SHALDRIL 2005 Cruise Report

The SHALDRIL Rig at Night

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ACKNOWLEDGEMENTS

The SHALDRIL initiative, utilizing the ice-breaking capabilities of the RV/IB *Nathaniel B. Palmer* as a drilling platform, provides an unprecedented opportunity for marine geologists to explore the Antarctic continental shelves without restraint from ice cover, land-based logistical facilities, or traditional barriers to conventional coring. We are indebted to the many scientists and administrators who have brought SHALDRIL to fruition in this inaugural cruise, and to the U.S. National Science Foundation-Office of Polar Programs, which supported this research.

SHALDRIL's shipboard complement of 64 souls devoted 24 days at sea late in the season on this demonstration cruise to test the new Seacore drilling rig in the most challenging of circumstances. Nature certainly did her part to make the test rigorous. We appreciate the dedication of all shipboard personnel, as well as the support of family and friends ashore. We especially thank Captain Michael Watson and Chief Mate Scott Dunaway, and all of the ECO personnel. We enjoyed the comradery of the stalwart Seacore drill crew, particularly Drilling Superintendent Andrew Frazer, and look forward to working with them again. We are pleased to have had the addition of Graham Tulloch, from the British Geological Survey. All of the Raytheon Polar Services Company personnel have offered us superb help, both during the cruise and as we prepared for it. We are lucky to have had Ashley Lowe, Marine Project Coordinator for SHALDRIL, among us. Alexander Injac, a pediatrician in real life, volunteered to sail as our ship's doctor, and all but found a second career as a photographer and journalist, posting his daily observations of life in the Antarctic on the web at http://SHALDRIL.rice.edu.

Drilling along the Antarctic Peninsula would not have been possible without the dedicated efforts of our colleagues over the past 20 years who have promoted the concept of shallow-water drilling in Antarctica. A series of formal workshops dates back to 1988 when Peter-Noel Webb convened a polar-drilling workshop at the Byrd Polar Research Center, Ohio State University, Columbus. This was followed in 1994 by workshops at Rice University and Florida State University, by which time an official SHALDRIL Committee had been organized and recognized by NSF. Thomas R. Janecek, now at IODP, left our ranks by the time this cruise happened, but his efforts remain invaluable. G. Leon Holloway, now at ConocoPhillips, gave advice on all matters of drilling and his enthusiasm for the project helped keep the project alive.

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CRUISE SUMMARY

INTRODUCTION AND HISTORICAL PERSPECTIVE

Our understanding of Antarctica's climatic, cryosphere, and biosphere evolution is still sketchy, in part due to the paucity of outcrops and drill core that record changes during the Neogene. Attempts to rectify the problem using conventional drill ships (*Glomar Challenger* and *JOIDES Resolution*) have met with moderate success, but access to key areas of the continental margin has been restricted because of the inability of these ships to operate in ice-covered waters. While we are restricted in our ability to acquire long sediment cores in ice-covered areas, nature has provided us with an alternative method. During past glacial maxima the ice sheets have advanced onto the continental shelf, eroding deeply into the stratigraphic section. Several areas of the continental shelf are characterized by seaward dipping strata that typically lie just meters beneath the seafloor. Unfortunately, the glacial sediments that overly these older strata have proven to be impenetrable by standard piston coring.

The concept behind SHALDRIL is to penetrate through the glacial strata and sample older deposits that contain a record of climate, cryosphere, and biosphere evolution. An icebreaking research vessel is used as the drilling platform so that drilling can be conducted in areas that are inaccessible to standard drill ships. But, even icebreaking vessels with drill stem hanging beneath them are highly vulnerable to the ever-present changes in sea state, winds, and sea-ice conditions. Given current drilling technology, we are lucky if we are able to lower pipe to the seafloor and sample more than a few tens of meters before being forced to abandon a site. So, the approach, by necessity, has to be one of "drill and move." This method is entirely dependent upon having a robust seismic stratigraphic framework from which the best drill sites can be selected, sites that enable sampling key stratigraphic horizons within a few tens of meters of the seafloor. It is also imperative to have as many backup sites as possible so that if sea ice covers a key site, that same stratigraphic target can be reached at another site. Thus, the success of SHALDRIL is entirely dependent on having a robust seismic stratigraphic framework for each area of study.

Detailed seismic stratigraphic analysis is used to identify specific surfaces that record changes in the style of sedimentation and erosion of the shelf by either rivers or ice sheets, for example, the oldest glacial unconformity that records initial glaciation on the shelf or a condensed section that would likely contain abundant fossils for biostratigraphic analysis. These surfaces make excellent drilling targets. The initial scientific challenge of SHALDRIL was the development of survey methods and acquisition of data needed to obtain the necessary seismic stratigraphic databases. The second technological challenge has been developing the drilling technology needed to penetrate tills and sample beneath them.

The National Science Foundation-Office of Polar Programs made its first commitment to SHALDRIL nearly two decades ago, and the first detailed seismic stratigraphic study was conducted in 1988 on the Antarctic Peninsula continental shelf (Bart and Anderson, 1995). Following that project, a study of the Ross Sea was conducted in 1990 (Anderson and Bartek, 1992) and later in the area offshore of Seymour Island in the northwestern Weddell Sea (Anderson et al., 1992; Sloan et al., 1995). All three surveys showed changes in stratigraphic architecture and seismic facies that have yielded interpretations about the climatic evolution of the continent and glaciation of the continental shelf. Sedimentological confirmation of these results and chronostratigraphic constraints on the timing of these changes await the acquisition of drill core from these areas, although existing drill core in the Ross Sea (DSDP Leg 28) and Antarctic Peninsula shelf (ODP Leg 178) provide some chronostratigraphic.

In 1994 we entered the second phase of SHALDRIL when a workshop was convened at Rice University in Houston, Texas. Fourteen scientists attended the workshop, which focused on newly acquired data from the continental shelf offshore of Seymour Island. There was strong consensus from the group that shallow drilling would yield key information about this critical region, the "Last Refugia of Antarctica." The workshop participants also focused on drilling technology, including a field trip to Fugro McClellan's facility in Houston. In the final analysis, it was determined that the drilling technology for SHALDRIL was not yet ready. Following that workshop, we patiently waited a decade while drilling technology improved to the point where SHALDRIL was achievable. In the meantime, a formal SHALDRIL committee was formed to monitor technical advances and to promote a proposal for funding (SHALDRIL Committee, 2001).

Many meetings later, SHALDRIL received its first funding and we began making serious plans for a drilling leg in the Seymour Island area. Progress was slow and met with some major, unpredicted hurdles, such as issues with the ship's stability and dynamic positioning. Fortunately, we had the advantage of having some of the smartest minds in the business on our side. People like Leon Holloway of ConocoPhillips, who spent countless hours, helping guide us through the foggy business of drilling and sampling. Jay Ardai, who seems to be an expert on just about everything, provided valuable guidance, as did Jim St. John, the marine architect who helped solve the stability issue, and Craig Shipp of Shell Oil Company and the entire IODP Safety Panel, who provided expert advice on safety issues. We are indebted to them for having made the first leg of SHALDRIL a success.

Scientific Objectives of SHALDRIL

Over the years, the scientific objectives of SHALDRIL have changed, specifically with the addition of sites intended to sample the Holocene section and a grounding zone wedge. The initial objective of acquiring a representative sampling of upper Paleogene and Neogene strata on the shelf has remained pretty much the same. As the date for the cruise approached, we were faced with concerns about ship stability and handling that threatened the success of the program. Fortunately, we were presented with an unexpected change in plans when it was decided to divide the cruise into two parts, one leg in 2005 and another in 2006. This provided us with the opportunity to address some of the technological concerns. While the timing of SHALDRIL 1 was not ideal (March 31 through April 23), it did present us with the opportunity to test the ships DP system, maneuverability of the ship, and the drilling and coring system in adverse conditions, and this proved to be a good thing.

Results from SHALDRIL I

We chose our first drill site in Maxwell Bay, on King George Island (Fig. 1-1). This site was chosen because it provided some protection from severe winds and seas and very little threat from sea ice. We were also driven by the desire to acquire a long Holocene sedimentary record in this more temperate part of Antarctica, especially the opportunity to look for warm excursions similar to those that occurring today in the region. From the first day of drilling, our concerns about maintaining position while on site were put to rest as the ship held position in winds of up to 30 knots. We sampled to a subbottom depth of 108 meters with approximately 81% recovery and preliminary examination of the core showed a fascinating record of sedimentological and paleontological changes and abundant carbonate material that will enable us to construct excellent radiocarbon stratigraphy for the site.

Our confidence level bolstered, we departed Maxwell Bay and conducted a seismic survey of some of our backup sites in Bransfield Basin before entering the Antarctic Sound in the morning. As we sailed into the northwestern Weddell Sea we had high hopes of actually drilling at least one of our offshore Seymour Island targets (Fig. 1-1). This would enable us to test our preliminary seismic stratigraphic model, which targeted a condensed stratigraphic section (onlap surface) that had been tentatively assigned a 30 Ma age based on seismic stratigraphic correlation to global cycle charts. Just as we reached the site the winds began to increase and within a few hours we found ourselves searching for cover from hurricane force winds. The weather data showed a huge low-pressure system within the Weddell Sea and we decided to go to another site until weather conditions improved. We chose one of our backup sites for sampling a Holocene section in Herbert Sound (Fig. 1-1). Unfortunately, the winds were so strong that we were not able to occupy our selected site and were forced to drill a site close to shore where we were sheltered from the wind. We drilled to a subbottom depth of 10.5 meters and reached what we interpreted as bedrock, but the 73% recovery in the poorly consolidated sediments was not as high as that in Maxwell Bay.

