AGSO

ANTARCTIC CRC MARINE GEOSCIENCE

VINCENNES BAY, PRYDZ BAY AND MAC.ROBERTSON SHELF

AGSO CRUISE 186
ANARE VOYAGE 5, 1996/97 (BRAD)

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E. Domack, L. DeSantis & B. Raker

AGSO RECORD 1997/51

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AUSTRALIAN
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POST-CRUISE REPORT

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October, 1997

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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Neil Williams

ISSN: 1039-0073
ISBN: 0 642 27316 2

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Acknowledgments

The work described in this report forms part of Australian National Antarctic Research Expediions (ANARE) project number 937. The authors are grateful for the financial support of the Cooperative Research Centre for the Antarctic and Southern Ocean Environment (Antarctic CRC), University of Tasmania, the Australian Antarctic Division and the Australian Geological Survey Organisation (AGSO). Thanks to Captain Peter Pearson and crew of the S.R.V. *Aurora Australis* Scott Laughlin, Cameron Harris, Les Morrow, Ian Moodie, Bill Rice, James McKenzie, Keith Thorpe, Robert Cave, Brian (Limbo) Lambert, Richard Perry, Shane Bevan, Dean McPhearson, James Hardcombe, Per Larson, Terence Ganim, Stephen Slater, Paul McGilchrist, Bill Robinson, Tony Alvarez, Shaun McQuaid, Frank Soutter, Sue Pickering, Peter Shanahan, Aubrey Allwood and Liam O'Neill. Thanks also to Alec Marr, and to our marine biological colleagues Tania Bardsley, Robyn Ickeringall and Chris Hayward who assisted with the data collection and ship-board analyses. We are grateful to Dr. Suzanne O'Connell (Wesleyan University, Connecticut, USA) who provided sidescan sonar equipment used during the Vincennes Bay part of the cruise, and to Dr. Neville Exon (AGSO) who provided a valuable review of an earlier version of the report.

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Executive Summary

This record is a summary of the preliminary results of the third AGSO/Antarctic Co-operative Research Centre/ANARE marine geoscience program in East Antarctica since 1993. The voyage included visits to Vincennes Bay, Prydz Bay and the Mac. Robertson Shelf, Antarctica and to Heard Island on the Kerguelen Plateau. The purpose of the voyage was to conduct a marine science geophysical survey and sediment processes/sampling program at several key areas in the Australian Antarctic Territory (AAT) during the 1996-97 season, namely: (i) the deep shelf basin located in Vincennes Bay; (ii) Prydz Bay grounding line moraines and trough mouth fan deposits, and (iii) the Nielsen shelf valley off Mac.Robertson Land. The objectives for the cruise included: (1) to collect cores and seismic data from shelf basins that preserve a record of the timing of ice sheet retreat from the shelf break following the last glacial maximum (LGM); (2) to collect geochemical data from the water column and underlying sediments which will improve interpretation of short-term (Holocene) palaeoenvironmental records preserved in biogenic sediment cores; (3) to obtain seismic data in support of proposed ODP drilling on the Prydz trough mouth fan; and (4) to quantify modern sedimentary processes for the purpose of deriving facies models and analysis of facies successions in the cores.

In Vincennes Bay, eight cores were collected at six stations; 3 are located on an outer shelf bank and 3 are from a deep (up to 1,850 m water depth) glacial trough on the inner shelf. The inner shelf cores are interpreted as Holocene in age throughout and contain a diatom and possible organic carbon record that looks promising for correlation with the Law Dome ice core record. About 200km of seismic data were collected in Vincennes Bay which show the inner shelf to be glacially incised and deeply eroded, exposing crystalline basement, whilst the mid- to outer shelf preserves much of its sedimentary cover, although glacial erosion is also exhibited.

A total of 19 gravity cores were collected in Prydz Bay. The cores indicate that the LGM was associated with grounding of a paleo-ice shelf only along the periphery of Prydz Channel and not to the shelf break. Most deposition in front of the grounding line was dominated by ice-rafted sedimentation, as opposed to sediment gravity flows. Beneath some LGM glacial marine deposits lies a key bed of reworked diatom ooze that is distinct in its size (species) sorting and abundance

of Pliocene diatoms. This "interstadial" unit can be traced between cores across more than 15,000 km^2 of the Prydz Channel. About 900 km of seismic and sidescan sonar data were collected from Prydz Bay and have provided an insight into the internal structure of several inner shelf moraines. A large (>80km long) iceberg was located on the slope off Prydz Bay and prevented site survey work on the proposed ODP sites. However, some outstanding sidescan sonar records were collected from inner Prydz Bay, which revealed iceberg gouges, flutes and some previously undescribed sedimentary bedforms in several areas.

On the Mac.Robertson shelf, two current meters were successfully deployed, 320 km of seismic and sidescan sonar data and 7 cores were collected. One seismic line was completed from the shelf break to the inner part of the Nielsen Basin and three gravity cores were also collected along this seismic line. Further to the west in "Iceberg Alley", an additional 4 gravity cores were collected and a seismic line was shot along part of a cross-shelf transect. Heavy sea ice prevented the completion of this line. A highlight of the Mac.Robertson shelf part of the survey was the observation of glacial flutes in sidescan sonar records from the outer shelf, which are interpreted as LGM in age and support the concept of a grounded ice sheet in this area; previously collected cores have documented the succession of sedimentary facies that are contemporaneous with this glacial event.

Moonlight in Prydz Bay

(to the tune of "Moonlight in Vermont")

This must be a dream
stardust and aurora glow
moonlight in Prydz Bay

sea ice on the swell
some penguins and a leopard seal
moonlight in Prydz Bay

Icebergs and growlers all green on my radar
mark every mile of the road
dragging the sidescan and dropping the corer
and changing the waypoints, it drives me crazy!

so, this must be a dream
stardust and aurora glow
moonlight in Prydz Bay
you and I and moonlight in Prydz Bay

CHAPTER 1. INTRODUCTION

This record is a summary of the preliminary results of the third AGSO/Antarctic Co-operative Research Centre/ANARE marine geoscience program in East Antarctica since 1993. The voyage included visits to Vincennes Bay, Prydz Bay and the Mac. Robertson Shelf, Antarctica, and to Heard Island on the Kerguelen Plateau (Fig.1). The purpose of the voyage was to conduct a marine science geophysical survey and sediment processes/sampling program at several key areas in the Australian Antarctic Territory (AAT) during the 1996-97 season, namely: (i) Prydz Bay grounding line moraines and trough mouth fan deposits, and (ii) the deep shelf basins located in Vincennes Bay and the Nielsen shelf valley off Mac.Robertson Land. The proposed objectives for the cruise derived from these overall aims, and included (1) to collect cores and seismic data from shelf basins that preserve a record of the timing of ice sheet retreat from the shelf break following the LGM; (2) to collect geochemical data from the water column and underlying sediments which will improve interpretation of short-term (Holocene) palaeoenvironmental records preserved in biogenic sediment cores; (3) to obtain seismic data in support of proposed ODP drilling on the Prydz trough mouth fan; and (4) to quantify modern sedimentary processes for the purpose of deriving facies models and analysis of facies successions in the cores. The cruise is designated AGSO cruise 186 in AGSO's data bases, whereas it has the acronym BRAD (Benthic Rocks And Drilling) in Antarctic Division data sets.

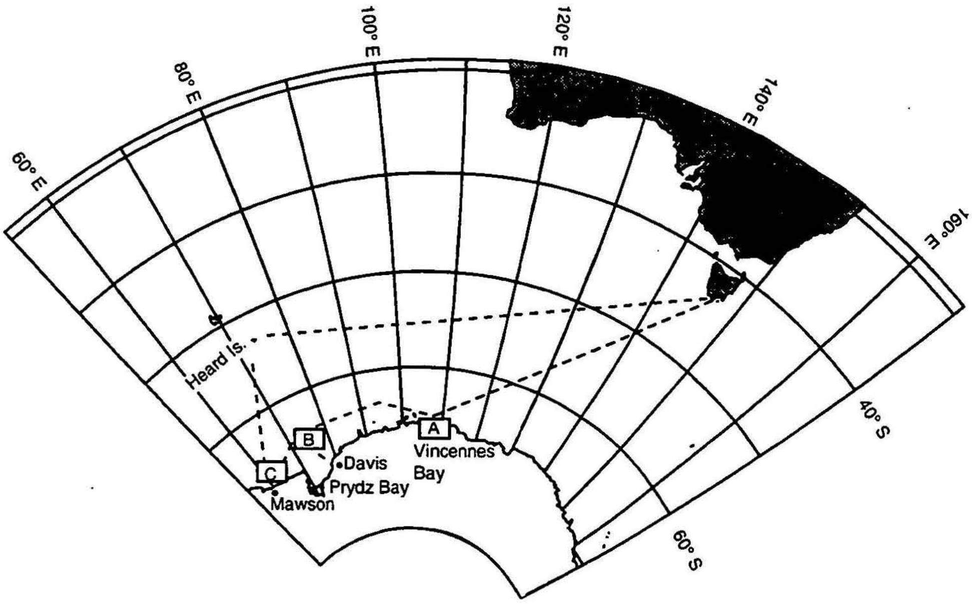

Figure 1.1 Cruise track of RV Aurora Australis in Feb.-March 1997 showing marine science field areas (A) Vincennes Bay; (B) Prydz trough mouth fan; and (C) Mac.Robertson shelf. The ship also made a stop at Heard Island.

The importance of understanding the stability of the East Antarctic ice sheet over the past 5 million years and the functioning of sedimentary systems on the Antarctic margin arises from two sources: (1) a need to model the behaviour of the ice sheet in order to be able to accurately predict the effects of global warming and climate change; and (2) a need to be able to effectively manage and define the boundaries of Australia's Ocean Territory (EEZ) . Ice sheet models suffer from a lack of hard field data that can be used to link specific past ice sheet volumes to specific environmental parameters. An example of this is the extent of the ice sheet during the last glacial maximum; we presently do not know if, when or where the ice sheet was advanced to the shelf break during this period. Results to date suggest that during the LGM the ice sheet was grounded at the shelf break in some areas (ie. the Antarctic Peninsula) but not at others (the Ross Sea). Estimates of the timing of glacial retreat and the onset of the present environmental conditions has been established for only 4 locations on the entire margin and these range from 11,000 to 5,000 yrs B.P. Time series records of glacial advance and retreat, such as would be provided through combined seismic profiling and deep drilling through trough mouth fan deposits, have not as yet been produced from the Antarctic margin. Accurate computer modelling of the ice sheet behaviour requires substantially improved constraints on these parameters. High resolution records (long sediment cores having a thick Holocene section) obtained in Vincennes Bay will enable correlations between the ice core (Law Dome; Morgan et al., 1991) and marine records which have not previously been attempted on the East Antarctic margin.

A key goal for the management of the Antarctic environment is the collection of environmental data related to seafloor properties and processes. The proposed survey will provide data that will contribute to environmental regionalisation and an understanding of sediment transport and production processes. These data contribute to AGSO's Australian Ocean Territory Management Program (AOTMP) and to Framework and Resources of the Marine Environment (FRAME) program. Characterisation of the substrate is also important in understanding benthic ecosystems.

In order to assess the consequences of increased atmospheric CO_2 content and other environmental disturbances resulting from human activity, it is necessary to understand natural palaeoenvironmental variations, particularly during the present interglacial period. The work carried out will provide information allowing reconstruction of palaeoenvironmental records, such as marine phytoplankton production and ice-sheet retreat, for the Mac. Robertson Shelf area during the Holocene. Phytoplankton production in the Southern Ocean is an important component of the global carbon cycle, and may exert important controls on global climate; Antarctic shelf waters are of particular interest in this respect as they are the most biologically productive areas of the Southern Ocean.

This marine geoscience cruise was designed to simultaneously collect data for three ANARE Strategic Plan Themes, as follows:

Theme 1. The geological record of past Antarctic environments,

Deposits and landforms on the Antarctic continental shelf and slope provide the most widespread and complete record of ice sheet advance and retreat, and the interactions between the ice sheet and the Southern Ocean. Post-glacial sediments record the Holocene history of environmental conditions. Study of these sediments around the East Antarctic margin and in the Southern Ocean will provide tests of ice sheet, oceanographic and biological models of the Antarctic environment.

Theme 2. Geological processes on the glaciated Antarctic landmass, its continental margins and neighbouring deep ocean basins.

Mapping the sediments and sedimentary structures on the Antarctic shelf will enable improved interpretation of the ancient record and improved understanding of oceanographic conditions on the shelf, and is fundamental to understand distribution of modern benthic biota. Biogeochemical research on the cruise will improve the understanding of the role of sediment-water interactions in sustaining and limiting primary production. These latter aspects contribute to the biological strategic plan.

Theme 3. The geodynamics of Antarctica, its continental margins and the adjacent Southern Ocean basins.

Mapping the structure and stratigraphy of the East Antarctic margin, much of which has never been studied, will improve the understanding of the Mesozoic and Cenozoic history of continental break up and drift around Antarctica.

Justification of research design

During major glaciations, the Antarctic ice sheet expands across the continental shelf, reaching the shelf break (Fig. 2). This means that sediments deposited on the shelf during an episode of contracted ice sheet with open marine conditions on the shelf (such as the present time) will be eroded away during the next advance of the ice sheet. Although sediments deposited on the slope are not eroded by the ice, they accumulate at a much slower rate than the shelf sediments. Slope deposits are also unstable and often slump down into the adjacent ocean basin. The problem is to find stable slope deposits which preserve a record of ice sheet advance and retreat (the long-term record) and to find shelf deposits which preserve changes since the ice sheet last retreated (the short-term record).

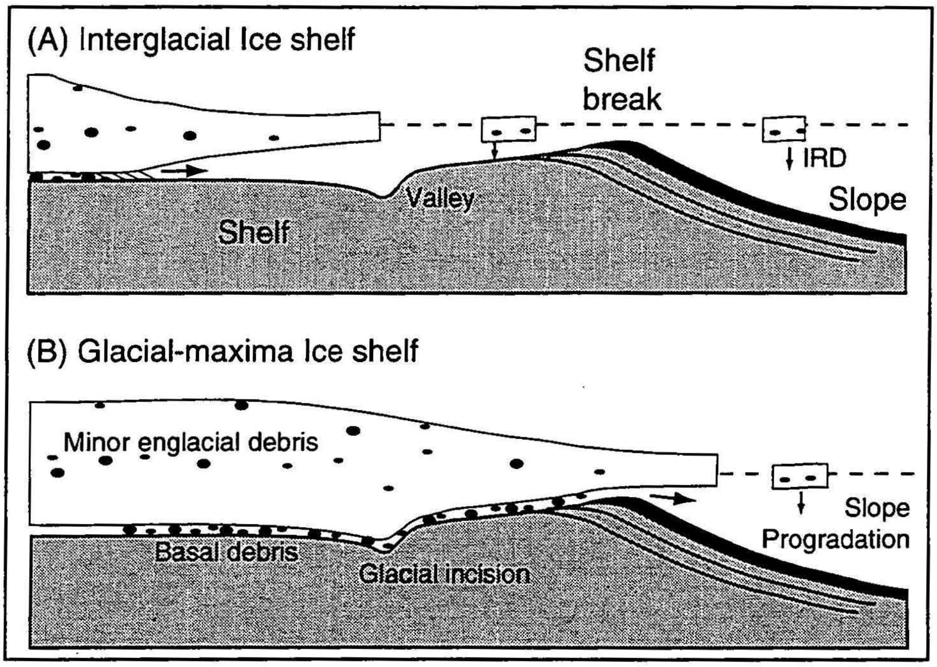

Figure 1.2. Diagram showing idealised cross-section of a continental margin ice sheet (A) during interglacial high sea level; and (B) during glacial low sea level stands.

The submarine fan built by the Lambert Glacier on the continental slope offshore from Prydz Bay is 148km wide and extends 93km out to sea. Correlation of major surfaces across the shelf from ODP hole 739 to the fan indicates that it has been prograding at least since the Miocene. Plio-Pleistocene sediments are about 1km thick. Seismic data (Fig. 3) show that the fan has gentle surface slopes of 1.2° to 2° and contains parallel foreset reflectors, indicating minimal slumping in this location (O'Brien and Harris, 1996). The preservation of interglacial muds (as seen in cores obtained from the fan) and the lack of major erosional features suggest that it preserves a near-continuous record of the advance and retreat of the Amery Ice shelf and Lambert Glacier, the largest glacial system in East Antarctica. Seismic profiling and gravity coring were the methods selected to study the composition and structure of this feature; we acknowledge that gravity coring does not provide enough penetration to enable correlation with seismic facies. However, it is the only coring method currently available to us. In the longer term, we have submitted proposals to ODP for a series of holes across the Prydz Fan, and the work carried out on the cruise will provide site survey data for such ODP drill sites.

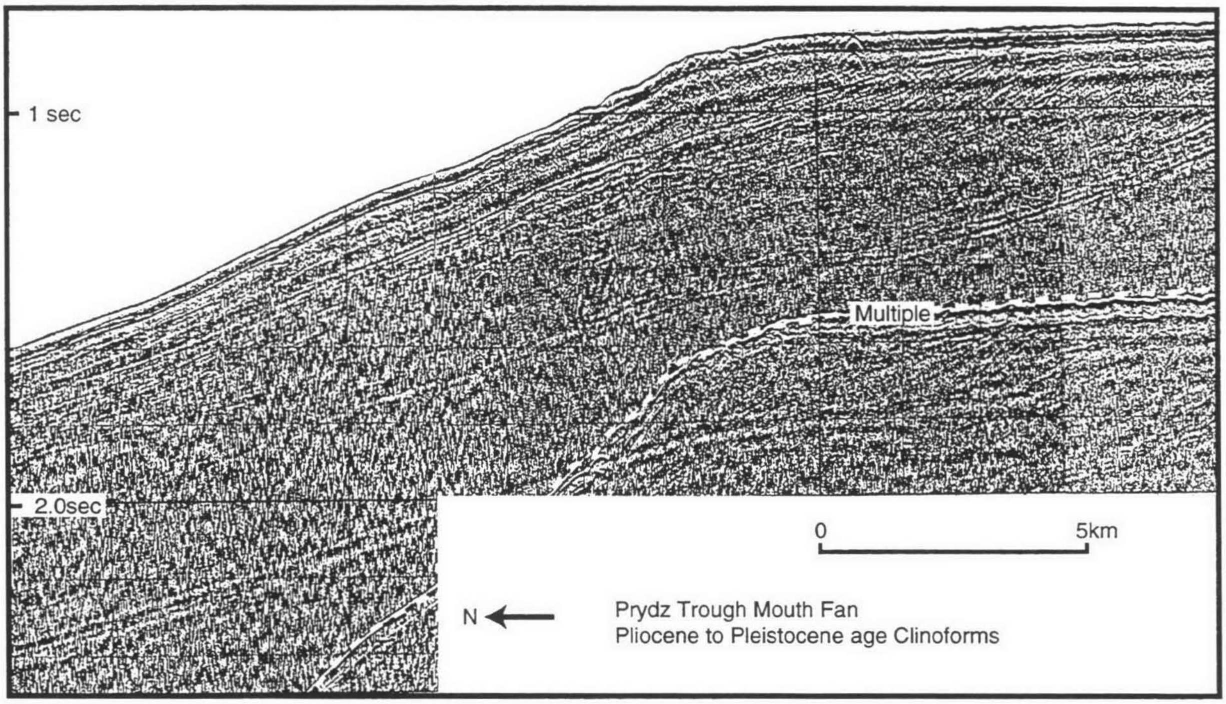

Figure 1.3. Example of GI gun seismic data collected in 1995 (cf O'Brien et al., 1995; O'Brien and Harris, 1996) across the gently dipping Prydz Bay trough mouth fan.

During glacial episodes, the Antarctic ice sheet extended over what is now the continental shelf and deep glacial troughs were incised into the sediments and bedrock, whilst grounding line moraines were deposited. We propose to exploit both of these features as records of glacial history. Shelf valleys are commonly >1,000m in depth and they are joined to the shelf break by U-shaped valleys (fjords). They have been incised into bedrock and older sediments crop out on the valley sides, with glacial (moraine) deposits found on some valley floors (Harris and O'Brien, 1996). Cores from the Nielsen Basin contain anoxic siliceous mud and diatom ooze (SMO) that overlies glacial marine sediments. Judging from radiocarbon dating, the SMO is accumulating at rates of up to 0.5m per thousand years. Preliminary interpretations of radiocarbon dates indicate that present open marine conditions were not achieved over this basin until after 10,000 yrs B.P. (Harris et al., 1996).

The purpose of studying grounding line moraines in Prydz Bay is to gain a better understanding of palaeogrounding zones of ice shelves and the timing of ice shelf retreat. Gounding zone deposits are key features in understanding the behaviour of ice sheets during climate change episodes. In Prydz Bay, individual moraines are on the order of 100 km in length, 10 km in width, and 50 m in height, and they trend sub-parallel to and across the axis of the Prydz Channel (Leitchenkov et al., 1994; O'Brien and Harris, 1996). The internal structure and overall morphology of these moraines (as seen in seismic profiles) will provide information regarding their formation. Dating of the base of the Holocene section overlying the moraines as seen in core samples will constrain their minimum ages.

The interpretation of cores from shelf valleys and moraines, and the ability to locate other shelf depositional environments, are based upon an understanding of physical and chemical sedimentary processes. In order to assess the possible consequences of increased atmospheric CO2 content and other environmental disturbances resulting from human activity, it is necessary to understand how past changes in oceanic biological (phytoplankton) production were related to variations in global climate and environment. Geochemical and radioisotopic studies of biogenic sediment cores from areas such as the Mac.Robertson Shelf have established records of paleoproductivity and palaeoenvironmental conditions for Antarctic shelf waters, which are among the most productive in the Southern Ocean.

Diatoms and Biostratigraphy

Diatoms have been extensively used for biostratigraphic purposes in high southern latitudes (e.g. Weaver and Gombos 1981, Ciesielski 1983 and 1985, Baldauf and Barron 1991, Harwood and Maruyama 1992), following the pioneering work of McCollum (1975). In comparison to calcareous microfossils, they offer several advantages (Barron 1985):

1. Diatoms are abundant and diverse in the water column and are preserved well in the sediment, in comparison to calcareous nannoplankton and foraminifera. The diatomaceous oozes of Antarctica have been described as the richest in the world (Jousé *et al.* 1971), with biogenic silica contributing between 40 - 75 % of the total sediment (Kozlova 1964, DeMaster 1981, Gersonde and Wefer 1987).
2. Diatom frustules are relatively small and easily prepared for study, and large quantities can be obtained from a small sample size.
3. They are excellent indicators of palaeoecology.

In the Southern Ocean, diatom biostratigraphy provides the finest time resolution. Based on the results of Harwood and Maruyama (1992), a resolution of ~0.5 MY within the last 4 million years, and ~0.5 - 4 MY within the last 4 - 23 million years, can be determined. Late Cretaceous to Eocene biostratigraphic zonations are primarily based on the species events of *Hemiaulus*, *Triceratium*, *Pyxilla*, and *Trinacria*. Oligocene to Quaternary zonations are based on the occurrence of *Rocella*, *Coscindodiscus*, *Actinocyclus*, *Nitzschia*, *Denticulopsis*, and *Thalassiosira* (Barron 1993).

Subsamples were taken from the sediment, using a disposable toothpick, and rinsed in distilled water to disaggregate and dilute the sample. A fraction was then pipetted onto a glass coverslip and allowed to dry on a warm hotplate. Norland optical adhesive was used to adhere the dry coverslip to a pre-labelled microscope slide and cured under a UV light. Diatoms were observed under a light microscope. Sediment age was based on the diatom biostratigraphic zonations of Harwood and Maruyama (1992).

International Links

Planning of future ocean drilling, and coordinating the international sharing of seismic survey data obtained in Antarctica, are coordinated by a multi-national effort called the Antarctic Offshore Acoustic Stratigraphy Project (ANTOSTRAT) that was conceived by the Scientific Committee for Antarctic Research (SCAR). Our program has cooperated fully with ANTOSTRAT in facilitating the sharing of Australian seismic data collected during the 1995 marine science cruise with the international community. Preparation of proposals for ODP drilling in Prydz Bay has been with full reference to ANTOSTRAT, and to this end ANTOSTRAT has endorsed the current proposal with regards to the collection of ODP site survey data.

International links have been established with Russian researchers who are the other group in the world (apart from the Antarctic CRC) that have carried out significant marine geoscience research in Prydz Bay. Two Russian scientists (G. Leitchenkov and Z. Pushina) visited the Antarctic CRC in December 1996, as part of a collaborative project funded by the Australian Antarctic Foundation to assemble a database of available Prydz Bay seafloor samples, seismic and gravity data (see report by Harris et al., 1996). This database was very useful in guiding the selection of core sites and seismic tracks for the present cruise.

International participants in cruise 186 included Dr. Eugene Domack, Hamilton College, New York, USA; Dr. Laura DeSantis, Osservatorio Geofisico Sperimentale, Italy; and Mr. Benjamin Raker, Wesleyan College, Hartford Connecicuit, USA. Collaborative projects that have been established with our international colleagues will ensure that the ANARE marine geoscience program is recognised by the community as being outward looking and inclusive.

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CHAPTER 2 - SHIPBOARD METHODS AND OVERVIEW OF RESULTS

Shipboard methods and operations

Measurements of temperature, salinity and depth were made using a Neil Brown Mark IIIB CTD mounted in a steel-framed sampling rosette. Also mounted in the rosette were up to twelve, 10-litre Niskin bottles for sampling bottom, mid-depth and surface water, and a Benthos bottom camera and strobe light. Water samples were used for calibration of the conductivity (salinity) probe and reversing thermometers were used to verify the temperature probe.

Seismic data were collected using AGSO's portable seismic system, which includes a compressor (2,000psi at 200 cubic feet per minute) built into a standard 20 ft shipping container. This is used to fire a 150 cubic inch Seismic Systems Inc. generator-injector (GI) air gun. The refill time of the gun limits the firing frequency which was not less than 6 seconds. Digital acquisition was via an AGSO-constructed system. A 25 m Teledyne streamer with 4 groups (4 channels) of ten hydrophones was used, which gave good results in water depths of up to 2,500 m.

Analogue (uncorrected) sidescan sonar data were recorded with an EG&G 960 tow fish and an EG&G 996 digital modem connected to an Geoacoustics SES 1000 recording system. The sidescan sonar was operated at ranges of 375 to 500 m. A Datasonics SIS-1000 tow fish and digital recording system was also brought along for the cruise, but this was not used apart from trial runs in Hobart and in Vincennes Bay. It was discovered that the ship's Netson armoured cable did not have the transmission properties needed to run this device; hence the EG&G system was used during the voyage.

Gravity cores were collected using a 1 tonne bomb connected to 3 or 6 m length by 10 cm diameter core barrels (9 cm diameter PVC core liner). The top of the corer is fitted with a one-way flapper valve which allows water to escape from the corer during the coring operation, but which denies access to water during corer ascent. The corer is deployed over the stern of the vessel using a purpose-built cradle which minimises disturbance of the corer during deployment and recovery operations. The cradle also ensures that the corer is never laid horizontally, which might cause disturbance of the sediment-water interface; rather the cradle maintains an angle of tilt of at least 15° at all times.

Magnetic susceptibility was measured on whole cores at 2 cm intervals, using a Bartington MS2-C meter connected to a 10 cm diameter coil. Data were corrected for instrument drift and end-of-core effects. Visual descriptions of the split cores were prepared taking note of sediment texture, colour, fossil content, apparent grain size, sorting, and sedimentary structures. Core logs giving visual core descriptions and magnetic data are attached in Appendix A.

Smear mounts were made by suspending a small portion of sediment in distilled water and mixing with a vortex mixer. Glass coverslips were placed on a warm hot-plate and pre-wetted distilled water. The diatom suspension was then pipetted onto the coverslips and allowed to dry. Slides were mounted in Norland optical adhesive dried under a UV light.

Qualitative species abundance and identification were determined using a Zeiss Standard 20 light microscope, at 400x magnification with an oil immersion lens. Slides were examined by traversing the coverslip, and diatom frustule abundance recorded as:

Abundant (A) - >1 frustule per field of view (* denotes dominant species);
Common (C) - 1 frustule per field of view;
Frequent (F) - 1 frustule in every 5 fields of view;
Rare (R) - 1 frustule observed in >5 fields of view;
Reworked species are indicated by a lower cased letter.

The quality of fossil preservation was recorded subjectively, based on valve morphology, mechanical damage, and dissolution:

Good (G) - frustules well preserved, having undergone little mechanical damage or visible dissolution;
Medium (M) - majority of frustules well preserved, but some evidence of mechanical damage or visible dissolution;
Poor (P) - frustules poorly preserved and primarily occurring as fragments.

Diatom abundances for each core interval examined are tabulated in Appendix B. In addition, samples were wet sieved and the residue examined under the microscope to identify foraminifer and general attributes of the sediment. These results are given in Appendix C.

Results

Overview of weather conditions during the cruise

Voyage 5 enjoyed remarkably fine weather for most of the voyage. Marine science days lost due to rough sea conditions and high winds numbered less than two (Fig. 2.1). The marine science program extended over a 35 day period, with most of the marine geoscience activities occurring between the first visit to Davis and the second visit to Mawson, with the main resupply of Mawson in between (Fig. 2.1). From the perspective of the marine science program, this timing of the Mawson resupply was somewhat inconvenient, as it forced the ship to backtrack between Prydz Bay and Mawson station, costing at least 3 days in transit time.

In subsequent chapters, details of weather and sea ice conditions encountered in each region are discussed.

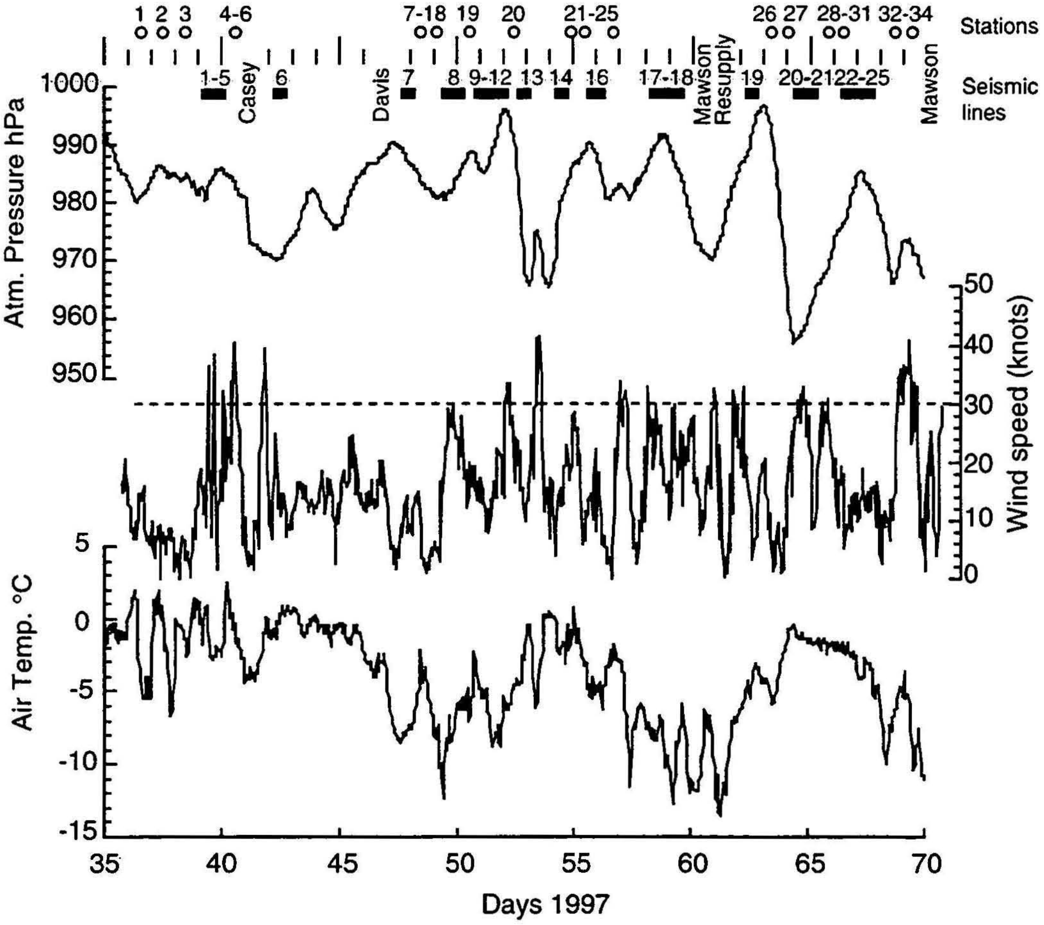

Figure 2.1 Summary of station and geophysical survey operations during cruise 186 in relation to shipboard observations of atmospheric pressure, wind speed and air temperature. The horizontal dashed line indicates the 30 knot wind speed threshold; wind speeds above this level hampered marine science operations on only a few occasions.

Equipment performance

Overall, the marine science equipment deployed on this cruise performed extremely well and with high reliability, particularly given the harsh (sub-zero) climatic conditions. Problems were encountered, however, using the Datasonics SIS-1000 45-55kHz FM (chirper) side-scan system that was borrowed from Wesleyan University in the U.S.A. This system was expected to provide sub-bottom profiling data that would otherwise be unavailable (the main justification for borrowing it in the first place). However, several problems were encountered: (1) trials in the Derwent River showed that the fibreglass tailplane mounts were damaged and these were repaired during the cruise; (2) the system was not supplied with user manuals. Eventually, extracts of a manual were faxed to the ship; (3) the 3km Netson tow-cable did not meet Datasonics specifications of a maximum of 50dB attenuation at 3.0Mhz. Tests on board showed an attenuation of 53dB over the entire cable run (i.e. deck cable, sliprings etc.). On the one occasion that this system could be used it was deployed with the supplied 75m cable, piggy-backed to our tow cable; (4) the supplied VGA monitor had a broken red signal line in the lead which was repaired during the trip.

Failure of the Datasonics system meant that the AGSO EG&G system was used instead; this system performed very well and gave good results. The only problem was with winch operations, which led to three collisions of the tow fish with the sheave; this was caused by the winch operator failing to reduce the tension setting for the winch as the length of cable out reduced during retrieval. After each collision, one of the joints on the tow cable was damaged and had to be replaced. Another incident saw the tow fish being dragged across the ice after it became snagged on thick pancake-ice. Eventually it was retrieved minus a set of tail-plane fins and in need of several other minor repairs. The unit was repaired and back in service after only a few hours. Steve Thomas deserves full credit for making all of these electronic and mechanical repairs during many extended shifts and extra hours, keeping the system operational.

Sediment Core and grab samples

A total of 35 gravity cores and 9 grab samples were collected during the cruise (Table 2.1). The core logs are attached in Appendix A, which also gives a list of core subsamples taken. In the case of grab 23GB9, a small mini-core was also taken from the sample as the sediment appeared to be more or less undisturbed in the Van Veen grab. Thus, the sediment-water interface may be well represented in this short core.

Table 2.1 Location, water depth and activities carried out at each station on AGSO cruise 186 to Vincennes Bay, Prydz Bay & Mac. Robertson Shelf (Antarctica). Activities included GC = Gravity Core, GB = Van Veen Grab, CTD = CTD probe, water samples and bottom photograph and CM = current meter deployment.

Station Number	Latitude	Longitude	Water Depth (m)	Activity
1	65° 22.8	109° 04.2	475	GC1, GB1
2	65° 28.7	108° 56.6	512	GC2, GB2, CTD1
3	65° 32.8	108° 47.3	592	GC3, GB3
4	66° 42.9	109° 09.3	1,850	GC4, GC5, CTD2
5	66° 30.3	109° 57.1	1,200	GC6, GC7, GB4, CTD3
6	66° 22.0	110° 10.4	1,740	GC8, GB5, CTD4
7	68° 04.0	72° 54.0	698	GC9
8	68° 04.2	72° 55.8	655	GC10, GC11
9	68° 04.5	72° 56.0	660	GC12
10	68° 11.9	73° 17.7	678	GC13
11	68° 13.2	73° 23.0	690	GC14
12	68° 11.8	73° 17.2	710	GB6, CTD5
13	68° 31.0	70° 24.5	1,050	GC15
14	68° 22.5	71° 18.4	726	GC16
15	68° 19.0	71° 27.9	716	GC17
16	68° 08.7	72° 01.2	608	GC18
17	68° 09.0	72° 10.0	775	GC19
18	68° 09.7	72° 16.4	780	GC20
19	67° 37.1	73° 18.0	570	GC21, GB7, CTD6
20	67° 41.5	72° 13.0	660	GC22
21	66° 55.1	64° 45.6	670	GB8, CTD7, CM1
22	66° 56.1	64° 56.1	363	CTD8, CM2
23	67° 31.7	64° 39.8	1,240	GC23, GB9, CTD9
24	67° 29.7	64° 57.3	1,240	GC24
25	67° 21.5	65° 58.8	785	GC25
26	67° 07.9	70° 47.7	390	GC26
27	67° 10.12	74° 30.2	436	GC27
28	67° 16.1	76° 23.9	338	GC28
29	66° 30.0	72° 16.5	1,230	GC29, GC30, CTD10
30	66° 24.1	72° 17.1	1,625	GC31
31	66° 19.1	72° 15.5	1,830	GC32
32	66° 44.9	63° 18.2	565	GC33
33	66° 56.55	63° 06.9	470	GC34
34	67° 10.8	62° 57.7	600	GC35

CTD data

CTD's with bottom photographs were collected at 10 stations (Table 2.1). The data were processed by Mark Rosenberg (Antarctic CRC) whose report is attached in Appendix D. Water samples and filter paper samples were also collected from each of the CTD's as listed in the Table attached to Appendix D. No interpretations of the data have been attempted in this report.

Seismic, and sidescan sonar data

Seismic and sidescan sonar data were shot on 25 separate lines (Table 2.3). These lines were of various duration, from less than one hour to a maximum of 13 hours (line 9), for a total of 151 hours. This is equivalent to a total length of 680 nautical miles (1,250 km) of seismic data. Sidescan sonar data were not collected on every seismic line (Table 2.2).

Table 2.2 List of seismic and sidescan sonar survey track line numbers with start/stop times.

Seismic Line Number	**Start/end time & shot point number**	**Sidescan Start/end time**	**Location**	**Notes**
186-01	039.0321/039.0547 100/1009	-	Vincennes bay	inner shelf
186-02	39.0610/039.0912 105/1330	-	"	"
186-03	039.1107/039.1830 105/3861	-	"	"
186-04	039.1841/039.2018 100-920	-	"	"
186-05	039.2051/040.0319 100-3386	-	"	"
186-06	42.0838/??? 100-2555	-	"	inner to middle shelf- Peterson bank
186-0601	???/42.1614 2591/3625	-	"	"
186-07	47.1519/47.1622 105/519	-	Prydz bay	inner shelf-Prydz channel moraines
186-0701	47.2024/47.2102 5000/5318	-	"	"
186-0702		-	"	"
186-08	49.0940/49.1952 110/5300	49.1627/50.0103 temporarily unreadable tape	"	inner shelf- Lambert basin moraines
186-0801	49.2026/50.0139 6023/8683	temporarily unreadable tape	"	"
186-09	50.1524/51.0443 110/6889	50.1434/51.0422		middle shelf - ODP site survey (PBS1)
186-10	51.1002/51.1428 105/2365	51.1007/51.1433	"	"

186-11	51.1527/51.1818 110/1568	51.1528/51.1753	"	"
186-12	51.1832/52.0451 100/5354	51.1832/52.0450	"	" (PBS2)
186-13	52.1302/53.0135 110-6500	-		middle to outer shelf
186-14	54.0701/54.0803 110/636	-	"	Fan- ODP site survey (PBF1)
186-15	54.0815/54.1123 100/1694	-	"	"
186-16	55.1413/56.0859 110/9659	55.1430/56.0229	Mac Robertson Shelf	Nielsen shelf valley
186-17	57.0748/57.0903 121/764	57.0749/57.0903	"	Shelf break over site of CM1
186-18	57.1401/57.1826 104/2351	57.1403/57.1755	"	Iceberg Alley
186-1801	57.1935/57.2039 3000/3544	57.2008/57.2039	"	"
186-19	58.1255/58.1552 100/1602	-	"	"
186-1901	62.1420/62.2010 2020/4990	-	"	"
186-20	64.0102/64.0310 100/1180	6.43/2.25	Prydz bay	outer shelf
186-21	64.0426/64.1353 100/4906	64.42/64.1325	"	"
186-2101	64.1525/65.0236 6000/11698	-	"	"
186-2102	65.1007/65.1046 12000/12328	-	"	"
186-2103	65.1111/65.1400 13000/14430	-	"	"
186-22	66.0706/66.1019 100/1744	66.0643/66.1029	"	"
186-23	67.0748/67.0929 100/959	-	"	ODP site survey (PBF5)
186-24	67.0935/67.1151 100/1254	-	"	" (PBF6)
186-25	67.1546/67.1702 100/743	-	"	"

CHAPTER 3 - VINCENNES BAY

Introduction

Vincennes Bay is a large embayment on the Budd Coast of East Antarctica, centred on the Antarctic Circle at 66°34'S; 109°E (Fig. 1.1). It is roughly triangular, 120km north-south and 150 km east-west at its northern extremity, and thus covers an area of about 9,000 km^2. To the east lies the icecap of Law Dome and the north-south oriented Windmill Islands coast of Precambrian basement, which is the setting for Antarctic stations Wilkes (USA, 1957-64) and Casey (Australia, 1959-present day). To the west, the coast trends west-northwest and merges into the ice-cliffed Knox Coast. The southern end of Vincennes Bay is marked by the Vanderford and Adams Glaciers which drain the subglacial Aurora Basin, a major feature of East Antarctica (Drewry, 1983). Peterson Bank (<200 m) is located on the eastern side of the bay and another shallow bank is located on the western side; however, much of Vincennes Bay lies deeper than 1000 m below sea level (Fig. 3.1).

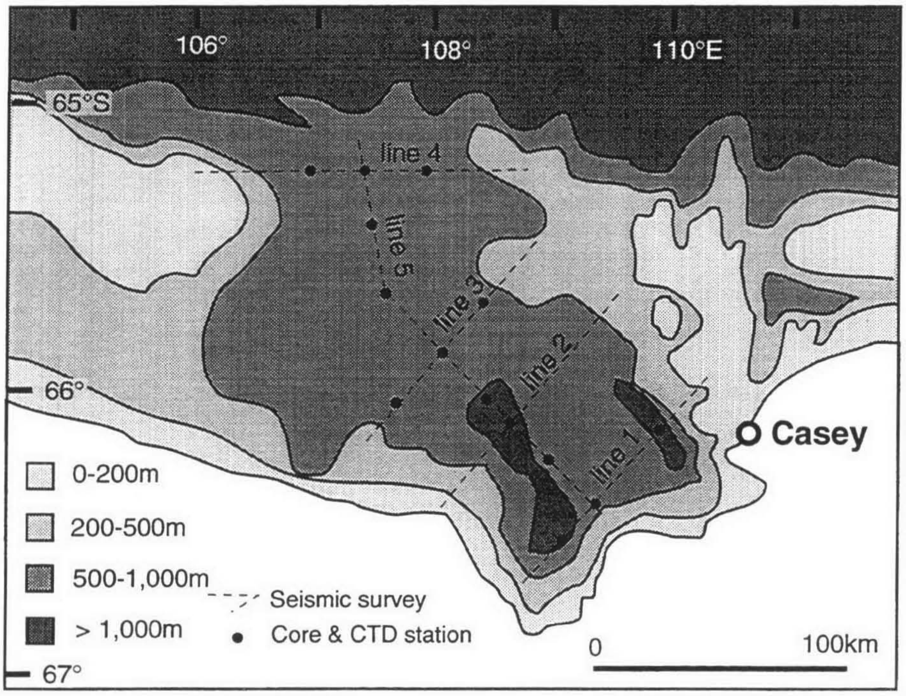

Figure 3.1. Location of proposed 5 seismic survey track lines and 14 core/CTD stations in Vincennes Bay.

Reasons for marine geological studies in Vincennes Bay include the proximity to the Law Dome ice coring site (Fig. 3.1) which presents an opportunity to link ice core records of atmospheric gases, air temperature (oxygen isotopes) and precipitation (Morgan et al., 1991), with offshore records of productivity and sea ice biota, and the discharge of glacially derived terrigenous sediments. Previous bathymetric surveys have shown that the bay includes several deep basins, which might act as sediment traps and thus provide the high resolution Holocene records that are needed for such comparative studies. The question of the extent of the Vanderford and Adams glaciers during the last ice age has been raised by Goodwin (1993). Allan & Whitworth (1968?) used gravity data to suggest the presence of a major crustal structure along the trough of the Vanderford Glacier that might have produced a long lived sedimentary basin, perhaps originating as early as the Proterozoic, and equivalent in part to the Perth Basin of Western Australia in a reconstituted Gondwana. Therefore, sediments sourced from the Aurora Basin may contain reworked fossils that could provide data on the age and environment of deposition of rocks comprising the basin fill.

Proposed Work Plan

The scheduled marine science program was originally allocated 26 days but this was subsequently reduced by five days (due to AGSO budget cuts), for a total of 21 marine science days. The Vincennes Bay seismic survey was designed as a series of 5 lines, shown in Figure 3.1. The survey way points are listed in Table 2.1. The total along-track distance is 340 nm (630 km) which would require 2.9 days at an assumed survey speed of 5 knots.

Table 2.1. Seismic way points for proposed Vincennes Bay survey.

Line No.	Latitude (S)	Longitude (E)	Length (km)
1	66° 00'	110° 15'	
	66° 40'	108° 45'	100
2	66° 25'	108° 00'	
	65° 40'	109° 30'	100
3	65° 30'	108° 45'	
	66° 10'	107° 20'	100
4	65° 15'	106° 00'	
	65° 15'	108° 45'	130
5	65° 00'	107° 15'	
	65° 40'	107° 30'	
	66° 30'	109° 30'	200

It was planned to locate the core and CTD stations based on results of the seismic survey, distributed more or less as shown on Figure 4. A total of 14 stations was planned and, allowing for 2 hrs per station, it was estimated that about 1.2 days would be spent on station. The transit distance between stations was estimated to be 180 nm which would require 0.75 days @ 10 knots. Thus the total Vincennes Bay work program was planned to use five days of marine science ship time.

Weather and sea ice conditions

Work in Vincennes Bay was greatly restricted by sea ice conditions, which precluded access to a major part of the Bay (Fig. 3.2). As a result, only one of the five proposed seismic track lines could be run. Furthermore, the ship was delayed by 3 days as we attempted to enter the Bay, due to heavy sea ice conditions. The time was used to the best possible advantage, as we collected cores each day we were beset by the ice, on the shallow bank (Peterson Bank) located on the mid- to outer-shelf.

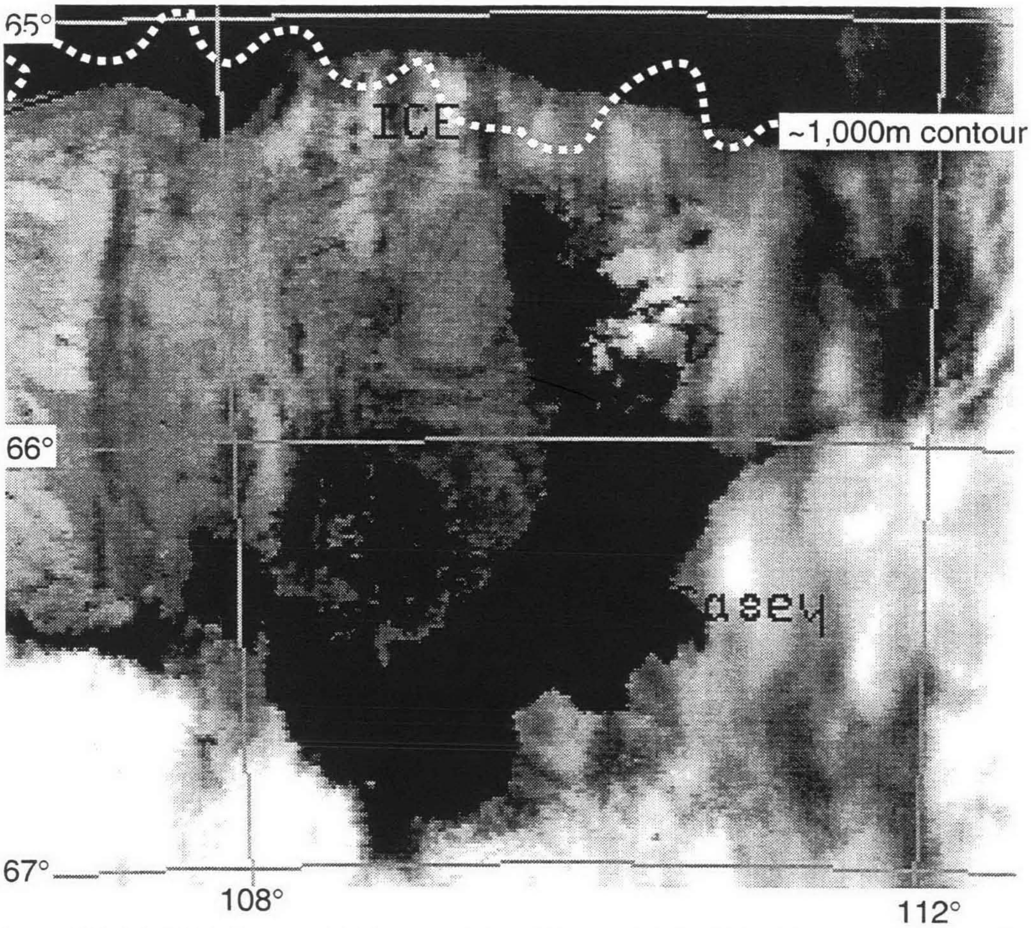

Figure 3.2. Satellite image of Vincennes Bay taken on 9-2-97 showing extensive sea ice cover on the mid- to outer-shelf. Open water was found only along a narrow belt at the head of the Bay adjacent to Vanderford Glacier.

Seismic, sidescan sonar and gravity core data

Seismic and sidescan sonar data were collected along 6 lines, over a total track length of about 200 km (Table 2.3). A total of 8 gravity cores, 4 grabs and 4 CTD's were collected at six stations in Vincennes Bay (Table 2.1 and Figure 3.3). Selected sub-samples were washed through nested 125 µm, 500 µm and 1 mm sieves for microscope examination of grain mineralogy and foraminifera. Detailed microscope analyses of diatoms were also carried out on slides of 27 core subsamples.

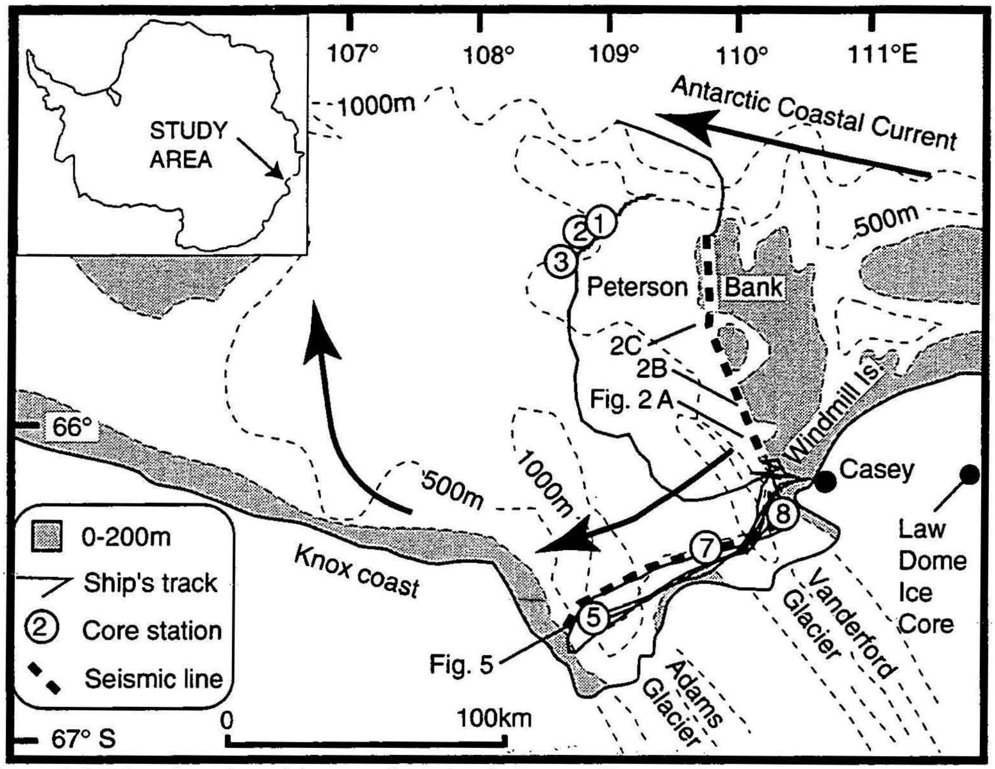

Figure 3.3 Map showing ships track, seismic survey lines and core stations in Vincennes Bay. The Antarctic coastal current and inferred circulation in Vincennes Bay are indicated.

Peterson Bank

The seismic data revealed that the inner bay is an exposed bedrock surface which is bathymetrically complex, with numerous ridges and valleys. Its geomorphology is similar to the inner Nielsen Basin (Harris and O'Brien, 1996) and probably to other glacial troughs along the East Antarctic margin. One north-south trending line of seismic data was shot over Peterson Bank (Figs. 3.3 and 3.4). The data show that the inner portion of the bank is mainly an exposed bedrock surface, and that this gives way northwards to partially eroded (truncated) sedimentary strata; at one location we have located the outcrop of the unconformity that separates the bedrock from the overlying sedimentary rocks (Fig. 3.4B). This unconformity has not been described from any seismic data previously collected in the region (Ishihara et al., 1985; Tsumuraya et al, 1996)

The inner portion of the bank is characterised by isolated, dome-shaped, steep sided bodies about 1-2 km wide and 150 m in vertical relief (Fig. 3.4A). These bodies have a highly reflective top surface and no internal reflections can be observed. Their flanks are onlapped by wedge-shaped packages of medium amplitude, continuos reflectors, generally sub-horizontal, sub-parallel, and locally folded and/or diverging near the onlap termination. The sea floor corresponding to these wedges is relatively smooth and flat. The actual thickness of these packages of strata cannot be estimated, until further processing of data is performed.

An asymmetrical valley (Fig. 3.4B), 600 m deep and 10 km wide, marks the boundary between the deeply eroded, inner continental shelf and the outer continental shelf. The orientation of this valley is questionable because of the paucity of data, but might be the westward continuation of a valley shown on the 200 m contour line bordering Peterson Bank (Fig. 3.4B). The southern side of the valley has a steeper slope (12 km/400 m) represented by a quite smooth, faulted scarp. Diffractions mask any reflectors that might have been observed below the sea floor. The sea floor profile of the northern, less-steep side of the valley (ca. 12 km/600 m) is characterised by steps with alternatively rough and flat surfaces, which suggest a differential erosion of hard and soft (sedimentary ??) rocks and/or faulted blocks. Further data processing is needed to define the actual geometry below the sea floor. The valley depocentre appears to be covered by a unit (at least 150 m thick) composed of sub-parallel, sub-horizontal to chaotic, medium amplitude, discontinuous reflectors.

The north-south trending line of seismic data shot over Peterson Bank (Fig. 3.3) shows that north of that valley (Fig. 3.4B) the acoustic basement becomes deeper and it is capped by a sedimentary bank, whose thickness increases from ca. 200 m to 800 m towards the north. The sea floor of this bank is quite smooth and flat, and it does not show any evidence of a morainal ridge. The average water depth is 150 m. This bank is composed of at least two sedimentary units. The upper unit is made of low amplitude sub-parallel, sub-horizontal reflectors, above a strong amplitude, continuos reflector, that can be traced from south to north (Fig. 3.4C). This reflector likely represents a major unconformity, that outcrops on the northern flank of the valley at a depth of 450 m below the sea surface and deepens northward up to 750 m (Fig. 3.4C). The internal geometry of the bank is mostly obscured by acoustic noise, but in the thicker section we can observe closely spaced sub-parallel reflectors gently dipping northward, sharply cut by a U-shaped trough (700 ms - 500 m deep, ca. 20 km wide; Fig. 3.4C). This trough is asymmetric and its south-facing steeper side is characterised by three steps (Fig. 3.4C). These steps do not apparently have a tectonic origin, because strata below the sea floor are not dislocated by faults. Also in this case, the U-shaped trough is located westward

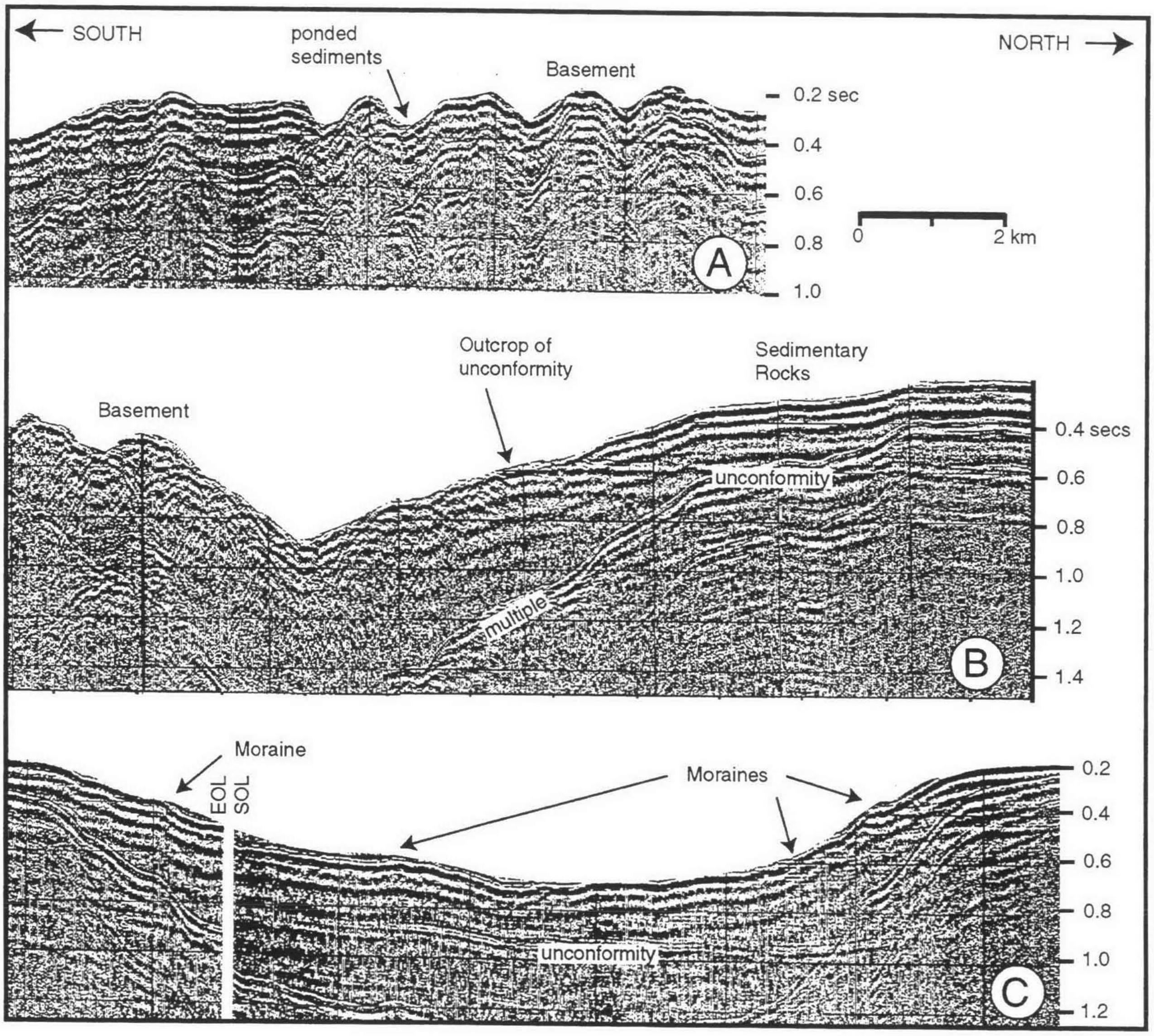

Figure 3.4 Seismic profiles collected over Peterson's Bank, Vincennes Bay, showing (A) bedrock outcrops, exhibiting a "mound" morphology with small basins which sometimes contain SMO deposits; (B) outcrop of unconformity with bedrock and overlying bedded sedimentary deposits; and (C) U-shaped valley on the mid-shelf exhibiting truncated sedimentary strata and possible Pleistocene galcial lateral moraines on valley sides and grounding line moraine on valley floor.

of a valley shown on the 200 contour line bordering Peterson Bank (Fig. 3.3). The sea floor of the U-valley is quite irregular.

