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SEDIMENTATION AND OCEANOGRAPHY BENEATH THE MCMURDO ICE SHELF AT WINDLESS BIGHT, 2006

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Executive Summary

This report documents the field activities, procedures and initial results of the most recent phase of an oceanographic and sedimentological investigation of the water column and shallow sub-seafloor sediments under the McMurdo Ice Shelf (MIS). The study site (HWD3-06) was located ~15 km west of Ross Island (77.91680°S, 167.30888°E), and ~ 5 km west of two sites (HWD03-1 and -2) studied in 2003 (Barrett et al., 2005). The site was accessed by a hot water drill system being field-tested for the ANDRILL Programme. A hole of ~800 mm diameter and 97 m depth was made through to the base of the ice shelf and kept open for four days. The seafloor was encountered at a depth of 854 m below the top of the ice shelf.

Here we present results from: (1) A high-frequency (3.5 kHz) seismic experiment, (2) seafloor photography, (3) a series of short (<40 cm) sediment cores and (4) temperature and salinity profiling through the water column.

The 3.5 kHz sub-bottom profile recorded distinct reflectors up to 275 m below the seafloor (mbsf), with weaker reflectors evident to 675 mbsf. This is unusually deep for 3.5 kHz penetration and most likely represents acoustic artifacts generated by reverberation within the ice shelf.

Eight gravity cores were collected. Seafloor sediments consist of a sandy diamict with pebbles up to 35 mm in diameter. The diamict was noticeably more compacted below 0.32 mbsf, suggesting deposition beneath grounded ice. Two radiocarbon ages indicate that grounded ice lifted off at this site sometime after 13,000 yr BP. To complement the interpretation of these cores, we analysed additional cores from earlier cruises (Deep Freeze 1980) in the Ross Sea and McMurdo Sound, and the data obtained during these analyses are included as an appendix in this report. Seafloor photos show an abundant benthic fauna and a noticeable lack of bedforms, indicating weak bottom flow at this site.

Water column temperature profiles showed a “warm” tongue between 97 and 184 m below surface (i.e., immediately beneath the ice shelf) with temperatures varying between -0.86°C and -1.04°C over a tidal cycle. This was almost 1°C warmer than observed in 2003, suggesting that the tongue is sourced directly from Antarctic Shelf Water. By contrast, in 2003 this tongue was saltier and colder, with characteristics that were intermediate between Low Salinity Shelf Water and Shallow to Deep Ice Shelf Water. Water below this tongue gradually cooled between 170 and 366 m from -1.68°C to -1.92°C, before becoming mostly isothermal.

Salinity profiles showed a steady increase from ~34.2 to 34.54 psu sharp gradient in the 100 m thick layer beneath the ice shelf. Below this depth, salinity gradually increased to 34.78 psu at 841 m. Compared to 2003, there was little variability in the water column structure over a tidal cycle.

Data from the survey will contribute to a broader understanding of the ice shelf dynamics and depositional history of the region during the most recent glacial-interglacial cycle of the West Antarctic Ice Sheet (WAIS) system. In October 2006, the ANDRILL Programme will attempt recovery of a continuous 1200 m sediment core from beneath the MIS near the HWD2-06 site. This, and previous shallow-sub seafloor studies (HWD03 and DF80), will guide the interpretation of the numerous glacial-interglacial climate cycles anticipated in Plio-Pleistocene ANDRILL record.

1 INTRODUCTION

This report presents new data on sedimentation and oceanographic conditions beneath the McMurdo Ice Shelf, south of Ross Island, measured in preparation for deep drilling in 2006/07 as part of the ANDRILL project. Fieldwork was carried out over a four-day period following the completion of a test hot water drill (HWD) hole (K001A; 77.91680ºS, 167.30888ºE) made using new ANDRILL equipment. This work follows on from a previous survey undertaken in 2003, when two HWD access holes were made through the McMurdo Ice Shelf (Figure 1), and sub-ice shelf measurements and sediment cores were taken (Barrett et al., 2005). Data from this survey will contribute to a broader understanding of the relationship between ice shelf dynamics and sedimentation in the McMurdo Sound region. Ultimately, we hope to use this information to interpret changes in the extent of the ice shelf over the past several million years, and therefore its sensitivity to climate change, based on expected sediment recovery from the ANDRILL core.

We also included data (Appendix 2-5) obtained from cores collected around Ross Island from USGCC Glacier "Deep Freeze" 1980 cruise. We conducted detailed descriptions and sampling on these cores during a 2006 visit to the Antarctic Research Facility at Florida State University, Tallahassee. These data have been integrated with the HWD cores taken in 2003 and 2006 to develop a retreat history of the Ross Ice Sheet/Shelf since the Last Glacial Maximum (McKay et al., submitted).

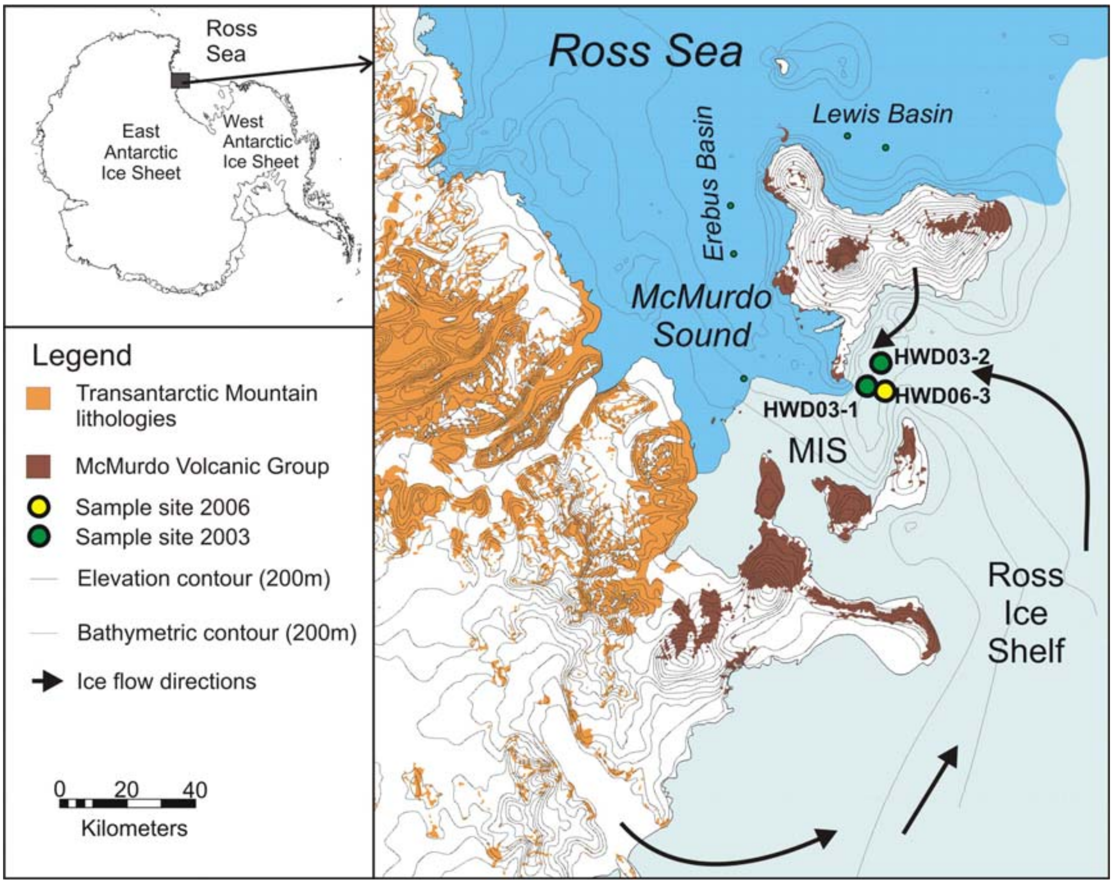


Figure 1. Map showing location of HWD06 site relative to the HWD03 sites drilled in 2003.

2 3.5 kHz SUB-BOTTOM PROFILE

High resolution, sub-bottom profiling was carried out using a GeoAcoustics receiver (Model 5210) and transmitter (Model 5430A) coupled to a single 3.5 kHz Massa transducer. The transducer was connected to the receiver using a 150 m long cable, which allowed deployment of the transducer at 100 m, 2.5 m below the base of the ice shelf. Profiles were simultaneously recorded for approximately two minutes at each pulse length on paper chart and analogue and digital tape recorders. The settings for the sub-bottom profile recordings are shown in Table 1. Settings for 3.5 kHz sub-bottom profiling.

Table 1. Settings for 3.5 kHz sub-bottom profiling.

Trigger:	2000 ms
Low pass filter cut off:	1kHz
High pass filter cut off:	10kHz
Gain:	40dB
Pulse cycles (length):	4, 8, 16, 32
Sweep:	1500 and 2000 ms

Analogue data from the chart recorder show a strong seafloor reflector at 1042 ms two-way travel time. Assuming a constant p-wave velocity of 1447 ms^{-1} for the seawater beneath the shelf ice (mean velocity for a salinity range of 33 to 34.8‰ and temperature range of -1.5 to -2°C), a water depth of 754 m is calculated between the transducer and the seafloor. Together with the shelf ice thickness, the total distance from the ice surface to the seafloor is determined as 854 m, which compares well with the seafloor depth measured by wire line of 855-856 m.

The sub-bottom profile shows 35 distinct reflectors up to 350 ms two-way travel time (TWTT) below the seafloor (Figure 2). Below that level, apparent reflectors become weak and indistinct but are still visible down to about 860 ms TWTT. To estimate the sound velocity in sediment, we have used the median p-wave velocity measured in core HWD03-1 C4 (1571 ms^{-1}) to calculate the depth of sub-bottom penetration. In this case, 350 and 860 ms correspond to 275 m and 675 m below the seafloor, respectively.

However, the depth of acoustic penetration reported here is anomalously large (30-100 m sub-bottom penetration is more typical of marine sediments in McMurdo Sound) and is most likely an artefact caused by the addition of energy from intra-ice shelf reverberations (~40Hz) to the outgoing pulse (S. Henrys, pers. com. 2006). As a result, the source pulse is in effect a complex function spread over ~600 ms and every reflector (sea-floor and sub-seafloor) will be convolved with this long source function, producing a complex and lengthy coda. Future 3.5 kHz sub-bottom profiles should consider placing the transducer closer to the seafloor to minimise ice shelf reverberation.

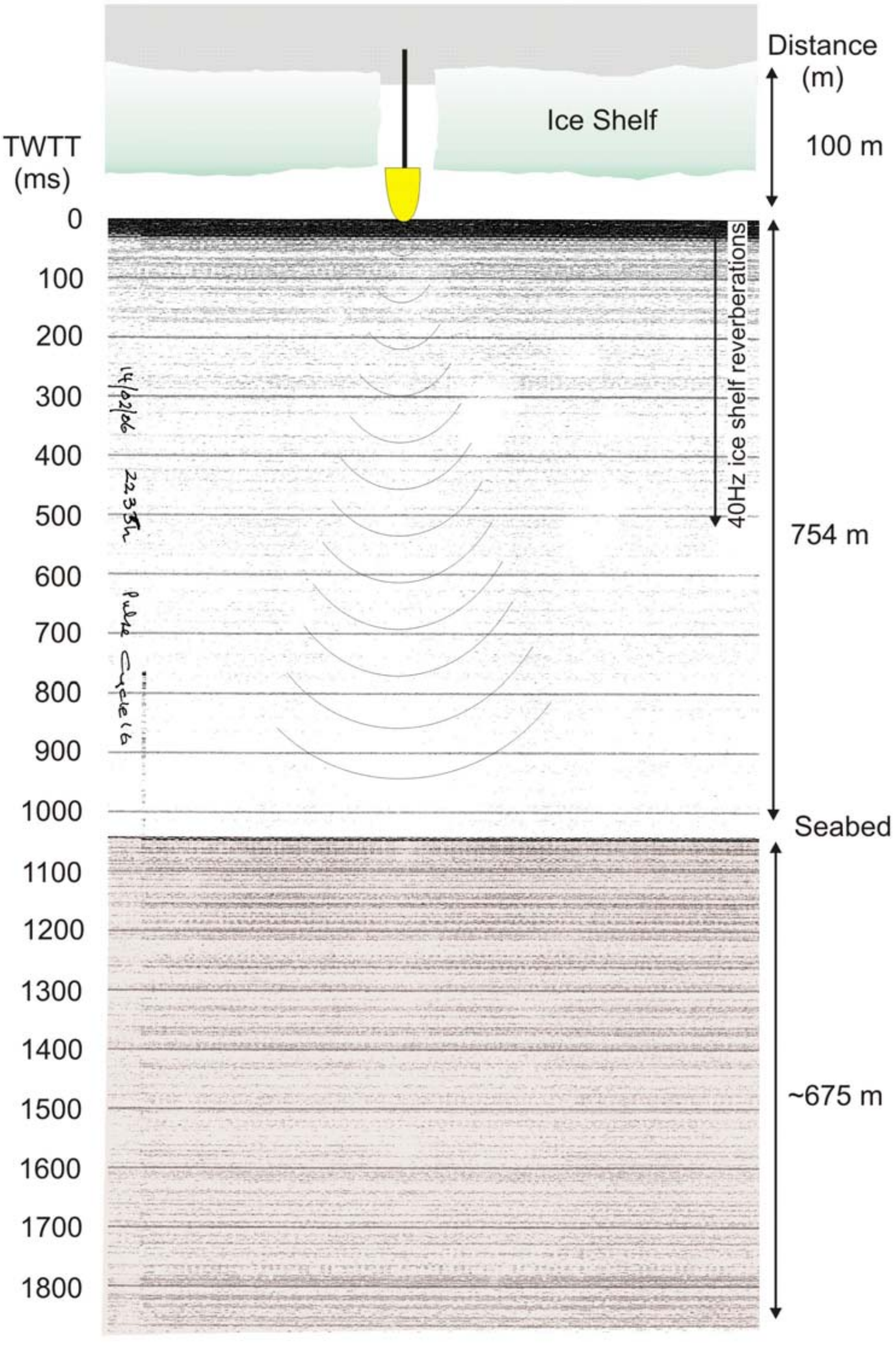


Figure 2. 3.5 kHz sub-bottom profile from the analogue chart recorder using a pulse length of 16 cycles. The transducer lies ~2.5 m below the base of the ice shelf. TWTT = two-way travel time (in milliseconds). Note 40 Hz reverberations from the ice shelf contributing to the source function which help to create sub-seafloor acoustic artefacts.

3 BENTHOS CAMERA SYSTEM

A series of 24 photographs of the seabed were obtained using a Benthos 371 film camera and a Benthos 381 Flash unit supplied by the University of Hawaii. All photographs were taken with Kodak T_{max} 400 ASA black and white 35 mm film. Photographs 1-12 were taken with an aperture of 8 and 13-24 with an aperture of 5.6. In each case, the distance above the seabed and flash illumination was identical. In contrast with normal practice, the camera and flash units were mounted one above the other to allow them to pass through the hot water drill hole (Figure 3). As a result, the back of the flash unit appears in the centre of each photo and obscures the trigger weight and compass hanging below it.