The winds subsided and we made our way back to the northwestern Weddell Sea sites, only to find that the storm had blown the ice back into the area of Proposal Site 2. So, we elected to drill Proposal Site 1, which was expected to yield upper Eocene deposits (Fig. 1-1). We washed through 20 meters of till and had just reached our stratigraphic target when the bit became stuck in the hole. Since ice conditions had worsened to 9 tenths, and we were forced to abandon both the site, and the area. What is important is that we did drill for 24 hours in 6 to 8 tenths ice cover and were able to maintain position without a problem. So, we all felt very good about the ability of the ship to operate in relatively concentrated sea ice.

Upon departing the Weddell Sea we elected to occupy a site in the Bransfield Basin where we would encounter a stratigraphic section similar to that of the Weddell Sea area (Fig. 1-1). Although pipe was run, the mudline was never reached. Once again, we found ourselves running from a second low-pressure system. This time we took cover in the Gerlache Strait and occupied a site near Hughes Bay (Fig. 1-1). After a day of drilling, weather conditions had deteriorated to the point that this site was abandoned and we began a seismic survey in search of another site in the area. The weather continued to worsen and we eventually found refuge in Lapeyrère Bay, on the northeast side of Anvers Island (Fig. 1-1). This is where we drilled our last site and tested the piggyback drilling system. We chose a site that, based on existing seismic data and piston cores, would yield a stratigraphic section with glacial-marine and subglacial sediments, similar to those at our Proposal Site 5 in the northwestern Weddell Sea. The winds continued to blow hard (up to 30 knots), but the ship held position with minimal stress on the mates. After several hours we began coring and on our first attempt broke the inner drill string at the seafloor. We moved the site approximately 200 meters and tried again. Again, the inner drill string broke, this time close to the hull of the ship. After consultation with the drilling superintendent, it was determined that we may have received a bad batch of drill pipe and that continued piggyback drilling would be futile. So, we decided to spend our last day doing conventional drilling with a diamond bit. We sampled 20 meters of very soft glaciomarine mud with only 40% core recovery. In the early morning hours, SHALDRIL I ended with what seemed to be a fitting finale. Without notice the wind suddenly shifted and increased to almost 40 knots, striking the ship on her starboard beam. The mate did an admirable job of holding the ship while the pipe was pulled from the hole. This was the only time in nearly three weeks of drilling that a site was abandoned because the ship was not able to hold position.

Was SHALDRIL I a success? Well, we certainly could not have asked for a greater variety of obstacles. But, then again April is not the best time of year to be drilling in Antarctica. What is important is that the ship and her crew performed magnificently under a range of adverse conditions. It is hard to imagine that SHALDRIL II will present such challenges. As for the drilling rig, it too performed well, but there were disappointments. Our inability to test the piggyback system was the greatest. The poor recovery in soft glacial marine sediments and tills was another disappointment. We never were able to sample sedimentary rock, although the Seacore people have had plenty of experience and success at this. We are confident that Seacore will put time and energy into trying to rectify these problems in the next year. As it currently stands, we have already obtained a beautiful Holocene section, the ship and DP system performed magnificently, and we are confident about our ability to work in ice and moderate winds. We are also confident that we will be able to sample sedimentary rock. So, only one of our SHALDRIL objectives, the grounding zone wedge, remains problematic. At Site 1, where core recovery was fast paced, our relatively small scientific party, made up mostly of students, performed magnificently. Thus, we feel very confident about our continued success with SHALDRIL II.

SITE BY SITE DETAILS

After crossing the Drake Passage, Site 1 (62° 16.931′ S, 58 45.230′ W, and water depth 488 m) was located in the center of the southern-most mini basin of outer Maxwell Bay on King George Island. The intent was to recover a high-resolution Holocene section deposited above the calcium carbonate compensation depth in a region of the peninsula that is experiencing the largest warming in the last century. A 108.2 m sequence (82% overall recovery) was recovered containing a modern assemblage of diatoms suggesting that the entire site is Holocene in age. The soft sediments of the Maxwell Bay site were cored with the extended core barrel push sampler inside the API drill string. API drill pipe and collars were run to the sea floor in approximately 12 hours plus about 3 hours of set up time for drilling operations once the vessel was on site. The clay-rich diamicton at the base of the sequence records the maximum glacial advance in the bay. The sequence above the diamicton records gradual warming and associated retreat of ice from the bay. Based on specific diatom indices, the middle section of Site 1 may have cored through the mid-Holocene climatic optimum.

Site 2 (63° 58.259′ S, 57° 45.511′ W, water depth 359 m) was located just south of a glacial trough in Croft Bay of Herbert Sound on the northern side of James Ross Island. In a sheltered region, we tested the drilling capabilities of penetrating through unconsolidated Holocene sediment into the underlying lithified Cretaceous volcaniclastic, deltaic bedrock. A 10.5 m sequence (73% overall recovery) was sampled. Because soft Holocene sediments were the target, extended push sampling was used. All sampling tools available were used in particular we tested the Shelby tube with a liner. Overall, recovery at this site (73%) is slightly lower than that at Site 1. Despite this, the Shelby tube is considered to be a good option for coring in very soft sediments and will continue to be considered as an option for soft sediments. The Holocene section in Herbert Sound is more condensed than that observed at Site 1. The thickness of the Holocene appears to be ~ 6.5 meters in comparison to the 100+ meters sampled at Maxwell Bay. It appears that this site has been proximal to sea ice. Whether this site experienced warming during the mid-Holocene is unclear.

Site 3 is located off Seymour Island in the James Ross Basin. A penetration depth of 20.74 m (0% effective recovery) into compacted Quaternary diamicton was obtained at this site. As part of the demonstration of the Seacore drilling capabilities, the primary drilling target was the Paleogene seaward dipping stratigraphic section that lay below that diamicton. Sampling the Quaternary, therefore, was only of secondary concern. Although the primary target was not reached, the *Palmer*'s dynamic positioning system was given a rigorous test for holding station in ice. The ship performed admirably in these difficult circumstances and exceeded expectations.

Site 4 is located at 62° 58.4982′ S, 58° 13.1368′ W in 544 m of water and was chosen as an alternative site to reach the Paleogene stratigraphic section. API drill string was run almost to the mudline. However, before coring operations could begin the wind and, more importantly, the heave increased dramatically. The *Palmer* was able to hold station. However, the heave compensation of the rig was close to maximum working conditions. Only a short kasten core, 48 cm in length including the intact core catcher sample, was sampled here. No preliminary scientific results could be made at this site.

Site 5 was drilled in Hughes Bay (64° 19' S, 61° 20' W) in 468 m of water. Based on cores from PD91, the expected bottom was a thin mud layer overlying compacted diamicton. The purpose of the site was to test the new "advance inner bit" or push rod manufactured on board in order to better penetrate the till. Two holes were attempted. No recovery was made and the bottom hole assembly became stuck in both holes.

Site 6 was another Holocene-age site that was chosen as weather conditions led us to find shelter from wind and waves. Located in Lapeyrère Bay on Anvers Island of the Palmer Archipelago, five holes were attempted at Site 6, but sediment was recovered only from three holes (~ 64^{o} 23.5143′ S, 63^{o} 14.9917′ W, water depth 390 meters). In this sheltered region, we tested the piggyback drilling capabilities of the drill rig in a bay that consisted of a glacial outwash fan overlying bedrock. Due to breaks in the HQ pipe, the piggyback system was abandoned after two failures. The soft sediments of the Lapeyrère Bay site were then cored with the extended core barrel push sampler inside the API drill string with 40% recovery. Sediments from Lapeyrère Bay contain a signature of a changing of bay having more proximal sea ice to open-marine conditions.

OVERVIEW OF SCIENTIFIC RESULTS

Located within the transition from subpolar to polar climate regimes, the Antarctic Peninsula has experienced some of the most dramatic increases in annual mean surface temperature ever-recorded (Leventer et al., 1996). This increase (increase of 2.5°C in 50 years recorded at Faraday Station) has been associated with increases in surface melting across ice shelves, smaller coverage of annual sea ice (Jacobs and Comiso, 1993), and most recently the collapse of the Larson B ice shelf (Rott el al., 1996; Scambos et al., 2003; Morris and Vaughan, 2003). These climate-related events make this region a sensitive indicator of paleoclimate. Therefore, the associated sediment deposition induced from the climate variability can contain a climate record as well. Numerous marine studies done at various locations within the Antarctic Peninsula have targeted Holocene sediment sites in an attempt to unravel the Holocene climate history. Only recently with ODP Leg 178, did a 50-meter sediment core obtain a record that extended through most of time since the Last Glacial Maximum (Domack et al., 2001). Prior to and since then, only piston and jumbo piston cores have been obtained. Jumbo piston cores routinely only reach a maximum depth of 20 meters.

Three successful Holocene sites were drilled during SHALDRIL. The three sites encompass a north to south transect. Site 1, Maxwell Bay, is located in the South Shetland Islands and experiences the warmest climate for the present day. South, but to the east, Site 2, Croft Bay in Herbert Sound is part of the Palmer Archipelago and experiences colder and drier conditions. Site 6, Lapeyrère Bay in Anvers Island, is the furthest south and west of the three sites drilled. Lapeyrère Bay has the coldest and highest precipitation of the three sites. Seismic surveys focused on locations that had a thick sedimentary sequence above glacially scoured bedrock.