Three cores from Peterson Bank were collected along a short transect across the inner, landward sloping flank of the bank in 475 to 592 m water depth (Fig.2.3). Core GC1 (475 m) includes massive beds of moderate yellowish brown sandy silt with minor forams, ice rafted debris and coal fragments, interspersed with dark greenish grey laminated intervals (Fig. 3.5). The lower section of the core contains a bioturbated interval, in which the upper boundary coincides with a strong peak in magnetic susceptibility (Fig. 3.5). Foraminifera occur only in the <1 mm fractions. The dominant planktonic foraminifer is *Neogloboquadrina pachyderma,* whilst the dominant benthic foraminifer is *Globocassidulina crassa* (taken during counting to include *G. biora*). Also present are *Astrononion echolsi, Cibicides refulgens,* and *Angulogerina earlandi,*. Agglutinated species were not found in the samples studied. There is no evidence of dissolution but many of the specimens were broken. The sand fraction comprised angular lithic grains, with rare, rounded, high sphericity quartz grains. Noteworthy in the <1 mm fraction are coal fragments, suggesting reworking of older sedimentary strata. In the <500 mm fraction, well rounded grains are common and occur as both clear and also reddish (iron-stained?) grains. *Fragilariopsis kerguelensis* dominates the core top diatom assemblages of GC01 and GC02; *F. curta* is sub-dominant. Frustules are abundant and well preserved, forming diatomaceous ooze. In GC01, diatoms are rare and poorly preserved below 203 cm. The presence of *Actinocyclus ingens* (LA 0.62 Ma) and *Denticulopsis hustedtii* (LA 5.7 Ma) indicates that the lower sections of the core have undergone reworking.

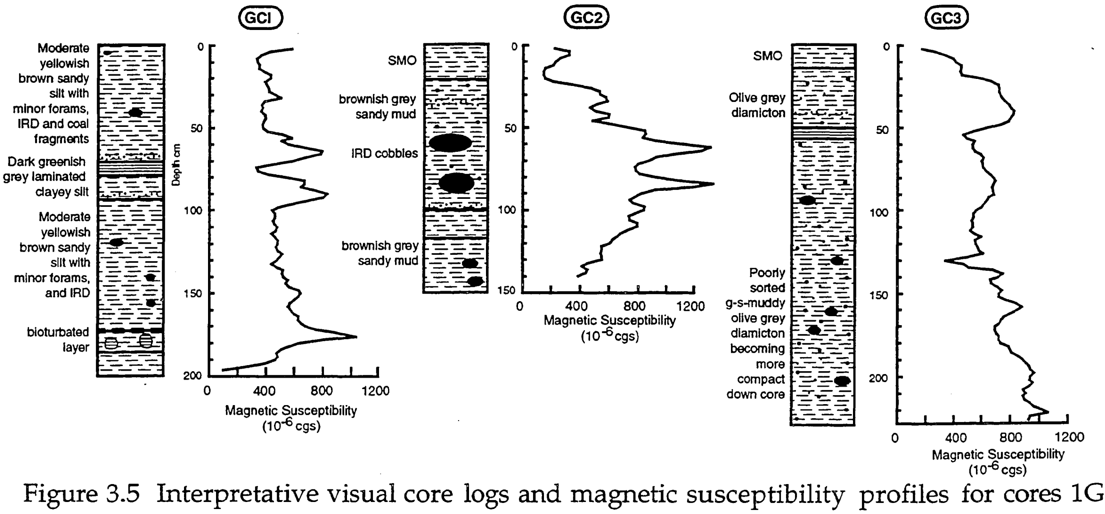

Figure 3.5 Interpretative visual core logs and magnetic susceptibility profiles for cores 1GC1, 2GC2 and 3GC3 collected from Peterson Bank.

Cores GC2 and GC3 (512 and 592 m water depth, respectively) contained an upper layer, 10 to 20 cm in thickness, of olive green siliceous mud and diatom ooze (SMO). Sediments in the upper part of the core (0-20cm) contain sponge spicules, radiolaria and a few calcareous foraminifers. The upper unit is delimited by relatively low magnetic susceptibility readings (Fig. 3.5). The dominant foraminifer is *Neogloboquadrina pachyderma* which occurs as a few tens of specimens; benthic species are rare.

Deeper than 40 cm, foraminifera are absent and the sediments consist of brownish grey sandy mud with angular to subangular particles and coal fragments. The presence of coal in the lower samples may indicate that there is a provenance difference between the lower and upper units. Large 'ice-rafted' grains include two cobbles >10cm in size in core GC2 and are randomly scattered throughout the unit but appear to form IRD-rich layers in a few locations (Fig. 3.5). Magnetic susceptibility is relatively high in this unit, and relative peaks coincide with sandy-gravel layers (core GC1) and with the two IRD cobbles mentioned above (core GC2; see Fig. 3.5).

Fragilariopsis curta is the most abundant species throughout cores GC02 - GC08. Sub-dominant species include *F. kerguelensis* and *Thalassiosira antarctica* cysts. Frustules are common to abundant, with good to medium preservation, throughout the entire length of all cores. Diatoms are absent at the base of GC03 (226.5 cm). GC03 is also characterised by layer of *Trichotoxin reinboldii* at 5 cm. This elongate diatom is rarely preserved in abundance in sediment, and may represent a period of higher than normal primary productivity and rapid settling.

Inner Vincennes Bay Glacial Trough

Seismic data were collected along SW - NE trending track lines in inner Vincennes Bay across the front of the Vanderford and Adams Glaciers (Fig. 3.3). Thick sea ice over much of the bay precluded a more extensive seismic survey. The data revealed that the inner bay consists of an acoustic basement (exposed bedrock) surface that is bathymetrically complex, with numerous ridges and valleys (Fig. 4). Its geomorphology is similar to the inner Nielsen Basin (Harris & O'Brien, 1996) and is probably similar to other glacial troughs found along the East Antarctic margin.

A deep glacial trough offshore of the Vanderford Glacier extends to 1,800 m water depth and another offshore of the Adams Glacier extends to 2,250 m. These two troughs are bounded by steep slopes, sometimes characterised by steps and narrow incisions, and separated by a shallow (450 m) incised bank (Fig. 3.6). At a depth between 600 and 1000 m, small (<1 km) areas of internally non-reflective ponded sediments, with a smooth and flat upper surface, onlap the flanks of the acoustic basement (Fig. 4). The probable thickness of these deposits ranges from 20-60 m, (assuming a seismic velocity of 1800 m/s) to 15-50 m (assuming a seismic velocity of 1400 m/s; see Bissell, 1993).

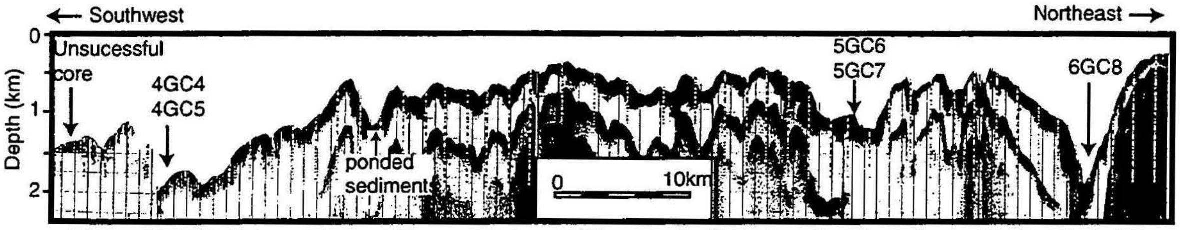

Figure 3.6 Bathymetric profile across inner Vincennes Bay showing location of incised valleys and coring stations.

Cores were collected at three locations within deep basins in 1,200 to 2,100 m water depth, where Holocene sediments are expected to have accumulated. The core attempted on concave bedrock was unsuccessful, indicating the paucity of sediments over this area. Deep basins provide the best local sediment traps where coring is successful (Fig. 3.6).

The glacial trough cores were markedly different from those collected from Peterson Bank, in texture, mineralogy, fossil content and absolute values of magnetic susceptibility. Peterson Bank cores are coarser, more poorly sorted, contain calcareous fossils and have magnetic susceptibilities of up to 1,200 x 10^{-6} cgs, whereas the glacial trough sediments are finer, medium to well sorted, devoid of calcareous fossils (consistent with deposition below the carbonate compensation depth) and have magnetic susceptibilities that do not exceed 400 x 10^{-6} cgs. Samples from the sand fraction of the glacial trough cores contain only agglutinated foraminifera, typically *Trochammina conica* (~50% of fauna) *T. antarctica* (~20%) and *Reophax difflugiformis* (~15%).

Down-core variation, as well as variation between glacial trough cores, is apparent in the lithological logs (Fig. 3.7) and in the results of the microscope analyses (Figs. 3.8). Core GC5 contains numerous laminae of brown and dark yellowish brown clay, which form graded couplets and which are interpreted as turbidites. Under the microscope, framboidal pyrite in the form of what appear to be tube or burrow linings are found; these have the appearance of lining part of a cylindrical tube, not the entire tube. Detrital grains and diatoms are nearly equally abundant in the upper 160 cm of this core; diatoms outnumber grains by a factor of 5 below 200 cm (Fig. 3.8). The abundance of spores is relatively low in the upper 160 cm of this core compared with the abundance below 160 cm (Fig. 7). *Fragilariopsis curta* is more abundant than *F.kerguelensis* throughout the core (Fig. 8) and the other counting groups also remained more or less constant down-core, with diatom fragments accounting for 56-78%, centrics 5-12%, and pennates 16-28% and spores 0-6% of total diatoms counted (Fig. 3.8). Down-core variation in magnetic susceptibility shows a distinctive low at 160cm with relative "highs" at around 30 cm and 280 cm depth down core (Fig. 3.7).

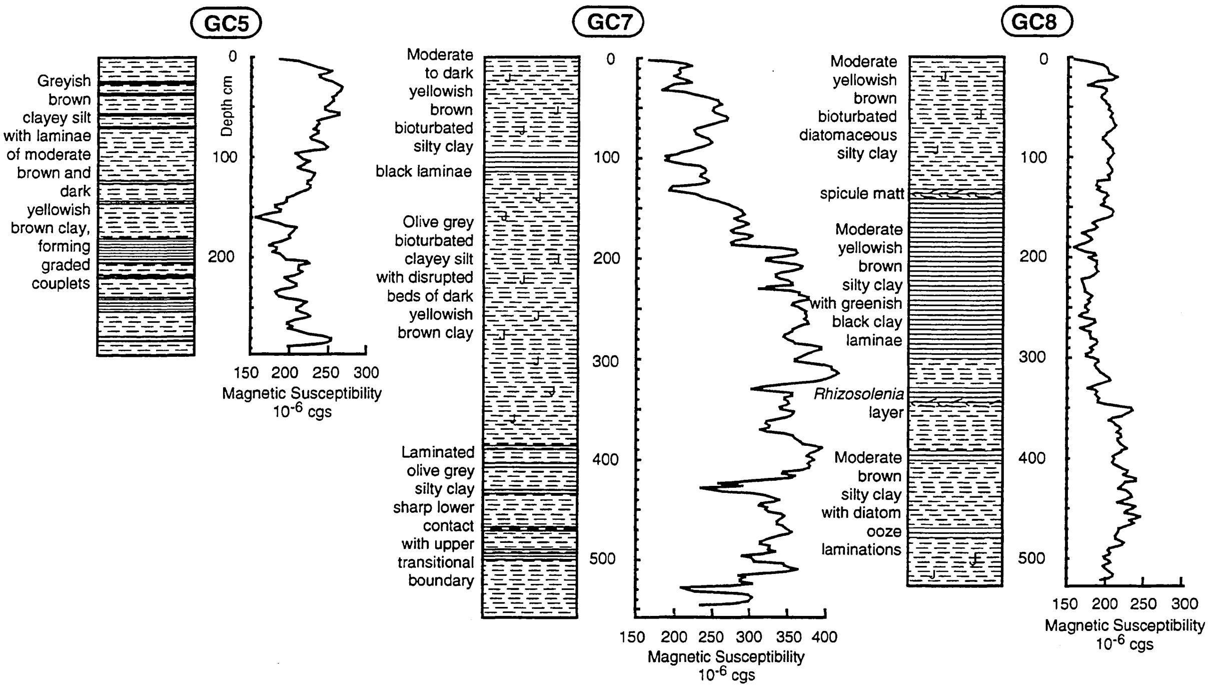

Figure 3.7 Interpretative visual core logs and magnetic susceptibility profiles for cores collected from inner Vincennes Bay. See Figures 2.3 and 2.6 for core locations.

Core GC7 is located in a perched basin in 1,200 m water depth (Fig. 3.6). The core exhibits a marked change in the occurrence of bioturbation structures, which are abundant above 400 cm and absent below this depth, and an increase in preservation of laminae (that are common below 400 cm core depth; Fig. 3.7). The laminae exhibit a sharp lower contact with an upper transitional boundary, indicative of turbidites. A distinctive feature of the core is the occurrence of gravel-sized macro-algae fragments, which appear to have become incorporated into the turbidites. This core also exhibits the greatest absolute values of magnetic susceptibility, which exceed 400x10-6 cgs at a depth of 310 cm (Fig. 3.7). A low in magnetic susceptibility occurs at 100 to 130 cm, with a broad peak at 200-300 cm and another low at 420 cm (Fig. 5). In contrast with the other cores, grains outnumber diatoms at most depths, apart from at 130 cm (magnetic susceptibility low) and below 350 cm, where diatoms are slightly more abundant (Fig. 3.8). Diatom counting groups (Fig. 3.8) are dominated by fragments (52-83%), whilst pennates account for 9-33%, centrics 5-14% and spores 1-10% of the diatoms counted.

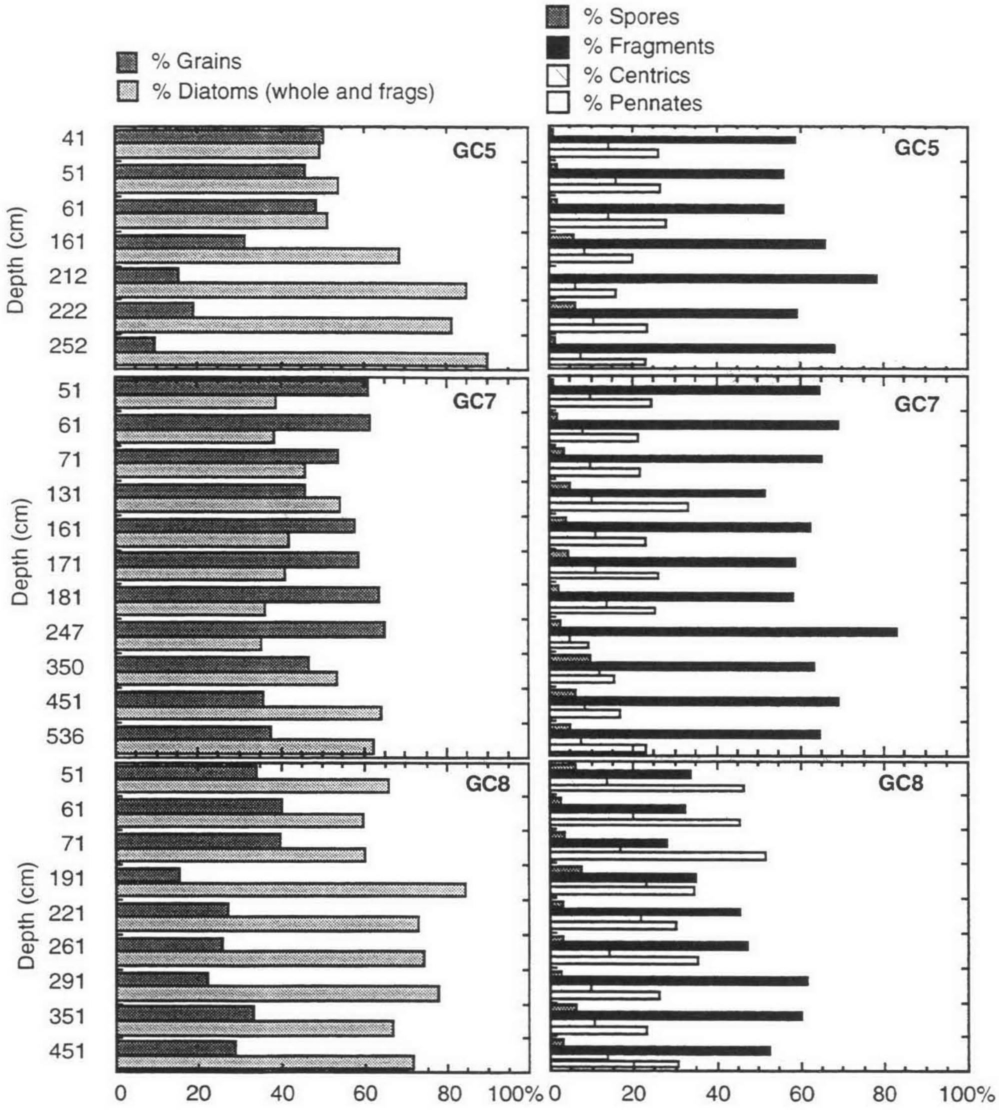

Figure 3.8 Bar graphs showing results of microscope analyses of 27 core subsamples. The data derived include relative abundance of lithic grains versus diatoms (left) and subdivision of diatoms into four groups: centrics, pennates, spores and fragments.

The upper 130 cm of core GC8 is similar in appearance to the upper 100 cm of core GC7 (Fig. 3.7). This similarity is reflected in the relative abundance of grains and diatoms (Fig. 6) in which grains are only slightly less abundant than diatoms, although diatoms are more abundant than grains in core GC8 in all of the samples studied (Fig. 3.8). Between 130 and 300 cm, however, the core contains a moderate yellowish brown silty clay with greenish black clay laminae (Fig. 3.6) in which diatoms outnumber grains by a factor of 5.4 at 191 cm (Fig. 3.8). This abundance of diatoms is also reflected by the differences between the counting groups, in which pennates outnumber diatom fragments in the upper 130 cm, a pattern that is not observed in any other core (Fig. 3.8). Below 130 cm, fragments outnumber other counting groups and there appears to be a trend of increasing fragments and decreasing pennates and centrics down-core (ie. from 191 to 291 cm; Fig. 3.8). Core GC8 contains a relatively greater abundance of *F. curta* (up to 28% of the diatoms counted) compared with the other cores which had maxima of 16% and 14% (for GC5 and GC7, respectively). Core GC8 also had the lowest absolute values of magnetic susceptibility of the three cores studied (Fig. 3.7). There is an apparent magnetic susceptibility low at 190 cm (Fig. 3.7).

Discussion of Vincennes Bay Results

Seismic facies

The seismic facies of the inner continental shelf are typical of exposed bedrock, likely composed of magmatic intrusive rocks and folded (Paleozoic?) sedimentary basins. Faults bounding the principal grabens show a SE-NW tectonic trend that is comparable to the coastal glacier (Vanderford and Adams glaciers) drainage pattern, which is also oriented SE-NW (Fig. 3.3)

No recent sedimentary drifts have been preserved on the inner continental shelf, apart from local sedimentary traps in the shallower areas, likely containing up to 60 m of SMO (Fig. 3.6). The middle- to outer-shelf part of Peterson Bank comprises a sedimentary wedge that thickens seaward. This has been cut by U-shaped valleys (Fig. 3.4C) that is clear evidence of glacial expansion toward the middle-outer continental shelf, probably from east Law Dome during sea level low stands. The steps observed on the valley walls might be lateral moraines deposited during episodic ice-sheet retreat. A dip-oriented line across the depocentre of the valley would verify the occurrence and the location of these grounding line moraines. The concave (depositional?) features in the middle of the valley floor may be (last glacial?) lift-off moraines. The flat and smooth top surface of Peterson bank (corresponding to stiff diamictite in Peterson Bank cores GC1, GC2 and GC3) resembles that of other banks of the Antarctic continental shelf, where it is interpreted as to be caused by erosion and deposition from the base of a quasi-stationary ice shelf (Boulton, 1990).

Lithostratigraphy of cores

Our interpretation of the lithologies of cores GC1, GC2 and GC3 is that the poorly sorted, compacted muddy sandy gravels probably represent Pleistocene subglacial to glacial marine sedimentation on the outer shelf banks. They appear to be similar to the diamictons described by previous workers from other locations around the Antarctic shelf (Domack, 1982; Anderson et al., 1984; Anderson and Molnia, 1989). However, there is evidence that the cores have been effected by iceberg turbation. This would explain why the thin (20 cm) layer of Holocene SMO is present in cores GC2 and GC3 but is absent in core GC1. The layer containing clasts at 180 cm in GC1 (Fig. 3) could also be interpreted as being caused by iceberg turbation. Further sidescan sonar survey work over the area would determine whether this was the case. Follow-up palynology is warranted to examine the origin of the coal (Permo-Triassic Beacon Group?) and of the reddish grains. Along the coast of East Antarctica, red sandstone is common as boulders, but the age and source of the sandstone are unknown.

In contrast with the Peterson Bank cores, GC5, GC7 and GC8 represent late Holocene glacial trough sedimentation. In the following discussion information from 27 points is correlated with the magnetic susceptibility signature to infer correlations of events between the cores, which represent temporal changes in the nature of particulate supply rate and/or source.

Sediment source and coastal circulation

The ratio of mineral grains to diatoms (Fig. 6) illustrates that cores GC5 and GC8 are similar. Both cores are dominated in most or all intervals by diatoms rather than mineral grains. The proportion of grains also increases sharply upwards in the cores at a depth of about 100 cm in core GC5 and at a depth of 130 cm in core GC8. This indicates a change in the relative supply of diatoms versus grains sometime in the recent past at these two sites, either an increase in terrigenous or a decrease in biogenic rate of sediment supply.

The ratio of grains to diatoms is quite different for core GC7 such that mineral grains dominate over diatoms for most of the upper part of the core, but not in the bottom of the core (between 350 to 536 cm; Fig. 3.6). This clearly indicates a source of particulate matter at this site that is different than that for the other two cores. If the increase of mineral grains found in the bottom of this core represents the same event as seen in cores GC5 and GC8 then the sedimentation rate for core 7 must be higher (by a factor of ~5) than the other two cores.

The Vanderford Glacier is likely to be the dominant source of siliciclastic grains in the region, supplied as ice rafted and plume suspension material that is transported into Vincennes Bay. Core GC7 is located just along the western margin of the submarine trough occupied by the Vanderford Glacier and it is from this glacier that it must be receiving its high load of silt and clay. The abundant supply of siliciclastic material dilutes the diatom component and produces a sediment record over time that is dominated by mineral grains over diatoms (Fig. 6). To the east, at the site of core GC8, the mineral input of the Vanderford Glacier does not have as great an impact. Here, instead of mineral grains, diatoms dominate beyond the influence of suspended sediment plumes formed at the grounding line of the Vanderford Glacier.

Core GC5 is similar to core GC8 because it too is beyond the direct influence of suspended sediment derived from the Vanderford Glacier. Core GC5 is located on the far western side of Vinncenes Bay, separated from the Vanderford system by a headland and a bathymetric high (Figs. 1 and 4). Although the smaller Adams Glacier does enter the sea near core GC5 it apparently does not supply terrigenous sediment at a sufficient rate to dilute the biogenous detritus settling at the core site.

These sedimentation patterns are probably explained by the regional ocean circulation patterns in Vincennes Bay being similar to those reported for Prydz Bay. In Prydz Bay, a westward flowing boundary current known as the Antarctic Coastal Current (Smith et al., 1984) flows along the northern margin of the bay, and a clockwise rotating gyre is centred over the middle part of the bay (Nunes Vaz and Lennon, 1996). Extrapolating this general circulation pattern to Vincennes Bay (Fig. 3.3) provides an explanation of how northwestward flowing meltwater plumes discharged by the Vanderford and Adams glaciers are deflected towards the southwest by the influence of the coastal current and by the Coriolis force.

Productivity regimes and diatom variability

Analyses of the diatoms from the three cores provide additional insight into the nature of the source areas for the three sites, and demonstrate a contrast in open water versus sea ice dominated conditions across Vinncenes Bay. The composition of the four major counting groups of diatoms (fragments, pennates, centrics, and spores) reveals significant differences between the three cores. Fragments dominate throughout cores GC5 and GC7. In core GC8 however, fragments are of secondary importance to pennate diatoms in the upper 130 cm, and this upper unit contains the greatest abundance of *F. curta*, which forms up to 30% of the diatoms counted in some samples (Fig. 8). In the middle part of core GC8 (130 to 250 cm) pennate and centric diatoms are of nearly equal abundance to fragments, and it is not until a depth of greater than 291 cm that diatom fragments become clearly dominant over whole diatoms (Fig. 7).

We interpret these observations as a reflection of open water conditions and higher productivity within the eastern portion of Vincennes Bay, near core GC8. Fragmented diatoms are likely to be produced by grazing zooplankton. The fragments are not attributed to glacial grounding line reworking processes because if this were the source we might expect there to be correlation between terrigenous grains and fragmented diatoms; in fact there is only a poor correlation between diatom fragments and mineral grains (R = 0.2). Rather, in highly productive open water environments, diatom blooms of water pennate species, *F. kerguelensis* , and the sea ice diatom, *F. curta* (Fig. 8) are sufficient to overwhelm the grazing zooplankton thus bypassing them and providing a direct source of whole diatoms to the seafloor. Furthermore, a polynya is known to consistently form within the inner portion of Vincennes Bay (Gloerson et al., 1992; Potter, 1995), so this could be conducive to earlier blooms and generally more productive conditions. The high index of fragmentation in cores GC5 and GC7 is explained because these locations are less productive and most of the diatoms are processed by grazing zooplankton.

Temporal variability

One other obvious difference between the cores is the relative magnitude of the magnetic susceptibility values; these are lowest in core GC8 and highest in core GC7 (Fig. 5). This variation is due to the relatively higher abundance of diatoms in GC8 compared with GC5 and particularly GC7. Plotting diatom (or terrigenous grain) abundance versus magnetic susceptibility shows a good correlation between the 27 samples studied (R = 0.71), and hence the magnetic susceptibility curves in Figure 5 are a guide to the natural variability in relative diatom/terrigenous grain abundance.

Temporal (down-core) changes in the proportion of diatoms and the abundance of mineral grains suggest a decrease in biogenic sedimentation or an increase in terrigenous input across the area, relatively recently (late Holocene). This trend is most easily explained as being caused by a cooling event, since the shift from biogenic to siliciclastic dominated sedimentation (Fig. 6) is paralleled by a shift from open water diatoms to sea ice diatoms (Fig. 8). Although colder conditions do not necessarily mean more sea ice and/or greater terrigenous sediment influx, this interpretation is consistent with the results of recently published studies that have been conducted along the Antarctic Peninsula (Shevenell et al., 1996; Leventer et al., 1996)

Conclusions

The initial results of our coring and seismic profiling survey of inner Vincennes Bay show that the area is (and probably has been throughout the late Quaternary) strongly influenced by terrigenous glacial marine sedimentation processes. Siliciclastic sediments dominate over biogenic sediments even in deep, inner shelf glacial trough settings, which have yielded mainly SMO in previous comparable studies. Glacial erosion has produced an over-deepened glacial trough on the inner shelf, up to 2,100 m in depth locally. Sediments deposited in 475 to 592 m water depth on Peterson Bank exhibit massively bedded diamictons overlain by a thin layer (<20 cm thickness) of SMO; core GC1 had no SMO layer. We infer that the sites have been subjected to iceberg turbation and mixing relatively recently.

Analysis of cores collected from the inner shelf glacial trough suggests an east-west variation in biogenic sediment supply, in which the highly productive site GC8 corresponds to an abundance of whole pennate diatoms and reduced abundance of diatoms fragments, that we attribute to the limited capacity of grazing zooplankton. Terrigenous sediment from the Vanderford Glacier is accumulating most rapidly at site GC7, which appears to be a local sediment trap; one perched basin located nearby (in <450 m water depth) contains as much as 60 m of unconsolidated sediment. Down-core variations in sediment properties and magnetic susceptibility reflect late Holocene changes in the relative biogenic/terrigenous sediment supply.

Our interpretations are preliminary and need to be supported by additional quantification of productivity signals and sediment sources, perhaps using water samples of suspended particulates, more detailed and standardised diatom studies and geochemical markers of organic carbon sourcing, such as $\delta^{13}C$. An absolute chronology also needs to be developed for these cores in order to place them into the growing data base of Holocene palaeoclimate variability for coastal Antarctica. The isolated location of Vincennes Bay and its close proximity to the Law Dome ice core, the only coastal high resolution ice core in Antarctica, should make additional study of these sediments a priority.

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CHAPTER 4 PRYDZ BAY

Introduction

Prydz Bay is a major re-entrant in the East Antarctic coast extending from 69°E to 80°E latitiude (Fig. 1). Its geometry reflects the structure of the underlying Lambert Graben, a major crustal structure with a history extending back to the Palaeozoic (Stagg, 1985; Barron et al., 1991). Through this structure flows the Lambert Glacier-Amery Ice Shelf ice drainage system, which drains about 20 percent of the East Antarctic interior (Allison, 1979). This convergence of drainage into the one system means that its grounding zone should fluctuate significantly with the waxing and waning of the East Antarctic Ice Sheet, uncomplicated by input from the West Antarctic Ice Sheet.

Past studies of Prydz Bay have identified three major features that have particular significance in understanding the Plio-Pleistocene geological history of Prydz Bay; grounding zone moraines left by the Lambert Glacier (O'Brien and Leitchenkov, in press), the trough mouth fan forming the continental slope offshore from Prydz Channel (O'Brien and Harris, 1996) and sediment drifts on the upper continental rise (Kuvaas and Leitchenkov, 1992). Ice shelf grounding zones are key regions in Antarctic ice sheet dynamics in being the zone of interaction between major ice streams and the Southern Ocean. The location of grounding zones is also sensitive to the ice sheet's response to sea level and climate change. Studies of sedimentation in grounding zones has been limited to indirect studies of the beds of ice streams (Alley et al., 1989), of modern temperate glaciers (Powell, 1990), work on northern hemisphere palaeo-ice margins (King et al., 1991) and interpretation of seismic data from the Antarctic shelf (De Santis et al., 1994). Sidescan sonar data has not been recorded for grounding zones moraines of any of the major ice streams around Antarctica.

The Prydz Channel Trough Mouth fan and the sediment drifts of the upper continental rise off Prydz Bay have been nominated as targets for the Ocean Drilling Program. Both deposits have the potential to contain major records of Antarctic glacial history, the trough mouth fan recieving siliciclastic sediment from the Lambert Glacier during major glaciations (O'Brien et al., 1995) and pelagic material during interglacials and the drifts recieving variable amounts of distal siliciclastic and pelagic sediment during the glacial cycle (Kuvaas and

Leitchenkov, 1992). Deep sea drift deposits are known world-wide as sources of high resolution sedimentary records. Earlier ODP drilling in Prydz Bay (Barron, Larson, et al., 1991) also found the oldest known Palaeogene glacigene sediments in Antarctica, reaching Eocene strata in site 742. However, sediment geometry on seismic lines indicates that the hole did not reach the base of the glacigene sequences. These sediments could be drilled more easily on the western side of Prydz Bay where glacial erosion has removed a large part of the younger section.

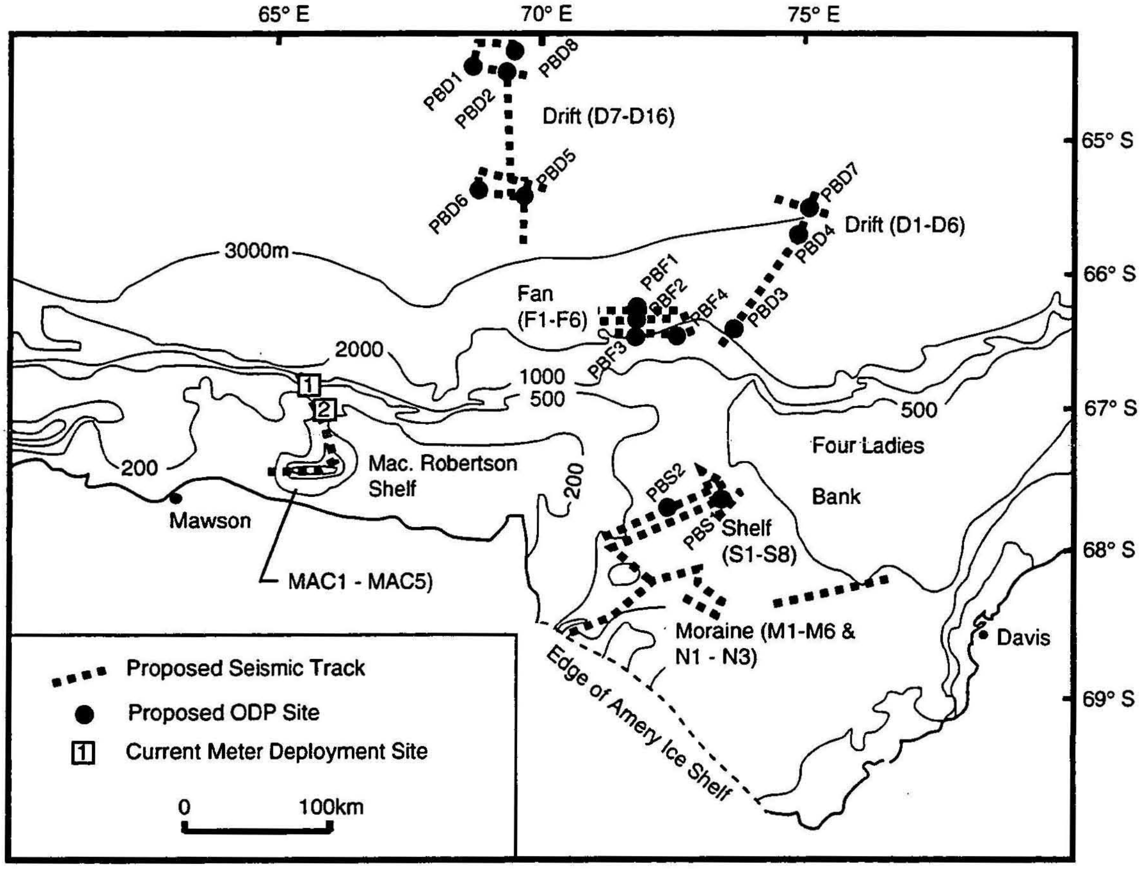


Figure 4.1 Location of proposed seismic survey tracks and core sites in Prydz Bay. The areas were subdivided into Moraine, Shelf, Fan and Drift areas. The Mac.Robertson shelf survey results are described in Chapter 5. Way points and locations of proposed ODP site are listed in Table 4.1.

Objectives

The outer shelf of Prydz Bay comprises relatively shallow banks with depths in the order of 400 to 100 m, separated by Prydz Channel which is 150 km wide and 500 to 600 m deep at the shelf edge (Fig. 1). Prydz Channel extends inshore to the Amery Depression that occupies the inner part of Prydz Bay. The Amery Depression is mostly 600 to 800 m deep with some deeper regions such as the Lambert Deep in the south-west corner of the Bay which reaches 1100 m deep (Fig. 1).

Hambrey et al., (1991) concluded that the morphology and stratigraphy of Prydz Bay results from advance of the Lambert Glacier and ice from the eastern side of the Bay to the shelf edge during major glaciations, with a fast-flowing ice stream occupying Prydz Channel. Moraines were identified in Prydz Channel, Lambert Deep and the Amery Depression by O'Brien (1994; Fig. 1). O'Brien and Leitchenkov (in press) interpreted them as having formed at grounding line positions temporarily occupied during the retreat of the Lambert Glacier from Prydz Channel, although they recognised the possibility that some of these moraines may have been the limit reached during the Last Glacial Maximum.

This cruise had multiple objectives for the Prydz Bay leg. They were:

1. Collect seismic, sidescan and core data from several grounding zone moraines in western Prydz Bay to develop a model of grounding zone sedimentation and chronology.
2. Conduct site surveys for ODP Proposal 790. Site surveys were to include, as a minimum, a seismic line through the site at 90° to the existing line upon which the site was chosen, and a gravity core from the site.
3. Collect seismic and sidescan data and sediment samples for sea floor characterisation to compare with benthic community studies undertaken on the voyage by staff from Deakin University and the Museum of Victoria.

Where possible, seismic lines were extended to improve the tying of existing lines.

Cruise Plan

Lines were planned (as shown in Fig. 4.1) using seismic and echo sounder date collected by previous cruises to Prydz Bay (Stagg, 1985; Mizukoshi et al., 1986; Kuvaas and Leitchenkov, 1992; O'Brien et al., 1995). ODP site selection is detailed in Proposal 790 by O'Brien et al. (in prep.) and the way points are listed in Table 4.1. Benthic trawl sites were selected by the benthic ecology project staff using bathymetric and surface sediment maps prepared by the Antarctic CRC Natural Variability Sub-program. A west to east seismic and sidescan line was planned to link these sites into the available survey data, and gravity cores were planned to be taken at each site.

Table 4.1. Seismic survey way points and current meter mooring locations in Prydz Bay

MORAINE							
MOR1	68°	08	00S	076°	10	00E	Seismic from MOR1 to M6
M1	68°	17	3.93S	074°	03	58E	
M2	68°	03	37.5S	072°	50	54E	
M3	68°	05	49.3S	072°	51	19E	
M4	68°	13	38.4S	073°	25	20E	
M5	68°	18	6.68S	073°	23	36E	
M6	68°	11	55.2S	072°	51	34E	Coring 0.5 days
M2							Seismic M2 to N3
N1	68°	08	30S	072°	01	48E	
N2	68°	22	24S	071°	16	46E	
N3	68°	31	00S	070°	24	00E	Coring N3 to N1
N1 to S2							Transit
SHELF							
S2	67°	54	38S	071°	17	59E	Seismic S2-PBS1-S1
PBS1	67°	36	57.3S	073°	18	20.9E	
S1	67°	34	52S	073°	33	36E	Core PBS1 + transit S3
S3	67°	41	29S	073°	09	25E	S3-S4-S5-PBS2-S6 SEISMIC
S4	67°	26	46.5S	072°	53	3.3E	
S5	67°	31	36S	073°	13	51E	
PBS2	67°	41	27S	072°	13	05E	
S6	67°	50	31S	071°	16	17E	TRANSIT S6-PBS1 + CORE
PBS2	67°	41	27S	072°	13	05E	
PBS1	67°	36	57.3S	073°	18	20.9E	TRANSIT TO S7
S7	67°	42	40S	072°	28	52E	SEISMIC TO S8
S8	66°	59	35S	071°	52	3.4E	TRANSIT TO F1
FAN							
F1	66°	31	4S	071°	21	15.7E	SEISMIC F1-PBF3-PBF4-F2-F3-
PBF3	66°	30	46S	071°	41	16.7E	PBF1-F4-F5-PBF2-F6
PBF4	66°	30	1.73S	072°	17	31.1E	CORING F6-PBF4-PBF3-PBF2-PBF1
F2	66°	29	59S	072°	24	38.7E	
F3	66°	19	44.6S	072°	29	4.5E	
F4	66°	20	42S	071°	00	28.5E	
F5	66°	23	18S	071°	04	33.9E	
F6	66°	23	2S	072°	21	14.3E	
PBF2	66°	23	20S	071°	38	2.13E	
DRIFT							
D1	66°	15	55S	073°	27	4E	
D4	65°	30	54.6S	074°	46	48.5E	
D5	65°	38	57S	075°	04	11.3E	
D6	65°	31	45.5S	074°	16	49.2E	
D7	65°	50	46.4				

Results of seismic and sidescan sonar surveys

The areas in which seismic and sidescan sonar data were actually collected are shown graphically in Figure 4.2 and listed in Table 2.2. As can be seen, the Prydz Fan area was not surveyed to the extent planned. This was caused by the presence of a large (~80km long) iceberg, which was situated over the planned core sites for the duration of our cruise. The drift sites had to be abandoned due to time limitations.

Sidescan data were examined as uncorrected paper records and seismic data were examined first as single channel monitor records. Seismic lines were then processesed by summing the four channels together. Important parts of lines were filtered using a bandpass filter (2/4 Hz-100/150 Hz), and various forms of deconvolution and gain enhancement were tried using VISTA software on a PC. It was found that, for shallow data, spiking deconvolution allowed detection of reflectors that were otherwise masked by the strong bottom signal.

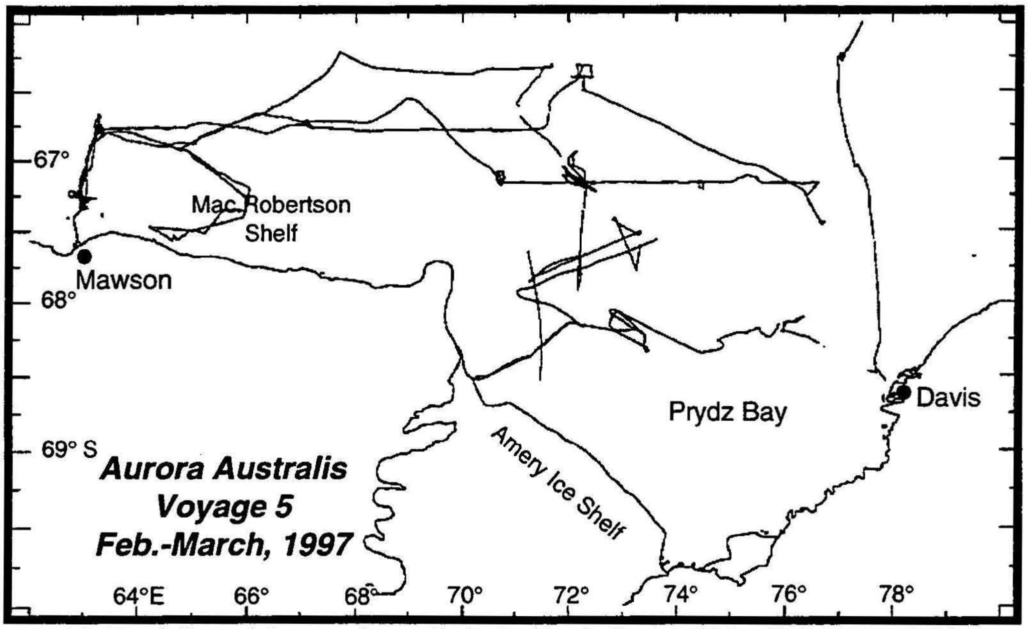


Figure 4.2 Track line of Aurora Australis in the Prydz Bay and Mac.Robertson shelf areas during cruise 186. The survey track lines on the Prydz Fan, and deep water sediment drift sites, were not completed because of the presence of a large iceberg over the study area, and due to time constraints.

Prydz Bay Moraines: Distribution and Nomenclature

Examination of existing seismic and echo sounder lines revealed a number of moraines and moraine-like banks and ridges (Fig. 4.3). It is not clear from the existing data that all these features are grounding zone moraines. Iceberg ploughing in particular degrades the morphology of those in shallower water. Moraines were named according to which major topographic feature they are on and numbered with the most seaward being number one (Fig. 4.3). The moraines which recieved the most detailed attention were East Prydz Channel -1 and 2 and West Prydz Channel-1 and Lambert Deep moraines 1 and 2.

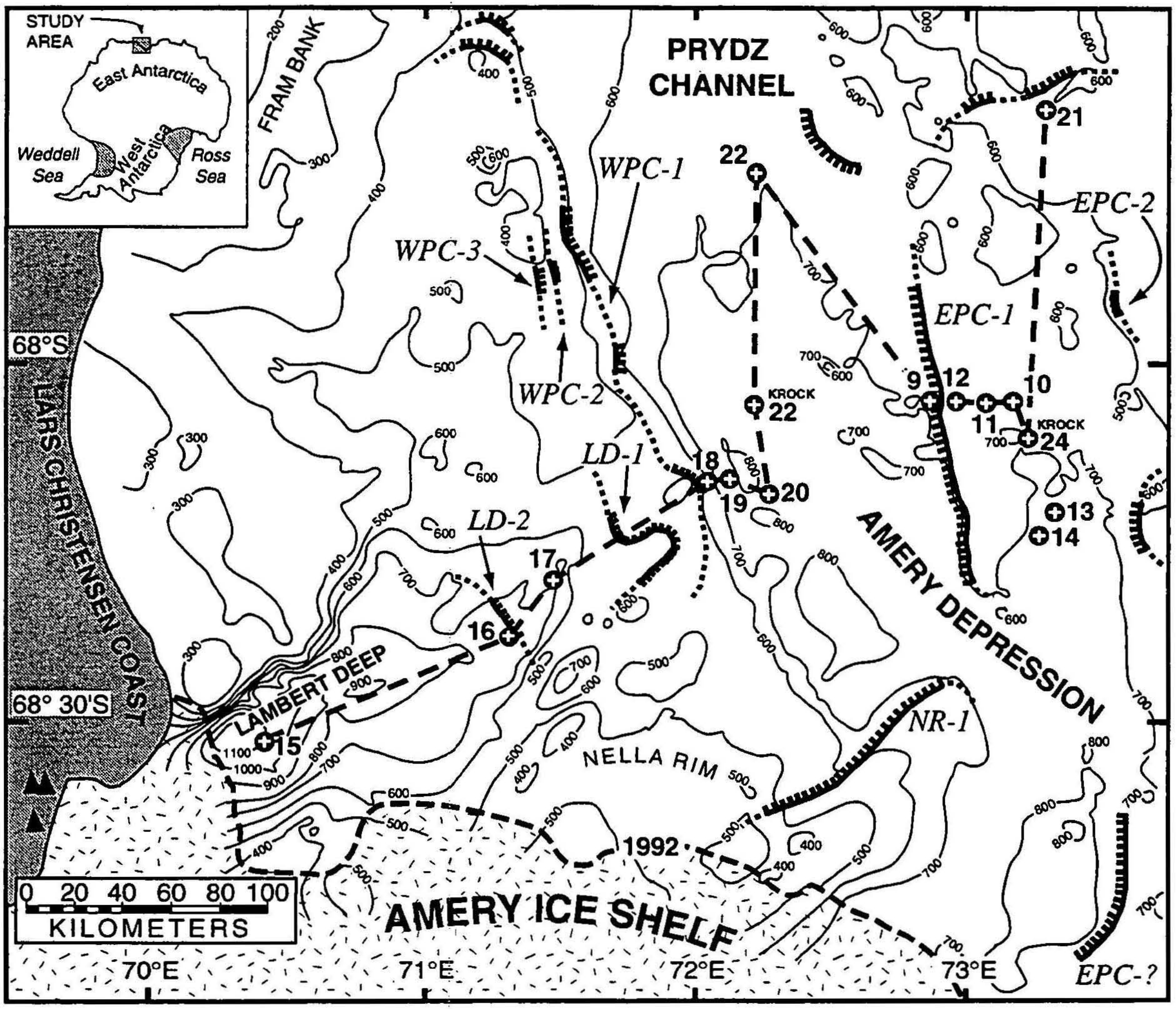


Figure 4.3 Location map and bathymetry of the continental shelf in eastern Prydz Bay. Illustrated are location of core sites and major grounding line positions as determined by seismic reflection, side scan sonar, and bottom record profiles (see O'Brien et al., this volume). Major bathymetric features include the Lambert Deep, Amery Depression, Prydz Channel, Nella Rim and Fram Bank. Gravity cores 10-22 were collected during Cruise 186 of the Aurora Australis in austral summer 1997 while cores KROCK 22 and 24 were collected during AGSO cruise 901 in 1992-1993. Grounding line "moraines" are named geographically and in progression from seaward to landward as follows: Eastern Prydz Channel 1 and 2 (EPC-1, EPC-2), Nella Rim 1 (NR-1), Lambert Deep 1 and 2 (LD-1, LD-2), and Western Prydz Channel 1, 2, and 3 (WPB-1, WPB-2, WPB-3).

East Prydz Channel 1

East Prydz moraines are asymetric banks 30 to 50 m high trending north-northwest across Prydz Channel and the Amery Depression. They have steep westerly faces (Fig. 4.4). O'Brien and Leitchenkov (in press) interpreted EPC-1 as being continuous with Nella Rim-1. The gently sloping eastern sides of both moraines displays ridges and swales which O'Brien (1994) interpreted as subglacial flutes oriented at a low angle to the moraine crests.

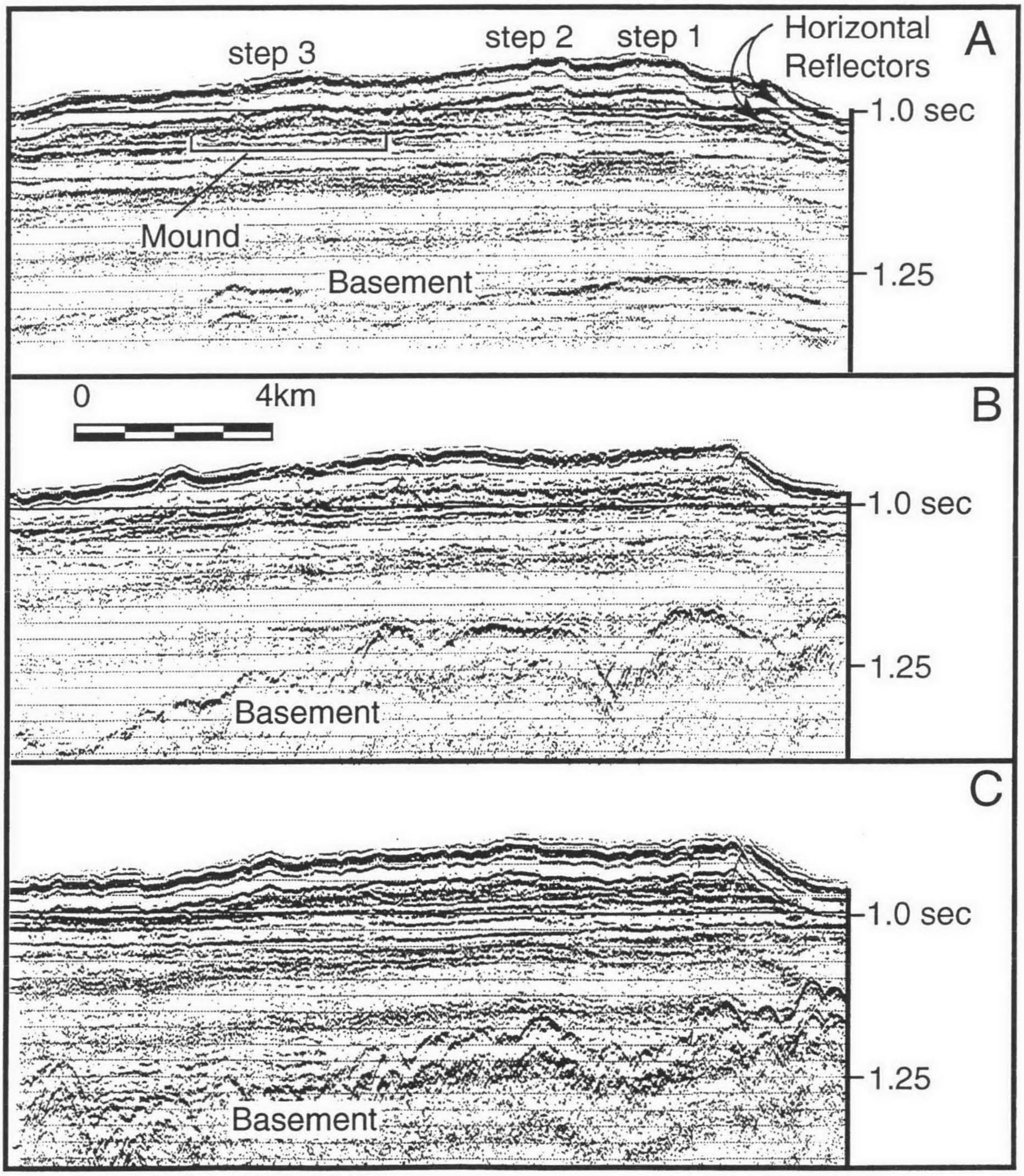


Figure 4.4. Examples of procesed GI gun seismic lines shot across Prydz Bay moraine EPC-1 (see Fig. 4.3 for location of moraine feature).

EPC-1 was crossed by 3 GI-gun seismic sections (Fig. 4.3). The most southerly, deepest water section shows the moraine as having a steep, west-facing slope and three asymmetric steps in in its upper surface, each having a steep westerly face and gentle easterly face (Fig. 4.4A). The other two profiles display a sharp notch in the moraine surface just east of the top of the steep face (Fig. 4.4B and C). The upper surface then is slightly concave-up, with numerous diffractions emanating from the moraine surface, before a slightly convex-up segment rise towards the eastern end of the moraine. The western face of the moraine is smooth and descends asymptotically to the floor of Prydz Channel (Fig. 4.4).

Internal reflectors are subhorizontal to slightly mounded, the most prominent mound being beneath the eastern end (Fig. 4.4A & C). Reflectors rise from east to west, towards the steep face. Application of spiking deconvolution reveals short, subhorizontal reflectors in the upper parts of the moraine, partly obscured by the sea floor reflector. In the most southerly section, one of these short reflectors intersects the moraine surface at the toe of the steep face of the first step in the moraine surface (Fig. 4.4A), probably representing a surface on which the uppermost part of the moraine was built.

Lambert Deep Moraines

Line 186/0801 was shot to study the moraines surrounding Lambert Deep (Fig. 4.3). West Prydz Channel-1 is the largest feature, rising about 300 m above the floor of Prydz Channel. It has a steep, slightly concave-up face sloping north-east and a gentler, convex-up face sloping south-west. This slope features two small, asymmetric ridges 10-30 m high and about 5 km across. These are probably moraines and so are numbered Lambert Deep 1 and 2. The crest of WPC-1 is shallower than 690 m and is rough, probably from iceberg ploughing. The rest of the moraine surface is smooth, apart from a small channel (1-2 km wide and 10 ms deep) between Lambert Deep 1 and 2.

The internal configuration of the ridge on line AGSO 186/0800 is characterised by sets of medium amplitude, continuous and slightly diverging reflectors, separated by unconformities (Fig. 4.4). The upper set is about 100 msec thick and underlies the steep, seaward side and crest of the West Prydz Channel-1 moraine. The reflectors downlap onto an erosion surface. The second sequence makes up most of West Prydz Channel-1 and consists of seaward dipping reflectors that are truncated at the sea floor beneath the landward side of the moraine. This sequence overlies a sequence of undulating, landward dipping reflectors that overlie basement.

The top of acoustic basement is a strong, high-amplitude reflector, marking a generally irregular surface that gradually deepens landward. Locally, the basement is faulted and shows asymmetric rift-basins (400 ms deep) filled by a wedge of diverging strata (growth fault in sequence PS4 of Barron et al., 1989). In the inner part of the Lambert Deep, the basement is underlie by strata featuring low amplitude, parallel folds cut by the sea floor.

Seaward of West Prydz Channel-1, in Prydz Channel, there is a seismic sequence ca. 200 ms thick above acoustic basement. It is characterised by sub-parallel, sub-horizontal, closely spaced, low to medium amplitude reflectors onlapping basement irregularities.

Sidescan Features

Smooth Sea floor - Smooth, featureless sea floor is confined to Prydz Channel west of EPC-1 and north of WPC-1 and a few small areas between other features in the Amery Depression (Fig. 4.5).

Iceberg scours - Iceberg scours are straight to meandering troughs with single or multiple keel marks in their floors (Fig. 4.6). Individual tracks may be a few tens of meters to 100 m across. Ridges of ploughed sediment around the scour are common, particularly on corners or around short pits dug by a single grounding event (Fig. 4.7). Most iceberg scours are found on the northern transects in shallower water, with most occuring where the sea floor is less than 690 m deep (O'Brien, 1994).

Flutes - Fluted surfaces display linear ridges and troughs that mostly continue for more than 1 km across the sidescan record (Fig. 4.8). Ridges are up to about 10 meters high and 200 meters across. In profile, most are rounded and smooth, but a few groups have more angular cross sections, suggesting erosion of the swales. Some very fine fluting appears as finely striated sea floor, striae being parallel and unidirectional (Fig. 4.8). A few areas display two sets of flutes, a prominent younger set superimposed on an older set preserved in the troughs (Fig. flute1). Flute orientations vary across the area but groups of flutes show minimal deviation from the overall direction. We interpret these features as fluted till surfaces formed by moulding of the subglacial bed, because they show extremely uniform orientations and continuity.

Flutes and bedforms - Many fluted surfaces display asymmetric, crescentic to sinuous-crested ridges (Fig. 4.9). Between each flute, these ridges are parallel and appear identical to current-formed dunes. Fluted surfaces with transverse bedforms have been observed in a number of locations. Solheim and Pfirman (1985) observed "washboard" structures in iceberg scours they attribute to pushing of the sea floor by an iceberg. These differ from the Prydz Bay features in being confined to one isolated furrow which is clearly an iceberg scour because it changes direction several times on the image. Josenhans and Zevenhuizen (1990) describe glacier sole marks and transverse ribs formed on till on the floor of Hudson Bay they attribute to lift off and touch down of the ice sheet during retreat. These features are less regular than the Prydz Bay forms and seem to disrupt the edges of the sole marks, clearly involving the material that forms the sole marks. The Prydz Bay features seem to wedge out against the side of the flutes and also occur in fields where flutes are separated by up to 420 meters. These characteristics suggest they are dunes formed in granular sediment overlying the fluted till surface. Bedform orientations indicate currents flowing parallel to the flute direction, in both a landward and seaward direction.

Grooves - Scattered across the region surveyed are straight to slightly curved, isolated grooves 50 to 70 meters across and 10 to 20 meters deep (Fig. 4.10). They have "levees" of sediment up to 10 meters high adjoining the central valley. In some sonographs, the levees appear to have rounded noses resembling mudflow fronts (Fig. 4.10). These grooves are younger than flutes and most other bed features and continue in water much deeper than the usual limit of iceberg scouring. They trend between northwest and northeast.

The sea floor of the Lambert Deep and its moraines is strongly fluted with fine scale flutes. The sea floor also features numerous small-scale steps oriented obliquely to the flutes, suggesting short term sites of the grounding line during retreat (Fig. 4.11). An enigmatic feature of the sediment surface in several places is a set of reticulate ridges. They resemble the pattern of ridges observed by Solheim and Pfirman (1985) produced by squeezing up of debris into crevasses in the sole of a recently-surged glacier in Spitzbergen.

