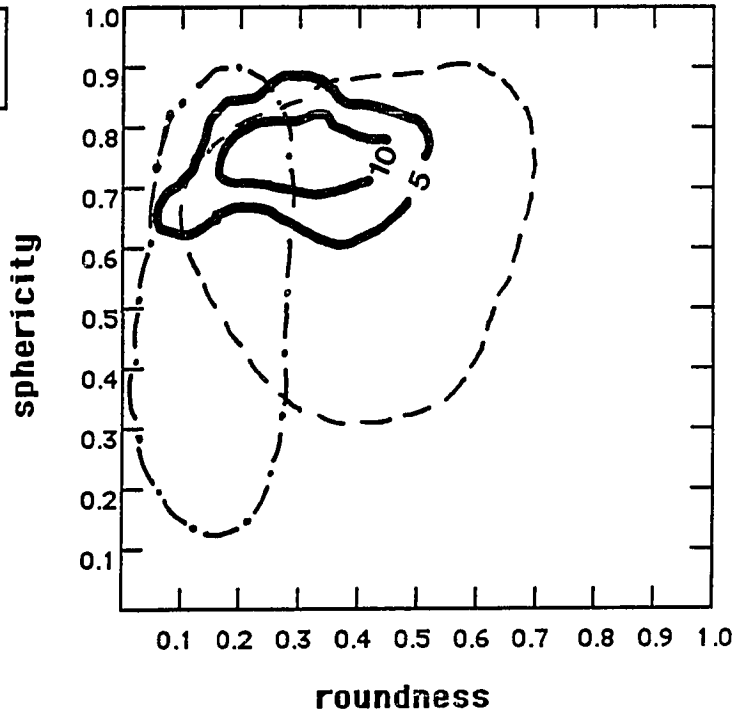
n=102



contour intervals at 5, 10, and 15 % per 1% of total area

residual glacial-marine

n=114



gneisses, and the strong foliation may exhibit lower sphericity than nonfoliated rock subjected to a similar transport history.

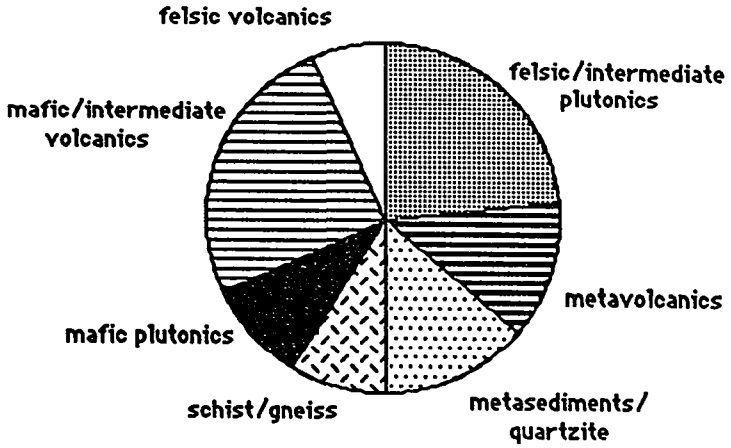
Twenty-five pebbles were extracted from the diamicton units, and twenty were of quartz mica schist/gneiss lithology. By contrast, no such monolithologic trends are found in transitional glacial-marine or compound glacial-marine units (Fig. 6.11). Grain counts of coarse sand (-1 to 1 Φ) were made at intervals of 50cm in the diamicton of core 118, and the counts mirror the striking textural homogeneity, showing an overwhelming preponderance of quartz mica schist/gneiss mineralogy (Appendix 2). The diamicton units of cores 115 and 116 show a very similar coarse sand mineralogy. Counts were also conducted on transitional glacial-marine and sediment gravity flow units in cores 92, 117, 119, 125, and 126. These units lack the remarkable monolithology of the diamictons, although the transitional glacial-marine units of cores 117, 119, and 125 show downcore mineralogic homogeneity. The implication of lithologic and mineralogic homogeneity in the diamictons is that the source area for these deposits is quite limited. Transitional glacial-marine units should also show mineralogic homogeneity, as these units also have a limited source area. Compound glacial-marine deposits receive IRD from icebergs, which may drift into the area from great distances, and thus these units have a much broader source. This is reflected in the lithologic heterogeneity found in compound glacial-marine units in the bay.

In summary, the total lack of sorting, the striking downcore textural and mineralogic homogeneity, overcompaction, and the

Figure 6.11: Diagram showing relative abundances of pebble lithologies in compound glacial-marine, transitional glacial-marine, and diamicton units, and total of all pebbles sampled in Marguerite Bay (n=number of pebbles sampled). The diamicton units show a striking monolithologic trend, with greater than 75% of the pebbles being of a quartz-mica schist/gneiss lithology. The transitional glacial-marine units show only a slightly restricted suite of lithologies.

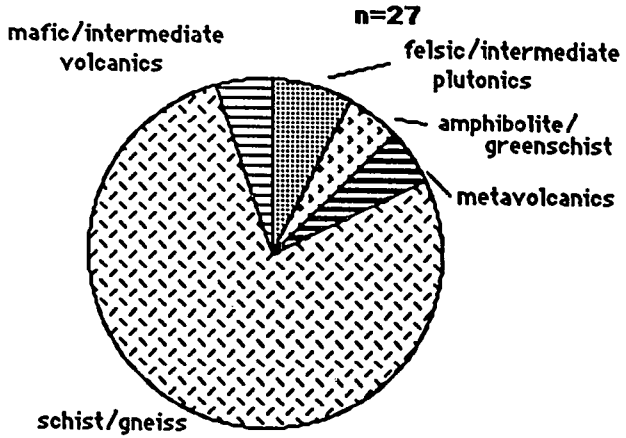
TOTAL -- ALL UNITS

n=392



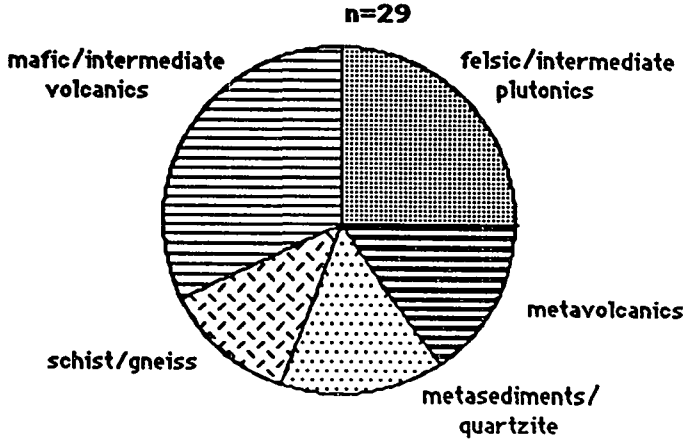
DIAMICTON UNITS

n=27



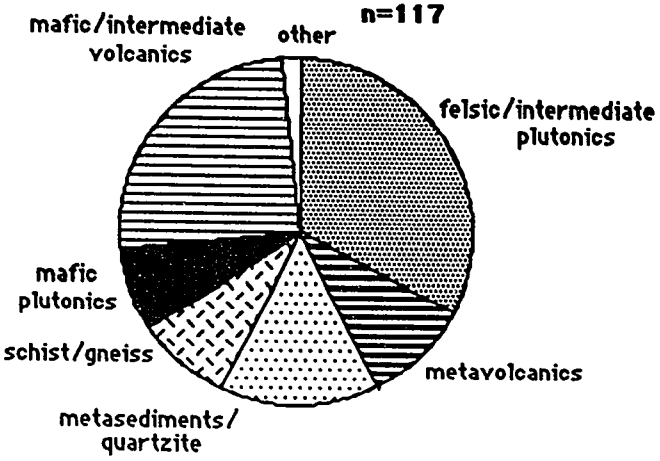
TRANSITIONAL GLACIAL-MARINE UNITS

n=29



COMPOUND GLACIAL-MARINE UNITS

n=117



stratigraphic placement in a correlative position to the transitional glacial-marine units of the western bay all substantiate the interpretation of the diamicton units as basal tills. The quartz mica schist/gneiss lithology is traceable to outcrops in northern Alexander Island (Fig. 6.12) described by Adie (1954) and Burn (1983). Ice advancing north over these outcrops would entrain debris and later deposit it at a considerable depth in the bay. The discovery of the basal till units has facilitated the construction of a model detailing the history of Marguerite Bay since the late Wisconsin glacial maximum, which will be described in the next chapter.

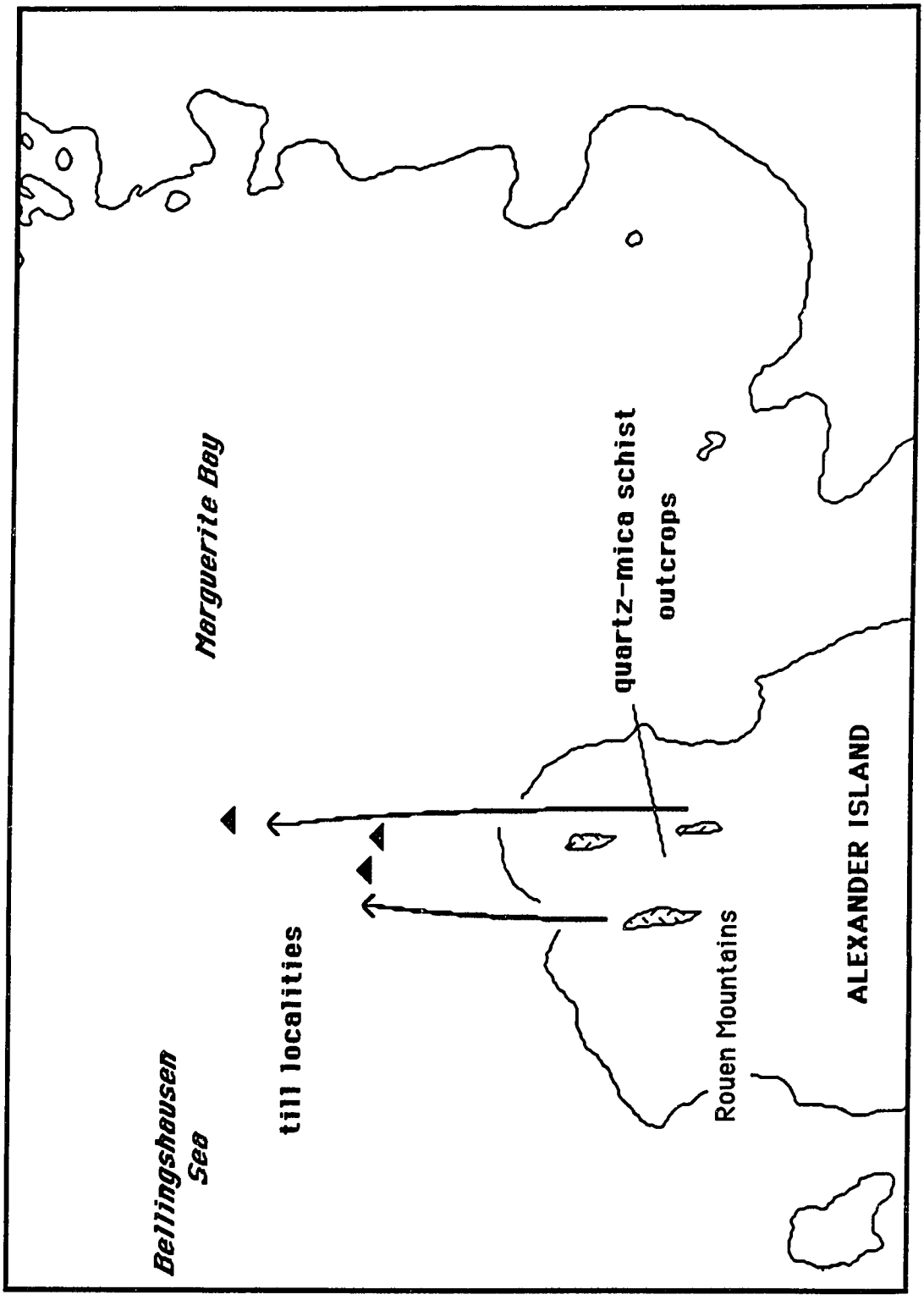
Bay-wide trends

The most consistent trend found across the bay is the downcore progression toward coarser, more terrigenous sediments. The siliceous mud units, representing conditions similar to the present, vary greatly in thickness due to the interrelated influences of sedimentation rate and water depth. The thin units in the western bay indicate that the entire bay has not uniformly experienced the glacial maritime environment that presently exists for more than a few thousand years at the most. High levels of organic matter are preserved in the siliceous muds throughout the bay, in both surface sediments and downcore. The gradational change from siliceous to terrigenous mud is found in most areas, and is often accompanied by reduced content of unsorted IRD sand and gravel. Downcore siliceous and terrigenous muds show very similar sand frequency modes in all areas of the bay.

A temporal relationship may exist among the basal till and

transitional glacial-marine units in the western bay and the sediment gravity flow units of the eastern bay. These units directly underlie the siliceous/terrigenous mud progression, and may be time-correlative, reflecting different sedimentary environments in the different sections of the bay. This relationship is an important element of the model describing Marguerite Bay from the last glacial maximum to the present, which is postulated in the following chapter.

Figure 6.12: Location of quartz-mica schist/gneiss outcrops that are the likely source area for basal till units found in the southwestern quarter. First identified by Adie (1954), these rocks were described in more detail by Burn (1983). Glacial Ice flowing north over these outcrops would entrain debris in its basal debris zone, and later deposit it at depth on the seafloor in the form of basal till.


Bellingshausen Sea
Marguerite Bay
till localities
quartz-mica schist outcrops
Rouen Mountains
ALEXANDER ISLAND

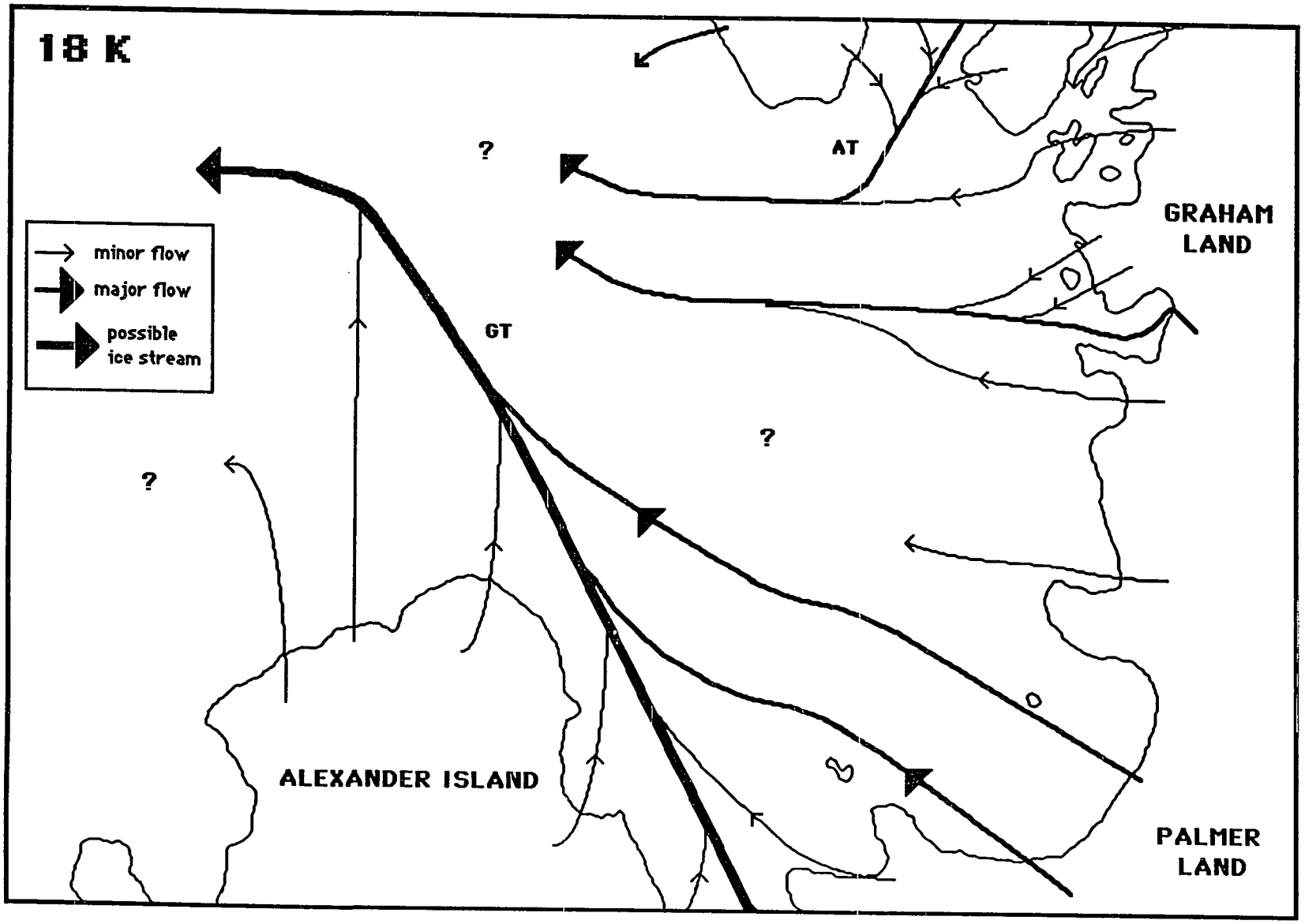
CHAPTER 7 RECONSTRUCTION

The accumulation of information gained from piston cores, seismic lines, and bathymetric profiles has allowed a reconstruction of the environment of Marguerite Bay from the late Wisconsin glacial maximum to the present. The reconstruction will outline climatic and glacial conditions in the bay, and the resulting effect on the sediments being deposited. Special emphasis will be placed on three time periods: glacial maximum (18,000 ybp), ice shelf period (10,000-12,000 ybp), and the recent glacial retreat to present conditions. The implications of the reconstruction will be discussed with respect to other models developed to describe advance and retreat of ice during the late Wisconsin.

Glacial maximum (18,000 ybp)

During the late Wisconsin glacial maximum, grounded ice covered the entire continental shelf of the Bellingshausen Sea, including Marguerite Bay, and extended out to the continental shelf break. Only isolated nunataks on the peninsula and on Alexander and Adelaide islands rose above the ice surface. The majority of the ice filling Marguerite Bay moved north from Alexander Island and Palmer Land, with subsidiary westward flow from Graham Land. A reconstruction of possible lines of major drainage is shown in Fig. 7.1. Ice thicknesses in

Figure 7.1: A reconstruction of glacial drainage in the Marguerite Bay region during the late Wisconsin glacial maximum (18,000 ybp). Ice draining from Palmer Land and Alexander Island coalesced into an ice stream that flowed down the George VI Sound and across the bay in the deep northern extension of the trough feature (GT). Drainage would also be concentrated in Adelaide Trough (AT), fed by glaciers from Graham Land and Adelaide Island. It is probable that ice was grounded out to the continental shelf edge; however the nature of drainage across the outer shelf is not known.


18 K
minor flow
major flow
possible ice stream
?
AT
GRAHAM LAND
GT
?
?
ALEXANDER ISLAND
PALMER LAND

the bay can only be approximated, but the ice sheet was probably at least 1500m thick, and possibly as great as 2000m. This marine ice sheet was wet-based, exhibiting basal flow and thereby both eroding and depositing sediment.