At all three sites similar sedimentary facies were observed and contained modern (extant) diatom species implying that the sites sampled Holocene-age deposits. The bottoms of Site 1 and 2 terminated in clay-rich diamicton. Once the clay-rich diamicton was encountered, no fossils were observed. Thus the top 105.2 m of Site 1 (Maxwell Bay) and the top 6.5 m at Site 2 (Croft Bay) recovered only Holocene sediments. At Site 6, Lapeyrère Bay, a granite boulder was encountered at 20 mbsf with modern (extant) diatom assemblages occurring above this depth. Using 10 kyrs as a date for the retreat of the glaciers in these bays and fjords (LGM - D. Heroy, per. comm.), sedimentation rates are estimated as 1.1 cm/yr, 0.7 cm/yr, and 0.4 cm/yr for Sites 1, 2, and 6 respectively. Site 6 is based on seismic thickness.

Above the diamicton layers, clay-rich or silty- or pebbly- mud units were observed. Only in Site 1 (Maxwell Bay) was there a surface layer that was classified as a diatomaceous mud though diatoms were found throughout the mud units.

The diatom assemblages at these three sites indicate a mixture of open-marine to sea-ice conditions. Site 6 (Lapeyrere Bay) and Site 1 (Maxwell Bay) have similar assemblages which reflect the changing of these bays with sea ice more proximal to open marine conditions. Site 2 (Croft Bay) appears to have been proximal to sea ice throughout.

Maxwell Bay (Site 1) contains an interval that reflects a time of warmer conditions and may be the mid-Holocene climatic optimum observed in other cores of this area and Palmer Deep. With abundant calcareous material within this core, Site 1 has the potential of giving the best resolution Holocene record to date on the Antarctic Peninsula.

SYNOPSIS OF TECHNICAL DETAILS

RV/IB *Nathaniel B. Palmer*

Dynamic Positioning and General Ship Handling

Overall, we were extremely impressed with how well the *Palmer* operated with the drilling rig aboard. The dynamic positioning system that was installed for SHALDRIL worked extremely well. In general, position was held within just a couple of meters, well within the tolerances set out before the cruise. The dynamic positioning continued to work well in up to 25 knots of wind. One positioning excursion did occur during the cruise. At Site 6, in Lapeyrère Bay, the dynamic positioning system failed during a wind gust and the ship was blown off station (Fig. 1-2). The drill bit was nearly 20 m below sea floor during this excursion; luckily the bottom was extremely soft and the drill pipe simply pulled out of the hole rather than bending or breaking. While such an excursion was always deemed possible or even likely in such a gust, we didn't necessarily expect such a wind gust to come as such a surprise, in essence, to be so "gusty." The lessons taken away from this experience are that drilling in a protected cove to avoid larger weather systems can expose the vessel to local winds that can shift more quickly than larger systems. Thus, there should maybe be a lower wind speed threshold for safety while drilling in an enclosed bay than there is while drilling farther offshore.

The ship held station in more ice than we had imagined possible with drilling operations taking place in 9/10 ice cover. Holding station in these conditions was extremely taxing on the bridge crew, one of the demonstrations that it was good to have an extra mate on each shift during which drilling took place.

The one issue that limited operations somewhat more than expected was sea swell. The rig has a 3 m heave compensation system, which should mean that it can work in swells up to 1.5 m. However, because the ship responds somewhat unpredictably in waves, the effective swell height that could stop drilling work is only about 1 m.

General On-Site Communications

The *Palmer* needs to have a communication system that links all key labs to the MT's on shift, so that all key personnel are simultaneously notified when a core is on deck (Helo Deck) and subsequently in the Baltic room for core sectioning. This needs to be addressed for the SHALDRIL 2006 Cruise.

The Seacore Rig and Tools

The Seacore drill rig performed admirably, delivering the pipe strings and tool assemblies to the seafloor in a timely manner. Breakdowns (oil leaks from seals made brittle by the cold, etc.) were minor and fixed expeditiously. No drilling time was lost due to ship motion or maneuvers to dodge icebergs except in the case of extreme weather and ice conditions that would have halted drilling on any other rig as well.

The Seacore crew was composed of seasoned veterans of many campaigns and were well experienced with a wide variety of tools and drilling systems, including those deployed on this cruise. Their knowledge and expertise is unquestioned, and they were most helpful in explaining the intricacies of the drilling procedures to the scientists.

Three types of core sampling were attempted during the cruise: 1) Push, 2) Rotary, and 3) Piggy-back. A hammer sampler was used only when obstructions needed to be cleared from the throat of the bit. A hydraulic piston corer was not available on this cruise.

The push, rotary and hammer samplers were used with the BGS MkII drilling system that uses API pipe. Two drill bits were used with this system: 1) roller cone and 2) polycrystalline diamond (PCD). A tungsten insert was used in conjunction with the roller-cone bit at one site to in an attempt to penetrate compacted diamicton.

The piggy-back system used an API pipe string with a clump weight for reaction and a 4" throat bit. The inner string was a standard HQ3 diamond coring system.

The results in terms of coring and recovery using of these various types of samplers and bits are discussed in turn below.

Push Cores

Push cores taken via an extended core barrel produced most of the sediment samples acquired during the cruise. This was because most of the material recovered turned out to be poorly consolidated muds.

The most extensive use of the push-core sampler was at Site 1 (Maxwell Bay), where samples for high-resolution Holocene studies were taken continuously from the surface to a total depth of 108.2 m. The interval cored on each run was generally between between 2.5 and 3.0 meters. The recovery at this site is detailed in Figure 3-C2, where it was broken down into three categories: 1) Competent, 2) Disturbed, and 3) Gaps (i.e., voids within the core). When the disturbed intervals and gaps were subtracted out, the overall recovery was calculated to be 80.6%.

The advantages of this sampler are that recovery was good, and it allowed the sediment sequence to be explored in small increments. The relatively short intervals cored lessened the overall risk of large gaps in the section if dropstones were encountered, causing low or disturbed recovery.

On the other hand, problems encountered with core quality in the push cores at this site were: 1) gaps within the cores, 2) slurry at the top of the barrel, and 3) incoherent sediment on occasion at the bottom. The gaps averaged about one per core and ranged up to 20 cm in length. The cause of these is not known, although 1) mechanical "stretch out" of the sediment from the coring process or 2) expanding gas within the sediment were suggested as possibilities by various members of the science and drilling teams; no consensus was arrived at on this point. Slurry at the top of the cores resulted from cavings or hydraulic disturbance that allowed material to accumulate in the bottom of the hole between core runs, perhaps when the string was raised to extend the barrel before the next "push" sample was taken. The cause of incoherence at the bottoms of some cores is unknown.

Another disadvantage of push cores relative to longer-barrel hydraulic piston cores is the greater numbers of gaps generated between cores. This is unavoidable because some material is invariably washed out from the bottom of the hole between core runs. Hydraulic piston cores for this drilling system would result in longer (5-m) cores that could be taken ideally in less time, at higher recovery rates, with fewer missing intervals within the section, and with less drilling disturbance and gaps. The overall result from using a hydraulic piston core in such terrane would be a more coherent stratigraphic section for high-resolution work. Time saved might permit additional holes to be piston-cored at a given site, thereby allowing gaps between cores to be spliced via

MSCL or electrical resistivity data to construct a continuous composite section for high-resolution study.

Rotary Cores

Rotary coring was conducted primarily to either recover or penetrate Quaternary diamicton at Sites 3, 5 and 6. Such an effort at Site 3 is described in some detail in the "Operations" section of the site report for that site, where 20.74 m of compacted diamicton was penetrated in just over 24 hours with no sample recovery (see fig. 5-C1). Drilling was terminated when no further progress could be made in the hole and bit failure was suspected. When the drill string was recovered to inspect the bit, the culprit turned out to be cobbles in the hole that had jammed the throat of the bit. These had not been dislodged from the bit despite repeated blows from the hammer sampler. Although we nearly penetrated the diamicton layer at this site, the encroachment of heavy sea-ice concentrations and large icebergs over the area denied us a second chance to offset a few meters and break through the till cover to reach our primary target, the subjacent Paleogene strata.

A second attempt to penetrate similar compacted diamicton was made at Site 5 using a tungsten-insert tool designed to break up or knock aside cobbles before they could jam off the bit. Because this tool had to rotate to function, the swivel "head" of a standard core barrel was welded tight so that the barrel would turn with the bit. This attempt failed after 2.5 m penetration when the welded joint broke, allowing the barrel to remain stationary and ineffective when the string was rotated.

A less consolidated diamicton was cored in the last hole at Site 6, where the polycrystalline-diamond bit was brought into play at 20 mbsf when resistance was met after a succession of push cores had been taken. This resulted a cleanly cut 13-cm cylinder of white granite from either a dropstone boulder or possibly basement.

Piggy-back Cores

The piggy-back drilling system was also deployed at Site 6 but obtained no useable recovery due to two failures of the inner drill string at pipe joints. It was concluded that this system should be effective in reasonably well consolidated or highly compacted diamictons if a more flexible pipe were used in the future.

In summary, the most difficult lithology from a drilling perspective encountered on this SHALDRIL cruise was diamicton. To put this problem into perspective, the reader should consider the experience that a sister scientific drilling enterprise, the Ocean Drilling Program (ODP), had with similar material in Prydz Bay off East Antarctica. At ODP Site 742, using a much larger and more robust drilling system at a water depth of 415.7 m, they expended some 24 hours to penetrate 109 m of Quaternary-upper Pliocene homogenous massive diamictite with pebbles, boulders, and up to 15% gravel. The drilling was described as "difficult" and their recovery was only 15.75%, consisting of "usually only a few cobbles, which apparently were rolling under the bit and also jamming the core catchers" (Barron, J., Larsen, B., et al., 1989, p. 400).