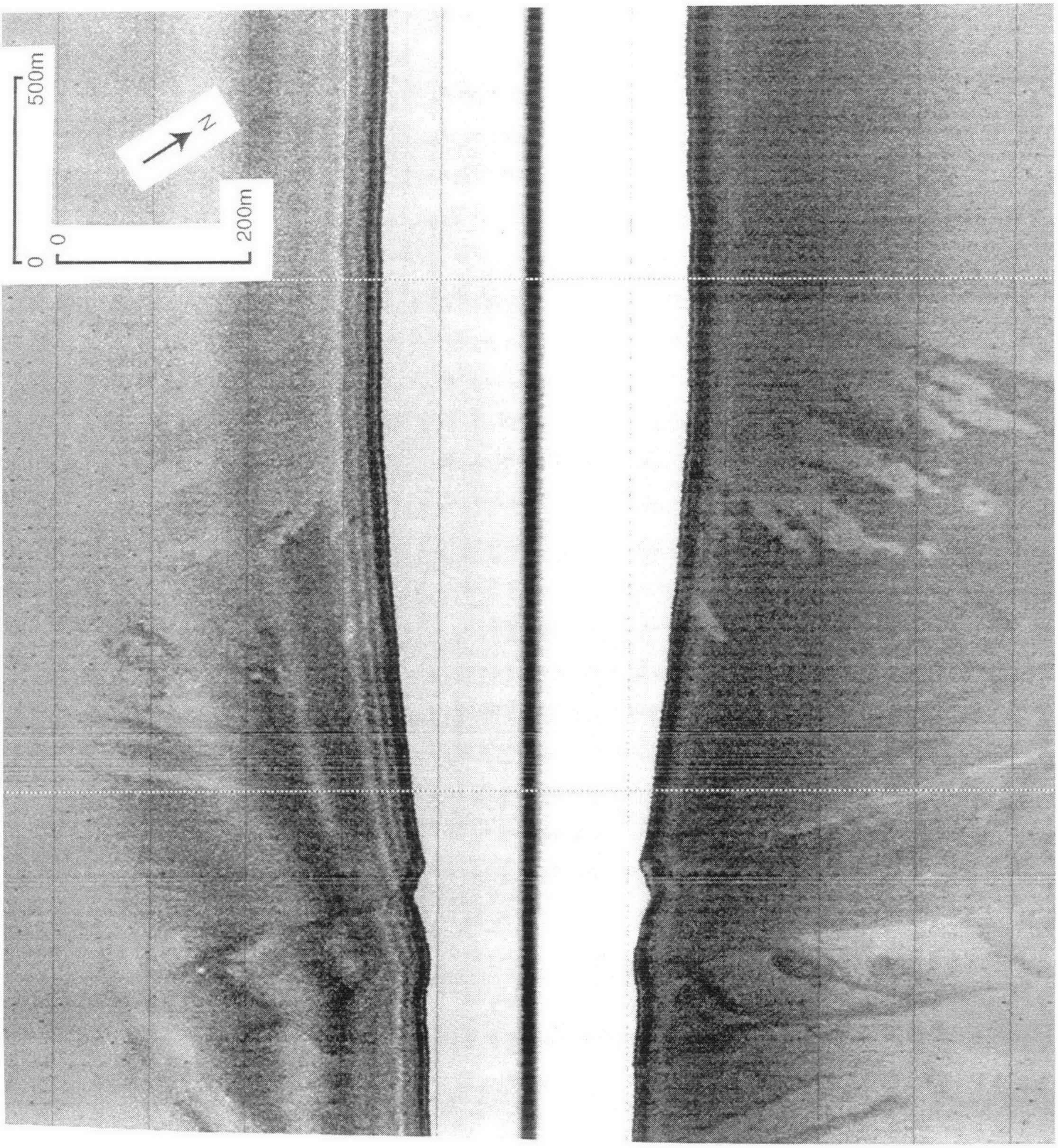


Figure 4.5. Sidescan sonograph showing smooth sea floor adjoining the flank of moraine West Prydz Channel-1 (see Fig. 4.3 for location). Note the light tone produced by fine grained sediments (SMO?) in the deeper trough, contrasts with the darker tone comprising the flank of the ridge (diamicton?).

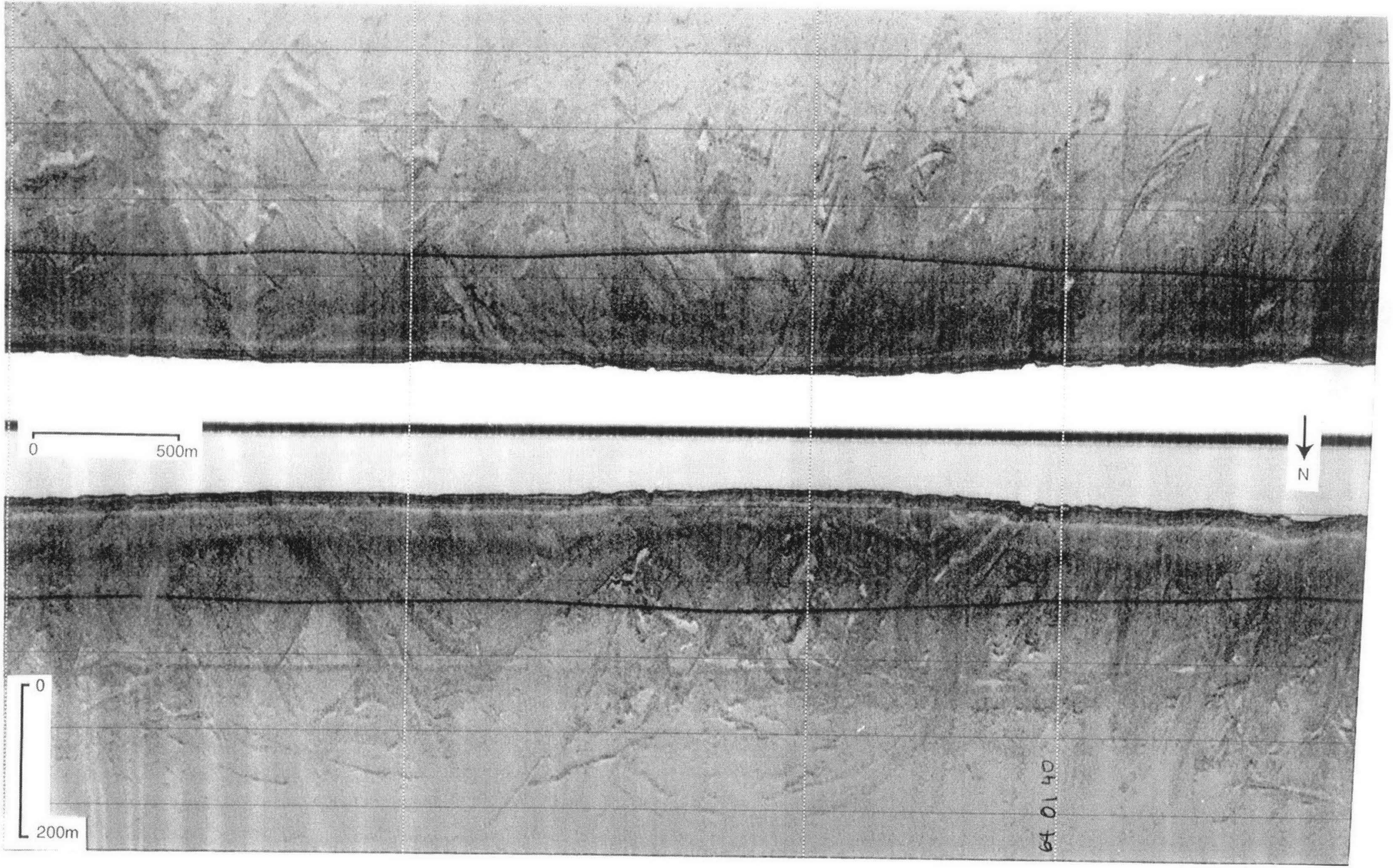


Figure 4.6. Sidescan sonograph showing iceberg scours on Fram Bank, near Benthic Trawl site #2.

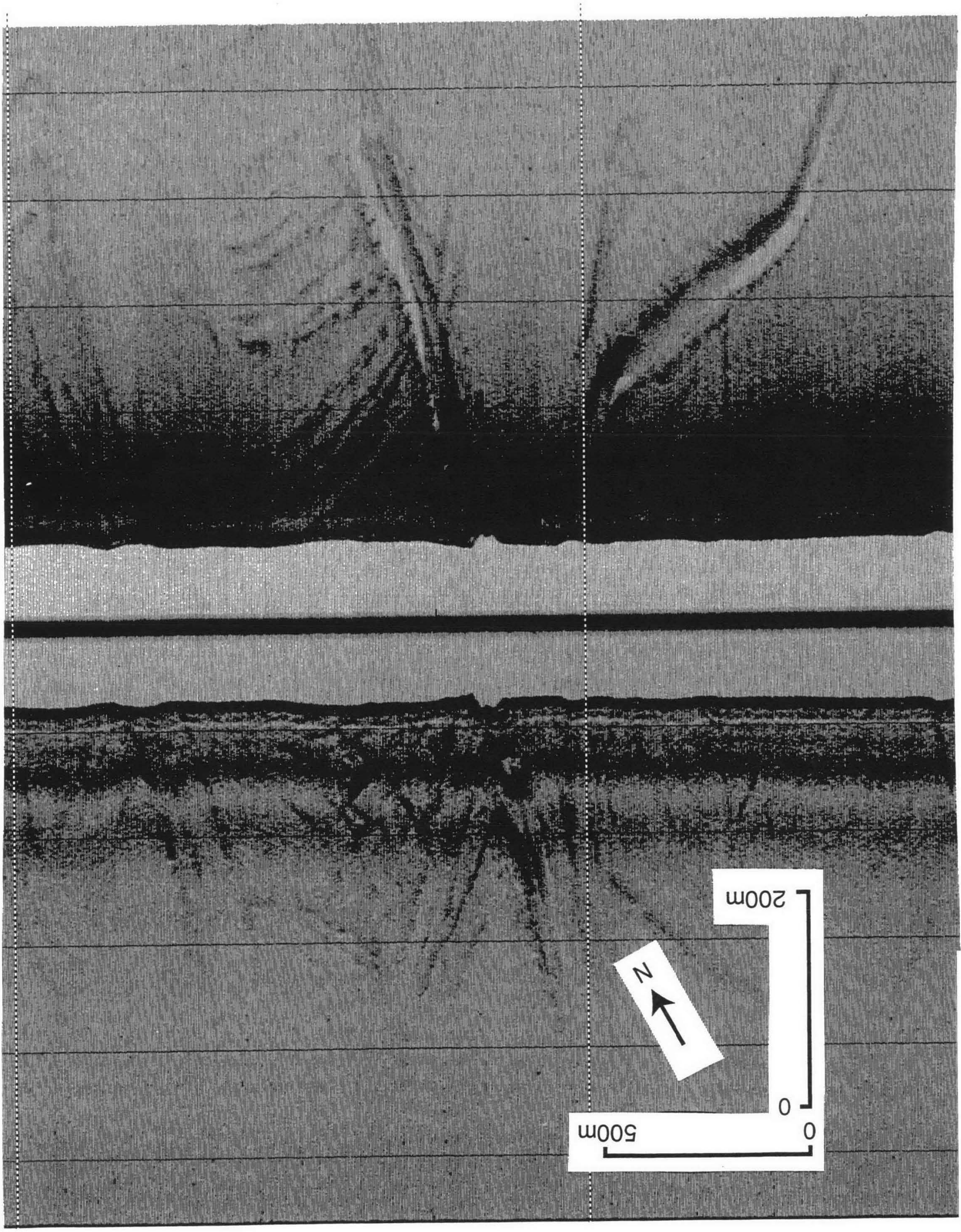
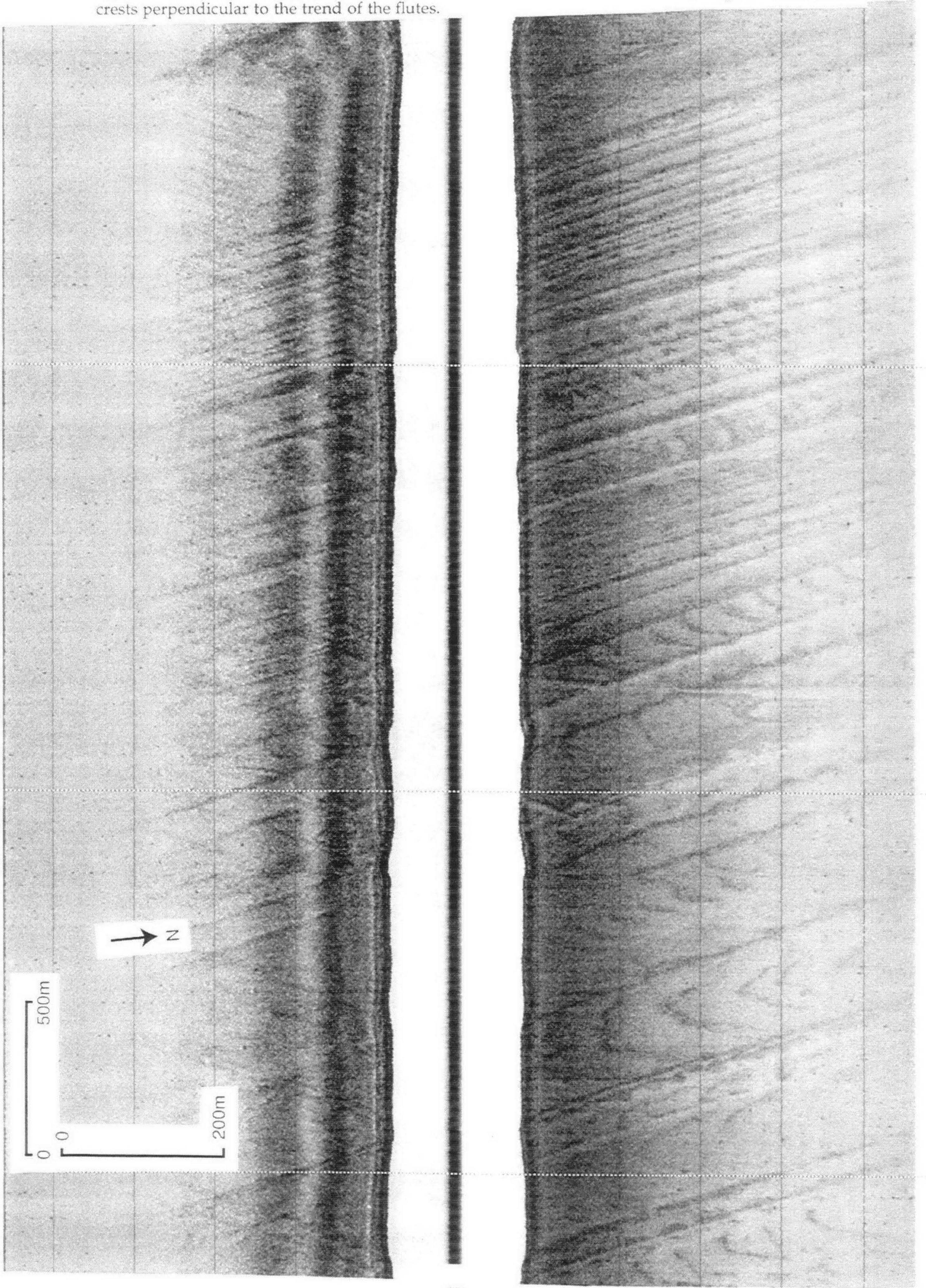


Figure 4.7. Sidescan sonograph showing iceberg scours, inner Prydz Bay.

Figure 4.8. Sidescan sonograph showing flutes with bedforms between them, aligned with their crests perpendicular to the trend of the flutes.



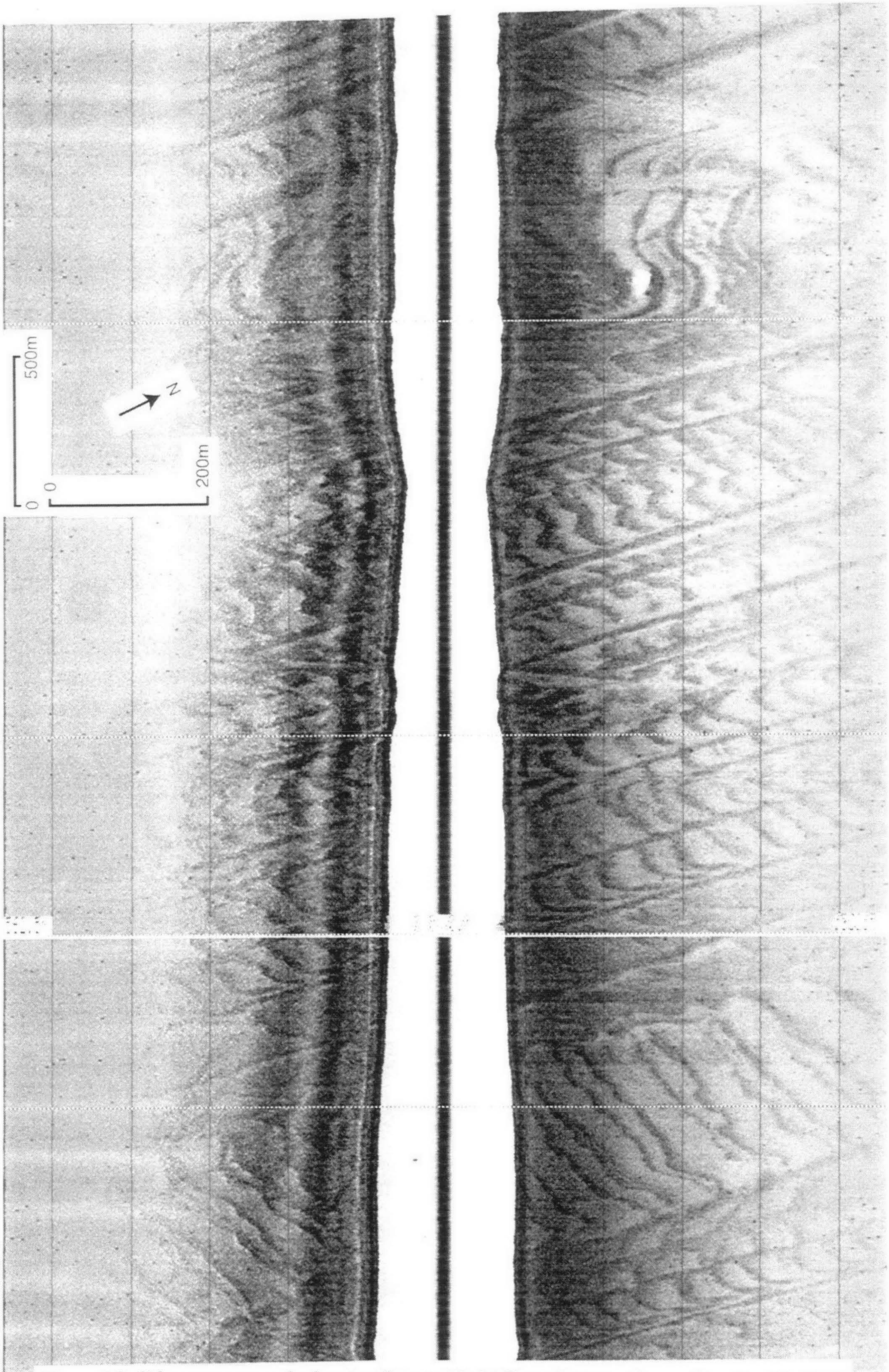


Figure 4.9. Sidescan sonograph showing flutes with bedforms between them, aligned with their crests perpendicular to the trend of the flutes. Iceberg gouges overprint the flutes and bedforms.

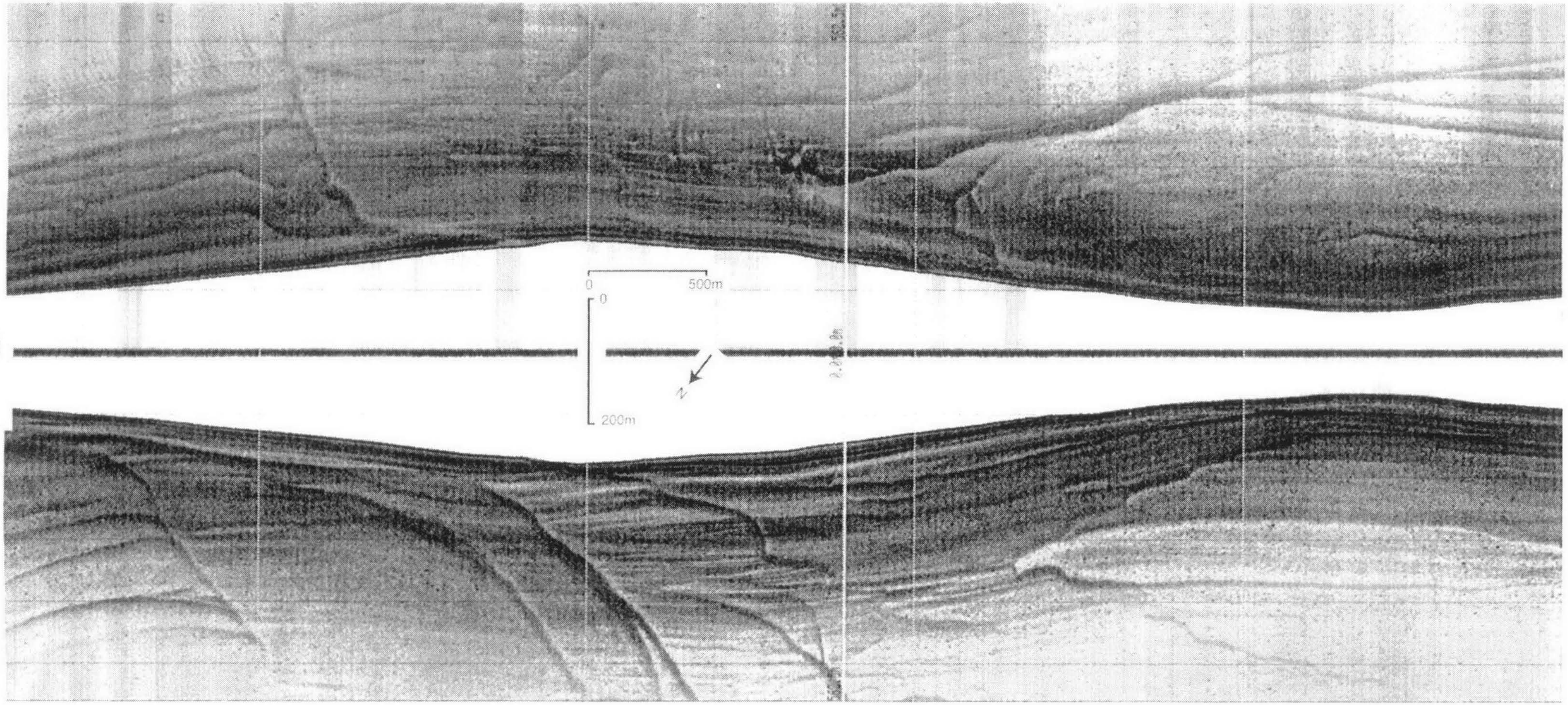


Figure 4.10. Sidescan sonograph showing elongate grooves.

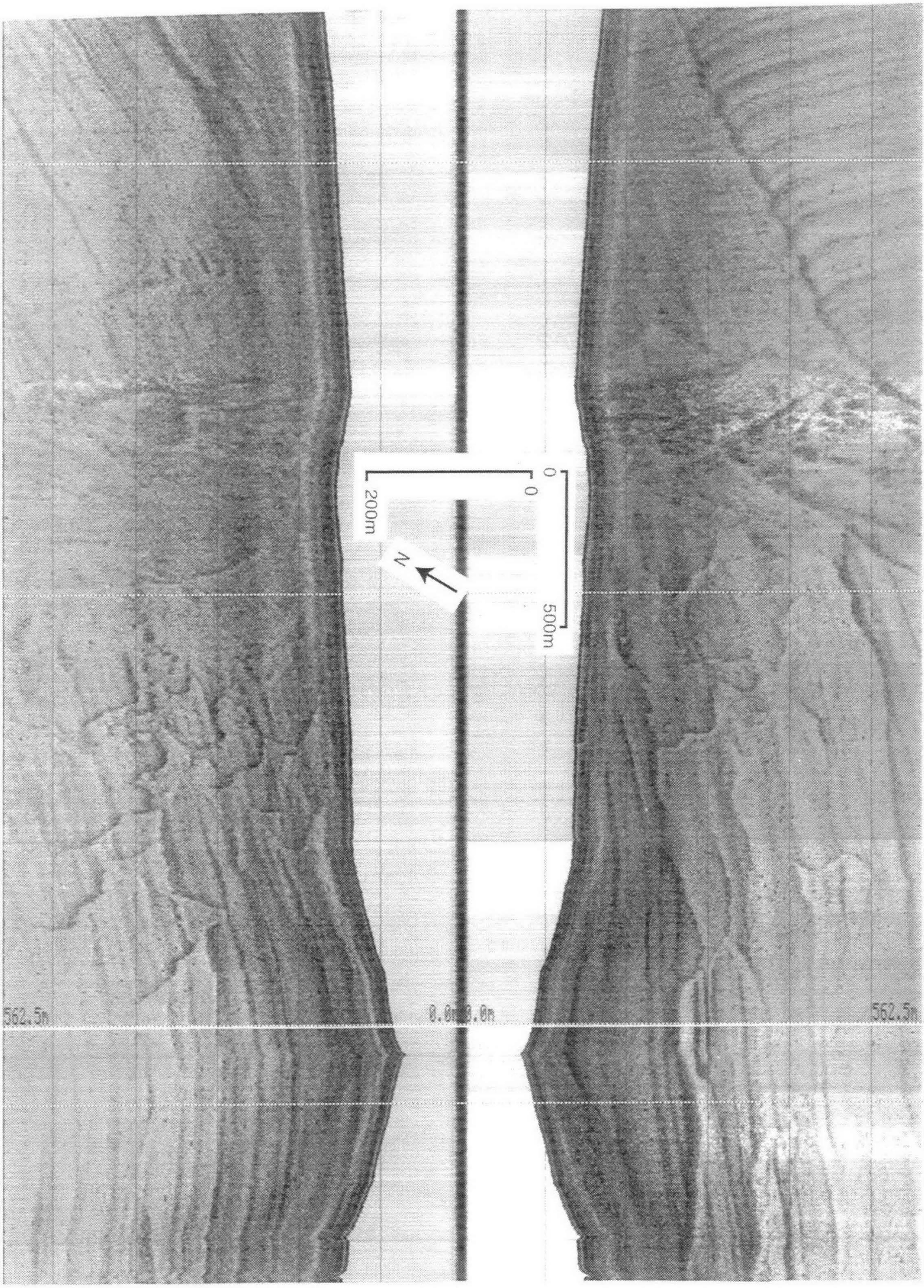


Figure 4.11. Sidescan sonograph showing reticulate ridges, possibly produced by squeezing up of debris into crevasses in the sole of a recently-surged glacier (see text).

ODP Site surveys

Proposed Ocean Drilling Program sites for Prydz Bay and adjacent slope and rise were set out in Proposal 490 (O'Brien et al., 1996). Seismic and sidescan lines were shot across sites PBS1 and PBS2 in Prydz Bay and gravity cores collected. Sonobuoys were unsuccessful, probably because of the cold water. Attempts to survey sites PBF1, PBF2 and PBF3 were prevented by a 80 km x 20 km iceberg covering all three sites during the entire period of the cruise. Alternative sites to PBF1 and PBF2 were identified and seismic lines and gravity cores collected. PBF4 was successfully cored. Heavy pack ice during transits resulted in lost time which prevented surveys of sites on continental rise sediment drifts.

Benthic ecology surveys

Seismic and sidescan data and sediment samples were collected for sea floor characterisation to compare with benthic community studies undertaken on the voyage by staff from Deakin University and the Museum of Victoria. Preliminary assessment of the results suggests that there is a strong correlation between the benthic communities and their geomorphic setting. Shallow, ice and current scoured banks are colonised by bryozoa and sponge dominated communities, whereas muddy shelf channel sites have a high abundance of Holothurians (sea cucumbers) and Pennatulacea (sea pens; T. Bardsley, pers. comm.).

Results of core analyses: Prydz Channel and associated moraine deposits

Sedimentary records from the Antarctic continental shelves are key pieces in the puzzle of Quaternary history of the Antarctic Ice Sheets (Anderson, 1989). Before linkages can be made between northern and southern hemispheres during glacial- interglacial cycles, the nature and extent of Antarctic glacial maxima need to be resolved to the same level as our knowledge of the boreal ice sheets (Broecker and Denton, 1989; Denton and Hughes, 1979).

The Lambert Glacier/Amery Ice Shelf complex is an important component of the Antarctic cryosphere, comprising some 20% of the ice drainage from the East Antarctic Ice Sheet (Hambrey, 1991). Seismic surveys show that the bay is underlain by thick sequences of prograded sediment deposited in response to expansion of the East Antarctic ice sheet and attendant advances of the Lambert glacier to the shelf break (Stagg, 1985; Cooper et al., 1991). Although glacial grounding line moraines have been recognised and mapped, based upon seismic and echo sounding records (Leitchenkov et al., 1994), the age and depositional history of these features is unknown despite preliminary knowledge of the chronology of late Pleistocene deposits on the shelf (Domack et al., 1991).

Herein, we describe the succession of facies observed in the cores and relate them to depositional environments and sedimentation patterns. In so doing we build upon the earlier work of others who have contributed to our understanding of the Antarctic glacial marine environment (Carey and Ahmad, 1961; Barrett et al., 1991; Alley et al., 1989; Anderson et al., 1980; 1991; Drewry and Cooper, 1981; Domack, 1982; Kellogg and Kellogg, 1988; Hambrey et al., 1992; Licht et al., 1996).

Sediment Facies

Sediment facies are designated by five general textural types and further subdivided by association with four groups of colours (using the Munsell scheme: Figs. 4.12 and 4.13).

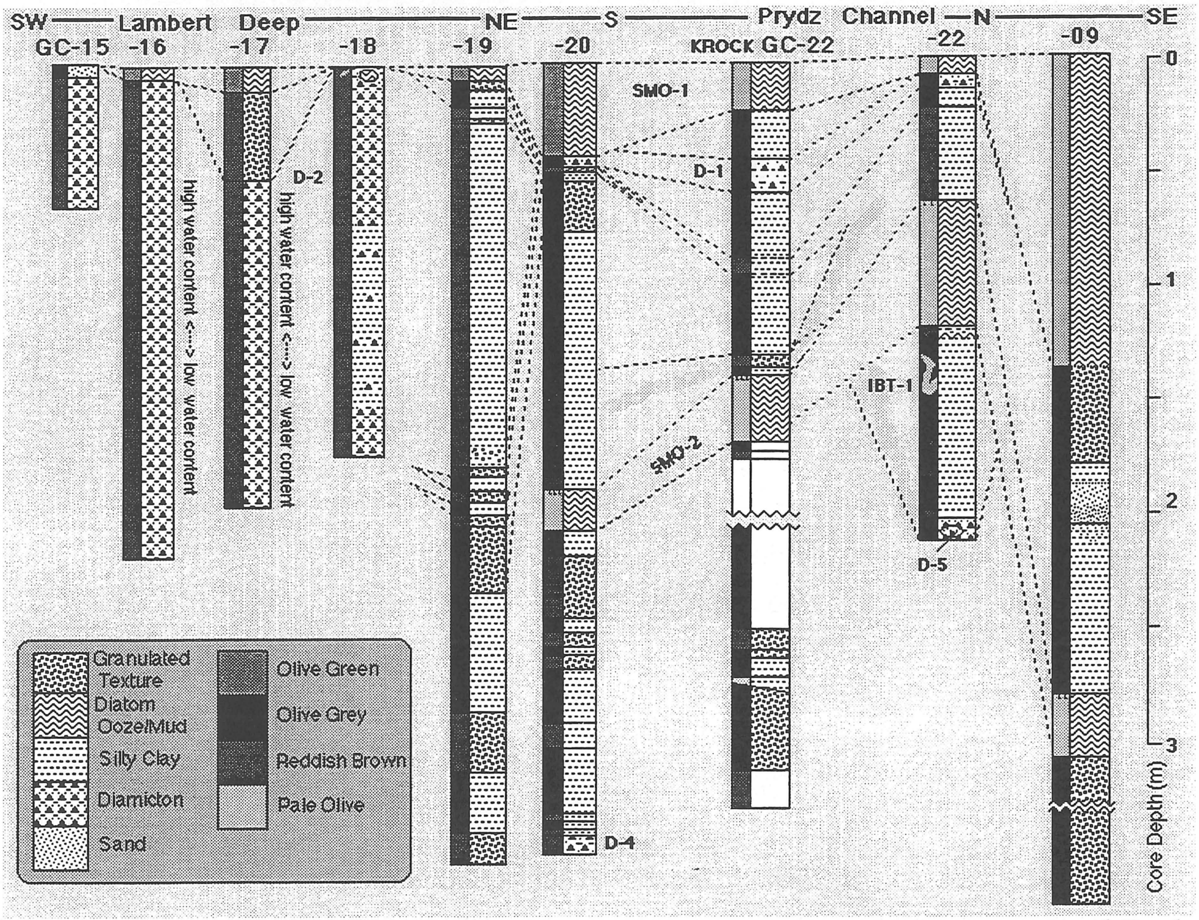


Figure 4.12. Fence diagram of core sediment types and colours across the Lambert Deep and Prydz Channel. Core locations can be seen in figure 1. Five basic sediment types include: granulated textures, diamicton, siliceous (diatom) mud and ooze, silty clay, and sand. Sediment colour types are summarised as olive green (Munsell hues of 10Y, 5Y), olive grey (10Y, 5Y, and N), reddish brown (5YR, 10YR) and pale olive (light values of 10Y, 5GY). Stratigraphic units are designated as: SMO-1 and SMO-2 (siliceous mud and ooze), D1-5 (diamicton), and IBT (iceberg turbate).

Siliceous Mud and Ooze, SMO Siliceous mud and ooze (SMO) comprise three distinct stratigraphic units designated here as SMO-1 and older SMO-2 and SMO-3. SMO units are defined by an abundance of diatoms, ranging from 20 to over 90 % of the total sediment mass. SMO-1 is the typical diatomaceous facies of the Antarctic continental shelf (Dunbar et al., 1985) and occurs across the entire area of study, within and beyond the Prydz Channel (PC; Figure 2 and 3). It is variable in thickness (a few cm to > 150 cm) and has colours of light olive, greyish olive, and moderate olive brown. Radiocarbon ages from core KROCK 24 indicate that SMO-1 represents deposition during the entire Holocene epoch (Fig. 4.12; Table 1). There is, in places, an abundant agglutinated foraminiferal assemblage in SMO-1.

SMO-2 is a key bed found in an intermediate stratigraphic position. It is limited in lateral extent to the floor of the Prydz Channel (some 15,000 km2) and is notably thicker near the seaward end of the channel (core 22; Fig. 4.3). Unlike the Holocene SMO-1 unit, however, SMO-2 is distinctly sorted by the size of diatom species. Smear slides of SMO-2 in outer Prydz Channel (core 22) demonstrate a dominance of large robust frustules, primarily those of the genus *Eucampia,* and a relative abundance of Pliocene diatoms, *Rouxia* spp. and *Thalassiosira torokenia.* Further into the Prydz Channel (cores 09 and 20) SMO-2 is composed primarily of diminutive diatoms such as *Fragiolopsis curta,* fragments, and rare *Rouxia* spp. and *T. torkenia.* The magnetic susceptibility signatures are distinctly higher for SMO-2 than SMO-1, and SMO-2 has colour values in the lighter hues, such as dusky, yellow green and pale olive (Fig. 4.13). A third SMO unit (SMO-3) is recognised in the base of core KROCK 22 (Fig. 4.12) and its diatom component is identical to that of SMO-2.

Diamicton, D: Poorly sorted, terrigenous sediments (diamictons) are the most diverse of the sediment facies recognised in our cores (Figs. 4.12 and 4.13). We have designated these as D-1 through D-5, based upon their magnetic susceptibility, provenance, and upon their stratigraphic order (Figs. 4.12 & 4.13). D-1 is a thin, stratified, but widespread diamicton of glacial marine origin. It is found across most of the Prydz Channel and to the east. It lies directly beneath SMO-1 and often contains transitional silt interbeds. Its distinctive characteristics include high magnetic susceptibility (100-200 x10^{-6} CGS) and a well preserved and abundant calcareous, foraminiferal assemblage. Foraminifera consist of abundant *Globacassidulina crassa, Cibicides refulgens,* and *Neogloboquadrina pachyderma.*

D-2 is a distinctive, reddish-brown diamicton associated with the Lambert Deep region, landward of the Western Prydz Channel grounding line 1 (WPC-1; Figs. 4.3, 4.12 & 4.13). D-2 underlies a very thin SMO-1 unit that, in places, is deformed into small lenses of SMO (core 18). This diamicton is quartzose, structureless, barren of fossils, and has a low MS signature (typically less than 100 x 10^{-6} CGS; Fig. 4.14). A gradational decrease in water content down-core is characteristic, best exemplified in cores 16 and 17 (Fig. 4.12). The uppermost portions of D-2 are easily deformed by shearing, while lower portions are considerably more cohesive and resist deformation.

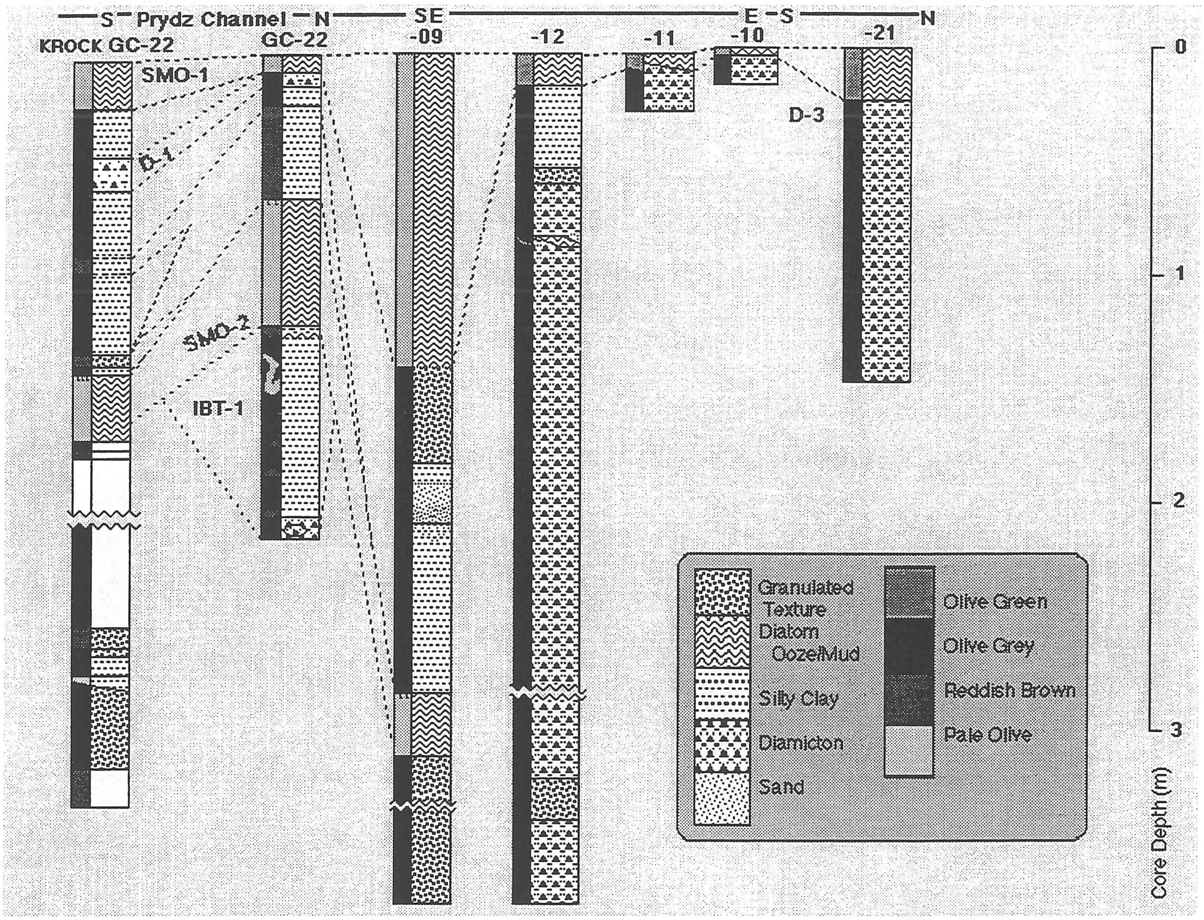


Figure 4.13. Fence diagram of core sediment types and colours across the Prydz Channel and Amery Depression. Core locations can be seen in figure 1. Five basic sediment types include: granulated textures, diamicton, siliceous (diatom) mud and ooze, silty clay, and sand. Sediment colour types are summarised as olive green (hues of 10Y, 5Y), olive grey (10Y, 5Y,N), reddish brown (5YR, 10YR) and pale olive (light values of 10Y, 5GY). Stratigraphic units are designated as: SMO-1 and SMO-2 (siliceous mud and ooze), D1-5 (diamicton), and IBT-1 (iceberg turbate).

The equivalent to D-2 on the eastern side of the Amery Depression is the dark grey to olive grey diamicton, D-3 (Figs. 4.3, 4.12, 4.13 & 4.14). D-3 is limited to areas east of the Eastern Prydz Channel 1 grounding line (EPC-1) where it is found directly below SM0-1. Hence, it is probably latest Pleistocene in age (Fig. 4.13). It has a very high MS (250-350 x 10^{-6} CGS), is rich in lithic grains, and generally barren of fossils (Fig. 4.14). It is found in cores 10-14, 21 and KROCK 24 (Figs. 4.3, 4.12 and 4.13). D-3 is structureless, compact throughout, and does not demonstrate the gradational water content characteristic of D-2.

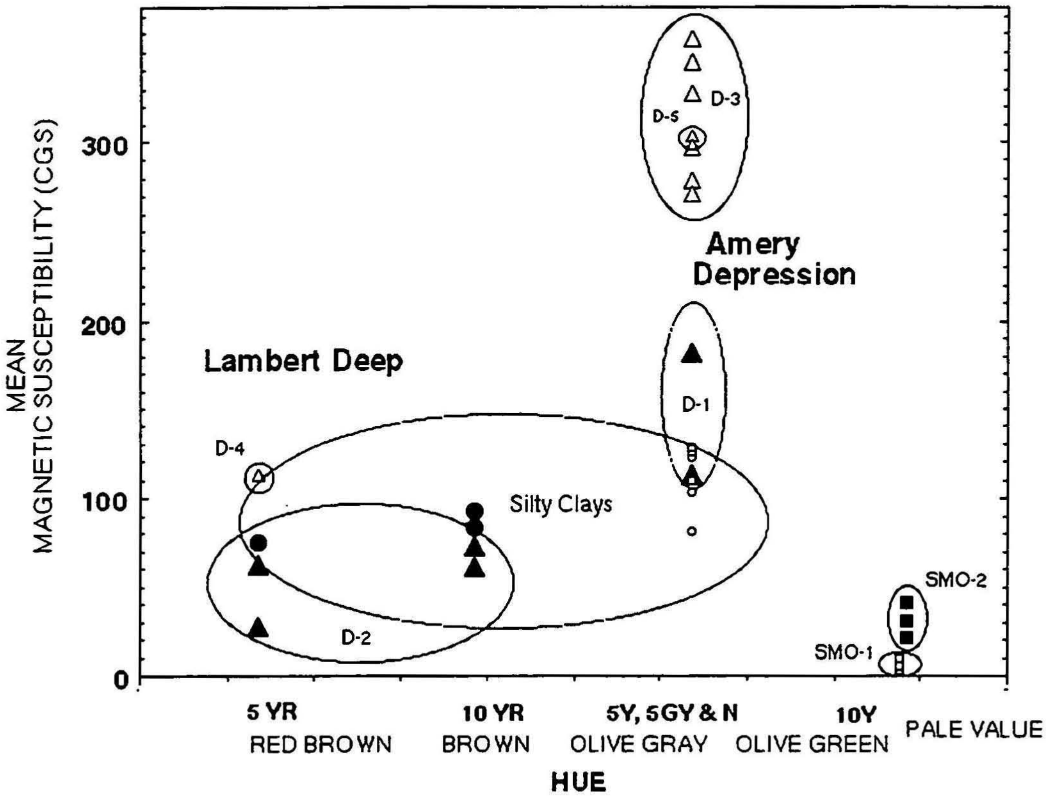


Figure 4.14. Bivariant plot of mean magnetic susceptibility (MS) versus Munsell hue of diamicton units (D1-5) and siliceous mud and ooze (SMO-1 and SMO-2). Each symbol represents a unit from an individual core and is based upon an N of 15 to 50 for each mean value of MS. Note distinct MS and colour signature of each unit. Lambert Deep diamictons (D-2) are characterised by red to brown hues and MS values less than 100, while diamictons from the Amery Depression and Prydz Channel (D-1,-3, and -5) are grey to olive grey and have high to moderate MS values. The two SMO units are distinct in both magnetics (SMO-1, Mean = 10; SMO-2, Mean = 20-40) and in the lightness of the value in the olive green chroma (SMO-2 has a colour of pale olive or dusky yellow green).

Diamictons older than D-2 and D-3 are limited to two units recovered in the lowermost portions of cores 20 and 22. These diamictons are distinct from each other in their colour and magnetic sucseptibility. At the base of core 20 is a structureless, reddish brown diamicton (D-4) that has a colour similar to D-2 but has a higher MS signature (>100 x 10^{-6} CGS). Because of this, and its low stratigraphic position it is designed as D-4. Within the base of core 22, a large clast of indurated diamicton (D-5) is found within an iceberg turbate deposit. It is not *in-situ* but is eroded from a relatively older stratigraphic unit present in the vicinity of core 22. It has a colour and MS similar to D-3, but clearly lies below it stratigraphically.

Granulated facies: In many of the cores a peculiar sediment is found that can best be described as having a granulated texture. It has previously been recognised in Antarctic marine sediments as a "brecciated" (O'Brien and Harris, 1996) or a "pelletised" texture (Domack et al., 1996). The characteristics of these sediments are as follows:

1) grain supported texture, matrix of sandy mud

2) granules of silty clay, and or diamicton matrix are lightly consolidated
3) granules are angular and very loosely compacted
4) units lack observable grading but are size sorted.

Colours of the granulated beds vary from reddish brown to olive grey, reflecting a difference in source similar to that of the diamicton units (Figs. 4.12 and 4.13). This sediment is found either interbedded with silty clay and SMO in the Prydz Channel or above massive diamictons outside of the Prydz Channel. Similar textures within cores from the Ross Sea were interpreted as a transitional ice shelf, rafted facies deposited beneath basal debris zones and above till units (Domack et al., 1996). The internal texture of the granules is similar to mud clots described from basal debris zones of the Greenland and West Antarctic Ice Sheets (Gow et al., 1979; Gow and Meese, 1996).

Silty Clay: Silty clay is a very common sediment type within the Prydz Channel and is less common landward of the major moraines that rim the channel (Figs. 4.3, 4.12 and 4.13). It is found in a variety of colours from reddish brown to olive grey, to moderate yellowish brown. It has a moderate and variable MS, reflecting a mixture of detrital magnetite within the mud (Fig. 4.15). Grey muds have a higher MS than reddish brown or yellowish brown muds (Fig. 4.15). Characteristic of these muds is a low content of coarse gravel grains, and poorly sorted sand (1-5%). The muds contain burrow structures, are mottled, and have gradational contacts with other units. Some of the silty clays from Prydz Channel contain isolated mud clots of a colour distinct from that of the surrounding matrix (Fig. 4.15). For instance, olive grey muds often have reddish brown mud clots within them, and reddish brown muds may have olive grey clots within them, similar to "drop clot" textures reported from Late Quaternary sub-glacial lacustrine sediments in central New York State (Ridge et al., 1991).

Sorted sand: Sorted sand is an uncommon sediment type in the Prydz Channel and is found as a single, 25 cm thick, normally graded unit in core 09 (Fig. 4.12). This sand is well sorted, free of mud, and grades from coarse to medium grained. It has a high MS (>300 CGS) and exhibits a sharp lower contact and a gradational upper contact with silty clay.

Sedimentary structures: Most sedimentary structures within the section are limited to mottling and/or burrow features in the silty clays and SMO; diamictons are structureless, as the granulated facies appear to be. Laminated portions of silty clay are rare and discontinuous. The most noticeable structures are deformation features found in core 22. Below 125 cm in core 22, small scale folds and faults are well preserved in a section that contains olive grey silty clay and convoluted beds of SMO-2 and reddish brown silty clay. Deformation fabric takes on the appearance of horizontal foliation near the base of the core where a large clast of diamicton (D-5) is surrounded by foliated, sandy silty clay (Fig. 4.12). Micro-faults with reverse offset are clearly preserved. The structures are compatible with iceberg turbation and are similar to features described by Woodworth-Lynas (1990).

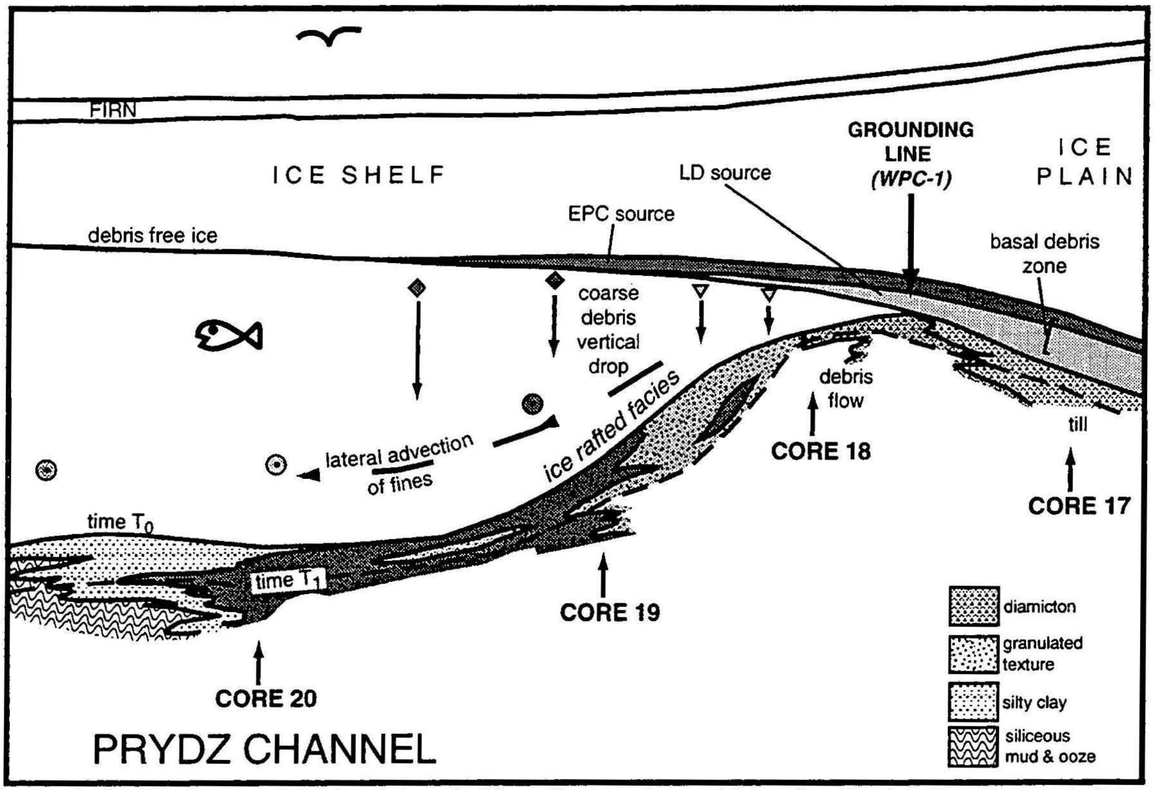


Figure 4.15. Facies model of sub-ice shelf sedimentation within the Prydz Channel and Amery Depression. Undermelt beneath the basal debris zone produces a granulated facies from direct settling of the coarse fraction and also a distal silty clay from the lateral advection of suspended fines. Debris sources may vary across the Amery Depression from debris derived from the Lambert Deep drainage (red brown sediments) and/or from the eastern side of the Amery Depression. Debris sources include local (low level basal debris) and distal (high level basal debris) sources along a single flow path

Microfossils: Siliceous microfossils (diatoms) can be found in all of the sedimentary units although the abundance varies from very rare (most diamictons and silty clays) to very abundant (SMO). Calcareous microfaunas are even less abundantly preserved and consist basically of two stratigraphic intervals. D-1 contains a well preserved foraminiferal assemblage (*G. crassa*, *C. refulgens*, and *N. pachyderma*) best exemplified by samples from core 22. This microfossil assemblage also contains echinoid spines and continues into the lower silty clay for some 10-20 cm. Cores 12 and 20 are the only other sections found to contain abundant calcareous microfauna. In core 20 the uppermost silty clay (at ~1 m depth) contains calcareous microfauna characterised by abundant ostracods (articulated valves) and a well preserved foraminifera assemblage consisting dominantly of *Ehrenbergia glabra, N. pachyderma,* and *Globacassidulina* spp. Below 330 cm in core 12, granulated facies and silty clay contain a unique foraminifera assemblage characterised by abundant *Patellina corrugata* and *Spirillina* spp., genera not common within modern faunas in the region (Quilty, 1985). The diamicton (D-3) above 330 cm in core 12 is essentially barren of microfossils.

Discussion and Interpretation

The most significant contribution of this study is the observation that facies changes observed in gravity cores are coincident with presumed grounding line positions across the shelf (Figs. 4.3, 4.12 & 4.13). Structureless to massive diamictons (D-1 and D-3) are found only landward of the grounding lines WPC-1 and EPC-1, thus indicating till deposition while the grounding line was occupying these positions around the Prydz Channel. Figure 4.15 illustrates that while till deposition was taking place beneath the ice sheet (ice plain), sub-ice shelf deposition via ice rafting was also occurring within PC. This led to a mixture of granulated sediment, representing undermelt of the basal debris zone (direct vertical settling) and lateral advection of suspended silt and clay. Very little of the material along the grounding line wedge seems to be of sediment gravity flow origin; a possible debris flow diamicton occurs in core 18 and a single, thin turbidite occurs in core 09 (Fig. 4.12).

Complex interbedding of the granulated facies and silty clay as seen in the cores from PC (Figs. 4.12 and 4.13) is explained by fluctuating ice discharge and/or flow directions. Two distinct sources are recognised and these could fluctuate as ice discharge is dominated by flow from the Lambert Deep (LD) or by flow from the east, Eastern Prydz Channel (EPC) source. The basal debris zone in Figure 4.15 is illustrated in order to show three-dimensional changes in debris source, but it may be that different levels of debris in the ice also reflect different sources. It is interesting to note that the granulated facies along WPC-1 is clearly of LD provenance while the silty clay is of EPC provenance (Figs. 4.12, 4.13 & 4.14). This clearly indicates the separation of coarse, vertically rafted, detritus from the advected fines that are transported under the influence of sub-ice shelf currents. Silty clays of LD provenance do not dominate until the outer-most portions of the channel, as at the site of core 22 (Fig. 4.12). The origin of the mud clots or granules can be related to regelation processes taking place upstream of the grounding line. Regelation of a mud-rich slurry at the base of the ice could produce clots of frozen clay that would be incorporated into the basal debris zone.

This product is observed at the base of debris zones in polar ice sheets (Gow and Meese, 1996).

We believe that deposition of granulated and silty clay facies within the Prydz Channel is dependent upon grounding of an ice sheet/ice shelf system along the periphery of the channel. As the grounding line receded back from LGM positions, at WPC-1 and EPC-1, siliciclastic sediment supply to the channel was cut off since the grounding line (sediment source) was now divorced from the PC deposystem due to the presence of the grounding line topography. Recession of the calving line across the channel led to the development of fossiliferous diamicton (D-1) and eventually to open marine SMO-1, which reflects seasonally open marine environments similar to the present. D-1 is essentially an iceberg rafted sediment; its diverse MS and fossil content reflect reflect a variety of sources and depositional settings, most consistent with concentrated iceberg rafting along the calving line of a receding ice shelf (Domack et al., 1996). Some contribution from aeolian sources (Dunbar et al., 1989; Barrett et al., 1991; Domack et al., 1995) could also be included in the origin of D-1. The age for the transition from grounded ice to open marine environments east of EPC-1 is constrained to about 11,000 radiocarbon years BP (O'Brien and Harris, 1996; Fig. 4.13). Hence the transition into SMO-1 across the entire study area is believed to be related to recession following the Late Wisconsinan glacial maximum or LGM.

The duration of ice shelf conditions across the Prydz Channel is difficult to determine except in relative terms. SMO-2 is a key bed that is restricted to the Prydz Channel, we interpret it as indicating a suppression of siliciclastic input into the channel at a time prior to the LGM. Deposition of SMO-2 is therefore related to a retreat of the grounding line from WPC-1 and EPC-1 positions. Subsequent readvance at the LGM lowstand removed SMO-2 in areas landward of WPC-1 and EPC-1. Deposition of SMO-2 was also contemporaneous with a lower stand of sea level. This is because it is clearly synchronous with iceberg or ice shelf turbation of the substrate at the site of core 22, which today is well below the depth of iceberg grounding (at 660 m; Barnes and Lein, 1988; Keys et al., 1990). The distribution and character of SMO-2 also suggest a sub-ice shelf setting for its deposition. Its diatom flora is not the same as modern SMO-1 assemblages and it has a lower C/Si_{bio} ratio than SMO-1. SMO-2 is dominated at any one site by diatoms of a given size. For instance, in core 22 large and robust forms of *Eucampia* and reworked Pliocene forms dominate while in the inner reaches of Prydz Channel small fragments and *F. curta* dominate the assemblage. This suggests that significant current sorting of the diatoms has taken place and that the source of reworked frustules is the outer reaches of the Prydz Channel. In fact, we observe an abundance of Pliocene diatoms in near-surface sediments of the Prydz Trough Mouth Fan. Circulation within the Prydz Channel at this time was likely in the form of a clockwise gyre, as previously suggested for LGM ice shelf conditions and as is presently found in Prydz Bay (Nunes Vaz, and Lennon, 1996). SMO-3 likely represents a similar Paleoenvironmental setting as SMO-2 but at an earlier time, prior to D-4.

In addition there was an earlier period of ice sheet grounding prior to SMO-2 along the periphery of Prydz Channel, as shown by granulated and silty clay facies that are older than SMO-2. Only in core 20 is a diamicton (D-4) similar in character to basal till recognised within the main axis of the PC itself. This unit lies at the base of the ice shelf facies and predates both SMO-2 and the LGM deposits. The age of D-4 is unknown but since it reflects grounding of ice within the Prydz Channel it is the one till most likely to be correlative to shelf-edge grounding of the East Antarctic Ice Sheet across Prydz Bay and sediment transport to the continental slope.

The questions that remain unanswered are when and why did the most extensive glaciation of the shelf pre-date the northern hemisphere LGM? Is it possible that a random oscillator which may determine advances of the West Antarctic Ice Sheet (MacAyeal, 1992) also applies to the Lambert Glacier system of the East Antarctic Ice Sheet? Alternatively, since stage 2 is widely regarded as one of the most extreme of the Quaternary isotopic enrichment events, we are left with the possibility that the duration of the glacial stage is more important than the magnitude of the ice volume and/or sea level change. For instance, stage 6 (the penultimate glaciation) is nearly twice the duration of the stage 2 low stand, using a threshold value of about -100 m (Martinson et al., 1987; Chappell, and Shackelton, 1986; Imbrie et al, 1984). Long periods of lower sea level might be more conducive to growth of the ice sheet across the continental shelf since response times vary between outlet systems feeding into the Lambert Graben (Amery Ice Shelf) and the ice sheet itself. The LGM glaciation of Prydz Bay is clearly reflecting an advance of outlet systems and subsystems (ie., Lambert Deep drainage) rather than wholesale advance of the East Antarctic Ice Sheet. The short duration of the LGM may not have allowed the entire ice sheet to expand. These ideas remain speculative, until more precise chronology can be provided for the sedimentary successions discussed above.

Diatoms

All core tops are dominated by *F. curta,* and sub-dominated by *F. obliquecostata* and *T. antarctica.* Frustules are abundant and well preserved, forming diatomaceous ooze throughout the upper sections. At the base of all cores, frustules are rare and poorly preserved. Cross-correlatable, reworked sections are evident in GC09 (278 cm), GC20 (208 cm), and GC22 (100 cm) with the presence of the extinct species *D. hustedtii, Nitzschia praecurta* (LA ~3.6 Ma), *Rouxia isopolica* (LA ~1.5 Ma), *Thalassiosira inura* (LA 1.8 Ma), and *T. torokina* (LA 1.8 Ma).

Core tops from Four Ladies Bank and Prydz Fan are dominated by *F. kerguelensis.* Frustules have medium preservation and are common in abundance. Reworking is evident at the surface of GC28 (Four Ladies Bank) with the presence of *Rouxia* fragments, and *T. torokina* at 85 cm. Similarly, the lower sections of GC29, GC30, and GC31 have undergone reworking. *Denticulopsis hustedtii, Pyxilla* fragments, *R. isopolica,* and *T. torokina* are present in rare abundance.

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CHAPTER 5. MAC.ROBERTSON SHELF

Introduction

The Mac. Robertson Shelf extends for about 400km west from Prydz Bay and lies adjacent to Mac. Robertson Land on the continental shelf of East Antarctica (Fig. 5.1). Shelf width is typically 90km and the depth of the shelf break averages 350m. The shelf contains relatively shallow banks (<200m depth) that extend from the coastline onto the mid- to outer shelf. These banks are separated by basins which are more than 1,200m in depth locally and which are probably a common feature on the Antarctic shelf (cf. Johnson et al., 1982; Anderson and Molnia, 1989). The basins are steep sided (up to 70°, locally) and are joined to the shelf break by arcuate shelf valleys. These shelf valleys are fjord-like, U-shaped in cross-section and probably represent episodes of glacial erosion (O'Brien et al, 1994).