Photographs were taken when the trigger weight touched the bottom, releasing the tension on the trigger and closing an internal switch which fires the flash and opens the camera shutter. Lifting the trigger weight off the bottom reset the flash and shutter. Trigger release was detected by a load-sensitive winch, which enabled accurate control of the number of exposures and prevented the flash unit impacting the seabed. Film was processed in the field using a dark bag. Although 12 photos were taken in quick succession at each location, there is no sediment disturbance evident after repeated raising and lowering of the trigger weight. In addition, no bedforms are visible, indicating that current velocities are very low across the seabed. A large number of gravel clasts up to ~10 cm in diameter are apparent in every image (Figure 4). Combined with sediment recovered in the grab sample, it appears the overall texture is extremely poorly sorted, unconsolidated, sandy diamict. There is an abundant benthic fauna visible in all images, which is consistent with that recorded by recent underwater photography carried out from *RV Tangaroa* in the Ross Sea (Figure 5). The lack of scouring around clasts together with preserved bioturbation structures, point to a weak bottom flow.

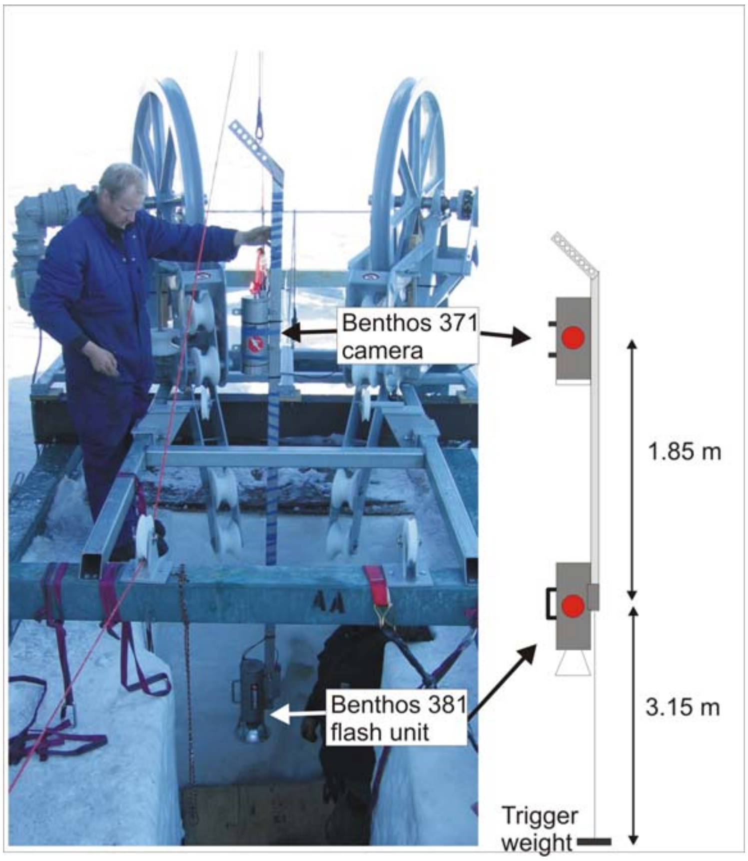


Figure 3. Benthos bottom camera system. Note the hole through the ice shelf is covered with plywood in this photo and the trigger weight has not been attached.

Figure 4. The seabed at HWD-06. The back of the flash unit is visible in the centre of the photo. Field of view is ~4.8 m.

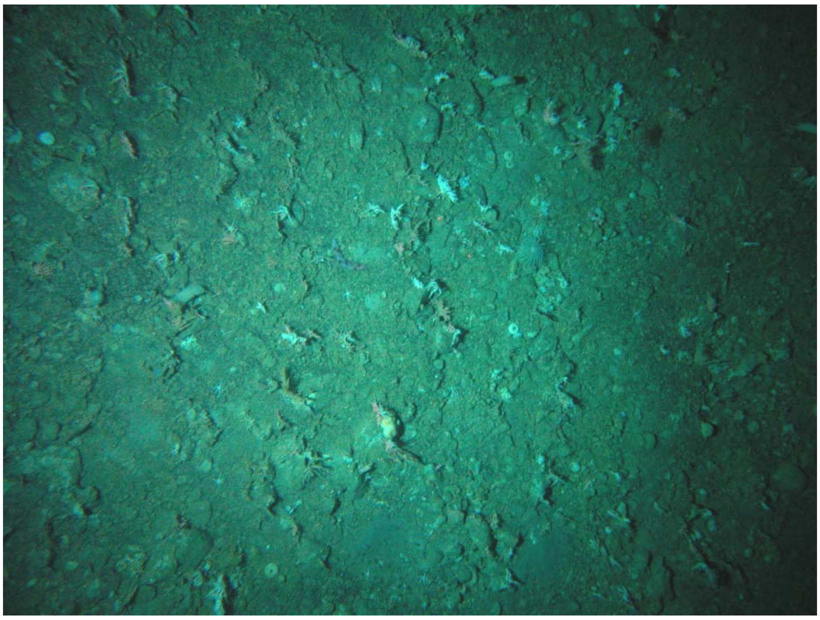


Figure 5. The seabed at the continental shelf edge in the eastern Ross Sea. Note similar biota to that in Fig. 4.

NIWA, 2006. Ross Sea Biodiversity Report in Voyage Report TAN0602. NIWA Library, Wellington.

4 SEDIMENT DESCRIPTION

4.1 Introduction

A modified "Shipek" grab and a gravity corer, built by the Alfred Wegener Institute (Germany), were lowered by winch to collect sediment samples from the sea floor. A total of two grab and eight core samples were collected (Appendix 1). Five cores were collected in stainless steel barrels, and the remaining three in clear plastic barrels.

One core (HWD06-3-11) recovered only the top few centimetres of the seafloor and was subsequently bagged for initial on-site analysis. It is notable for a striated granite clast measuring 49 mm in length (Figure 6). The maximum core length for the plastic barrels was 34 cm (HWD06-3-8). This core was split, described, and sampled for radiocarbon (^{14}C) dating, grain size and petrographic analysis. The stainless steel barrels have yet to be split, but estimate a maximum core length of 40 cm.

Figure 6. Striated granite clast from HWD06-3-11 (left photo). Faceted basalt clasts from compacted diamiction at 32-34 cm depth, HWD06-3-8 core (centre and right photos). Scale bar is in centimetres.

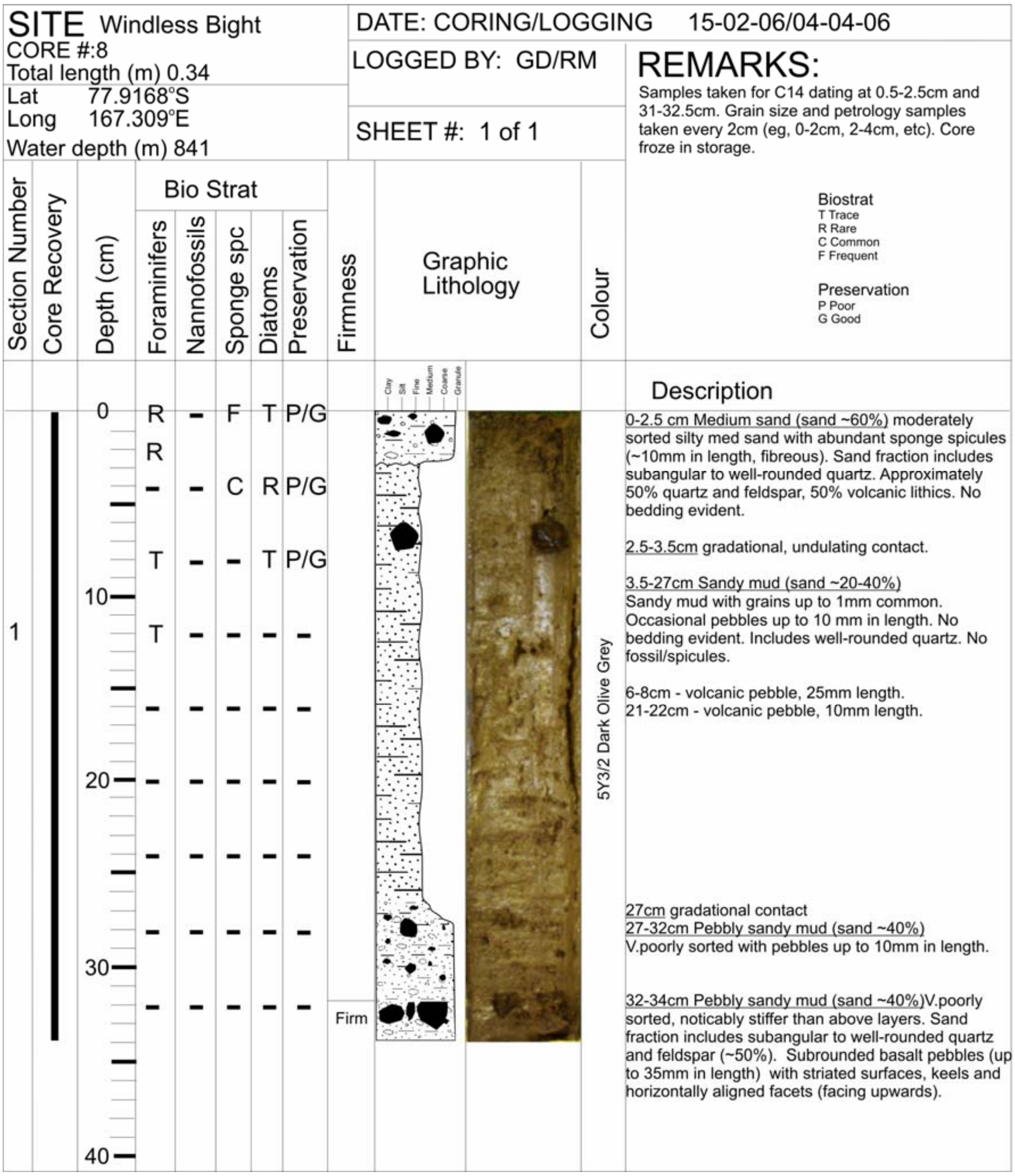
4.2 Core description

HWD06-3-8 was described in terms of lithological units based on colour, sedimentary structures and textures, as shown in Figure 7. Four distinct units are identified:

- Unit 1 (0-3.5 cm) is a medium sand with abundant siliceous sponge spicules. Sand fraction contains approximately 50% quartz and feldspar, and 50% volcanic grains.
- Unit 2 (3.5-27 cm) is a soft sandy mud (diamict) with occasional pebbles (up to 25 mm long) and coarse sand. The upper part of this unit contains rare forams and diatoms, and occasional sponge spicules.
- Unit 3 (27-32 cm) is also a pebbly sandy mud (diamict), similar in texture and colour to the Unit 4, but is less firm. The contact is sharp and corresponds to the top of the faceted pebbles described above.
- The oldest unit (Unit 4, 32-34 cm) is a pebbly sandy mud (diamict) with sub-rounded basaltic pebbles up to 35 mm long. The top of this unit is

characterised by three striated basaltic pebbles displaying faceted faces and keels (Figure). These facets appear to be horizontally aligned and are facing upwards within the core. The unit is noticeably firmer than overlying layers. Quartz and feldspar constitute approximately 50% of the coarse sand fraction.

Samples were collected every 2 cm for grain size and petrographic analyses. These are currently being analysed. Grain size results are shown in Figure 8.



SITE Windless Bight
CORE #:8
Total length (m) 0.34
Lat 77.9168°S
Long 167.309°E
Water depth (m) 841

DATE: CORING/LOGGING 15-02-06/04-04-06
LOGGED BY: GD/RM
SHEET #: 1 of 1

REMARKS:
Samples taken for C14 dating at 0.5-2.5cm and 31-32.5cm. Grain size and petrology samples taken every 2cm (eg, 0-2cm, 2-4cm, etc). Core froze in storage.

Description

0-2.5 cm Medium sand (sand ~60%) moderately sorted silty med sand with abundant sponge spicules (~10mm in length, fibreous). Sand fraction includes subangular to well-rounded quartz. Approximately 50% quartz and feldspar, 50% volcanic lithics. No bedding evident.

2.5-3.5cm gradational, undulating contact.

3.5-27cm Sandy mud (sand ~20-40%)
Sandy mud with grains up to 1mm common. Occasional pebbles up to 10 mm in length. No bedding evident. Includes well-rounded quartz. No fossil/spicules.

6-8cm - volcanic pebble, 25mm length.
21-22cm - volcanic pebble, 10mm length.

27cm gradational contact
27-32cm Pebbly sandy mud (sand ~40%)
V.poorly sorted with pebbles up to 10mm in length.

32-34cm Pebbly sandy mud (sand ~40%)V.poorly sorted, noticably stiffer than above layers. Sand fraction includes subangular to well-rounded quartz and feldspar (~50%). Subrounded basalt pebbles (up to 35mm in length) with striated surfaces, keels and horizontally aligned facets (facing upwards).

Figure 7. Core log for HWD06-3-8.

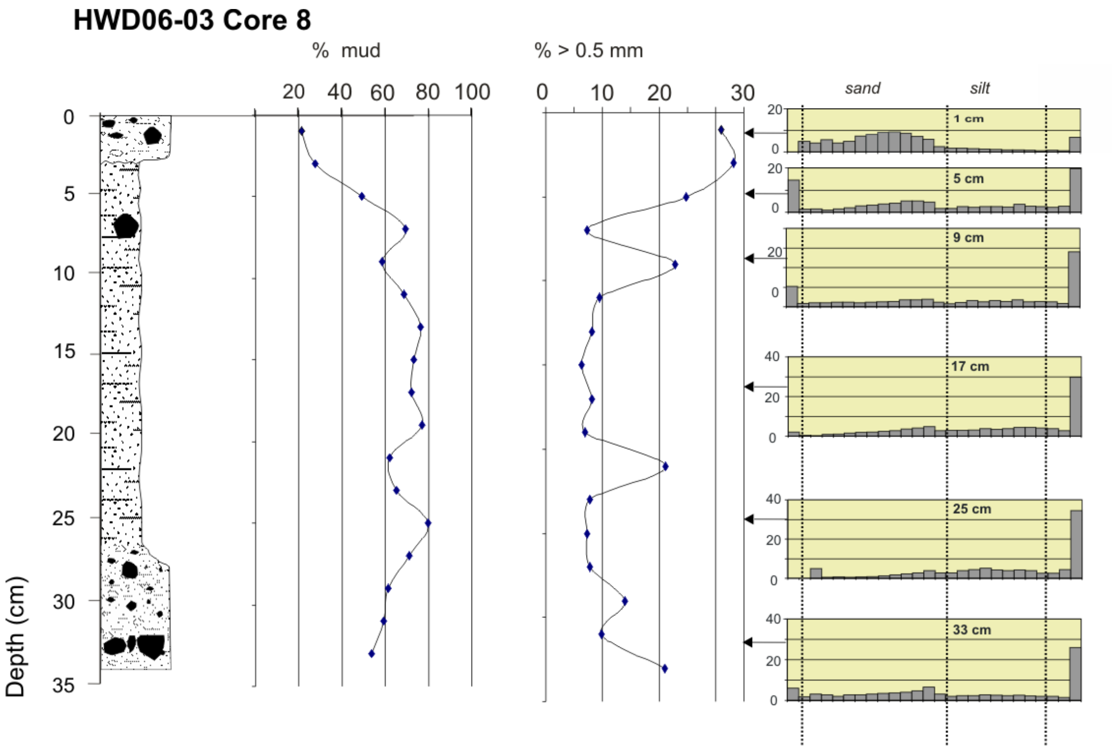


Figure 8. Histograms of grain size results show an increase in sand in upper 5 cm, with a relatively even distribution beneath this. Between 5 and 29 cm, the distribution is dominated by mud, in particular by clays finer than 1 μm. The largest gravel clasts (>10 mm) were removed prior to grain size analysis.