The technical promise of SHALDRIL is that its piggy-back coring system should be able to core and have good recovery of Neogene diamictons whenever that is the scientific objective. Alternatively, its rotary coring system should be able to penetrate through such material when older outcrops below are the desired target. The rotary system with the polycrystalline diamond bit showed considerable ability to core this material, particularly the dropstones. The problem in dealing with the diamicton at Site 3 was primarily the lack of an adequate ice window to allow the drillers sufficient time do their work. We are confident that with further retooling, the BGS rotary and Seacore piggy-back systems will be able to sample or penetrate such material given sufficient time and reasonable sea and ice conditions.

Core Flow Through The Labs

Core Handling

Core handling between the Helo Deck and the Baltic room was awkward. Originally, core was to be delivered directly from the rig to the outside doors of the Baltic room, but space problems prevented this from happening. As a result, the core was extruded on the Helo Deck and lowered to the lower deck at the risk of disturbing the core. **We request that ECO and Seacore explore ways of having the core lowered directly from the rig to the deck outside the Baltic room.**

The experience gained from having to handle a considerable amount of core over a relatively short period highlights the necessity to have additional core racks available. Racks in the Baltic room are necessary to stack more cores prior to logging, and an added core rack in the Aft Dry Lab would allow the cut liners to be stored in numerical sequence prior to further core handling. **We request that Raytheon construct additional core racks in the Baltic room and in the Aft Dry Lab.**

Core Processing Flow

Generally, the core processing flow plan worked very well. The station layout in the Aft Dry Lab as previously designed (see Fig. 2-3) with core sections moving between the Baltic room and around the Dry Lab worked well. The set-up for core photography will need to be improved to address ease of use and better illumination of light on the cores. **We request that Raytheon construct a dedicated table and lighting system specifically for digital photography**. The only additional issue that arose was related to the quality of the core liners. For all coring devices, the liners were too thin and flexible, hence moving the sediments around between stations created unnecessary risk to the material. **Better quality or thicker core liners would be helpful in the future.**

Microscopes/Microscopy Labs

A. Facilities

"Resident" shipboard microscopes located at the beginning of the cruise and used throughout SHALDRIL I included a:

1. Zeiss Axioskop with plain transmitted light, POL (polarizing light), DIC (differential interference contrast) and PH (phase

contrast) optics, a fixed x-y (non-rotating) stage installed, with 10x, 20x, 40x, and 100x (oil) objectives on a 5-position nose piece. A video camera is attached.

2. Nikon E800 also with plain transmitted light, POL, DIC, and phase optics, fixed x-y non-rotating stage with 10x, 20x, 40x, 60x (oil), and 100x (oil) objectives on a 5-position nosepiece. A video-capture camera is attached.

3. Zeiss Standard 25 for transmitted light with 10x, 20x, 40x, and 100x phase contrast objectives/condensers and a fixed x-y stage.

4. Wild MC3 binocular dissecting microscope.

Toward the end of the cruise, we also located a:

5. Nikon Labophot polarizing microscope with 4x, 10x, and 40x POL objectives and a rotating stage.

In addition to the above, the science party brought to the ship a:

6. Zeiss Standard 16 with POL and phase optics for various objectives (10x, 16x, 40x, 63x, and 100 [oil]) plus a rotating stage. This was set up on a temporary table in the Microscope Room (01 Deck) opposite the first two transmitted-light microscopes listed above.

The Zeiss Standard 25 was installed in the Core Lab (Aft Dry Lab) for use by the litho-stratigraphers describing the cores. They also used the Wild dissecting scope installed across the hall in the Bio Lab as needed. The Bio Lab served as the prep area for the paleontologists.

The paleontology group consisted of two-person teams on opposite 12-hr shifts to cover diatoms and calcareous nannofossils for biostratigraphic control. In addition, there were two radiolarian specialists who used the microscope facilities on an ad hoc basis as needed and as available. The micropaleontology analyses were carried out in the Microscope Room located one deck up from the core and prep labs that are on the Main Deck.

B. Recommendations

Equipment

The resident shipboard microscopes are state-of-the-art and well maintained. Air-cushioned platforms to dampen ship vibration were available for all.

A resident shipboard microscope to analyze calcareous nannofossils would be most useful. Unless such a scope is already present in the Raytheon inventory, we recommend converting the Zeiss Standard 25 for this purpose. The proper condenser is already in place, as are the necessary phase objectives. Needed are a polarizer, analyzer, and possibly polarizing objectives (unless the phase objectives are expected by Zeiss to double for those). An optivar would also be highly desirable.

To assist with the search for larger microfossils, such as radiolarians, it would be desirable to locate or purchase some lower power objectives (2.5x to 4.0x) for the Zeiss Axioskop, Nikon E800, and the Zeiss Standard 25.

Currently there is only one Petrolane X-15A single-bulbul lamp on board. This was used to cure all lithologic and paleontologic preps mounted with Norland-61 cement. To ensure necessary redundancy and efficient operations, we recommend three such units, one for the Core Lab, one for the Bio-Lab, and one for the Microscope Room, along with an adequate stock of sprune light bulbs. In addition, a set of slide storage trays is needed for processing the slides through the UV system.

Space

The Microscope Room on the 01 Deck is located in one of the quietest, most vibration-free areas of the ship, but is barely adequate for two micropaleontologists to work in at the same time; there is very little free desk/table space on which to lay out reference literature, microscope slides, notebooks etc. The room is clearly not large enough for more than two micropaleontologists to work in efficiently at once. In the event that more dedicated paleontologists than two per shift are required for future SHALDRIL operations, more space will be needed.

The Microscope Room also has no sink or prep area, but this was not considered to be a major inconvenience in that the Bio Lab on the Main Deck was adequate for this purpose.

Moving the microscope lab to another location on the ship on an ad hoc basis for subsequent SHALDRIL cruises is a possibility but probably not practical in that the Axioskop and Nikon E800 are mounted on large pneumatic tables hooked into the ship's air system. In addition, other areas we looked at for such a possible relocation had more vibration from the thrusters (e.g., Hydro Lab) or were being used for other purposes.

In the event more space is needed for micropaleontology on a future cruise, we recommend that Room 106 ("Change Room-Sauna") adjacent to the Microscope Room be utilized for this purpose.

Literature

We were delighted to find onboard in the ship's library most of the older volumes from DSDP/ODP cruises to the Antarctic as these are important sources of reference literature for micropaleontology and related work. The more recent ODP *Initial Reports* and *Science Results* volumes are now in much more compact form, mostly on CD-ROM. **We recommend that all such ODP/IODP and related Southern Ocean geologic literature is stocked in the ship's library. Items most useful would be:**

1. **ODP *IR* and *SR* volumes for Legs 177, 178, 183, 188, and 189.**

2. **The complete set of Cape Roberts Project volumes (available through Dr. Peter-Noel Webb, Ohio State University);**

3. **The special GSA publication on Seymour Island, namely: Woodburne, M. O. and Feldmann, R. (eds.) *The Geology and Paleontology of Seymour Island*, Geological Society of America Memoir 169).**

Equipment Set-up and Use

The Geotek MSCL core logger that was utilized on SHALDRIL is seven years old and is showing its age, both from a hardware and software perspective. The computer is still running on the Windows 98 operating system and the software versions while useable, are no longer supported by Geotek

Several operational issues surfaced during the initial shipboard use of the MSCL. Before leaving the Antarctic Research Facility, the logger was operating according to specifications. However, prior to its initial operational use on board, both hardware and software problems were encountered as the MSCL failed to operate during testing prior to Hole 1B. The MSCL failed because the computer and logger were not communicating. This issue was rectified by the shipboard ET's. In addition, the calibration software for the P-wave was corrupted, as was the calibration curve for the magnetic susceptibility data, so that only relative magnetic susceptibility and core logging for gamma-ray attenuation were collected. If we are to use this equipment on further shipboard operations in the future, these should be rectified by a total upgrade of the system, including the camera system, and a contract established with Geotek to regularly test and service the equipment. **A better alternative would be to purchase a new MSCL that is designed for field-based operations, one that could serve both the SHALDRIL and ANDRILL communities.**

FUTURE OF SHALDRIL

The 2005 SHALDRIL cruise focused on testing the drilling rig and coring system, the DP system and the ship's capability to maintain station under different sea-ice and wind conditions. The DP system performed better than expected, and the ship was able to maintain station in 30-knot winds and moderate sea ice cover. There were problems with drilling and coring, but we are confident that these can be rectified before 2006. Thus, SHALDRIL 2006 will focus on science. The drilling targets will be the same as outlined in the original SHALDRIL proposal.

The long-term future of SHALDRIL will depend upon the level of success of SHALDRIL 2006, but there are a number of areas where future drilling projects could be conducted. Among these are the Ross Sea, particularly the western Ross Sea where drill sites are limited to one DSDP site (Leg 28, Site 273), and existing MSSTS, CIROS and Cape Roberts sites (SHALDRIL Committee, 2001). There are also a number of sites proposed by Andrill. Crary Trough in the southeastern Weddell Sea, contains a stratigraphic section of more than a kilometer thickness that, based on reworked palynomorphs includes Upper Cretaceous marine deposits (Truswell and Anderson, 1985). Furthermore, piston cores from the area have sampled unlithified eolian sands and beach sands (Anderson, 1999). This would be an ideal location to investigate East Antarctica's Late Cretaceous climatic setting. In fact, glacial troughs all around Antarctica dissect strata that span most of the Mesozoic and Tertiary (Anderson, 1999). So, there are a number of drilling targets that have high potential for yielding a geological record of Antarctica's climatic, glacial and biological evolution.