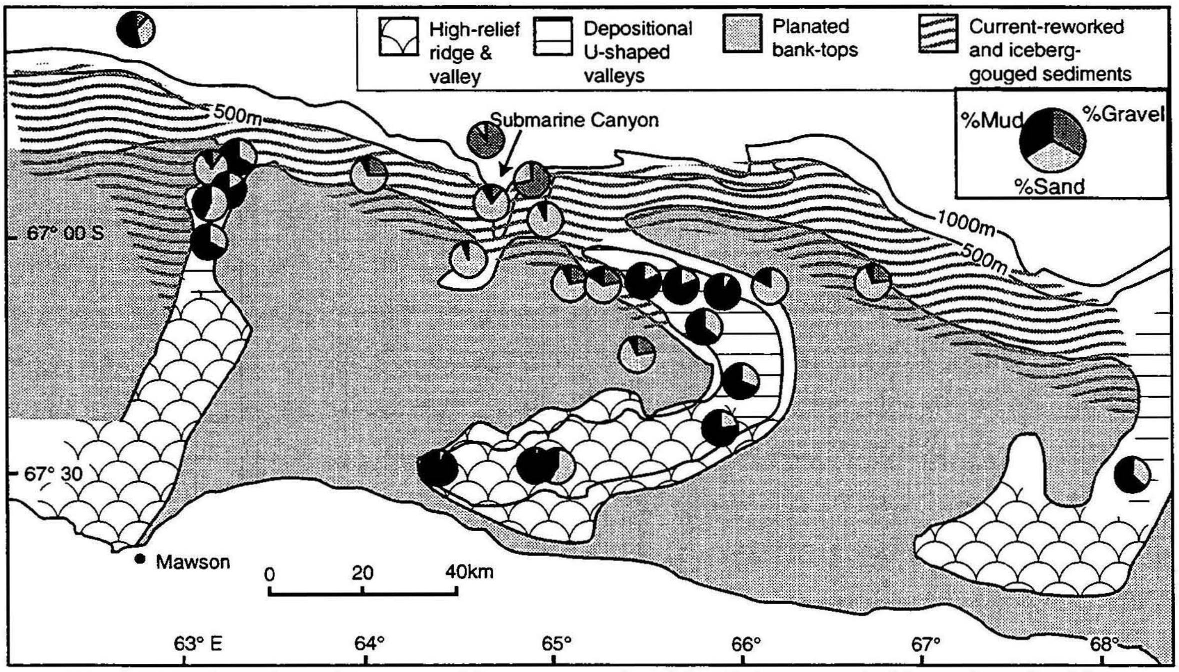

Figure 5.1 Location of geomorphic zones on the Mac.Robertson shelf as described by Harris and O'Brien, 1996) and surficial sediment grain size distributions.

A marine geophysical expedition carried out in 1982 by the Australian Bureau of Mineral Resources (now the Australian Geological Survey Organisation (AGSO)) and the Australian National Antarctic Research Expeditions (ANARE) obtained 5,000km of six-fold seismic data in the Prydz Bay - Mac. Robertson shelf area (Stagg et al., 1983; Stagg, 1985). The inner part of the Mac. Robertson shelf was found to be floored by shallow acoustic basement, considered to be Precambrian metamorphic and metasedimentary rocks. On the outer shelf, Stagg (1985) described a 750m to at least 1,000m thick sedimentary sequence (PS2), containing complex sigmoid-oblique reflectors, prograding near the shelf edge with erosional truncation at the seabed and onlapping onto acoustic basement.

Geomorphology

O'Brien et al. (1994) described the general morphology of the Mac. Robertson shelf based on a compilation of geophysical, sediment sample and bathymetric data. These workers contrasted the thick, Quaternary glacial sediment packages found in Prydz Bay (particularly the Prydz Trough Mouth Fan) with the largely erosional surface forming the Mac. Robertson shelf. The morphology of Storegg Bank (Fig. 5.1) was noted to include 20 to 40m steps, against which icebergs ground, similar to the ice erosion knick-points described from the north slope of Alaska by Barnes et al. (1987). The sedimentary sequence PS2 described by Stagg (1985) was determined by O'Brien et al. (1994) to be Late Eocene in age based on a sample containing spores, pollen and dinoflagellates dredged from Iceberg Ally (Fig. 5.1).

Harris and O'Brien (1996) described bathymetric, sidescan sonar and seismic data which suggest the presence of at least 4 physiographic provinces on the shelf (Fig. 2). These are: (i) a high relief ridge and valley topography found in association with deep (>1000m) inner shelf basins; (ii) U-shaped depositional valleys in 400 to 600m water depth, which connect the inner shelf deeps to the upper slope; (iii) smooth, planated bank tops in 100 to 200m water depth; and (iv) iceberg gouged and current reworked outer shelf and upper slope (Fig. 5.1; Harris and O'Brien, 1996).

Surficial sediments

Surficial shelf deposits have been described by Quilty (1985) based on 18 pipe-dredge samples. These samples included one from Nielsen Basin in 1,250m water depth and another from 415m water depth located about 10km offshore from Mawson Base (Fig. 5.1). These two stations comprised a "dominantly mud with diverse siliceous skeletal component" association. The other 16 samples were located on the upper continental slope and on low relief bank tops in depths of from 71 to 1,166m and comprised a "coarse sediment (biogenic and terrigenous)" association (Quilty, 1985).

Outer shelf and upper slope sediments contain more sand and gravel than inner shelf deposits and sidescan sonographs from the outer shelf banks exhibit iceberg gouges and three-dimensional dunes. These grain size distributions and bedforms are indicative of strong bottom currents and sediment reworking (Harris and O'Brien, 1996). Fine-grained, siliceous mud and ooze is deposited within deep basins and arcuate valleys, that trend across the shelf (Fig. 5.1). Seafloor photographs show the occurrence of sponges, holothurians, anemones and brittle stars with evidence of bioturbation and iceberg ploughing. None of the photographs showed evidence of current ripples or small dunes, although gravelly seabeds at some stations appeared to be armoured. Also, current-tilted sessile forms were observed and interpreted to indicate bottom current activity (Harris and O'Brien, 1996).

Cruise Plan

Our plan for the Mac.Robertson shelf portion of the voyage included the deployment of two current meters at the following positions:

CM 1 66° 56′S 64° 56′E (375m water depth)
CM 1 66° 55′S 64° 45′E (600m water depth)

This was to be followed by a seismic line along the axis of the Nielsen Valley as shown in Figure 5.2. The way points for the survey are given in Table 5.1

Sidescan sonar with a Chirper unit were also to be deployed along the survey track to search for sedimentary bedforms on the outer shelf and to seek out any thick, soft sediment deposits that might produce long Holocene cores for environmental work. At the end of the seismic line it was planned to turn back and to collect core samples and CTD data at as many stations as possible in the time available, with selection of the core sites based upon the results of the seismic and sidescan sonar data.

Table 5.1. Nielsen Basin seismic line way points.

Latitude	Longitude
66° 55′S	64° 45′E
66° 56′S	64° 56′E
67° 05′	65° 28′
67° 09′	65° 45′
67° 11.5′	66° 02′
67° 17′	66° 02′
67° 24.2′	65° 56′
67° 30′	65° 00′
67° 28.5′	64° 21′

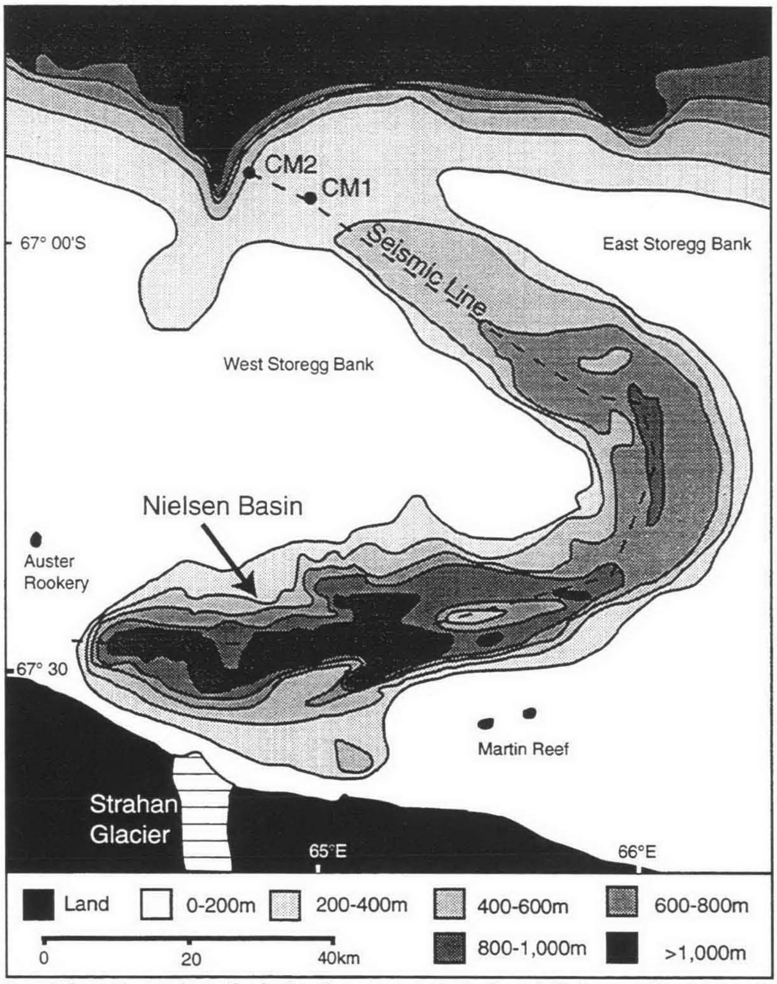

Figure 5.2. Map showing detailed bathymetry of the Nielsen Shelf valley with locations of current meter deployment sites and proposed seismic/sidescan sonar track line. Total distance travelled = 220km =12nm = 24hrs @ 5knots.

Results

Current Meter Deployments

The two current meter moorings were deployed without incident at the planned coordinates. Sea ice conditions at the time of deployment were about 60% ice cover at station 21 (CM1) and about 40% ice cover at station 22 (CM2). CTD casts and water samples were collected at each station and filtered (using pre-weighed papers) to derive suspended sediment measurements for calibration of the transmissometers. Log sheets giving details of the deployments, acoustic release codes, etc. are included in Appendix D.

Seismic and sidescan sonar data

Weather conditions in the Nielsen Basin area at the time of the survey were excellent, with minimal sea ice and calm sea conditions. The only area effected by sea ice was the outer shelf portion of the survey area. Hence, the start of line 16 was shifted to the vicinity of CM2 and seismic and sidescan sonar data were shot along the remainder of the line without difficulty. Following completion of work at stations 29, 30 and 31, the ship returned to the location of CM2 to assess the area and it was found that the sea ice conditions were improved. Thus seismic line 17 was shot from CM2 to the shelf edge, completing the Nielsen Basin transect.

Line 18 was shot starting from the mid-slope in the vicinity of a previous current meter mooring site (Site 85/4 of Hodgkinson et al., 1988) where strong bottom flows were reported. This line was terminated prematurely as heavy sea ice conditions forced the ship off the selected track line down the axis of Iceberg Alley. Line 19 was shot along the landward part of this selected shelf transect, and line 20 completed the middle section of the transect.

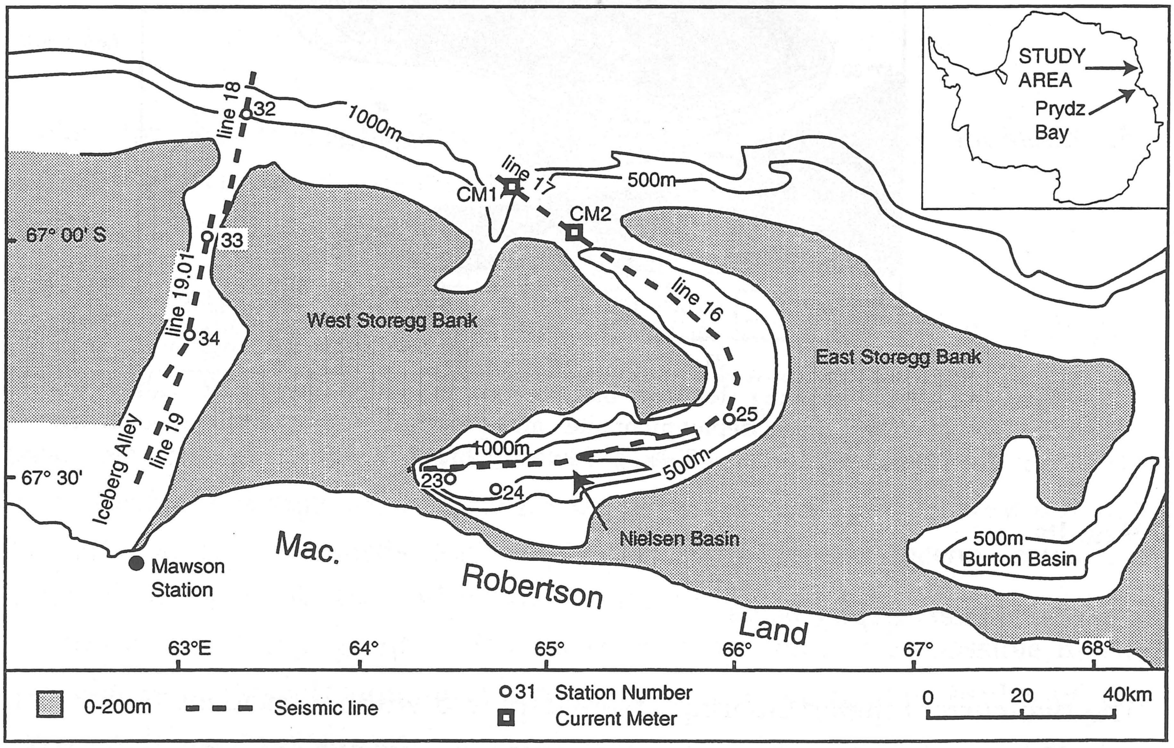

Figure 5.3. Map showing location of seismic survey tracks and stations in the Mac.Robertson shelf area completed during cruise 186.

The seismic data from the Nielsen shelf valley show a sedimentary basin with seaward dipping reflectors on the seaward part of the line, giving way to basement outcrops on the landward section of the line (Fig. 5.3). These strata have been interpreted as Jurassic to Cretaceous aged sediments, based on an assessment of their palynology in gravity core samples (Harris et al., 1996). Positive-relief depositional features, interpreted as moraines, are also evident in at least two locations (Fig. 5.4). These would have been deposited during the last glaciation of the shelf.

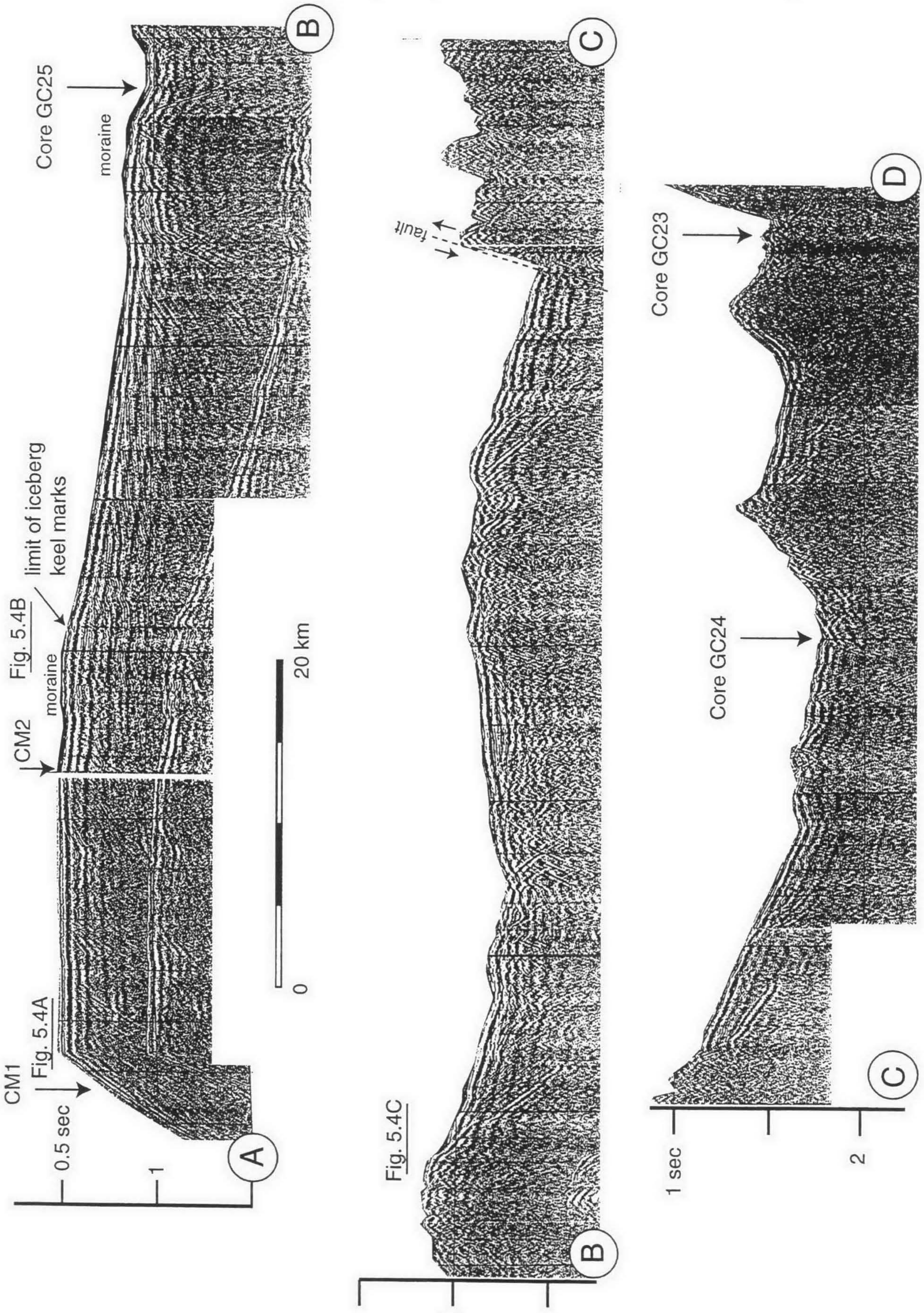

Figure 5.4 Seismic profile shot down the axis of the Nielsen Shelf Valley. See Figure 4.3 for the positions of points A, B, C and D. The approximate positions of previous core stations and of sidescan sonar images shown in Figure 4.5 are indicated.

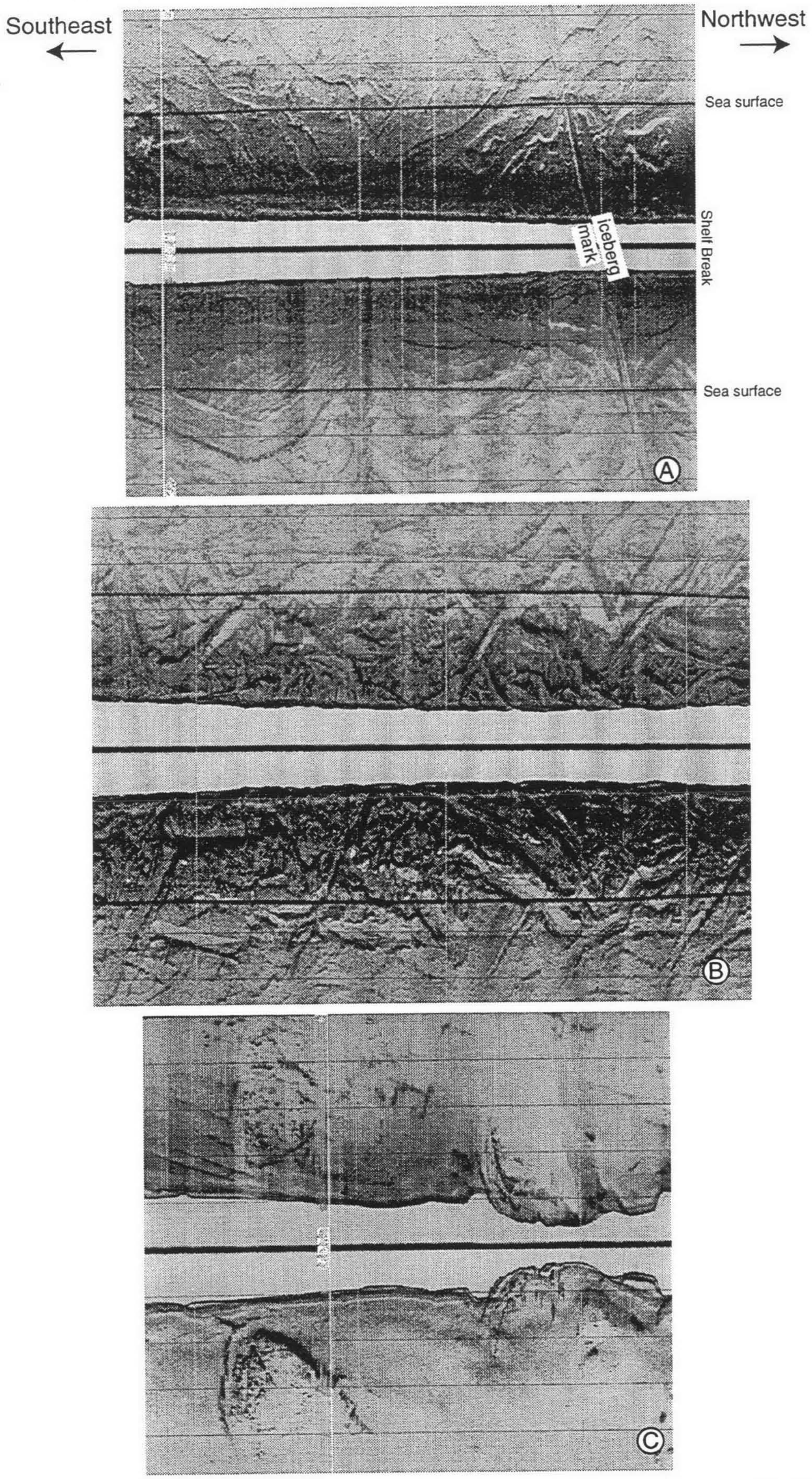

Figure 5.5 Examples of sidescan sonographs, showing (A) modern iceberg gouges near the shelf break; (B) relict iceberg gouges in the vicinity of station CM2; and (C) bedrock outcrops on the seafloor in the vicinity of previous core site 149/39GC38.

Sidescan sonar images from the Nielsen shelf valley show the occurrence of iceberg keel marks (Fig. 5.5 A & B). Keel marks in the vicinity of CM2 (Fig. 5.5B) are arcuate and exhibit no preferred orientation; they are interpreted as being relict features, formed probably during glaciated shelf conditions. In such cases, icebergs that were calved from the front of a floating ice shelf would have been constrained by the morphology of the Nielsen shelf valley (fiord), trapped for prolonged time periods by the configuration of the flanking shallow banks and the sill. The observed keel mark morphology (Fig. 5.5B) is related to icebergs undergoing irregular and sporadic movements.

In contrast with these features, iceberg keel marks that occur near the shelf break exhibit an elongate morphology and appear to overprint the older (relict) keel marks (Fig. 5.5A). Their orientation is sub-parallel to the shelf break and reflects movement under the influence of the westward-flowing Antarctic Coastal Current. For these reasons they are interpreted as being modern (Holocene) features.

Another interesting feature evident in the sidescan sonar data is the occurrence of elongate ridges in the sediments adjacent to bedrock outcrops on the seafloor (Fig. 5.5C). These elongate features are interpreted as flutes, formed by glacial ice ploughing the sediments and molding them into long furrows; their orientation is parallel to the valley axis, suggesting that this was the direction of glacial ice flow.

Sediment Cores - Nielsen Shelf Valley

A grab sample (21GR08) was taken at the site of Current Mooring CM1. The grab yielded a poorly sorted, sandy sample with considerable modern (living specimens) material taken by the benthos project. There was also a boulder about 15 cm in diameter. The recovered sample is very diverse. The terrigenous content is coarse, and contains angular/subangular and a few very well rounded grains. Garnet makes up about 30% of the fine fraction. There is a trace of glauconite attesting to a source in older sediments. Fauna includes echinoderms, barnacles, gastropods, bryozoans, ostracods, sponge spicules, agglutinated and calcareous foraminifera. Although not examined in detail, the foraminiferal fauna is diverse and contains two modes of preservation, although there is no evidence of difference in age. It may be only that some of the larger forms (e.g. of *Cibicides*) have survived when smaller specimens have been winnowed out. The fauna is dominated by *N. pachyderma* (about 60%) with

Globocassidulina/Cibicides the main benthics. The sample yielded two micrometeorites. The area clearly is subject to considerable seafloor current action, to judge from the coarseness of the material, lack of mud, and the high content of garnet. There is no evidence of any dissolution but some of the older foraminifera have been severely burrowed. Palynological study is warranted in light of the presence of glauconite, and the ostracods are worthy of further study.

Cores GC23, GC24 and GC25 were collected further landward in the Nielsen shelf valley and supplement those previously collected from this area and described by Harris et al., 19996). The diatom analysis shows that *Fragilariopsis curta* dominates all core sections. *Fragilariopsis angulata, F. cylindrus, F. obliquecostata,* and *Chaetoceros* cysts are sub-dominant. Frustules are abundant and well preserved. The spinose centric diatom *Corethron criophilum* occurs in abundance at distinct intervals from all Nielsen Basin cores (see Appendix A). Unusually high abundances of *Chaetoceros* cysts and *Corethron* in sediment has been previously recorded from deep basins in the northern Weddell Sea (Jordan *et al.* 1991), McMurdo Sound (Leventer *et al* 1993), and on the western side of the Antarctic Peninsula (Leventer *et al.* 1996). These anomalous layers are suggested to be indicative of higher than usual primary production, due to melt-water stabilisation of the water column (Leventer *et al.* 1996).

A 150 g sample of green (H_2S odorous) SMO from Grab 9 (Stn. 23) was washed to yield a very light residue. There is no >1 mm residue. Terrigenous content is minute and very fine grained. Even though the sample was distinctly malodorous, there is no evidence of diagenetic pyrite, in contrast with some other samples. The fines consist of felts of sponge spicules and diatom filaments which act as filters on which other material (centric diatoms, radiolaria, agglutinated foraminifera) are caught. Material that is not part of the felt is difficult to separate and little could be done with the facilities on board. Two otoliths were separated and must be phosphatic as any carbonate (typical of nototheniids) would have dissolved.

A sample of green SMO from core 23GC23 taken 100 cm down-core (at the contact between sections A and B; Appendix A) was washed over 125 µm, 500 µm and 1 mm sieves and examined under the microscope. The small amount of residue consists of a few coarse grains of garnet granulite including pyrite, some crystallised as a component of the granulite, and individual grains in the sediment. The same terrigenous sediment is in the finer fractions. The fauna and flora are restricted to the fine fraction and include an excellent and diverse array of siliceous groups (radiolaria, sponge spicules, diatoms) and a good agglutinated foraminiferal fauna. It is a typical SMO fauna even though it appears to be from an anoxic environment (NB no diagenetic pyrite was seen, unlike sample 24GC24CC, see below).

For comparison, a sample of grey/green sandy SMO was taken from the core catcher (bottom) of core 24GC24. The small residue after washing contained mostly terrigenous material, all angular grains. In addition, there are grey shale fragments and they may be remnants of clasts which are unrepresented as a result of washing. Garnet is a minor component. The bulk of the fine fraction consists of a felt of fine sponge spicules and filamentous diatoms. In addition, there are abundant radiolaria, centric diatoms, and agglutinated foraminifera including *Miliammina*. The latter occurrence is in contrast to many agglutinated faunas in the region which lack *Miliammina*. A feature of this residue is the amount of framboidal pyrite pseudomorphic after sponge spicules and other irregular meandrine forms not represented in the residues, perhaps some of the meandrine lagynacean foraminifera. Branching was not evident in any meandrine forms. Often the pyrite is in the form of half cylinders indicating that pyrite may form on the lower half of the host 'cylinder'. These pyrites are consistent with an anoxic environment in contrast to other SMO samples (ie 23GC23 100 cm) which lack diagenetic pyrite.

What are interpreted as pre-Holocene sediments were encountered in the core catcher of core 25GC25. The sample consists of a very clean residue of angular fragments of local country rock and lacks diversity in clast composition. Pyrite occurs in the local rocks and as individual pyrite grains, often crystallised. Garnet occurs as grains and also in the local rock. There are traces of coal and black shale/siltstone. There is no obvious glauconite or carbonate. The sample lacks obvious fossils, but the presence of coal and shale indicates that palynology may be worthwhile.

Sediment Cores - Iceberg Alley

Core GC33 was a core-catcher only sample collected on the upper continental slope - the substrate is assumed to have been an outcrop of bedrock, judging from the bent core barrel and badly dented core cutter. Small samples (3 ml) of a dark grey, not very firm mud were scraped from the inside of the core cutter; the core catcher contained a handful of pebbles etc, obviously modern from a high energy area. The mud samples were washed through 125 µm and 500 µm sieves and the washings were found to be fine, angular to very well rounded grains of terrigenous debris, and higher in their proportion of rounded grains than modern sediments such as those normally encountered on the Antarctic margin. The fauna is dominated by the modern *N. pachyderma/Globocassidulina* group (a highly mixed fauna), but also yielded mixed Palaeogene (?), and possibly even Cretaceous forms. A significant planktonic foraminiferal fauna contained *Glibigerinatheka semiinvoluta* of Late Eocene (P15) age. The other dominant species appears to be *Morozovella pseudbulloides* of Early Palaeocene age (P2/3). Modern radiolaria are present but rare, and one filled with pyrite was recovered. Whether this is 'modern' or Palaeogene is unknown. Sponge spicules, mostly broken and some physically eroded, are present but not abundant. Physically eroded sponge spicules are uncommon in the samples studied on this voyage. One *Inoceramus* prism was recovered from each sample, possibly indicating Cretaceous-aged source material in the area. Enough of one of the samples has been retained for nanoplankton and palynology. Other faunal elements (not modern) are bryozoans, ostracods, molluscs and echinoderm fragments. Glauconite is quite abundant, and there are a few grains of coal akin to that recovered from the area during the 1995 expedition to this area (O'Brien et al., 1995). There are a few fragments that seem to show evidence of chertification, but otherwise preservation is excellent.

Two other cores, GC34 and GC35, were collected from what were interpreted as thick SMO deposits on the seismic records. Diatoms in these Iceberg Alley cores are dominated by *F. curta,* in association with *F. cylindrus* and *Chaetoceros* cysts. Frustules are abundant and well preserved. Reworking is evident in GC35 with the presence of *D. hustedtii* at 0 cm and 105 cm. Sediment layers containing higher than normal abundance of *Corethron* and *Chaetoceros* cysts are present in both cores. GC35 is dominated by *Corethron* at 105 cm; *Chaetoceros* cysts dominate at 288 cm and 375 cm.

A sample from the base of core 34GC35 comprised a bedded intermixture of SMO and dark sandy textured material, perhaps slumped from valley side. Inspection of the sieved residue under the microscope shows that the coarser fraction consists of angular to subangular, terrigenous debris with garnet conspicuous. There are black mud flakes and grains of white siltstone, unlike what has been seen in other residues and suggesting that palynological processing might be worthwhile. The fine fraction is similar in composition, but has diatoms, radiolaria, sponge spicules and a typical SMO agglutinated foraminiferal fauna, plus the calcareous benthics *Globocassidulina crassa* and *Loxostomum,* the latter not obvious in samples studied above. There was no obvious glauconite or coal.

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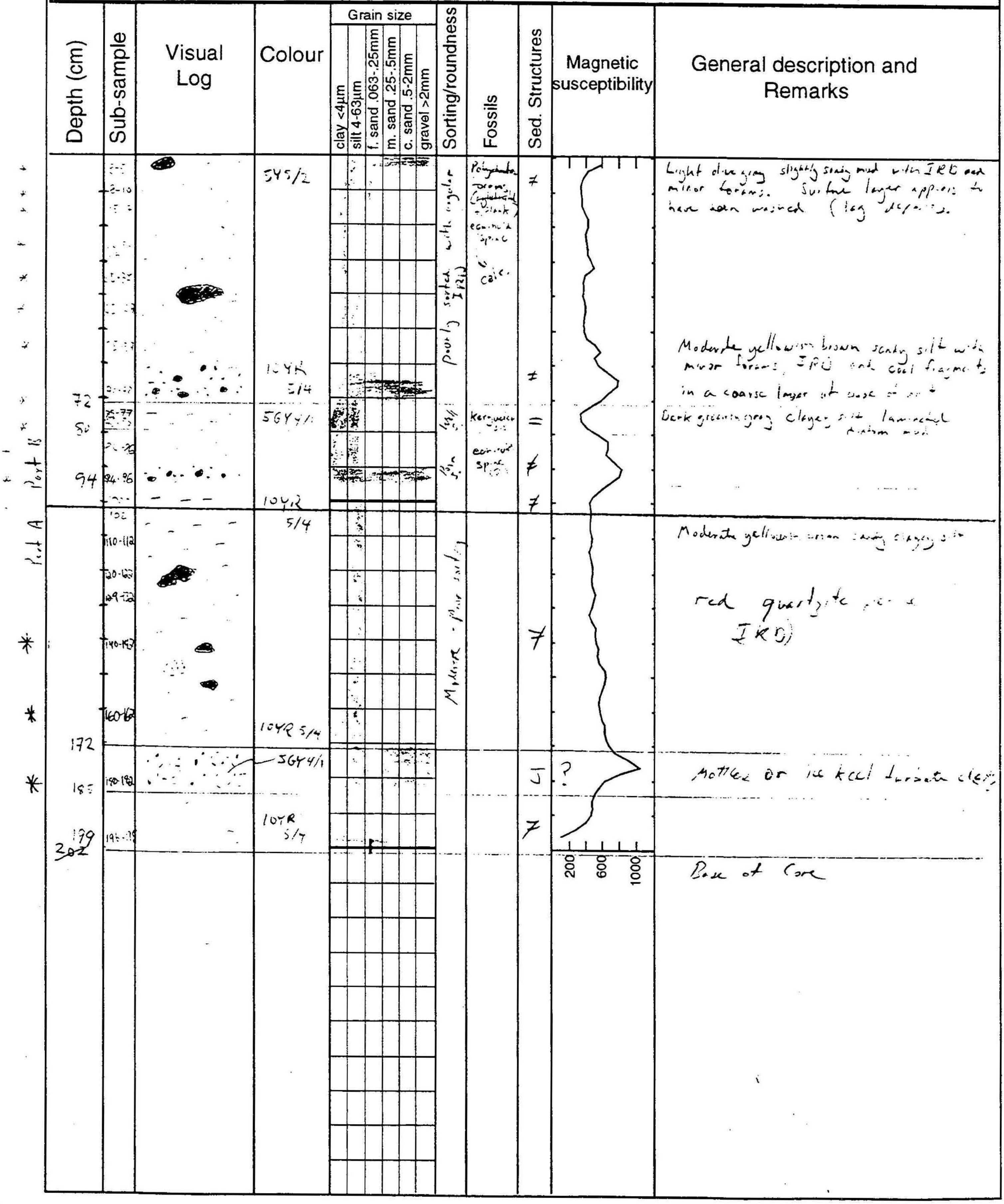
Appendix A.

Core Logs

Core Number: 1GC1 Cruise 186 Location: Vincennes Bay Core Length: 203cm

Latitude: 65° 22.84'S Longitude: 109° 04.22'E Date: 5-2-97 Water Depth: 475m



Light olive gray slightly sandy mud with IRD and minor forams. Surface layer appears to have been washed (log departs.

Moderate yellowish brown sandy silt with minor forams, IRD and coal fragments in a coarse layer at base of unit

Dark greenish gray clayey silt laminated diatom mud

Moderate yellowish brown sandy clayey silt

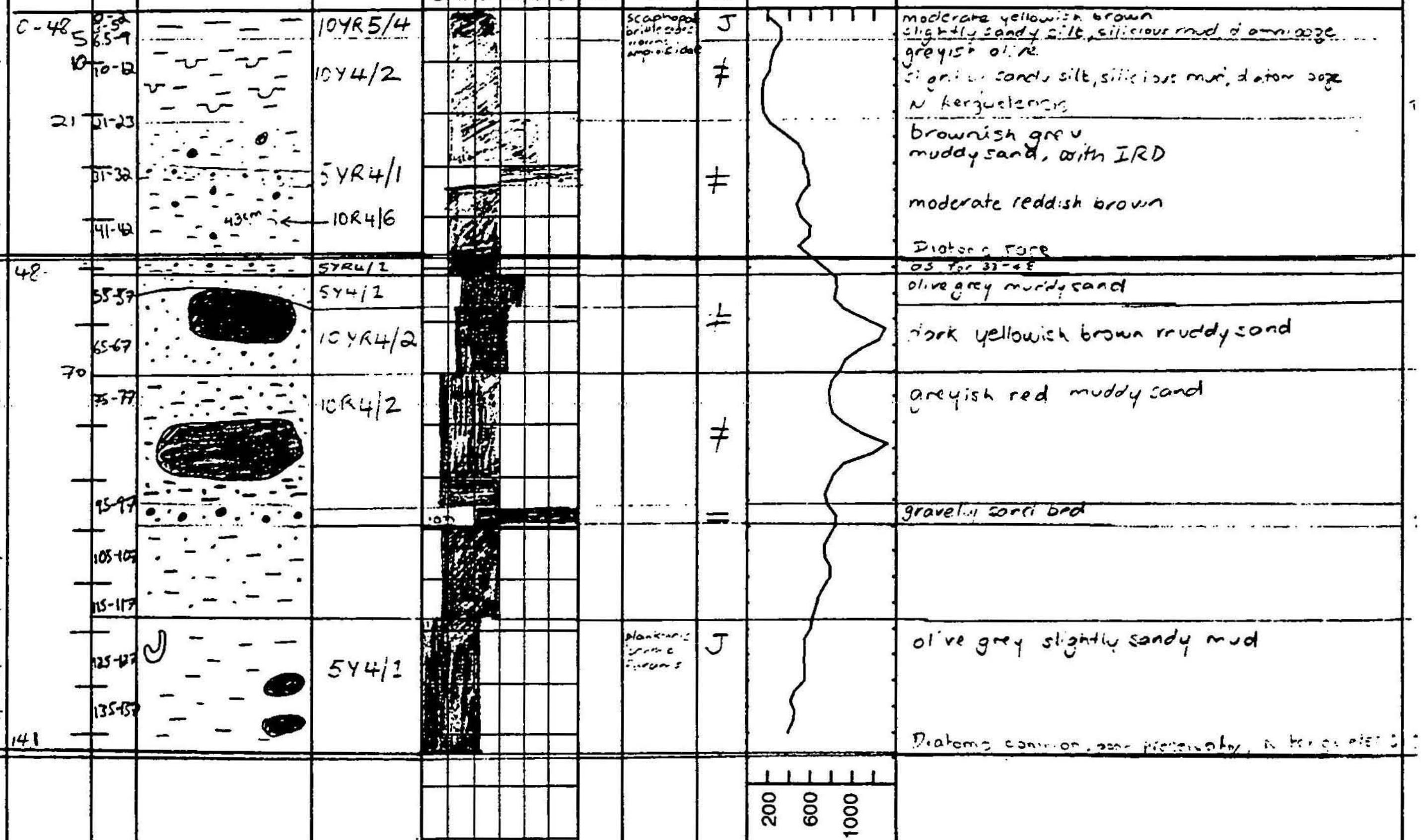
red quartzite piece (IRD)

Mottled or ice keel turbate clay

Base of Core

Core Number: 186/~~[illegible]~~ 2GC02 Location: Vincennes Bay Core Length: 142cm

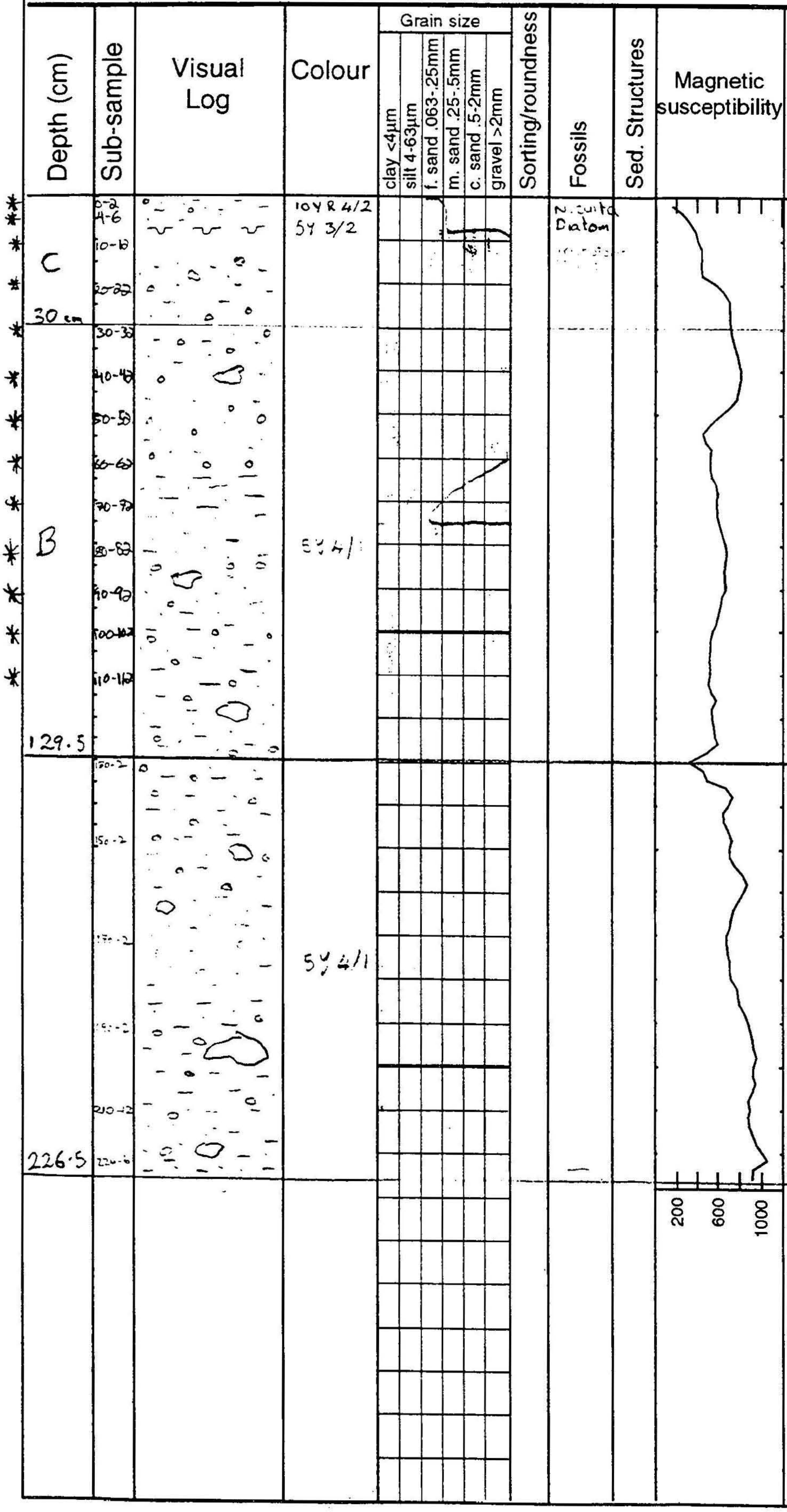
Latitude: 65° 28.62'S Longitude: 108° 56.60'E Date: 6-2-97 Water Depth: 512m



	Depth (cm)	Sub-sample	Colour	Grain size: clay <4µm, silt 4-63µm, f. sand .063-.25mm, m. sand .25-.5mm, c. sand .5-2mm, gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	General description and Remarks
* * *	0-48	0-5 6.5-9	10YR5/4			scaphopod bivalve[illegible] worms amp[illegible]idae	J	moderate yellowish brown slightly sandy silt, siliceous mud diatom ooze
B *	5 10	10-12	10Y4/2				≠	greyish olive slightly sandy silt, siliceous mud, diatom ooze N kerguelensis
*	21	21-23						brownish grey muddy sand, with IRD
*		31-32	5YR4/1				≠	
*		41-42	10R4/6					moderate reddish brown Diatoms rare
	48		5YR4/2					as for 33-48
*		55-57	5Y4/1					olive grey muddy sand
*		65-67	10YR4/2				≠	dark yellowish brown muddy sand
*	70	75-77	10R4/2				≠	greyish red muddy sand
A *		95-97					=	gravelly sand bed
*		105-107						
*		115-117						
*		125-127	5Y4/1			planktonic [illegible] forams	J	olive grey slightly sandy mud
*	141	135-137						Diatoms common, some fragmentary, N kerguelensis

Core Number: 186/3GC3 Location: Vincennes Bay Core Length: 240cm

Latitude: 65° 32.90'S Longitude: 108° 46.82'E Date: 7-2-97 Water Depth: 599m



General description and Remarks

Grayish olive diatom ooze [illegible]
mottled bioturbated olive grey very fine sandy clay with diatom ooze

[illegible]

50 [illegible]

70-72 [illegible]

80-82 [illegible] ~~clasts~~ sand

90-92 Sandy clay, clasts

100-102

110-112 - gravelly, sandy clay.
Olive grey dimicton

130-132

Olive grey diamicton

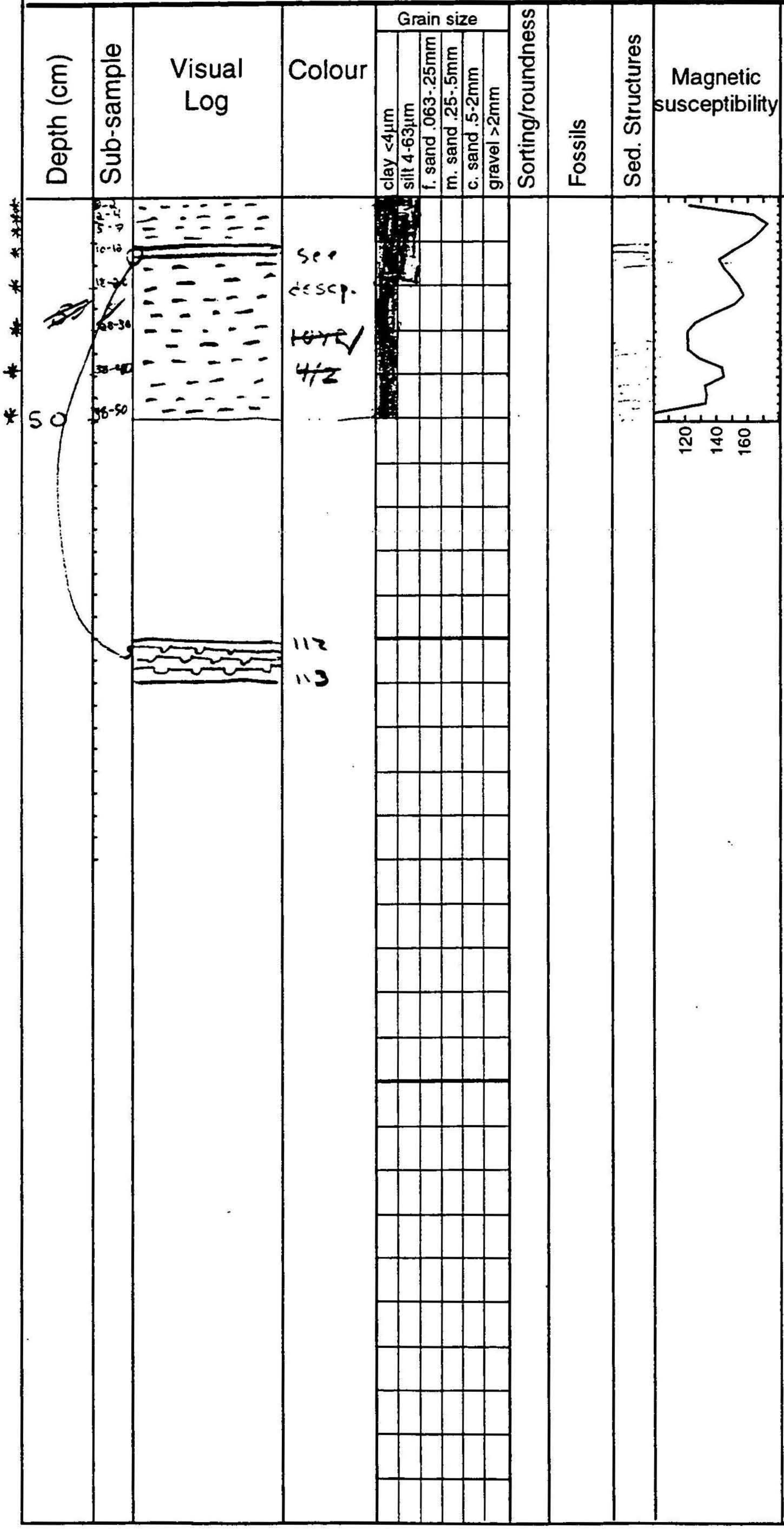
Becoming more compact down core.

Diatoms absent

Bottom

Core Number: 186/4GC4 Location: Vincennes Bay Core Length: 50cm

Latitude: 66° 42.90'S Longitude: 109° 8.8'E Date: 10-2-97 Water Depth: 2180m



General description and Remarks

Laminated silty clay - marked by discontinuous blk. laminations in upper ½ and continuous v. thin blk. laminations in lower ½. One thin laminea at 112-113 of diatom ooze bounded by blk. laminea at (10YR 2/2) base another one at 41-42 cm.

Oxidized 1-2cm layer at top of core (5YR 4/4)

No smell.

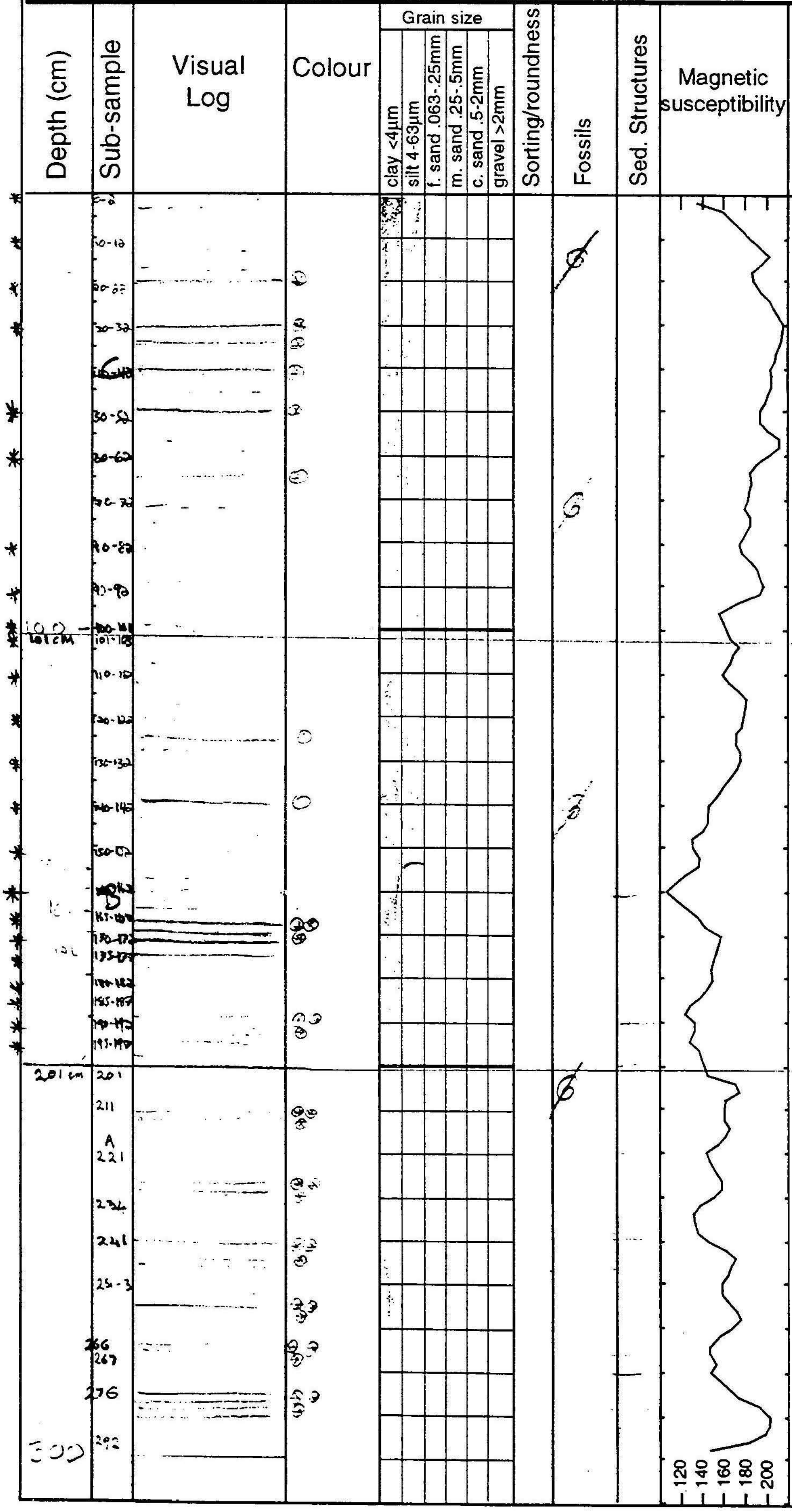
More clay below 30 cm.