4.3 Radiocarbon ages

Two bulk samples were taken for dating at the Rafter Laboratory, GNS Science, and ^{14}C ages obtained from total organic carbon in acid insoluble organic (AIO) residues. The results of these analyses are presented in Table 2

Table 2. ^{14}C ages from total organic carbon in AIO residues from core WB06-3-8.

Lab Code #	*Depth (cm)*	*^{14}C age (yrs BP)*	*δ^{13}C ‰*	*Calibrated age (yrs BP)*
NZA 25403	0.5-2.5	4675±40	-28.0	5465-5285 (2σ)
NZA 25420	31.0-32.5	10982±60	-24.3	13049-12845 (2σ)

4.4 Discussion

Although a detailed lithological interpretation is reliant on the establishment of a ^{14}C chronology and further laboratory analysis, some observations can be made on the basis of the data currently available. First, the petrography of the sand grains shows that quartz is abundant, indicating a provenance in the Transantarctic Mountains. Second, the presence of common gravel-sized clasts and the poorly-sorted nature of the sediment suggest sub-glacial transport rather than deposition and reworking by ocean currents. The increase in firmness of the matrix in the lower 2-3 cm of the core and presence of faceted pebbles may be evidence for deposition beneath grounded ice. The combination of factors suggests this site has been covered with an ice shelf of variable thickness throughout the period of time represented by the core.

5 PHYSICAL OCEANOGRAPHY

5.1 Introduction

Ross Sea shelf waters originate from Circumpolar Deep Water (CDW) that has upwelled near the Antarctic Slope Front (e.g., Jacobs et al., 1985; Table 3). Through the introduction of brine rejected from freezing ice, precipitation and melt water, together with cooling and mixing processes, the following shelf water masses form:

- **Antarctic Surface Water** (AASW),
- **High and Low Salinity Shelf Water** (HSSW and LSSW),
- **Ice Shelf Water with shallow and deep components** (SISW and DISW).

The extent of ice shelf modification of CDW makes the Ross Sea a significant source of very cold, saline bottom water that helps drive the global thermohaline *Ocean Conveyor* system (e.g., Jacobs et al., 1985). The data obtained from HWD06-3, together with previous observations (e.g., Heath, 1977; Barrett et al., 2005) provide short-term observations of water mass variability in this key "bottom water factory".

Table 3. Physical oceanographic characteristics of Ross Sea shelf waters; modified from Jacobs et al. (1985).

Water mass and boundary	***Depth [m]***	***Potential Temp θ [^{0}C]***	***Salinity [ppt]***	***Comments***
Antarctic Surface Water – open shelf [**AASW**]	0 -100	0 to -1.5 x = -0.96 σ = 0.57	34.1 to 34.5 x = 34.12 σ = 0.18	Upwelled CDW; found in all Ross Sea in summer; mainly in mixed layer
Antarctic Surface Water near RIS [**AASW**]	~50 -100	x = -1.17 σ = 0.33	x = 34.24 σ = 0.13	Not modified AASW but CDW affected by contact with RIS
Temperature Minimum	10 -100	x = -1.64 σ = 0.18	x = 34.3 σ = 0.05	Lies in halocline a base of AASW
Shelf Water Low Salinity Shelf Water [**LSSW**]	~100 -500	x = -1.59 σ = 0.21 with warm core of -0.84	x = 34.53 σ =0.04	Also Ross Sea Shelf Water [RSSW]. Most widespread shelf water; lies midway AASW and HSSW
High Salinity Shelf Water [**HSSW**]	~500 -750	x = -1.91 σ = 0.02	x = 34.84 σ = 0.05	Densest water in Antarctic ocean with low T & high S
Ice Shelf Water [**ISW**]				Assoc. with glacial ice and T < sea surface freezing
Shallow [**SISW**]	~50 - 250 @RIS	x = -2.04 σ = 0.04	x = 34.36 σ = 0.02	Probably formed from interaction ice shelf &/or sea ice with LSSW
Deep [**DISW**]	~250 -500 @RIS	x = -2.03 σ = 0.08	x = 34.68 σ = 0.04	Probably formed from interaction ice shelf &/or sea ice with HSSW
Antarctic Slope Front	10-45 km seaward shelf break; strong T / S gradients and currents; separates CDW from shelf waters			
Circumpolar Deep Water [**CDW**]	Off-shelf upwelling to 100m	1.25 to –1.0 x = 1.17 σ = 0.25	34.5 to 34.72 x = 34.7 σ = 0.02	Upwells along slope and is source for all shelf waters by cooling, mixing and addition of brine, melt-water, precipitation

5.2 Methods

Hot Water Drill site HWD06-3 penetrated 97.5 m of the McMurdo Ice Shelf. Sea level established within the hole at 17.3 m below the site datum (i.e., plywood floor at the top of the HWD06 drill hole) and all measurements are referred to sea level unless otherwise specified. A total of eight hydrological casts were made using a Seabird Electronics 37-SM CTD set to sampling rate of 5s. The instrument's vertical travel speed averaged 30 m/minute but was variable resulting in between ~200-400 measurements on each downcast and upcast. Data were converted to salinity, potential temperature, density (θ t) and depth (m) using the Seabird Seaplot software.

CTD casts were made at ~2hr intervals to observe water mass properties during a full diurnal tidal cycle. Tidal data for Ross Island (Table 4; Figure) were derived from the Tide and Current Predictor:
http://tbone.biol.sc.edu/tide/tideshow.cgi?site=Ross+Island%2C+Antarctica

Table 4. High and low tides for Ross Island (77.8667° S, 166.8000° E) over the 4 day period encompassing the CTD casts with Test Cast HWD06-3-12 ON 1318hr, 16.02.06 and HWD06-3-17_23 FROM 0934hr to 2151hr, 18.02.06.

Date	***Time***	***Event***	***Tidal height (m)***
2006-02-16	04:44 NZST	High Tide	0.71
2006-02-16	10:05 NZST	Moonset	
2006-02-16	19:36 NZST	Low Tide	0.35
2006-02-16	23:06 NZST	Moonrise	
2006-02-17	05:24 NZST	High Tide	0.61
2006-02-17	12:47 NZST	Moonset	
2006-02-17	21:51 NZST	Low Tide	0.46
2006-02-17	21:57 NZST	Moonrise	
2006-02-18	16:04 NZST	Moonset	
2006-02-18	17:12 NZST	High Tide	0.59
2006-02-18	20:08 NZST	Moonrise	
2006-02-19	05:34 NZST	Low Tide	0.40
2006-02-19	20:25 NZST	High Tide	0.71

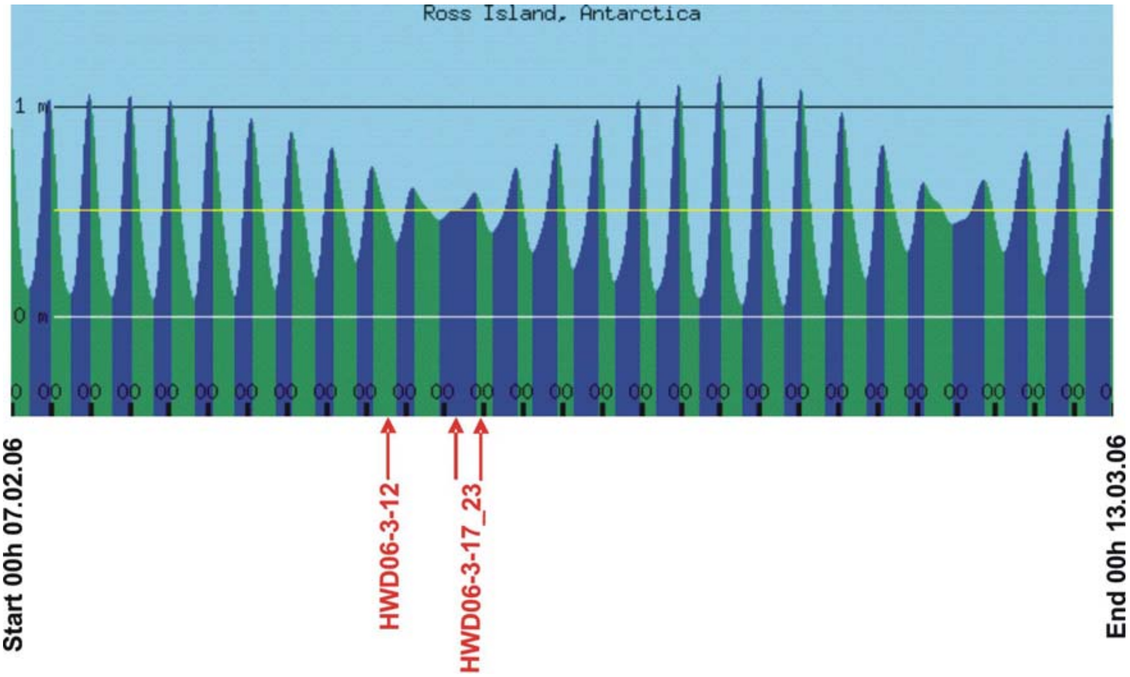


Figure 9. Predicted tidal record for Ross Island with Test Cast [HWD06-3-12] and tidal station HWD06-3-17_23.

Eight casts were run (Stations HWD06-3-17 to 23) including an earlier test cast (Station HWD06-3-12). Tidal time-series sampling commenced at 0934 hr, 18.02.06, with casts made at 1.5 hr to 3.0 hr intervals. The resultant up-down profiles are very similar for each of T and S in depths >200 m, but departures occurred in the upper water column especially with salinity, which exhibited diminished and irregular values for the down-profile. In contrast, differences in the up-profiles were relatively minor. We suggest that the variability in salinity is due largely to entrapment of ice near the CTD conductivity cell either during its descent through the ice shelf hole, where slush ice was observed at sea level, or approaching the base of the ice shelf where ice platelets may have collected. Accordingly, this report focuses on the upcast T and S data (Figure 10 to Figure).

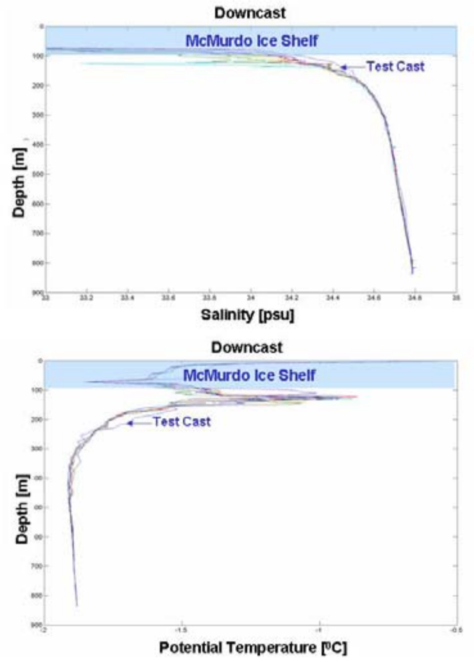


Figure 10. Downcast T/S data for all casts emphasizing the variability of the upper part of the water column which probably reflects ice effects on the CTD sensors.

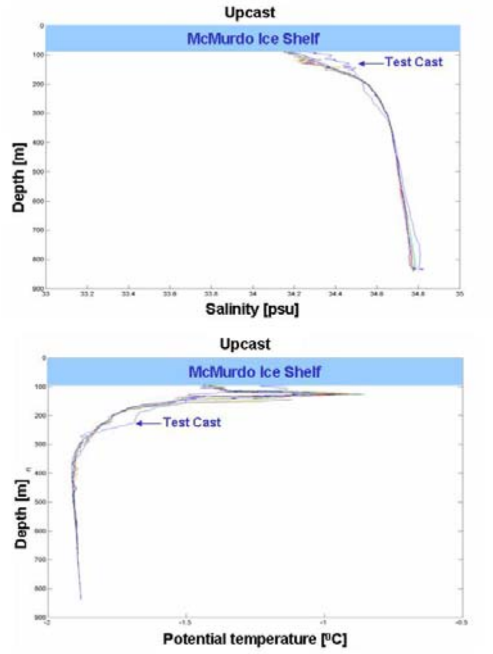


Figure 11. Upcast T/S data for all casts highlighting improved data consistency.

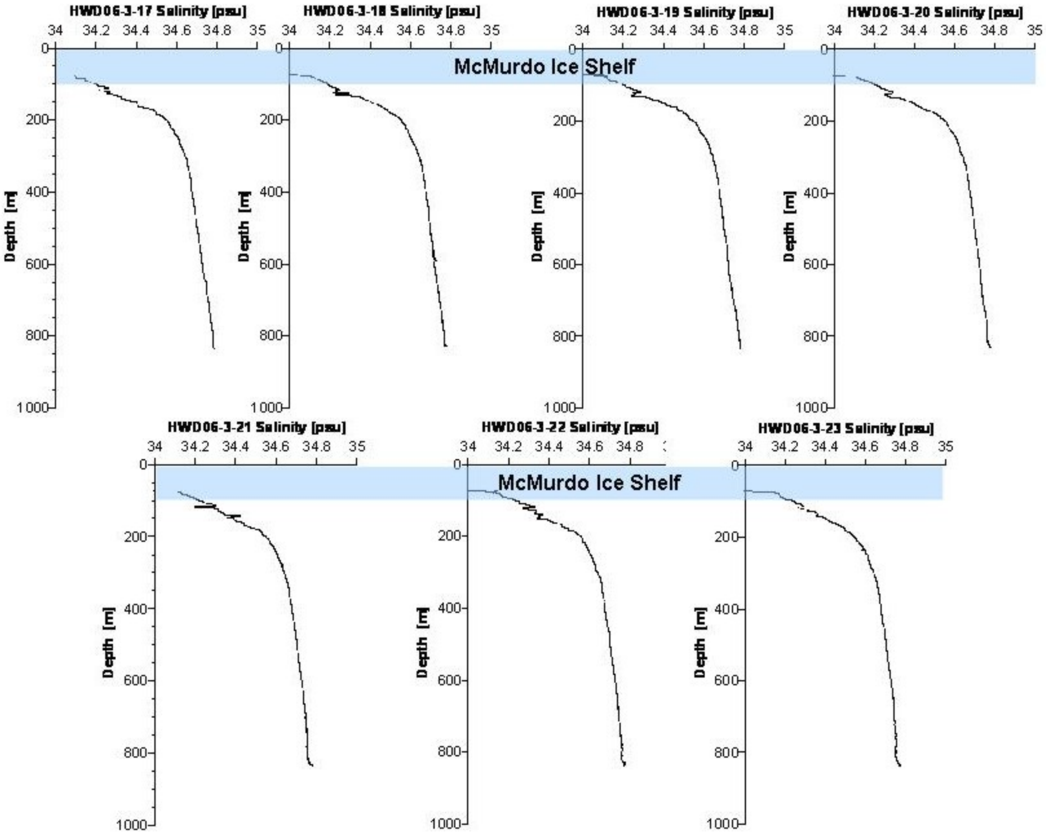


Figure 12. Plots of salinity over 1 tidal cycle showing consistent structure.