Evidence for complete grounding of the ice sheet out to the shelf break during the last glacial maximum has been extensively discussed by Stuiver et al (1981). On the basis of theoretical modeling and geomorphological observations, Stuiver et al (1981) placed Marguerite Bay under 2000m of grounded ice during the late Wisconsin. The geomorphological evidence for a former expanded ice sheet was first discussed by Nichols (1960), who concluded that ice was grounded in the bay east of Neny Fjord and the southern stretches of the Fallières Coast, to a thickness of at least 600m. The flow of ice in the region was probably dominated by the larger glaciers and drainage basins of Palmer Land and Alexander Island, although the input from Graham Land may have been substantial.

Clapperton and Sugden (1982) reconstructed the late Wisconsin ice dome over Alexander Island and showed drainage to the north in the George VI Sound, and off the northern end of the island, into Marguerite Bay. Western flow from Graham Land across Horseshoe Island has been proposed by Matthews (1983a). Ice flow paths would also be modified, perhaps channelized, by bathymetric features. The George VI and Adelaide troughs are ideal conduits for concentration of drainage, the former having over 1000m of relief (Fig. 1.3). The Adelaide Trough would receive ice flowing west from Graham Land and deflected to the south by the high north-south mountain range of Adelaide Island.

lack of any sedimentary cover over acoustic basement, as seen in the seismic profiles. The basement may represent crystalline bedrock or earlier compacted glacial deposits. Sediment ponding is seen only locally in the northeast quarter, and at water depths below about 500m. It is conceivable that during the late Wisconsin, advancing ice scraped the sediment cover away, depositing it over the shelf edge or in outer shelf canyons. The existence of a 1300m deep trough (the George VI) with no sediment accumulation in the basin is persuasive evidence for glacial erosion. The fact that ponded sediment is found in the Adelaide Trough reflects the much higher sedimentation rate in the northeastern quarter.

The strongest evidence for grounded ice in the bay is the occurrence of the basal tills in the southwestern quarter. If ice was grounded at 726m (site 117), then an ice thickness in excess of 1000m is probable for this area of the bay. This estimation, combined with the theoretical work of Stuiver et al (1981), allows extension of grounded ice throughout the bay, although evidence is circumstantial in the northern parts of the bay. The likely source area for these tills is the Rouen Mountains (Fig. 6.12), which is consistent with northward flow off Alexander Island. Ice from the eastern side of the George VI Trough, where similar lithologies occur, would have to cross the >1000m deep trough with basal debris zone intact to deposit the basal till units; this appears extremely unlikely. Presumably basal till units lie below the units retrieved in most cores in the bay, especially in the southwestern quarter, where flow was concentrated. The presence of tills in the eastern bay is dependent on whether the marine ice sheet was erosive or depositional.

The sedimentary effects of grounded ice throughout the bay are clearcut: cessation of all marine influence, and possible deposition of basal tills. There is evidence of erosive action in the lack of sediment cover over acoustic basement, although no indication of the whereabouts of the eroded material is found within the confines of the bay. It is quite possible that deposition and erosion were taking place contemporaneously in different areas of the bay.

Ice shelf period (10,000-12,000 ybp)

The combination of warmer climate and rising sea level caused the retreat of marine ice sheets covering the continental shelves of Antarctica. During this initial period of retreat, previously grounded ice on the outer shelf began to float, followed by rapid retreat of the grounding line to the inner shelf (Fig. 7.2). Marguerite Bay has a number of shallow banks (Alejandro Rios, Faure, Kirkwood) that would serve as an ideal grounding line (and subsequently as pinning points) to buttress an ice shelf (Fig. 7.3). Grounded ice existed to the south and east of these banks, fed principally by ice moving northward up the George VI Sound. The ice shelf stretched to the north and west of the grounding line, and this unbuttressed ice retreated gradually over time. Beyond the ice shelf lay a protective belt of permanent pack ice, perhaps covering the outer continental shelf. Over the course of several thousand years, the ice shelf retreated from the northern parts of bay to the south and back up into the northern fjords.

The idea of a large ice shelf filling Marguerite Bay in the recent past is not a new one. Fleming (1940) noted "fringing" glaciers rimming many coastlines in the bay, and theorized that these glaciers and the

Figure 7.2: A reconstruction of glacial drainage in the Marguerite Bay region during the early Holocene (10,000-12,000 ybp). An ice shelf, pinned on shallow banks, filled most of the bay. It was fed primarily by the ice stream moving north from the George VI Sound. Seaward of the ice shelf, permanent pack ice prevents the onset of primary production. F=Faure Bank; K=Kirkwood Bank; AR=Alejandro Rios Bank.

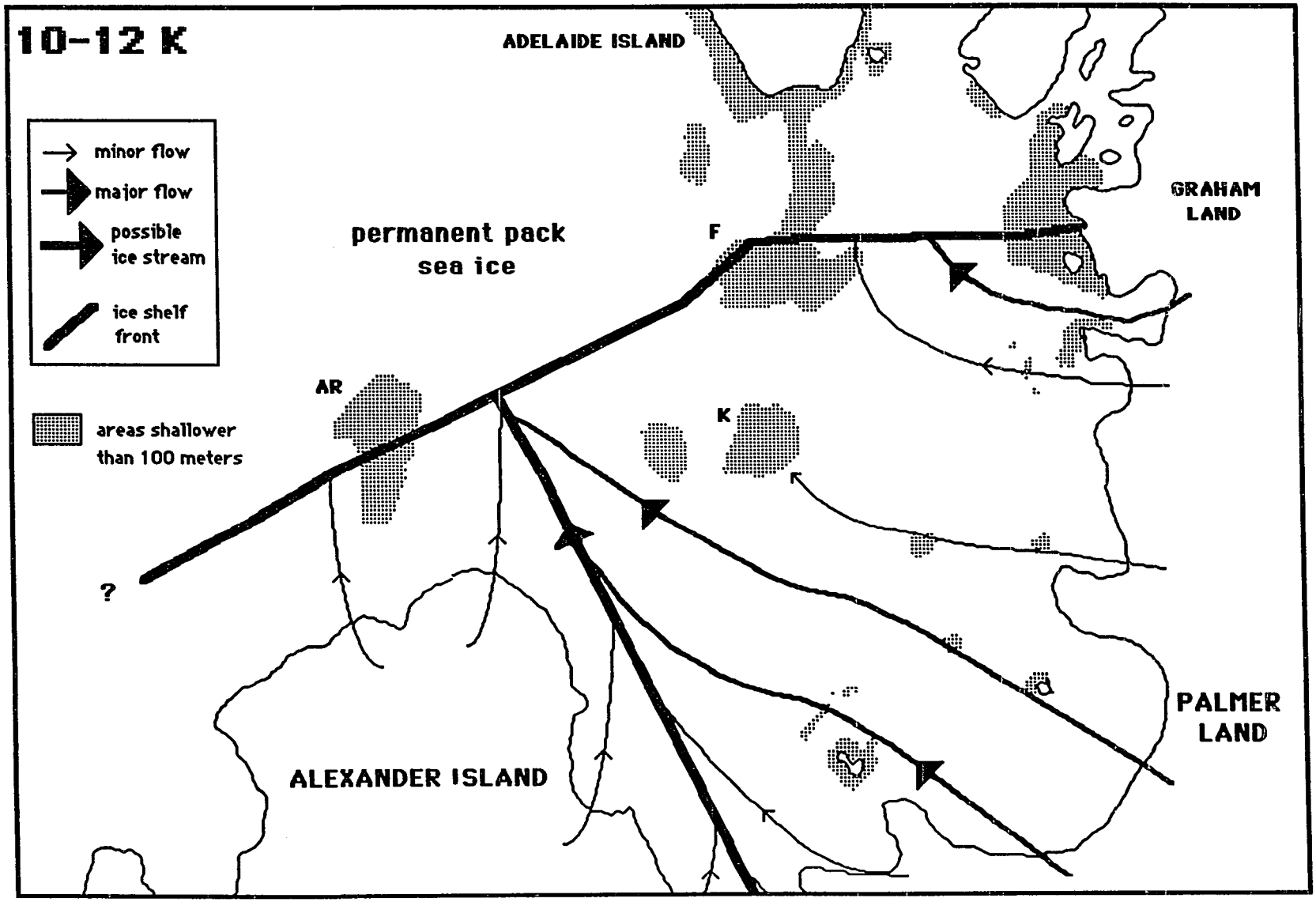
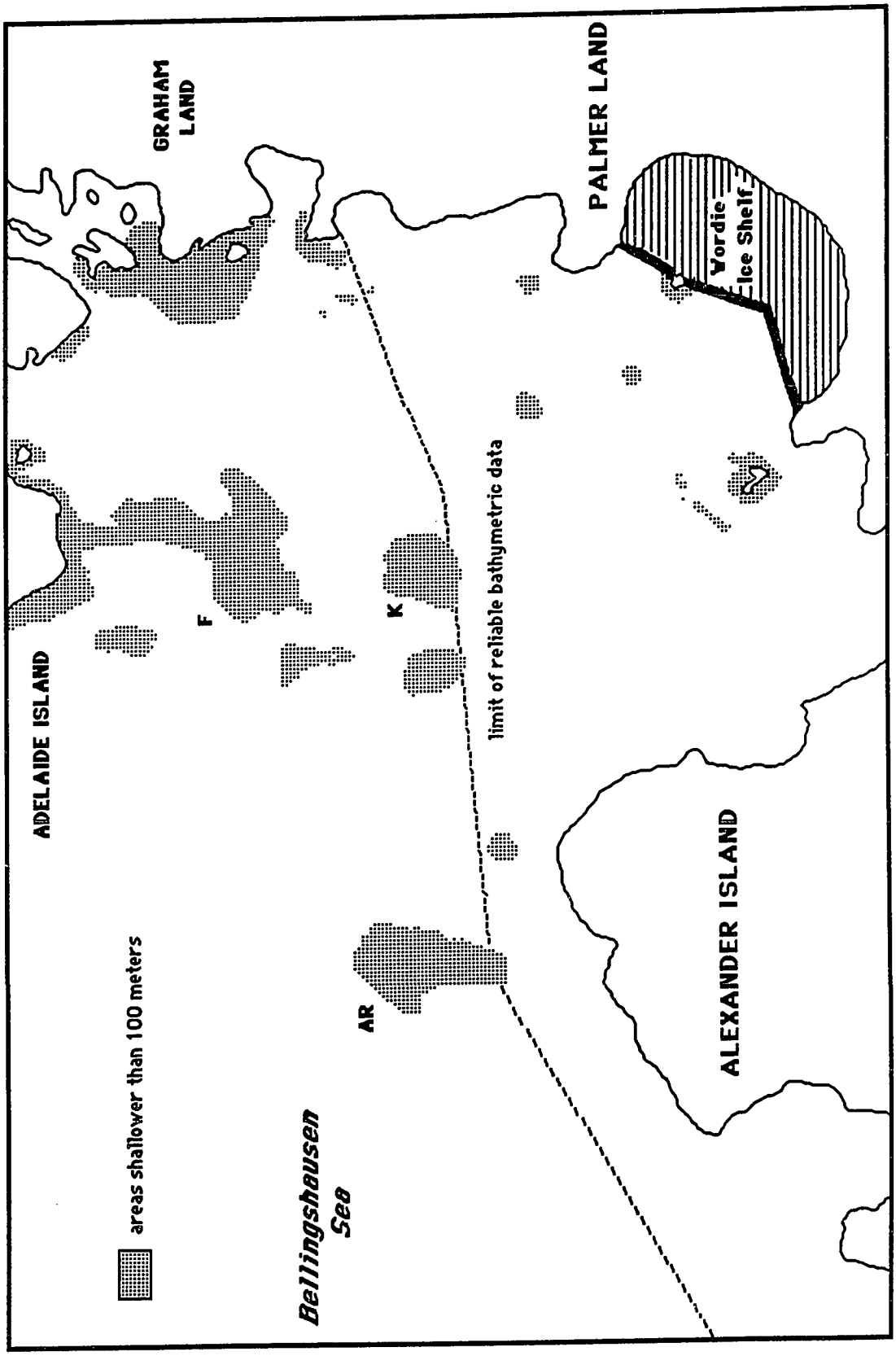

10-12 K
ADELAIDE ISLAND
minor flow
major flow
possible ice stream
ice shelf front
areas shallower than 100 meters
permanent pack sea ice
F
GRAHAM LAND
AR
K
?
PALMER LAND
ALEXANDER ISLAND

Figure 7.3: Location of areas in Marguerite Bay with present water depth of less than 100 m; the major banks in the bay are Alejandro Rios (AR), Faure (F), and Kirkwood (K). These areas would be above sea level during glacial maxima, and would serve as pinning points to buttress an ice shelf during the early stages of glacial retreat in the Holocene (10,000-12,000 ybp). Extensive regions of shallow depth are present seaward of the Graham Land coast, and possibly also the Palmer Land coast, although bathymetric data is not sufficient to confirm the nature of the nearshore area.


GRAHAM LAND
PALMER LAND
Wordie Ice Shelf
ADELAIDE ISLAND
F
K
limit of reliable bathymetric data
AR
ALEXANDER ISLAND
Bellingshausen Sea
areas shallower than 100 meters

ice caps of small offshore islands could not have been formed in situ solely by snow accumulation. He concluded that these glacial features were remnants of a recently retreated ice shelf, and as evidence cites the merging of a "fringing" glacier into the Wordie Ice Shelf at Cape Berteaux. The "fringing" glaciers are found in many places along the Fallières Coast (Fleming, 1940) and on the south coasts of Adelaide and Pourquoi-Pas islands.

The existence of transitional glacial-marine sediments provides key evidence for this expanded ice sheet stage of glacial retreat. These units are located immediately seaward of the shallow banks, which would be expected if the banks had once been the grounding line of an ice shelf. With further sea level rise and climatic amelioration, the grounding line retreated south, and the banks became pinning points. At this period sub-ice shelf sediments (B1 sandy mud units) were deposited as englacial/supraglacial debris melted out of the ice shelf. The lack of gravel-sized material, and the relatively low sand contents, indicates that the ice shelf no longer carried basal debris. To the west and north of the banks, compound glacial-marine sediments (B2) were being deposited underneath the permanent pack ice. Meltwater issuing from beneath the ice at the grounding line supplied the great majority of the fine material found in both B1 and B2 glacial-marine deposits.

The delivery of coarse material via the ice shelf to sites in the eastern bay led to a different style of sedimentation than found in the western bay. Glacial-marine sediments reflecting close proximity to the grounding line are found at only two sites in the eastern bay (65, P106); these units may represent deposition from the smaller glaciers

of the northern islands as they join the ice shelf. The sediment gravity flow deposits of the eastern bay are roughly correlatable to the transitional glacial-marine units, in the sense that subsequent deposition atop both sediment types is similar. The close proximity of the ice sheet grounding line would provide a much higher supply of unsorted material, and also a mechanism for initiation of mass flow ("ice push"). The sediment gravity flows may have eroded earlier transitional glacial-marine units, which have not been identified in the eastern bay.

The existence of an ice shelf in Marguerite Bay greatly restricted deposition, and the sedimentation rate was probably quite low. As basal melting was most likely taking place seaward of the grounding line, only sites within 10km or so of the grounding line would receive appreciable influx of ice-transported material. The wide areal expanse of ice shelf and permanent pack ice precluded any biogenic sediment input. Fine material carried by subglacial meltwater is by far the most important component of sediments deposited during this stage.

Retreat to present

The last 11,000 years saw a general consistent warming trend in Antarctica, with the warmest period occurring between 11,000 and 8000 years ago (Lorius et al, 1979). Due to the presence of numerous shallow banks and islands in Marguerite Bay that could act as pinning points, a slow retreat of the ice shelf was taking place. At some point in the last several thousand years, the floating ice divided into two separate ice shelves, the George VI and the Wordie. The permanent pack

ice filling the bay was also waning in response to the warmer climate, with retreat taking place much faster in the eastern than the western bay. The southwestern quarter was the last area to be clear of pack ice, perhaps as recently as 1000 years ago. Ultimately, the present day positions of the ice shelves and pack ice were reached, and it appears that the former may still be retreating (Doake, 1982). For much of the last 10,000 years, the northern half of the bay was seasonally free of ice.

A slow, orderly retreat of the ice shelf is quite a different scenario than that envisioned by other workers. It has been proposed that the grounded ice sheet filling the Ross Sea retreated very rapidly during the Holocene under the stress of rising sea level, without an extensive ice shelf, chiefly due to lack of pinning points on the outer shelf (Thomas, 1979; Anderson et al, 1984). In the central Ross Sea, basal till units are directly overlain by siliceous muds and oozes, with transitional units being very rarely found. Anderson et al (1984) proposed that this stratigraphy indicates extremely rapid retreat of the ice sheet, without intermediate ice shelf/meltwater stages. Clapperton and Sugden (1980) suggested that the George VI Sound may have been ice-free 6500 years ago, based on the discovery of pelecypod shells of that age in a moraine on Alexander Island. The present study does not support either of these scenarios for Marguerite Bay, and instead points to a steady, gradual retreat.

The main body of evidence for a slow waning of glacial/ice influence is found in the downcore progression of sedimentary units. The great majority of cores show a pattern of transitional

glacial-marine (B1) to compound glacial marine (B2) to siliceous mud deposition. This progression delineates the slow change from distal ice shelf through permanent pack ice to the modern seasonal ice environment. The restricted zone in which B1 deposition takes place may explain why this sediment type is thin or missing at a number of sites. The contacts between units are for the most part gradational, again denoting a gradual change in environment toward lessening impact of ice. A rapid ice shelf retreat should involve an abrupt change in sedimentary facies, which is not observed. Indeed, it appears that pack ice retreat from the southwestern quarter was very recent, judging by the [thinness] or total lack of the capping siliceous mud units as compared to other areas of the bay. Similarly, a total collapse of the ice shelves approximately 6500 years ago should be strongly reflected in the sediments of Marguerite Bay, which would presumably also be free of ice. The gradational sediment changes and the thin siliceous units capping the cores of the southwestern quarter argue strongly against a total collapse of the ice shelf in mid-Holocene time.

The earlier retreat of ice in the eastern bay is also evident in the cores. Eastern bay cores exhibit much thicker siliceous mud units than cores in the western bay, often ten times the thickness in cores of similar depth and setting. Although a higher sedimentation rate may be responsible for some of the discrepancy, it is doubtful that differences in rate could be the sole explanation for such a magnitude change. If higher rates of biogenic production were the cause of the greater thicknesses, a much higher IRD content would be expected in the thin units, which is not seen. Moreover, as the Palmer Land glaciers

furnished the great majority of ice for the ice shelf in the bay, reduction of ice supply from this source would generate a southern retreat of the ice front. The strong katabatic winds that today clear the eastern bay of seasonal ice each year may also have hastened the clearing of perennial ice in the past.