Future drilling will require robust seismic stratigraphic frameworks for site selection and for re-enforcement of interpretations from core data. Some areas already have good seismic coverage and others will require site surveys. Our experience has already demonstrated the need for good backup sites that can be drilled when weather and ice conditions prevent occupation of priority targets.

Safety is another factor. Because there is no established geohazards protocol for SHALDRIL, SHALDRIL 2005 relied on ODP and outside consultants to provide us with input about potential drilling hazards. We could not have met their demands without good high-resolution seismic data and information about sea-ice conditions and other environmental data. We strongly recommend that future proposals for SHALDRIL address these issues. It may be advisable to establish a panel for the specific purpose of evaluating SHALDRIL proposals to assure that sufficient site survey data exists for selecting sites as well as meeting the necessary safety issues.

Specific future plans for SHALDRIL II

During our cruise, we were informed that a second SHALDRIL season has been scheduled for the austral summer of 2006. We are pleased and gratified to have an opportunity to conclude the unfinished business of our abbreviated SHALDRIL I campaign, particularly the Paleogene-Neogene transect of six sites along the prograding shelf sequence off Seymour Island that was targeted in our original portfolio. Much has been learned during the current cruise on how to approach the difficult geologic terrane represented by compacted and loosely consolidated diamictons. We expect to be armed with an additional suite of tools next season to press the attack during a much more favorable weather and ice window, and look forward with enthusiasm to the taking up the challenge again.

SHALDRIL I was intended not only to test out and demonstrate a new approach to Antarctic exploration, but if successful, to make the results known to the broader scientific community and to invite their participation in the post-cruise analysis of the material. We envision at some point in the future a post-cruise core workshop open to all qualified investigators.

The cruise demonstrated beyond any doubt the stability and adequacy of the *Palmer* as an efficient drilling platform, including her ability to hold station in DP mode and her agility in maneuvering around oncoming icebergs and patches of moderately thick sea ice. At no time was the drilling operation negatively impacted by the routine operations of the ship. The Seacore drill rig performed equally well as mentioned previously. Our inability to recover Tertiary sections was primarily due to the difficulty in dealing with the overlying compacted diamicton that barred us from the intended target. The problem was both a lack of adequate time/ice/weather windows and the right combination of drilling tools and pipes to better handle with the material.

In the end, recovery of Holocene sediment was excellent, and the 108.2-m greatly expanded section at Site 1 (Maxwell Bay) should attract interest from specialists in that field. Unfortunately, we have no material yet in hand to offer the larger community of Antarctic Cenozoic specialists.

For that reason, we plan to hold our open post-cruise workshop after SHALDRIL II drilling is complete. The tentative date will be the second week in August, 2006. The meeting will be held at the Antarctic Marine Geology Facility of Florida State University, which is the repository for the SHALDRIL cores.

The primary goal of the workshop is to allow geoscientists interested in studying the SHALDRIL cores to view the cores and receive briefings from shipboard scientists on the basic characterization of the cores carried out aboard ship. A copy of the shipboard descriptions of the cores as contained in the respective *SHALDRIL Initial Reports* will be provided all participants in advance of the workshop. Investigators will then be free to propose further study of the materials through normal NSF channels. By making this information available to the larger user community, a broader understanding of the capabilities and future potential of shallow drilling in the Antarctic will be promulgated as will interest in applying SHALDRIL techniques to a wider variety of marine-geology problems around the continent.

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FIGURES

Figure 1-1. Cruise track of NBP05-02 with six drill sites marked.

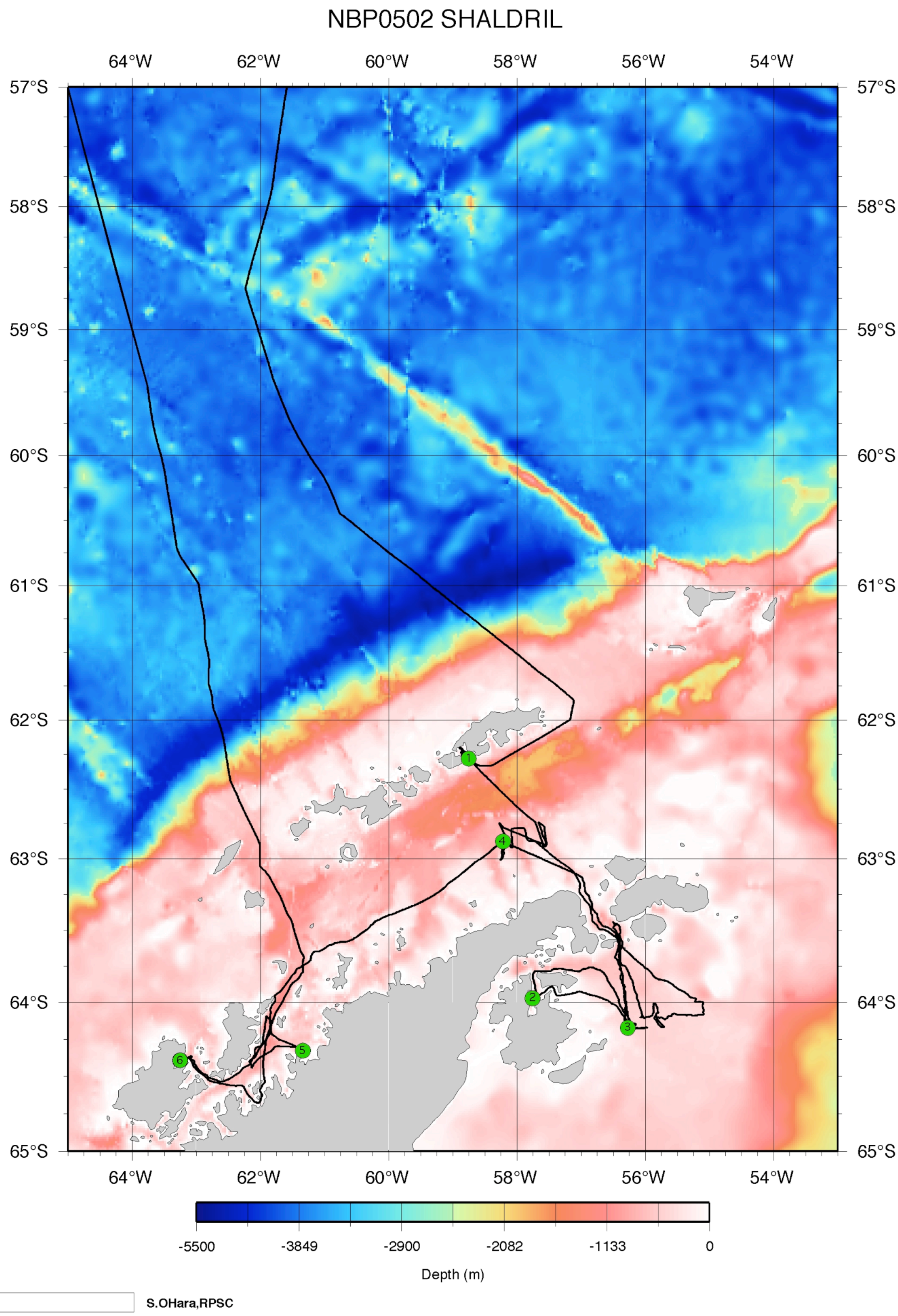
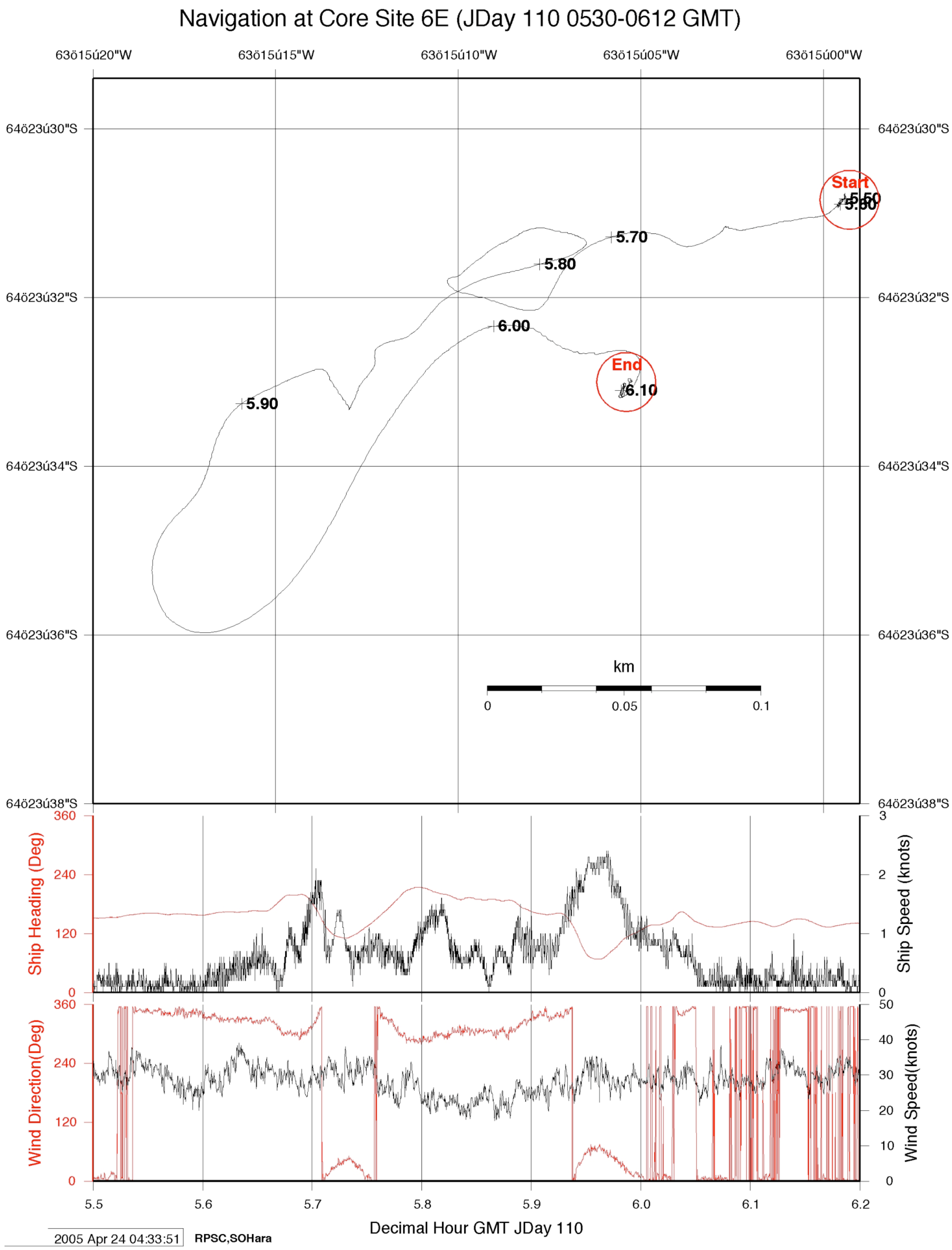