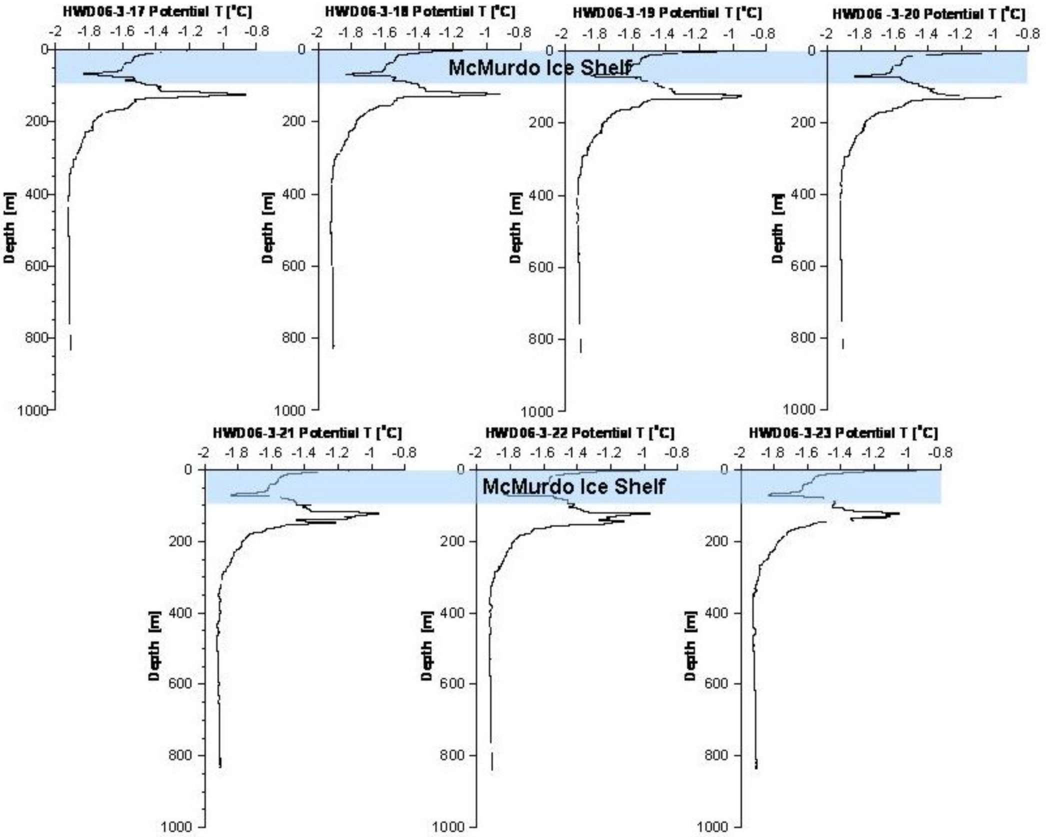


Figure 13. Plots of potential temperature over 1 tidal cycle highlighting warm water tongue below ice shelf.

5.3 Results: Water Mass Structure

Salinity profiles are simple, comprising a sharp gradient in the 100 m thick layer under the McMurdo Ice Shelf. There salinity increases rapidly from ~34.2 to 34.54 psu. Thereafter, values increase gradually to a maximum of 34.78 psu at 841 m (Figure and 12). There was very little variability over the neap tidal cycle, but comparison with the test cast HWD06-3-12, made two days earlier, revealed small changes in salinity with the sub-ice, low salinity layer being thinner and saltier compared to the main tidal station measurements (Figure 11).

In comparison, temperature profiles have a more defined structure that is persistent throughout the tidal cycle, but which differs slightly from the previous test cast (Figure and 11). The 70-85 m range below the ice is occupied by a "warm" tongue of water with temperatures reaching –0.86°C, but reducing to -1.04°C at the end of the tidal cycle (Figure). Water below the tongue cooled gradually from –1.68°C at 170 - 184 m depth to –1.92°C at 356 - 366 m depth. Below this transitional zone, the water mass is near-isothermal, exhibiting a very slight warming of 0.02°C with depth (Figure 11 and 13). Over the tidal cycle there was an upward expansion of the thermal structure with "warm", transitional and cold isothermal layers shallowing by ~10 m. The earlier test cast shows a similar thermal structure except that the uppermost warm layer is more substantial, extending right to the ice-water interface whereas the tidal station "warm" tongue is separated by thin, cooler layer.

In terms of the shelf water masses outlined by Jacobs et al. (1985) (Table 3; Figure), the T/S characteristics for the aforementioned zones show that the "warm" tongue of Zone A is essentially Antarctic Surface Water (AASW), whereas Zones B and C are intermediate between Low Salinity Shelf Water (LSSW) and Deep Ice Shelf Water (DISW) with Zone C being more related to DISW (Table 5; Figure).

Table 5. Water column zones based on T/S profiles.

Zone	*Depth range [m]*	*Salinity [psu]*	*Temperature [^{0}C]*
A warm	97 – 184	34.25 to 34.28	-0.86 to -1.04 [max]
B transitional	168 – 366	34.51 to 34.67	-1.68 to -1.92
C cold	366 – 841	34.67 to 34.79	-1.92 to -1.90

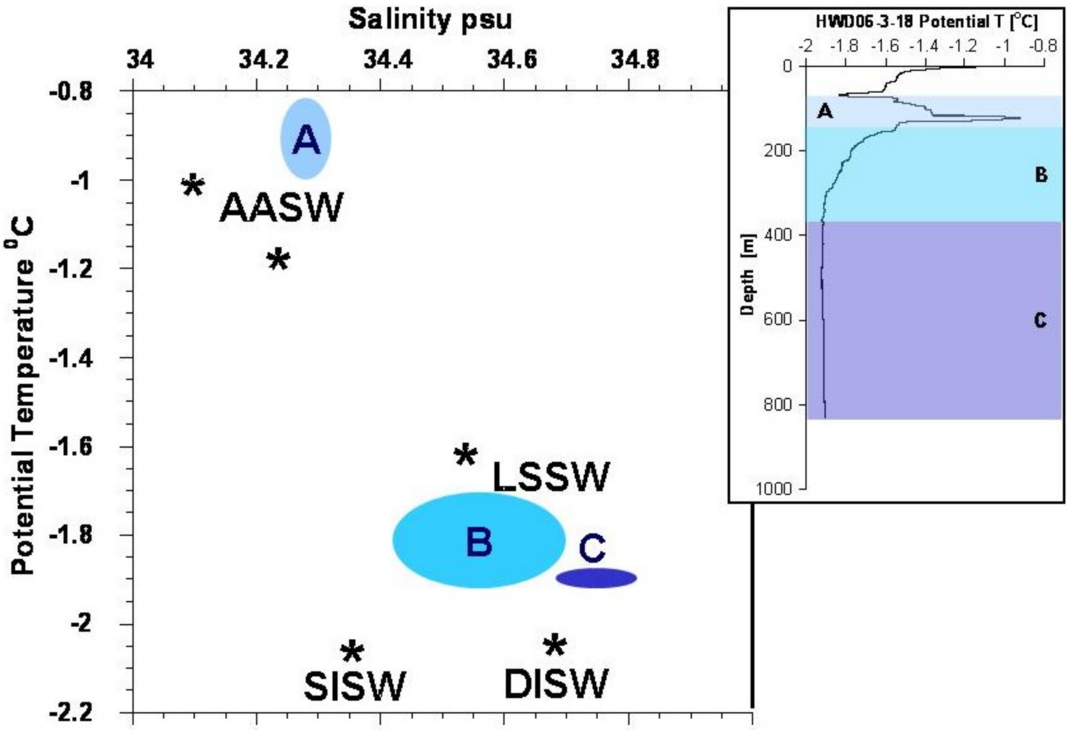


Figure 14. Mean T/S plot of main shelf water masses including Antarctic Shelf Water [AASW], Low Salinity Shelf Water [LSSW], Shallow Ice Shelf Water [SISW] and Deep Ice Shelf Water [DISW]. A, B and C refer to water mass zones at Site HWD06-3 as indicated from inset of potential temperature profile at HWD06-3-18.

5.4 Discussion: Comparison with HWD03 (Sites 1 and 2)

CTD casts were made over tidal cycles at two other ice shelf sites in Windless Bight. The two sites were occupied in the austral summer of 2003 and the physical oceanography is reported in Barrett et al., (2005). While the basic water mass structures, observed in 2003 and 2006, are similar, there are also significant differences.

- Zone A in 2006 was almost 1°C warmer than in 2003.

- T/S data show Zone A waters in 2006 were sourced directly to Antarctic Shelf Water (Figure 14), whereas 2003 waters were saltier and colder with characteristics that were intermediate between Low Salinity Shelf Water and Shallow to Deep Ice Shelf Water.
- While the 2006 structure was fairly constant over a tidal cycle, the 2003 structure displayed marked variability.
- Transitional Zone B was substantially thinner in 2006 compared to 2003.
- Basal Zone C was markedly thicker and near-isothermal in 2006, whereas the 2003 counterpart exhibited incursions of slightly less cold water in its upper reaches.

Although it is beyond the scope of this field report to determine the causes behind the different physical oceanographic conditions in 2003 and 2006, it is nonetheless pertinent to draw attention to known differences in potential forcing mechanisms as a means of identifying future research in the region. Clearly, Zone A was substantially warmer in 2006. However, such warming is not unusual as revealed by two years of continuous temperature records collected in McMurdo Sound by Hunt et al. (2003). Their data show a strong seasonal warming of up to 1.0ºC in January-February of 1999-2001. Spot measurements by Heath (1977) and Littlepage (1965) suggest similar summer incursions in the region. In the case of the HWD06-3 data, the incursions are sourced directly to Antarctic Shelf Water (Figure).

The short time span and sporadic nature of the datasets allow for only tentative comments. In that light, the cold temperatures recorded in Zone A in 2003 may be anomalous, assuming summer warming is the norm. One possibility for the 2003 event could be a change in circulation in McMurdo Sound and Windless Bight, instigated by a blocking effect of the Sound by the giant B15 iceberg. It may be that the iceberg altered the circulation to inhibit incursions of Antarctic Shelf Water from the open continental shelf.

The stability of the thermal structure in 2006 contrasts with the tidally variable 2003 profiles – a feature that may simply reflect different phases of the lunar tidal cycle. The 2006 data were collected during the neap phase when tidal elevations were ~ 0.6 m above mean sea level (Figure). In contrast, the 2003 data were collected during periods that coincided with spring tides when flood tides were > 1 m above mean sea level. However, we do not discount modification of the 2003 tidal circulation by iceberg B15.

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APPENDIX 1: Experiments conducted through the HWD06 access hole at Windless Bight.

Station	*Date*	*Time (seafloor bottom)*	*Depth*	*Gear*	*Comments*
HWD06-3-1	14.2.06	Test run from 2227-2251 hr	MIS 97.5 m Thick	3.5kHZ=Octopus recorder, AIWA DAT Recorder; Thermal Printer	Potentially up to 400 ms penetration
HWD06-3-2	15.2.06	#1 1110 hr #2 1146 hr	832 m	Shipek grab	Attempt #1failed to trip, #2 small sample; olive grey v.poorly sorted muddy grv sand
HWD06-3-3	15.2.06	1222 hr	842 m	Shipek grab	Olive grey v.poorly sorted muddy grv sand, clasts up to 1 cm; worm tubes
HWD06-3-4	15.2.06	#1 1259 hr #2 1357 hr	842 m	Corer: #1 1 Pb Wgt Plastic barrel # 2 3 Pb wgts Stainless barrel	No sample; valve not closed; ~400mm core
HWD06-3-5	15.2.06	#1 1559 hr #2 1638 hr	844 m	Corer: #1 3 Pb wgts Plastic Barrel #2 3 Pb wgts, stainless barrel	Core barrel broken, no core; ~400 mm core; valve not closed
HWD06-3-6	15.2.06	1715 hr	842 m	3 Pb wgts, stainless barrel, short, no catcher	~300 mm core
HWD06-3-7	15.2.06	1755 hr	843 m	3 Pb wgts, stainless barrel, long [1.5 m], catcher	~300 mm
HWD06-3-8	15.2.06	1833 hr	842.m	3 Pb wgts, plastic barrel, short, no catcher	~340 mm - med-crs sand above gravelly, muddy sand
HWD06-3-9	15.2.06	1910 hr	842 m	3 Pb wgts; short plastic barrel	Core base lost during return to surface
HWD06-3-10	15.2.06	1947 hr	842 m	3 Pb wgts; short plastic barrel	Barrel lost
HWD06-3-11	15.2.06	2019 hr	842 m	3 Pb wgts, stainless barrel, long [1.5 m], catcher	Small core, bagged, contains 5 cm granite clast
HWD06-3-12	16.2.06	1353 hr	843 m	Microcat CTD SM37 on hot water winch 750m/hr	Successful cast
HWD06-3-13	16.2.06	2015-2044 hr	853 m*	Camera, b/w Kodak Tmax ASA400 F8, 12 shots	12 shots developed; flash hot spot in centre but seabed texture shown
HWD06-3-14	17.2.06	1600-1632 hr	856 m*	Camera, b/w Kodak Tmax ASA400; F5.6, 12 shots	Camera did not wind - no images
HWD06-3-15	17.2.06	1737 hr	841 m	Corer 3 Pb wgts; short plastic Si greased tube	220 mm core ; poorly sorted sandy mud; some carbonate

HWD06-3-16	17.2.06	1800 hr	841 m	#1; Corer 3Pb wgts; short plastic	No core; valve iced in opened position;
		1845 hr	839 m	#2; corer as above	Core 22 cm; poorly sorted sand on mud
HWD06-3-17	18.2.06	0934-1006 hr	841 m	CTD 5sec sample; 5 m above bed	Full data set
HWD06-3-18	18.2.06	1107-1242 hr	841 m	CTD 5sec sample; 5 m above bed	Full data set
HWD06-3-19	18.2.06	1339-1554 hr	841 m	CTD 5sec sample; 6 m above bed.	Full data set; winch reversed 570-560 m upcast
		1447-1507 hr		Camera b/w Kodak TMax ASA400; F5.6, 12 shots	Images under exposed but usable
HWD06-3-20	18.2.06	1624-1714 hr	842 m	CTD 5sec sample; 5 m above bed	Full data set
HWD06-3-21	18.2.06	1756-1904 hr	Frozen m-block	CTD 5sec sample; 5 m above bed	Full data set
HWD06-3-22	18.2.06	1952-2059 hr	Frozen m-block	CTD 5sec sample; 5 m above bed	Full data set
HWD06-3-23	18.2.06	2151-2253 hr	Frozen m-block	CTD 5sec sample; 5 m above bed	Full data set

APPENDIX 2: Core logs for DF80 cores, held at the Antarctic Research Facility, Florida State University, Tallahassee.