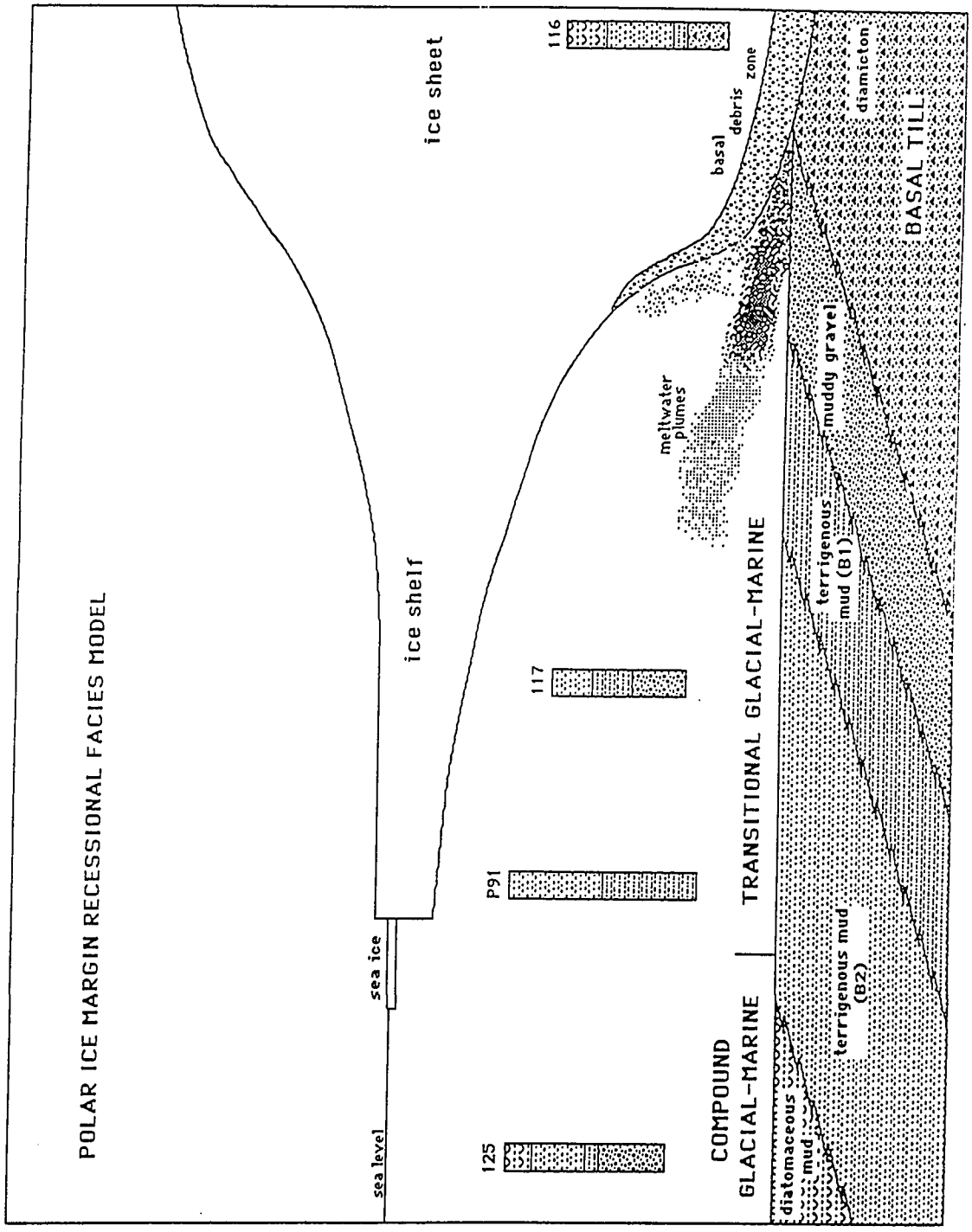
It is difficult to determine the time of commencement of the water column winnowing that is presently so prevalent in the bay, but it most likely began sometime during this more recent stage. As the sea surface cleared of permanent ice, both normal wind influences and wind-driven currents would begin to be felt in the water column. The sand/silt mode found in the B2 units is slightly finer than the mode found in the siliceous muds, and probably is a reflection of subglacial meltwater flow velocities. In fact, a large component of the sand mode in siliceous mud units may have been deposited via meltwater processes.

CHAPTER 8 FACIES MODEL

The downcore progression of sedimentary units showing increasing influence of ice is one of the most striking features of cores from the western bay. The general similarity of units downcore throughout the southwestern quarter has allowed the construction of an ice margin recessional facies model. The model depicts the different sedimentary environments found at the slowly retreating ice margin of a marine ice sheet, based on distinct sedimentary units in the cores.

The model incorporates five sedimentary environments -- grounded ice, ice shelf grounding line, proximal ice shelf, distal ice shelf/permanent pack ice, and open marine (Fig. 8.1). Basal till may be deposited in the grounded ice zone, although erosion or nondeposition is also possible. At the grounding line, where the glacial ice begins to float and becomes an ice shelf, debris in the basal debris zone of the ice is released by melting processes. The resulting deposit is a poorly sorted muddy gravel or gravelly mud, with much of the textural and lithologic features of basal till deposits, although the transitional glacial-marine (TGM) sediments have not been overcompacted. The pebbles and sands of these TGM sediments reflect a limited source area. Seaward of the grounding line, two distinct terrigenous muds are deposited -- a proximal mud with unsorted sand fraction (B1) and a distal mud with a very fine sand/coarse silt size mode (B2). The B1 mud

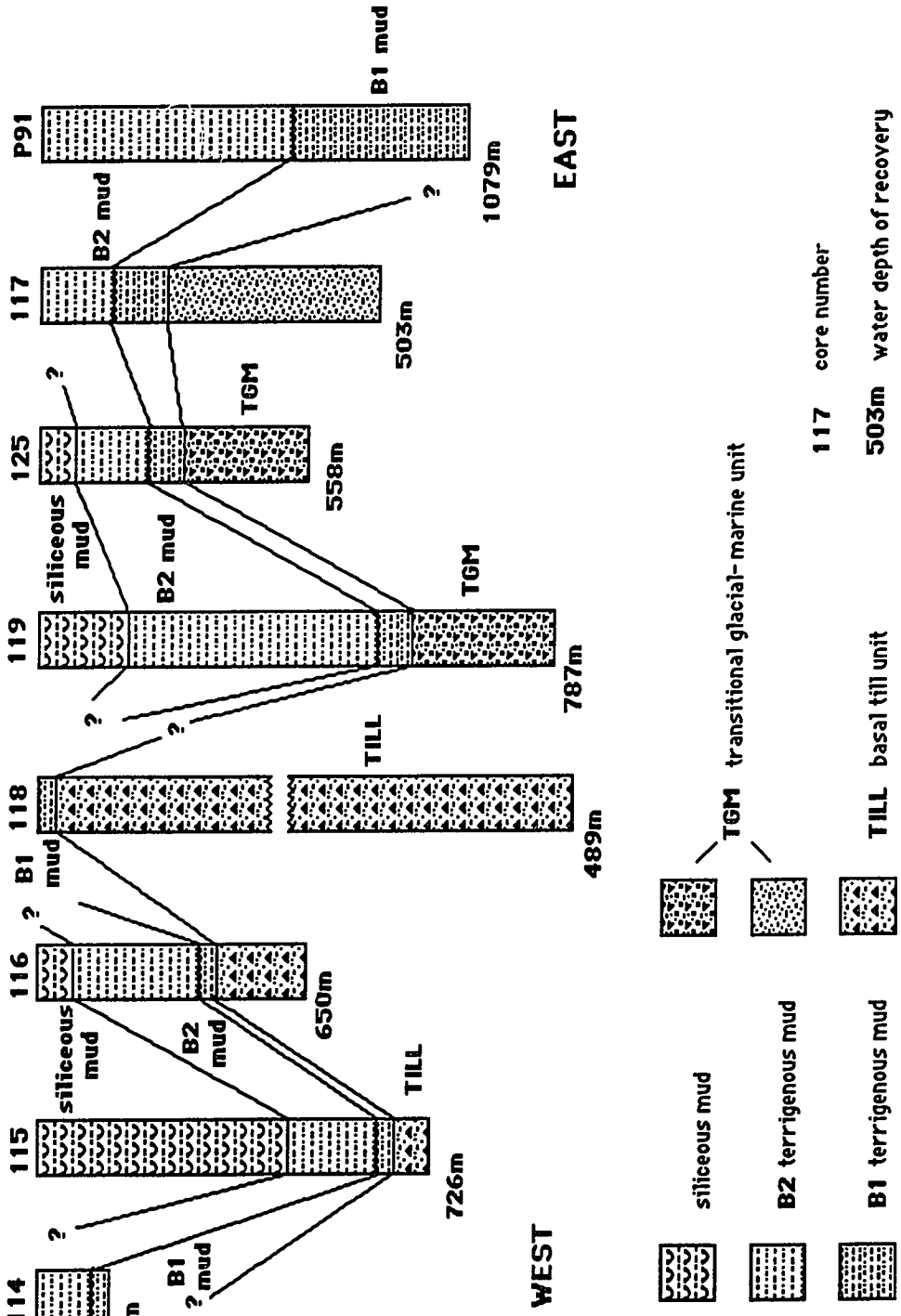
Figure 8.1: Polar ice margin recessional facies model, showing sedimentary zones and representative cores. Due to the limited extent of the muddy gravel (TGM) zone, deposits of this facies may be missing in the sedimentary record at any one site.


POLAR ICE MARGIN RECESSIONAL FACIES MODEL
ice sheet
ice shelf
sea ice
sea level
116
117
P91
125
basal debris zone
meltwater plumes
COMPOUND GLACIAL-MARINE
TRANSITIONAL GLACIAL-MARINE
diatomaceous mud
terrigenous mud (B2)
terrigenous mud (B1)
muddy gravel
diamicton
BASAL TILL

facies represents deposition of englacial material melting out of the base of the ice shelf. In the distal part of the ice shelf, this material has been released, and thus the sand content of B2 muds is very low. The sand mode is a result of current energy near the margins of the ice shelf, and may also be the consequence of meltwater current action. Meltwater plumes issuing from beneath the grounded ice carry great amounts of fine material, which is the most important constituent of these sub-ice shelf deposits. B2 muds may also reflect deposition under thick permanent pack ice, which would prohibit entry of icebergs carrying coarse exotic IRD. Open marine conditions allow the growth of siliceous microfossils, and these are an important component of the siliceous muds found in this zone. These muds may also have the current-derived sand mode found in B2 muds. Coarse IRD, including exotic lithologies and mineralogies, may be present in the siliceous muds, as ice-rafting may be a more influential process during ice sheet recession than in the present environment.

A number of cores in western Marguerite Bay penetrate the sedimentary zones of this model (Fig. 8.2). The most complete sequences are found in cores 115 and 116, which lack only the grounding line (TGM) facies. Cores 119 and 125 penetrate into the TGM unit, but do not reach the presumed basal till unit beneath. Siliceous mud units are missing atop cores 92, 114, 117, and 118, which may reflect a very recent retreat out of the permanent pack ice/distal ice shelf zone (see Chapter 4 for discussion of surface sediments). Cores 114, 117 and 125 show a sharp contact between the B1 and B2 muds, whereas cores 115, 116, 119, and P91 show a gradational contact. Although units are

Figure 8.2: Lithologic logs of cores in western Marguerite Bay, aligned roughly from west to east. Correlations between cores show a thickening of B1 units to the west, and a change from basal till to transitional glacial-marine units.


WEST
EAST
114
115
116
117
118
119
125
P91
713m
726m
650m
503m
489m
787m
558m
1079m
B1 mud
B2 mud
siliceous mud
TGM
TILL
?
transitional glacial-marine unit
core number
water depth of recovery
basal till unit
B1 terrigenous mud
B2 terrigenous mud
siliceous mud

sometimes missing, most often the coarse TGM unit, all cores show a steady recession from an ice-proximal to an ice-distal environment.

Several observations can be made regarding the facies model in relation to the cores. B2 units are thicker than B1 units in all cores where both units were penetrated; this reflects either a longer duration of distal ice shelf sedimentation, or a wider zone of B2 deposition with respect to B1. It is possible that both factors may be at work in Marguerite Bay. With high basal melting rates, it may be expected that both the grounding line and proximal ice shelf (B1) depositional zones are quite narrow, at least as compared to the distal ice shelf zone. Although this model proposes a steady ice retreat, this has been mainly facilitated by the numerous pinning points that could serve to buttress a retreating ice shelf. The retreat from one set of pinning points to a set further upstream would be rapid, though the retreat may encompass only a few tens of kilometers. This distance is most likely greater than the width of the grounding line depositional zone, and perhaps that of the proximal ice shelf zone. Therefore, it is possible for sediment from these zones to be absent from the downcore sequence at any one site. The missing grounding line zone unit above the basal till units in cores 115, 116, and 118 reflects that the initial recession was large enough to place these sites directly into the proximal ice shelf zone. The coarse TGM unit in core 119 was probably being deposited while ice was still grounded at the shallower site 118. The subsequent ice margin retreat placed both cores in the B1 mud zone.

The slow retreat of the ice shelf in Marguerite Bay has allowed separate facies to be deposited at a single site. This is quite different

than the sequence found in the Ross Sea, where basal tills are directly overlain by siliceous muds (Anderson et al, 1984). One important contrast in the two cases is the availability of pinning points in Marguerite Bay, thus avoiding the several hundred kilometer catastrophic recession of the ice in the Ross Sea as envisioned by Thomas and Bentley (1978). However, the crucial difference may be that the ice shelf in Marguerite Bay was primarily responding not to rising sea level, as in the Ross Sea, but to the gradual climatic amelioration taking place since the end of the late Wisconsin. It appears that ice on the Antarctic Peninsula would be more subject to climatic controls, as the present limits of ice shelves seem to be limited by climatic factors (Doake, 1982). The combination of climatic-induced retreat and the large number of pinning points to serve as buttresses makes the model of slow ice margin retreat in Marguerite Bay very plausible.

CHAPTER 9 CONCLUSIONS

1. Piston cores taken in Marguerite Bay reveal a fundamental difference in sedimentation between the eastern "inner" bay and the western "outer" bay. The eastern bay is characterized by thicker sequences of compound glacial-marine (CGM) sediments, primarily diatomaceous muds, underlain generally by sediment gravity flow deposits. The western bay has thin CGM units underlain by transitional glacial- marine (TGM) or basal till deposits.

2. Single-channel seismic reflection data recovered from the bay show a marked lack of sediment cover, with only a thin layer of sediment draped over acoustic basement, which may represent bedrock or older glacial deposits. The lack of any appreciable accumulation of sediment in the deep troughs of the bay gives credence to the theory that these troughs were avenues for grounded ice advance during glacial maxima, and strengthens the argument that these troughs were enlarged through glacial erosion.

3. The surface sediment distribution in the bay shows the predominance of diatomaceous muds, with a few small areas of terrigenous mud deposition. Ice-rafted debris is not an important component of modern deposits. Most surface sediments have a

moderately well-sorted sand fraction, reflecting the action of ephemeral wind-driven currents. Residual glacial-marine (RGM) deposits are found at water depths of less than 350m, indicating that current energy is felt to this depth.

4. The CGM units are generally much thicker in the eastern bay, probably reflecting hgher sedimentation rates in conjunction with a longer history of open water. The very fine sand mode found in the surface deposits is found throughout most CGM units, pointing to an environment much like that of the present. The western bay CGM deposits often show increased IRD components.

5. Clast shapes of pebbles sampled from CGM units in the bay suggest that high-level (englacial/supraglacial) transport is the most important mode of transport of ice-rafted pebbles now entering the bay. Pebbles from RGM units show a mixed signature, implying that basal debris zone transport may have been more important in the recent past.

6. The TGM units of the western bay fall into three categories: terrigenous muds with sorted sand fraction (B2); terrigenous muds with unsorted sand fraction (B1); and terrigenous gravelly muds. B2 muds are interpreted as distal ice shelf/permanent pack ice deposits, and are virtually devoid of IRD. B1 muds reflect a proximal ice shelf environment, receiving sand-sized material melting out of the base of the ice shelf. Meltwater silts are by far

the most important component of these muds. The gravelly muds represent depositon from melting of the basal debris zone of the ice sheet at the grounding line.

7. Basal tills, indicating deposition by grounded ice, were recovered in the southwest quarter of the bay at water depths greater than 700m. It is postulated that these units are late Wisconsin in age, and were deposited by ice flowing north from Alexander Island. The till units are virtually monolithologic, and this lithology (quartz-mica schist/gneiss) is found in outcrop in the Rouen Mountains, at the north end of Alexander Island.

8. Sediment gravity flows are found in many areas of the bay and constitute an important part of the Holocene sedimentary record. Debris flows and turbidites were recovered, attesting to the influence the bay's rugged bathymetry has on deposition. The frequency of sediment gravity flows increase downcore, implying that this mechanism was of greater importance during intervals when ice expanded into the bay.

9. A reconstruction of the glacial history of Marguerite Bay, based on the piston core stratigraphy, is proposed from the late Wisconsin to present time span. At the height of the last glacial maxima, ice was grounded at the seafloor throughout Marguerite Bay and possibly out to the continental shelf edge. Rising sea level, and more significantly climatic amelioration, caused the ice sheet to

uncouple from the seafloor and gradually retreat as an ice shelf. The final retreat to modern conditions was also slow, with the eastern bay clearing of ice before the western bay. The exact timing of this sequence of events awaits the acquisition of radiocarbon dates, the next step in the study of this area.

10. A polar ice margin recessional facies model has been developed, utilizing piston cores from the western bay. The model shows the various sedimentary environments found in a slowly retreating ice shelf situation, from open marine through sub-ice shelf to sub-grounded ice depositon. Due to the limited width of the proximal ice shelf and grounding line facies, these units may be missing at a particular site.

REFERENCES CITED

Adie, R.J., 1954, The petrology of Graham Land, I. The basement complex; Early Paleozoic plutonic and volcanic rocks, Falkland I. Depend. Surv., Scient. Rep. 11.

Adie, R.J., 1955, The petrology of Graham Land, II. The Andean granite-gabbro intrusive suite. Falkland I. Depend. Surv., Scient. Rep. 12.

Anderson, J.B., 1972, Nearshore glacial-marine deposition from modern sediments of the Weddell Sea, Nature, v. 240, p. 189-192.

Anderson, J.B., Kurtz, D.D., Domack, E.W., and Balshaw, K.M., 1980a, Glacial and glacial marine sediments of the Antarctic continental shelf, J. Geol., v. 88, p. 399-414.

Anderson, J.B., Domack, E.W., and Kurtz, D.D., 1980b, Observations of sediment-laden icebergs in Antarctic waters: implications to glacial erosion and transport, J. of Glaciology, v. 25, p. 387-396.

Anderson, J.B., Brake, C., Domack, E., Myers, N., and Wright, R., 1983a, Development of a polar glacial-marine sedimentation model from Antarctic Quaternary deposits and glaciological information, in Molnia, B. F., ed., Glacial-marine sedimentation, Plenum Press, p. 233-264.

Anderson, J.B., Brake, C., Domack, E.W., Myers, N.C., and Singer, J., 1983b, Sedimentary dynamics of the Antarctic continental shelf, in Oliver, R., and James, P., eds., Antarctic Earth Science, Australian Academy of Science, Canberra, p. 387-389.

Anderson, J.B., Brake, C.F., and Myers, N.C., 1984, Sedimentation on the Ross Sea continental shelf, Antarctica, Marine Geol., v. 57, p. 295-333.

Anderson, J.B., and Kurtz, D.D., 1985, The use of silt grain size parameters as a paleovelocity gauge: a critical review and case study, Geomarine Letters, v. 5, p. 55-59.

Andrews, B.A., 1984, A petrologic study of Weddell Sea sediments: implications for provenance and glacial history, unpublished Masters thesis, Rice University, Houston, 203pp.

Antarctic Journal of the United States, 1983, Weather data, National Science Foundation, Washington, v. 18, nos. 1-4.

Antarctic Journal of the United States, 1984, Weather data, National Science Foundation, Washington, v. 19, nos. 1-4.