Alternating 10 YR 4/2 + 5 YR 3/2 at base

Diatom abundant; & centa
[illegible]
[illegible] preservation

Core Number: 186/4GC5 Location: Vincennes Bay Core Length: 300cm

Latitude: 66° 43.17'S Longitude: 109° 07.91'E Date: 10-2-97 Water Depth: 2100m



L. [illegible] +
E. Domack

General description and Remarks

CLAYEY SILT, VERY THINLY 5Y [illegible] LAMINATED 0-15 cm
[illegible] (-16 cm)

SILTY CLAY/CLAY INTERSTRATIFIED LAMINATED, MARKED BY BLACK CONTINUOUS AND DISCONTINUOUS LAMINAE [illegible] 5Y 3/2 AND VERY THIN BEDS OF RED CLAY (5Y [illegible]
[illegible] /0.2

[illegible]

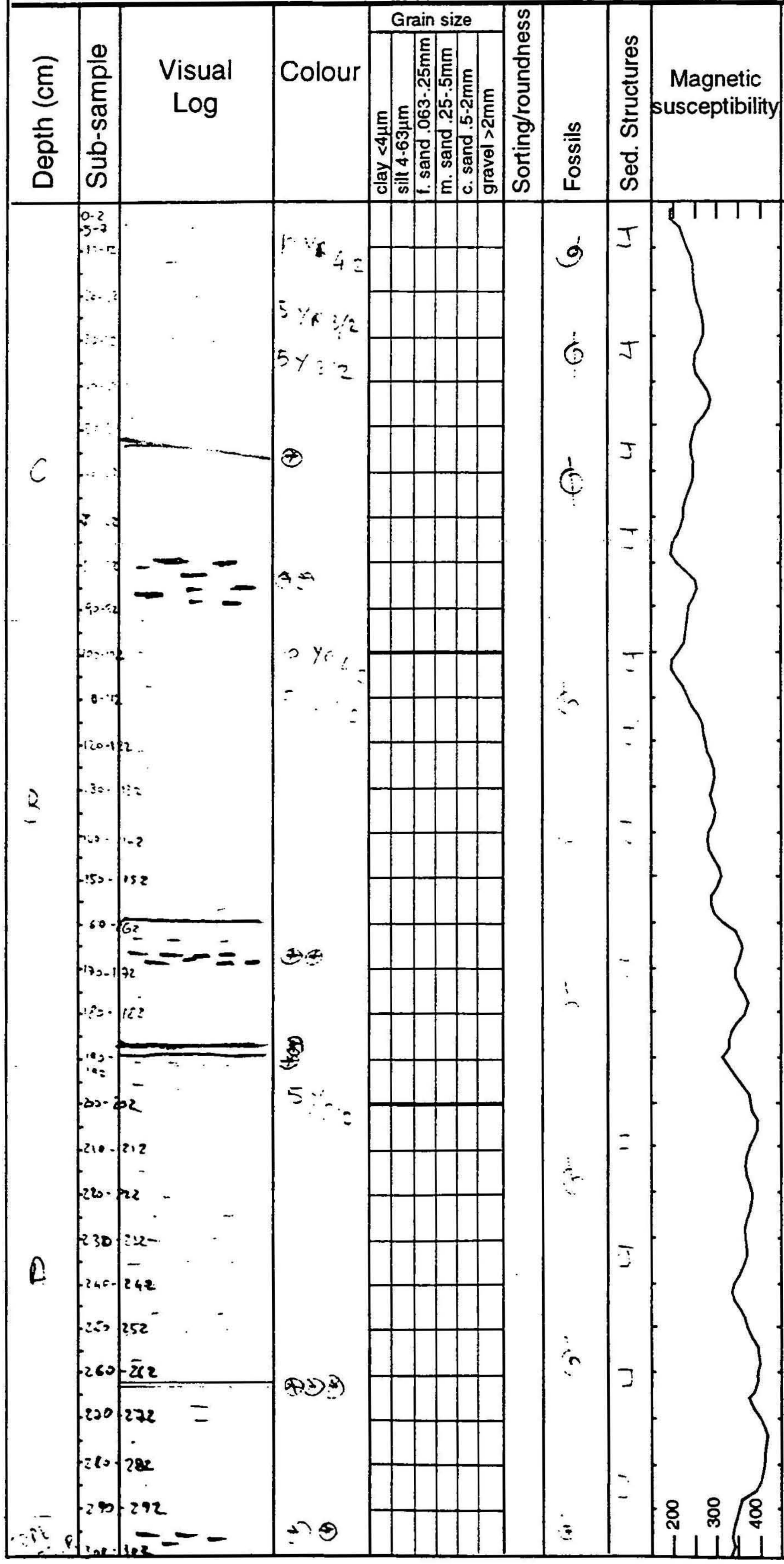
THE DIATOM[illegible] [illegible]
[illegible]
THE RED CLAY [illegible]
UPPER [illegible] SILTY CLAY

⊙ GREEN (10Y [illegible]
LAMINAE [illegible]

⊛⊛ BLACK [illegible]

Diatoms abundant throughout [illegible]
[illegible]
[illegible]

Core Number: 186/5GC6 (0-300cm)	Location:	Vincennes Bay	Core Length: 320cm
Latitude: 66° 30.32'S	Longitude: 109° 57.06'E	Date: 11-2-97	Water Depth: 1,200m



General description and Remarks

HOMOGENEOUS SILTY CLAY WITH MOTTLED RED CLAY BANDS AND SPORADIC GREENISH DIATOMACEOUS LAMINAS (0.5-1 cm)

BIOTURBATION

⊛ ⊛ SPORADIC BLACK FLACKES HORIZONTALLY ORIENTED AT THE BASE

⊛ DIATOMACEOUS LAMINA

SILTY CLAY (DARKER WITH MOTTLED RED CLAY BANDS AND BIOTURBATION

⊛⊛ - RED CLAY SMALL [illegible] SUB-HORIZONTAL CONTACT WITH MOTTLED UPPER [illegible] THE LOWER BOUNDARY IS IRREGULAR AND SHARPLY CUT A DARK LAMINA

Core Number: 186/5GC6 (300-330cm) Location: Vincennes Bay Core Length: 320cm

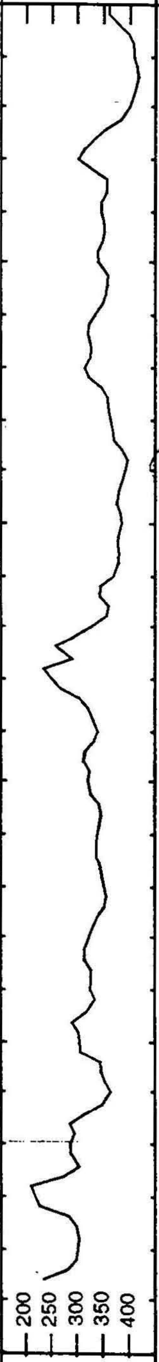
Latitude: 66° 30.32'S Longitude: 109° 57.06'E Date: 11-2-97 Water Depth: 1,200m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
[illegible]													200 300 400	

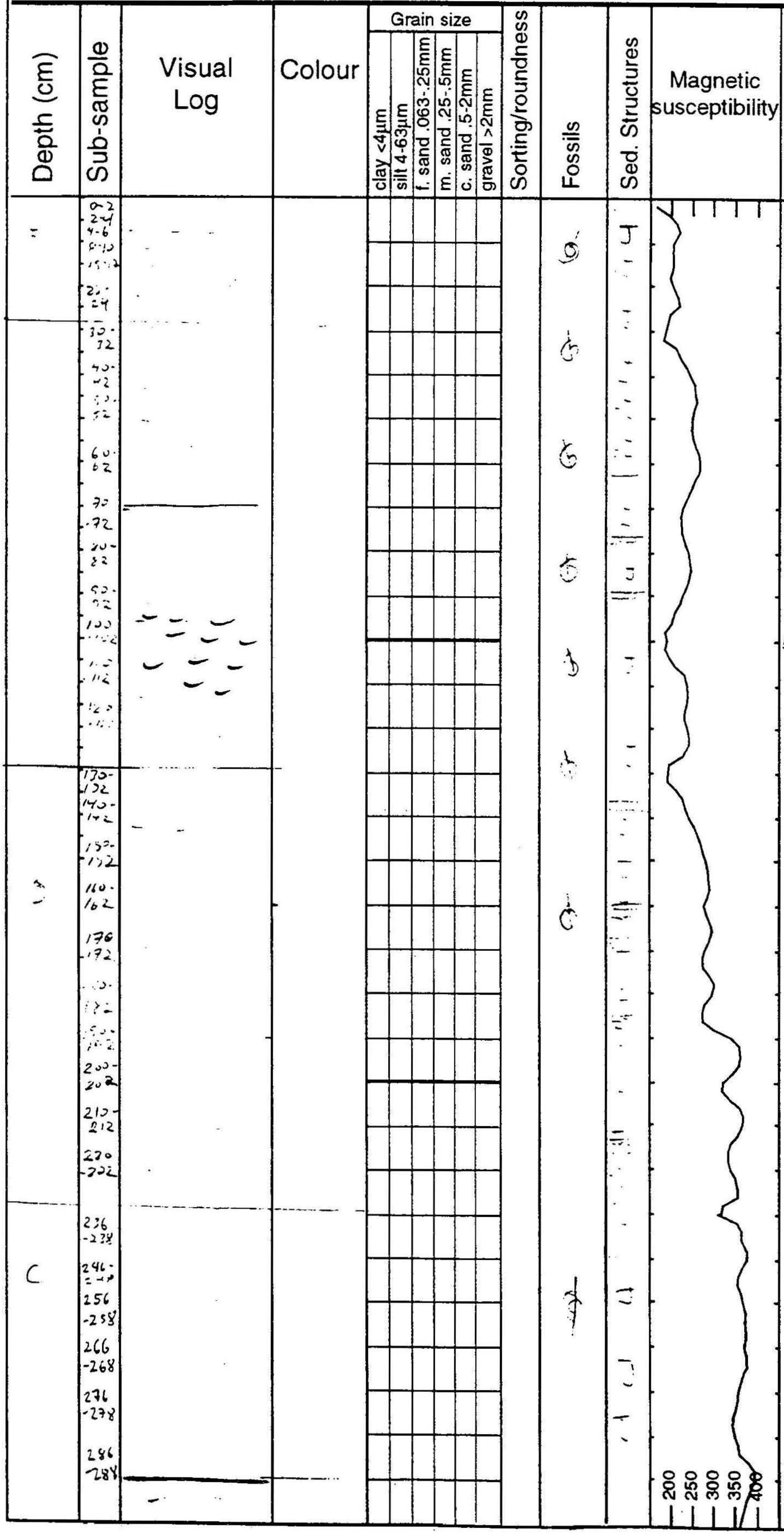
Core Number: 186/5GC7 (300-545cm) Location: Vincennes Bay Core Length: 545cm

Latitude: 66° 30.38'S Longitude: 109° 57.02'E Date: 11-2-97 Water Depth: 1200m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility	General description and Remarks
329	306-308 316-318 326-328 339-341 349-351 359-361 369-371 379-381 389-391 396-398 399-401 409-411 415-421 430-432 440-442 450-452 460-462 470-472 480-482 490-492 500-502 510-512 520-522 534-536 544-546		*											SILTY CLAY HOMOGENEOUS (5Y 3/2) HIGLY BIOTURBATED CLAYEY SILT WITH DISSEMINATED [illegible] OF PEBBLES (10 YR [illegible]) BIOTURB. SILTY CLAY [illegible] BIOTURB *BLACK LAMINE [illegible] (0.5-1.5 cm THICK) WITH UPPER TRANSITIONAL BOUNDARY TO RED CLAY AND SHARP LOWER CONTACT [illegible] CLAY [illegible] LITTLE BIOTURBATION. 529cm - Diatom abundant [illegible] (5Y 3/2) SILTY CLAY LITTLE BIOTURBATION [illegible] AND BLACK BAND
429														
529														



Core Number: 186/5GC7 (0-300cm)	Location: Vincennes Bay	Core Length: 545cm
Latitude: 66° 30.38'S	Longitude: 109° 57.02'E Date: 11-2-97	Water Depth: 1200m



General description and Remarks

OXIDISED SILTY CLAY (10YR 5/4 1-2 cm). Diatom [illegible]

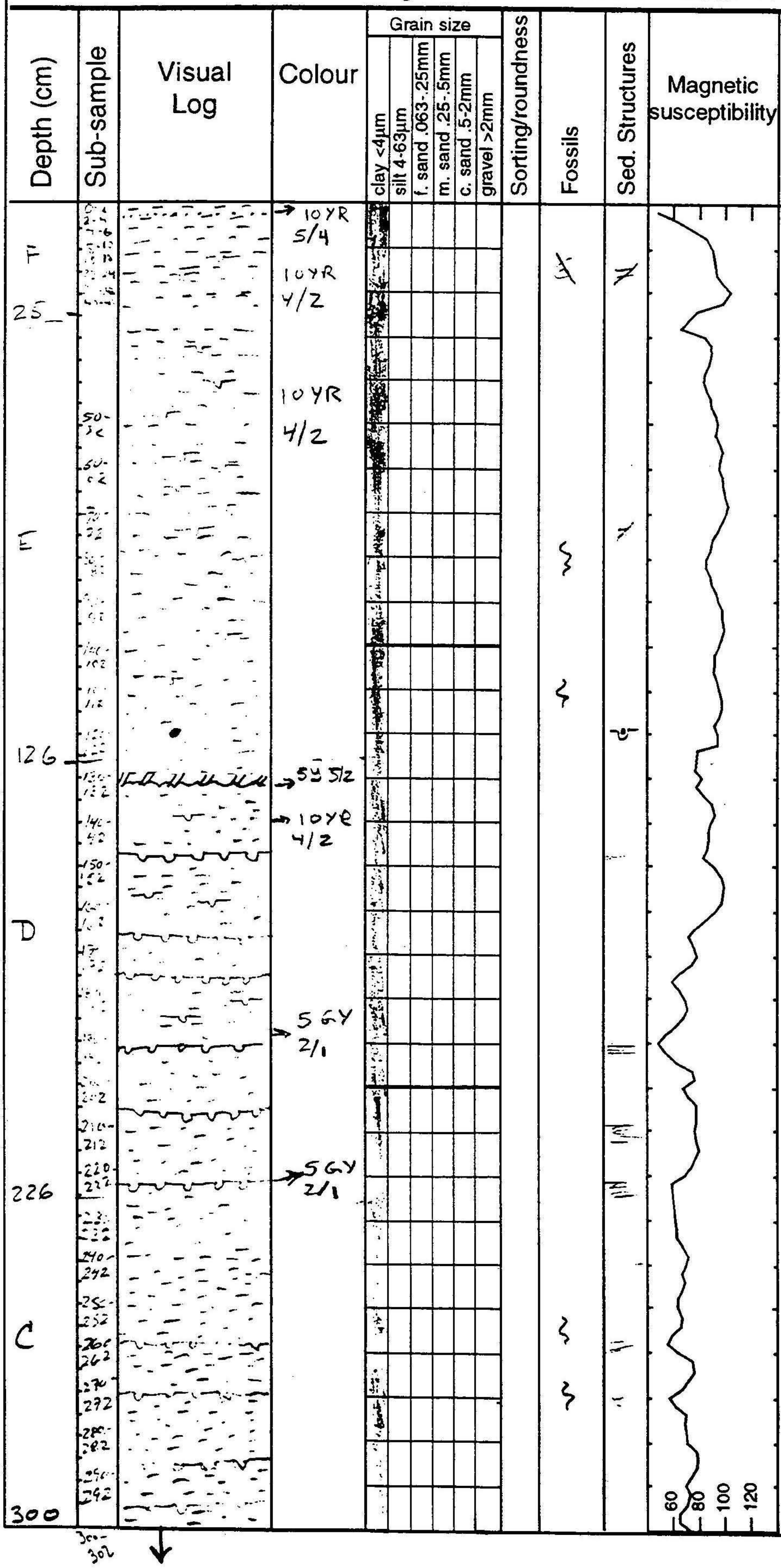
SILTY CLAY (10 YR 4/2) MARKED BY THIN BEDS [illegible] (5 YR 4/6) DISCONTINUOUS WITH SHARP LOWER BOUNDARY AND TRANSITIONAL UPPER BOUNDARY / VERY BIOTURBATED HORIZONTAL BIOTURBATED BURROWS (0.5 cm THICK)

MORE HOMOGENEOUS CLAYEY SILT (10YR 4/2) WITH [illegible] BLACK FLECKS HORIZONTALLY ORIENTATED
LITTLE BIOTURBATION

BANDS OF RED CLAY
HIGLY DISRUPTED [illegible]

Core Number: 186/6GC8 (0-300cm) Location: Vincennes Bay Core Length: 545cm

Latitude: 66° 21.98'S Longitude: 110° 10.35'E Date: 11-2-97 Water Depth: 1740m



General description and Remarks

diatom.
F = 0-25 Homogeneous silty
clay, lighter oxidizing
surface layer at 0-4 cm.
top, seasonable close to sed/H2O
interface

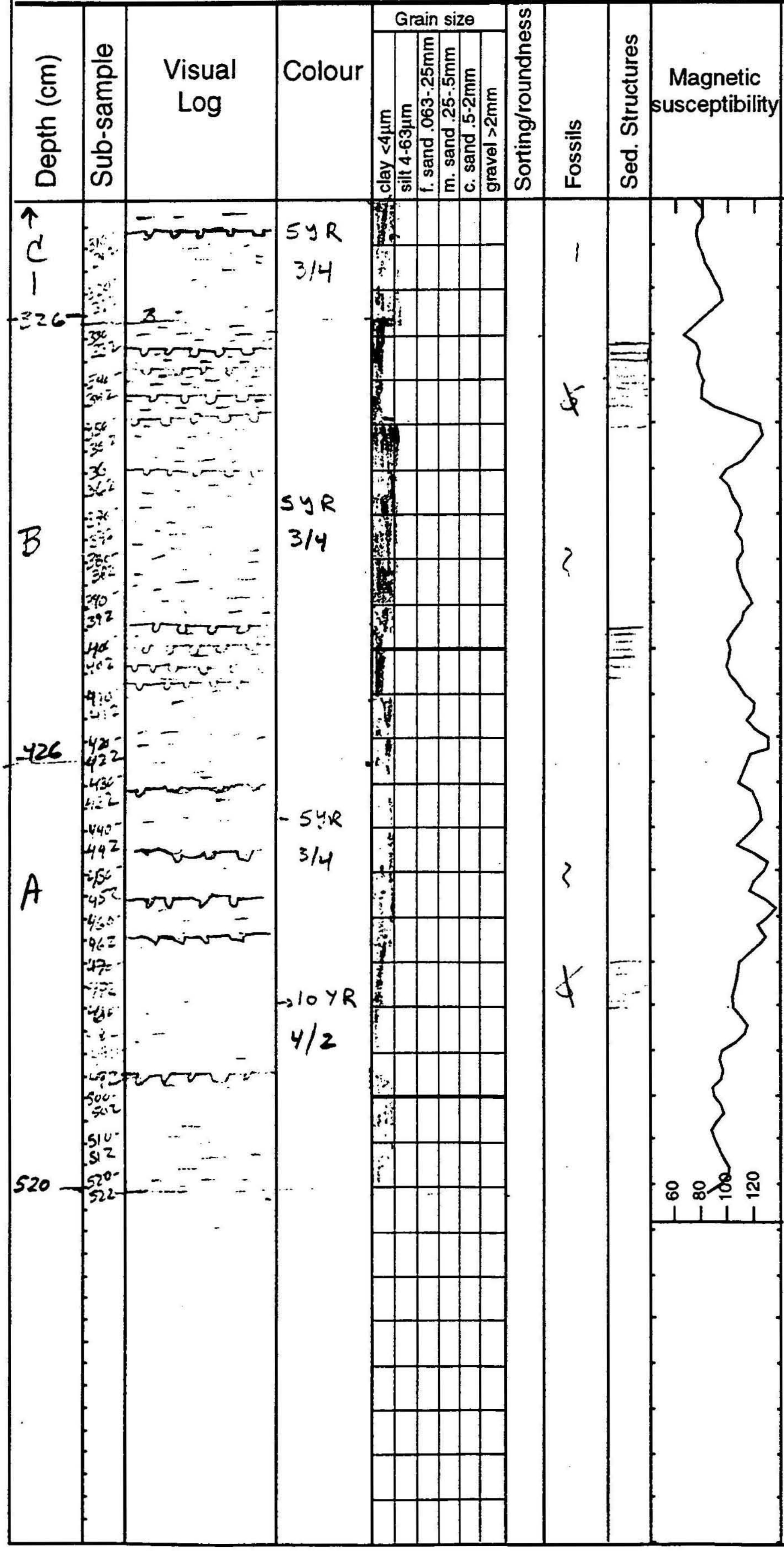
diatom
chocolate brown, silty
clay, a few cr. grains
fine gravel, homogeneous
A few small open
burrows 2-3 mm in
diam.

[illegible]

diatom.
126 - 168 choc. brown silty
clay, v. thn. bdd. with
spicule mat @ 131 - 134
Below 133 - discontinuous
blk. laminea occur.
More abundant down-core
168 - 226 Thinly bdd.
siliceous clay interbed.
w/ olive green diatom
ooze laminea @ 163,
176, 189, 206, 224. These
become blk. below 176 cm
instead of olive brown
226 - 310 Interbedded
diatom
diatom mud, silty clay
and diatom ooze laminea
Abundant bioturbation,
filled microzoophycos
mkd. by black laminea.
Increase in red silty
clay below 230cm

Core Number: 186/6GC8 (300-540cm) Location: Vincennes Bay Core Length: 545cm

Latitude: 66° 21.98'S Longitude: 110° 10.35'E Date: 11-2-97 Water Depth: 1740m



General description and Remarks

300 - 326 choc. brown silty clay w/ discontinuous blk. streaks throughout.
Below 310 No diatom ooze layers
326 - 328 silty clay
328 - 347 Laminated diatom ooze & mud w/ black + olive green alternations
347 - 394 choc brown - olive green silty clay
34-- [illegible] layer.
394 - 411 Laminated olive green - black diatom mud + ooze
411 - 426 choc. brown / oliv. grn. silty clay.

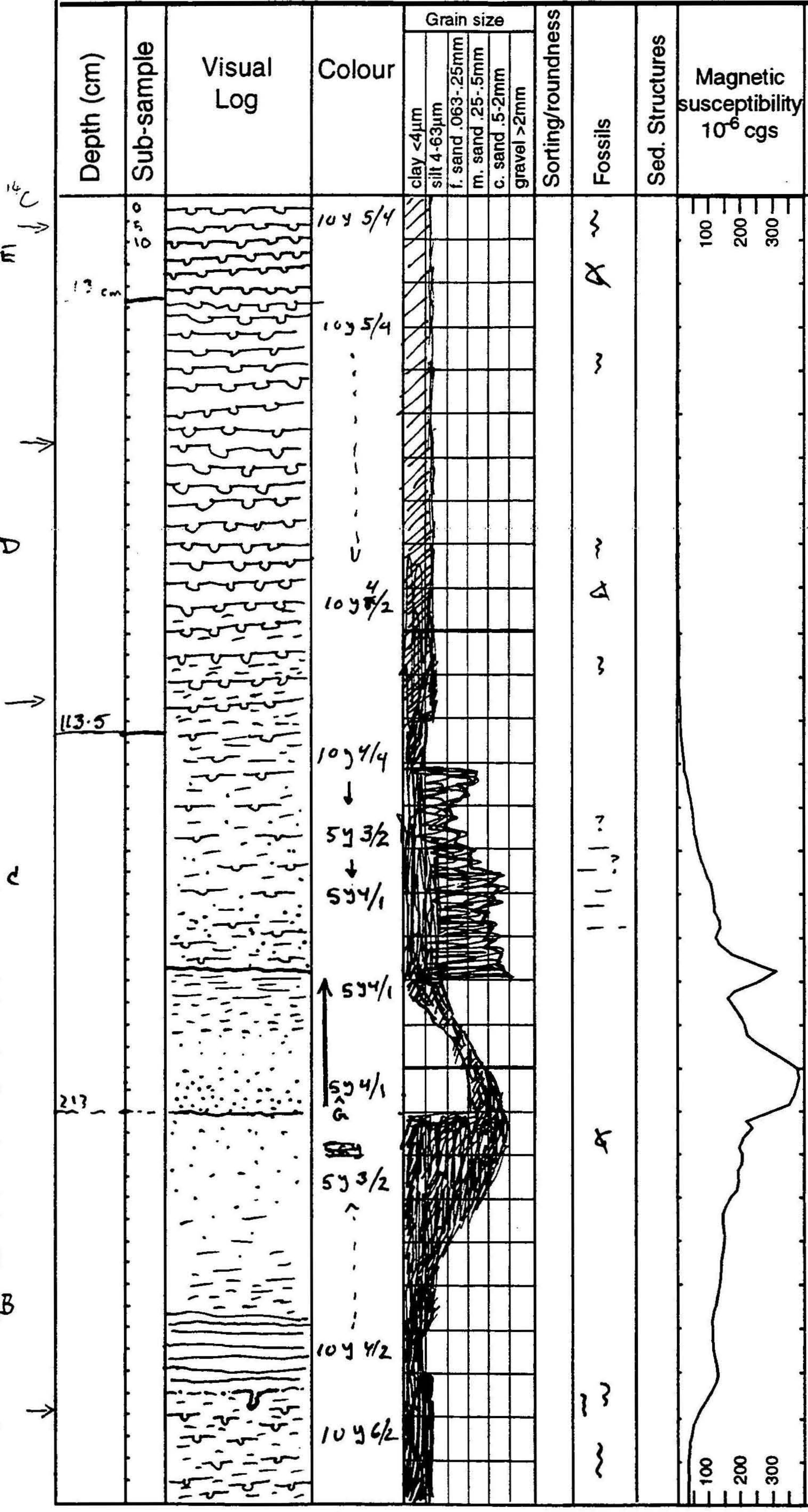
426 - 460 choc. brown ~~[illegible]~~ silty clay w/ diatom ooze laminations at MS lows.
460 - 520 olive brown diatom rich clay - silty clay.
Increase in diatom content overall toward base.
↓ odoriferous [illegible] base
Diatom ooze laminea boundra on lwr cut w/ black mud, mottled
↳ 5Y 2/1

426cm - Diatoms abundant + well preserved ~ [illegible]

520 [illegible]
— [illegible]

Core Number: 186/7GC9 (0-300cm) Location: Prydz Bay Core Length: 410cm

Latitude: 68° 04.01'S Longitude: 72° 54.01'E Date: 18-2-97 Water Depth: 698m



Domack

General description and Remarks

0-13 cm Diatom. ooze, w/ small 3 mm scale burrows No clear sed/H_2O interface. Light olive

13 - 113.5 Diatom. ooze w/ small open 3 mm scale burrows. clay content increases near base. w/ darker color.

113.5 - 122 Diatom silty. w/ few 3 mm scale burrows 122 trans. cut. w/ 179 → stratified?

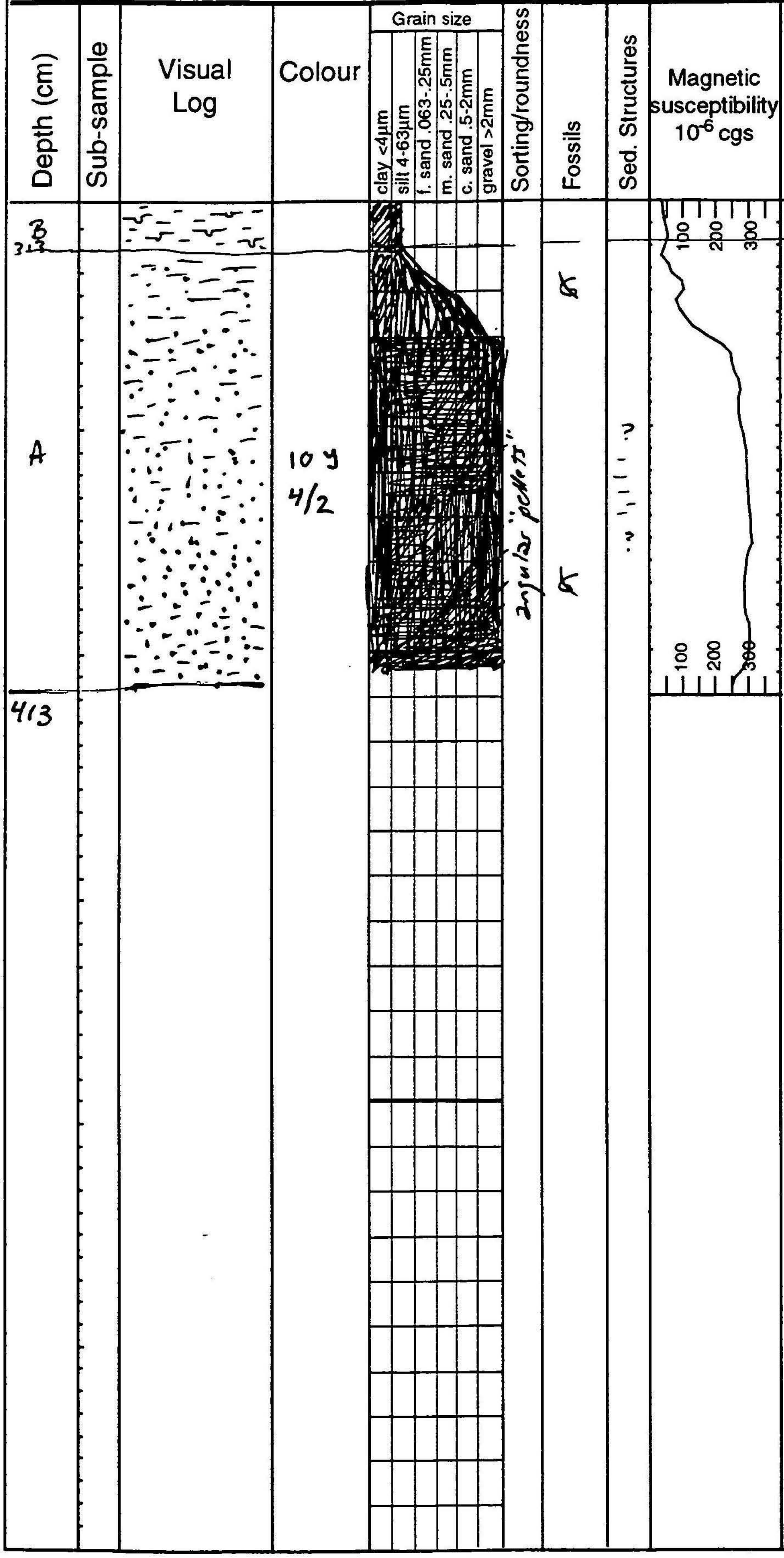
122- ~~210~~ Fining upwards poorly sorted md. - cr. muddy sand up into sandy diatom. mud. Shp. cnt. at 179. 179 - 210 Fining upwards md. - cr. gr. sand to clay. sand lacks app. mud w/ some ? mud pellets

210 - 278 Coarsening upwards clay to sandy, mud down mixed burrow at cnt. w/ diatom mud @ 278. Large pebble @ 258

278 - 310 Pale olive diatom. mud grades down into clay. burrows.

Core Number: 186/7GC9 (300-410cm) Location: Prydz Bay Core Length: 410cm

Latitude: 68° 04.01'S Longitude: 72° 54.01'E Date: 18-2-97 Water Depth: 698m



Pomack

General description and Remarks

320 – Bottom (410)

Dilatent, cr. granule mud pellets, water saturated fines upwards from 330 – 320 cm.
?stratified, muddy vs. cr. sand.

0cm - diatoms abundant & well preserved N. curta

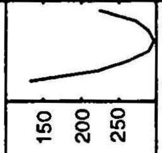
135cm - diatoms common & well preserved; T antarctica

278cm - diatoms common to abundant good to med. preservation N curta + reworked T inura & T. torokina

413cm - diatoms rare. poor preservation

Core Number: 186/8GC10 Location: Prydz Bay Core Length: 18cm

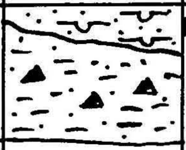
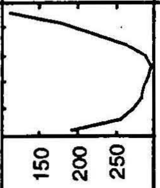
Latitude: 68° 04.17'S Longitude: 72° 55.95'E Date: 18-2-97 Water Depth: 655m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	Domack General description and Remarks 0 - 15cm olive
0-2 14-15			5y 3/2							X	NO	X		Grey, hard compacted muddy diamicton., very stiff. No obvious H_2O contact (irregular lws. shp. contact) low H_2O content @ 14cm olive diatom. sand [redacted] prly. sorted [redacted] (looks like it should be top of core ?) Md-Cr. grained
15 [redacted]cm			5y 5/2								Diatom.	X		

Core Number: 186/8GC11 Location: Prydz Bay Core Length: 26cm

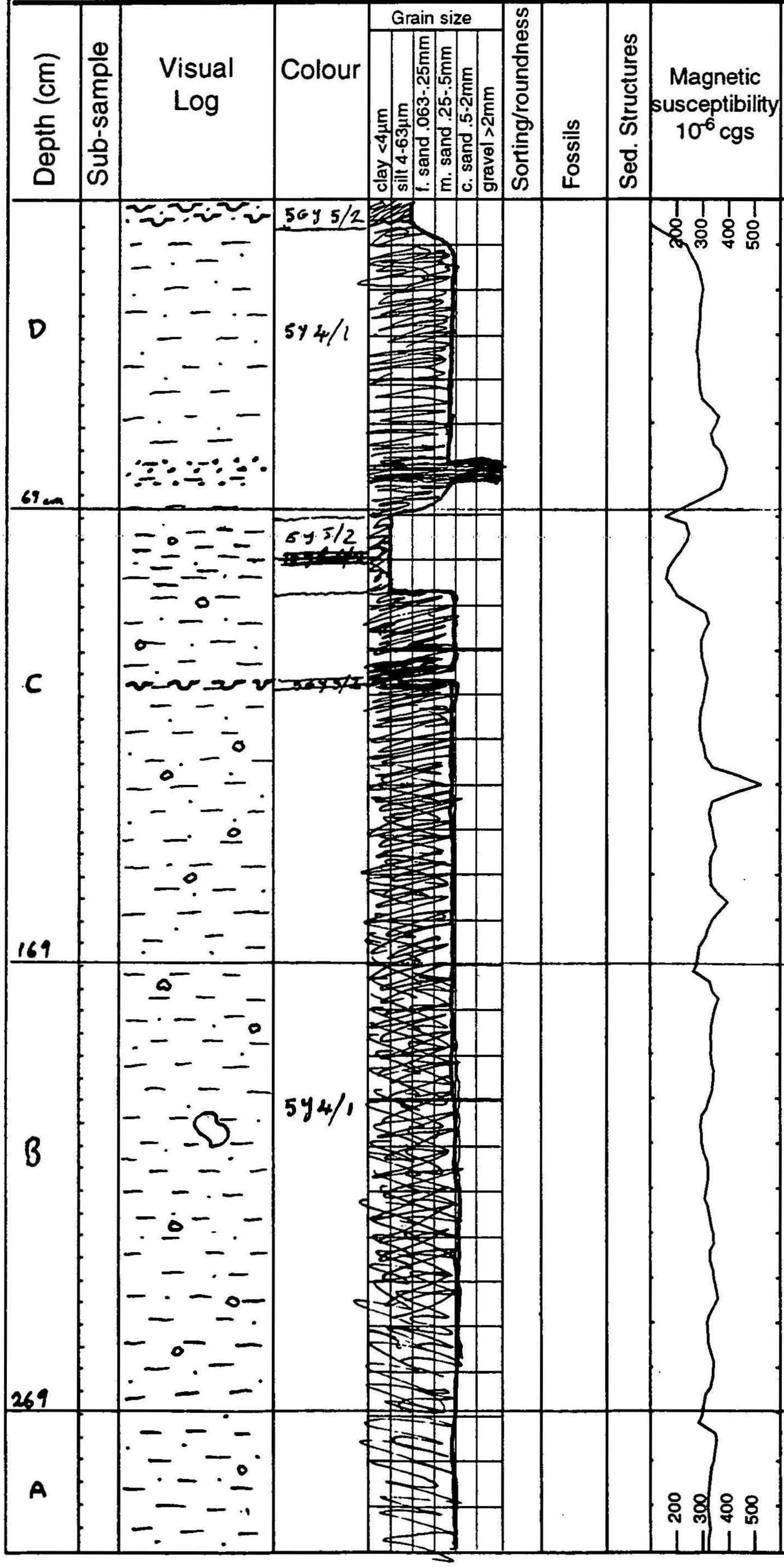
Latitude: 68° 04.25'S Longitude: 72° 55.75'E Date: 18-2-97 Water Depth: 655m

Domack

	Depth (cm)	Sub-sample	Visual Log	Colour	Grain size clay <4µm silt 4-63µm f. sand .063-.25mm m. sand .25-.5mm c. sand .5-2mm gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
	0-2			10Y 5/4					 150 200 250	0 - 6 cm Light Olive sandy diatom ooze. Shp. angular cnt. w/ 6 - 25 cm Grey stiff muddy diamicton. Low H_2O content. compact. Homogeneous
A	10-12									
	20-22			5Y 4/1						
5cm										

Core Number: 186/9GC12 (0-300cm) Location: Prydz Bay Core Length: 368cm

Latitude: 68° 04.45'S Longitude: 72° 56.02'E Date: 18-2-97 Water Depth: 660m



General description and Remarks

Soft, dusky yellow green, sandy (quartz, coal, glauconite) diatom oo

Olive grey sandy clay with sparse small drop stones

Firm sandy (clast supported) angular clay clast bed

Light olive grey
~~Pale yellowish~~ brown clay.

Olive gray sandy clay

Thin bed of diatom ooze
or f band?

"

↑

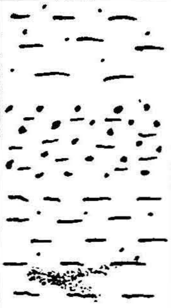
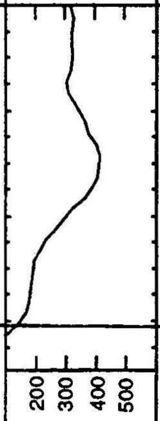
Olive gray sandy clay with sparse small drop stones and rare large drop stones.

"

"

Core Number: 186/9GC12 (300-368cm) Location: Prydz Bay Core Length: 368cm

Latitude: 68° 04.45'S Longitude: 72° 56.02'E Date: 18-2-97 Water Depth: 660m

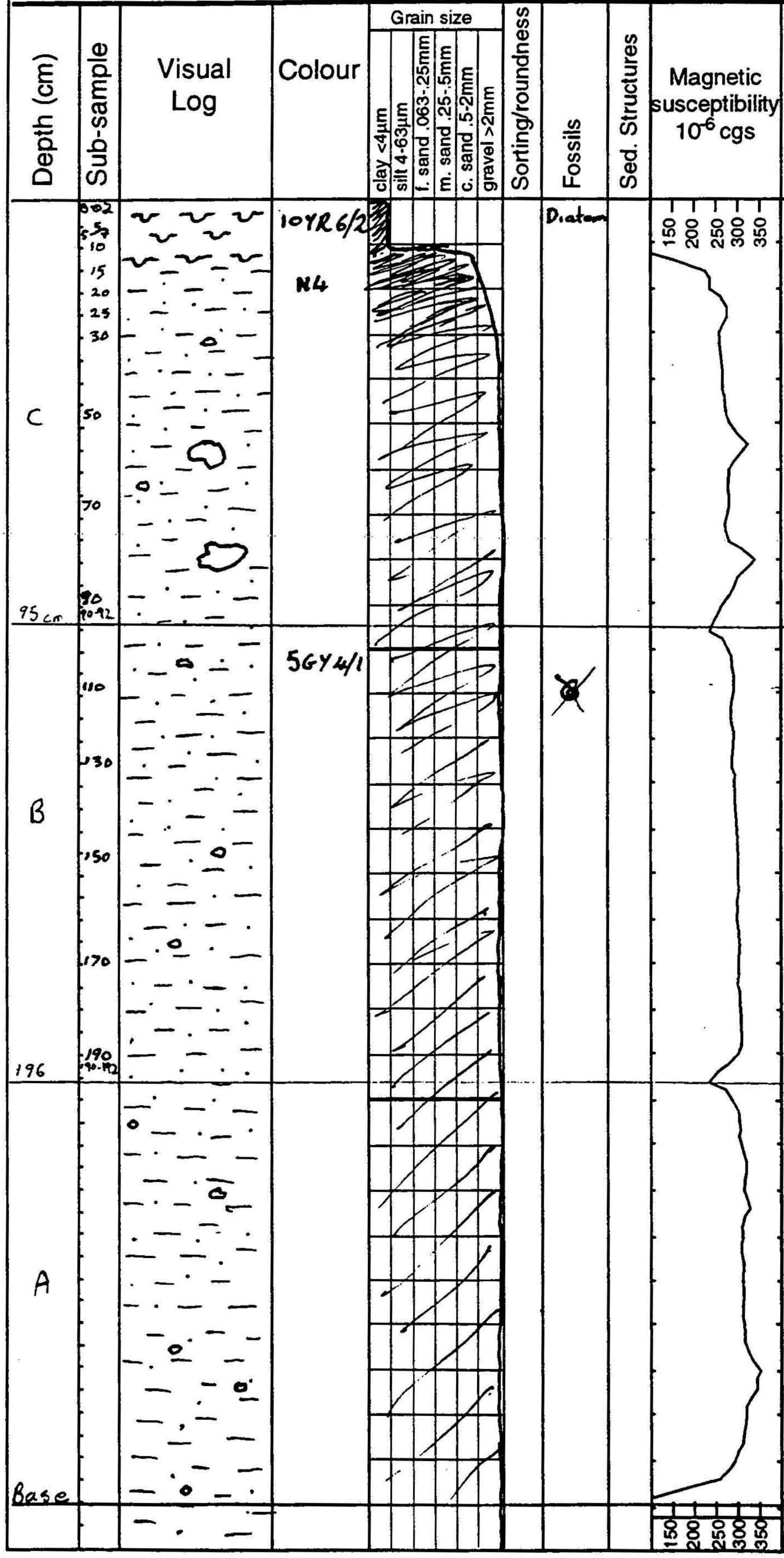
Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm, silt 4-63µm, f. sand .063-.25mm, m. sand .25-.5mm, c. sand .5-2mm, gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
364			5Y4/1 5Y6/1						Soupy sloppy sandy angular clay clasts ~~in~~ clast supported. Light olive gray clay t.u. Base of Core

0cm - diatoms abundant + well preserved. N. curta

6cm - " "

107cm - diatoms rare + poorly preserved.

Core Number: 186/10GC13	Location:	Prydz Bay	Core Length: 292cm
Latitude: 68° 11.87'S	Longitude: 72° 17.66'E	Date: 18-2-97	Water Depth: 678m



General description and Remarks

Pale olive diatom ooze grades rapidly into

Sandy clay with sparse small drop stones Medium dark gra

Dark greenish gray sandy clay with sparse small drop ston

//

//

//

//

Base of core

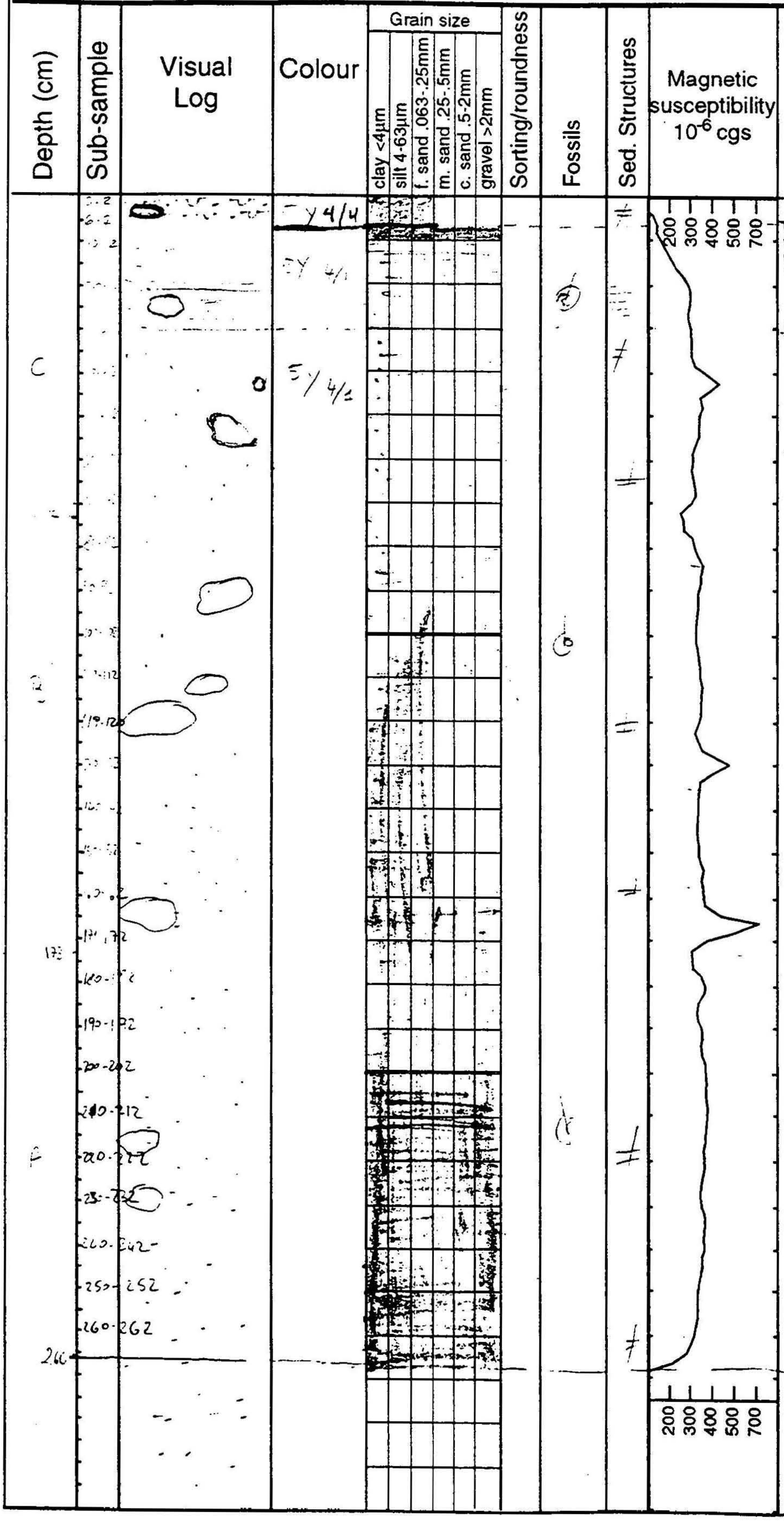
0cm - diatoms abundant, well preserved N. curt

16cm - " " medium preservatn.

T antarctica

Core Number: 186/11GC14 Location: Prydz Bay Core Length: 374cm

Latitude: 68° 13.22'S Longitude: 72° 22.99'E Date: 18-2-97 Water Depth: 690m

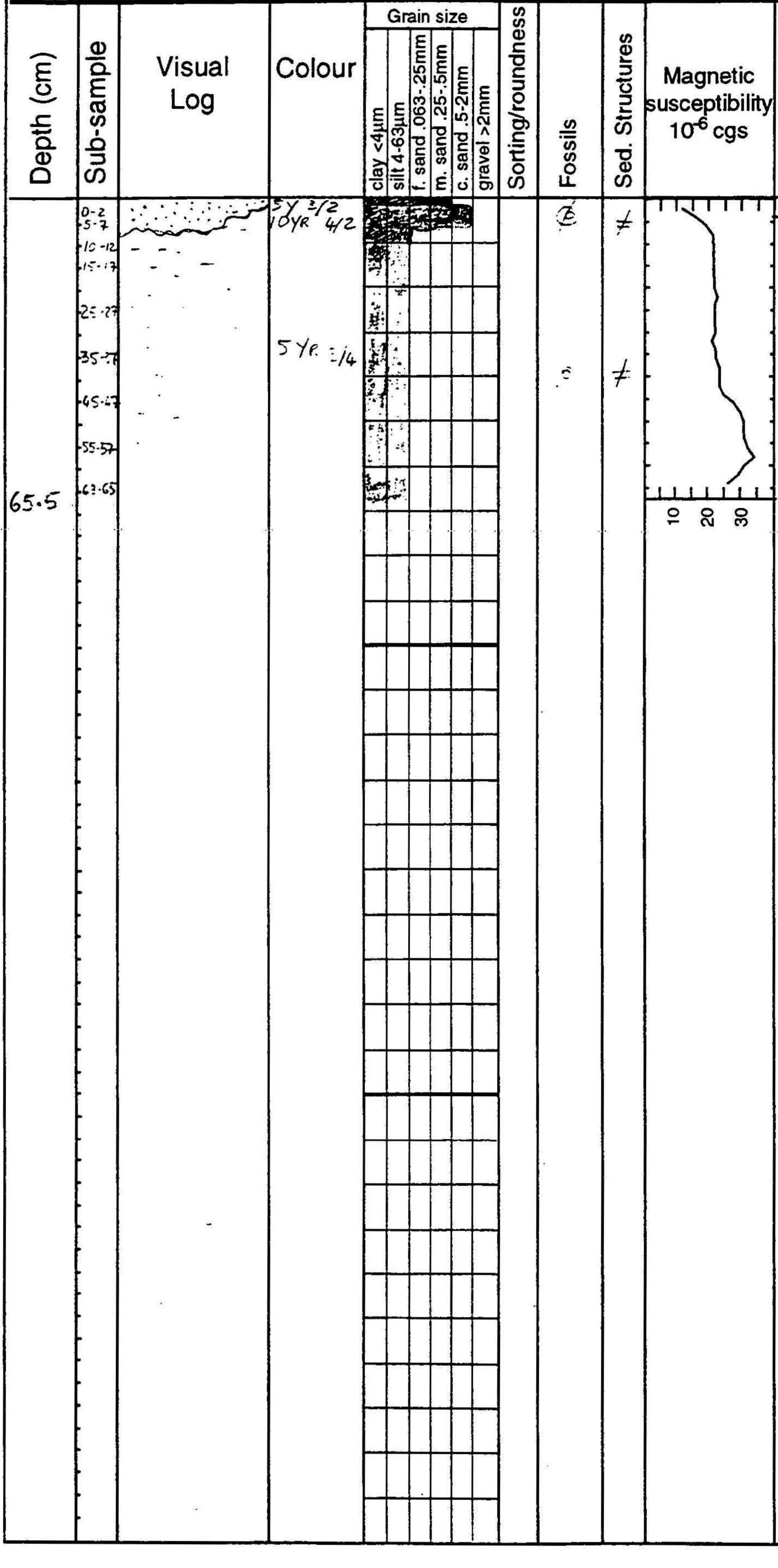


General description and Remarks

MODERATE OLIVE BROWN
SPARSELY SANDY CLAY [illegible]
LOWER BOUNDARY SHARP
OLIVE GRAY
SILTY CLAY WITH BLACK LAMINA
(2-3 mm THICK) AND PEBBLE
TRANSITIONAL BOUNDARY
OLIVE GRAY
SANDY SILTY CLAY WITH
PEBBLES. MORE SANDIER THAN
THE UPPER FACIES

Core Number: 186/13GC15 Location: Prydz Bay Core Length: 66cm

Latitude: 68° 31.05'S Longitude: 70° 24.45'E Date: 19-2-97 Water Depth: 1050m



General description and Remarks

OLIVE GRAY SAND (~1cm)
DARK YELLOWISH BROWN ANGULAR
COARSE QUARTZ SAND FRIABLE
WITH DIATOMACEOUS OOZE (1-5cm)
SHARP LOWER BOUNDARY

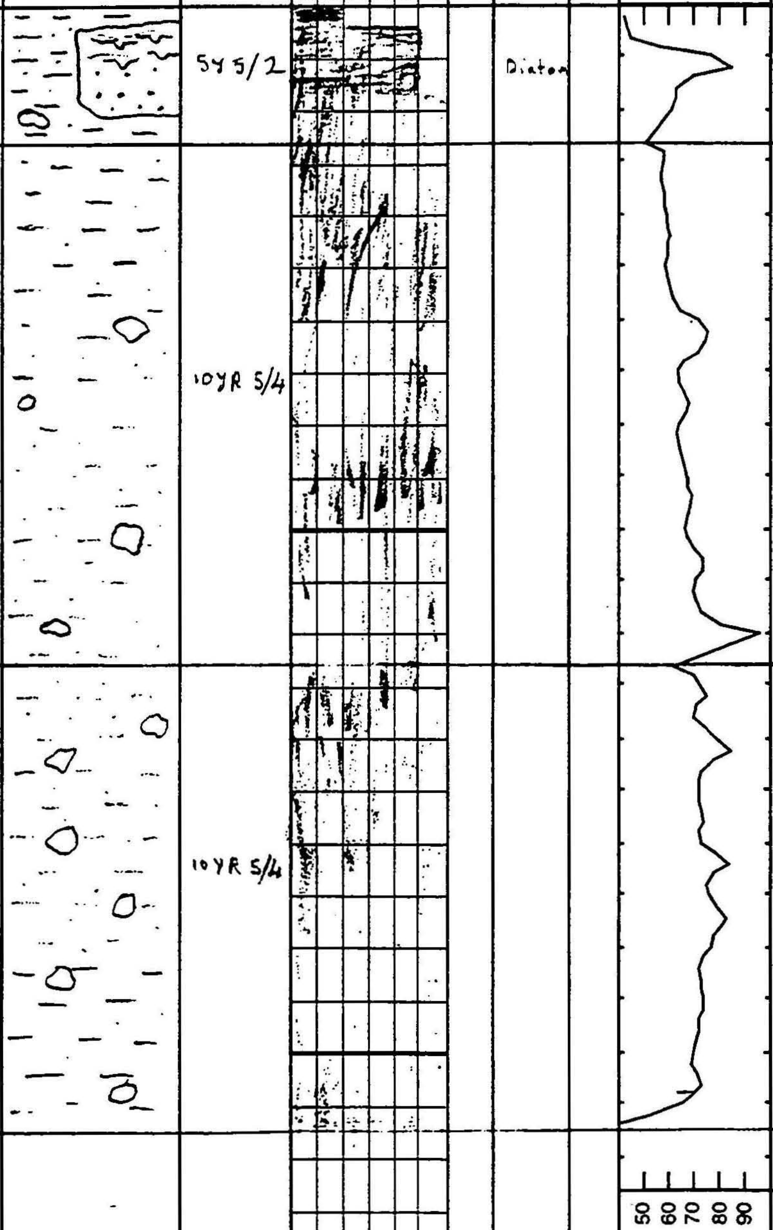
MODERATE BROWN SILTY CLAY
HOMOGENEOUS, FEW SMALL DROPSTONES
VERY FIRM AND STICKY

0cm- diatoms abundant & well
preserved. N. curta

Core Number: 186/14GC16 Location: Prydz Bay Core Length: 226cm

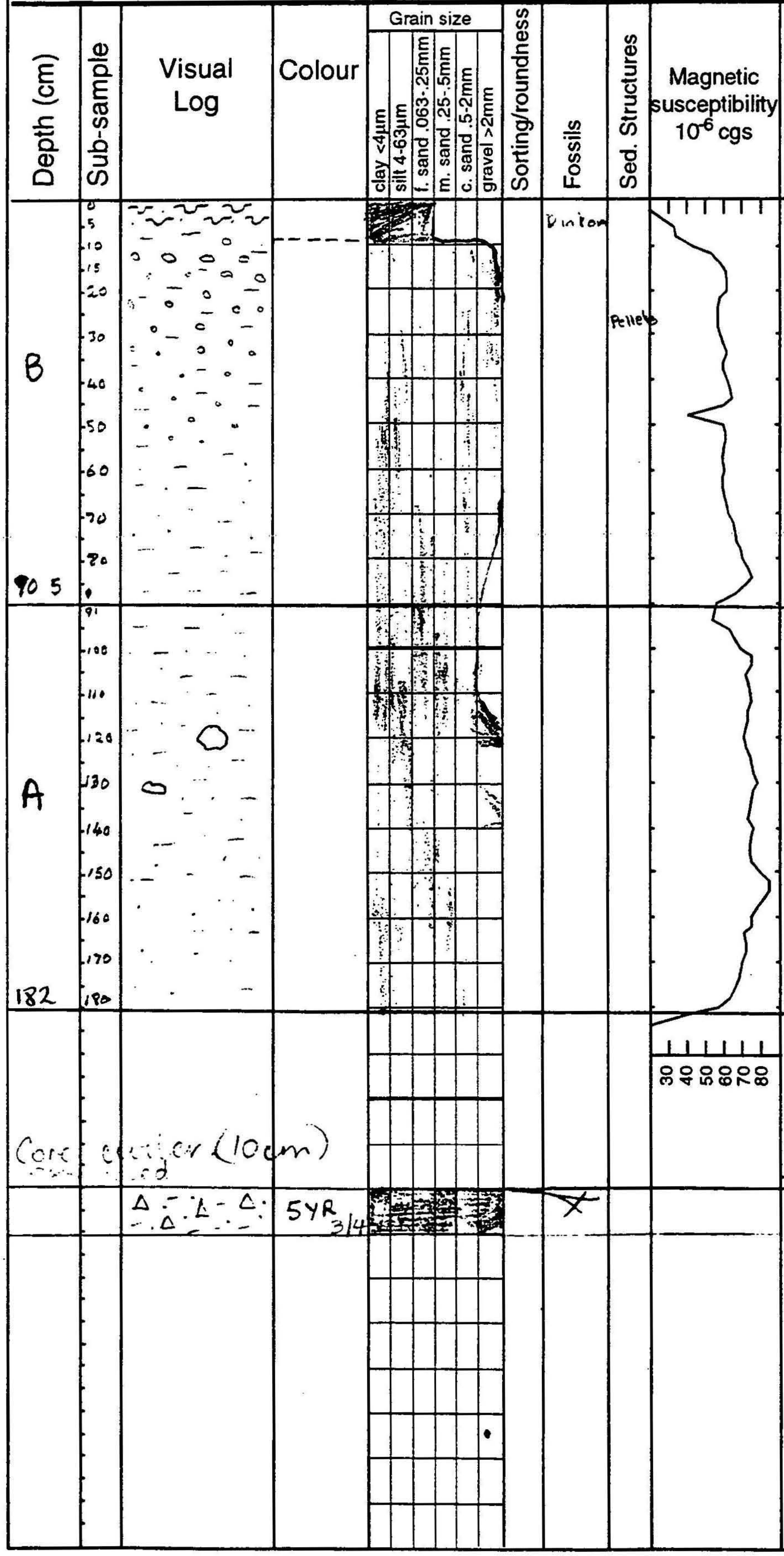
Latitude: 68° 22.48'S Longitude: 71° 18.42'E Date: 19-2-97 Water Depth: 726m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm, silt 4-63µm, f. sand .063-.25mm, m. sand .25-.5mm, c. sand .5-2mm, gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
C 24cm	0 2 13 22		5Y 5/2			Diatom			Coring artefact Lense of top material (Coarse quartz sand with diatom ooze grad upwards to sandy ooze.
B 124	30 40 50 60 70 80 90 100 110 120		10YR 5/4						Higher H2O content lwr. bk. density Firm sticky Moderate reddish brown Sandy clay with pebble - cobble dropstones.
A 217	130 140 150 160 170 180 190 200 210		10YR 5/4						Lower H2O content than above ~~As above but without~~ Base of core



Core Number: 186/15GC17 Location: Prydz Bay Core Length: 190cm

Latitude: 68° 18.95'S Longitude: 71° 27.88'E Date: 19-2-97 Water Depth: 716m



General description and Remarks

Firm but soupy pale olive grey fine sandy diatom ooze.

Medium reddish brown soupy loosely packed sandy mud pellets

Pellets compacted fused dewatered

Med red. brown sandy mud

Medium red brown sandy mud

Base of Core

0cm - diatoms abundant + well preserved. N. curta

5cm - " " "

182cm - diatoms rare, medium preservation

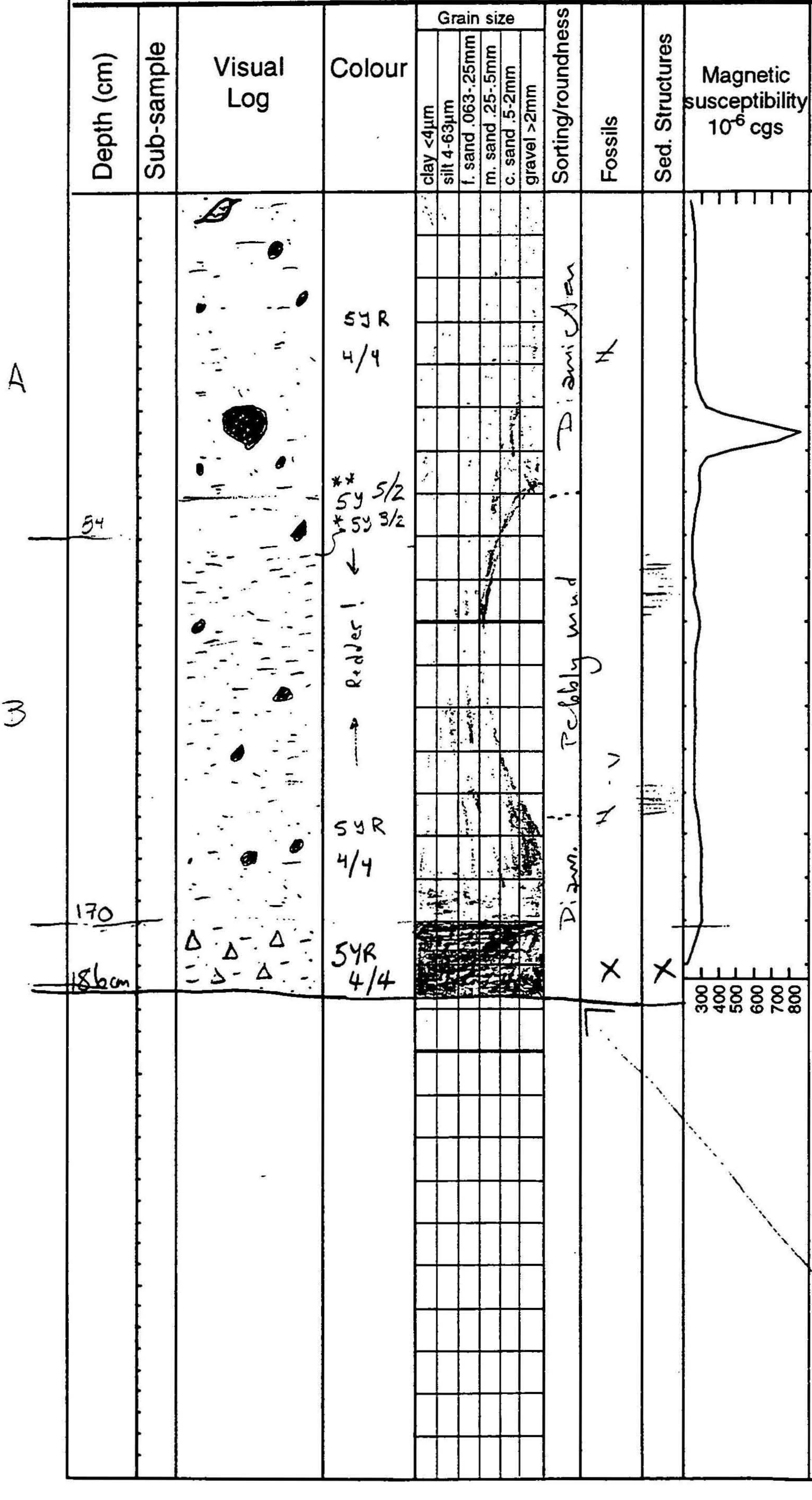
Diamicton, muddy 5YR 3/4 mod brown compact

Red brown mud becomes increasing firm coherent and lower H_2O content down core *

SAVE FOR GENE

Core Number: 186/16GC18 Location: Prydz Bay Core Length: 182cm

Latitude: 68° 08.71'S Longitude: 72° 01.21'E Date: 19-2-97 Water Depth: 608m



General description and Remarks

0 - 170 cm

Red brown pebbly mud - muddy diamicton very lg. pebble @ 50 - 59cm. Grey mottling around cobble. Olive green sno clots @ 0-3cm.

*Grey + **green silty clay lamina between 91 - 115 cm. These are very thick and (deformed) lamina. Gets more red in middle more brown near top and bottom. Otherwise homogeneous + compact.

clay rich!

0cm - diatoms abundant + well preserved
N curta

100cm - diatoms common; medium preservation!
N. curta + E. antarctica common.
Reworked T. torokina frequent

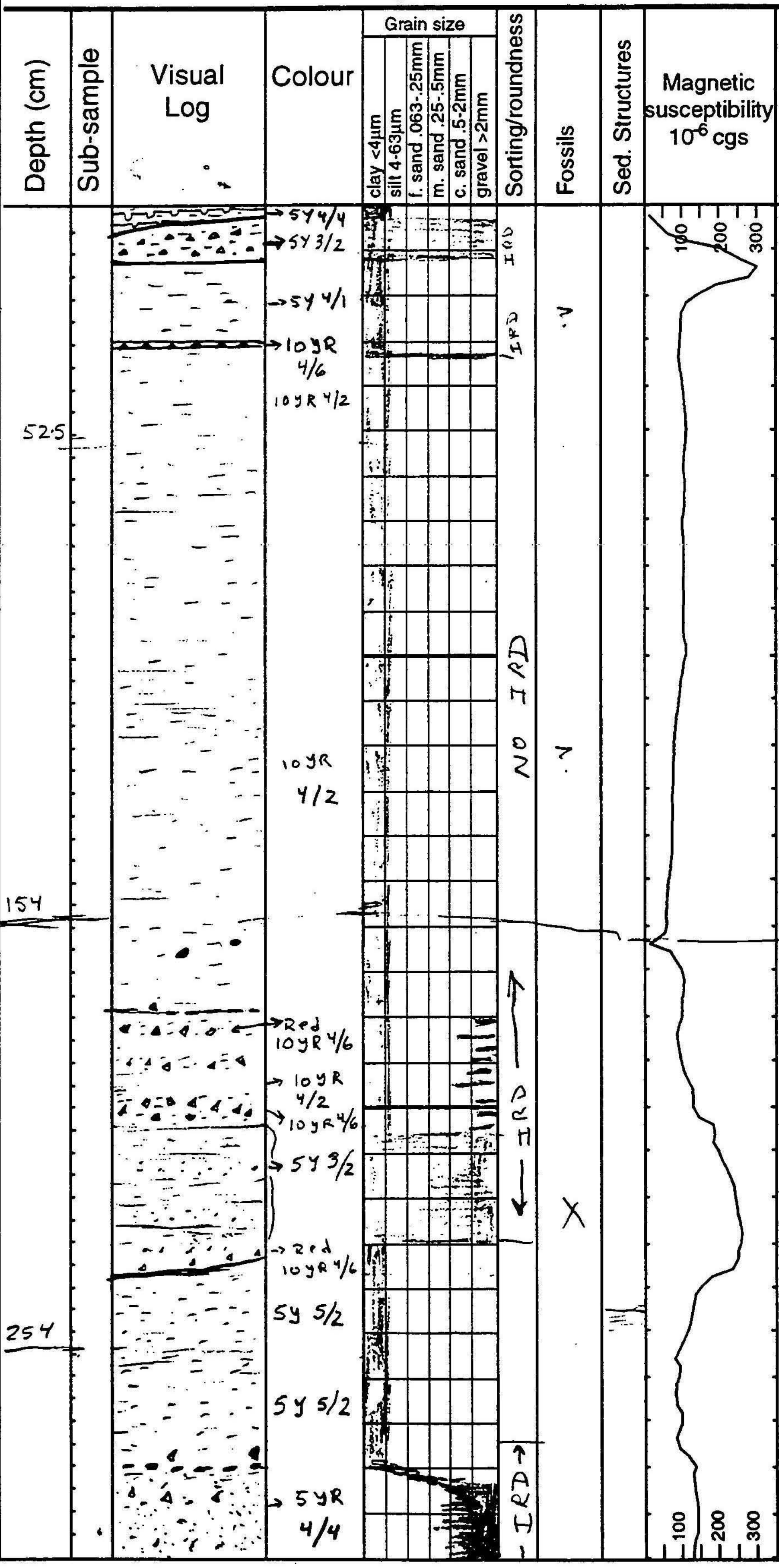
170-186 cm

Diamicton, structureless and compact

SAVE FOR GENE

Core Number: 186/17GC19 (0-300cm) Location: Prydz Bay Core Length: ~~352~~cm 349 cm

Latitude: 68° 08.07'S Longitude: 72° 10.02'E Date: 19-2-97 Water Depth: 775m



General description and Remarks

0-4 cm sandy, olive diatom ooze, Shp. lwr. cnt. @ 4-6 cm w/

4-16 cm cr. pelletized muddy sand, dilatent texture. water sat.