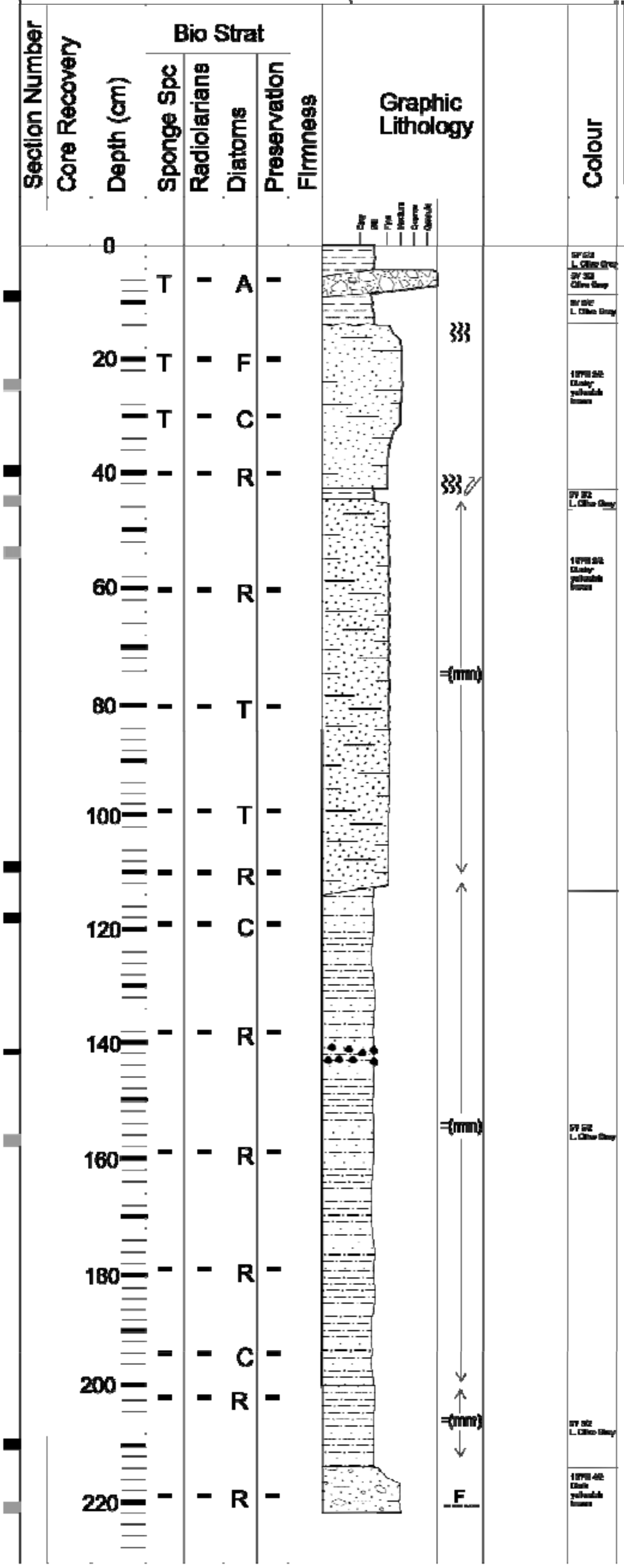
SITE: Erebus Basin
CORE #:DF 80-70
Lat 77°25'
Long 165°45'
Water depth (m) 856

DATE: CORING

LOGGED BY: McKay/Naish

SHEET #: 1 of 2

REMARKS:



⌇ Bioturbation (low, mod, high)
Burrow
=(mm) mm-scale laminations
Load structures
..F... Fining upwards
— Gradational boundary
Cross bedding

BioStrat
T Trace (<1%)
R Rare (1-2%)
C Common (2-10%)
F Frequent (10-50%)
A Abundant (50-100%)

Preservation
P Poor
G Good

Description

<u>0-4cm Diatomaceous ooze</u> with dispersed subangular to subrounded basalt pebbles (<0.5cm)

<u>Sharp inclined contact</u>

<u>4-8cm Conglomerate</u>, poorly sorted, clast-supported basalt scoria

<u>Sharp inclined contact</u>

<u>8-13.5cm Mud</u> *(diatomaceous?)* with dispersed basalt granules (~3mm).

<u>Diffuse contact</u>, intensely bioturbated with mud-filled burrows in underlying sand

<u>13.5-42cm Fine to medium vitric sand</u>, (locally muddy sand), well sorted with sparsely dispersed basalt granules and occassional mud rip-up clasts and deformed mud stringers. Coarsens up to centre and then fines up to the top.

<u>42-44cm Mud</u> (*diatomaceous?)*

<u>44-45cm Diffuse bioturbated contact</u>

<u>45-114cm Fine to medium vitric? sand</u>
well sorted and slightly laminated

<u>Sharp dipping lower contact</u> with rip-up clasts of underlying mud up into base of overlying unit

<u>114-216cm Mud</u>, moderately laminated with dispersed angular to subangular basalt clasts (>1cm).
140-142cm Layer of concentrated basalt clasts.
204cm Fine-medium sand *(vitric?)* lens (2mm thick)

<u>214-218cm Diffuse, gradational contact</u>

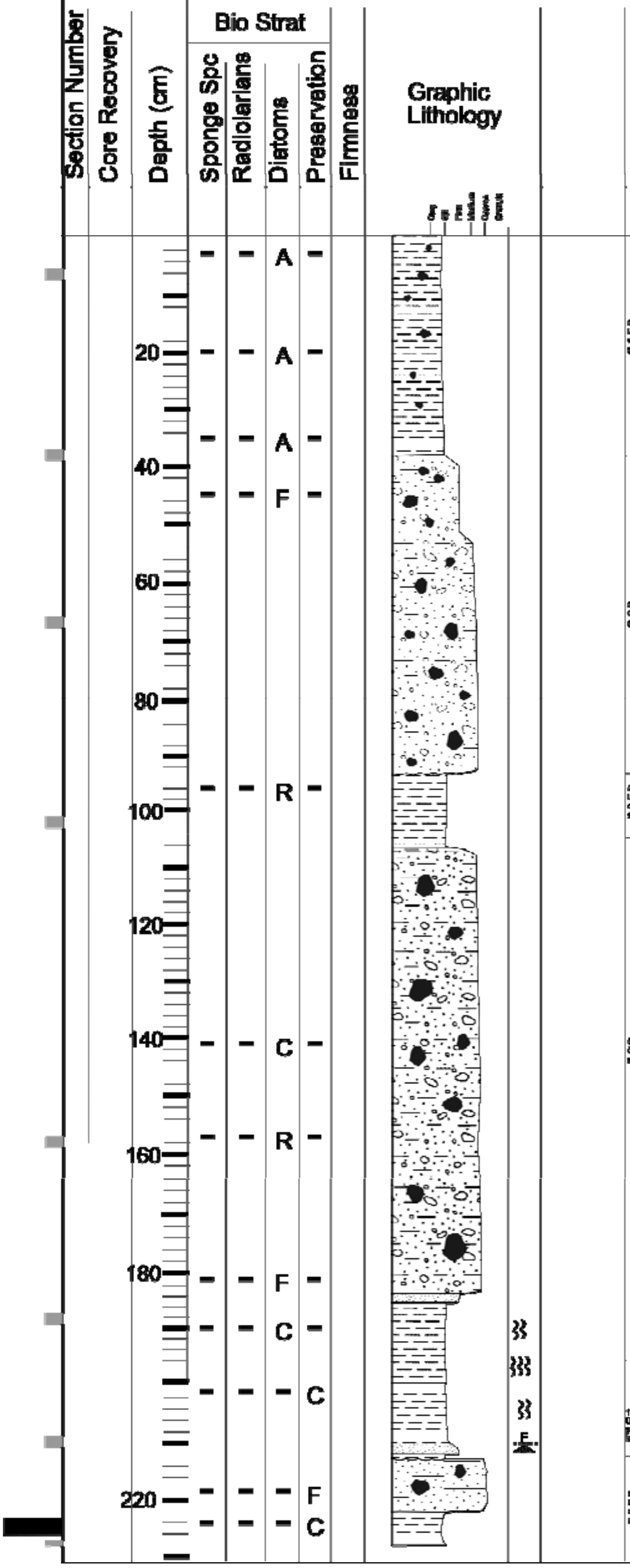
<u>218-222cm Gravelly muddy sand</u>, abundant basaltic and granitic/crystalline clasts (<5mm). Possible weak reverse grading. Stiff.

SITE: Erebus Basin
CORE #:DF 80-78
Lat 77°08'S
Long 165°45'E
Water depth (m) 827

DATE: CORING
LOGGED BY:
Dunbar/Naish
SHEET #: 1 of 2

REMARKS:

⦚	Bioturbation (low, mod, high)	**BioStrat**	
	Burrow	T	Trace (<1%)
=(mm)	mm-scale laminations	R	Rare (1-2%)
	Load structures	C	Common (2-9%)
F	Fining upwards	F	Frequent (10-49%)
—	Gradational boundary	A	Abundant (50-100%)
	Cross bedding	**Preservation**	
		P	Poor
		G	Good



Description

<u>0-38cm Diatomaceous ooze,</u> weakly laminated with sparse pebbles <0.5cm in lenght (angular to

<u>gradational contact (38-40cm)</u>
- bioturbated

<u>40-52cm Muddy fine sand</u> massive, with sparse pebbles <1cm (subangular-subrounded)

<u>gradational contact (52-54cm)</u>

<u>54-93cm Muddy gravelly sand</u> w/ abundant gravel clasts <4cm (subangular-subrounded basalt and granitic/crystalline clasts). Ungraded, except for top 2cm.

<u>96-106cm Mud</u>, weakly laminated, no visible pebbles.

<u>106-184cm Muddy gravelly sand</u> massive, abundant gravel sized clasts <4cm (subrounded-subangular basalt and granitic/cyrystalline clasts)

<u>182-184cm Well-sorted fine sand</u> bioturbated

<u>184-194cm Mud</u>, weakly laminated, moderate bioturbation, no visible pebbles. mm scales black specs (Mn, Fe nodules?)

<u>gradation contact</u>

<u>194-199 Mud/vitric silt</u> intensely

<u>199-211 Sandy silt</u>, vitric, weakly laminated, moderately bioturbated. Fining upwards from well-sorted fine sand to silt.

<u>211-212cm Fine sand</u>, vitric, well sorted, planar cross bedding (top truncated ripples?) Base has scour marks.

<u>212-212.3 Silt</u>, vitric with scour marks (airfall?).

<u>212.3-222cm Muddy gravelly sand</u>, ungraded, basaltic clasts <1cm, diatom bearing. Sharp base.
<u>222-228cm Mud,</u> weakly laminated, no visible pebbles.

SITE: Erebus Basin
CORE #:DF 80-79
Lat 77°28'
Long 165°41'
Water depth (m) 845

DATE: CORING

LOGGED BY:
McKay/Naish

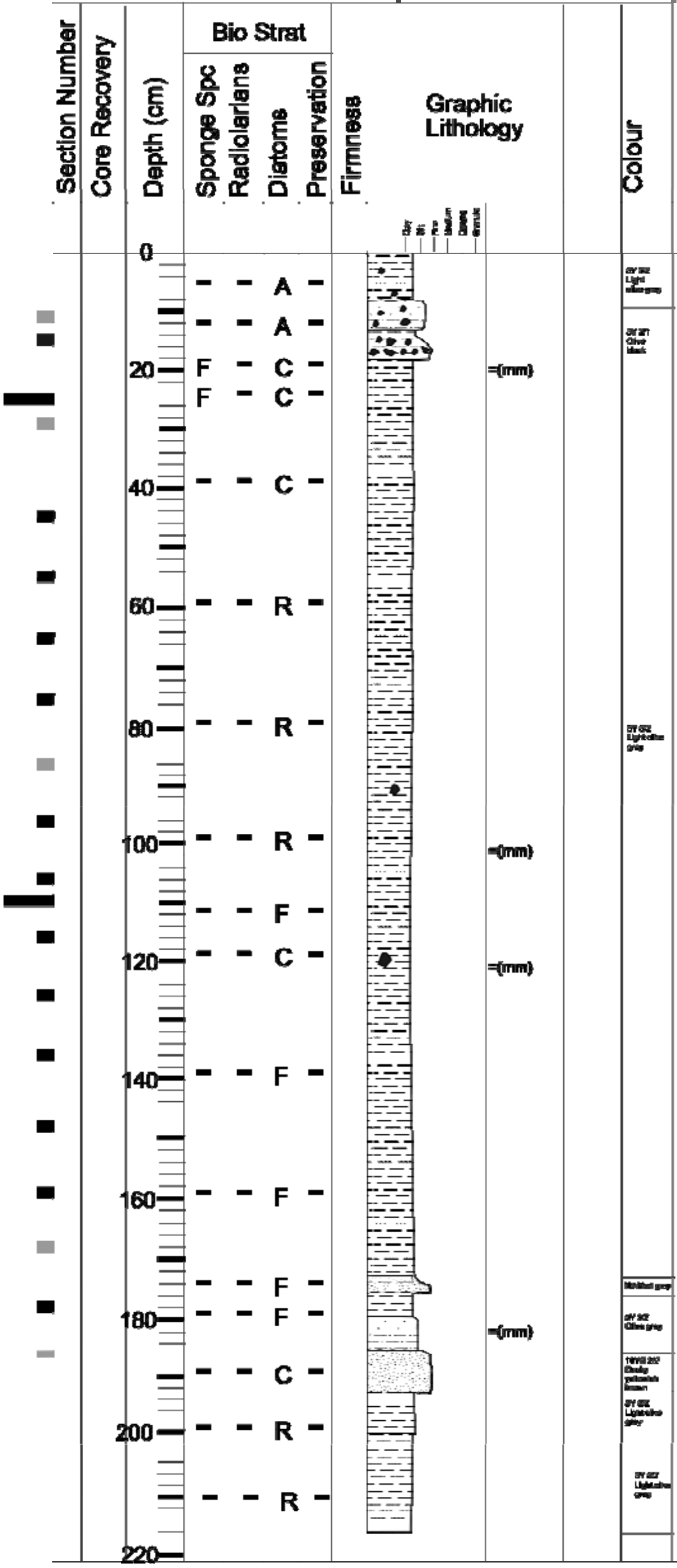
SHEET #: 1 of 2

REMARKS:

⌇ Bioturbation (low, mod, high)
Burrow
=(mm) mm-scale laminations
Load structures
_F_ Fining upwards
— Gradational boundary
Cross bedding

BioStrat
T Trace (<1%)
R Rare (1-2%)
C Common (2-9%)
F Frequent (10-49%)
A Abundant (50-100%)

Preservation
P Poor
G Good



Description

<u>0-9cm Diatomaceous ooze</u>, with fine to medium, angular to subangular basalt pebble clasts (moderately weathered)

<u>9-13cm Fine sandy mud</u> with abundant lappilli-sized pebbles of angular to subangular basalt (<0.5cm) *(volcaniclastic →primary)*

<u>13-18cm Mud</u>, with an increased abundance of fine to medium basalt pebbles (angular to subangular)

<u>sharp lower contact</u>

<u>18-20cm Mud</u> mm-scale laminated light and dark muds *(possibly ash bearing)*

<u>sharp lower contact</u>

<u>20-173cm Mud</u> sparsly laminated light and dark muds with occassional basalt pebble clasts (<3cm)

<u>gradational lower contact</u>

<u>173-175cm Fine sand</u> with scoured base and mm-scale

<u>175-180cm Mud</u>, laminated (light/dark) with lenses of light olive grey (5Y 5/2) *diatomaceous (?)* mud/silt.