Antarctic Journal of the United States, 1985, Weather data, National Science Foundation, Washington, v. 20, nos. 1-4.

Barker, P.F., 1982, The Cenozoic subduction history of the Pacific margin of the Antarctic Peninsula: ridge crest-trench interactions, J. Geol. Soc. London, v. 139, p. 787-801.

Blatt, H., Middleton, G., and Murray, R., 1980, Origin of sedimentary rocks, Prentice-Hall, New Jersey, 782 pp.

Bell, C.M., 1974, Geological observations in northern Alexander Island, BAS Bull., v. 39, p. 35-44.

Bell, C.M., 1975, Structural geology of parts of Alexander Island, BAS Bull., v. 41&42, p. 43-58.

Birkenmajer, K., 1984, Pre-Quaternary glaciations of West Antarctica: evidence from the South Shetland Islands, Polish Polar Research, v. 5, p. 319-329.

Bishop, J.F., and Walton, J.L., 1981, Bottom melting under George VI Ice Shelf, Antarctica, J. of Glaciology, v. 27, p. 429-447.

Boulton, G.S., 1978, Boulder shapes and grain-size distributions of debris as indicatiors of transports paths through a glacier and till genesis, Sedimentology, v. 254, p. 773-799.

Burn, R.W., 1984, The geology of the LeMay Group, Alexander Island, BAS Scient. Rep., no. 109, 65 pp.

Burn, R.W., and Thomson, M.R.A., 1981, Late Cenozoic tillites associated with intraglacial volcanic rocks, Lesser Antarctica, in Hambrey, M.J., and Harland, W.B., Earth's Pre-Pleistocene Glacial Record, Cambridge University Press, p. 199-203.

Care, B.W., 1983, Petrology of the Rouen Mountains, northern Alexander Island, BAS Bull., v. 52, p. 63-86.

Carey, S.W., and Ahmad, N., 1961, Glacial marine sedimentation, 1st International Symposium on Arctic Geology, Proc., v.2, p. 865-894.

Chriss, T., and Frakes, L.A., 1972, Glacial marine sedimentation in the Ross Sea, in Adie, R.J., ed., Antarctic Geology and Geophysics, Oslo, Universitetsforlaget, p. 747-762.

Clapperton, C.M., and Sugden, D.E., 1982, Late Quaternary glacial history of George VI Sound area, West Antarctica, Quat. Res., v. 18, p. 243-267.

Crabtree, R.D., 1981, Subglacial morphology in northern Palmer Land, Antarctic Peninsula, Annals of Glaciology, v. 2, p. 17-22.

Crabtree, R.D., Storey, B.C., and Doake, C.S.M., 1985, The structural evolution of George VI Sound, Antarctic Peninsula, Tectonophysics, v. 114, p. 431-442.

Crary, A.P., 1966, Mechanism of fjord formation indicated by studies of an ice-covered inlet, GSA Bull., v. 77, p. 911-930.

Curl, J.E., 1980, A glacial history of the South Shetland Islands, Antarctica, Insitute of Polar Studies, Ohio State University, Rep. 63, 116 pp.

Dalziel, I.W.D., and Elliot, D.H., 1971, Evolution of the Scotia Arc, Nature, v. 233, p. 246-252.

Davies, T.G., 1975, The physiography of part of northern Palmer Land, BAS Bull., v. 41&42, p. 99-111.

Denton, G., Hughes, T., and Karlén, W., 1986, Global ice-sheet system interlocked by sea level, Quat. Res., v. 26, p. 3-26.

Dewar, D.J., 1967, Some aspects of the topography and glacierization of Adelaide Island, BAS Bull., v. 11, p 37-47.

Dewar, G.J., 1970, The geology of Adelaide Island, BAS Scient. Rep. 57.

Doake, C.S.M., 1982, State of balance of the ice sheet in the Antarctic Peninsula, Annals of Glaciology, v.3, p. 77-82.

Domack, E.W., Anderson, J.B., and Kurtz, D.D., 1980, Clast shape as an indicator of transport and depositional mechanisms in glacial marine sediments: George V continental shelf, Antarctica, J. Sed. Petrol., v. 50, p. 813-820.

Domack, E.W., 1982, Sedimentology of glacial and glacial marine deposits on the George V - Adelie continental shelf, East Antarctica, Boreas, v. 11, p. 79-97.

Drewry, D.J., and Cooper, A.P.R., 1981, Processes and models of Antarctic glaciomarine sedimentation, Annals of Glaciology, v. 2, p. 117-122.

Drewry, D.J., ed., 1983, Antarctica: Glaciological and Geophysical Folio, Sheet 4, Cambridge, Scott Polar Institute.

Edwards, C. W., 1982, New paleontologic evidence of Triassic sedimentation in West Antarctica, in Craddock, C., ed., Antarctic geoscience, U. of Wisconsin Press, Madison, p. 325-329.

Fleming, W.L., 1940, Relic glacial forms on the western seaboard of Graham Land, Geogr. J., v. 96, p. 95-100.

Fleming, W.L., Stephenson, A., Roberts, B.B., and Bertram, G.C., 1938, Notes on the scientific work of the British Graham Land expedition, 1934-1937, Geogr. J., v. 91, p. 508-532.

Galehouse, J.S., 1971, Point counting, in Carver, R.E., ed., Procedures in Sedimentary Petrology, New York, Wiley-Interscience, p. 385-408.

Gledhill, A., Rex, D.C., and Tanner, P.W., 1982, Rb-Sr geochronology of rocks from the Antarctic Peninsula between Anvers Island and Marguerite Bay, in Craddock, C., ed., Antarctic geoscience, U. of Wisconsin Press, Madison, p. 315-323.

Grosval'd, M.G., and Glazovskiy, A.F., 1983, Glacial erosion of continental margins (the origin of fiords and troughs within glaciated shelves), Geomorfologiya, no.1, p. 3-14.

Hawkes, D.D., 1981, Tectonic segmentation of the northern Antarctic Peninsula, Geology, v. 9, p. 220-224.

Heap, J.A., 1964, Pack ice, in Priestley, R., Adie, R.J., and Robin, G. de Q., eds., Antarctic research, London, Butterworth, p. 308-317.

Hughes, T.J., 1981, Numerical reconstruction of paleo-ice sheets, in Denton, G., and Hughes, T., eds., The Last Great Ice Sheets, Wiley and Sons, N.Y., p. 222-260.

Jordan, C.F., Fryer, G.E., and Hemmen, E.H., 1971, Size analysis of silt and clay by hydrophotometer, J. Sed. Petrology, v. 41, p. 489-496.

King, L., 1964, Pre-glacial geomorphology of Alexander Island, in Adie, R.J., ed., Antarctic geology, Amsterdam, p. 53-64.

Krumbein, W.C., 1941, Measurement and geological significance of shape and roundness of sedimentary particles, J. Sed. Petrol., v. 11, p. 64-72.

Lennon, P.W., Loynes, J., Paren, J.G., and Potter, J.R., 1982, Oceanographic observations from George VI Ice Shelf, Antarctic Peninsula, Annals of Glaciology, v. 3, p. 178-183.

Lorius, C., Merlivat, L., Jouzel, J., and Pourchet, M., 1979, A 30,000-yr isotope climatic record from Antarctic ice, Nature, v. 280, p. 644-47.

Matthews, D.W., 1983a, Geology of Horseshoe and Lagotellerie islands, Marguerite Bay, Graham Land, BAS Bull., v. 52, p. 125-54.

Matthews, D.W., 1983b, Geology of Pourquoi-Pas Island, northern Marguerite Bay, Graham Land, BAS Bull., v. 52, p. 1-20.

Middleton, G.V., and Southard, J.B., 1977, Mechanics of sediment movement, SEPM Short Course notes no. 3, 191 pp.

Moyes, A.B., and Hamer, R.D., 1984, The geology of the Arrowsmith Peninsula and Blaiklock Island, Graham Land, Antarctica, BAS Bull., v. 65, p 41-55.

Myers, N.C., 1982, Marine geology of the western Ross Sea: implications for Antarctic glacial history, unpublished Masters thesis, Rice University, 234 pp.

Nichols, R.L., 1960, Geomorphology of Marguerite Bay area, Palmer Peninsula, Antarctica, GSA Bull., v. 71, p. 1421-50.

Orheim, O., and Elverhøi, A., 1981, Model for submarine glacial deposition, Annals of Glaciology, p. 123-127.

Pankhurst, R.J., 1982, Rb-Sr geochronology of Graham Land, Antarctica, J. Geol. Soc. London, v. 139, p. 701-711.

Pearson, M.R., and Rose, I.H., 1983, Dynamics of George VI Ice Shelf, BAS Bull., v. 52, p 205-220.

Potter, J.R., and Paren, J.G., 1985, Interaction between ice shelf and ocean in George VI Sound, Antarctica, in Jacobs, S.S., ed., Oceanology of the Antarctic Continental Shelf, Washington, American Geophysical Union, p. 35-58.

Potter, J.R., Paren, J.G., Loynes, J., 1984, Glaciological and oceanographic calculations of the mass balance and oxygen isotope ratio of a melting ice shelf, J. of Glaciology, v. 30, p. 161-170.

Renner, R.G., Dikstra, B.J., and Martin, J.L., 1982, Aeromagnetic surveys over the Antarctic Peninsula, in Craddock, C., Antarctic geoscience, U. of Wisconsin Press, Madison, p. 363-370.

Renner, R.G., Sturgeon, L.J., and Garrett, S.W., 1985, Reconnaissance gravity and aeromagnetic surveys of the Antarctic Peninsula, BAS Scient. Repts., no. 110, 49 pp.

Reynolds, J.M., 1981, The distribution of mean annual temperatures in the Antarctic Peninsula, BAS Bull., v. 54, p. 123-133.

Robin, G. de Q., 1979, Formation, flow, and disintegration of ice shelves, J. Glaciology, v. 24, p. 259-271.

Rowe, P.J., 1973, The geology of the area between Riley and Bertram glaciers, Palmer Land, BAS Bull., v. 35, p. 51-72.

Saunders, A.D., Weaver, S.D., and Tarney, J., 1982, The pattern of Antarctic Peninsula plutonism, in Craddock, C., ed., Antarctic geoscience, U. of Wisconsin Press, Madison, p. 305-314.

Schwertdfeger, W., 1984, Weather and climate in the Antarctic, Elsevier, New York, 261 pp.

Schwertdfeger, W., and Amaturo, L.H., 1979, Wind and weather around the Antarctic Peninsula, University of Wisconsin Press, Madison, 65 pp.

Singer, J., 1987, Terrigenous, biogenic, and volcaniclastic sedimentation patterns of the Bransfield Strait and bays of the northern Antarctic Peninsula: implications for Quaternary glacial history, unpublished PhD dissertation, Rice University, 342 p.

Skinner, A.C., 1973, Geology of northwestern Palmer Land between Eureka and Meiklejohn Glaciers, BAS Bull., v. 35, p. 1-22.

Smellie, J.L., 1981, A complete arc-trench system recognized in Gondwana sequences of the Antarctic Peninsula region, Geol. Mag., v. 118, p. 139-159.

Smith, M.J., 1985, Marine geology of the northwestern Weddell Sea and adjacent coastal fjords and bays: implications for glacial history, unpublished Masters thesis, Rice University, 151 pp.

Storey, B.C., and Garrett, S.W., 1985, Crustal growth of the Antarctic Peninsula by accretion, magmatism and extension, Geol. Mag., v. 122, p. 5-14.

Stuiver, M., Denton, G., Hughes, T., and Fastook, J., 1981, History of the marine ice sheet in West Antarctica during the last glaciation: a working hypothesis, in Denton, G., and Hughes, T., The Last Great Ice Sheets, Wiley and Sons, N.Y., p. 375.

Sugden, D.E., and Clapperton, C.M., 1980, West Antarctic ice sheet fluctuations in the Antarctic Peninsula area, Nature, v. 286, p. 378-381.

Sugden, D.E., and Clapperton, C.M., 1981, An ice-shelf moraine, George VI Sound, Antarctica, Annals of Glaciology, v. 2, p. 135-141.

Tchernia, P., and Jeannin, P.F., 1980, Observations on Antarctic East Wind Drift using tabular icebergs tracked by satellite Nimbus F, Deep Sea Res., v. 27A, p. 467-474.

Thomas, R.H., 1979, Ice shelves: a review, J. Glaciology, v. 24, p. 273-286.

Thomas, R.H., and Bentley, C.R., 1978, A model for Holocene retreat of the West Antarctic Ice Sheet, Quat. Res., v. 2, p. 150-170.

Thomson, M.R.A., and Pankhurst, R.J., 1983, Age of post-Gondwanian calc-alkaline volcanism in the Antarctic Peninsula region, in Oliver, R., and James, P., eds., Antarctic Earth Science, Australian Academy of Science, Canberra, p. 328-333.

United States Navy, 1974, Antarctic ice charts 1973-74, United States Navy Fleet Weather Facility, Suitland, Maryland.

United States Navy, 1976, Antarctic ice charts 1975-76, United States Navy Fleet Weather Facility, Suitland, Maryland.

United States Navy, 1978, Antarctic ice charts 1977-78, United States Navy Fleet Weather Facility, Suitland, Maryland.

Vanney, J.R., and Johnson, G.L., 1976, Geomorphology of the Pacific continental margin of the Antarctic Peninsula, in Hollister, C.D., and others, Initial reports of the Deep Sea Drilling Project, v. 35, p. 279-289.

Weaver, S.D., Saunders, A.D., and Tarney, J., 1982, Mesozoic-Cenozoic volcanism in the South Shetland Islands and the Antarctic Peninsula: geochemical nature and plate tectonic significance, in Craddock, C., ed., Antarctic geoscience, U. of Wisconsin Press, Madison, p. 263-272.

Wright, R., and Anderson, J.B., 1982, The importance of sediment gravity flow to sediment transport and sorting in a glacial marine environment: Weddell Sea, Antarctica, GSA Bull., v. 93, p. 951-963.

Wyeth, R.B., 1977, The physiography and significance of the transition zone between Graham Land and Palmer Land, BAS Bull., v. 46, p. 39-58.

APPENDIX 1

CORE AND BOTTOM GRAB LOCATIONS

-- all locations are given as latitude S/longitude W
-- TC = trigger core
GRAB = Dietz-LaFonde or Shipek bottom grab
NR = no recovery

CORE/GRAB	LOCATION	WATER DEPTH (meters)	CORE LENGTH (cm)	OTHER
DEEP FREEZE 85				
DF85-64	67°46.6/68°15.1	399		GRAB
DF85-65	67°46.1/68°16.1	358	119	
DF85-66	67°48.3/68°06.3	859	597	GRAB
DF85-67	67°55.9/68°32.8	412	188	GRAB
DF85-68	67°57.6/68°25.1	576	54	GRAB
DF85-69	67°59.9/68°24.8	256	NR	
DF85-70	68°00.1/68°28.5	207		GRAB
DF85-71	67°59.2/68°34.0	607	217	GRAB
DF85-72	67°54.9/68°26.9	808	716	TC
DF85-73	68°06.1/68°33.5	275		GRAB
DF85-74	68°06.1/68°34.1	338	105	GRAB
DF85-75	68°05.5/68°26.6	366	261	
DF85-76	68°05.4/68°07.5	594	280	
DF85-77	68°05.1/67°52.5	316	55	GRAB
DF85-78	68°08.7/68°04.3	470	71	
DF85-79	68°11.7/68°15.2	485	514	GRAB
DF85-80	68°14.3/68°23.0	275	NR	GRAB
DF85-81	68°14.6/67°04.2	421	205	GRAB

CORE/GRAB	LOCATION	WATER DEPTH (meters)	CORE LENGTH (cm)	OTHER
DF85-82	68°14.4/67°30.2	275	131	
DF85-83	68°17.9/67°42.0	155		GRAB
DF85-84	68°16.8/67°54.5	329	191	GRAB
DF85-85	68°16.3/68°02.1	406	BAGGED	
DF85-86	68°15.7/68°11.0	448	274	GRAB
DF85-87	68°15.2/68°19.9	622	595	GRAB
DF85-88	68°17.5/68°31.5	220	137	
DF85-89	68°17.5/68°54.9	201		GRAB
DF85-90	68°19.9/69°32.2	302	13	GRAB
DF85-91	68°20.9/69°40.7	153		GRAB
DF85-92	68°26.7/69°46.2	348	123	GRAB
DF85-114	68°19.9/70°49.5	713	44	
DF85-115	68°26.6/70°45.8	726	209	
DF85-116	68°29.0/70°36.0	650	144	
DF85-117	68°29.7/70°12.5	503	185	
DF85-118	68°18.9/70°27.5	489	481	
DF85-119	68°20.6/70°22.8	787	287	
DF85-120	68°17.6/69°49.4	933	BAGGED	
DF85-121	68°14.2/69°49.1	412	BAGGED	
DF85-122	68°15.9/69°33.2	676	284	
DF85-123	68°15.1/69°21.0	538	251	
DF85-124	68°12.7/69°29.0	215	BAGGED	
DF85-125	68°13.9/69°40.7	558	141	
DF85-126	68°10.3/69°41.0	860	120	TC
DF85-127	68°08.5/69°36.3	247		GRAB
DF85-128	68°02.5/69°37.3	774	295	
DF85-129	67°49.9/67°34.9	256	144	GRAB
DF85-130	67°54.3/67°39.6	137		GRAB
DF85-131	67°50.7/67°32.2	247	BAGGED	GRAB
DEEP FREEZE 86				
DF 86-89	68°19.7/70°24.0	695	45	
DF 86-90	68°30.1/70°55.6	228		
DF 86-91	68°28.7/70°05.6	1079	227	TC
DF 86-92	68°26.7/70°03.1	1370	46	

CORE/GRAB	LOCATION	WATER DEPTH (meters)	CORE LENGTH (cm)	OTHER
DF 86-93	68°19.0/68°39.6	210		
DF 86-94	68°15.8/68°33.1	641	168	TC
DF 86-95	68°17.3/67°52.9	454	17	
DF 86-96	68°19.1/68°17.9	723	50	
DF 86-97	68°17.5/67°56.8	604	45	
DF 86-98	68°27.9/67°44.2	493	138	TC
DF 86-99	68°14.1/67°45.7	292	140	TC
DF 86-100	68°08.3/67°42.3	406	130	TC
DF 86-101	68°03.6/67°40.3	258	222	TC
DF 86-102	67°58.2/67°37.2	238	244	TC
DF 86-103	67°53.3/67°37.1	370	165	TC
DF 86-104	67°53.6/67°38.2	300	25	
DF 86-105	67°51.5/67°49.0	219	BAGGED	TC
DF 86-106	67°49.2/67°58.9	520	175	TC
DF 86-107	67°50.1/68°12.0	915	45	
DF 86-108	67°53.7/68°21.8	840	40	
DF 86-110	67°55.1/68°25.4	832	NR	TC
DF 86-111	67°55.7/68°25.1	815	282	TC
DF 86-112	68°01.9/68°17.2	490	143.5	TC
DF 86-113	68°02.1/68°17.9	470	40	
DF 86-114	68°07.9/67°50.8	480	43	
DF 86-115	68°10.4/68°20.1	630	40	
DF 86-116	68°09.5/68°24.5	503	246	TC
DF 86-117	68°11.2/68°39.5	293	BAGGED	
DF 86-118	68°04.6/69°16.9	582	302	TC
DF 86-119	67°57.0/69°51.8	567	NR	TC