Figure 1-2. Plot of position, ship speed and heading, and wind speed and heading for the duration of the positioning excursion.



Chapter 2: Explanatory Notes
Table of Contents

EXPLANATORY NOTES

INTRODUCTION

In this chapter, we describe the shipboard procedures and observations that led to our preliminary conclusions. These data are also useful for selecting samples for shore-based research. This information concerns only shipboard operations and analyses described in the site reports in this Initial Reports volume.

Authorship of Site Chapters

The separate sections of the site chapters were written by the following shipboard scientists (authors are listed in alphabetical order):

A. Background and Objectives: John Anderson plus Patricia Manley, Julia Smith Wellner or Woody Wise as appropriate

B. Operations: Julia Smith Wellner

C. Lithostratigraphy: John Anderson, David Heroy, Kristy Milliken, Tyler Smith, Julia Smith Wellner

D. Biostratigraphy: Steven Bohaty, Lindsey Geary, Wesley Ingram, Matthew Sumner, Woody Wise

E. Physical Properties: Donovan Dums, Katherine Kirsch, Patricia Manley, Bradley Michalchuk

F. Seismic Stratigraphy: John Anderson, Julia Smith Wellner

G. Site Summary: John Anderson plus Patricia Manley or Woody Wise as appropriate

Appendix (optional): Shipboard Scientific Party

In addition to each site chapter, summary core descriptions ("barrel sheets" and images of each core) are presented (see "**Core Descriptions**").

HANDLING OF DRILL CORES DURING SHALDRIL OPERATIONS

The following guidelines are intended to standardize the processing and archiving of core material, especially drill core, collected during SHALDRIL operations on the RVIB *Nathaniel B. Palmer*. The different activities involved in the processing and archiving of the material are divided among several groups, including Raytheon Polar Services Company (RPSC) personnel, Antarctic Research Facility (ARF) personnel, the Shipboard Science Party, and Seacore personnel. Seacore personnel are responsible for retrieving the core. Once the core leaves the rig floor, a combination of RPSC, ARF, and Science Party personnel complete the tasks outlined below in Section II. Upon completion of these tasks, RPSC manages the refrigerated shipment of cores to the Antarctic Research Facility at Florida State University.

Core Nomenclature

Numbering of Sites, Holes, Cores

SHALDRIL sites are numbered consecutively and refer to one or more holes drilled while the ship is positioned over one acoustic beacon or at one GPS location. Multiple holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of the hole), moving the ship some distance from the previous hole, and then drilling another hole.

For all SHALDRIL sites, a letter suffix distinguishes each hole drilled at the same locality. The first hole drilled is assigned the site number modified by the suffix “A”; the second hole takes the site number modified by the suffix “B”; and so forth. It is important to distinguish among holes drilled at a site because stratigraphically equivalent sediments or rocks from the different holes may not have the same sub-bottom depths. Conventional kasten or piston cores taken at the site will follow this same nomenclature.

The cored interval is measured in meters below seafloor (mbsf). The depth interval assigned to an individual core begins with the depth below the seafloor at which the particular coring run begins and extends to the depth that the coring run ends (see Fig. 2-1). Each cored interval is generally the length of a core barrel. It may well be less, however, particularly for push cores taken with the extended core barrel. Coring intervals may be shorter and may not necessarily be consecutive if they are separated by drilled (i.e., non-cored) intervals.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored intervals in meters below seafloor ideally are unique in a given hole. The top mbsf of a core is calculated by adding the depth of the intervals of the all cored (or drilled) intervals above that core. When the recovered core is shorter than the cored interval, the top of the recovered core is equated with the top of the cored interval for curation purposes (e.g., Cores 2 and 5 in Fig. 2-1).

A core-type designator to follow all core numbers for all drill cores will be “R” for standard rotary cores, “E” for extended core barrels, “H” for “hammer” cores, and “PB” for “piggy-back” diamond-rotary cores. These various types of cores come in different lengths, i.e., up to 5 m for standard rotary cores, 1 to 3 m for extended core barrels that are pushed rather than drilling into the sediment (and which include “push” and “Shelby” cores), 3 m for diamond-rotary cores, and a variable amount of rubble for hammer cores.

When full recovery is obtained, the core is subdivided into sections 1.5 m in length (Fig. 2-2). The lowermost section will generally be shorter than 1.5 m. In some cases, all sections may be cut into intervals less than 1.5 m to preserve features of interest. Sections <1.5 m in length also may be cut when the core liner is severely damaged.

By convention, material recovered from the core catcher (Fig. 2-2) is placed immediately below the last section where the core is described and is labeled "core catcher" ("CC"). The core catcher is assigned the depth of the top of the cored interval in cases when material is recovered only in the core catcher (even though information from the driller or other sources may indicate from what depth it was actually recovered).

Labeling of Cores and Sections

All core sections are labeled with a waterproof permanent marker (or electric scribe). Each core liner section is labeled twice, once on each side, 180° apart. The following information is included on each core section:

- Ship name and year
- Cruise number
- Site number
- Hole: A, B, C, etc.
- Core number
- Core type: (**R** *Rotary Core*, **E** *Extended Core Barrel*, **H** *Hammer Core*, **PB** *Piggy-back Diamond Core*)
- Section number

For example, Core 2 from the second hole drilled with the extended core barrel at Site 1 during the second cruise of the year 2005 on the *N.B. Palmer* would be labeled: NBP05-02-1B 2E.

Individual sections of a core are labeled numerically from the top to the base. The uppermost section is designated 1, the next as 2, and so on. Note: this protocol is the opposite of standard piston coring nomenclature. Section numbers appear on the core liner after the Core number. Thus, NBP05-02-1B 2E-1 would designate the first (uppermost) section of Core 2. The next section of Core 2 would be NBP05-02-1B 2E-2. Figure 2-2 graphically depicts the core-labeling scheme for a variety of core recovery scenarios.

The orientation of the core is also marked on each core section. An arrow pointing in the up direction is drawn directly on the core liner in two places, 180° apart. If a foam insert is placed in a whole core to fill a sediment gap prior to splitting, a note is made on the core liner marking its location.

Other types of Cores Obtained during Drilling Cruises

Kasten cores were collected during the inaugural SHALDRIL cruise and there is a chance that in the future piston cores could be collected during other drill cruises. These cores are labeled according to standard convention modified to match the terminology described above. In other words, a kasten core is labeled by the cruise name (e.g., NBP05-02 represents the second cruise of 2005), then the site number (01 for the first site of the cruise), then A-KC for the first kasten core obtained there (thus NBP05-02-1A-KC). If another kasten core is taken at a site, it will be NBP05-02-1B-KC. Drill core obtained from that site after kasten coring twice will be labeled NBP05-02-1C. Sites that are occupied for kasten coring without drill cores will still be numbered sequentially with the drill core sites. Thus, the second site to be drilled might have core that is labeled NBP05-02-4B if two sites had kasten cores without drill cores and a kasten was taken at the fourth station before drilling commenced. Piston cores should be labeled "P".

Drill-Core Processing Steps

In this section the individual steps for processing core, from the time the core leaves the rig floor to its final storage location in the refrigerated container, are specified in detail. The steps are shown graphically in Figures 2-3 and 2-4.

SECTION CORE (STATION 1):

Core from each run is carried from the rig floor into the Baltic room and laid out horizontally on the core sectioning rack (starboard side of Baltic Room). The following protocol assumes core will be in liners.