<u>180-185.5cm Fine sandy mud</u>

<u>185.5-187cm - wavy basal contact</u>

<u>185.5-192.5cm Fine sand</u>, well sorted, fining upwards. Occassional mud clasts up to 2mm *(rip-up clasts?) - volcaniclastic deposit?*

<u>Sharp wavy contact</u>

<u>192.5-216cm Mud</u>, massive

SITE: Erebus Basin
CORE #:DF 80-133
Lat 77°05' S
Long 166°10'E
Water depth (m) 897

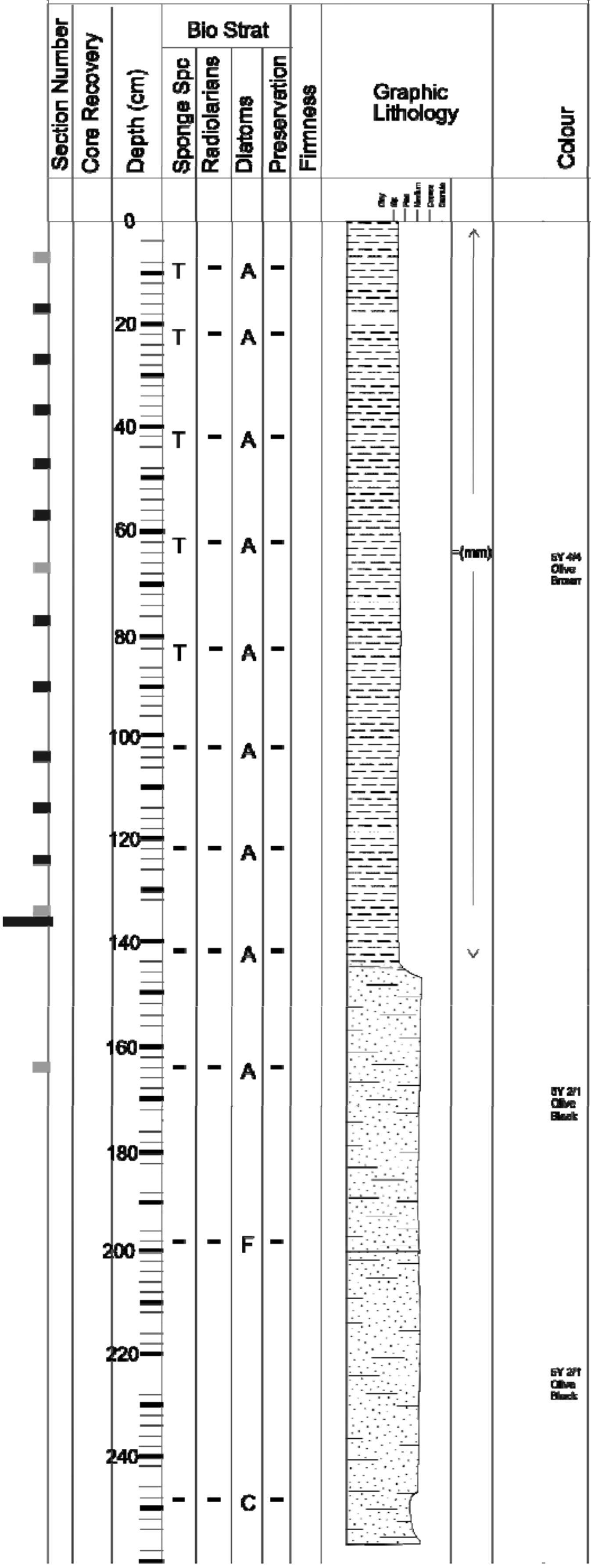
DATE: CORING

LOGGED BY:
Naish/Dunbar

SHEET #: 1 of 2

REMARKS:

⌇ Bioturbation (low, mod, high)	**BioStrat**
Burrow	T Trace (<1%)
=(mm) mm-scale laminations	R Rare (1-2%)
Load structures	C Common (2-9%)
.F. Fining upwards	F Frequent (10-49%)
— Gradational boundary	A Abundant (50-100%)
Cross bedding	**Preservation**
	P Poor
	G Good



Description

0-144cm Weakly laminated, silty diatomaceous ooze with rare dispersed subangular to subangular basalt pebbles (<1cm)

144-147cm Gradational contact

147-247cm Gravelly sandy mud, highly disturbed (washed). Poorly sorted with clasts of subangular to subrounded basaltic and granitic/cyrstalline basement (clasts <3cm)

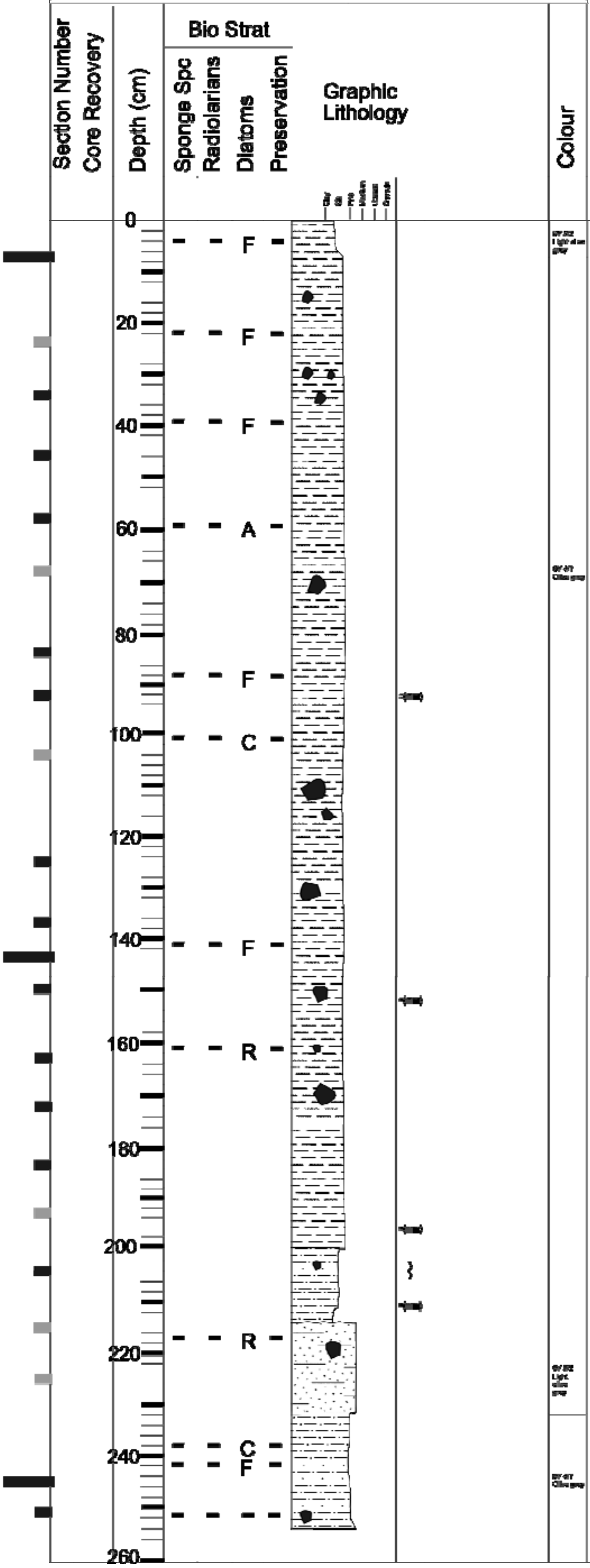
247-248cm Gradational contact

248-258cm Muddy fine sand, fines upwards into a fine sandy mud with dispersed angular to subangular granules of basalt

SITE: Lewis Basin
CORE #:DF 80-138
Lat 77°11'S
Long 166°37'E
Water depth (m) 914

DATE: CORING
LOGGED BY: Dunbar/Naish
SHEET #: 1 of 2

REMARKS:



⌇ Bioturbation (low, mod, high)
Burrow
mm-scale laminations
Load structures
Fining upwards
— Gradational boundary
Cross bedding

BioStrat
T Trace (<1%)
R Rare (1 2%)
C Common (2-9%)
F Frequent (10 49%)
A Abundant (50-100%)

Preservation
P Poor
G Good

Description

0-6cm Diatomaceous mud

5-6cm Gradational contact

6-214cm Diatomaceous mud with sparse to moderately abundant subangular to subrounded, fine to very coarse pebbles (<5cm length - mostly basalt, some crystalline basement lithologies)
94-95cm mm-scale laminated diatomaceous mud
153-160cm mm-scale laminated diatomaceous mud
194-198cm mm-scale laminated diatomaceous mud
203-211cm faint laminations and mild bioturbation

6-214cm Diatomaceous Mud (cont'd)
203-211cm faint laminations and mild bioturbation
211-214cm abundant coarse sand and fine pebbles

Sharp wavy contact

214-232cm Fine to medium sandy mud with subrounded to subangular (some faceted) fine to coarse basalt pebbles

232-233cm Sharp to undulose gradational contact

232-254cm Mud *(ash bearing?)*

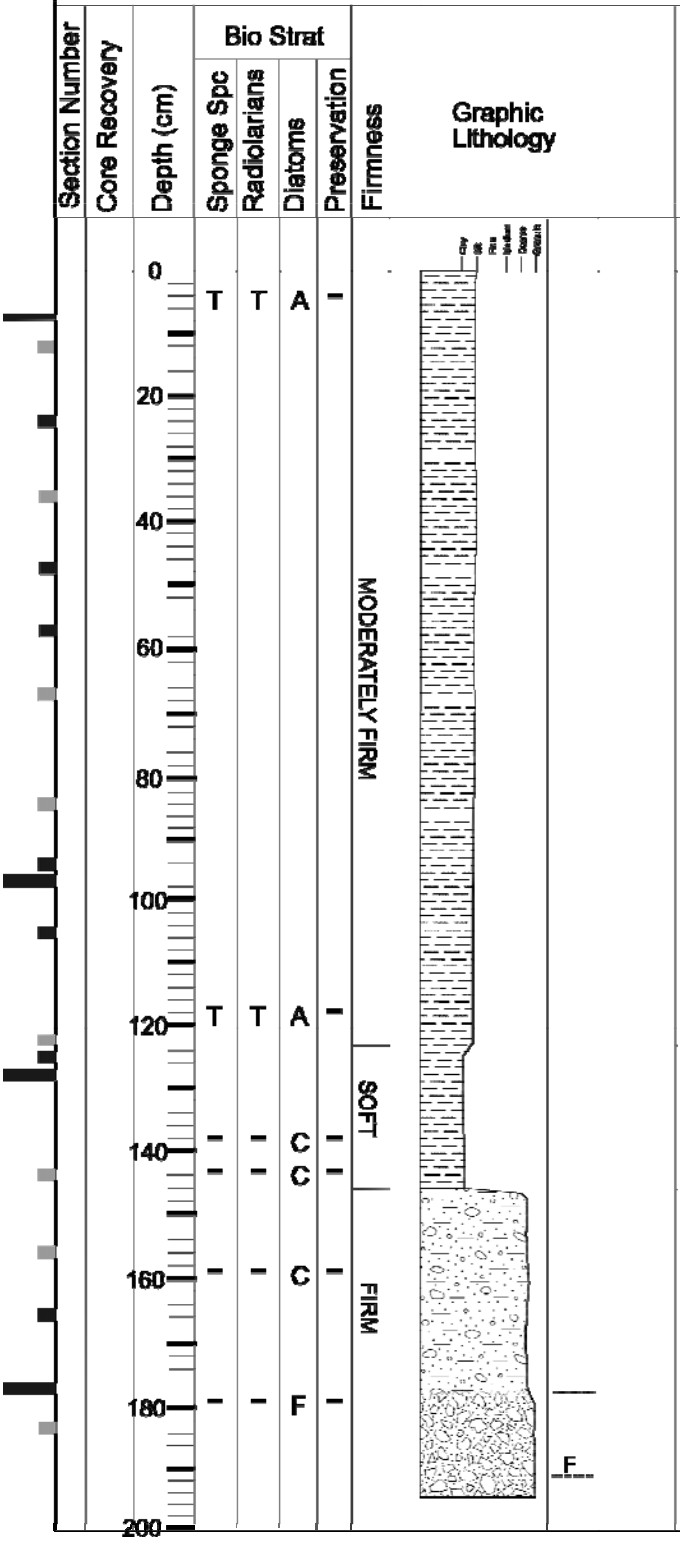
Oversized clasts >10mm - depth, lithology (length)
14cm, basalt (16mm)
30cm, basalt (17mm)
30cm, basalt (10mm)
34cm, basalt (12mm)
71cm, basalt (29mm)
92cm, crystalline basement (22mm)
107cm, basalt (43mm)
113cm, basalt (28mm)
131cm, basalt (35mm)
152cm, basalt (22mm)
161cm, basalt (13mm)
167cm, basalt (50mm)
203cm, basalt (14mm)
217cm, basalt (22mm)
247cm, basalt (14mm)

SITE: Lewis Basin
CORE #: DF 80-189
Lat 77°12'
Long 167°53'
Water depth (m) 907

DATE: CORING
LOGGED BY: Dunbar/McKay/Naish
SHEET #: 1 of 1

REMARKS:

⌇	Bioturbation (low, mod, high)	BioStrat	
⫽	Burrow	T	Trace (<1%)
-(mm)	mm-scale laminations	R	Rare (1-2%)
⌣⌣	Load structures	C	Common (2-9%)
_F_	Fining upwards	F	Frequent (10-49%)
—	Gradational boundary	A	Abundant (50-100%)
⌒	Cross bedding	Preservation	
		P	Poor
		G	Good



Sponge Spc	Radiolarians	Diatoms	Preservation
T	T	A	-
T	T	A	-
-	-	C	-
-	-	C	-
-	-	C	-
-	-	F	-

Colour

5Y 4/3 Olive

5Y 5/2 L.Olive gray

5Y 4/1 Olive gray

Description

<u>0–123cm Diatomaceous ooze</u>
moderately sorted, massive silty mud. ~80% diatoms (sea ice and oceanic forms with decrease in oceanic downcore).
Probably bioturbated, but difficult to tell as surface has dried out.

<u>123-146cm Silty mud</u>, massive, moderately sorted. <1% diatoms (mostly fragmented).

<u>sharp contact</u>

<u>146-180cm Diamict</u>, poorly sorted, matrix supported, clasts <25mm, subrounded to rounded basalt, granite, sedimentary rock fragments. Some clasts faceted and striated.

<u>gradational contact</u>

<u>180-196cm Diamict</u>, poorly sorted, clast supported, clasts <50mm, muddy coarse sand matrix. Subrounded to rounded basalt, granite, sedimentary rock fragments. Some clasts faceted and striated.

APPENDIX 3: Frequency percent in each size class (phi units) for grain-size analyses.