APPENDIX 2

COARSE SAND GRAIN COUNTS

Mineralogic and lithologic percentages of coarse sand (-1 to 1 Φ) taken from basal till and transitional glacial-marine (TGM) units in western Marguerite Bay.

qtz quartz
fld feldspar
mrf metamorphic rock fragments
msf metasedimentary rock fragments
fpf felsic plutonic rock fragments
mpf mafic plutonic rock fragments
mvf mafic volcanic rock fragments
o other
total total number of grains counted

core depth (cm)	qtz	fld	mrf	msf	fpf	mpf	mvf	o	total
DF85-118 (basal till)									
22	46.5	2.9	48.2	1.3	-	-	-	1.0	477
62	34.7	0.1	64.5	0.1	-	-	-	-	346
102	38.1	0.1	59.4	0.1	-	-	-	1.0	473
142	38.7	1.6	59.1	-	-	-	-	0.1	494
178	46.3	1.2	52.5	-	-	-	-	-	259
202	31.3	0.7	67.3	0.3	-	-	-	0.3	300
242	24.6	-	73.9	0.1	-	-	-	1.1	349
282	22.0	1.1	75.8	-	-	-	-	1.1	368
322	26.6	0.9	71.4	-	-	-	-	1.2	346
362	28.7	0.6	68.4	0.3	-	-	-	2.3	345
402	29.2	0.3	68.1	-	-	-	-	2.1	339
462	20.6	0.3	75.5	0.7	-	-	-	2.9	306
DF85-115 (basal till)									
202	14.2	2.7	80.4	1.3	-	-	-	1.3	225

core depth (cm)	qtz	fld	mrf	msf	fpf	mpf	mvf	o	total
DF85-116 (basal till)									
108	19.7	1.4	77.2	-	-	-	-	1.7	360
134	27.4	-	69.2	0.6	-	0.9	-	2.2	325
core depth (cm)	**qtz**	**fld**	**mrf**	**msf**	**fpf**	**mpf**	**mvf**	**o**	**total**
DF85-92 (TGM)									
8	20.3	16.9	8.3	11.5	32.7	0.9	2.0	7.4	349
38	15.2	25.4	5.7	18.1	28.6	-	6.7	0.3	315
72	17.7	19.8	12.1	19.5	25.4	-	6.2	-	339
108	15.5	19.1	11.7	24.6	19.1	-	10.0	0.6	309
core depth (cm)	**qtz**	**fld**	**mrf**	**msf**	**fpf**	**mpf**	**mvf**	**o**	**total**
DF85-117 (TGM)									
42	11.2	2.7	70.0	6.7	7.2	0.6	1.0	0.6	330
82	15.7	4.1	55.4	16.9	5.0	-	2.8	0.3	319
125	11.2	0.9	68.3	7.1	9.6	-	3.1	-	322
170	10.1	0.6	69.9	9.2	7.1	-	3.1	-	326
DF85-119 (TGM)									
202	6.9	2.4	7.3	16.7	24.0	0.3	42.3	-	246
216	7.0	2.6	13.1	20.8	24.9	0.3	34.5	0.3	313
236	9.6	4.8	17.6	14.7	22.4	-	30.7	0.3	313
272	11.2	2.6	20.8	16.3	18.6	0.3	30.4	-	312
core depth (cm)	**qtz**	**fld**	**mrf**	**msf**	**fpf**	**mpf**	**mvf**	**o**	**total**
DF85-125 (TGM)									
92	13.5	11.9	10.4	19.2	33.0	2.8	8.8	0.3	318
122	19.3	11.8	7.8	13.4	32.1	2.8	12.8	1.9	321
DF85-126 (TGM)									
52	11.3	10.7	20.7	8.8	25.7	2.5	18.5	1.6	319

APPENDIX 3

TEXTURAL DATA

core depth in cms (BG=bottom grab; SG= Shipek grab; PC=bagged piston core)
g/s/z/c gravel/sand/silt/clay
gravel/sand//silt+clay
mΦ mean grain size in Φ (see **analysis**)

dominant mode in Φ units
analysis **F** full (hydrophotometer + settling tube)
H hydrophotometer only (4.75 to 8 Φ)
S settling tube only (-1 to 4.75 Φ)
note: the **mΦ**, **s.d.**, and **dominant mode** entries **s.d.** standard deviation are based on the first analysis noted in the **analysis** column

comments sediment types
A1 diatomaceous mud with unsorted sand fraction
A2 diatomaceous mud with sorted sand fraction
B1 terrigenous mud with unsorted sand fraction
B2 terrigenous mud with sorted sand fraction
RGM residual glacial-marine
TGM transitional glacial-marine
till basal till
CGM compound glacial-marine
flow-in disturbed core
SGF sediment gravity flow
2/1 mixed unit, with first mud type predominating

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
DEEP FREEZE 85 SAMPLES							
85-64	SG	2/26//72	3.48	1.54	3.50	S	A2
85-65	106		1.67	1.91	1.50	S	B1
	116	41/29//30					CGM? TGM?
85-66	BG	0/3//97	3.31	1.84	4.00	S	A2
	5	0/1//99					A2
	42	0/2//98					A2
	92	0/2//98					A2
	152	0/1//99					A2
	202	0/3//97					A2
	252	0/3//97					A2
	302	0/3//97					A2
	352	0/3//97					A2

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
85-66	402	0/2//98					A2
	452	0/2//98					A2
	486	0/2//98					A2
	502	0/2//98					A2
	535	0/1//99					A2
	578	0/5//95					A2
85-67	BG	4/7//89	3.37	1.78	4.25	S	A2
85-68	BG	3/5//92	3.28	1.78	3.50	S	A2
85-71	5	0/5//95					A2?
	62	0/8//92					A2?
	102	0/5//95					A2?
	145	0/9//91					A2?
	175	0/5//95					A2?
	208	0/5//95					A2?
85-73	SG	1/5//94	3.38	1.85	4.25	S	A2
85-74	BG	3/4//93	3.34	1.89	4.00	S	A2
	18					S	A2
	44	4/8//88	3.19	2.01	4.00	S	A2
	68	0/9//91	3.51	1.68	3.75	S,H	A/B2
	94	0/18//82	2.82	1.88	4.25	S	B1
85-75	5	1/10//89	3.00	2.05	3.75	S	A2
	25	0/7//93					A2?
	62	0/9//91					flow-in
	122	0/8//92					flow-in
	182	0/10//90					flow-in
	232	0/9//91					flow-in
85-77	BG	23/37//40	1.88	1.92	0.50	S	RGM
	4	23/62//15	1.60	1.92	0.75	S	RGM
	18	35/25//40	2.00	2.01	2.00	S	RGM
	32	12/37//51	2.12	2.04	0.50	S	RGM
	44	43/44//13					RGM
85-79	BG	0/3//97	2.99	2.20	3.75	S	A2/1
	8	2/7//91					
	46	3/6//91					
	86	0/4//96					
	126	0/5//95					
	166	0/3//97					
	196	0/5//95					
	218	2/16//82	2.28	1.97	3.00	S	B1
85-80	BG	52/26//22	2.05	2.02	3.00	S	RGM

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
85-81	BG	0/3//97	3.42	1.66	4.00	S	B2
	8	0/4//96				H	B2
	28	0/7//93	2.90	2.20	3.75	S, H	B2
85-82	5	1/30//69	3.15	1.61	3.50	S, H	B2
	25	6/35//59	2.70	1.69	2.75	S, H	B1
	55	24/42//34					RGM
	85	13/49//38					RGM
	122	23/38//39					RGM
85-83	SG	49/18//33	2.03	2.13	1.50	S	RGM
85-84	5	0/15//85	3.16	1.84	3.50	S	A2
	22	1/32//67	2.39	1.89	2.25	S	B1
	52	8/50//42					flow-in
	92	19/51//30					flow-in
	132	18/56//26					flow-in
	172	16/56//28					flow-in
85-86	BG	0/2//98					A2
	8	0/4//96					A2
85-87	BG	0/2//98					A2
	8	0/3//97					
	52	0/3//97					
	102	0/3//97					
	152	0/5//95					
	202	0/5//95					
	262	0/4//96					
	302	0/5//95					
	352	3/5//92					
	402	0/4//96					
	452	0/4//96					
	482	0/3//97					
	502	0/8//92					
	518	0/6//94					
85-87	536	0/12//88					
	552	0/12/71/17	5.67	2.56	5.00	F	B2/1
	565	0/4/74/22	6.14	1.95	6.50	F	A2/1
	586	0/11/71/18	5.74	2.19	7.00	F	B2
85-89	SG	0/30//70	3.69	1.26	3.50	S	RGM
85-90	BG	41/29//30	1.51	2.08	0.75	S	RGM

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
85-92	BG	46/22//32	1.44	1.98	0.25	S	RGM
	8	40/43//17	1.41	1.81	0.25	S	RGM
	38	33/26/35/6	3.11	3.17	2.25	F	TGM?
	72	36/36/21/7	2.98	3.29	0.25	F	TGM?
	108	34/36/24/6	3.04	3.29	0.25	F	TGM?
85-114	4	0/4/71/25	6.13	2.07	7.25	F	B2
	34	0/9/72/19	6.05	2.37	6.25	F	B1
85-115	5	0/4/75/21	6.41	1.60	6.25	H	A2
	45	0/2/76/21	6.17	1.83	5.75	F	A2
	72	0/4/81/15	6.11	1.68	6.50	F	A2
	102	2/4/73/20	6.36	1.51	6.25	H	A2
	142	0/1/65/34	6.66	1.28	6.75	H	B2
	172	0/0/76/24	6.27	1.69	7.50	H	B2
	188	0/1/75/24	6.24	1.61	7.00	H	B2
	202	30/34/28/8	3.78	3.25	6.75	F	till
85-116	6	0/6/74/20	5.98	2.07	6.50	F	A1
	22	0/1/58/41	6.27	1.61	7.75	H	B2
	72	0/1/79/20	6.37	1.47	5.75	H	B2
	95	2/2/79/17	5.87	1.89	5.50	F	B1
	108	20/35/39/6	4.12	3.01	2.00	F	till
	134	3/38/52/7	4.31	2.99	6.25	F	till
85-117	5	0/13/60/27	5.80	2.45	7.25	F	B2
	32	0/15/69/16	5.43	2.50	6.00	F	B2
	42	4/36/51/9	4.52	2.84	5.75	F	B1
	62	0/29/59/12	5.01	2.38	5.50	F	B2?
	82	15/36/39/10	3.98	2.95	5.75	F	TGM
	105	6/41/44/9	4.02	2.92	5.25	F	TGM
	125	13/36/44/7	4.17	2.81	5.00	F	TGM
	170	10/49/36/5	3.61	2.77	3.25	F	TGM
85-118	5	0/10/69/21	5.84	2.41	6.50	F	B1
	22	17/36/41/6	3.86	3.37	7.00	F	till
	62	15/39/39/7	3.73	3.06	5.00	F	till
	102	27/36/32/5	3.60	3.22	5.75	F	till
	142	18/36/35/11	3.97	3.46	6.50	F	till
	178	11/44/39/6	3.60	3.28	6.50	F	till
	183	5/43//52	2.30	1.61	3.25	S	???
	202	15/29/49/7	4.39	3.24	6.25	F	till
	242	34/27/33/6	4.31	3.01	6.00	F	till
	282	8/29/52/10	4.74	3.12	6.50	F	till
	322	11/30/52/7	4.45	2.96	5.50	F	till
	362	9/31/54/6	4.44	3.05	6.50	F	till
	402	13/37/43/7	4.12	3.20	6.00	F	till
	462	12/33/46/8	4.11	2.97	5.50	F	till

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
85-119	6	0/3/55/42	6.80	1.18	6.50	H	A
	44	3/7/56/34	5.91	2.54	7.00	F	A1
	54	0/5/75/20	6.28	1.60	5.25	H	B2?
	94	0/4/80/16	5.90	1.98	6.00	F	B2
	144	0/2/71/27	6.27	1.69	6.25	F	B2
	184	0/5/75/20	6.00	1.88	5.75	F	B2
	202	3/10/45/42	5.38	2.73	7.75	F	B1
	216	14/34/37/15	4.13	3.36	1.25	F	TGM
	236	47/23/23/7	3.73	3.47	7.25	F	TGM
	272	20/34/36/10	3.47	3.41	-0.75	F	TGM
85-122	5	0/3//77	2.72	2.20	4.00	S	B1
	25	18/20/37/25	4.59	3.17	7.75	F	SGF
	62	41/15/31/13	4.71	3.16	5.50	F	SGF
	92	8/28/49/15	4.46	3.22	6.25	F	SGF
	118	25/34/35/6	3.73	3.18	5.25	F	SGF
	162	15/35/38/11	3.79	3.18	2.00	F	SGF
	202	8/36/44/12	3.84	3.06	5.00	F	SGF
	262	37/24/33/6	3.78	3.13	5.00	F	SGF
85-125	5	1/4/70/25	6.49	1.86	7.25	F	A2/1
	25	0/3/78/19	5.98	1.77	5.25	F	B2
	52	0/3/76/21	6.12	1.84	6.25	F	B2
	68	0/4/71/25	6.24	2.14	6.50	F	B1
	92	16/51/26/7	3.14	2.98	1.25	F	SGF?
	122	40/23/30/7	3.67	3.20	6.50	F	SGF?
85-126	5	3/8/73/16	5.82	2.32	7.75	F	A2/1
	22	0/4/62/34	6.00	2.03	7.75	F	B2/1
	52	2/21/56/22	5.20	3.13	7.50	F	B1
	62	53/22/20/5	3.52	3.40	6.75	F	TGM
	92	38/38//24					TGM
	116	35/37/20/8	3.00	3.32	6.00	F	TGM
85-127	SG	0/87//13	2.67	1.46	3.00	S	RGM
85-128	5	1/10/71/18	5.87	2.46	6.25	F	A1
	45	1/13/76/10	5.33	2.58	5.00	F	A1
	84	37/10/44/9	5.47	2.98	6.25	F	A1
	112	4/15/68/13	5.48	2.79	6.50	F	A1
	162	1/12/69/18	5.75	2.71	7.75	F	A1
	202	1/14//86	2.02	2.23	2.00	S	A1
	242	1/13/65/21	5.79	2.87	7.50	F	A1
	264	21/11//68	2.04	2.11	1.25	S	A1
	288	6/10/64/20	5.91	2.74	7.50	F	A1

sample	core depth	g/s/z/c	mΦ	s.d.	dominant mode	analysis	comment
85-129	BG	0/10//90	3.53	1.75	4.00	S	A2
	5	0/22//78					A2
	22	0/15//85	3.35	1.55	3.50	S	A2
	62	0/13//87	2.86	1.85	3.50	S	A1/2
	95	13/40//47					SGF
	108	0/15//85	2.70	1.83	3.50	S	B1/2
	144	1/39//60	2.65	1.57	2.50	S	B1?
DEEP FREEZE 86 SAMPLES							
86-91	5	0/2/66/32	6.42	1.80	7.75	F	B2/1
	52	1/3/66/30	5.99	2.07	5.25	F	B2/1
	102	0/3/75/22	6.09	1.87	5.50	F	B2
	148	1/5/66/28	6.05	2.22	5.50	F	B1
	192	14/5/59/22	6.06	2.23	5.50	F	B1
86-98	5	0/2//98	3.62	1.50	4.00	S	A2
86-100	5	2/2//96	3.33	1.84	4.25	S	A2
86-101	5	14/40//46	2.19	1.80	2.75	S	RGM
86-102	5	0/4//96	3.70	1.41	4.50	S	A2
86-106	5	0/3//97	3.58	1.57	4.25	S	A2
	138	0/8//92	2.96	1.82	3.50	S	B1/2
	168	25/47/22/6	2.74	3.17	0.25	S	TGM?
86-116	5	0/2//98	3.60	1.60	4.25	S	A2
86-117	PC	39/45//16	1.62	1.88	0.00	S	RGM
86-118	5	0/3//97	3.70	1.56	4.25	S	A2
	22	0/5/77/18	6.18	1.83	6.50	F	A2
	62	0/6/82/12	6.07	1.90	6.00	F	A2
	112	0/11/69/20	5.82	2.34	6.25	F	B1
	152	21/33/40/6	3.81	3.07	5.00	F	SGF?
	182	0/23/64/13	4.87	2.69	5.00	F	B1? SGF?
	215	0/24/66/10	5.02	2.34	5.50	F	B2? SGF?
	265	1/27/51/22	4.53	2.96	5.00	F	SGF
	288	2/34/51/13	4.36	3.17	5.50	F	SGF

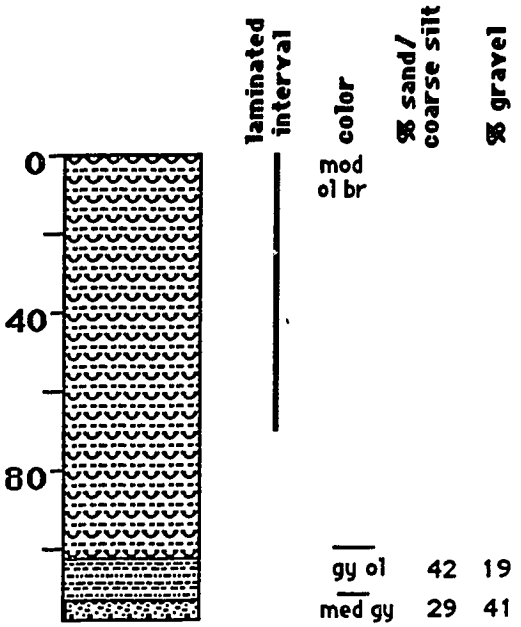
APPENDIX 4

LITHOLOGIC LOGS -- PISTON CORES

DF85-65 NORTHEASTERN QUARTER

358 m

67°46.1'/ 68°16.1'W
119 cm



description

0-102cm: **diatomaceous mud**
- sandy, with abundant organic matter; laminated 0-48cm, faintly laminated 48-68cm

102-114cm: **muddy sand (B1)**
- gravelly, with rare diatoms, poorly sorted coarse fraction