16-180 silty clay w/out significant I.R.D.
32-33 Red mud clast band.
Silty clay is mottled + bioturbated

180-202cm
Interbedded silty clay and horizons of red clay clots (angular) up to granule size
→ Moderate reddish brown core kk.

202-236
Interbedded sandy granular pelletized muddy sand, lg. dpst. at 204 cm. Dilatent

Grey
236-280
Shp. angular cnt w/ silty clay light olive grey Trans. lwr cnt.

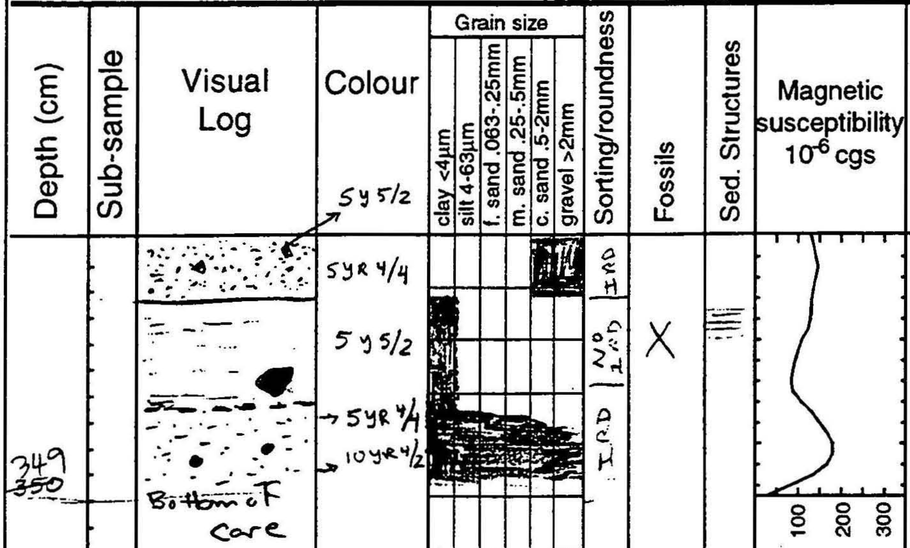
w/
280-312 Red, gravel-sand sized clay clots angular. Shp. lwr cnt w/

SAVE FOR GENE

A

Core Number: 186/17GC19 (300-352cm) Location: Prydz Bay Core Length: 352cm

Latitude: 68° 08.07'S Longitude: 72° 10.02'E Date: 19-2-97 Water Depth: 775m



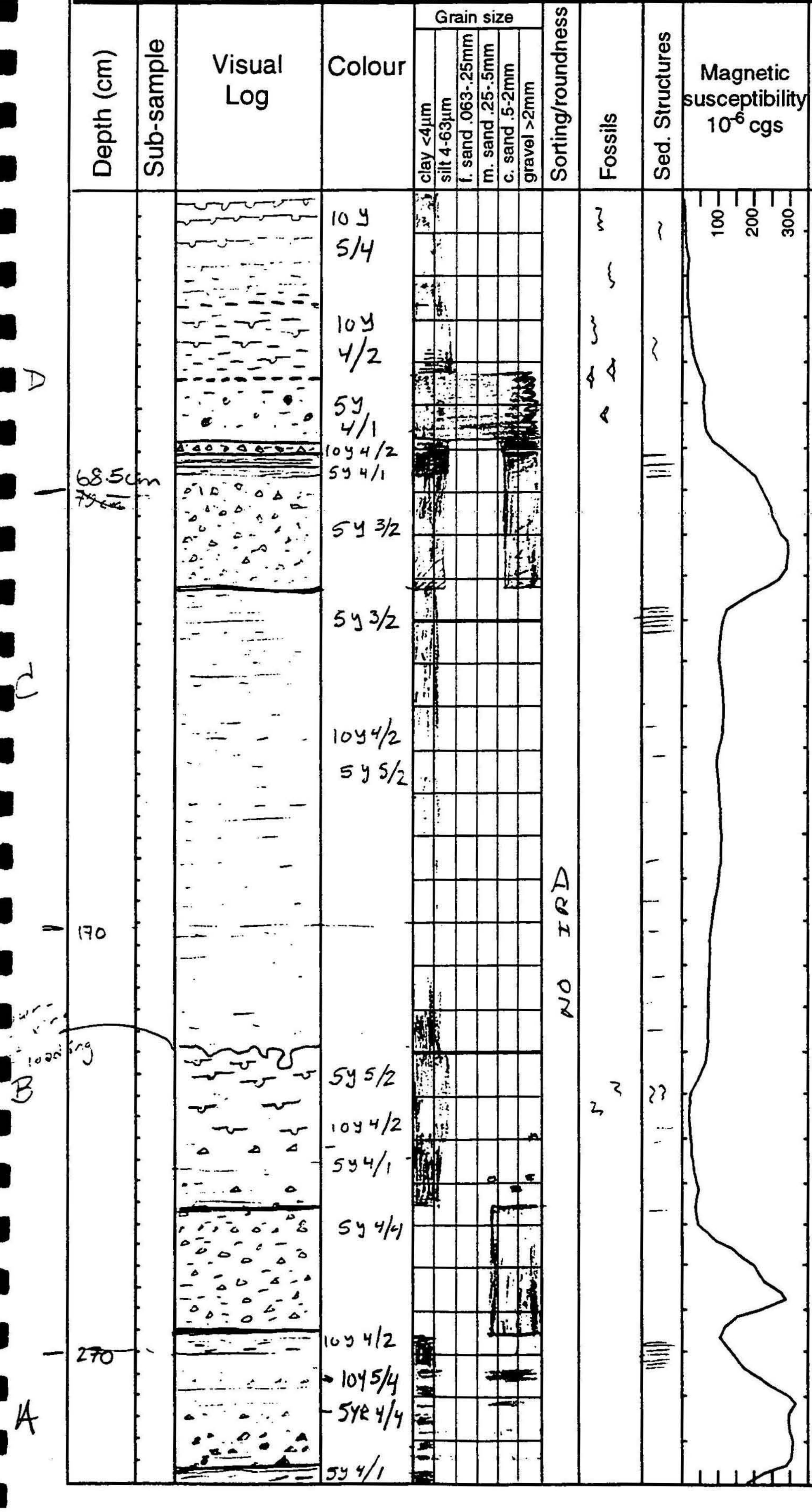
General description and Remarks

312-332 silty clay
Lg. stone at base
transitional cnt. at
332 w/ Red-brown granular
pebbly ~~=~~ sandy mud.
More dk. at base.

0cm - diatoms abundant + well
preserved. N. curta

Core Number: 186/18GC20 (0-300cm) Location: Prydz Bay Core Length: 368cm

Latitude: 68° 09.70'S Longitude: 72° 16.46'E Date: 19-2-97 Water Depth: 780m



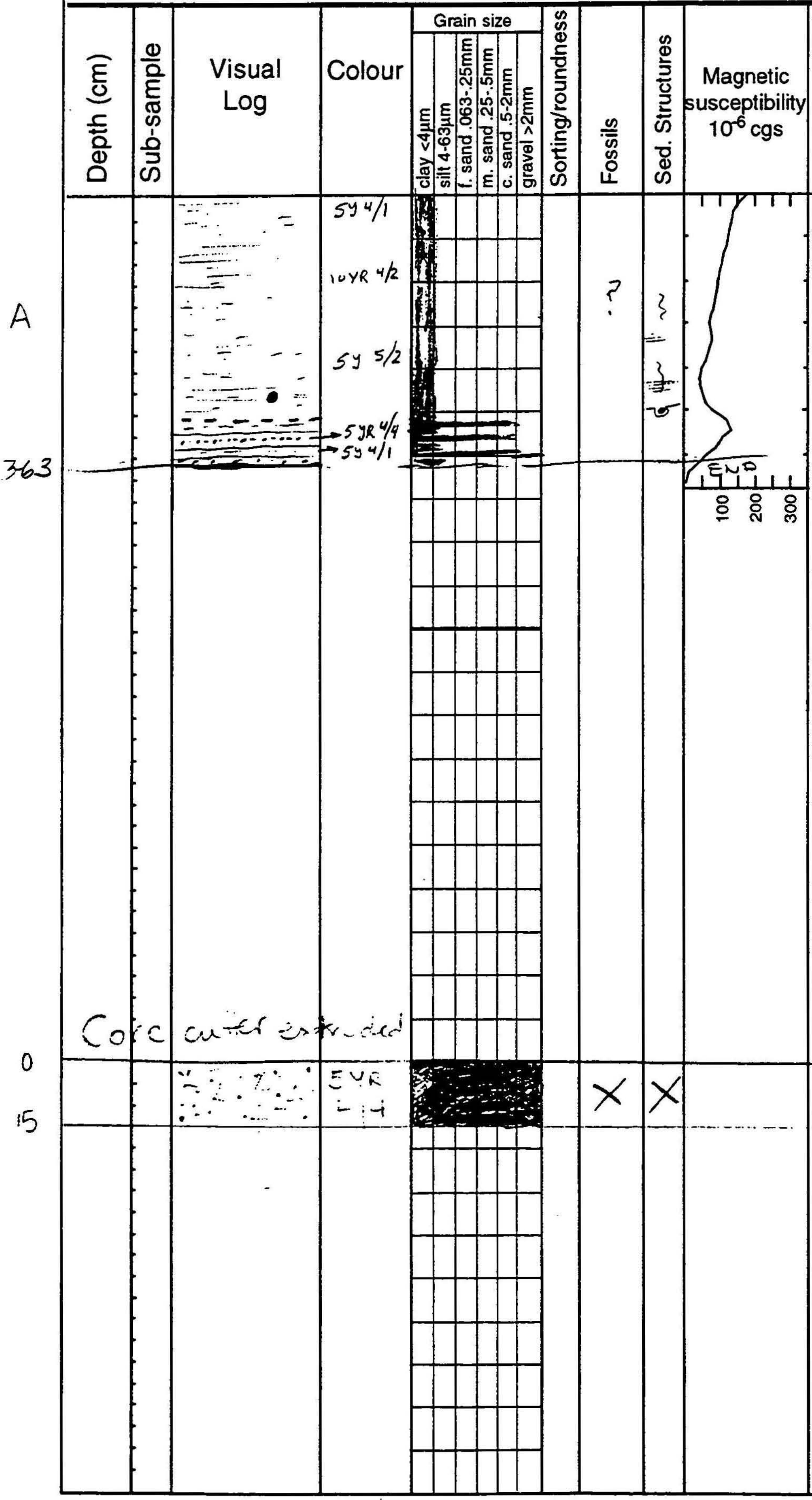
General description and Remarks

NICE CORE GOOD ON YA!

0-25 Olive diatom ooze
w/ 3-4mm open burrows
Good ccr top water saturated
increasing silt content
down transitionally w/
25-42 Olive grey diatom.
mud few burrows
42-56 Grey sand pebbly
mud grades up into overlying
siliceous facies.
56-62 pellet red mud
interbedded with silty clay
62-67 laminated
68-92
Grey coarse dilatent, muddy
gravel (pelletized), water
saturated. Shp lwr cnt.
with
92-170 Grey laminated
silty clay grades
down into brown mud
w/ a few red mud
clots.
170-197 red brwn. silty
clay Bioturbated.
197-244 Variegated -
~~burrowed~~ bioturbated
light green → olive →
red + grey silty diatom
clay, mud
244 Shp. cnt. with
dilatent brown
"coffee ground"
pelleted mud to 263

Core Number: 186/18GC20 (300-368cm) Location: Prydz Bay Core Length: 368cm

Latitude: 68° 09.70'S Longitude: 72° 16.46'E Date: 19-2-97 Water Depth: 780m



General description and Remarks

263-298 Thinly bedded silty clays and gram supported pelletized muddy sand, some interlaminations, coarses texture at 394-396. Shp lwr. cnt.

298-352 silty clay mottled bioturbated grey - olive grey

352-363 interlaminated grey clay and red sandy mud.

0cm - diatoms abundant + well preserved N curta

25cm - diatoms common/abundant. Medium preservatn, T antarctica + N curta

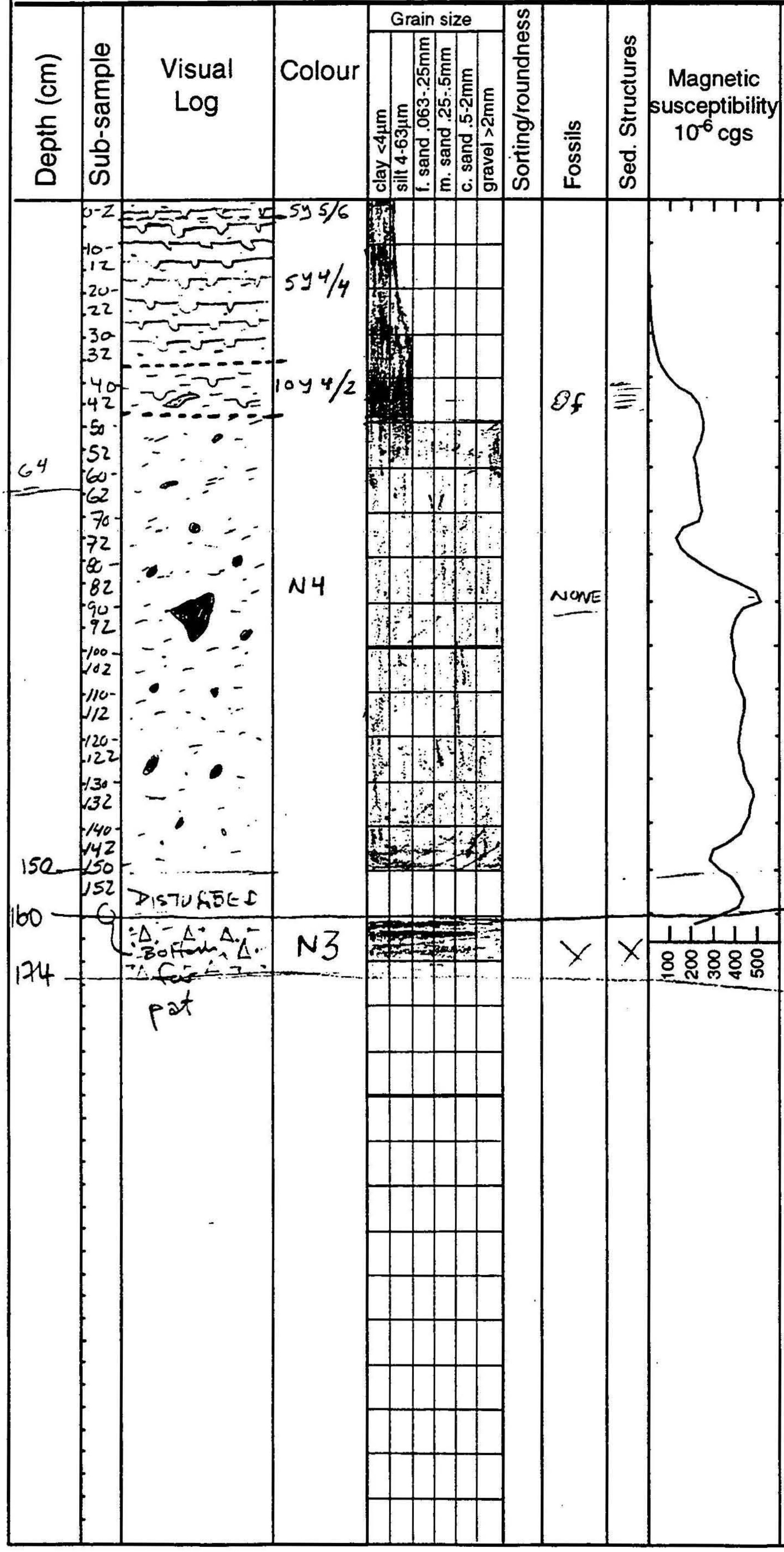
208cm - diatoms common/abundant Medium preservatn,

240cm - diatoms rare + poorly preserved Reworked Denticulopsis fragments possibly D. hustedtii

Diam [illegible] & [illegible] brown

Core Number: 186/19GC21 | Location: Prydz Bay | Core Length: 164cm

Latitude: 67° 37.05'S | Longitude: 73° 18.00'E | Date: 20-2-97 | Water Depth: 570m



General description and Remarks

0 - 37cm Olive green diatom ooze trans. lwr. cnt. w/

37 - 49 Diatom mud w/ tiny ≈1cm sand lenses!
f= forams

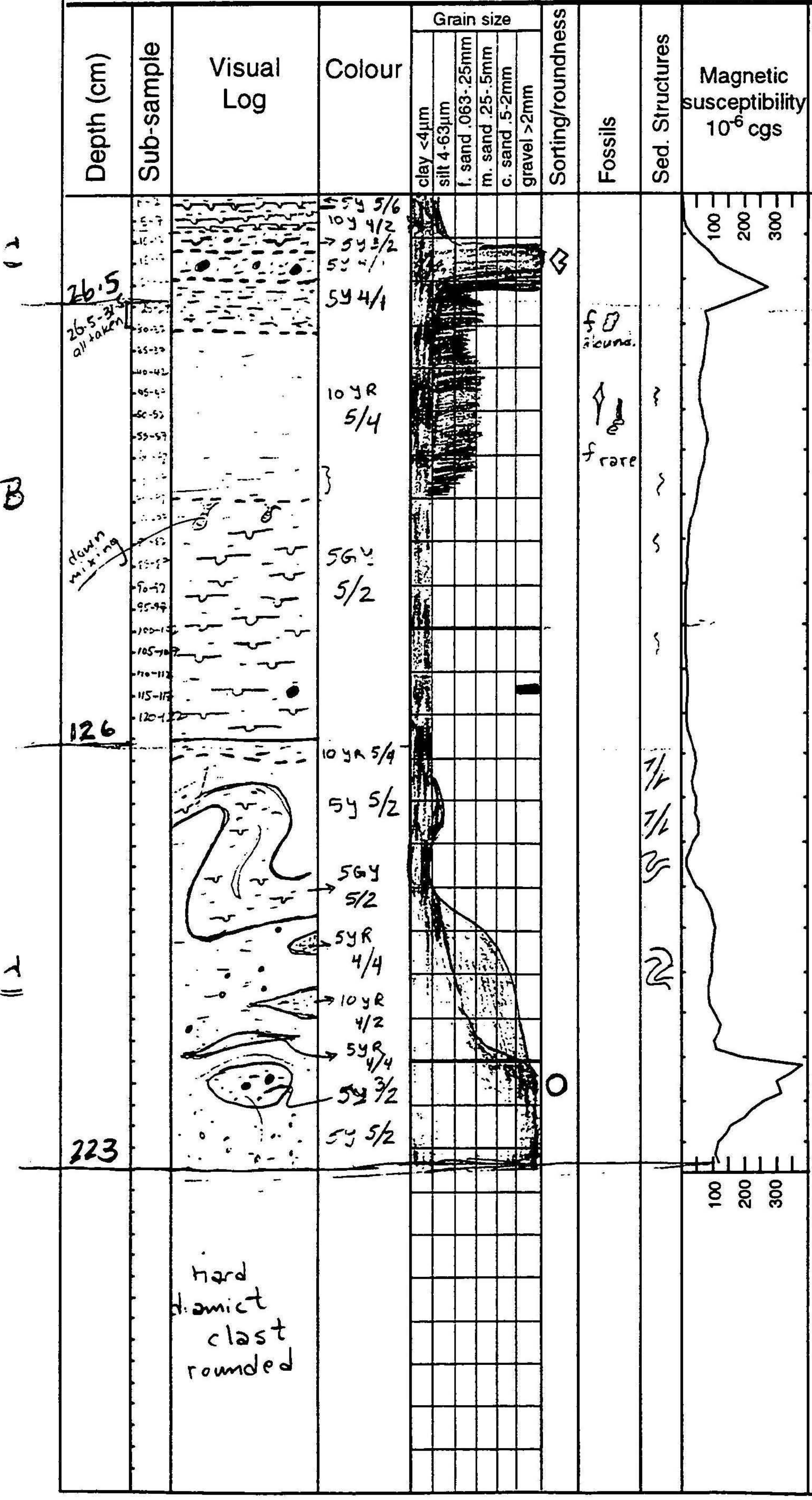
49 - 150 cm

Grey, homogeneous diamicton, muddy. No visible structures.

160 - 174 cm ~~(real depths)~~. grey compact diamicton structureless. Dark grey

Core Number: 186/20GC22 Location: Prydz Bay Core Length: 226cm

Latitude: 67° 41.47'S Longitude: 72° 13.04'E Date: 21-2-97 Water Depth: 660m



General description and Remarks

outer, middle Prydz Channel

<u>0-7</u> cm Greyish olive siliceous, diatom ooze, Light olive brown @ <u>0-2cm.</u> Gradational lwr. contact w/

<u>7-11cm</u> olive diatom mud and olive grey muddy diamicton interbedded @ <u>11 - 14</u> cm.

<u>14 - 23</u> grey muddy diamicton, H2O sat

<u>23 - 28 cm</u> Grey sandy mud transitional lwr. cnt. @ <u>28 - 34 cm</u> w/ Moderate yell. brown silty clay

<u>34 - 70</u> cm. Tran. cnt. biotwisted + down mixed w/ light olive siliceous mud w/ scattered gravel (rare)

<u>70 - 126</u> Light olive siliceous mud mottled

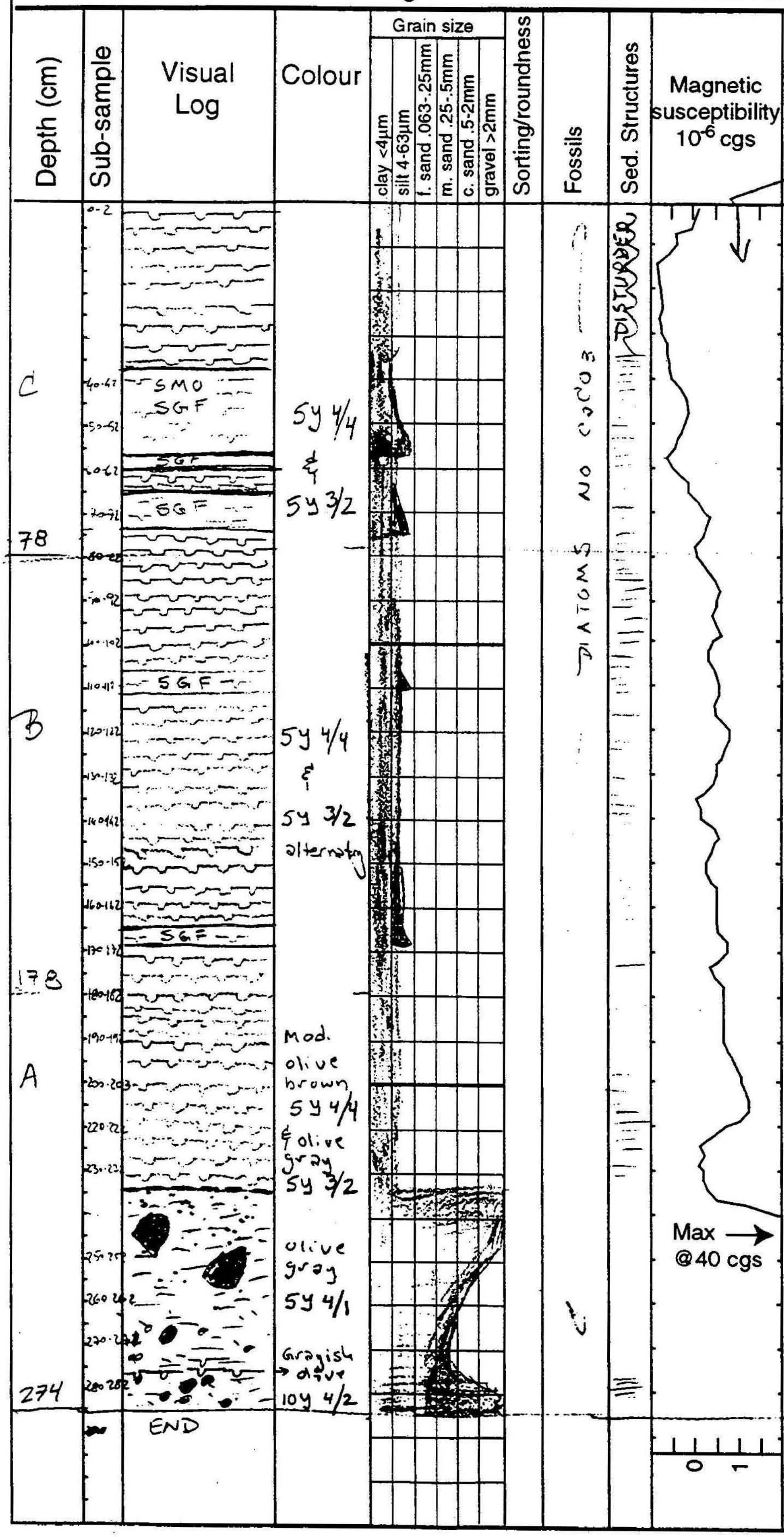
<u>126- 130</u> cnt. w/ brown silty clay

<u>130 - 200</u> Swirled light olive clay, red clay and brown silty clay

<u>200</u> - end compact [illegible] colored diamicton.

Core Number: 186/23GC23 Location: Nielsen Basin Core Length: 282cm

Latitude: 67° 32.02'S Longitude: 64° 39.78'E Date: 25-2-97 Water Depth: 1,240m



General description and Remarks

Deformation upon cutting (compression)

0-34 Highly fluidized olive/black diatom ooze. Water saturated + fluid.

34-78 Stratified diatom ooze composed of thin units as follows

53-52 sharp basal cont. fluffy diatom cotton ooze grades into homogeneous diatom. mud from 52-36 trans upper cont w/ thinly laminated olive grey diatom mud. Another such unit @ 74-65 + 60-52 (SMO SGF)

78-178 well stratified diatom ooze + diatom mud Two prominant SMO SGFs as described above at 111 to 106 and 165-169.

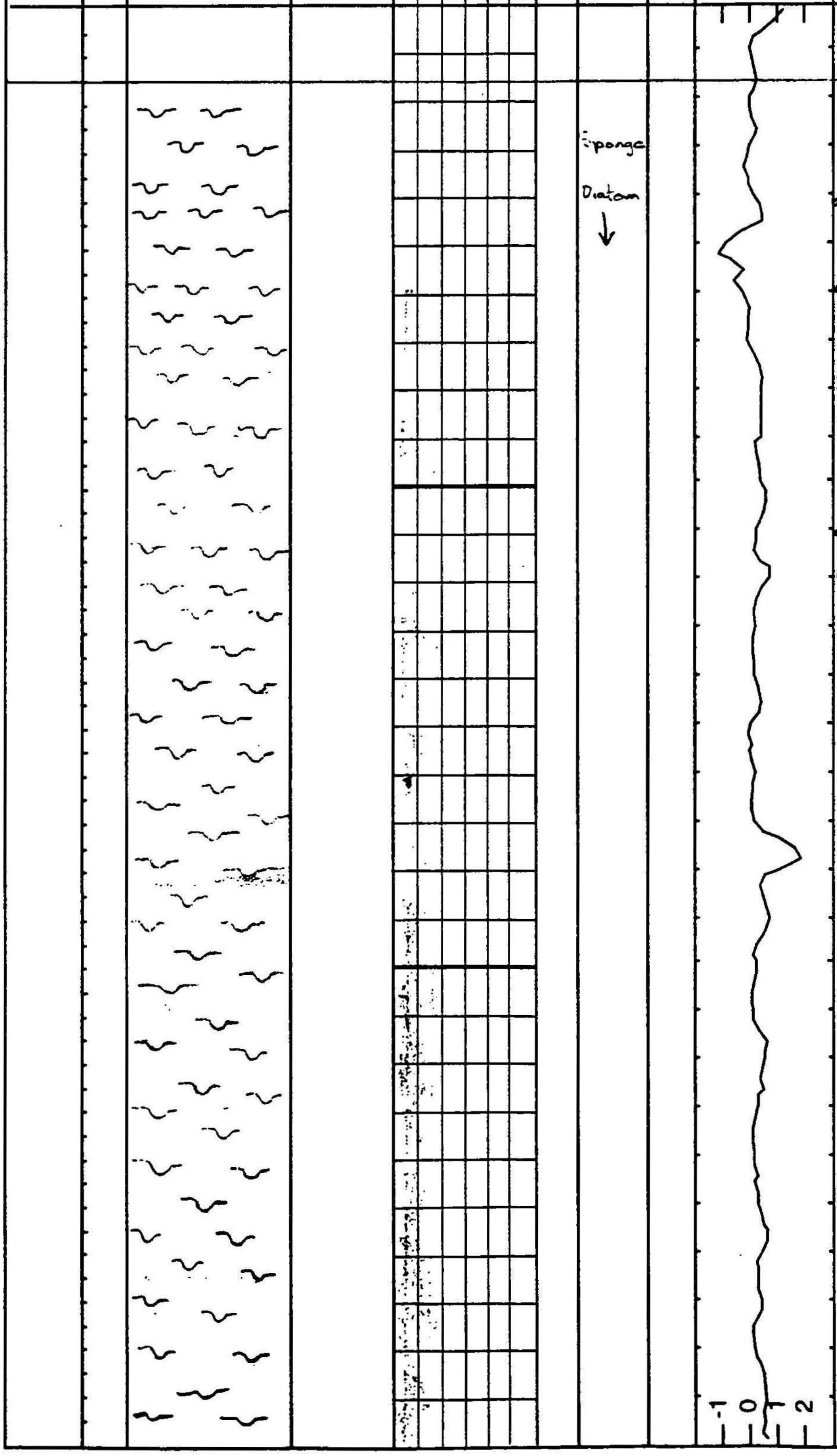
Much more compact than Section C.

OIIF R

Core Number: 186/24GC24 0-300 Location: Nielsen Basin Core Length: ~~386~~ 379cm

Latitude: 67° 29.70'S Longitude: 64° 57.18'E Date: 26-2-97 Water Depth: 1,240m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks



Ooze has dewatered - shrunk!

Top & core

Soupy soft fluffy diatom ooze

Distinctly colour banded varying from dark grey green "anoxic" bands to dusky yellow to greyish olive.

Colour bands sometimes match textural changes but often don't

Texture varies from very fluffy beds to very fine smooth "muddy" beds.

Laminations (colour) become thinner and more frequent down core (Compaction ?)

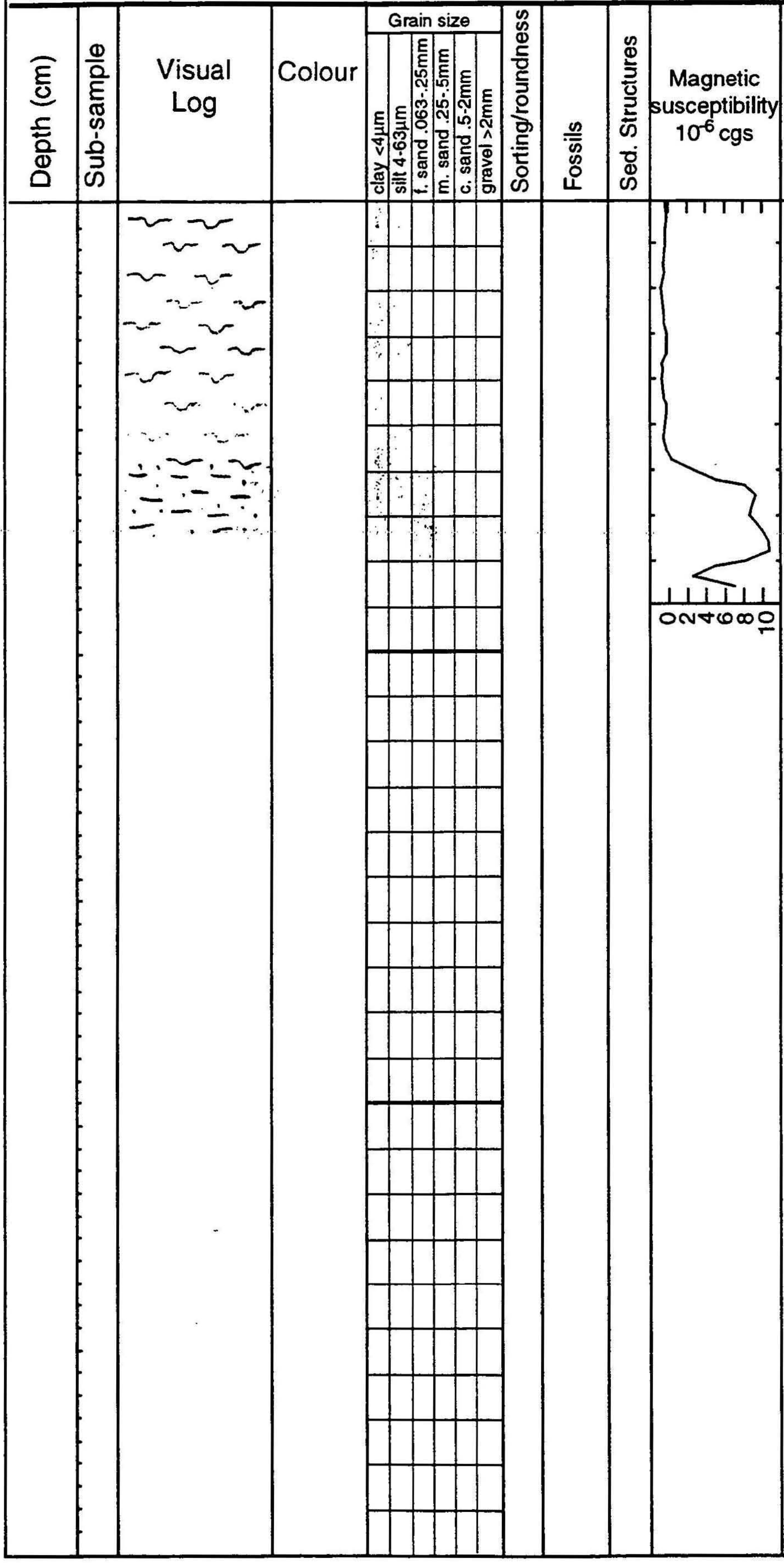
Colour becomes lighter down core

All beds are laminar planar no evidence of bioturbation

73 85
7 94
379

Core Number: 186/24GC24 300-386 Location: Nielsen Basin Core Length: 386cm

Latitude: 67° 29.70'S Longitude: 64° 57.18'E Date: 26-2-97 Water Depth: 1,240m



General description and Remarks

Ooze (see above)

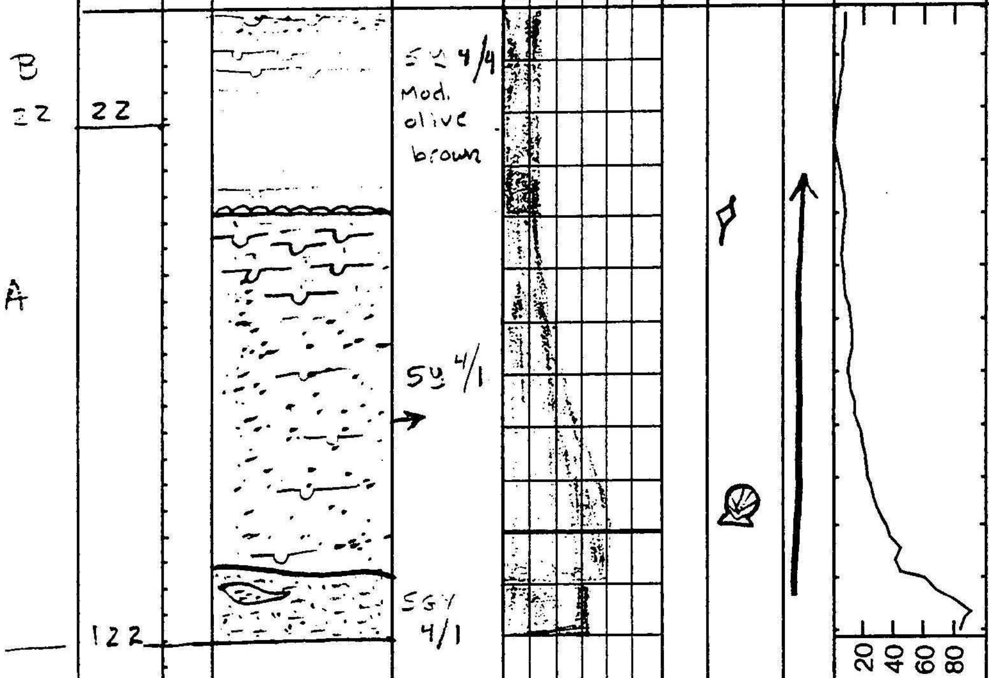
↑

Gradational change from medium light gray fine sandy clay up to light olive gray diatom ooze.

Core Number: 186/25GC25 Location: Nielsen Basin Core Length: 122cm

Latitude: 67° 21.45'S Longitude: 65° 58.3'E Date: 26-2-97 Water Depth: 785m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks



0-38cm

olive green, structureless siliceous mud and ooze Sandy w/ calc. microfauna 0-3cm.

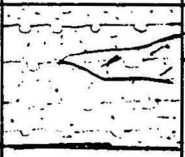
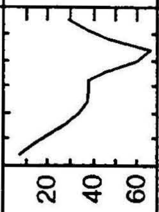
38-40 olive green Sponge spicule layer. Hummocky upper surface, sharp planar lwr. surface.

40-106 olive Grey Normally graded medium → fine sand → silty diatom. mud. carbonaceous layer @ 69-70 cm, scallop (horizontal) @ 95cm

106-122 interbedded lenses of silty clay and muddy sand. sand is md.-fn. grain Grey in color

Core Number: 186/26GC26 Location: Prydz Bay /Fram Bank Core Length: 30cm

Latitude: 67° 07.87'S Longitude: 70° 47.69'E Date: 5-3-97 Water Depth: 390mm

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
A 25 30cm	0-1 10-11 20-21		5Y 4/4 →10Y 4/2 5Y 4/4											0-9 Sandy, olive diatom. mud/ooze. 9-12 lense of granule rich ooze. 12-25 s.a. 0-9. Disturbed @ bottom w/ plastic sleeve. Calcareous fragments throughout the core

Core Number: 186/27GC27 Location: Four Ladies Bank Core Length: 112cm

Latitude: 67° 10.12'S Longitude: 74° 30.22'E Date: 6-3-97 Water Depth: 436

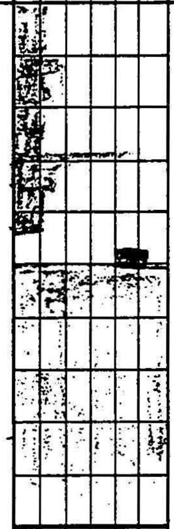
Depth (cm) | Sub-sample | Visual Log | Colour | Grain size: clay <4µm, silt 4-63µm, f. sand .063-.25mm, m. sand .25-.5mm, c. sand .5-2mm, gravel >2mm | Sorting/roundness | Fossils | Sed. Structures | Magnetic susceptibility 10^{-6} cgs | General description and Remarks

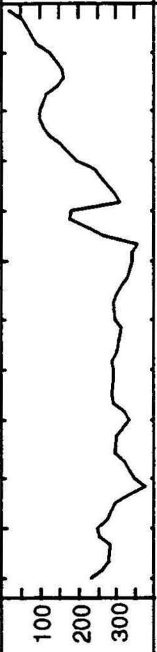
E. Domack

Depth (cm): A, 83, 2

Sub-sample: 0-2, 4-6, 8-10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110

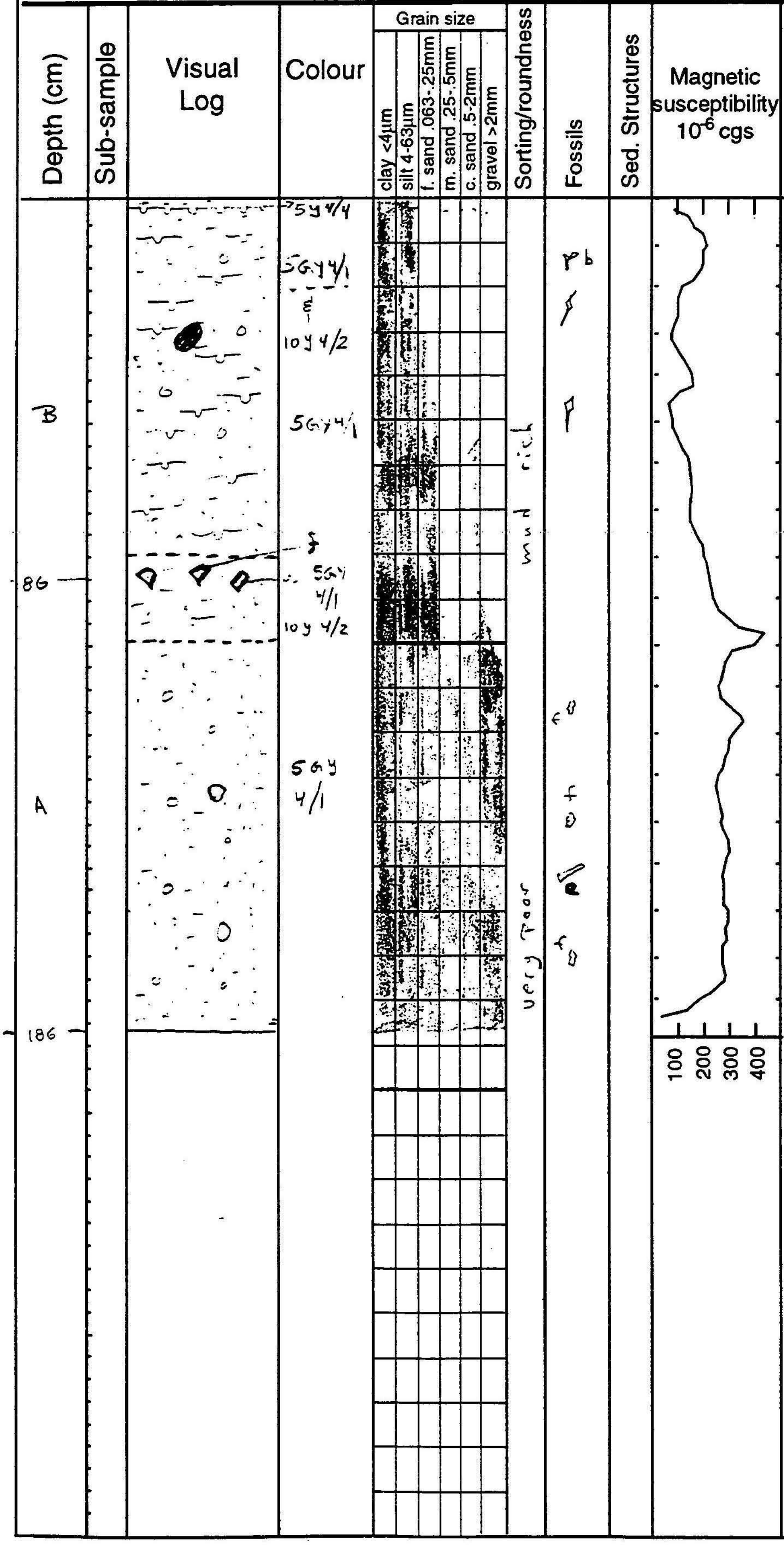
Colour:
- 5Y 4/4
- 7.5Y 3/2
- 10Y 4/2
- 5Y 4/1
- 5Y 4/2
- N4
- 5GY 4/1
- N4





0-12 Diatom ooze/mud
12-14 sandy grey silt
14-30 diatom ooze/mud
30-35 grey sandy silt
sand-sz at top
35-45 diatom mud
45-48 vv cr. sand + granules
48-83
grey muddy diamicton
elongate pebble, horizontally aligned.
83-110 grey muddy diamicton, sed clast of sandy diamicton 94-103 (indurated)

Core Number: 186/28GC28	Location: Four Ladies Bank	Core Length: 186cm
Latitude: 67° 16.05'S	Longitude: 76° 23.92'E Date: 7-3-97	Water Depth: 338



General description and Remarks

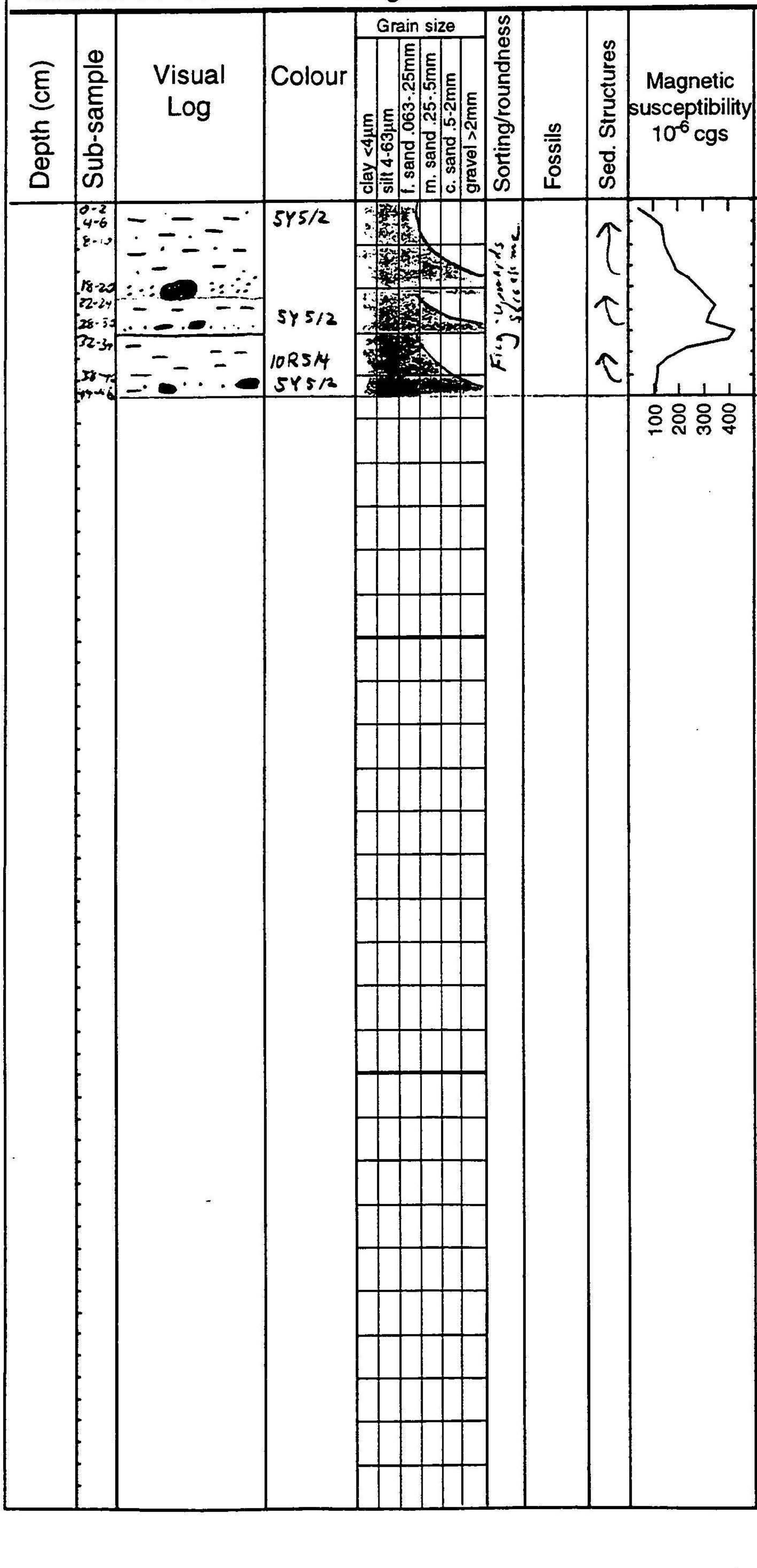
0-80 Homogenized, olive + grey, siliceous diamicton muddy w/ carbonate fragm. bryozoan (b) Transitional color change throughout btwn. olive + grey. Sponge balls, diatoms etc. H2O saturated.

80-100 muddy diamicton w/ distinct sed. clasts of darker diamicton matrix. Trans. cnt w/ ↳ w/ forams.

100-186 Compact sandy diamicton w/ abundant calcareous foraminifera (f echinoid spines (e) Blk. + green laminea @ 160-165 cm - could be fissility.

Core Number: 186/29GC29 | Location: Prydz Fan | Core Length: 46 cm

Latitude: 66° 30.02'S | Longitude: 72° 16.32'E | Date: 8-3-97 | Water Depth: 1,230 mm



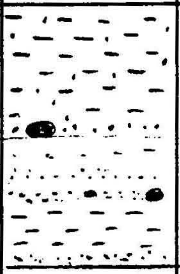
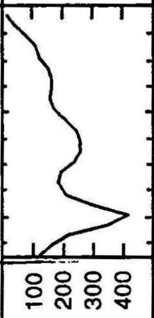
General description and Remarks

Turbidite, grading from msG to sM in at least 3 distinct [illegible]
The sand fraction contains black grains (coal ?)

sandy silt pale reddish brown layer coincides with the MS peak.

Core Number: 186/29GC30	Location: Prydz Fan	Core Length: 50 cm

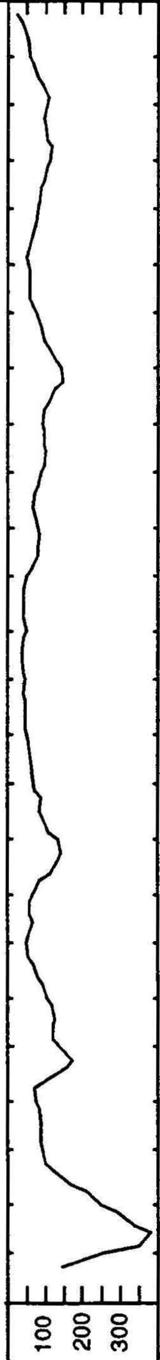
Latitude: 66° 30.10'S	Longitude: 72° 17.36'E	Date: 8-3-97	Water Depth: 1,230 mm

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
			5Y 5/2 5Y 5/2 10R 5/4 5Y 5/2							poor to moderately sorted				Very similar to 29GC29 Again a series of at least 3 distinct turbidites. The upper 20cm light olive grey sM. Base of turbidites is msG. Sand fraction contains black mineral grains, particularly 19-32cm The MS peak @ 40cm coincides with the upper portion of a pale reddish brown sandy mud unit.

Core Number: 186/30GC31 Location: Prydz Fan Core Length: 264cm

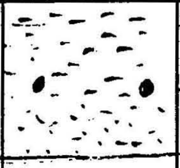
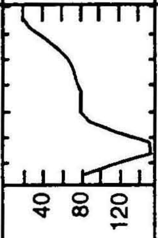
Latitude: 66° 24.11'S Longitude: 72° 17.11'E Date: 8-3-97 Water Depth: 1625m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
C														
[illegible]														
B														
[illegible]														[illegible]
[illegible]														[illegible]



Core Number: 186/31GC32 | Location: Prydz Fan | Core Length: 30cm

Latitude: 66° 19.11'S | Longitude: 72° 15.51'E | Date: 8-3-97 | Water Depth: 1830m

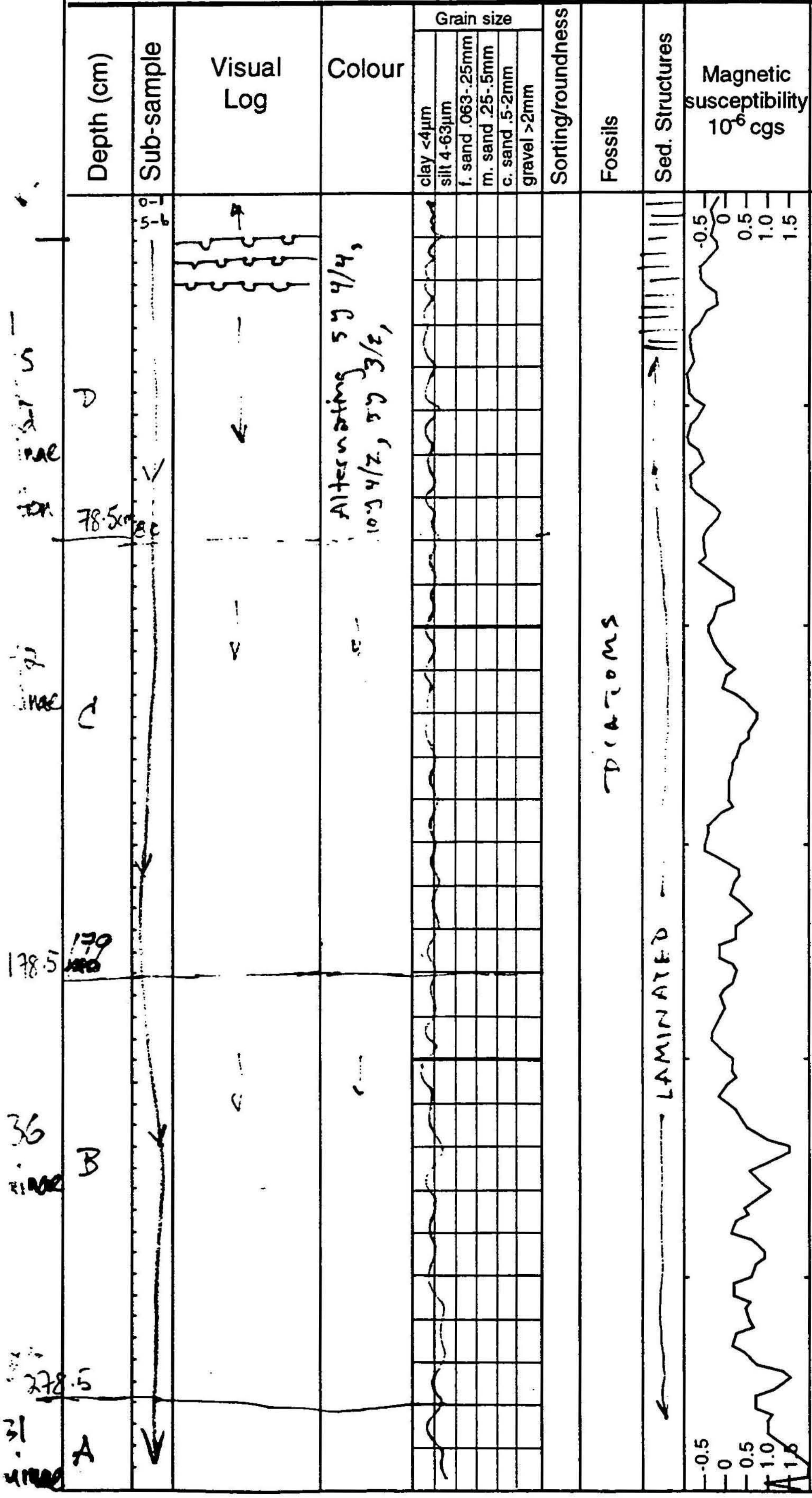
Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
31			5Y5/2 5YR 4/4 5Y5/2											0-31 olive, wat. sat pebbly mud. Disturbed 21-25 red brown silty clay interbeds 2 cm thk. Sandier near base.

ote:
ore has compacted by ~10 cm.
[redacted] After it was pulled up.

∴ core length @ sampling = 374 cm.

Core Number: 186/33GC34 0-300 | Location: Iceberg Alley | Core Length: 388cm

Latitude: 66° 56.55'S | Longitude: 63° 06.93'E | Date: 11-3-97 | Water Depth: 470m



General description and Remarks

0 ~ 384cm
olive green + dk. olive grey diatom ooze. Very thinnly bedded + laminated throughout. Monospecific "bloom" laminea abundant. water sat. in sect. D, disturbed 0 - 60cm. NO apparent x-laminea or siliciclastic intervals. Increasing consolidation downcore. Disturbed at bottom ~20 cm of core. No observable bioturbation.

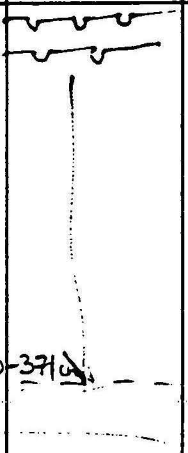
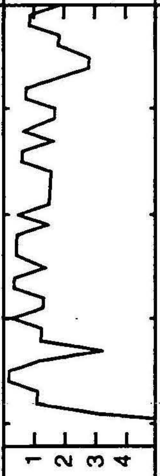
forams present at 230 cm → 235cm?

*Core sampled @ 5cm intervals whole length of core

NO compacted top section ∴ sampled 0-1cm (core top), but this = 10-11 cm on core barrel. rest of samples taken at 5cm intervals from this (where section not compacted

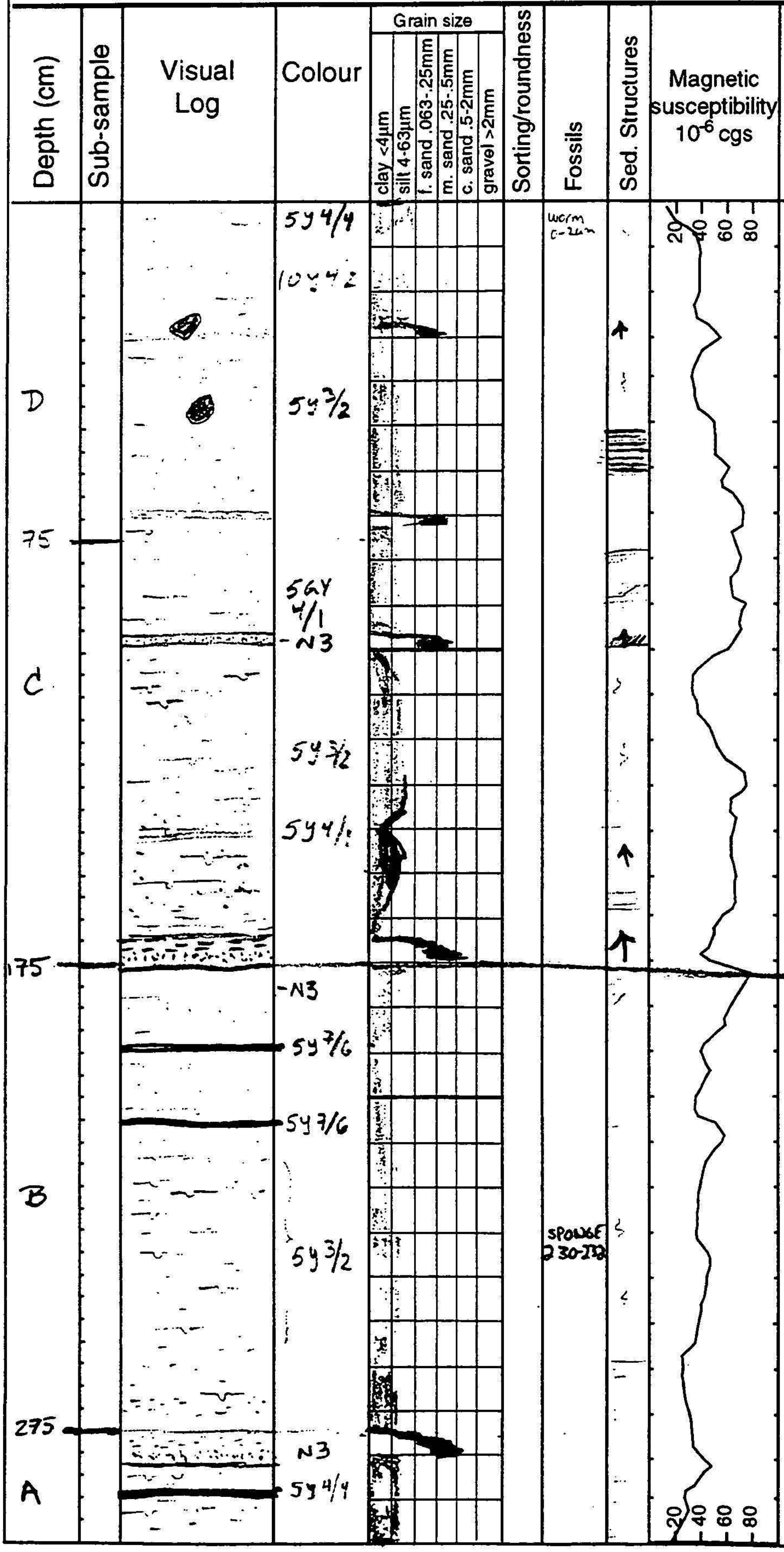
Core Number: 186/33GC34 300-388 Location: Iceberg Alley Core Length: 388cm

Latitude: 66° 56.55'S Longitude: 63° 06.93'E Date: 11-3-97 Water Depth: 470m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm, silt 4-63µm, f. sand .063-.25mm, m. sand .25-.5mm, c. sand .5-2mm, gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
A 374 ~~384~~	370-371		see above			DIATOMS	LAMINATED		see above.