The liner is marked off in 1.5-m intervals starting at the top of the recovered material in the core. The liner is then cut into sections and the sediment is separated using a stainless steel spatula, chisel or saw. Electrical tape is used to affix the end caps. End caps must also be labeled ("top" and "bot") if they are not color-coded. If the end caps are color-coded for the extended core-barrel liners, yellow is for the top and black is for the bottom.

"FAST-TRACK" SAMPLE (STATION 1):

Fast-track sampling for biostratigraphic analysis initially comes from the Core Catcher samples when present (otherwise the base of the core), and if needed from the base of each 1.5-m section. No sections will be cut from any of the liners for fast track analysis.

EQUILIBRATE CORES (STATION 2):

Once cores are labeled, sectioned, and sampled for "fast-track" analyses, they are taken into the main core lab (i.e., Aft Dry Lab) to equilibrate to room temperature before being analyzed on the Multi-Sensor Core Logger (MSCL). This process usually takes 3-4 hours.

CORE LOG SPREADSHEET (STATION 2):

Throughout the cruise a spreadsheet was compiled that includes a list of all the cores brought on deck. Once cores are sectioned, labeled, and brought into the main core lab (= Aft Dry Lab) for equilibration, pertinent core data (ID, length, sub-bottom depth, etc) is entered into the Core Log Spreadsheet (Fig.2-5).

MULTI-SENSOR CORE LOGGING (STATION 3):

Once the core sections have equilibrated to room temperature, they are run on the MSCL for gamma-ray attenuation, p-wave velocity, and magnetic susceptibility. The core is usually logged at 1-cm intervals. After all the sections of a core have been run, the data are processed, and then downloaded to the local server.

CORE SPLITTING, CLEANING AND DEPTH LABELING (STATION 4):

After each section is run on the MSCL, it is carried back into the Baltic Room for splitting. Soft sediment cores are split using the soft-sediment carriage on the core splitter. This carriage cuts each side of the liner (but not the sediment) along the whole length of the section. Once the liner is cut, the sediment is split by pulling a wire along the length of the section. Indurated cores are cut using the "super-saw" carriage on the core splitter. In this mode, a water-cooled saw is pulled along the length of the core cutting both the liner and sediment in half.

Once the core is cut in half, each section is cleaned by scraping the surface with a 4" stainless-steel spatula in perpendicular motion to the long-axis of the core. Depth markers are then placed at appropriate intervals along the length of the core. Each section of core is labeled on both the work and archive sides with the appropriate Core/Section designation (See Section IB for core-labeling protocols). In case the sediment is not equally distributed within the liner, the half with the most sediment will be designated the sample half.

CORE PHOTOGRAPHY (STATION 5):

The archive and sample half of each split section are placed side-by side with an appropriate label on the core photography table, and digital photos are taken in appropriate increments down-section. The photographs are then downloaded, renamed with the proper core/section designator, spliced to create an image of the entire core, and placed on the local server.

CORE DESCRIPTION (STATION 6):

The archive section of the core is placed on the Core Description table after the section is photographed. The core is logged for color (using Munsel charts), structure, grain size, and basic lithologic variation. See Figure 2-6 for an example of a Graphic Core Description Log for the barrel sheets and Figure 2-7 for lithologic symbols for the barrel sheets. Smear slides are taken to verify lithologic components.

ELECTRICAL RESISTIVITY (STATION 7):

The working half of the core is placed on the Core Sampling table. The ER probe will take resistivity measurements every 5 cm. This is a non-invasive probe and does not disturb the core.

*PHYSICAL PROPERTY SAMPLING (STATION 7): **

Five cc of sediment is taken with a syringe every 5-10 cm for discrete physical property measurement. The samples are placed in a weighed vial, sealed with electric tape, and placed in travel containers in the cool room for storage until shipment. Discrete samples will be processed on shore for water content, saturated bulk density, porosity and void ratio. Final physical property measurements for SHALDRIL NBP05-02 will be performed at Middlebury College.

*ADDITIONAL SHIPBOARD SAMPLING (STATION 7): **

Any additional sampling required for basic core characterization or ephemeral properties is conducted at the station. Samples taken are placed in bags and hand labeled, and the sample data will be entered into a spreadsheet. Standard sampling supplies (bags, bag sealer, foam plugs, sampling tubes, etc) are stored at this station.

__**SAMPLING WILL ONLY BE CONDUCTED AS IS DEEMED APPROPRIATE BY THE PI'S FOR NECESSARY SCIENCE AND ONLY TO THE EXTENT THAT CORE PRESERVATION IS NOT COMPROMISED.__

CORE WRAPPING (STATION 8):

After the core is described and sampled, the work and archive halves are wrapped in plastic wrap (Reynolds 900 film) and then placed into standard ODP-style "D-tubes", which is labeled with each core's information.

MAIN LAB CORE STORAGE (STATION 9):

A movable core rack with space for 120 sections (60 archive and 60 work) is utilized to temporarily store core in the Aft Dry Lab. This storage rack will allow 90 meters of core to be held in the lab at any one time.

BOX CORES FOR REFRIGERATED STORAGE (STATION 8):

In preparation for refrigerated storage and shipment of cores, 10 individual D-tubes are packed into a shipping box. Each box is then labeled (with cruise, hole and core designations), the ends stapled shut, and wrapped with strapping tape.

TRANSPORT OF CORES TO REFRIGERATED STORAGE (STATION 10):

The boxes containing the cores are carried to the deck area just aft of the Baltic Room. Boxes are stacked five on a pallet and securely strapped into place. The pallet is then lifted by electric winch and placed on the Helo deck near the refrigerated storage container (Fig. 2-4).

CORE STORAGE ON HELO DECK (STATION 11):

The boxes can be stacked in the refrigerated van (Fig. 2-8). There is a stacking limitation of 8 boxes high, which is primarily a weight limitation to avoid crushing the core.

Kasten-Core Processing Steps

After coming on deck, kasten cores are carried to the sampling table where electric resistivity measurements are made at 2 cm interval. Discrete samples are taken at this interval. After sampling, the kasten cores are archived by means of half-liner sampling. The archive core then proceeds to have depth labels affixed and is then sent to the camera station for photography (station 5). The half-liner sample is run through the MST track to obtain magnetic susceptibility for correlation purposes. Final steps are the same as above for Station 6 and then to Station 8.

Shipping

Material headed to the Antarctic Research Facility should be shipped to:

Antarctic Research Facility:
108 Carraway Building
Florida State University
Tallahassee, FL 32306-4100
ATTN: Fred M. Weaver &/or Matthew Curren
Telephone: 850-644-2407
FAX: 850-644-4442

via:

NSF Contractor Representative
U.S. Naval Construction Battalion Center
Building 471, North End
Port Hueneme, California
93043
ATTN: Jackie Samuels

SITE GEOPHYSICS

Core sites for the NBP05-02 SHALDRIL cruise were selected based on several previous cruises. The seven sites planned for the northwestern Weddell Sea are based on a seismic survey completed during R/V *Polar Duke* Cruise PD91 (Anderson et al., 1992, 1994). The selected sites were further surveyed during cruise RVIB *Nathaniel B. Palmer* Cruise NBP02-01 in preparation for SHALDRIL (Wellner and Anderson, 2004). Ice conditions in the Weddell Sea did not allow drilling to commence there at the start of operations. The alternate Maxwell Bay site (NBP05-02-1) was selected based on seismic data from Cruises Deep Freeze DF86 and PD91 (Anderson, 1999). Seismic data was collected during NBP05-02 to further constrain alternate sites as needed for weather and ice conditions. The data were collected using two 50 in^3 airguns and a single channel ITI streamer.

LITHOSTRATIGRAPHY

Core Description Procedures

General Description Procedures

Procedures used for describing the cores in this volume are similar to those used in previous studies published by the Antarctic Marine Geology Research Facility (e.g., Kaharoeddin et al., 1988; Bryan, 1992a, b). These procedures are presented below.

The description of each core consists of four types of information:

1. The primary information (latitude, longitude, water depth, core length);
2. The lithologic description (using megascopic and smear-slide observations);

3. Information concerning core conditions that are not inherent to the lithologic character of the sediments (disturbance, missing section, etc.);
4. Whole-core magnetic susceptibility data. Magnetic susceptibility data were collected on-board the RVIB *Nathaniel B. Palmer*. The data are corrected for end-of-core effects and are plotted next to the graphic lithology.

Most of the primary information is obtained from the deck-log, or from other information provided by the chief scientist(s) of the cruise. Core conditions not inherent to the lithologic character of the sediments are recorded from the deck log and from initial observations after cutting the core liner.

Each core description is accompanied by a graphic log illustrating the main lithologic boundaries, inclusions, sedimentary structures, and disturbances of the sedimentary units. The positions of the core section breaks are indicated on the log in order to inform the investigator as to where samples should not be taken, since the cutting of cores into sections may result in sediment disturbance. Not all information appearing in the written portion of the lithologic description is illustrated in the graphic log.

Megascopic Examination and Description

The elements of description of each unit are presented below:

1. The upper and lower boundaries of the unit. Lithologic units are recognized on the basis of compositional, textural, and other sedimentological characteristics.
2. Lithologic name and Munsell color code of the sediment. Gradual changes in texture or color of the unit are described accordingly. The term "graded" can be applied to the name of the unit (see the following section on sediment classification). Interlayering with other types of sediment is also noted.
3. Observable distribution of volcanic ash, manganese nodules, and staining.
4. Internal structures within the unit: zone, layer, lamina, lense, stringer.
5. Inclusions: Sedimentary clasts, pebbles, lapilli, manganese nodules.
6. Bioturbation.
7. Disturbances due to the coring operation and/or transportation.
8. Nature of the bottom contact of the unit: sharp, gradational, unconformable, etc.