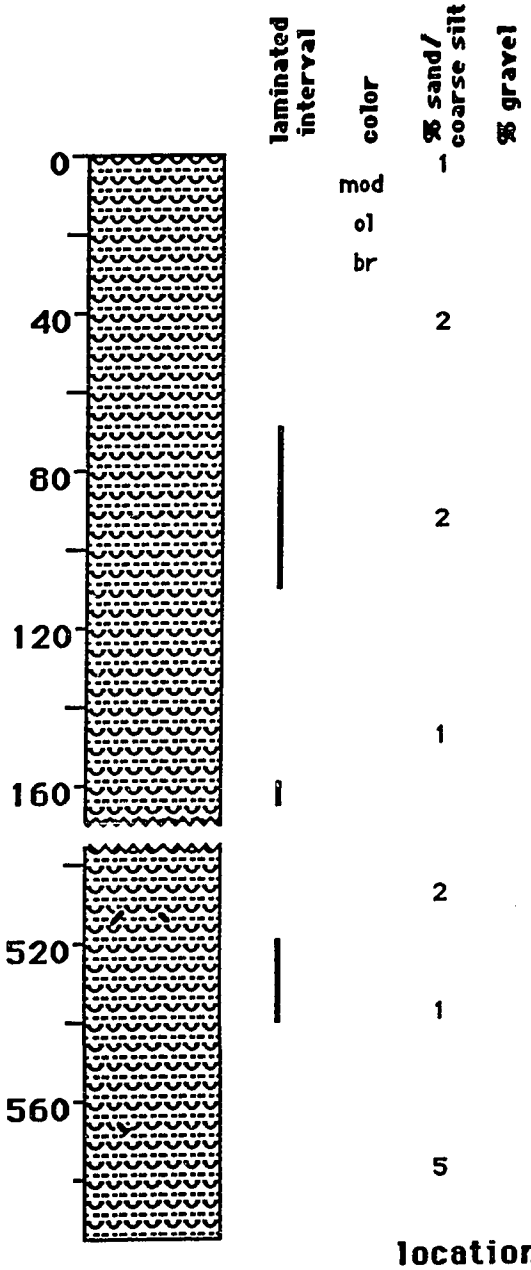
114-119cm: **diamicton**
- unsorted sandy gravel, no biogenic or organic material

location: western flank, Adelaide Trough

DF85-66 NORTHEASTERN QUARTER

859m

67°48.3'S/68°06.3'W
597cm



description

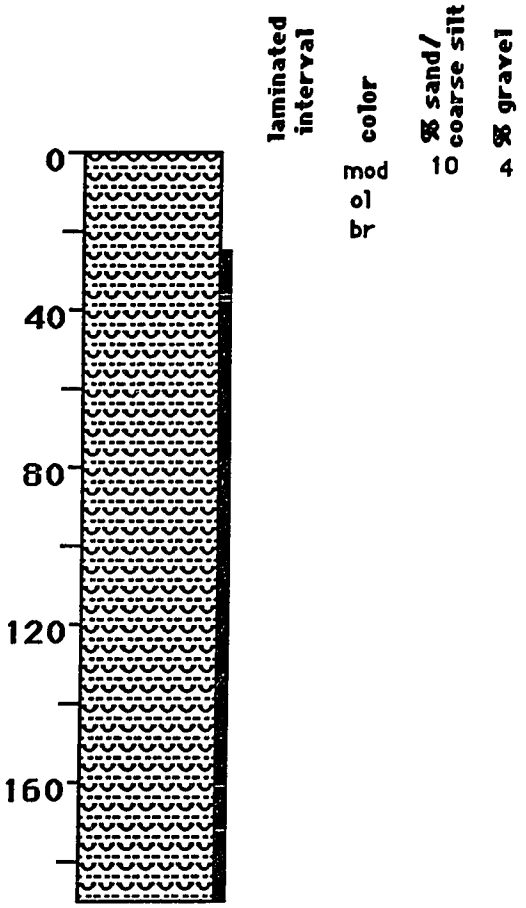
0-597cm: **diatomaceous ooze/mud** - very sparse IRD; sand fraction sorted; high organic matter content; increased diatom content by 60cm; scaphopod fossils at 415cm, 512cm, 514cm, 565cm; 7 pebbles sampled (A-D, A-C)

location: near base of Adelaide Trough

DF85-67 NORTHEASTERN QUARTER

412m

67°55.9'S/68°32.8'W
188cm



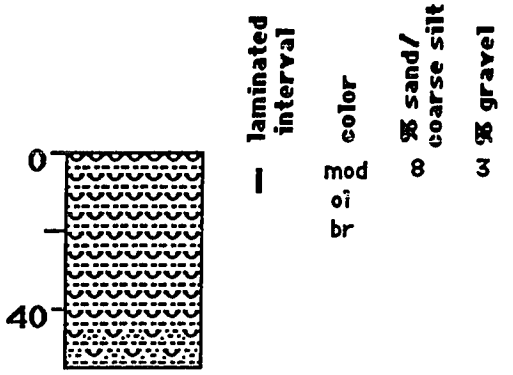
description

0-188cm: **diatomaceous mud** - silty, with very little organic matter; flow-in 24-188cm

location: western slope, Adelaide Trough

DF85-68 NORTHEASTERN QUARTER

576m **67°57.6'S/68°25.1'W**
54cm



description

0-54: **diatomaceous mud**
-high organic content, increasing IRD downcore; grades to terrigenous/ diatomaceous mud by 45cm

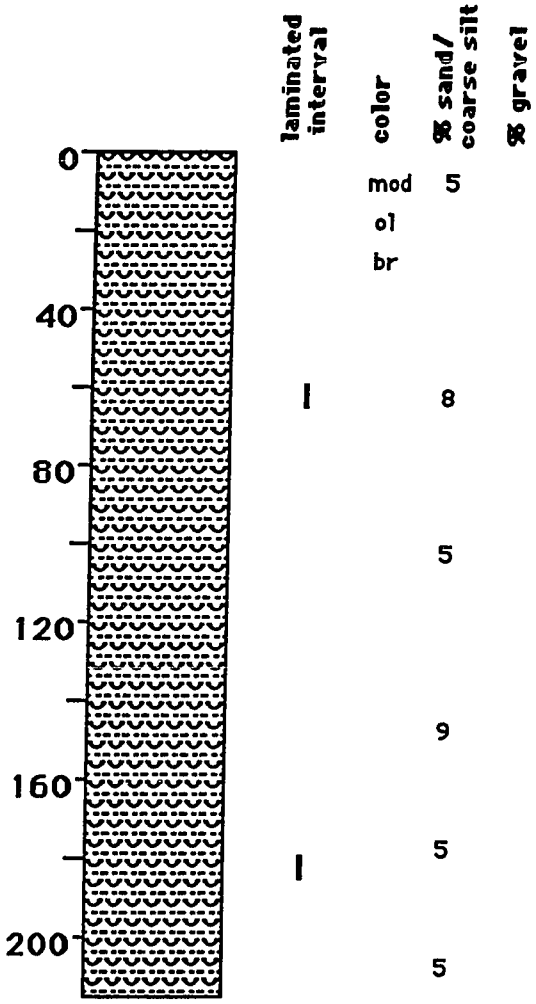
location: southeast slope, Adelaide Trough; rugged bottom profile; near 3.6° slope

note:
this core is actually a subcore taken from the top of a piston core that could not be extruded; another subcore was taken of the lower end of the piston core, but as the exact sub-bottom depth of this sample is unknown, it has not been included in this core log

DF85-71 NORTHEASTERN QUARTER

607m

67°59.2'S/68°34.0'W
217cm



description

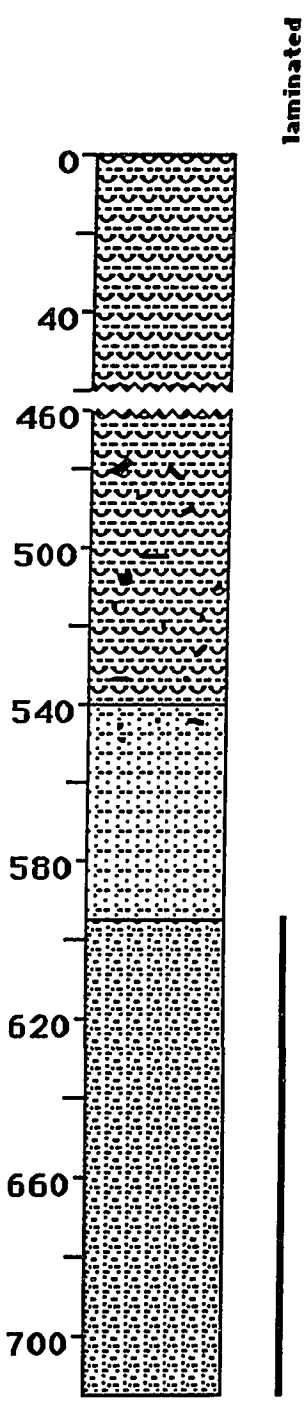
0-217cm: **diatomaceous mud**
- high organic content, thin organic-rich layer at 145cm; very sparse IRD throughout

location: southeast slope, Adelaide Trough

DF85-72 NORTHEASTERN QUARTER

808m

67°54.9'S/68°26.9'W
716cm



description

0-540cm: **diatomaceous ooze/mud**
- very sparse IRD; high organic matter content; increase in biogenic material by 70cm; scaphopod and pelecypod fossils found at 215cm, 279cm, 350cm, 360cm, 381cm, 411cm, 419cm, 468-540cm; 4 pebbles sampled (A-B, A-B)

540-596cm: **terrigenous mud**
- very little IRD; some diatoms present; ?pelecypod fragment 540-552cm; basal contact sharp; 2 pebbles sampled (A,B)

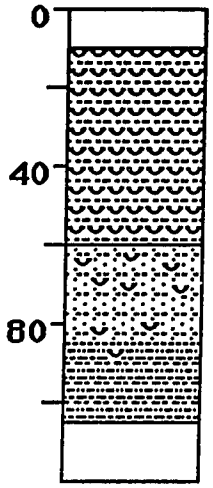
596-716cm: **sandy/silty mud (SGF)**
- individual lamina (1-4cm) graded; rare diatoms and sponge spicules; 1 pebble sampled (C)

location: at base of Adelaide Trough

DF85-74 SOUTHEASTERN QUARTER

338m

68°06.1'S/68°34.1'W
105cm



laminated interval	color	% sand/ coarse silt	% gravel
	mod ol br	9	
		11	4
	ol gy	14	
		21	

description

*12-60cm: **diatomaceous mud/ooze**

- silty, sandy deeper in unit; high organic content; faintly laminated between 40-60cm; lower contact sharp

60-105cm: **terrigenous mud**

- sandy, with minor gravel; rare diatom tests and sponge spicules, little organic matter; grades from B2 to B1 mud at 90cm

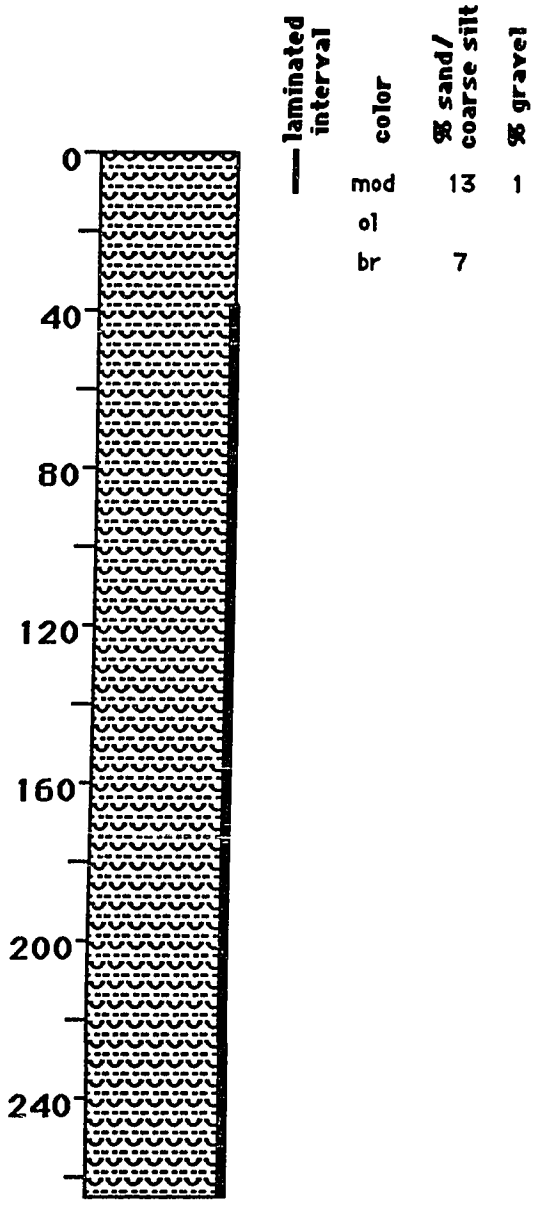
location: southeast slope, Faure Bank

***note:** top 12cm and bottom 15cm of this core were bagged

DF85-75 SOUTHEASTERN QUARTER

366m

68°05.5'S/68°26.6'W
261cm



description

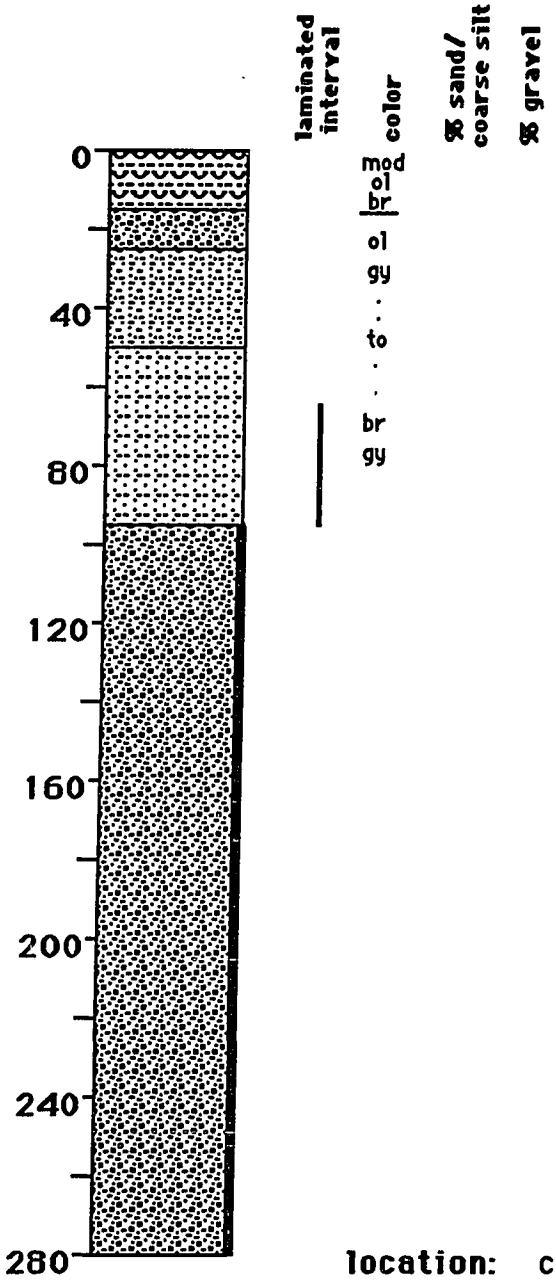
0-261cm: **diatomaceous mud/ooze** - silty, with some organic matter; faintly laminated 0-12cm; flow-in from 40-261cm; 3 pebbles sampled (A-C)

location: steep southeast slope, small basin

DF85-76 SOUTHEASTERN QUARTER

594m

68°05.4'S/68°07.5' W
280cm



description

0-12cm: **diatomaceous mud**
- little coarse material; some organic matter; basal contact sharp

12-22cm: **muddy sand/gravel (SGF)**
-crudely graded, basal contact sharp; 2 pebbles sampled (A,B)

22-50cm: **silty sand (SGF)**
- crudely graded, with increasing gravel content with depth; basal contact sharp; 8 pebbles sampled (C-K)

50-108cm: **silty mud/muddy silt**
- finely laminated, alternating layers of olive gray muddy silt and brownish gray silty mud; very low sand content; basal contact sharp; meltwater deposit?

108-280cm: flow-in muddy sandy gravel; 20 pebbles sampled (L-EE)

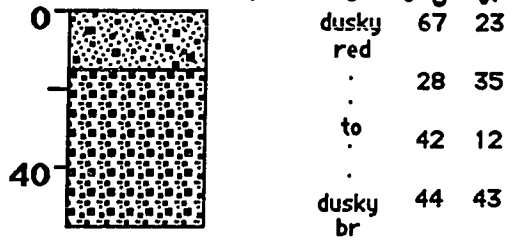
location: center of small basin

DF85-77 SOUTHEASTERN QUARTER

316m

68°05.1'S/67°52.5'W

55cm



description

0-14cm: **gravelly sand (SGF)**
- crudely graded; basal contact sharp; 2 pebbles sampled (A,B)

14-55cm: **gravel /sand**
-massive, without microfossils; more compacted than above units; residual glacial-marine? 4 pebbles sampled (C-F)

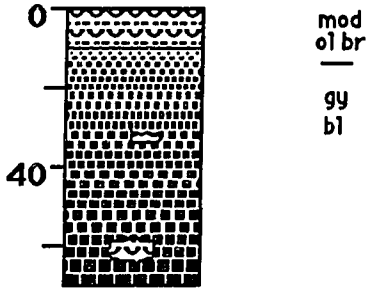
location: in shallow nearshore area

DF85-78 SOUTHEASTERN QUARTER

470m

68°08.7'S/68°04.3'W

71cm



0-11cm: **diatomaceous mud**
- some organic matter; little IRD material

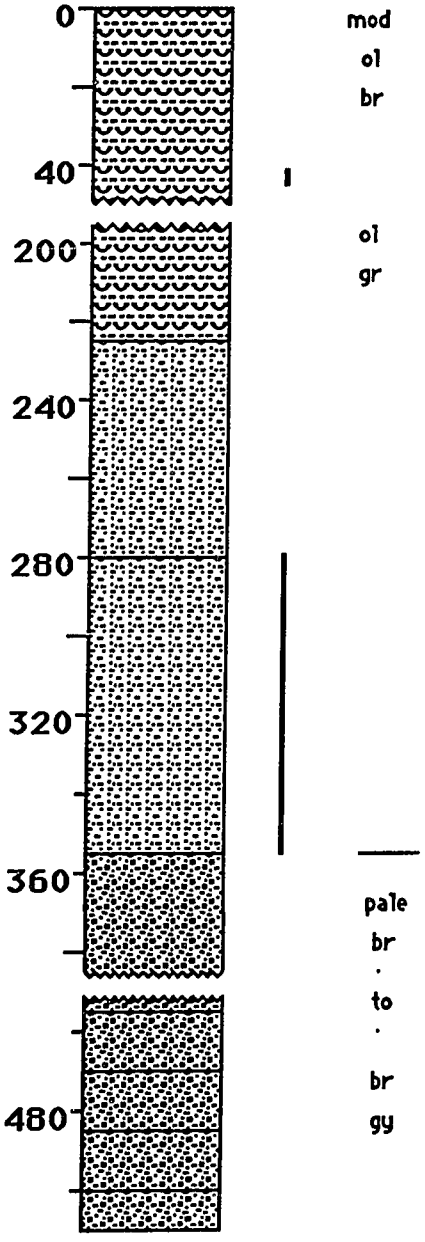
11-71cm: **sand/gravel (SGF)**
- perfectly graded fine sand to gravel turbidite; diatomaceous mud clasts at 36cm and 60cm; gravel is angular, mostly volcanic and metamorphic lithology

location:
southeast slope, small basin

DF85-79 SOUTHEASTERN QUARTER

485m

68°11.7'S/68°15.2'W
514cm

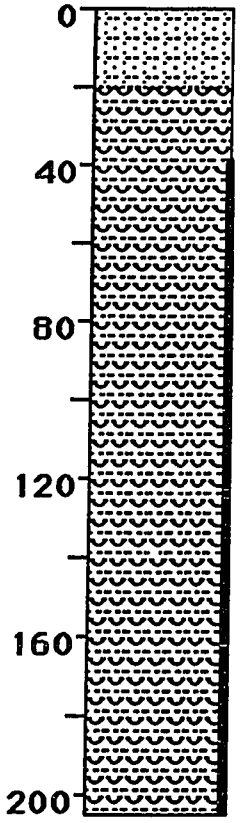


laminated interval	color	% sand/ coarse silt	% gravel	description
	mod ol br	7	2	0-224cm: **diatomaceous mud/ooze** - very sparse IRD; sand fraction moderately well sorted; scaphopod fossil at 112cm; increase in IRD at 218cm; 4 pebbles sampled (A-D)
I		6	3	
	ol gr	17	2	224-280cm: **terrigenous mud** - sand fraction poorly sorted; rare diatoms 220-230cm; some organic matter; basal contact sharp; 2 pebbles sampled (A,B)
				280-364cm: **muddy sand (SGF)** - individual laminae(1-4cm) graded; rare sponge spicules; coarser laminae 308-364cm; basal contact sharp
	pale br . to . br gy			364-514cm: **gravelly mud (SGF)** - distinct units (10-25cm) with sharp contacts; reverse graded unit 364-384cm; no biogenic material; 13 pebbles sampled (C-Q)

location: east slope, small basin

DF85-81 SOUTHEASTERN QUARTER

421m **68°14.6'S/67°04.2'W**
206cm



description

0-14cm: **terrigenous silt (B2)**
- moderately sorted silt, with very sparse IRD; basal contact gradational