Frequency																									
Class midpts	**-2.00**	**-1.25**	**-0.75**	**-0.25**	**0.25**	**0.75**	**1.25**	**1.75**	**2.25**	**2.75**	**3.25**	**3.75**	**4.25**	**4.75**	**5.25**	**5.75**	**6.25**	**6.75**	**7.25**	**7.75**	**8.25**	**8.75**	**9.25**	**9.75**	**12.50**
Class limits	**-1.50**	**-1.00**	**-0.50**	**0.00**	**0.50**	**1.00**	**1.50**	**2.00**	**2.50**	**3.00**	**3.50**	**4.00**	**4.50**	**5.00**	**5.50**	**6.00**	**6.50**	**7.00**	**7.50**	**8.00**	**8.50**	**9.00**	**9.50**	**10.00**	**Rest**
HWD06 (0-2cm)	4.81	4.17	5.73	4.15	4.83	7.36	8.06	8.97	9.20	8.66	7.13	5.80	2.48	1.65	1.76	1.46	1.34	1.04	0.94	0.98	0.80	0.64	0.68	0.54	6.84
HWD06 (2-4cm)	2.56	3.18	3.52	4.20	4.39	5.87	7.27	8.46	8.64	7.98	6.27	6.16	2.14	1.56	2.02	1.81	1.78	1.50	1.62	1.75	1.41	1.38	1.35	0.98	12.20
HWD06 (4-6cm)	1.57	1.73	1.24	1.70	2.40	3.41	3.84	4.43	4.76	5.99	5.90	5.46	2.01	2.09	2.91	2.56	3.08	2.91	2.79	4.25	3.14	2.91	2.68	3.14	23.10
HWD06 (6-8cm)	1.23	0.60	1.12	0.86	1.52	1.99	2.70	3.10	3.44	4.33	4.59	5.23	1.94	1.87	3.87	2.77	4.01	3.11	3.04	3.74	3.53	3.11	2.70	2.42	33.20
HWD06 (8-10cm)	1.96	2.33	2.18	2.63	2.56	2.19	2.63	2.81	3.03	3.88	4.03	4.38	2.63	1.77	2.47	3.52	2.73	3.65	2.99	3.91	2.80	2.93	2.73	1.89	31.38
HWD06 (10-12cm)	1.70	1.47	1.09	1.32	1.79	2.10	2.75	3.18	3.42	4.05	4.15	4.38	2.46	2.18	3.06	3.40	3.94	3.53	3.94	4.35	4.42	4.01	3.74	3.87	25.69
HWD06 (12-14cm)	0.98	0.00	0.88	0.80	0.95	1.24	1.49	1.94	2.28	2.99	3.37	4.06	1.77	2.47	4.17	4.01	4.72	3.77	5.03	4.56	4.40	3.38	2.91	0.94	36.88
HWD06 (14-16cm)	0.43	0.36	1.44	1.12	1.28	1.71	2.31	2.67	3.02	3.80	4.10	4.68	2.95	1.89	3.25	3.32	4.04	3.32	3.97	4.55	4.69	4.11	4.19	3.97	28.80
HWD06 (16-18cm)	0.43	0.25	0.94	0.98	1.59	1.94	2.10	2.52	2.86	3.75	4.13	4.84	2.77	3.05	2.96	3.18	3.83	3.54	3.90	4.62	4.48	4.26	3.90	2.82	30.39
HWD06 (18-20cm)	1.70	1.06	0.99	0.87	0.91	1.40	1.69	2.06	2.26	2.90	3.25	3.89	2.48	2.23	2.12	3.34	3.19	3.49	3.34	4.48	3.79	3.72	3.26	2.96	38.62
HWD06 (20-22cm)	0.00	1.74	1.68	1.46	1.41	1.70	2.08	2.31	2.68	3.47	4.16	5.11	2.33	2.38	2.98	3.05	2.70	3.62	3.41	3.83	3.26	2.91	2.55	3.41	35.76
HWD06 (22-24cm)	0.00	0.47	1.42	1.56	1.95	2.36	3.02	3.52	4.03	4.93	5.30	6.25	2.68	2.76	2.81	3.07	3.00	3.13	3.39	3.83	4.09	3.71	3.64	4.15	24.93
HWD06 (24-26cm)	0.00	4.96	0.47	0.60	0.57	0.71	0.93	1.26	1.62	2.29	2.78	4.01	2.82	2.80	3.95	4.42	5.21	4.34	3.95	4.26	3.95	2.60	2.53	4.42	34.57
HWD06 (26-28cm)	2.14	0.72	0.96	1.11	1.31	1.59	1.90	2.28	2.64	3.70	4.76	5.86	3.12	2.85	3.33	4.37	4.99	3.81	4.23	3.60	3.33	2.56	2.29	2.63	29.93
HWD06 (28-30cm)	0.62	1.39	1.21	2.27	2.30	2.52	2.91	3.44	3.80	4.73	5.01	5.93	3.16	3.63	4.27	4.78	4.34	2.95	3.21	3.14	2.26	2.14	1.89	0.82	27.28
HWD06 (30-32cm)	2.21	0.60	1.58	1.63	1.51	2.26	2.98	3.90	4.55	5.68	6.57	7.23	3.39	2.48	3.18	3.64	3.59	2.72	2.95	3.18	2.60	2.08	1.91	1.00	26.58
HWD06 (32-34cm)	1.85	3.34	2.82	2.17	2.81	2.88	3.34	3.64	3.80	4.35	5.12	6.89	3.25	2.10	2.59	2.48	2.86	2.64	2.59	2.70	2.37	2.20	2.04	1.49	27.70
DF80-189 (11-13cm)	0.00	0.00	0.00	0.17	0.14	0.05	0.09	0.20	0.25	0.66	1.55	3.29	2.09	5.31	7.81	5.67	6.23	5.02	5.58	6.42	5.49	3.35	3.07	8.00	29.57
DF80-189 (23-25cm)	0.00	0.00	0.00	0.19	0.08	0.06	0.08	0.09	0.14	0.36	1.13	2.54	3.32	3.34	4.93	3.88	4.26	5.87	5.02	6.63	6.06	5.31	5.31	6.54	34.87
DF80-189 (35-37cm)	0.00	0.00	0.00	0.00	0.33	0.22	0.59	0.39	0.31	0.53	1.00	2.40	3.50	3.35	5.86	5.29	7.27	6.71	5.48	6.33	5.57	5.95	5.29	0.66	32.96
DF80-189 (46.5-48.5cm	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.13	0.32	1.15	2.72	1.90	2.24	5.07	4.20	4.49	5.27	6.64	6.83	6.44	5.47	3.90	43.14
DF80-189 (56-58cm)	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.06	0.02	0.10	0.18	1.00	1.36	3.12	4.65	3.88	4.85	5.14	5.33	6.79	6.69	6.01	6.11	6.11	38.58
DF80-189 (66-68cm)	0.00	0.70	0.66	0.00	0.06	0.04	0.10	0.09	0.26	0.59	1.36	3.51	3.46	2.71	2.71	5.88	6.60	6.87	6.33	8.05	5.97	4.79	4.97	5.06	29.21
DF80-189 (83-85cm)	0.00	0.00	0.00	0.23	0.05	0.06	0.12	0.12	0.12	0.36	0.86	2.40	1.33	4.15	5.55	6.79	6.31	6.22	5.84	7.17	5.84	5.17	4.78	3.64	32.91
DF80-189 (93-95cm)	0.00	0.00	0.00	0.15	0.11	0.24	0.20	0.13	0.14	0.33	0.67	1.41	1.59	2.06	4.92	5.90	4.72	5.90	5.41	6.20	5.41	5.21	4.82	3.74	40.73
DF80-189 (104-106cm)	0.00	0.00	0.00	0.05	0.04	0.03	0.10	0.18	0.40	0.44	0.82	1.48	0.36	3.33	5.39	5.39	5.49	6.47	5.88	7.45	5.69	6.08	5.59	5.39	33.93
DF80-189 (124-126cm)	0.00	0.00	0.00	0.14	0.23	0.55	0.38	0.40	0.69	0.88	1.10	1.68	1.07	1.93	1.68	2.43	3.36	3.27	4.02	6.54	5.61	5.14	4.58	2.15	52.15
DF80-189 (143.5-145.5	0.00	0.00	0.00	0.00	0.02	0.17	0.08	0.13	0.18	0.28	0.65	1.17	0.65	1.12	1.93	3.28	3.86	3.57	4.15	6.27	5.79	5.30	4.73	5.30	51.40
DF80-189 (155-157cm)	9.63	8.90	7.21	6.70	7.88	7.91	8.79	8.26	6.13	3.14	1.72	1.48	0.99	0.68	0.90	0.75	1.17	1.13	1.25	1.46	1.40	1.31	1.19	0.79	9.23
DF80-189 (164.5-166.5	6.59	6.73	7.19	7.46	10.36	14.15	12.02	9.23	6.09	2.79	1.44	1.17	0.71	0.32	0.68	0.50	0.49	0.77	0.89	1.08	0.80	0.77	0.82	0.10	6.84
DF80-189 (182-184cm)	10.90	4.34	7.37	9.98	10.02	14.89	13.38	9.50	5.78	2.61	1.28	1.07	0.32	0.13	0.07	0.02	0.68	0.54	0.37	0.77	0.66	0.40	0.47	0.27	4.17
DF80-133 (6-8cm)	0.00	0.00	0.00	0.00	0.00	0.16	0.10	0.12	0.17	0.35	0.49	1.44	3.54	4.85	8.26	4.04	4.28	3.79	6.10	6.11	6.84	3.60	5.17	5.10	35.48
DF80-133 (26-28cm)	0.00	0.00	0.00	0.00	0.05	0.14	0.19	0.23	0.16	0.20	0.49	0.65	0.49	3.42	4.68	5.07	4.09	4.48	6.82	7.60	6.82	6.24	5.17	5.95	37.04
DF80-133 (46-48cm)	0.00	0.00	0.00	0.11	0.03	0.07	0.08	0.13	0.09	0.13	0.29	0.61	1.95	4.32	3.87	4.45	4.35	4.83	5.99	7.93	6.67	6.38	6.67	5.61	35.47
DF80-133 (66-68cm)	0.00	1.28	1.21	0.00	0.11	0.07	0.18	0.17	0.47	1.07	2.48	6.40	8.57	8.60	9.54	6.74	4.88	3.50	5.47	4.25	5.69	4.01	3.04	4.41	17.86
DF80-133 (89-91cm)	0.00	0.00	0.00	0.09	0.32	0.40	0.42	0.36	0.30	0.54	0.62	1.54	0.82	4.11	7.57	5.73	6.21	5.92	6.89	7.67	6.21	5.63	3.88	9.03	25.72
DF80-133 (113-115cm)	0.00	0.00	0.39	0.22	0.05	0.28	0.39	0.35	0.35	0.49	0.54	1.10	0.69	3.01	5.71	4.57	5.81	4.85	7.04	6.66	6.47	5.71	5.62	9.33	30.36
DF80-133 (133-135cm)	0.00	0.00	0.48	0.00	0.41	0.59	0.65	0.96	1.33	2.64	0.97	1.27	0.76	1.78	3.19	5.48	4.93	5.75	5.57	7.21	7.03	5.93	5.38	2.65	35.04
DF80-133 (163-165cm)	0.34	3.34	3.14	3.41	5.49	8.83	13.89	14.07	10.19	7.21	4.80	4.08	1.55	0.96	1.05	1.39	1.13	0.99	1.39	1.61	1.31	1.27	1.11	1.07	6.42
DF80-133 (247-249cm)	0.37	0.70	0.86	1.33	1.98	2.49	3.25	4.18	6.50	11.44	12.10	9.58	3.43	2.09	1.73	2.25	2.29	2.16	2.42	3.35	2.89	2.38	2.29	4.71	13.24
DF80-79 (10-12cm)	2.29	0.72	2.68	3.55	3.98	6.60	8.36	8.30	7.29	6.33	5.00	5.53	2.71	2.34	2.59	2.88	2.62	3.48	2.17	2.77	2.32	2.39	1.61	2.39	9.12
DF80-79 (18-19cm)	0.00	0.66	0.22	0.55	0.73	0.52	0.76	0.78	0.89	0.87	0.58	1.75	1.06	2.60	2.56	2.47	2.56	2.28	2.28	2.92	3.38	3.01	3.29	1.92	61.36
DF80-79 (28-30cm)	0.00	0.00	0.00	0.27	0.34	0.32	0.34	0.33	0.42	1.11	2.15	6.19	5.70	5.32	4.89	4.52	5.34	3.94	4.19	4.52	4.60	4.68	4.27	2.71	33.84
DF80-79 (54-56cm)	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.08	0.09	0.20	0.81	3.40	2.63	3.82	4.58	4.48	5.92	5.92	6.49	8.20	7.82	7.16	6.01	7.63	24.71
DF80-79 (74-76cm)	0.00	0.00	0.22	0.15	0.14	0.14	0.25	0.23	0.28	0.44	0.82	1.89	0.71	2.63	5.06	5.15	5.63	4.96	6.01	6.20	6.87	5.54	5.44	6.11	35.12
DF80-79 (85-87cm)	0.00	0.00	0.53	0.36	0.25	0.18	0.26	0.30	0.39	0.58	1.01	3.26	3.54	2.71	4.65	7.20	5.47	5.93	6.56	6.29	6.29	5.84	5.11	8.21	25.07
DF80-79 (105-107cm)	0.00	0.25	0.00	0.06	0.04	0.10	0.09	0.11	0.13	0.23	0.33	1.36	1.27	0.07	0.78	5.47	4.78	4.98	6.35	8.10	8.88	7.71	7.52	7.71	33.68
DF80-79 (125-127cm)	0.00	0.00	0.00	0.19	0.15	0.25	0.35	0.43	0.46	0.65	1.09	1.92	2.36	3.51	4.77	4.68	5.33	4.21	5.70	7.39	5.89	5.99	5.14	4.77	34.79
DF80-79 (147-149cm)	0.00	0.00	0.27	0.24	0.17	0.15	0.20	0.21	0.24	0.35	0.59	1.44	0.82	1.98	4.50	4.60	4.50	6.04	5.17	6.42	5.17	5.65	4.22	2.01	45.03
DF80-79 (158-160cm)	0.00	0.00	0.00	0.35	0.04	0.10	0.19	0.22	0.28	0.30	0.44	0.55	1.43	3.46	6.44	8.79	8.30	6.25	6.64	6.83	5.76	5.08	4.69	2.34	31.53
DF80-79 (167-169cm)	0.00	0.00	0.00	0.15	0.20	0.28	0.49	0.56	0.63	0.87	1.02	1.73	1.74	4.65	7.14	6.58	6.86	5.38	5.56	6.03	5.28	4.36	4.82	3.52	32.17
DF80-79 (177-179cm)	0.00	0.36	0.00	0.00	0.03	0.01	0.02	0.01	0.02	0.06	0.26	1.04	0.39	0.98	2.15	2.34	3.71	4.10	6.25	5.76	6.44	6.15	6.05	2.54	51.35
DF80-79 (185-186cm)	0.00	0.00	0.00	0.00	0.04	0.07	0.04	0.05	0.32	3.47	8.75	9.00	4.63	2.81	4.78	3.43	3.66	3.73	4.78	5.30	4.93	4.78	4.10	1.57	29.77
DF80-79 (194-196cm)	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.09	0.43	0.54	0.66	0.20	0.79	1.19	1.98	3.17	4.55	6.03	7.52	8.01	7.62	6.53	50.64
DF80-79 (209-211cm)	0.00	0.00	0.00	0.04	0.01	0.00	0.01	0.00	0.01	0.05	0.15	0.20	0.69	1.26	1.26	3.89	5.88	6.72	9.45	10.40	11.13	9.35	7.98	8.93	22.58

APPENDIX 4: Statistics for grain-size analyses.