Core Number: 186/34GC35 0-300 Location: Iceberg Alley Core Length: 390 cm

Latitude: 62° 10.91'S Longitude: 62° 57.73'E Date: 11-3-97 Water Depth: 600



General description and Remarks

0 - 375

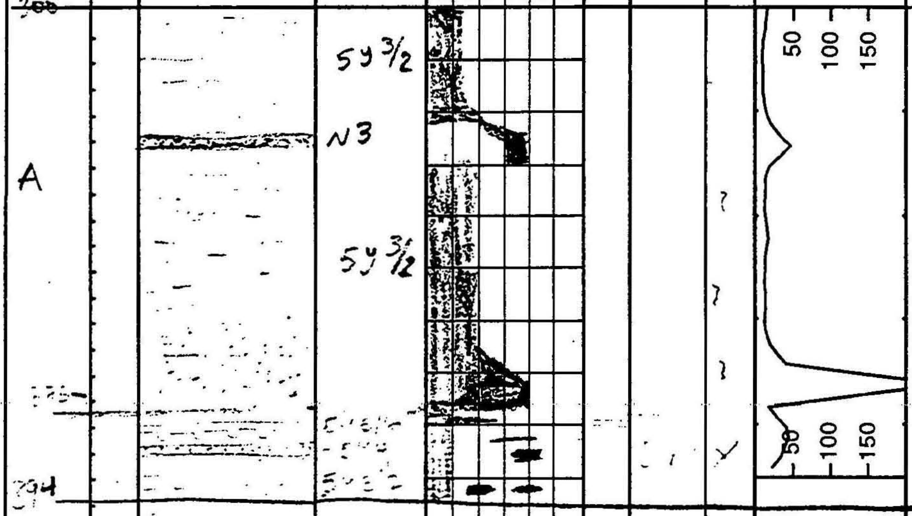
Thinnly bedded to laminated, interstratified olive diatom. silt and grey silt, clay and sand. Some beds are distinct fining up sand to clay. Sand is fn. - vr. fn grained + well sorted. Sand beds as shown. Laminations thinner + more distinct in lwr. half of core.

} mottled

Core Number: 186/34GC35 300-390 Location: Iceberg Alley Core Length: 390cm

Latitude: 67° 10.91'S Longitude: 62° 57.73'E Date: 11-3-97 Water Depth: 600m

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks



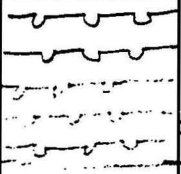
} mottled

←
3~~7~~6-394

Finely laminated diatom ooze (olive), grey clay and sand.
No samples taken
[illegible]

Core Number: GRAB 9.1 Location: Core Length:

Latitude: Longitude: Date: Water Depth:

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size: clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm	Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10-6 cgs	General description and Remarks
30			5y 3/2 5y 4/4 5y 3/2								Di			0 - 30 cm wat. sat. diatom ooze, well strat. and undisturbed 0-5 very water sat. dk. ooze 5 - 14 olive strat. clayey d. ooze 14 - 30 lamin. dk. ooze. 0-2 For AMS date 28-30 For AMS date

Genes[illegible]
[illegible]
[illegible])

CRUISE 186

E. Domack

Core Number: Location: Core Length:

Latitude: Longitude: Date: Water Depth:

Depth (cm)	Sub-sample	Visual Log	Colour	Grain size						Sorting/roundness	Fossils	Sed. Structures	Magnetic susceptibility 10^{-6} cgs	General description and Remarks
				clay <4µm	silt 4-63µm	f. sand .063-.25mm	m. sand .25-.5mm	c. sand .5-2mm	gravel >2mm					
GC 17		Δ Δ Δ Δ Δ ?	5YR 3/4								X			GC17 0-10 Diamicton, muddy 5YR 3/4 mod. brown compact
376 GC -35			5Y [illegible] 5Y 4/1 5Y 3/2								DIAT.	X		376-394 GC-35 (real depth) Finely laminated diatom ooze (olive), grey clay and sand. No sample.
GC 20 15		Δ Δ Δ	5YR 4/4								X	X	—	GC-20 "0-15" thickness Diamicton, structureless + compact, Moderate brown
GC 21 160 174		Δ Δ Δ Δ	N3								X	X		GC-21 → Real depth 160-174 cm Grey, compact diamicton structureless. Dark grey
GC 18 170 186		Δ Δ Δ Δ Δ	5YR 4/4								X	X		GC-18 170-186 cm Diamicton, structureless + compact.

Appendix B.

Diatoms sample analyses

(F. Talyor)

Core, interval (cm)	Abundance	Preservation	*Actinocyclus actinochilus*	*Actinocyclus ingens*	*Asteromphalus spp.*	*Azpeitia tabularis*	*Chaetoceros cysts*	*Chaetoceros spp.*	*Corethron criophilum*	*Coscinodiscus spp.*	*Dactyliosolen antarcticus*	*Denticulopsis hustedtii*	*Distephanus speculum*	*Eucampia antarctica*	*Hemidiscus ovalis*	*Navicula directa*	*Fragilariopsis angulata*	*Fragilariopsis curta*	*Fragilariopsis cylindrus*	*Nitzschia interfrigidaria*	*Fragilariopsis lineata*	*Fragilariopsis kerguelensis*	*Fragilariopsis obliquecostata*	*Nitzschia praecurta*	*Fragilariopsis ritscheri*	*Fragilariopsis separanda*	*Pseudonitzschia turgiduloides*	*Odontella sp.*	*Porosira glacialis*	*Porosira pseudodenticulata*	*Pxyilla spp.*	*Rhizosolenia spp.*	*Rouxia isopolica*	*Rouxia fragments*
GC01																																		
0	C	M	R						R				R	R			R	C/A				A*	R			R								
23	A	G	R			R					R		R	R			R	C/A				A*	R			R				R				
203	R	P	R									r		R				R				F/C							R					
c.c.	R	P	R	r		R						r		R				R				F/C	R			R								
GC02																																		
0	A	G	F		R	R		R			F		R	F			F	A	R		R	A*	F			R			R					
20	A	G	F			R				R	R		C/A	R			F	A				A*			R	R			R	R				
48	R	M			R						R			R								R												
142	C	P	R			R					R		R	R		R		C				C	R		R	R								
GC03																																		
0	A	G	R		R		A				R		R	R			R	A*				A	F			R	R							
5	A	G	R		R		A		R		R		F	R		R	R	A*	A			A	F				R							
226.5	-																																	
GC04																																		
0	C/A	M	R				F			R	R		R	R			R	A*	R		R	C	F		R		R	R	R	R		R		
12	A	G	R		R	R	A	R			F		R	F		R	C	A*	C		R	C/A	C		R		R		R	R				
GC05																																		
0	A	M	R		R	R	F			R	R		R	F/C			F	A*	R		R	F/C	F/C		R	R		R	R	R		R		
140	A	G	R		R	R	A	R	R	R	R		R	R			C/A	A*	R			C/A	C		R				R			R		
273	A	G	R		R		C		R	R	R		R	R		R	C	A*	R			F	C		R				R			F		
302	A	M	R		R	R	C				R		R			R	F	A*	R			F/C	F/C		R	R	R		R			R		
GC06																																		
0	C/A	M	R		R		F			R	R		R	R		R	R	C	R		R	C	C			R			R			R		
291	C	M	R		R	R	R				R		R	R			R	F/C	R			F/C	F			R						R		
GC07																																		
0	C	M	R		R		R				R			R			R	C	R		R	F	R			R		R						
Bottom	A	G	R		R	R	R				R		R	F			R	A*	R		R	A	F			R			R					
GC08																																		
0	C/A	M	R		R		F	R	R	R	R		R	R			R	C/A	R		R	C	F			R		R	R	R		R		
344	A	G	R		R		R				R		R	R		R	A	A*	A		R	F	C/A		R	R	R		R			A		
426	A	G	R				F	R			R		R	R		R	C	A*	C		R	C	C		R	R	R			R		R		
520	A	G	R		R		A			R	R		R	R			F	A	R			C	C/A						R	R		R		
GC09																																		
0	A	G	R		R		F				R		R	R		R	F	A	R		R	R	C		R	R			R	R		R		
135	C	G					R			R	R			R			R	F				R	F											
278	C/A	G/M	R		R		R	R	R	R	R		R	R/F			R/F	C/A			R	F	F/C			R			R				r	
Bottom	R	P												R																				
GC12																																		
0	A	G	R		R		R				R		R	R			F	A	R			F	C		R	R		R	R	R		R		
6	A	G	R		R		R		R		R		R	R			C	A	R			R	F			R			R					
106	R	P												R				R				R												
GC13																																		
0	A	G	R				R			R	R		R	R			F/C	A	R		R	R	F/C		R	R		R	R	R				
16	A	M	R		R		C	R		R	R			F			F	A	R		R	R	F		R	R		R	R	R				

Core, interval (cm)	Abundance	Preservation	*Actinocyclus actinochilus*	*Actinocyclus ingens*	*Asteromphalus spp.*	*Azpeitia tabularis*	*Chaetoceros cysts*	*Chaetoceros spp.*	*Corethron criophilum*	*Coscinodiscus spp.*	*Dactyliosolen antarcticus*	*Denticulopsis hustedtii*	*Distephanus speculum*	*Eucampia antarctica*	*Hemidiscus ovalis*	*Navicula directa*	*Nitzschia angulata*	*Nitzschia curta*	*Nitzschia cylindrus*	*Nitzschia interfrigidaria*	*Nitzschia lineata*	*Nitzschia kerguelensis*	*Nitzschia obliquecostata*	*Nitzschia praecurta*	*Nitzschia ritscheri*	*Nitzschia separanda*	*Nitzschia turgiduloides*	*Odontella sp.*	*Porosira glacialis*	*Porosira pseudodenticulata*	*Pxyilla spp.*	*Rhizosolenia spp.*	*Rouxia isopolica*	*Rouxia fragments*
GC15																																		
0	A	G	R		R		R			R	R		R	R			F/C	A	R		R	F	F/C		R	R		R	R	R		R		
GC17																																		
0	A	G	R		R		R			R			R/F	R			F	A*				R	F/C		R				R/F	R				
5	A	G	R		R		R			R	R		R	R			R	A	R		R	R	F			R			R	R				
182	R	M															R	R					R											
GC19																																		
0	A	G	R		R	R		R	R		R		R	F			C	A*	C		R	R	C		R	R			R	R		R		
GC20																																		
0	A	G	R		R		R/F		R	R	R		R	R			C/A	A*	F		R	R	C			R		R	R					
25	C/A	M					F	R	R				R	F			R	C	R			R	F			R								
208	C/A	M	R						R	R	R		R	R/F			R	F			R	F	F	r					R					
240	R	P										r						R				R												
GC22																																		
0	A	G	R		R	R	F		R		R		R	R			F	A	F		R	R	C			R			R	R				
100	C	M	R		R		R	R	R	R	R	r	R	F/C		R		F			R	R	F		R			R	R				f	
GC23																																		
0	A	G	R		R		C/A	R	R		R		R	R		R	C	A	C		R	R	C		R		R	R	R	R		R		
99	A	G	R		R		F/C	R	F	R	R		R	R		R	C	A	C		R	R	C			R	R	R	R	R		R		
103	A	G	R		R		C/A	R	R/F		R/F		R	R/F		R	F	A	C/A			R	C			R	R		R					
230	A	G			R		C/A	R	R		R/F		R	R			C	A	F		R	F	C		R	R	R	R	R	R		R		
268	A	G	R		R		C	R	R/F	R			R	R/F		R	F	A	C		R	F	F			R		R	R	R				
272	A	G	R		R		R	R	F	R	R		R/F	R		R	F	A	R		R	F	C		R	R	R		R	R		R		
GC24																																		
0	A	G	R		R		C	R	R		R		R	R		R	C	A	C/A		R	R	C		R	R	F/C	R	R	R		R		
185	A	G	R				C	R	R/F		R		R	R			C	A	C/A			R	F		R		R	R	R	R				
331	A	G	R		R		F/C	R	R/F	R	R		R	R		R	F	A	A*		R	R	C				F	R	R	R				
359	A	G	R		R		A	R	R		R		R	F/C			A	A	F		R	F	A		R	R			R					
379	C	G	R		R	R	F		R	R	R		R	F			R	F	R			F	F			R	R		R					
GC25																																		
0	A	G	R		R		C			R	R		R	R		F	F	A	F			F	C		R	R	R	R	R	R				
122	C	M					R	R	R				R	R			R	C				R	F					R	R	R				
GC26																																		
0	A	G	R		R		R				R		R	R			F/C	A	F			R	F/C			R	R		R	R				
25	A	G	R				R	R			R		R	R			F	A	C			R	C		R		R		R			R		
GC27																																		
0	A	M	R		R		R		R		R		R	R			F	A	F		R	F	F		R	R				R		R		
45	C/A	M	R		R		F		R	R	R		R	R			R	A	R		R	F	F									R		
GC28																																		
0	C	M	R		R		R	R			R		R	R			R	C	R		R	F	F		R	R			R					r
85	C	M	R		R		R				R		R	R		R	R	F	R		R	F	F			R		R	R			R		
GC29																																		
0	C	M	R		R	R	R				R		R	R			R	F			R	C	F			R			R					
46	C	M	R							R	R	r		R/F	r			R				R	F					R					r	

Core, interval (cm)	Abundance	Preservation	Actinocyclus actinochilus	Actinocyclus ingens	Asteromphalus spp.	Azpeitia tabularis	Chaetoceros cysts	Chaetoceros spp.	Corethron criophilum	Coscinodiscus spp.	Dactyliosolen antarcticus	Denticulopsis hustedtii	Distephanus speculum	Eucampia antarctica	Hemidiscus ovalis	Navicula directa	Nitzschia angulata	Nitzschia curta	Nitzschia cylindrus	Nitzschia interfrigidaria	Nitzschia lineata	Nitzschia kerguelensis	Nitzschia obliquecostata	Nitzschia praecurta	Nitzschia ritscheri	Nitzschia separanda	Nitzschia turgiduloides	Odontella sp.	Porosira glacialis	Porosira pseudodenticulata	Pxyilla spp.	Rhizosolenia spp.	Rouxia isopolica	Rouxia fragments
GC31																																		
0	C/A	M	R		R		R				R		R	R				R	R			C	R			R						R		
48	R	P										r		R								R									r			
97	C/A	G	R		R	R	R	R	R	R	R	r		F		R	R	F	R		R	C/A	F		R	R		R		R				r
240	R	P										r										R												
GC32																																		
0	A	M	R			R					R	r	R	R				F				A	R			R			R	R				
GC34																																		
0	A	G	R		R		C/A	F	R/F				R	R		R	F	A*	C			R	R		F		R	R	R	R		R		
126	A	G	R		R		F		R	R	R		R			R	F	A	C		R	R	R		R	R	R		R	R				
134	A	G	R		R		F	R	C/A		R		R	R		R	F	C	C			R	F		R		F			R		R		
372	A	G	R		R		C		R		R		R	R		R	C	A	A			C	F			R	R	R	R					
GC35																																		
0	A	G	R		R		F		R	R		r	R	R			F	A	R		R	R	C			R		R	R	R		R		
105	A	G			R		A		A*		R	r	F/C	R		R	R	C	F			R	R				R			R		R		
288	A	G	R			R	A*	R					R	R		R	R	A	A		R	R/F	F		R		C/A		R	R		R		
375	A	G	R		R		A*		R	R	R		R			R	R	A	C			C	C		R		F		R	R		R		

Core, interval (cm)	*Stellarima microtrias*	*Thalassiosira antarctica (cysts)*	*Thalassiosira frenguelli*	*Thalassiosira gracilis*	*Thalassiosira inura*	*Thalassiosira lentiginosa*	*Thalassiosira maculata*	*Thalassiosira oestrupii*	*Thalassiosira oliverana*	*Thalassiosira torokina*	*Thalassiosira sp. A*	*Thalassiothrix antarctica*	*Trichotoxin*
GC01													
0		R/F		R		R			R		R		
23				R		R	R	R				R	
203													
c.c.						R						R	
GC02													
0	R	F/C	R	R		F	R	R	R		R		
20		C		R		C/A	R	R	R		F		
48													
142		R										R	
GC03													
0		F/C	R	R		F/R					R		R
5	R	R		R		F/R		R			R	R	A*
226.5													
GC04													
0	R	F	R	R		R		R					R
12	R	A*		R		R					R		F
GC05													
0	R	C		R		R			R		R	R	R
140	R	A		R		R		R	R		R	R	R
273	R	F		R		R					R		R
302	R	C	R	R		R			R			R	
GC06													
0	R	C		R		R	R	R			R	R	R
291	R	C		R		R			R				
GC07													
0	R	R		R		R							R
Bottom	R	A	R	R		R		R			R		
GC08													
0	R	C		R		R					R		R
344	R	F		R		R							
426	R	F/C	R	R		R					R	R	
520	R	A*		R		R	R		R		R		R
GC09													
0	R	C		R		R	R	R	R		R	R	
135		C		R		R					R		
278		F			r	F	R	R	R	r	R	R	R
Bottom		R				R							
GC12													
0	R	C		R		R		R			R		
6	R	C		R		R		R	R				
106		R				R							
GC13													
0	R	C		R		R	R		R		R	R	
16	R	A*	R	R		R			R		R		

Core, interval (cm)	*Stellarima microtrias*	*Thalassiosira antarctica* (cysts)	*Thalassiosira frenguelli*	*Thalassiosira gracilis*	*Thalassiosira inura*	*Thalassiosira lentiginosa*	*Thalassiosira maculata*	*Thalassiosira oestrupii*	*Thalassiosira oliverana*	*Thalassiosira torokina*	*Thalassiosira sp. A*	*Thalassiothrix antarctica*	*Trichotoxin*
GC15													
0	R	C		R		R			R		R		R
GC17													
0	R	A		R		R	R		R		R		R
5	R	C		R		R			R		R		
182		R											
GC19													
0	R	A		R		R		R	R		R		R
GC20													
0	R	A		R			R		R		R		
25		C/A		R			R				R		
208	R	R		R		R/F			R	r	R	R	
240													
GC22													
0	R	C		R		R			R		R	R	
100		R		R				R		f			
GC23													
0	R	F/C	R	R		R		R	R		R		R
99	R	R		R		R					R		R
103		R	R	R		R					R/F		R
230	R	F	R	R		R			R		R		
268		R		R		R	R		R		R		
272		R		R		R		R					
GC24													
0	R	R	R	R		R	R				R		
185	R	R		R		R					R		R
331	R	R	R	R		R			R		R	R	
359	R	C		F		F		R	R		R		
379		F	R	F		R			R		R		
GC25													
0	R	C		R		R			R		R		R
122		F/C	R	R		R			R		R		R
GC26													
0	R	R		R		R					R	R	
25	R	R		R		R					R		R
GC27													
0	R	F/C		R		R	R		R				R
45		F		R		R			R				
GC28													
0	R	R	R	R		R	R	R	R		R		R
85	R	F		R		R				r			R
GC29													
0	R	R		R					R			R	R
46	R	R		R		R				r			

Core, interval (cm)	*Stellarima microtrias*	*Thalassiosira antarctica (cysts)*	*Thalassiosira frenguelli*	*Thalassiosira gracilis*	*Thalassiosira inura*	*Thalassiosira lentiginosa*	*Thalassiosira maculata*	*Thalassiosira oestrupii*	*Thalassiosira oliverana*	*Thalassiosira torokina*	*Thalassiosira sp. A*	*Thalassiothrix antarctica*	*Trichotoxin*
GC31													
0	R	R		R		F	R		R		R		R
48													
97	R			R		R	R	R		r	R		
240													
GC32													
0	R	R		R		F	R	R	R				
GC34													
0	R	R		R		R			R		R		
126	R	R	R	R		R					R		
134			R	R		R		R				R	R
372		R	R	R		R			R				
GC35													
0	R	R		R		R			R		R		
105	R	R	R	R		R					R		
288	R	A		R							R		
375		F				R					R		

Appendix C.

Foraminifer sample descriptions

(P. Quilty)

Sample 186GC01/CC

Source: Outside of core catcher

Sediment: Sandy brown firm mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present.

Neogloboquadrina pachyderma, the dominant form

Globocassidulina crassa, dominant benthic

Astrononion echolsi

Cibicides refulgens

Angulogerina earlandi (typical but also pustulose).

Comment:

An interesting sample. Considerable coarse content of angular lithic grains locally sourced, but with rare, rounded, high sphericity quartz grains. Noteworthy in the <1 mm fraction are a few coal fragments suggesting a sedimentary source. Foraminifera occur only in the <1 mm fractions. In the <500 micron fraction, well rounded grains are quite common and seem to come from two sources: one consists of clear grains, the other of reddish grains.

The foraminiferal fauna is essentially modern and lacks agglutinated species. There is no evidence of dissolution but many of the specimens are broken. Radiolaria, diatoms, sponge spicules are absent from these washed samples.

Followup palynology is warranted to examine two questions: One is the origin of the coal (and probably also of the clear rounded grains) and would probably give an answer of Permo-Triassic Beacon Group. The second question concerns the origin of the reddish grains. Along the coast of East Antarctica, red sandstone is common as boulders, some quite large. Its age and source are unknown. If an early Palaeozoic palynomorph assemblage emerge from palynology of this sample, it may provide an answer to this question.

SAMPLES FROM CORE GC02

These were examined to see if there was any sample-sample difference that could be related to changes with depth noted on the magnetic susceptibility signal.

Nothing very obvious emerges. The upper samples (22-24 and 40-42 cm) are more calcareous, consistent with a lower magnetic susceptibility readings but the content of fossils is unlikely to be responsible for the difference detected.

The lower three samples are very similar in being virtually barren and composed of angular-subangular particles.

All samples processed were of roughly the same size and the proportions of the three grade sizes is similar throughout the section. The magnetic difference would then seem to lie in the finer than 125 micron fraction and may depend on variation in proportion of biogenic silica/terrigenous fines.

The presence of coal in the lower samples may indicate that there are some provenance differences between lower and higher in the sequence.

Sample 186 2GC02 22-24 cm

Source: Core sample

Sediment: Brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

Globocassidulina crassa

G. subglobosa

Neogloboquadrina pachyderma

Comment:

Sample is very dominantly angular/subangular terrigenous debris but well rounded, high sphericity grains are present. There are a few radiolaria and spongs spicules but overall the fossil content is very small.

Sample 186 2GC02 40-42 cm

Source: Core sample

Sediment: Very soft brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

Neogloboquadrina pachyderma

Comment: *N. pachyderma* occurs as a few tens of specimens and benthics are very rare. There are a few sponge spicules and radiolaria. Otherwise the sample is like that above.

Sample 186 2GC02 56-58 cm

Source: Core sample

Sediment: Brown mud with pebbles to 2 cm.

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: Fossil material is very rare and consists of a few foraminifera, radiolaria and a trace of coal. Otherwise the sediment consists of angular/subangular terrigenous grains, with a few highly rounded, high sphericity grains.

Source appears to be local plus some reworked from preexisting coal bearing sediment.

Sample 186 2GC02 80-82 cm

Source: Core sample

Sediment: Firm brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: The sample is barren of fossils and consists only of angular/subangular terrigenous debris with a few traces of coal and a few highly rounded, high sphericity grains.

Sample 186 2GC02 100-102 cm

Source: Core sample

Sediment: Very fine brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: The sample is barren of fossils and consists only of angular/subangular terrigenous debris with a few traces of coal and a few highly rounded, high sphericity grains.

Sample GC05

Source: Top of core

Sediment: Very fine brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present.

Trochammina conica (50% of fauna)

T. antarctica (10%)

Unidentified friable species (25%)

Reophax scorpiurus

Cribrostomoides contortus

Saccorhiza ramosa

Hyperammina cylindrica

Spiroplectammina biformis

Comment:

A fine sample with a few coarse angular grains. Fauna totally agglutinated but lacking *Miliammina*). Fine fraction dominated by radiolaria, diatoms and sponge spicules. Some fine terrigenous material but biogenic silica dominant.

Sample GC05 CC

Source: Core catcher

Sediment: Very fine brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present.

Trochammina conica(45% of fauna)

Trochammina antarctica (20%)

Reophax difflugiformis (15%)

Reophax sp.A Earland

Hyperammina sp. a

H. sp. b

Saccammina sp.

Dorothia pusilla

Cribrostomoides arenacea

Comment:

The sample is very dominantly in the <500 micron fraction and consists of a felt of acicular diatoms and sponge spicules. There is also a small 'scolecodont'. The good, modern foram fauna is entirely agglutinated.

Terrigenous residue >125 micron is not abundant and consists of angular grains.

A considerable part of the small residue consists of beautiful framboidal pyrite in the form of what appear to be tube or burrow linings. They have the appearance of lining part of a cylindrical tube, not the entire tube.

Sample 186 GC08

Source: Bottom of core

Sediment: grey/brown mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

N. pachyderma

Miliammina arenacea

Trochammina nana

Comment:

A very small residue with a few angular grains coarser than 500 microns. Fine fraction mainly a felt of diatoms, sponge spicules and radiolaria with very few foraminifera (6 recovered in total, with 1 *N. pachyderma*. Traces of pyrite (incipient pyritisation?), and a few brown hollow tubes and spheres (spores?), some of the latter with characteristic rib patterns on them. Tubes are akin to what seems to be the host for framboidal pyrite elsewhere.

Also a small bone fragment.

Generally like a SMO sample but wrong colour.

Sample 186 GC09

Source of sample: Outside of the bomb on top of the corer and thus should represent the surface.

Sediment: Green SMO (siliceous ooze)

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

Miliammina arenacea (90%)

Reophax difflugiformis (5%)

R. pseudodistans tenuis

Pelosina rotundata

Trochammina conica

Portatrochammina weisneri

Ammoflintina argentea

Cribrostomoides contortus

Comment:

The sample yielded a very small residue consisting of essentially only that retained by a 125 micron sieve. It is dominated by radiolaria and *Miliammina*. There are a few sponge spicules and scolecodonts but no diatoms. There is little terrigenous material but the few coarse grains consist of two populations, one angular and fresh, the other more rounded and frosted suggesting wind transport as the source.

The fauna is entirely agglutinated and the best *Miliammina* fauna I have seen from the Antarctic.

Sample 186 8GC10

Source: Top of core

Sediment: Green SMO (siliceous ooze) with pebbles

Processing: Simple washing and sieving over 125, 500 micron and 1 mm sieves. The sample disaggregated very easily.

Foraminifera present: Foraminifera are well preserved and there are small numbers of **calcareous species**. Diversity is relatively high and no species stands out as particularly dominant but *M. arenacea, R. fusiformis* and species of *Hyperammina* are more common than others.

?*Saccorhiza* sp

Pelosina rotundata

Psammosphaera fusca

Hyperammina friabilis

H. sp. medium size

H. sp. large

Reophax fusiformis

R. spiculifer

R. ovicula

Miliammina arenacea

Cribrostomoides contortus

Haplophragmoides canariensis

H. sp.

Trochammina glabra

Conotrochammina bullata

Glandulina sp.

Globocassidulina subglobosa

Comment:

In addition to the foraminifera, there are scolecodonts and rare fragments of echinoderms.

The coarse fractions contain what appears to be glauconite, and a specimen of what appears to be an earlier generation bryozoan.

The detrital component is very dominantly angular, but there are rare rounded grains.

Fine fraction contained radiolaria, sponge spicules and acicular diatoms which felted together.

Sample 186 8GC11

Source: Bottom of core.

Sediment: Drak grey firm mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

The sample is essentially barren of fossils other for a few sponge spicules in the fine fraction, but contains a trace of coal in otherwise angular-subangular terrigenous grains. Fine fraction contains a significant component of subrounded grains.

The sample is very similar to GC13 and 14, but very different from GC12.

Sample 186 9GC12CC

Source: Core catcher

Sediment: Dark grey, not very firm mud

Processing: Simple washing a sieving over 125, 500 micron and 1 mm sieves.

Foraminifera present:

A very diverse and abundant fauna, not documented here.

About 40% planktonic, dominated by *N. pachyderma*, but also *G. bulloides* and perhaps another species if present.

Benthics dominated by *Globocassidulina* (*crassa* and *subglobosa*), *Cassidulina* sp., and *Patellina corrugata.*

This fauna deserves a lot of work.

Comments:

This is a typical mid shelf assemblage with full diversity and with no hint of abnormal salinity conditions. The generic balance is unusual in my experience.

The sample yielded a very diverse fauna including echinoderms, molluscs (bivalves, pteropods), brachiopods, bryozoans, very diverse ostracods worthy of separate study, serpulids and a few sponge spicules.

A few specimens of bryozoan are very motheaten and appear to be out of place here.

Terrigenous component is poorly sorted and angular.

Sample 186 GC13CC

Source: Core catcher

Sediment: Dark grey firm mud.

Processing: Simple washing over 125, 500 micron sieves.

Foraminifera present:

Globocassidulina subglobosa (one specimen).

Comment: The sample is virtually identical with 14CC, but seems to be marginally less fossiliferous, bordering on barren. There are a very few radiolaria, a sponge spicule and a serpulid fragment. The heavy mineral suite is more diverse than in 14CC and includes some garnet.

Sample 186 GC14CC

Source: Core catcher

Sediment: Dark grey firm fine mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

Cibicides refulgens

Lagena elongata

Globocassidulina subglobosa.

Comment:

The sample is dominated by the 125-500 micron fraction. It is almost entirely angular terrigenous debris and almost barren of fossils. There are very rare radiolaria (I saw 2) and one each of the foraminifera listed. There are traces of coal and very rare grains of crystalline pyrite. No garnet.

Sample 186 GC15CC

Source: Red mud in core catcher.

Sediment: Red mud, feels clayey

Processing: Simple washing through 125, 500 micron and 1 mm sieves.

Comment: Virtually unfossiliferous (rare radiolaria, sponge spicules and *Hyperammina* were seen).

The red colour is due to Fe oxide coating on sand grains. In the coarse fraction, there are some subangular grains but the fine fraction, quite red, also has a significant component of rounded grains. There is a noteworthy component of elongate angular grains.

Sample 186 GC16CC

Source: Core catcher

Sediment: Red mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

Essentially unfossiliferous but for a few *N. pachyderma* and sponge spicules.

Very much like GC15CC but differs in that the fine fraction is a very clean sand, apparently lacking the grains with the red stained surface. It also appears to be finer than GC15CC.

Sample 186 GC17CC

Source: Core catcher

Sediment: Red firm fine mud.

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: Foraminifera and sponge spicules are present but very rare and there is a trace of coal in the fine fraction. The rest is very clean sand lacking any Fe staining.

Sample 186 GC18CC

Source: Core catcher

Sediment: Red firm fine mud

Processing: Simple washing over 125, 500 micron ans 1 mm sieves.

Comment: Barren of fossils.

Entire sample is of diverse, angular terrigenous debris. The >1 mm and 500 micron-1 mm fractions contain a few grains of very fine white-pink siltstone that has not appeared in samples before. The finest fraction contains a significant proportion fo fresh, elongate angular grains. Some grains are surface Fe stained.

Sample 186 GC 19CC

Source: Core catcher.

Sediment: Grey, fine, not very firm mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

Barren of fossils.

The sample consists of diverse, angular-subangular terrigenous debris

Sample 186 GC20CC

Source: Core catcher.

Sediment: Red, sandy firm mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: Taken as barren of fossils although a single specimen of *Pullenia* was seen and had not been seen before on this voyage.

The entire sample consists of diverse, angular-subangular terrigenous debris. The fine fraction included some grains of chert, a trace of coal and a few green grains that could be glauconite.

Sample 186 GC21CC

Source: Core catcher

Sediment: Dark grey, sandy, not very firm mud.

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

N. pachyderma

N. sp.

Biloculinella sp.

Globocassidulina crassa

G. subglobosa

Ehrenbergina glabra

Comment:

Marine indices are not common but include foraminifera, sponge spicules and radiolaria. Planktonic species are dominant and the benthic fauna is very dominantly of cassidulind species.

The sample is almost completely of clean terrigenous sand with a noteworthy component of subrounded grains with a trace of coal.

If needed, flotation would probably yield a reasonable foraminiferal fauna. *N.* sp needs work to identify it. It may be a juvenile form of *N. pachyderma* but there is value in separating it from *N. pachyderma* because there are faunas (times?) in which it constitutes a considerable part of the fauna and the ratio may turn out to be of biostratigraphic value.

Sample 186 20GC22, 26.5-31.5 cm

Source: Core at 26.5-31.5 cm

Sediment: Dark grey sandy mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: This sample was processed check whether or not there would be enough carbonate to conduct AMS dating.

Carbonate occurs in each size fraction and consists of echinoderm/bryozans in the coarse fraction, through *Globocassidulina / Cibicides* in the medium, to abundant, divers fauna in the fine. Radiolaria are rare. The sample is mainly of angular-subangular terrigenous debris, but the carbonate content is enough that dates probably can be run separately on *Globocassidulina, Cibicides, N. pachyderma* and echinoid spines.

The fauna is dominated by *Globocassidulina* and *Cibicides*, with abundant *N. pachyderma.* Diversity is not high.

N.B. Four separate samples for AMS dating have been separated. They consist of *Globocassidulina crassa* (including *G. biora*), *Neogloboquadrina pachyderma*, *Cibicides refulgens* and echinoid spines. There is plenty material for U-series dating as well.

Sample 186 23GC23, 1m in core

Source: At the contact between sections A and B in the core, about 1 m from the core top

Sediment: Green SMO (siliceous ooze)

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

This is a SMO core and the sample has an unsavoury odour about it. The residue is minute and consists of a few coarse grains of garnet granulite including pyrite, some crystallised, as component of the granulite and individual grains in the sediment. The same terrigenous sediment is in the finer fractions.

The fauna and flora are restricted to the fine fraction and include an excellent and diverse array of siliceous groups (radiolaria, sponge spicules, diatoms) and a good agglutinated foraminiferal fauna. It is a typical SMO fauna.

The fauna appears to be from an anoxic environment but no diagenetic pyrite was seen (contrast with 24GC24CC sample).

Sample 186 24GC24CC

Source: Core catcher

Sediment: Grey/green sandy SMO(?)

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

The sample yielded a small residue.

Terrigenous material dominates, all angular grains. In addition, there are grey shale fragments and may be remnants of clasts which are underrepresented as a result of washing. Garnet is a minor component in contrast to some samples from this area.

The bulk of the fine fraction consists of a felt of fine sponge spicules and filamentous diatoms. In addition, there are abundant radiolaria, centric diatoms, and agglutinated foraminifera including *Miliammina*. The latter occurrence is in contrast to many agglutinated faunas which lack *Miliammina*.

A feature of this residue is the amount of framboidal pyrite pseudomorphic after sponge spicules and other irregular meandrine forms not represented in the residues, perhaps some of the meandrine lagynacean foraminifera. Branching was not evident in any meandrine forms. Often the pyrite is in the form of half cylinders indicating that pyrite may form on the lower half of the host 'cylinder'.

These are consistent with an anoxic environment in contrast to other SMO samples which lack diagenetic pyrite.

Sample 186 25GC25CC

Source: Inside core cutter (excellent sample)

Sediment:

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:

The sample consists of a very clean residue of very fresh, very angular fragments of local country rock and lacks diversity in clast composition. Pyrite occurs in the local rocks and as individual pyrite grains, often crystallised. Garnet occurs as grains and also in the local rock.

There are traces of coal and black shale/siltstone. There is no obvious glauconite or carbonate.

The sample lacks obvious fossils, but the presence of coal and shale indicates that palynology may be worthwhile.

Sample 186 GC27CC

Source: Core catcher

Sediment: Sandy grey, soft mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Fossils present: *Miliammina arenacea* (3 specimens - the only foraminifera)

sponge spicules, trace coal, few sponge spicules (one large one with framboidal pyrite in it)..

Comment: Residue dominantly of angular-subrounded (rare) terrigenous grains, with trace coal, even in the coarsest material.

The fine fraction has a few diatoms, radiolaria, sponge spicules, but fossils are very rare.

Sample 28GC28

Source: Top ofs section B, therefore about 1 m in core

Sediment: SMO (probably not in reality)

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: Doesn't yield a typical SMO residue, too large and too diverse a biota.

Residue consists of significant sand with angular to very well rounded grains (small amount) with traces of coal, **glauconite**, minor radiolaria, diatoms and sponge spicules. Good calcareous foram fauna, *N. pachyderma-G. subglobosa, Angulogerina,* plus a small agglutinated fauna with *Miliammina.* An otolith recovered.

The sample deserves palynology because of the evidence from glauconite and coal of reworking from marine and nonmarine sections.

No trace of dissolution.

Sample 186 28GC29CC

Source: Core catcher

Sediment: Sandy grey mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Foraminifera present:

N. pachyderma (est. 60%)

Globocassidulina crassa

Cibicides refulgens

Ehrenbergina glabra

etc

Comment:

The sample is very dominantly of angular-subrounded (rare) grains, including a trace of coal, a few echinoderm fragments, and **glauconite** suggesting that there is significant reworking and that palynology would be worthwhile.

G. crassa and *C. refulgens* occur even in the coarse fraction but are dominated in the fine fraction by *N. pachyderma.* The small form akin to *G. falconensis* is present as a few specimens.

The fauna is well preserved and very clean and could warrant more work to search for hints of reworking.

Sample 186 29GC30CC

Source: Core catcher (and additonal sample probably from this core but on outside of core barrel (taken after next core which failed to take a sample).

Sediment: muddy sand (second sample firm grey mud)

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: The well located sample consists of angular to very well rounded, high sphericity grains (quite common, and some frosted). Coal occurs even in the coarse fraction.

Fossils are rare and consist of a few *N. pachyderma* and a few radiolaria, sponge spicules and diatoms.

The second sample is similar, consist with it belonging to this core but it is a much firmer mud, contains traces of glauconite and has a more abundant, more diverse calcareous fauna consisting of *G. subglobosa, N. pachyderma, Angulogerina* spp. and *C. refulgens* in descending order of abundance. There are afew sponge spicules and radiolaria. Echinoid spines are present

Again, no evidence of dissolution.

Sample 186 34GC35

Source: From base of core

Sediment: Bedded intermixture of SMO and dark sandy textured material, perhaps slumped from valley side.

Processing: Simple washing over 125 and 500micron sieves.

Comment: The coarser fraction consists of angular to subangular, terrigenous debris with garnet conspicuous. There are black mud flakes and grains of white siltstone, unlike what has been seen in other residues and suggests that palynology processing might be worthwhile.

The fine fraction is similar in composition but has diatoms, radiolaria, sponge spicules and a typical SMO agglutinated foraminiferal fauna plus the calcareous benthics *Globocassidulina crassa* and *Loxostomum,* the latter not obvious in samples studied above.

There was no obvious glauconite or coal.

Palaeogene!!

Samples from GC33

Source: Two very small samples amounting in total to about 2-3 mls were recovered from the outside of the core cutter and the bottom of the outside of the core barrel.

Processing: Simple washing over 125 and 500 micron sieves.

Sediment: Both samples are dark grey, not very firm mud, in contrast with the inside of the core catcher which contained a handful of pebbles etc, obviously modern from a high energy area.

Comment (preliminary):

The residue is dominantly of fine angular to very well rounded grains of terrigenous debris and very different in proportion of rounded grains from modern sediments encountered elsewhere.

The fauna is dominated by the modern *N. pachyderma / Globocassidulina* group as is normal. Thus it is a highly mixed fauna.

Both samples yielded very interesting and very similar, but slightly different faunas, probably mixed Palaeogene, and possibly even Cretaceous. Recovered are a significant planktonic foraminiferal fauna, one with *Glibigerinatheka semiinvoluta* of Late Eocene (P15) age. The other dominant species appears to be *Morozovella pseudbulloides* of Early Paleocene age (P2/3). Unfortunately I do not have the full literature to help sort this out.

Modern radiolaria are present but rare and one filled with pyrite was recovered. Whether this is 'modern' or Palaeogene is unknown. Sponge spicules, mostly broken and some physically eroded, also are present but not abundant. Physically eroded sponge spicules are uncommon in the samples studied on this voyage.

One *Inoceramus* prism was recovered from each sample, possibly indicating some Cretaceous in the area.

Enough of one of the samples has been retained for nannoplankton and palynology.

Other faunal elements (not modern) are bryozoans, ostracods, molluscs and echinoderm fragments.

Glauconite is quite abundant, and there are a few grains of coal akin to that recovered from the area last visit. There are a few fragments that seem to show evidence of chertification, but otherwise preservation is excellent.

This sample will be a high priority subject on return to Australia and will be incorporated in the paper in preparation on the Palaeogene of the Mac. Robertson Shelf.

Sample 186 GR04

Source: Bulk sediment of GR04

Sediment: Red very fine mud

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment: There is no residue on the coarser sieves, other than a few specimens of the agglutinated *Hyperammina* sp. The fine fraction is very dominantly diatoms, radiolaria, sponge spicules plus a diverse agglutinated benthic foraminiferal fauna and a few *N. pachyderma.* It was not studied further than a brief examination. It deserves considerable further work.

Sample 186 21GR08

Source: Grab sample at the site of Current Mooring CM1.

Processing: Simple washing over 125, 500 micron and 1 mm sieves.

Comment:
The grab yielded a poor sandy sample with considerable modern material taken by the benthos project. There was also a boulder about 15 cm in diameter.

The recovered sample is very diverse. The terrigenous content is coarse, and contains angular/subangular and a few very well rounded grains. Garnet makes up about 30% of the fine fraction. There is a trace of glauconite attesting to a source in older sediments. Fauna includes echinoderms, barnacles, gastropods, bryozoans, ostracods, sponge spicules, agglutinated and calcareous foraminifera.

Although not examined in detail, the foraminiferal fauna is diverse and contains two modes of preservation, although there is no evidence of difference in age. It may be only that some of the larger forms (eg of *Cibicides* have survived when smaller specimens have been winnowed out. The fauna is dominated by *N. pachyderma* (about 60%) with *Globocassidulina / Cibicides* the main benthics.

The sample yielded two micrometeorites.

The area clearly is subject to considerable seafloor current action to judge from the coarseness of the material, lack of mud, and the high content of garnet. There is no evidence of any dissolution but some of the older foraminifera have been severely burrowed.

Palynology is warranted in the light of the glauconite, and the ostracods are worth looking at.

Sample 23GRAB

Source: Large sample from 19 kg SMO sample. **Is this registered as a formal sample?**

Sediment: Dark SMO (siliceous ooze), smells of H_2S

Processing: 'Simple' washing over 125, 500 micron and 1 mm sieves.

An estimated 100-200 gm was washed to yield a very light residue. There is no >1 mm residue. Terrigenous content is minute and very fine grained. Even though the sample was distinctly malodorous, there is no evidence of diagenetic pyrite, in contrast with some other samples.

The fines consist of felts of sponge spicules and diatom filaments which then in turn act as filters on which other material (centric diatoms, radiolaria, agglutinated foraminifera) are caught. Material that is not part of the felt is difficult to separate and little can be said with the facilities on board.

Two otoliths were separated and must be phosphatic as any carbonate (typical of nototheniids) would have dissolved.

Questions

In agglutinated faunas, why do some contain and others lack, *Miliammina*? What is the relationship between faunas in samples with and without framboidal pyrite?

The relationship between all these elements and SMO?

What are the different carbonate faunas and what is their relationship to environment?

Wash lots of SMO samples.

Sandy-Muddy-Ooze (SMO) (arenolutaceous ooze?) (siliceous ooze of Milam & Anderson, 1981) samples

Samples from SMO contain three separate foraminiferid faunas or forms of preservation. They are documented here and compared with the results of other studies in the Antarctic, particularly those by Milam & Anderson (1981) who reported on material collected from the East Antarctic continental shelf in a range environments similar to those encountered here, and along the same coast but 30° longitude east. Quilty (1985) reported on the faunas from Prydz Bay and Uchio (1960) from Lutzow-Holm Bay. Unfortunately, Uchio's pioneering work was on few samples from a wide depth range and he could not recognise fine subdivision of faunas in the shallower range. His work is considered no further.

Association 1

The sample from the top of core GC05 is typical of one type and contains an entirely agglutinated fauna consisting of *Trochammina conica* (50% of fauna),*T. antarctica* (10%), unidentified friable (and non preservable) species (25%), *Reophax scorpiurus, Cribrostomoides contortus, Saccorhiza ramosa, Hyperammina cylindrica* and*Spiroplectammina biformis.* Often this fauna may include a few specimens of *Miliammina arenacea* (*M. earlandi* of Milam & Anderson?), but this species is then in a very small minority. This appears to be the Shallow Basin Assemblage of Milam & Anderson (1981) but they record some calcareous benthic species in their samples, as is the case with 186 GC10. The calcareous content may reflect shallower water above the CCD, and also lack of time postdeposition for solution(either CCD related or due to acid conditions in the anoxic zone below the sediment/water interface). This is Quilty's (1985) *Trochammina* dominated association, except that in some cases, *Trochammina* may not be dominant and other agglutinated genera take this role.

Association 2

Sample GC09 is typical of the second type which consists of agglutinated species dominated by *Miliammina arenacea.* The following fauna is *Miliammina arenacea* (90%), *Reophax difflugiformis* (5%), *R. pseudodistans tenuis, Pelosina rotundata, Trochammina conica, Portatrochammina weisneri, Ammoflintina argentea* and *Cribrostomoides contortus.* This may be Milam & Anderson's Deep Basin Assemblage but if so, the content of *Miliammina* is higher in these samples and the trochamminid content lower. It is Quilty's (1985) *Miliammina* dominated agglutinated association.

The first and second types are very similar except for the role of *Miliammina* which is either dominant or essentially absent. Both assemblages in Milam & Anderson's study are associated with high salinity, very cold water, consistent with location on the shelf under a zone of seaice formation.

Association 3

The third type is typified by samples from 24GC24CC or GC05CC, in which the bulk of the fine fraction consists of fine sponge spicules, filamentous diatoms, abundant radiolaria, centric diatoms, and agglutinated foraminifera including abundant*Miliammina.* A feature of these residues is the amount of pyrite (in framboidal mode) pseudomorphic after sponge spicules and other irregular meandrine forms not represented in the residues, perhaps some of the meandrine lagynacean foraminifera such recorded by Barker (1961, pl. 29, figs.1-4) as 'chitinous rhizopod tubes, probably related to *Rhizammina'*. Branching was not evident in any meandrine forms. Often the pyrite is in the form of half cylinders indicating that pyrite may form on the lower half of the host 'cylinder'. The organic walled 'lagynaceans' that may be the host are not evident in other faunas and are not abundant in these. This assemblage is similar to the second type noted above but has abundant pyrite, consistent with anoxic conditions below the sediment-water interface. It is not so much a biocoenotic association (as the others are) but due to postdeposition diagenesis.

References

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Appendix D.

CTD Data

(table of filter and water samples taken and raw data plots)

Filter no.	tare weight:	CTD:	Station:	depth:	vol filtered:	weight:	weight on filter:	SPM
					(L)		(mg)	(mg/L)
118	7.3768	1	2	50	4	7.3836	6.8	1.7
113	7.2838	1	2	300	4	7.2917	7.9	2.0
120	7.4765	1	2	555	5	7.4831	6.6	1.3
75	7.3958	2	4	100	4	7.4045	8.7	2.2
80	7.3963	2	4	1300	4	7.4047	8.4	2.1
74	7.3878	2	4	2100	4	7.3955	7.7	1.9
78	7.4047	3	5	9	4	7.4138	9.1	2.3
77	7.4941	3	5	703	4	7.5022	8.1	2.0
76	7.3966	3	5	1175	4	7.4051	8.5	2.1
79	7.4858	4	6	9	4	7.4939	8.1	2.0
73	7.5024	4	6	1204	4	7.5096	7.2	1.8
72	7.4768	4	6	1966	4	7.4823	5.5	1.4
42	7.3936	5	12	10	3	7.4057	12.1	4.0
41	7.3909	5	12	430	4	7.3981	7.2	1.8
50	7.3814	5	12	706	4	7.3892	7.8	1.9
71	7.398	6	19	10	4	7.4067	8.7	2.2
44	7.3946	6	19	331	4	7.4027	8.1	2.0
49	7.405	6	19	575	4	7.4136	8.6	2.1
46	7.5074	7	21	10	4	7.5153	7.9	2.0
47	7.395	7	21	301	4	7.402	7	1.8
48	7.4955	7	21	622	4	7.5027	7.2	1.8
137	7.4679	8	22	11	4	7.4745	6.6	1.6
43	7.5035	8	22	161	4	7.5107	7.2	1.8
45	7.402	8	22	360	4	7.4087	6.7	1.7
136	7.3891	9	23	10	4	7.3995	10.4	2.6
135	7.3739	9	23	749	4	7.3798	5.9	1.5
134	7.2945	9	23	1195	4	7.3015	7	1.7
20	7.5347	10	29	12	4	7.5429	8.2	2.1
15	7.5176	10	29	751	4	7.5253	7.7	1.9
17	7.5252	10	29	1279	4	7.5339	8.7	2.2

R.S.V. AURORA AUSTRALIS CRUISE AU9705 (Voyage 5, Jan.-Mar. 1997) - CTD DATA PROCESSING NOTES

Mark Rosenberg, Antarctic CRC, July 1997.

Data collection, calibration and processing methods

CTD 1103 (unit no. 7) used for the entire cruise
CTD parameters processed - pressure, temperature, salinity
bottle samples processed - salinity only

CTD laboratory calibrations - the pre cruise pressure, platinum temperature and pressure temperature calibrations for CTD 1103 performed at CSIRO in June-July 1996 were applied to the cruise data set.

Salinity bottle samples - analysed by Neale Johnston in April 1997 on a Guildline Autosal (serial 62549), and using International Seawater Standard batch number P130. The salinometer temperature bath setting was set to 21°C. No significant salinometer drift was observed throughout the analyses (i.e. the salinometer performed well).

This report outlines details relevant to the calibration of cruise au9705. For a complete description of data calibration and processing methodology, see Appendix 2 in Rosenberg et al. (1995).

Results

CTD station positions are shown in Figure 1. The final calibration results for conductivity/salinity, along with the performance check for temperature, are shown in Figures 2 to 4. Note that in Figure 2, Temp(DSRT) is the reversing thermometer temperature. Table 1 lists important data quality information relevant to the CTD 2dbar averaged data. Vertical profile plots are also provided.

Temperature

The comparison of CTD temperature to reversing thermometer measurements is poor (Figure 2) (an offset of 0 and a standard deviation <0.02 are usually hoped for). The problem is most likely due to reversing thermometer measurements - they display large scatter, and should not be trusted. Thus no reliable performance check of the CTD temperature is available.

Conductivity/salinity

The conductivity calibration for CTD 1103 was of good quality (Figures 3 and 4), with salinity accurate to well within the WOCE specification of 0.002 (PSS78) for the bottle samples available. Obviously more bottle samples would have increased the reliability of the calibration, particularly for stations 1 and 2. However given the limited time and resources available for CTD data collection, salinity bottle sampling was adequate, and sample depths were chosen well.

The following salinity bottles were manually flagged out for conductivity calibration:

stn 1, rosette position 11
stn 5, rosette position 12

On Aurora Australis cruise au9601 along the SR3 transect (August to September 1996), a discrepancy was found between International Seawater Standard (ISS) batch numbers P128 and P130. The standards were compared by standardising a Guildline Autosal with one standard, measuring the other standard, and comparing the measurement with the second standard's nominal value. It was found that P128 read 0.0018 ± 0.0003 (PSS78) higher than P130. As a result, salinity samples standardised against P128 were lower by 0.0018 (PSS78) than samples standardised against P130. At the time of writing, it is not known which ISS batch is at fault (the supplier Ocean Scientific have been alerted to the problem). For cruise au9705, ISS batch P130 was used for the entire cruise. If it turns out that P130 is a faulty batch, then all salinities for this cruise will need to be corrected by -0.0018 (PSS78).

Pressure

Pressure signal noise was minimal.

For stations 1, 3 and 10, logging of CTD data appears to have commenced when the CTD was already in the water. Thus some surface data is missing for these stations, and surface pressure offsets were chosen manually, taking into account values from surrounding stations. Any resulting additional error in pressure for these stations is small (<0.5 dbar).

Several bottle firing depths as recorded on the CTD sheets were found to be incorrect (or were not recorded). This applies to the following bottles:

station	rosette position
1	2
2	1, 2
5	11

Note that calibrated CTD upcast burst data at the time of bottle firings (i.e. pressure, temperature and salinity) are available in the bottle data file (a9705.bot). These values, not values from the CTD sheets, should be used when supplying data for other samples drawn (helium).

Table 1: Data quality information relevant to CTD 2dbar averaged files.

suspect 2dbar bins (refers to all parameters except pressure):

station	pressure (dbar)	flag	comment
6	2	suspect	transient error when entering water
9	2	suspect	transient error when entering water

missing 2 dbar bins:

station	pressure (dbar)
1	2, 4, 86
3	2 - 10
10	2 - 58

raw CTD data points deleted

station	point number range
1	1, 681
1	9050, 9055
3	1, 4
10	1, 5

Table 2: Altimeter elevations above the ocean bed at the bottom of each CTD cast.

station	elevation above bottom (m)	station	elevation above bottom (m)
1	-	6	-
2	15	7	-
3	-	8	10.0
4	10.5	9	18.0
5	13	10	-

Density inversions

Numerous small vertical density inversions appear throughout the CTD data. These typically occur in regions of high local vertical gradients where mixing is occuring, and are assumed to be real. Note in particular station 1, near the bottom of the cast, where larger density inversions occur - bottle data is unavailable for confirmation (see profile plot), however there is no indication of CTD sensor problems, so the data are real. For this particular example however, salinity spiking may be exaggerated due to sensor mismatch in the extremely high vertical gradients.

Station data

All station positions and sounder depths are as recorded on the CTD sheets. Start and end times of CTD casts are recorded automatically by the CTD logging PC. Altimeter elevations at the bottom of CTD casts are listed in Table 2.

4. Data formats

2 dbar averaged CTD data file

The final format in which CTD data is distributed is as 2 dbar averaged data, contained in column formatted ascii files, named a9705ixxx.all (Table 3), for i=CTD unit number, and xxx=station number. Averaging bins are centered on even pressure values, starting at 2 dbar. A 15 line header is followed by the data, as follows:

column	parameter
1	pressure (dbar)
2	temperature (^{O}C) (ITS-90)
3	salinity (PSS78)
4	σ_T = density-1000 (kg.m^{-3})
5	specific volume anomaly x 10^{8}(m^{3}.kg^{-1})
6	geopotential anomaly (J.kg^{-1})
7	dissolved oxygen (μmol.l^{-1}) (blank for this cruise)
8	number of data points used in the 2 dbar averaging bin
9	standard deviation of temperature values in the 2 dbar bin
10	standard deviation of conductivity values in the 2 dbar bin

All files start at the 2 dbar pressure level, incrementing by 2 dbar for each new data line. Missing data are filled by blank characters (this most often applies to dissolved oxygen data).

Table 3: Example 2 dbar averaged CTD data file (*.all file).

```
SHIP               : R.V. Aurora Australis
 STATION NUMBER    :  4
 DATE              : 02-JAN-1994  (DAY NUMBER  2)
 START TIME        : 1020 UTC = Z
 BOTTOM TIME       : 1100 UTC = Z
 FINISH TIME       : 1222 UTC = Z
 CRUISE            : Au94/07
 START POSITION    : 44:07.03S 146:13.35E
 BOTTOM POSITION   : 44:07.14S 146:13.71E
 FINISH POSITION   : 44:06.61S 146:13.95E
 MAXIMUM PRESSURE: 1038 DECIBARS
 BOTTOM DEPTH      :  1015    METRES

 PRESS TEMP SAL SIGMA-T S.V.A. G.A.   D.O.
     (T-90)
  2.0 11.899 34.773 26.432 158.69  0.032            30 0.001 0.007
  4.0 11.899 34.778 26.436 158.41  0.063            30 0.001 0.001
  6.0 11.903 34.779 26.436 158.46  0.095            45 0.001 0.002
  8.0 11.903 34.778 26.435 158.55  0.127            41 0.000 0.000
 10.0 11.903 34.778 26.435 158.60  0.159            32 0.001 0.001
 12.0 11.904 34.778 26.435 158.66  0.190            32 0.001 0.001
 14.0 11.905 34.778 26.435 158.72  0.222            40 0.000 0.000
 16.0 11.907 34.779 26.435 158.76  0.254            34 0.002 0.002
 18.0 11.908 34.780 26.435 158.77  0.286            25 0.002 0.002
```

Bottle data file

The bottle data file, named a9705.bot, is a column formatted ascii files containing the hydrology data, together with CTD upcast burst data (Table 4). The columns contain the following values:

column	parameter
1	station number
2	CTD pressure (dbar)
3	CTD temperature (^{o}C) (ITS-90)
4	reversing thermometer temperature (^{o}C)
5	CTD conductivity (mS.cm^{-1})
6	CTD salinity (PSS78)
7	bottle salinity (PSS78)
8	ortho phosphate concentration (µmol.l^{-1}) (no data for this cruise)
9	nitrate + nitrite concentration (µmol.l^{-1}) (no data for this cruise)
10	reactive silicate concentration (µmol.l^{-1}) (no data for this cruise)
11	bottle dissolved oxygen concentration (µmol.l^{-1}) (no data for this cruise)
12	bottle quality flag (-1=rejected, 0=suspect, 1=good)
13	niskin bottle number

Missing data values are filled by a decimal point (surrounded by blank characters). Parameters 2,3,5 and 6 are mean values from the upcast CTD burst data at the time of bottle firing, where each burst contains the data 10 sec previous to the time of bottle firing. Parameters 7 to 11 are laboratory values for the hydrology analyses. Parameter 12, the bottle quality flag, is relevant to the calibration of CTD salinities - bottles flagged 1 and 0 are used for calibration, while those flagged -1 are rejected. Parameter 13, the niskin bottle number, is a unique identifier for each bottle. Note that the Niskin bottle numbers were not recorded on the CTD sheets, so I have arbitrarily equated Niskin bottle number with rosette position (not a good practice).

Table 4: Example hydrology data file (*.bot file).

```
2  148.516 11.904   .    40.025 35.052 35.067  .     .     .     .     -1  4
2  200.278 11.085   .    39.174 34.963 34.965  .     .     .     .     -1  3
2  247.807 10.678 10.691 38.758 34.914 34.914  .     .     .     .      0  2
2  289.188  9.625   .    37.640 34.769 34.794  .     .     .     .     -1  1
3    8.609 15.984   .    44.199 35.274 35.275  .     .     .     .      1 16
3   21.504 15.975   .    44.198 35.276 35.275  .     .     .     .      1 15
3   48.210 15.935   .    44.171 35.277 35.276  .     .     .     .      1 14
```

Station information file

The station information file, named a9705.sta (Table 5), contains position, time, bottom depth and maximum pressure of cast for CTD stations. The CTD instrument number is specified in the file header. Position and time (UTC) are specified at the start and end of the cast, while the bottom depth is for the start of the cast. Positions at the bottom of each cast are unavailable (obtain underway logging data for this information). Note that small inconsistencies may exist between bottom depth and maximum pressure, due to drift of the vessel between the start and bottom of the cast.