14-36cm: **diatomaceous mud**
- some organic matter; faintly laminated 32-36cm

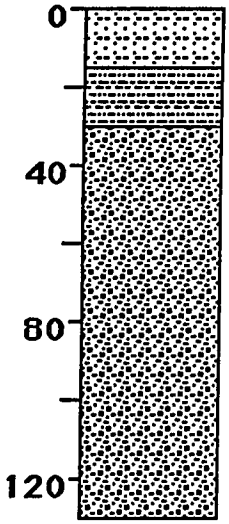
36-206cm: flow-in
- 1 pebble sampled (A)

location: in Neny Fjord basin

DF85-82 SOUTHEASTERN QUARTER

275m

68°14.4'S/67°30.2'W
131cm



laminated interval	color	% sand/ coarse silt	% gravel
	gy ol	35	1
		40	6
		42	24
		49	13
		38	23

description

0-30cm: **terrigenous sandy mud**
- no diatomaceous or organic matter present; unit grades from B2 to B1 mud; basal contact sharp; 1 pebble sampled (A)

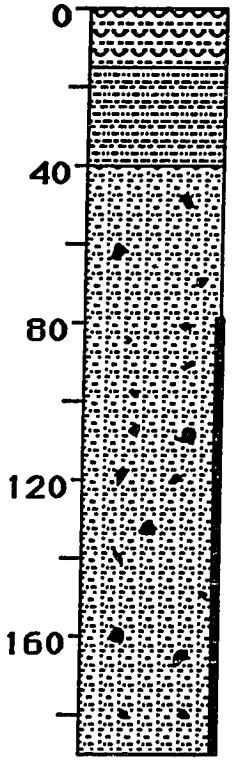
30-131cm: **gravelly muddy sand (RGM)**
- well compacted, with no organic matter present; 16 pebbles sampled (B-S)

location: seaward of mouth of Neny Fjord

DF85-84 SOUTHEASTERN QUARTER

329m

68°16.8'S/67°54.5'W
191cm



laminated interval	color	% sand/ coarse silt	% gravel
	gy ol	20	
	dusky yl	35	1
	br	50	8
		51	19
		56	18
		56	16

description

0-13cm: **diatomaceous mud**
- no organic matter present; faintly laminated; basal contact sharp

13-41cm: **terrigenous sandy mud (B1)**
- some sponge spicules present; moderately compact; basal contact sharp; 1 pebble sampled (A)

41-82cm: **muddy sand (SGF?)**
- with some gravel; poorly sorted; 3 pebbles sampled (A-D)

82-191cm: flow-in
- 14 pebbles sampled (E-T)

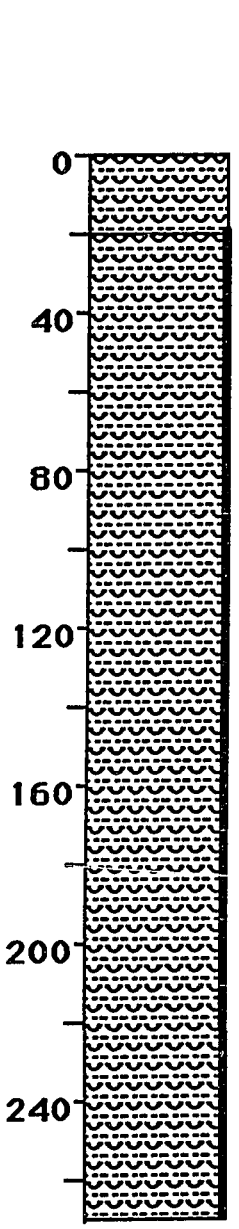
note: bottom 60 cm of core bagged

location: on eastern slope of thin trough

DF85-86 SOUTHEASTERN QUARTER

448m

68°15.7'S/68°11.0'W
274cm



description

0-18cm: **diatomaceous mud**
- very sparse organic matter and IRD

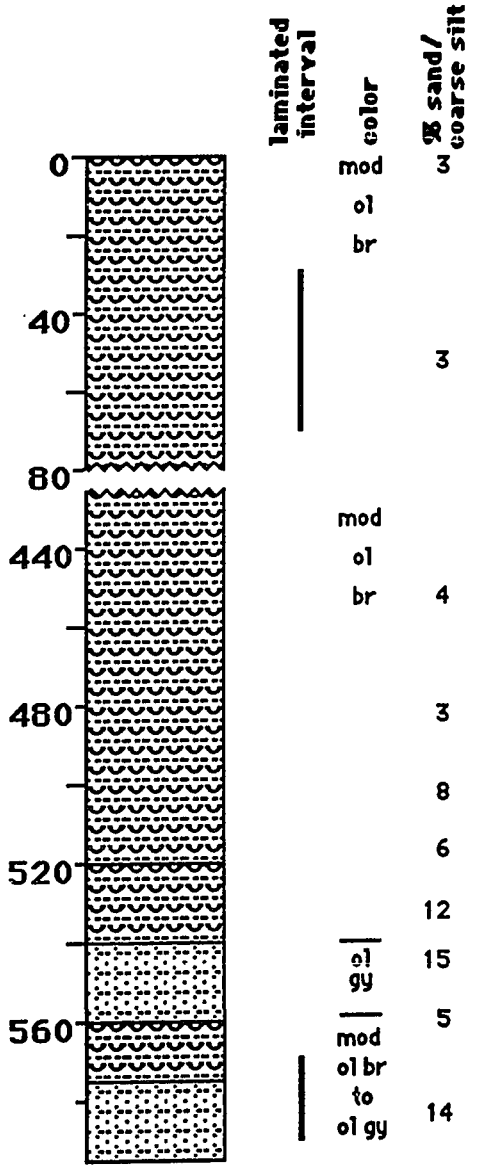
18-274cm: flow-in
(diatomaceous mud/ooze)

location: eastern slope, narrow trough

DF85-87 SOUTHEASTERN QUARTER

622m

68°15.2'S/68°19.9'W
595cm



description

0-540cm: **diatomaceous mud/ooze**
- very sparse IRD; sand fraction sorted; some organic matter present; faintly laminated intervals at 28-71cm, 300-315cm; internal contact at 520cm, with decrease in biogenic material and organic matter; 4 pebbles sampled (A-C, A)

540-560cm: **terrigenous mud (B2)**
- increased sand content (moderately well sorted); some diatoms present; basal contact gradational

560-580cm: **diatomaceous mud**
- sand fraction moderately well sorted; high organic matter content; scaphopod fossils at 568cm; basal contact gradational; 1 pebble sampled (B)

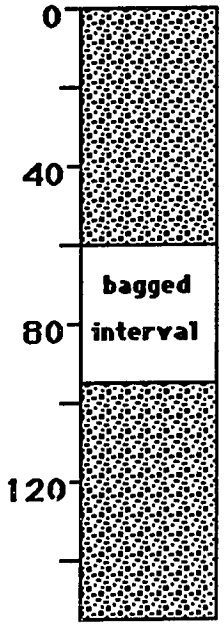
580-595cm: **terrigenous mud (B2)**
- sand fraction well sorted; no biogenic or organic material present; 1 pebble sampled (C)

location: near base, narrow trough

DF85-88 SOUTHEASTERN QUARTER

68°17.5'S/68°31.5'W
137cm

220m



description

0-137cm*: **sandy muddy gravel (RGM)**
- extremely poor sorting; little change downcore; 4 pebbles sampled (A-D)

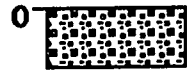
***note:** the interval 60-98cm is bagged

location: western slope, large basin

DF85-90 SOUTHEASTERN QUARTER

68°19.9'S/69°32.2'W
12cm

302m



laminated interval	color	% sand/ coarse silt	% gravel
	gy	31	41

description

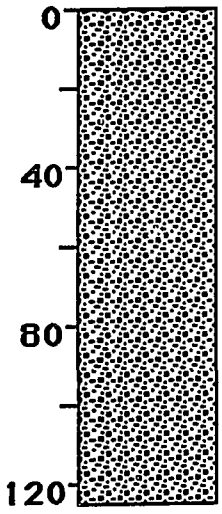
0-12cm: **sandy gravel (RGM?)**

- poorly sorted, with some biogenic material at top

DF85-92 SOUTHWESTERN QUARTER

68°26.7'S/69°46.2'W
125cm

348m



laminated interval	color	% sand/ coarse silt	% gravel
	ol	45	40
	gy		
		41	33
		38	36
		40	34

description

0-125cm: **gravelly sand (TGM)**

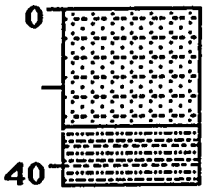
-poorly sorted; no biogenic or organic material; top 25cm may be RGM; 6 pebbles sampled (A-F)

location: near top of eastern flank, George VI Trough

DF85-114 SOUTHWESTERN QUARTER

713m

68°19.9'S/70°49.5'W
44cm



laminated interval	color	% sand/ coarse silt	% gravel
	gr	6	
	gy		
		11	

description

0-34cm: **terrigenous mud (B2)**
- rare biogenic material; basal contact inclined and sharp; 1 pebble sampled (A)

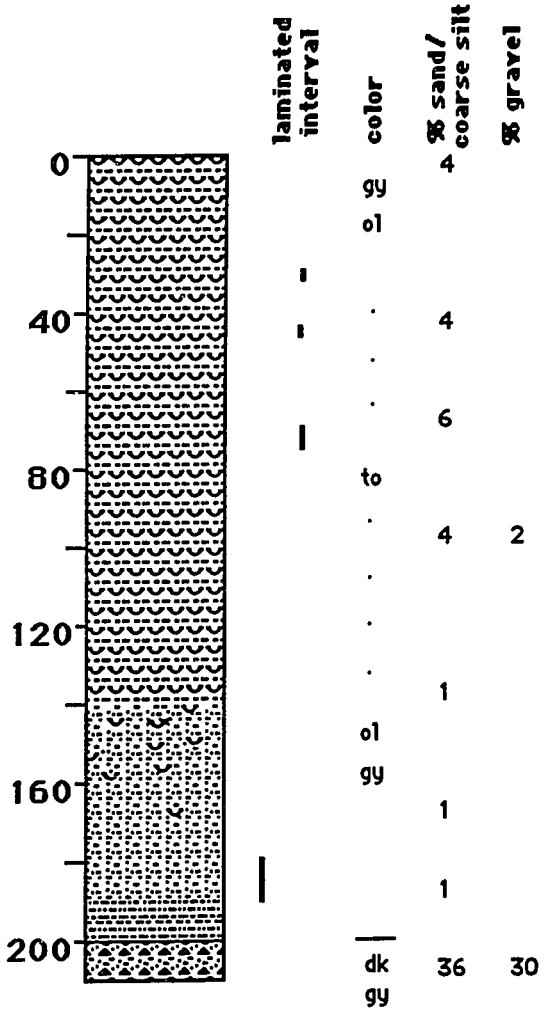
34-44cm: **terrigenous mud (B1)**
- increase in IRD over top unit; 2 pebbles sampled (B,C)

location: western slope, widened George VI Trough

DF85-115 SOUTHWESTERN QUARTER

726m

68°26.6'S/70°45.8'W
209cm



description

0-140cm: **diatomaceous mud**
- little organic matter; laminated intervals at 37cm, 45cm, and 65-75cm; basal contact gradational; 3 pebbles sampled (A-C)

140-198cm: **terrigenous mud**
- very little IRD; faintly laminated 172-183cm; basal contact sharp; B2 mud may grade to B1 by 190cm

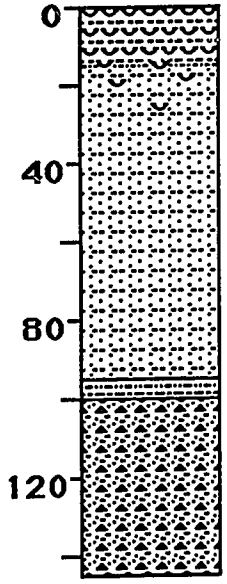
198-209cm: **diamicton (basal till)**
- unsorted sandy gravelly mud; very compact; 1 pebble sampled

location: in deep basin, west of George VI Trough

DF85-116 SOUTHWESTERN QUARTER

650m

68°29.0'S/70°36.0'W
144cm



laminated interval	color	% sand/ coarse silt	% gravel
	gy ol to ol gy	7 1 1	
—	med dk gy	5 39 44	2 20 4

description

0-16cm: **diatomaceous mud**
- little IRD; unsorted sand fraction; basal contact gradational

16-93cm: **terrigenous mud (B2)**
- very little IRD; rare diatoms; basal contact sharp

93-98cm: **terrigenous mud (B1)**
- silt, with unsorted sand fraction; basal contact sharp

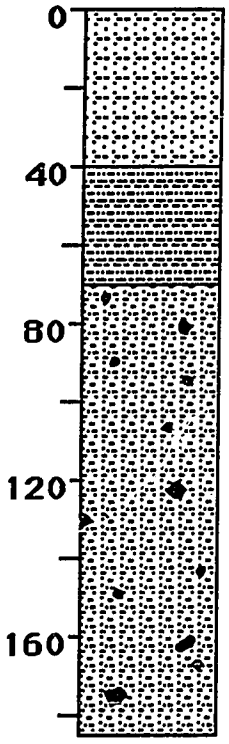
98-144cm: **diamicton (basal till)**
- unsorted sandy gravelly mud; very compact; 2 pebbles sampled (A,B)

location: eastern slope, large basin west of George VI Trough

DF85-117 SOUTHWESTERN QUARTER

503m

68°29.7'S/70°12.5'W
184cm



laminated interval	color	% sand/ coarse silt	% gravel
	ol gy	19	
		18	
		38	4
		34	3
		42	15
		45	6
		42	13
		58	11

description

0-40cm: **terrigenous mud (B2)** - very little IRD; faintly laminated 0-17cm; basal contact sharp

40-68cm: **terrigenous mud (B1)** - increased IRD; possibly disturbed section 46-68cm; basal contact sharp; 3 pebbles sampled (A,A,B)

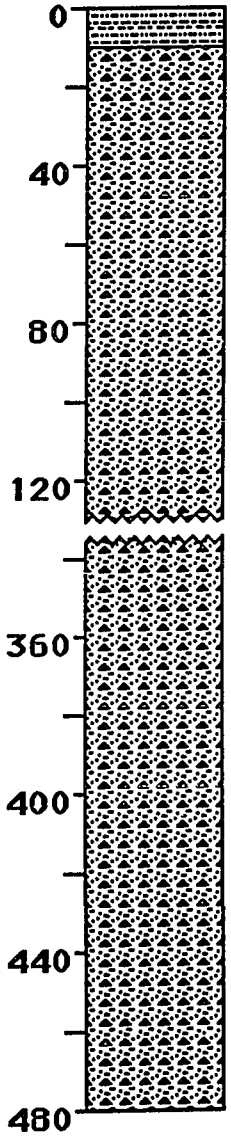
68-186cm: **muddy sand (TGM)** - poorly sorted, with some gravel; more compact than above units; 14 pebbles sampled (C-E, A-L)

location: western slope, George VI Trough

DF85-118 SOUTHWESTERN QUARTER

68°18.9'S/70°27.5'W
481cm

489m



laminated interval	color	% sand/ coarse silt	% gravel
	ol gy	12	
	dk gy	37	17
		42	16
		38	27
		35	9
		40	13
		38	12

description

0-10cm: **terrigenous mud (B1)**
- silty, with very rare (possibly reworked) diatoms and sponge spicules; basal contact sharp

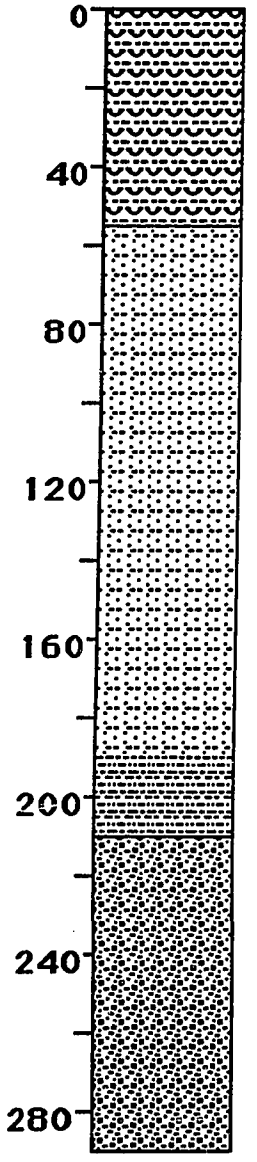
10-481cm: **diamicton (basal till)**
- unsorted sandy gravelly mud; very compact; 24 pebbles sampled (A-G, A-R)

location: on slope of bank in widened George VI Trough

DF85-119 SOUTHWESTERN QUARTER

787m

68°20.6'S/70°22.8'W
287cm



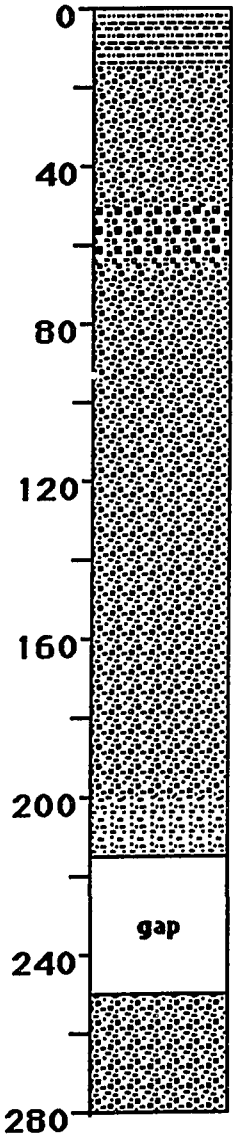
laminated interval	color	% sand/ coarse silt	% gravel	description
	gy	3		0-48cm: **diatomaceous mud**
	ol			- little organic material and IRD; basal contact sharp
		8	3	48-208cm: **terrigenous mud (B2)**
	—			- very little IRD; faintly laminated
		6		125-170cm; grades to B1 mud by
	ol			200cm; basal contact sharp
	gy			
				208-287cm: **sandy gravelly mud (TGM)**
		7		- very poorly sorted, uncompacted;
				no biogenic material; 6 pebbles
				sampled (A-F)
		4		
		9		
		11	3	
		36	14	
		25	47	
		36	20	

location: near base of widened George VI Trough

DF85-122 NORTHWESTERN QUARTER

676m

68°15.9'S/69°33.2'W
284cm



laminated interval	color	% sand/ coarse silt	% gravel
	br	9	1
	gy	21	18
		17	41
		29	8
		35	25
		35	15
		38	8
		26	37

description

0-15cm: **terrigenous mud (B1)**
- with some gravel; basal contact gradational; may be fine top of underlying debris flow