	Percentiles								Moment measures				Graphic (Folk)				Inman		Proportions			
	1%	5%	16%	25%	50%	75%	84%	95%	Mean	StDev	Skew	Kurt	Mean	StDev	Skew	Kurt	StDev	Skew	Gravel	Sand	Silt	Clay
HWD06 (0-2cm)	-2.53	-1.47	-0.34	0.60	2.10	3.66	5.28	11.97	2.77	3.53	1.37	4.66	2.35	3.44	0.30	1.80	2.81	0.13	8.98	69.87	11.65	9.50
HWD06 (2-4cm)	-2.01	-1.09	0.30	1.09	2.62	5.71	8.47	15.09	3.84	4.09	0.98	2.95	3.80	4.49	0.49	1.43	4.08	0.43	5.74	62.75	14.19	17.32
HWD06 (4-6cm)	-1.78	-0.35	1.51	2.49	5.61	9.69	11.30	14.56	6.12	4.44	0.16	1.77	6.14	4.71	0.18	0.85	4.89	0.16	3.30	39.14	22.60	34.96
HWD06 (6-8cm)	-1.75	0.40	2.42	3.45	7.29	11.82	14.26	19.20	7.31	4.40	-0.16	1.73	7.99	5.81	0.22	0.92	5.92	0.18	1.83	28.87	24.35	44.96
HWD06 (8-10cm)	-1.89	-0.82	1.41	2.85	6.81	11.80	14.84	21.03	6.79	4.72	-0.13	1.69	7.69	6.67	0.25	1.00	6.71	0.20	4.29	30.31	23.67	41.73
HWD06 (10-12cm)	-1.89	-0.21	2.09	3.26	7.00	10.09	11.47	14.28	6.86	4.32	-0.13	1.89	6.86	4.54	-0.02	0.87	4.69	-0.05	3.18	28.23	26.86	41.73
HWD06 (12-14cm)	-0.99	1.06	3.37	4.96	7.84	16.81	23.23	36.28	7.97	4.09	-0.33	1.97	11.48	10.30	0.58	1.22	9.93	0.55	0.98	20.00	30.50	48.51
HWD06 (14-16cm)	-0.89	0.62	2.73	3.80	7.53	10.51	11.93	14.81	7.36	4.13	-0.18	1.86	7.40	4.45	-0.01	0.87	4.60	-0.05	0.79	26.15	27.29	45.77
HWD06 (16-18cm)	-0.78	0.73	2.83	3.87	7.55	11.02	13.05	17.17	7.45	4.13	-0.17	1.83	7.81	5.05	0.12	0.94	5.11	0.08	0.68	25.65	27.84	45.83
HWD06 (18-20cm)	-2.01	0.22	3.03	4.41	8.31	12.52	14.61	18.85	7.99	4.34	-0.47	2.04	8.65	5.72	0.11	0.94	5.79	0.09	2.76	20.21	24.67	52.36
HWD06 (20-22cm)	-1.07	0.05	2.64	3.73	7.73	11.72	13.50	17.12	7.59	4.41	-0.27	1.76	7.96	5.30	0.08	0.88	5.43	0.06	1.74	26.07	24.30	47.90
HWD06 (22-24cm)	-0.74	0.41	2.22	3.17	6.64	9.99	11.26	13.85	6.76	4.20	0.05	1.73	6.71	4.30	0.05	0.81	4.52	0.02	0.47	34.34	24.67	40.52
HWD06 (24-26cm)	-1.16	-0.95	3.47	4.86	7.77	11.18	12.55	15.32	7.80	4.22	-0.42	2.17	7.93	4.73	-0.01	1.05	4.54	0.05	4.96	15.24	31.74	48.07
HWD06 (26-28cm)	-2.72	0.03	2.69	3.67	6.81	11.00	13.15	17.52	7.11	4.30	-0.12	1.91	7.55	5.26	0.22	0.98	5.23	0.21	2.85	26.11	30.29	40.74
HWD06 (28-30cm)	-1.31	-0.09	1.91	2.98	5.79	11.44	17.99	31.31	6.47	4.39	0.15	1.77	8.56	8.78	0.57	1.52	8.04	0.52	2.01	34.12	29.48	34.38
HWD06 (30-32cm)	-3.04	-0.30	1.92	2.84	5.53	10.81	16.11	26.88	6.30	4.45	0.18	1.79	7.86	7.66	0.53	1.40	7.09	0.49	2.81	37.89	25.12	34.18
HWD06 (32-34cm)	-1.76	-1.02	1.02	2.29	5.32	10.94	14.59	22.01	6.11	4.76	0.12	1.67	6.98	6.88	0.41	1.09	6.79	0.37	5.19	37.81	21.21	35.79
DF80-189 (11-13cm)	2.60	3.82	5.16	5.81	7.96	10.31	11.04	12.52	8.42	3.12	0.05	1.82	8.05	2.79	0.05	0.79	2.94	0.05		6.39	44.14	49.47
DF80-189 (23-25cm)	3.01	4.06	5.48	6.55	8.69	10.83	11.76	13.66	8.92	3.05	-0.18	1.88	8.64	3.02	0.01	0.92	3.14	-0.02		4.66	37.26	58.08
DF80-189 (35-37cm)	1.41	3.86	5.30	6.09	8.04	16.42	25.21	43.09	8.53	3.18	-0.02	1.89	12.85	10.92	0.76	1.56	9.96	0.73		5.78	43.78	50.44
DF80-189 (46.5-48.5cm	3.76	4.67	6.29	7.26	9.23	12.54	14.16	17.46	9.54	2.86	-0.30	1.74	9.90	3.91	0.27	0.99	3.94	0.25		1.69	32.53	65.78
DF80-189 (56-58cm)	3.86	4.89	6.18	7.06	9.06	11.23	12.25	14.32	9.34	2.82	-0.17	1.71	9.16	2.95	0.08	0.93	3.04	0.05		1.39	35.12	63.49
DF80-189 (66-68cm)	-0.74	3.69	5.46	6.23	8.00	10.45	11.57	13.86	8.42	3.17	-0.21	2.54	8.34	3.07	0.16	0.99	3.06	0.17	0.70	6.66	42.62	50.02
DF80-189 (83-85cm)	2.94	4.27	5.55	6.24	8.20	11.18	12.80	16.10	8.71	3.03	0.00	1.84	8.85	3.60	0.30	0.98	3.62	0.27		4.31	43.37	52.33
DF80-189 (93-95cm)	2.54	4.51	5.86	6.71	8.93	12.31	13.98	17.39	9.23	3.05	-0.29	1.92	9.59	3.98	0.28	0.94	4.06	0.24		3.39	36.70	59.91
DF80-189 (104-106cm)	2.76	4.69	5.83	6.62	8.58	10.91	12.02	14.29	8.94	2.92	-0.08	1.86	8.81	3.00	0.15	0.92	3.10	0.11		3.54	39.78	56.68
DF80-189 (124-126cm)	1.11	3.70	6.43	7.59	10.50	16.74	19.70	25.71	9.81	3.18	-0.83	2.66	12.21	6.65	0.38	0.99	6.64	0.39		6.05	24.32	69.63
DF80-189 (143.5-145.5	3.15	5.16	6.86	7.81	10.13	12.65	13.85	16.28	10.04	2.81	-0.68	2.31	10.28	3.43	0.08	0.94	3.50	0.06		2.66	24.82	72.51
DF80-189 (155-157cm)	-2.76	-1.92	-1.12	-0.55	1.10	3.13	7.25	13.43	2.38	4.21	1.31	3.64	2.41	4.42	0.54	1.71	4.19	0.47	18.53	59.23	8.32	13.92
DF80-189 (164.5-166.5	-2.54	-1.67	-0.80	-0.19	0.91	2.10	3.48	20.37	1.87	3.62	1.84	5.73	1.20	4.41	0.48	3.95	2.14	0.20	13.32	71.90	5.44	9.33
DF80-189 (182-184cm)	-4.16	-2.50	-0.94	-0.37	0.75	1.70	2.30	8.88	1.27	3.08	2.27	8.50	0.70	2.54	0.19	2.25	1.62	-0.04	15.25	75.88	2.91	5.97
DF80-133 (6-8cm)	3.13	4.34	5.31	6.18	8.45	11.13	12.32	14.75	8.86	3.08	-0.07	1.67	8.69	3.33	0.16	0.86	3.50	0.10		2.82	40.98	56.20
DF80-133 (26-28cm)	3.03	4.88	6.03	7.05	8.85	11.12	12.15	14.26	9.22	2.87	-0.19	1.92	9.01	2.95	0.12	0.95	3.06	0.08		2.11	36.67	61.22
DF80-133 (46-48cm)	3.57	4.71	5.99	6.97	8.82	11.03	12.11	14.33	9.14	2.85	-0.15	1.90	8.98	2.99	0.11	0.97	3.06	0.07		1.53	37.68	60.79
DF80-133 (66-68cm)	-1.03	3.10	4.17	4.68	6.32	9.05	10.23	12.30	7.03	3.28	0.23	2.61	6.91	2.91	0.30	0.86	3.03	0.29	1.28	12.15	51.56	35.02
DF80-133 (89-91cm)	1.25	4.26	5.44	6.18	8.04	10.04	10.66	11.91	8.41	2.93	-0.01	2.25	8.05	2.47	0.01	0.81	2.61	0.00		4.60	44.92	50.48
DF80-133 (113-115cm)	1.09	4.53	5.78	6.61	8.59	10.32	10.95	12.24	8.80	2.97	-0.26	2.49	8.44	2.46	-0.07	0.85	2.59	-0.09		4.15	38.36	57.49
DF80-133 (133-135cm)	0.61	2.62	5.59	6.46	8.43	12.06	14.33	18.94	8.70	3.33	-0.39	2.35	9.45	4.66	0.32	1.19	4.37	0.35		9.31	34.66	56.03
DF80-133 (163-165cm)	-1.29	-0.76	0.52	1.02	1.91	3.54	6.12	10.78	2.99	3.41	1.53	4.67	2.85	3.15	0.52	1.88	2.80	0.50	3.68	75.11	10.05	11.17
DF80-133 (247-249cm)	-1.04	0.45	2.07	2.66	3.75	8.08	9.69	11.34	5.29	3.81	0.66	2.33	5.17	3.56	0.48	0.82	3.81	0.56	1.07	53.71	19.72	25.50
DF80-79 (10-12cm)	-2.90	-0.61	0.73	1.32	2.99	6.67	8.39	11.17	4.15	3.85	0.78	2.72	4.04	3.70	0.40	0.90	3.83	0.41	3.01	57.62	21.54	17.83
DF80-79 (18-19cm)	-0.37	2.44	5.80	7.65	12.86	19.54	22.71	29.15	10.00	3.59	-1.21	3.39	13.79	8.27	0.19	0.92	8.45	0.17	0.66	7.65	18.73	72.96
DF80-79 (28-30cm)	1.12	3.45	4.41	5.26	8.01	11.76	13.95	18.41	8.30	3.47	-0.05	1.70	8.79	4.65	0.32	0.94	4.77	0.24		11.47	38.42	50.11
DF80-79 (54-56cm)	3.40	4.08	5.54	6.42	8.21	9.98	10.69	12.13	8.49	2.78	0.12	2.00	8.15	2.51	-0.03	0.93	2.57	-0.04		4.63	42.04	53.33
DF80-79 (74-76cm)	1.73	4.31	5.81	6.63	8.70	10.91	11.91	13.94	8.98	3.02	-0.26	2.18	8.81	2.98	0.07	0.92	3.05	0.05		4.56	36.36	59.08
DF80-79 (85-87cm)	0.24	3.70	5.29	5.99	8.04	10.00	10.67	12.03	8.27	3.07	-0.11	2.42	8.00	2.61	-0.03	0.85	2.69	-0.02		7.12	42.36	50.51
DF80-79 (105-107cm)	3.00	5.52	6.60	7.40	8.93	10.62	11.41	13.00	9.27	2.69	-0.29	2.63	8.98	2.33	0.06	0.95	2.40	0.03	0.25	2.44	31.80	65.51
DF80-79 (125-127cm)	1.60	3.89	5.49	6.40	8.56	11.12	12.39	14.97	8.84	3.12	-0.22	2.03	8.81	3.40	0.13	0.96	3.45	0.11		5.47	37.95	56.58
DF80-79 (147-149cm)	1.40	4.59	6.03	6.90	9.15	15.42	18.58	24.99	9.42	3.12	-0.48	2.23	11.25	6.23	0.53	0.98	6.28	0.50		3.88	34.04	62.08
DF80-79 (158-160cm)	2.21	4.69	5.64	6.15	7.96	11.49	13.95	18.96	8.60	2.99	0.09	1.93	9.18	4.24	0.49	1.10	4.16	0.44		2.46	48.14	49.40
DF80-79 (167-169cm)	1.40	3.75	5.28	5.93	8.01	11.10	12.76	16.14	8.49	3.20	-0.04	1.92	8.68	3.75	0.29	0.98	3.74	0.27		5.92	43.93	50.15
DF80-79 (177-179cm)	3.65	5.44	7.05	7.79	10.26	15.55	18.06	23.16	10.06	2.76	-0.70	2.70	11.79	5.44	0.44	0.94	5.51	0.42	0.36	1.44	25.67	72.53
DF80-79 (185-186cm)	2.65	3.09	3.70	4.36	7.54	11.61	15.18	22.46	7.82	3.55	0.14	1.58	8.81	5.81	0.44	1.10	5.74	0.33		21.75	33.11	45.15
DF80-79 (194-196cm)	3.91	6.28	7.71	8.36	10.05	12.10	13.07	15.04	10.31	2.43	-0.60	2.27	10.28	2.67	0.13	0.96	2.68	0.13		1.12	18.56	80.32
DF80-79 (209-211cm)	4.41	5.70	6.71	7.27	8.45	9.86	10.45	11.64	8.87	2.29	0.34	2.32	8.53	1.84	0.07	0.94	1.87	0.07		0.47	39.56	59.98

APPENDIX 5: Petrographic data for DF80 cores determined by modal analysis from thin sections of the 63-500 µm fraction.

		TAM						Uncertain			MVG	
Core	*Depth (cm)*	Dolerite/Pigeonite	Sedimentary lithic	Carbonates	Beacon Quartz	Quartz	Microcline	Plagioclase	Plain feldspar	Heavy Minerals	Volc glass/lithics	Total
DF80-189	*12.0*	0	0	0	0	1	0	6	46	19	227	300
	24.0	0	0	0	0	5	0	7	53	11	224	300
	36.0	0	0	0	1	4	0	12	43	22	218	300
	47.5	0	1	0	0	2	0	4	59	28	206	300
	57.0	0	0	0	0	5	0	9	45	19	222	300
	67.0	0	3	4	0	4	0	12	55	15	207	300
	84.0	0	2	0	0	4	0	9	48	23	214	300
	94.0	1	1	0	0	5	0	5	33	11	244	300
	105.0	0	2	0	0	3	0	4	34	9	248	300
	125.0	0	0	0	0	1	0	7	48	13	231	300
	144.5	2	2	0	2	3	1	9	80	15	186	300
	156.0	6	23	3	18	41	3	18	89	14	85	300
	165.5	9	39	7	28	39	2	10	75	25	66	300
	183.0	11	53	5	33	55	2	13	46	25	57	300
DF80-133	*7.0*	0	0	1	0	3	0	1	18	21	230	274
	27.0	0	1	0	0	8	0	10	58	18	205	300
	47.0	0	0	2	0	4	0	3	48	26	217	300
	90.0	0	5	3	8	31	2	16	63	16	156	300
	114.0	0	4	2	7	21	0	13	53	13	187	300
	134.0	0	1	0	1	7	0	7	47	16	221	300
	164.0	7	18	1	28	30	1	14	66	13	122	300
	248.0	2	7	0	16	29	0	15	93	12	126	300
DF80-79	*11.0*	0	1	0	1	0	0	29	20	14	235	300
	18.5	0	1	1	1	8	0	17	37	22	213	300
	29.0	0	2	0	0	4	0	6	43	11	234	300
	55.0	0	0	0	0	3	0	9	44	7	225	288
	75.0	1	1	1	1	6	1	9	38	20	208	286
	86.0	0	2	1	0	3	0	0	29	7	258	300
	106.0	1	5	0	14	13	0	8	52	16	192	301
	118.0	0	1	0	4	4	1	9	10	22	249	300
	126.0	0	1	1	3	9	1	6	43	12	224	300
	148.0	0	2	2	4	9	0	7	39	8	229	300
	159.0	1	3	0	8	18	2	13	48	26	182	301
	168.0	1	7	0	7	21	1	10	36	13	204	300
	185.5	0	0	0	0	0	0	5	21	6	268	300

Supplementary Notes.

Datum refers to plywood floor covering the HWD06 test drill hole.

Ice sheet at HWD06-3 is 97.5 m thick.

Water depth is 855-856 m by more accurate hot water drill winch line; 842-844 m by mechanical metre block

Camera was well supplied with spares, but required attention involving, 1. Addition of missing O ring on camera housing, replacement of external connectors on flash (missing neoprene) and trigger (corroded); trigger failed to operate in horizontal position which may be a design feature or fault; batteries for camera did not cope with cold temperatures indicating high quality 9v batteries are needed.

Thicknesses of cores recovered with stainless steel barrels are estimates; true length will be determined upon core extrusion.