Table 5: Example CTD station information file (*.sta file).

```
--------------------------------------------------------------------------------------------------------------------
|                                                                                                                  |
|  RSV Aurora Australis      Cruise : Au93/09            CTD station list          (CTD unit 4)                    |
|                                                                                                                  |
--------------------------------------------------------------------------------------------------------------------
|stat|                          start                   bottom   |max P |            bottom           |          end                 |
|no. |time    date       latitude    longitude     depth(m)  |(dbar) |time  latitude    longitude   |time  latitude    longitude   |
--------------------------------------------------------------------------------------------------------------------
|    |                                                          |       |                             |                              |
| 1  |2032  11-MAR-93  44:06.73S  146:14.35E      1000       |  956  |2118 44:06.37S  146:14.35E  |2154 44:06.19S  146:14.60E  |
|    |                                                          |       |                             |                              |
| 2  |0027  12-MAR-93  44:00.06S  146:18.61E       300       |  289  |0042 44:00.03S  146:18.77E  |0115 43:59.97S  146:18.64E  |
|    |                                                          |       |                             |                              |
| 3  |0513  12-MAR-93  44:07.51S  146:14.89E      1100       | 1115  |0549 44:07.48S  146:15.06E  |0632 44:07.39S  146:15.23E  |
|    |                                                          |       |                             |                              |
--------------------------------------------------------------------------------------------------------------------
```

Matlab files

The CTD and bottle files are available in matlab format, as follows:

(i) a9705.mat This file contains the CTD 2 dbar averaged data from the *.all files, along with header information. Matrix column numbers correspond to CTD station number. All blanks are filled by NaN. Matrices are as follows:

ctd_press = ctd pressure
ctd_temp = ctd temperature
ctd_sal = ctd salinity
ctd_sigma_t = σ_T
ctd_sva = specific volume anomaly

ctd_ga = geopotential anomaly
ctd_npts = no. of data points used in the 2 dbar averaging bin

botd = bottom depth (i.e. ocean depth)
maxp = maximum pressure of cast
day
month
year

and the following header information at the start and end of each cast:

decimaltime = decimat time from start of year e.g. midday on January 2nd is 1.500
lat = latitude
lon = longitude
time

(ii) a9705bot.mat This file contains the bottle data information from the *.bot file. Matrix column numbers correspond to CTD station number. All blanks are filled by NaN. Matrices are as follows:

ctd_press, ctd_temp, ctd_sal, ctd_cond = CTD pressure, temperature, salinity and conductivity from upcast CTD burst data (see above)
hyd_sal = bottle salinity
therm = protected reversing thermometer temperature
flag = bottle quality flag
niskin = Niskin bottle number
station

References

Rosenberg, M., Eriksen, R., Bell, S., Bindoff, N. and Rintoul, S., 1995. *Aurora Australis marine science cruise AU9407 - oceanographic field measurements and analysis.* Antarctic Cooperative Research Centre, Research Report No. 6, July 1995. 97 pp.

Figure 1

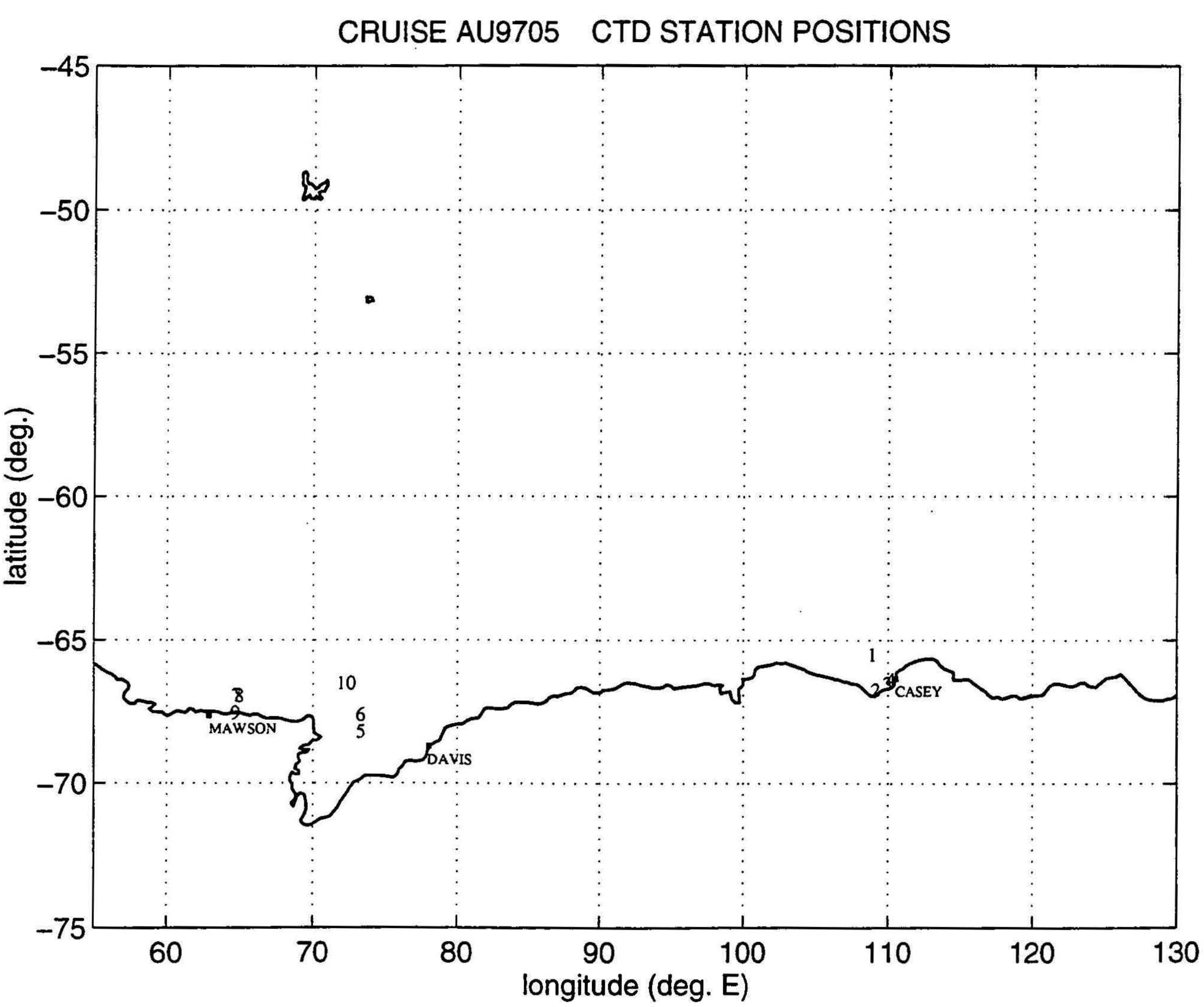
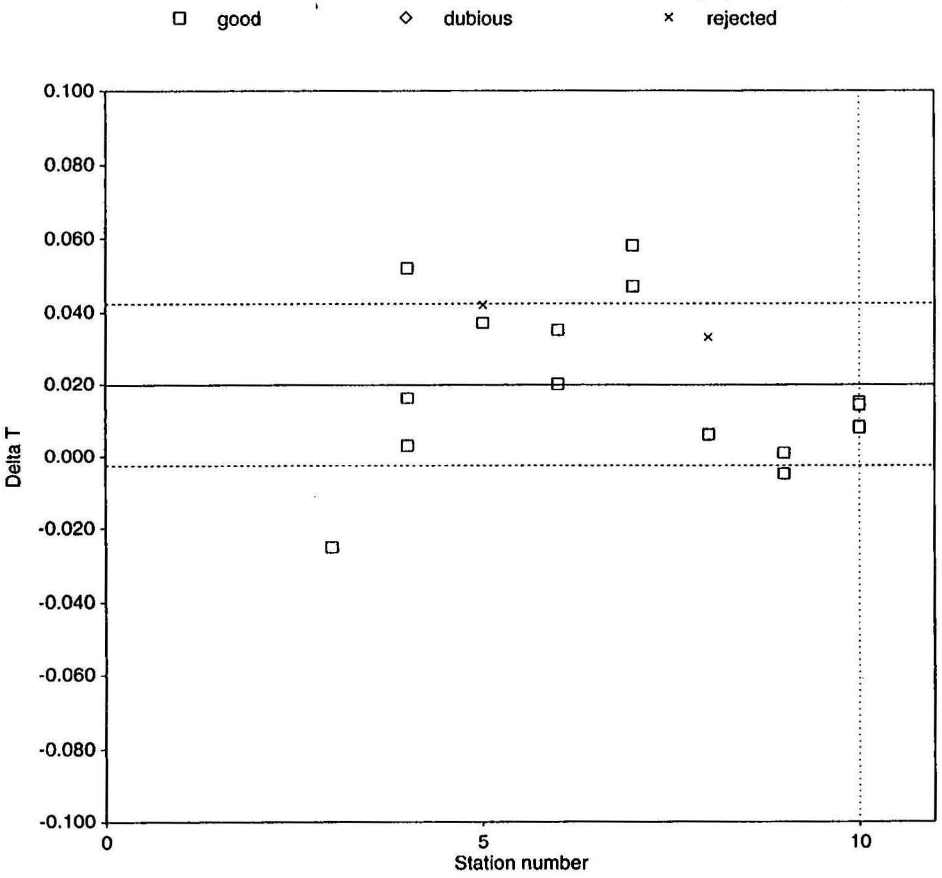

CRUISE AU9705 CTD STATION POSITIONS
latitude (deg.)
-45
-50
-55
-60
-65
-70
-75
longitude (deg. E)
60
70
80
90
100
110
120
130
1
2
3
4
5
6
7
8
9
10
MAWSON
DAVIS
CASEY

Figure 2

Dtplot
Temp(DSRT) - Temp(CTD)



Calibration data for cruise : Au97/05

Calibration file : histcal.lis

Mean offset Temperature = 0.01981312c (s.d. = 0.0226 ˚c)

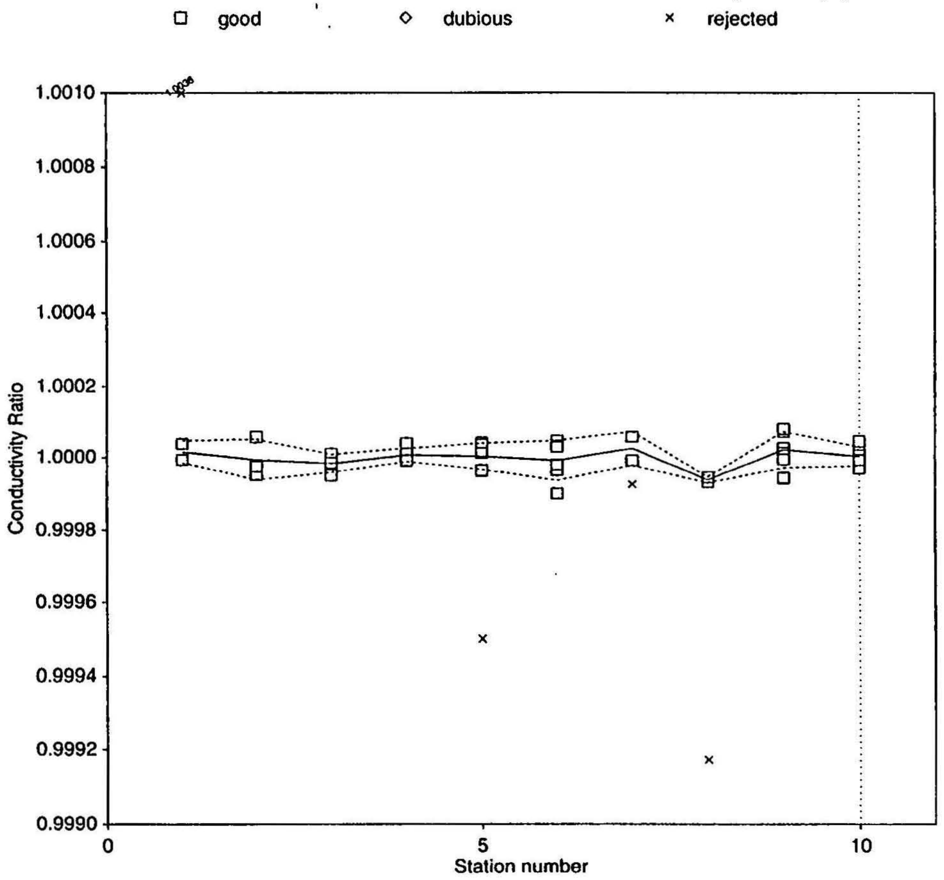
Number of samples used = 16 out of 18

Calplot

Cond(Samp) / Cond(CTD)

Wed Jul 16 11:57:29 1997

Figure 3



Calibration data for cruise : Au97/05

Calibration file : histcal.lis

Conductivity s.d. = 0.00003

Number of bottles used = 44 out of 48 Mean ratio for all bottles = 1.00000

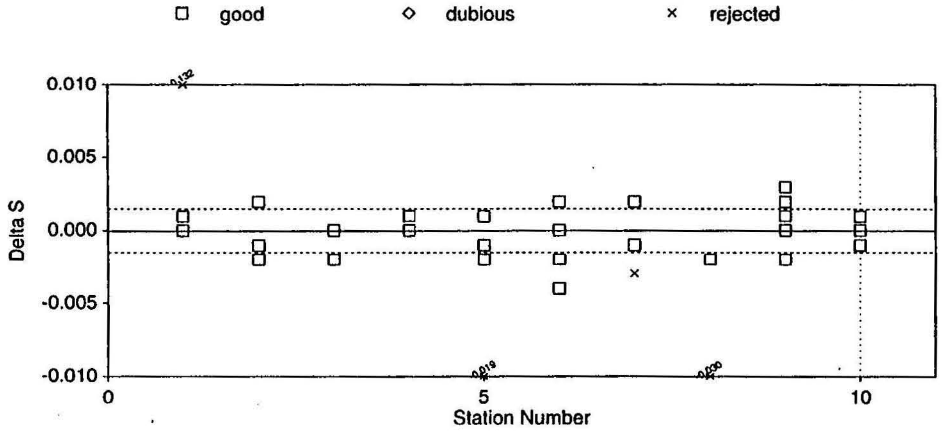
Figure 4

Page 1

Dsalplot

Sal(Samp) - Sal(CTD)

Wed Jul 16 11:57:40 1997



Calibration data for cruise : Au97/05

Calibration file : histcal.lis

Mean offset salinity = 0.0000psu (s.d. = 0.0015 psu)

Number of bottles used = 44 out of 48

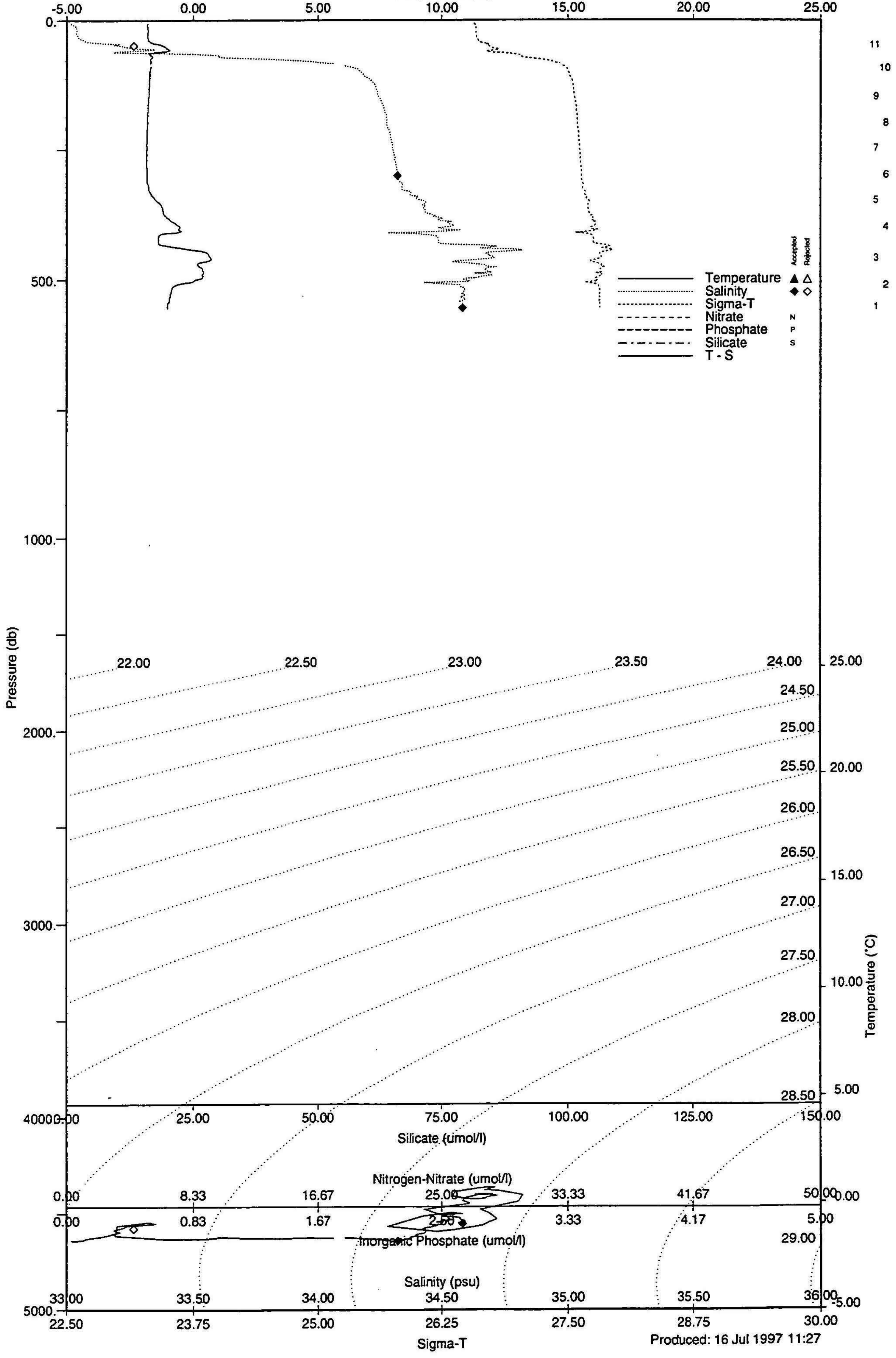
Position : 65:30.24S 108:54.45E
Date : 06-FEB-1997
Time : 0553 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 1

Sample Bottles Plotted
Sonic Depth : 549 metres



Produced: 16 Jul 1997 11:27

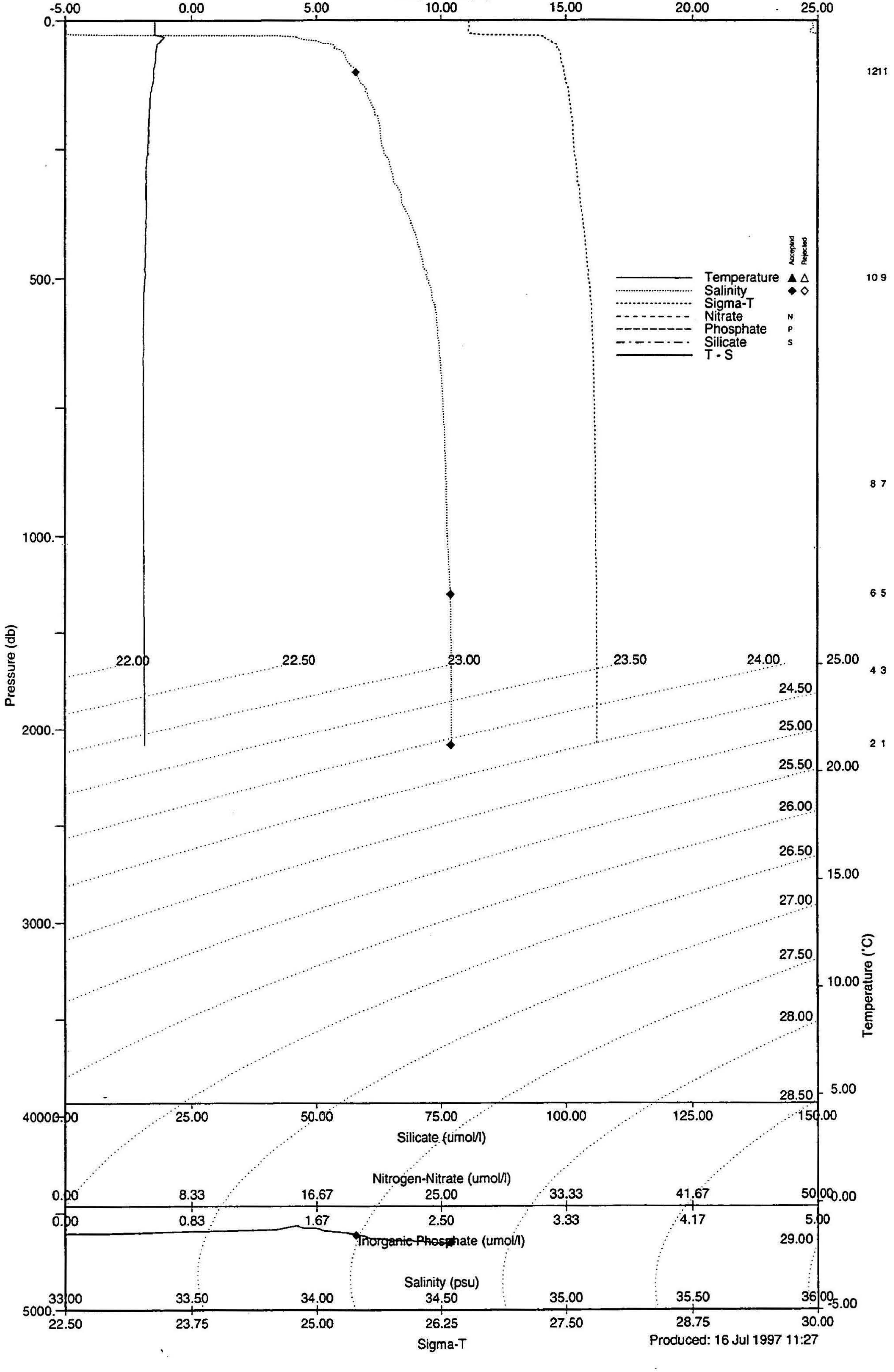
Position : 66:43.78S 109:09.47E
Date : 10-FEB-1997
Time : 1043 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 2

Sample Bottles Plotted
Sonic Depth : 2100 metres



Produced: 16 Jul 1997 11:27

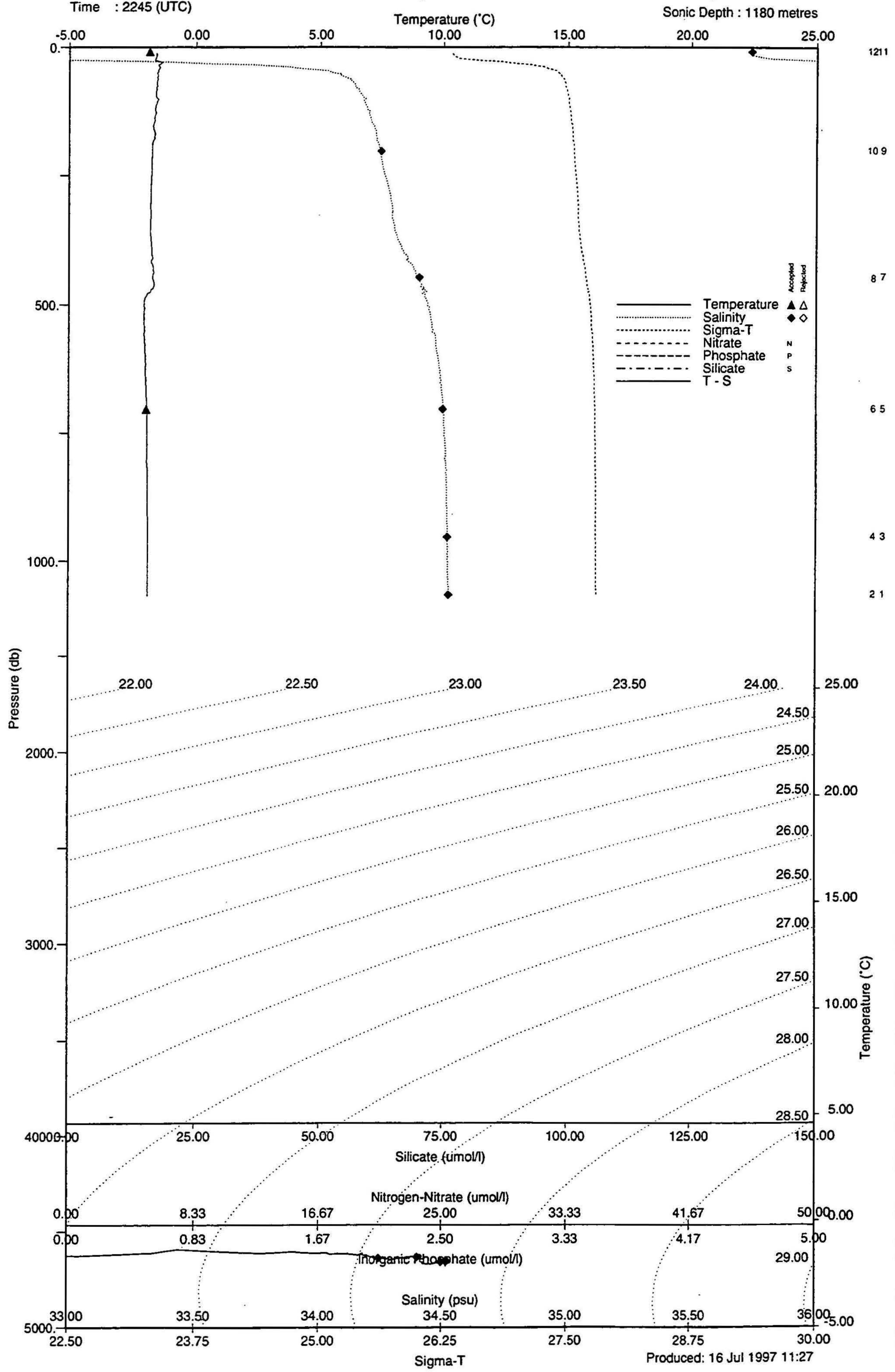
Position : 66:30.57S 109:56.12E
Date : 10-FEB-1997
Time : 2245 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 3

Sample Bottles Plotted
Sonic Depth : 1180 metres



Produced: 16 Jul 1997 11:27

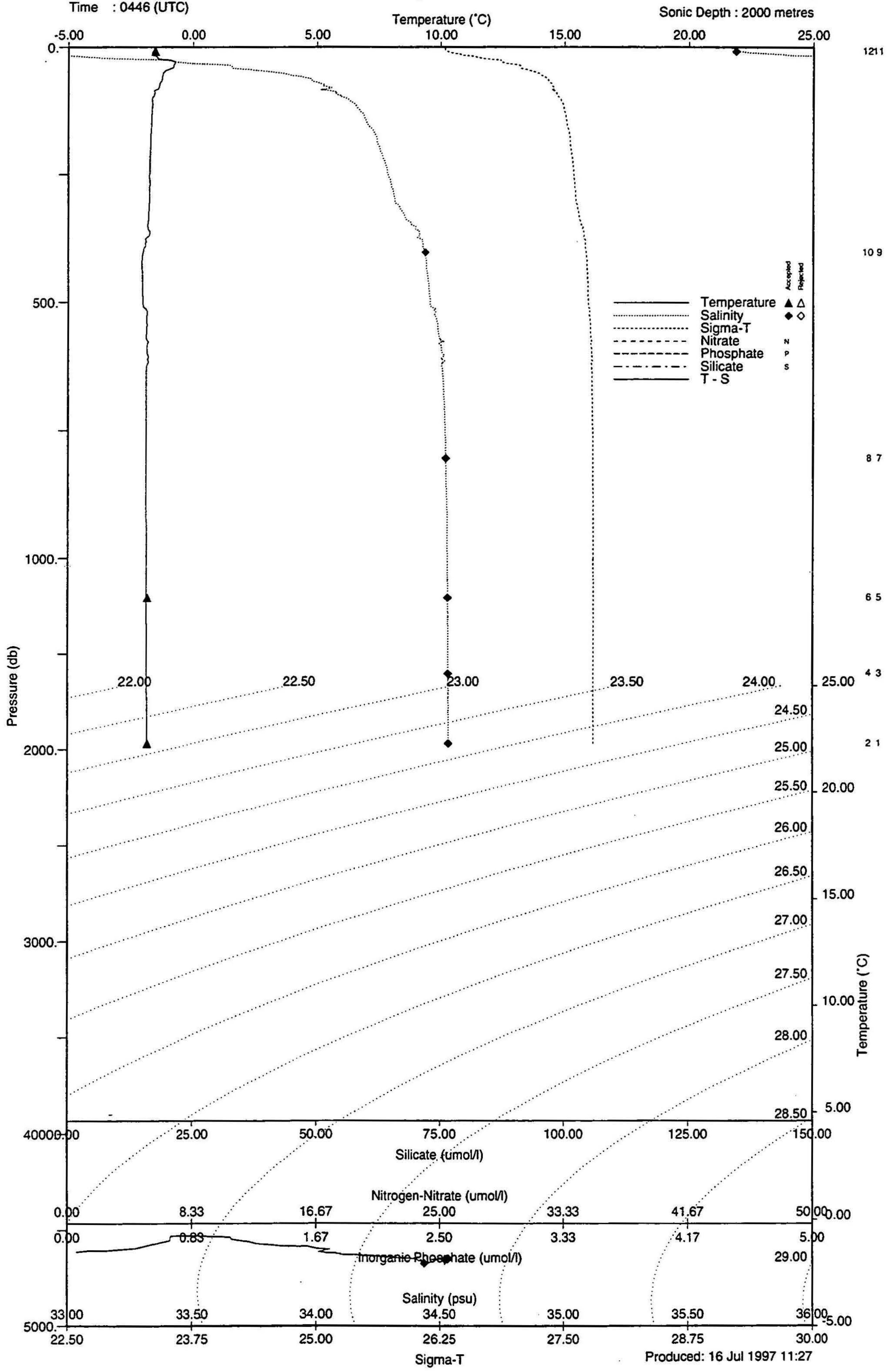
Position : 66:21.89S 110:11.47E
Date : 11-FEB-1997
Time : 0446 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 4

Sample Bottles Plotted
Sonic Depth : 2000 metres



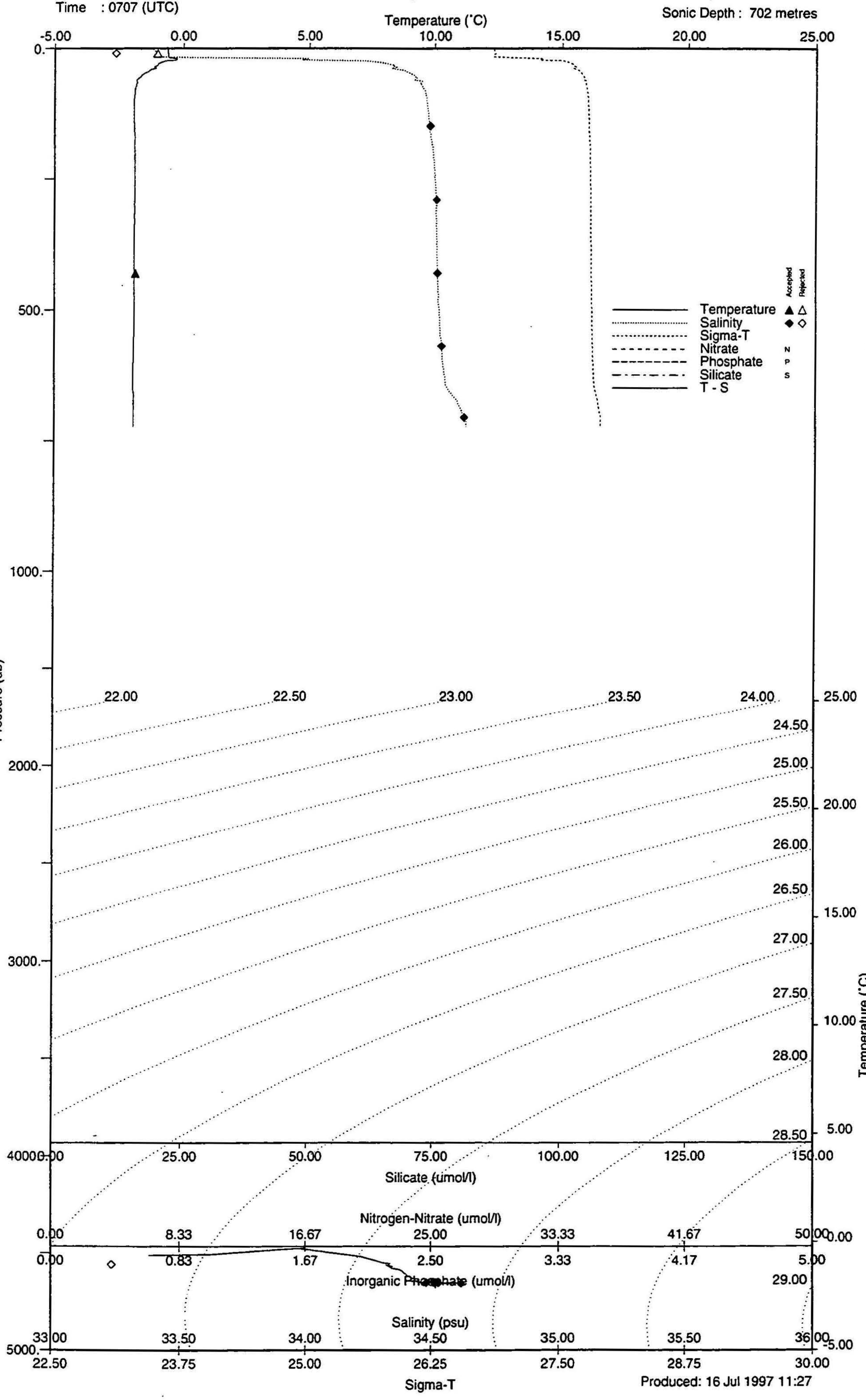
Position : 68:11.37S 73:17.45E
Date : 18-FEB-1997
Time : 0707 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 5

Sample Bottles Plotted
Sonic Depth : 702 metres



Produced: 16 Jul 1997 11:27

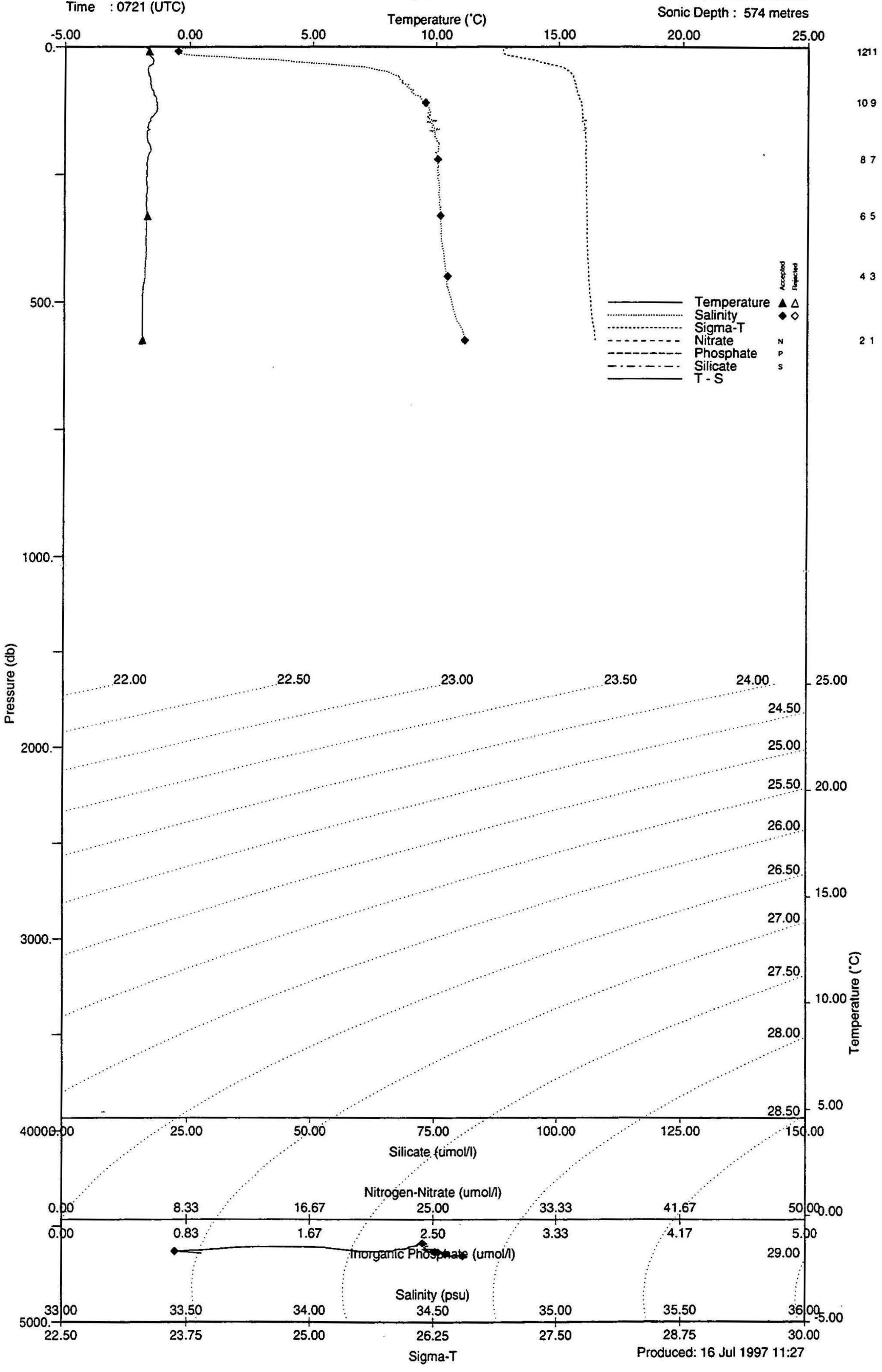
Position : 67:36.84S 73:18.58E
Date : 20-FEB-1997
Time : 0721 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 6

Sample Bottles Plotted
Sonic Depth : 574 metres



Produced: 16 Jul 1997 11:27

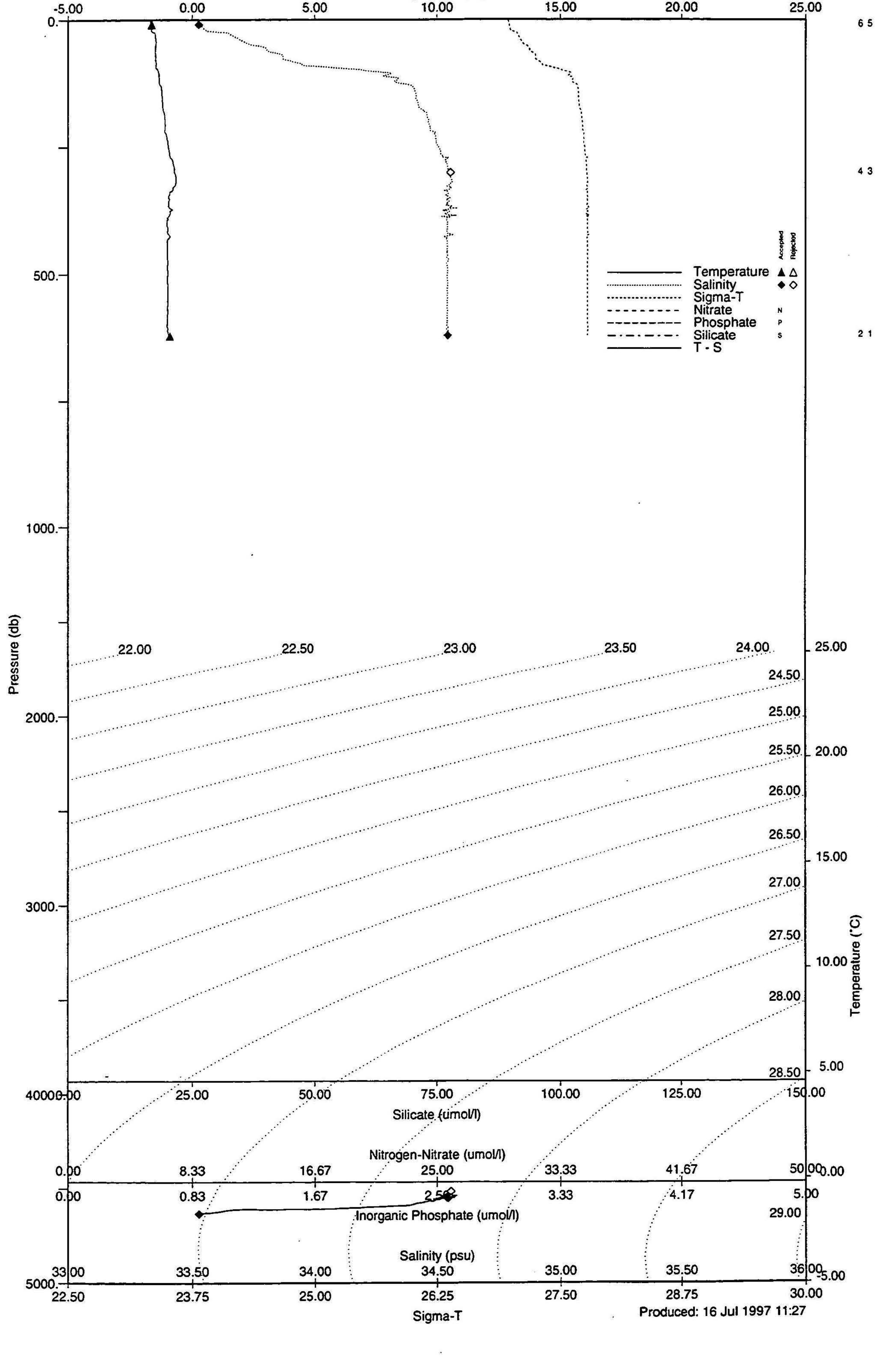
Position : 66:55.15S 64:45.61E
Date : 24-FEB-1997
Time : 0939 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 7

Sample Bottles Plotted
Sonic Depth : 650 metres



Produced: 16 Jul 1997 11:27

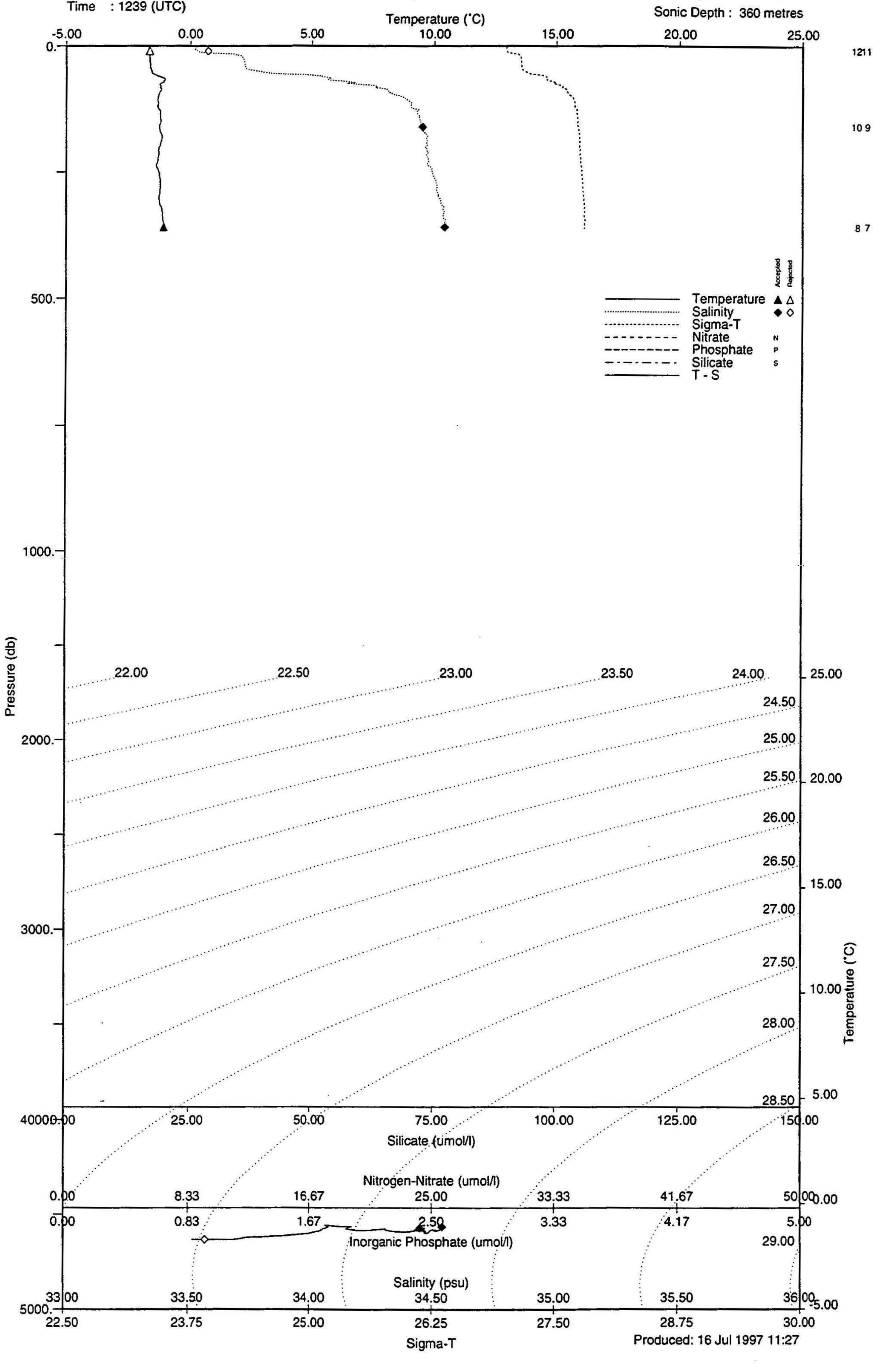
Position : 66:55.83S 64:56.01E
Date : 24-FEB-1997
Time : 1239 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 8

Sample Bottles Plotted
Sonic Depth : 360 metres



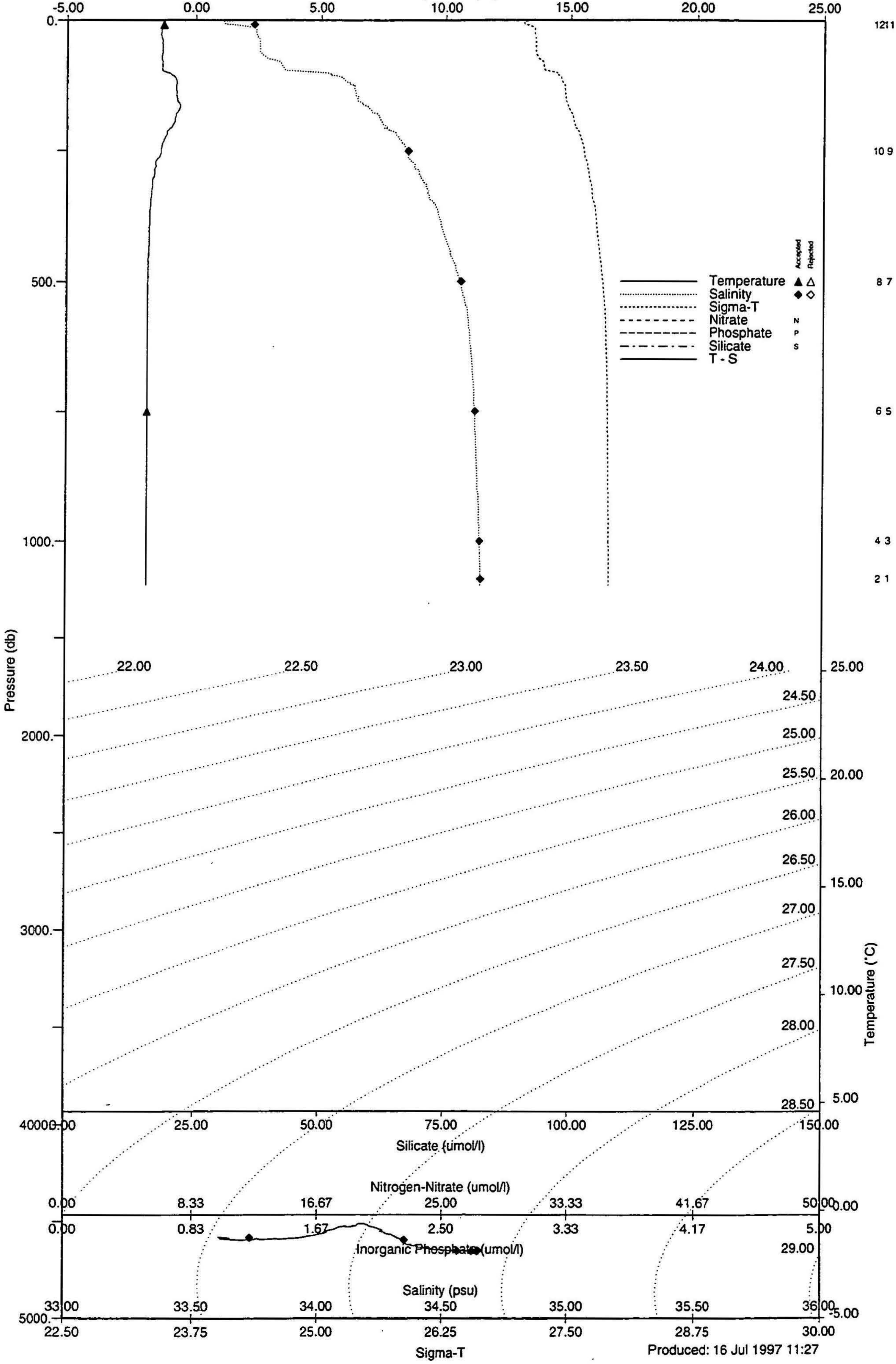
Position : 67:31.91S 64:39.40E
Date : 25-FEB-1997
Time : 1427 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 9

Sample Bottles Plotted
Sonic Depth : 1250 metres



Produced: 16 Jul 1997 11:27

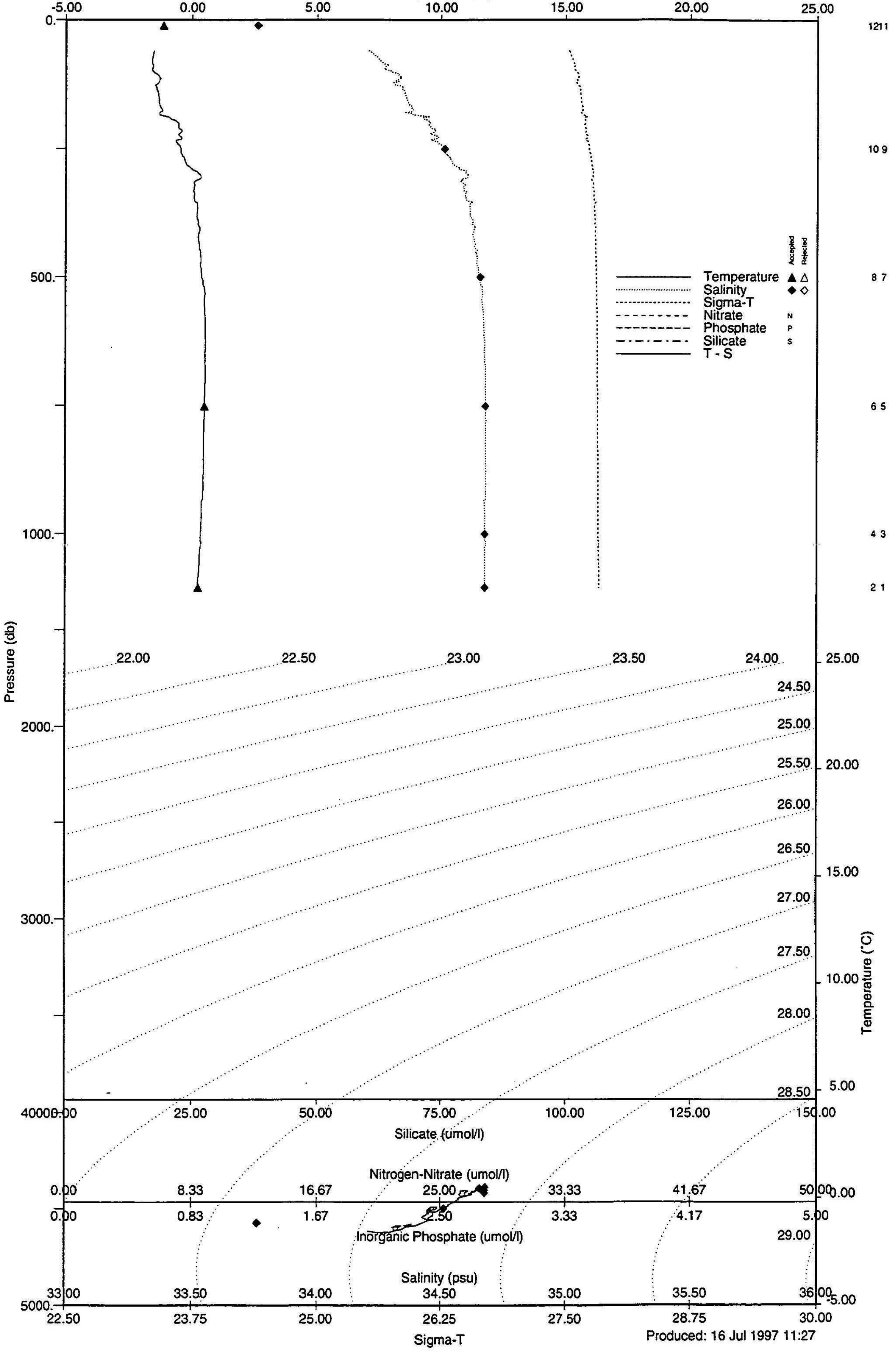
Position : 66:29.70S 72:16.87E
Date : 08-MAR-1997
Time : 0145 (UTC)

Cruise : Au97/05

Fully Calibrated

Stn No: 10

Sample Bottles Plotted
Sonic Depth : 1260 metres



Produced: 16 Jul 1997 11:27

Appendix E.

Current Meter Deployment Forms

Stn 21

ANTARCTIC
C R C

University of Tasmania
GPO Box 252C
Hobart Tasmania 7001
Ph: (002) 202 504
Fax: (002) 202 973

Current Meter Deployment Form

Instr. Serial Number 11464 Data Storage Unit No. 7328

Sensor	Serial No.	Range		Checked by	Date
Temperature		-2.6 - 5.4	°C		24-2-97
Conductivity		0 - 77	mmho/cm		
Pressure	N/A		psi		
Transmissometer	624	25cm path			
Compass	20102	360 ± 5	°		
Rotor Counter	2145	1/2	revs/count		

Pre-Deployment Checks

Main battery type: Anderaa 3382 Voltage: ________ Date: ________

Secondary battery type: Ultralife Voltage: ________ Date: ________

Date/Time Switch On: 24/2/97 0300 hrs [✓ GMT]/local/other __________

Sampling Interval: 60 minutes Transmissometer Path Blocked from: 0500 to 0900 hrs = 4 (No. of Records) Check "O" ring: ✓ Check "C" Clamps: ✓ Check Zinc Anodes: ✓ Check Case Alignment: ✓ Check Rotor Bearings: ✓ Acoustic Release Type / Serial No.: Benthos 866 / 212 Acoustic Release Frequency Code: Receive 11.0 khz Checked by:

Transmit 12.0 kHz Enable Code C Release Code D

Deployment Checks

Name of Ship: Aurora Australis Cruise No.: 186 Location: Mac. Robertson Shelf

Check Rotor Play 0.1 - 0.5mm: ✓ Check Vane Assembly: ✓ Check RCM Cotter Pin: ✓

Check All Mooring Shackles Lock-Wired: ✓ Check Transmissometer Path Clear: ✓

Date/Time in Water: 24/2/97 1131 hrs [✓ GMT]/local/other __________

Date/Time Mooring Complete: __/__/__ ________ hrs GMT/local/other __________

Date/Time First Reading: 24/2/97 1200 hrs [✓ GMT]/local/other __________

Latitude: 66 ° 54.86 Longitude: 64 ° 44.9 Water Depth 690 m

Geographic Setting: Nielsen Shelf Valley

Other Instruments on this Mooring: __________

Sketch Mooring Set-up On the Back of this Page: ___

ATTN: Peter HARRIS

	Ref.	Temp	Cond.	Xmissometer	Current Direction	Current Speed.
1:	7	96	12	20	0	43
2:	71	1001	0	965	910	0
3:	71	1004	0	970	918	216
4:	71	1008	0	965	918	995
5:	71	1011	0	970	961	364
6:	71	340	0	965	213	0
7:	71	422	391	592	216	0
8:	71	603	390	0	217	0
9:	71	723	391	0	217	0
10:	71	804	391	965	219	0

Number of Listed Records: 11

Test Record for RCM7 S/No: 11464

Each parameter was "affected" in turn, and results recorded as shown. OK.

New Main Lithium & 2x 9V Lithiums fitted 20-12-96 ✓

DSU (S/No: 7328) - Erased & memory check performed. 20.12.96 ✓

Date set, & clock set to GMT (ie 11 hours behind Hobart Time) ✓

New 'o' rings fitted & greased.

Temp. Range set to Low (1)

Time interval set to 8 (1 Hour)

Sta 22

ANTARCTIC
C R C

University of Tasmania
GPO Box 252C
Hobart Tasmania 7001
Ph: (002) 202 504
Fax: (002) 202 973

Current Meter Deployment Form

Instr. Serial Number 11594 Data Storage Unit No. 7726

Sensor	Serial No.	Range		Checked by	Date
Temperature		-2.6-5.4	°C	P. Harri	24-2-97
Conductivity		0-77	mmho/cm		
Pressure	N/A		psi		
Transmissometer	608	25cm path			
Compass	20317		°		
Rotor Counter	2276		revs/count		

Pre-Deployment Checks

Main battery type: Aurora 3382 Voltage: ________ Date: ________

Secondary battery type: Ultralife Voltage: ________ Date: ________

Date/Time Switch On: 24 / 2 / 97 0300 hrs [✓ GMT]/local/other __________

Sampling Interval: 10 minutes Transmissometer Path Blocked from: 0500 to 0900 hrs = 4 (No. of Records) Check "O" ring: ✓ Check "C" Clamps: ✓ Check Zinc Anodes: ✓ Check Case Alignment: ✓ Check Rotor Bearings: ✓ Acoustic Release Type / Serial No.: 866 / 200 Acoustic Release Frequency Code: Release Code A Checked by: P. Harri

Enable Code B

Recieve 11.5 kHz
Transmit 12.0 kHz

Deployment Checks

Name of Ship: Aurora Australis Cruise No.: 186 Location: Mac. Robertson Shelf

Check Rotor Play 0.1 - 0.5mm: ✓ Check Vane Assembly: ✓ Check RCM Cotter Pin: ✓

Check All Mooring Shackles Lock-Wired: ✓ Check Transmissometer Path Clear: ✓

Date/Time in Water: 24/2/97 ~~[illegible]~~ 1235 hrs [✓ GMT]/local/other __________

Date/Time Mooring Complete: __/__/__ ________ hrs GMT/local/other __________

Date/Time First Reading: 24/2/97 1300 hrs [✓ GMT]/local/other __________

Latitude: 66 ° 56.04 Longitude: 64 ° 56.10 Water Depth ~~690~~ 363 m

Geographic Setting: Nielsen Valley

Other Instruments on this Mooring: ______________________

Sketch Mooring Set-up On the Back of this Page: ___

ATTN: PETER HARRIS

	Ref.	Temp	Cond.	Xmissometer	current Direction	current speed.
1:	7	96	12	20	3	49
2:	581	1023	0	1013	955	0
3:	581	1023	0	1016	952	304
4:	581	1023	0	1016	948	952
5:	581	1023	0	1011	688	968
6:	581	293	1	1016	667	80
7:	581	533	0	442	132	0
8:	581	688	0	0	135	0
9:	581	789	390	1013	135	0
10:	581	858	39	1014	135	0
11:	581	984	0	1016	135	0

Number of Listed Records: 12

Test Record for RCM 7 S/No: 11594

Each parameter was "affected" in turn, and Results recorded as shown OK ✓.

New Main Lithium & 2 × 9V Lithiums fitted 20.12.96 ✓

DSU Erased & Memory check performed (S/No. 7726) 20.12.96 ✓

Date set & clock set to GMT (ie. 11 hours behind Hobart time) ✓

New 'O' rings fitted & greased.

Temp. range set to Low (1)

Time interval set to 8 (1 hour)