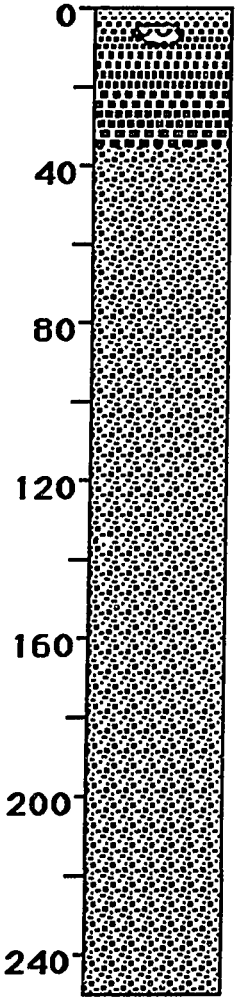
15-284cm: **sandy/gravelly mud (SGF)**
- crude grading from 15-64cm, 64-180cm; gap in core 214-250cm; no biogenic material; 10 pebbles sampled (A-L)

location: small basin in widened George VI Trough

DF85-123 NORTHWESTERN QUARTER

538m

68°15.1'S/69°21.0'W
251cm



description

0-34cm: **turbidite**
- perfectly graded fine sand to gravel unit; basal contact gradational

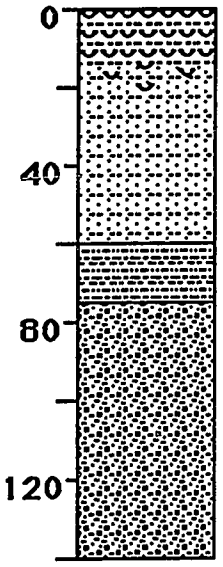
34-251cm: **gravelly sandy mud (SGF)**
- poorly sorted, with no internal contacts; no biogenic material present; 24 pebbles sampled (A-Z)

location: northeast slope of deep basin

DF85-125 NORTHWESTERN QUARTER

558m

68°13.9'S/69°40.7'W
142cm



laminated interval	color	% sand/ coarse silt	% gravel
	gy ol to ol gy	5	
		4	
		4	
		6	
		55	16
		31	40

description

0-15cm: **diatomaceous mud**
- some organic matter; basal contact gradational

15-62cm: **terrigenous mud (B2)**
- very little IRD; basal contact sharp

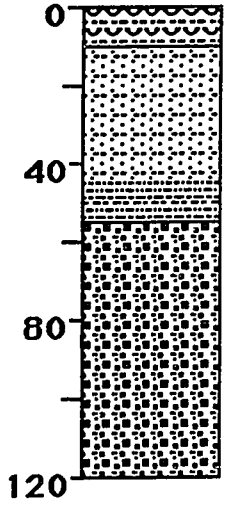
62-73cm: **terrigenous mud (B1)**
-no biogenic material; basal contact sharp

73-142cm: **muddy sand/gravel (SGF)**
- poorly sorted; no internal contacts or visible grading; 6 pebbles sampled (A-F)

location: in widened George VI Trough

DF85-126 NORTHWESTERN QUARTER

68°10.3'S/69°41.0'W
860m **120cm**



laminated interval	color	% sand/ coarse silt	% gravel
-	gy	12	3
	ol		
	ol	6	
	gy		
		23	2
		24	53
		39	38
		37	35

description

0-8cm: **diatomaceous mud**
- some organic matter; basal contact sharp; 1 pebble sampled (A)

8-58cm: **terrigenous mud**
- grades from B2 to B1 by 45cm; becomes sandier by 40cm; basal sharp; 1 pebble sampled (B)

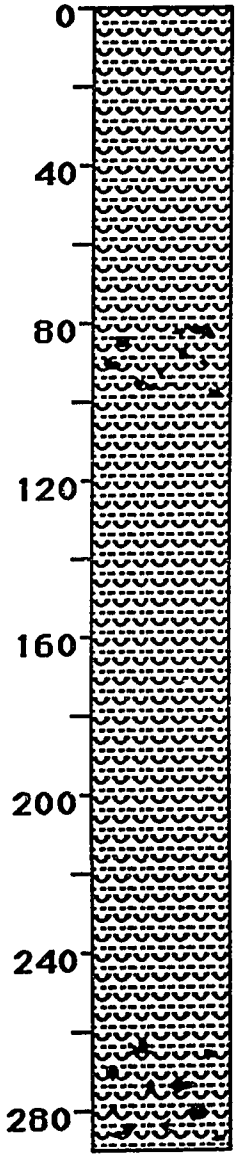
58-120cm: **sandy gravel (TGM?)**
- very poorly sorted; no internal contacts; 14 pebbles sampled (C-P)

location: bottom of small basin, widened George VI Trough

DF85-128 NORTHWESTERN QUARTER

774m

68°02.5'S/69°37.3'W
295cm



laminated interval	color	% sand/ coarse silt	% gravel
	mod ol br	12	1
		13	1
		11	33
		15	4
		12	1
		12	2
		14	1
		11	21
		10	6

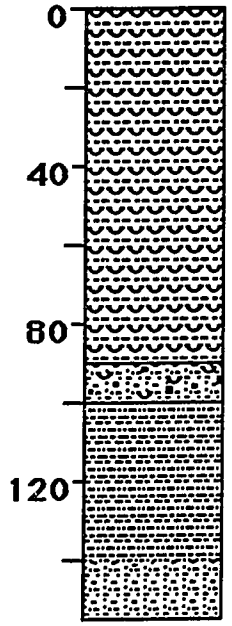
description

0-295cm: **diatomaceous mud**
- unsorted sand fraction; little organic matter; gravelly intervals 80-105cm, 260-295cm; 12 pebbles sampled (A-M)

location:
near bottom, small basin, widened George VI Trough

DF85-129 NORTHEASTERN QUARTER

67°49.9'S/67°34.9'W
256m **156cm**



laminated interval	color	% sand/ coarse silt	% gravel
	mod	22	
	ol		
	br		
		20	
		16	
		40	13
		17	
	to		
	ol		
	gy	43	1

description

0-90cm: **diatomaceous mud**
- little organic matter; faintly laminated intervals 8-22cm, 38-45cm basal contact sharp; 2 pebbles sampled (A,B)

90-100cm: **sandy mud (SGF)**
- increased IRD; rare diatoms and gravel; basal contact sharp

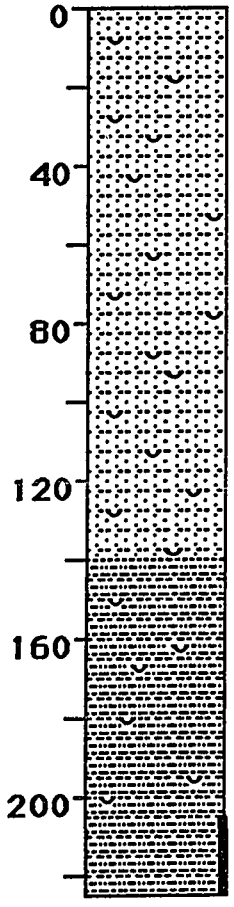
100-156cm: **sandy terrigenous mud**
- very faintly laminated; increased sand with depth in unit; rare diatoms and sponge spicules; sand fraction not well sorted

location: on slope south of Pourquoi-Pas Island

DF86-91 SOUTHWESTERN QUARTER

1079m

68°28.7'S/70°05.6'W
227cm



laminated interval	color	% sand/ coarse silt	% gravel
	lt ol gy	2	
		4	1
		5	
		6	1
		6	15
	br gy		

description

0-140cm: **terrigenous mud (B2)**
- with some diatoms and organic matter; sand fraction fairly well sorted; basal contact gradational

140-203cm: **terrigenous mud (B1)**
- increased IRD; sand fraction poorly sorted; decreased diatom fraction; basal contact gradational

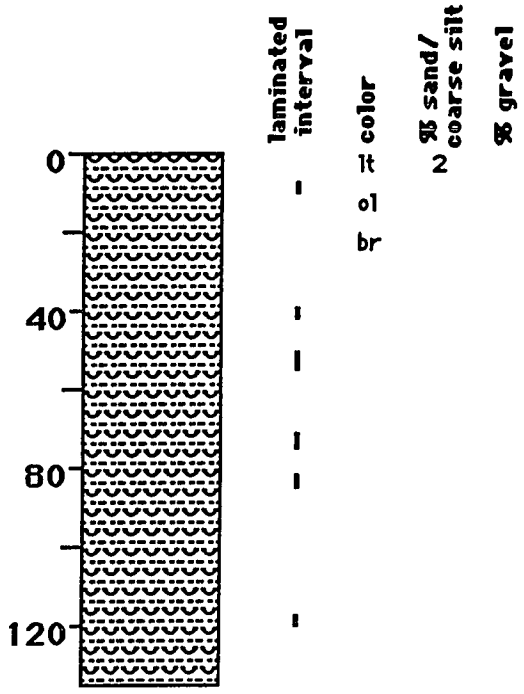
203-227cm: flow-in
- terrigenous mud

location: lowermost western flank, George VI Trough

DF86-98 SOUTHEASTERN QUARTER

493m

68°27.9'S/67°44.2'W
136cm



description

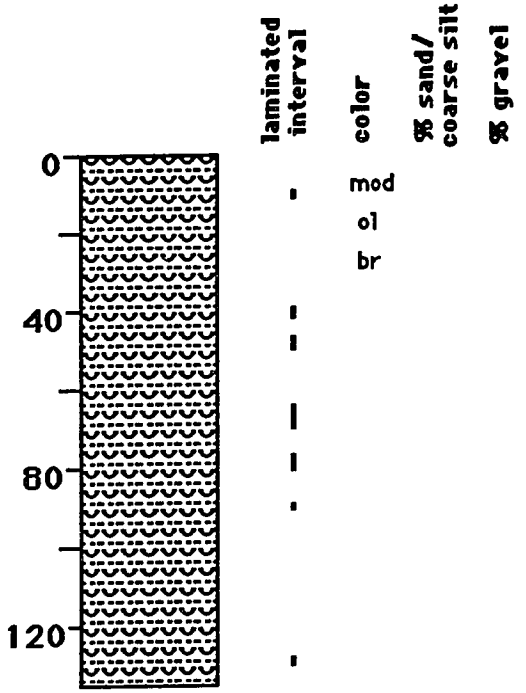
0-136cm: **diatomaceous mud/ooze** - sand fraction well-sorted; very little IRD; increase in organic matter and biogenic material by 60cm

location: ?southwest flank of trough in southern bay

DF86-99 SOUTHEASTERN QUARTER

293m

68°14.1'S/67°45.7'W
134cm



description

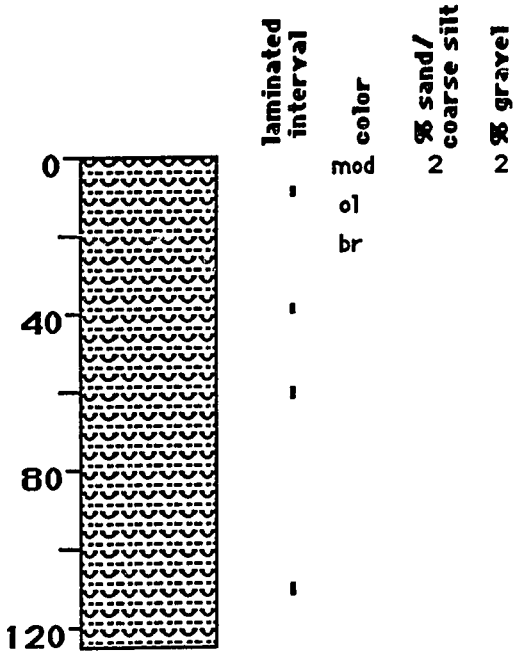
0-134cm: **diatomaceous mud/ooze** - sand fraction well sorted; very little IRD; increase in organic matter and biogenic matter by 40cm; faint laminations at several intervals

location: in small nearshore basin

DF86-100 SOUTHEASTERN QUARTER

406m

68°08.3'S/67°42.3'W
126cm



description

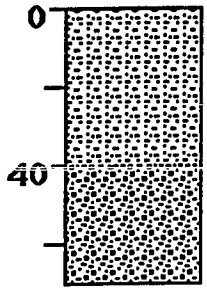
0-126cm: **diatomaceous mud/ooze** - high organic matter; sand fraction sorted; very little IRD; increase in organic material by 40cm; faint laminations at several intervals; 1 pebble sampled (A)

location: in small nearshore basin

DF86-101 **SOUTHEASTERN QUARTER**

68°03.6'S/67°40.3'W

258m **70cm**



laminated interval	color	% sand/ coarse silt	% gravel
	gy / ol	43	14
	ol		
	gy		

description

0-41cm: **muddy sand (RGM)**
- with some gravel; poorly sorted; rare sponge spicules; gravel fraction finer by 15cm; basal contact gradational

41-70cm: **gravelly sand (RGM)**
- poorly sorted

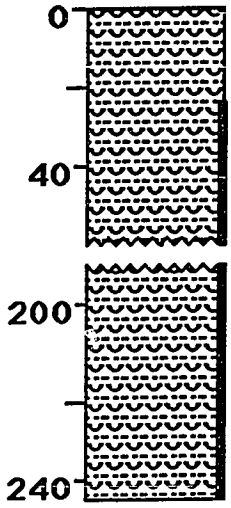
location: nearshore area

DF86-102 SOUTHEASTERN QUARTER

67°58.2'S/67°37.2'W

238m

243cm



description

0-24cm: **diatomaceous mud**
- sand fraction sorted; very little IRD; high organic matter content

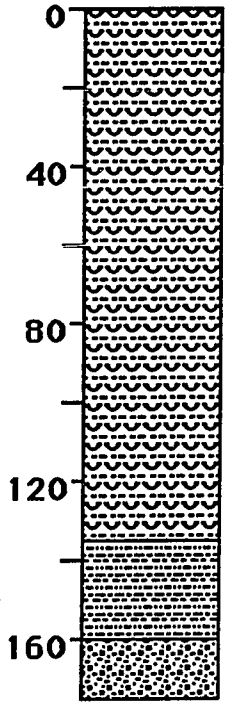
24-243cm: flow-in
- diatomaceous mud

location: small nearshore basin

DF86-106 NORTHEASTERN QUARTER

520m

67°49.2'S/67°58.9'W
174cm



laminated interval	color	% sand/ coarse silt	% gravel
	mod ol br	5	
	gy ol	10	
	ol gy	48	25

description

0-135cm: **diatomaceous mud**
- very little IRD; sand fraction sorted; some organic matter; faintly laminated 0-25cm, 72-80cm; 106-109cm

135-161cm: **terrigenous mud (B1)**
- some gravel; some biogenic and organic material; unsorted sand fraction; basal contact sharp

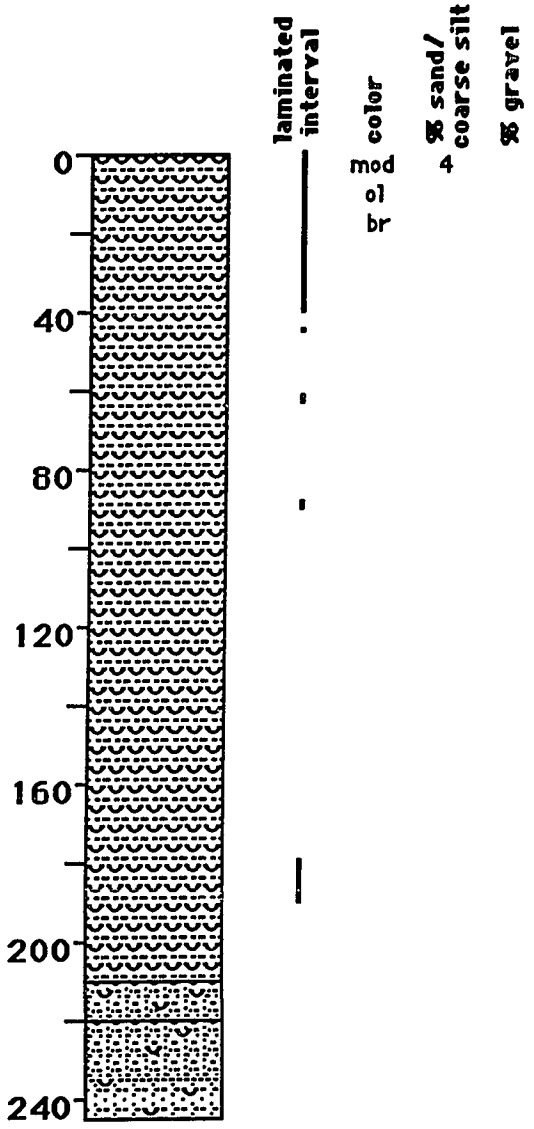
161-174cm: **gravelly sand (CGM)**
- unsorted; uncompacted; no organic matter and rare diatoms

location: north flank, eastern arm of Adelaide Trough

DF86-116 SOUTHEASTERN QUARTER

503m

68°09.5'S/68°24.5'W
246cm



description

0-206cm: **diatomaceous mud**
- very little IRD; sand fraction sorted; very faintly laminated 0-140cm, 180-192cm; basal contact sharp

206-211cm: **sandy terrigenous mud**
- graded unit (SGF?); some diatoms present; basal contact sharp

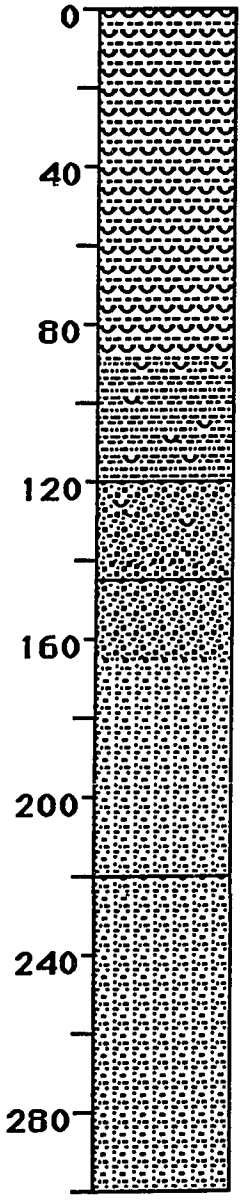
211-246cm: **sandy terrigenous mud**
- sand fraction poorly sorted; gradational change to less IRD by 235cm; rare diatoms

location: northern slope, small basin

DF86-118 NORTHWESTERN QUARTER

582m

68°04.6'S/69°16.9'W
301cm



laminated interval	color	% sand/ coarse silt	% gravel
	gy	5	
	ol		
	.	7	
	.		
	.	8	
	.		
	.	12	
	.		
	to		
	.		
	.	37	21
	ol		
	gy		
		27	

description

0-90cm: **diatomaceous mud**
- silty, with some organic matter; sand fraction sorted; basal contact gradational

90-120cm: **terrigenous mud (B1)**
- poorly sorted sand fraction; slight increase in IRD; little biogenic material; basal contact sharp

120-142cm: **sandy mud**
-crudely graded (SGF); some diatoms present; basal contact sharp

142-220cm: **sandy terrigenous mud**
- gravelly 142-160cm; sand fraction well sorted 160-190cm; poorly sorted 142-160cm, 190-220cm: basal contact sharp

220-301cm: **sandy terrigenous silt (SGF)**
- individual laminae (1-5cm) graded; massive interval 270-301cm; no organic or biogenic matter

location: on west flank of Faure Bank