The classification primarily is based on visual and smear-slide observations. Sediments larger than 63 μm in size must usually be avoided in smear-slide preparations. In the case of sediments with mixed sizes (> and < 63 μm), an estimate of coarse -vs.- fine fraction is necessary for sediment classification. If there is an obvious coarse fraction within an otherwise muddy lithology, a small portion of the sediment is wet-sieved (63 μm sieve) and observed under the binocular microscope. A rough visual estimate is then made of the amount of coarse -vs.- fine sediment (based on the amount sieved -vs.- residual coarse sediment >63 μm). For example, if a smear slide is a diatomaceous mud, but approximately half of the original lithology is sand, the sediment will be a diatomaceous sandy mud. Thus, estimated values of dominant constituents from smear-slide analyses, wet-sieving, and megascopic examination are used in classification.

Glacial-marine sediments generally consist of mixed-size classes (such as pebbles in mud). However, no attempt is generally made to utilize a separate classification for these sediments. Instead, the matrix is classified according to the guidelines outlined herein for fine-grained sediments, and clasts are described separately as inclusions within the lithology. Where a separate classification is used, see section on “Terrigenous and Volcanic Detrital Sediments” below.

The size class and sorting of a sand or pebble unit are usually mentioned in the description. Size classes of sand-size fractions are determined by use of the AMSTRAT (American/ Canadian Stratigraphic) size-class comparison card. On this card, each of the five size classes (very coarse, coarse, medium, fine, very fine) of sand-size particles has been divided into two subclasses (very coarse-upper, very coarse lower; coarse-upper, coarse lower; etc.). The ten subclasses (separated by 0.5 phi intervals) are graphically depicted on the card for comparison with the sediment. Determination of the mean grain size of sand is a matter of matching the size of the most abundant grains to one of the five size classes exhibited on the card.

A unit may exhibit several colors, and color changes within a unit are described as being gradational or sharp (abrupt). Mottling refers to irregular spots of differing color within the sediment, and the color of mottling may be included in the description. The color of the sediment is determined by visual comparison of fresh sediment with the Munsell color chart. If the color of a sediment cannot be matched exactly with the color chart, the closest color is used.

Any variation in the abundance of a major component in a unit, observable either megascopically or through smear-slide analyses, is given in the description. Minor constituents that are scattered within a unit (micro-manganese nodules, lapilli, ash, etc.) may also be identified on smear slides. Their abundance is determined after a thorough examination of the core and described as scattered, common, or abundant. Manganese and ferrous oxides that occur as staining materials can be either in the form of small patches, or spread uniformly within a certain interval. These stainings are described by the terms slightly, moderately, or highly stained.

In describing the internal structures within a sedimentary unit, the stratigraphic position of each structure is noted, and when applicable, the composition and the color are also described. Each structure is defined as follows: Zones are defined as small intervals (less than 20 cm) in which a notable change in the abundance of some components or inclusions in the unit can be detected, either through megascopic examination or in the smear-slide analysis. Layers have a thickness of between 1 to 10 cm and are separated from the main unit by a discrete change in lithology and distinct planes of contact. Layers less than 5 cm thick are usually not included on the graphic lithology column of the core description form but are denoted by a symbol in the structure column. Laminae are similar to layers, but have a thickness of less than 1 cm. Stringers are laminae that are discontinuous and often irregular in form. In the description of a unit, the following sequence is used: zones, layers, laminae, and stringers.

Inclusions within a unit are described in the following manner:

1. Sedimentary clasts are described in detail including size, composition, color, and position in the core (Example: "sedimentary clasts up to 12 mm composed of calcareous, ash-bearing mud, diatomaceous mud, and muddy diatomaceous ooze, all olive gray (5Y 4/1), common throughout").
2. Manganese nodules are described as to their size and position in the core.
3. Volcaniclastics are described as to their textural class and position in the core. Sometimes the rock type (pumice, scoria) is also mentioned.
4. Pebbles are described as to their size, roundness, and position in the core (Example: " subangular to subrounded, very fine to fine pebbles common throughout"). Occasionally, their rock type is also given. Coatings, encrustations, and cementation by manganese or ferrous oxides are common on clastics and volcaniclastics; they are mentioned when present.
5.

Bioturbated sediments are described in terms of slightly, moderately, or highly bioturbated. The qualifiers can be approximated as follows:

Slightly:	less than 5% bioturbation
Moderately:	between 5% to 30% bioturbation
Highly:	30% or more bioturbation

Operational disturbances may occur during coring, transportation, and occasionally during the splitting of the core and may result in partial or total loss of the primary sedimentary structures and the stratigraphic integrity of the sediment. The degree of the operational disturbance is described in terms of slightly, moderately, or highly disturbed. Slightly disturbed sediments still retain most of their primary sedimentary structures, particularly along the central axis of the core. Moderately disturbed sediments have lost almost half of their original structures and must be sampled carefully if they are to be stratigraphically meaningful. Highly disturbed sediments have lost most or all of their primary structures; it is not recommended that these be sampled for stratigraphic study because of mixing of sediment components. Highly mixed sediment that has randomly entered the core by suction during the coring operation is described as flow-in and is usually characterized by vertical striations that can be traced from the base of the core.

Water entrapped in the liner can wash sediment along the side of the liner during transport. Sediments disturbed in this manner are described as slightly or moderately washed along the side, and can still be sampled carefully for stratigraphic work. The term, "highly washed along the side", is not used because such sediment is almost always highly disturbed. An uncommon disturbance occurs when the overlying sediment is dragged along the side of the liner. Cores described in this manner can be sampled (carefully) for stratigraphic work.

Smear-Slide Analysis

Smear slides are routinely made from each macroscopically visible lithologic unit in the core (as recognized by compositional, textural, and color changes). If the core is homogeneous in composition (e.g., a diatomaceous ooze), only one or two slides may be made for the entire core.

Smear slides are made as follows: Using a toothpick, a small amount of sediment is obtained from the core. This sample is mixed with a drop of distilled water on a standard 1" x 3" glass slide until the sediment and water are smeared into a very thin film. The slide is then dried on a hot plate (using low temperature). When the slurry is dry, 1 to 3 drops of Norland Optical Adhesive (NOA 61) are put over the dried sediment film and covered with a glass cover slip. The slide is then placed under an ultraviolet lamp for 2 or 3 minutes to cure the adhesive. After curing, the slide is then ready for viewing under a petrographic microscope. Using transmitted light and phase contrast, biogenic sediment components and heavy minerals are readily visible. Polarized light is used to view most clastic components.

For each smear slide, the percentage abundance of the following constituents are estimated using the percentage composition chart of Shvetsov (Terry and Chilingar, 1955) and reported on the core description logs:

1. Minerals: quartz, feldspar, mica, heavy minerals, volcanic glass, glauconite, pyrite, and micromanganese nodules.
2. Biogenic constituents: foraminifera, calcareous nannofossils, unspecified carbonate, diatoms, radiolarians, sponge spicules, silicoflagellates, ebridians, and ostracodes.
3. Sand-silt-clay ratios of the terrigenous fraction.

On the basis of the dominant sedimentary constituents, the sediment is classified according to the guidelines outlined below. On the core description form a symbol “D” by the smear-slide percentage denotes a dominant lithology, a symbol “M” denotes a minor lithology, zone, layer, laminae, or stringer, and “TR” denotes trace quantity.

Sediment Classification

The system of sediment classification used in this volume is modified from Kaharoeddin et al. (1988). This classification is based on abundance estimates of constituent particles (from smear-slide observations) and megascopic examination.

The three major groups of sediment are (Fig. 2-9):

1. Pelagic sediments, consisting of pelagic clay, siliceous ooze, calcareous ooze, or mixtures of siliceous and calcareous ooze;
2. Transitional sediments consisting of mixtures of biogenic and clastic sediments; and
3. Terrigenous and volcanic detrital sediments, which includes glacial and glaciomarine sediments.

Pelagic Sediments

A. Pelagic Clay

This type of sediment accumulates at a very slow rate and generally has a brown hue. Authigenic components are common (5% or more in estimated abundance), however, they may be present only in small quantities and distributed in such a manner that they are not found on the smear slide. Usually, a careful examination of the core, aided by the smear-slide analysis, is necessary to determine whether or not a sediment is a pelagic clay. The primary components of pelagic clay are clay minerals and silt-size quartz particles, and the clay may contain less than 30% biogenic components. A qualifier cannot be added to pelagic clay; hence, pelagic clay containing 25% diatoms is not called diatomaceous pelagic clay.

B. Pelagic Biogenic Sediments

Included in this group are sediments containing at least 30% biogenic skeletons, but containing less than 30% silt and clay. They are named according to their principle fossil types: diatomaceous ooze, radiolarian ooze, siliceous ooze, foraminiferal ooze, nannofossil ooze, or calcareous ooze. A second (lesser) biogenic component may be used as a qualifier if more than 15%. The following rules apply for naming pelagic biogenic sediments:

1. If both the principal and lesser fossil types are similar in their chemical composition (i.e., calcareous or siliceous), the sediment may be called a siliceous ooze or calcareous ooze, depending on its chemical composition.
2. Calcareous sediment that has unspecified carbonate more than one-third of the total carbonate is called calcareous ooze.
3. If the principal and lesser fossil types differ in chemical composition, then both components are used in the sediment name, joined by a hyphen (e.g., diatomaceous-foraminiferal ooze).

C. Transitional Biogenic Sediments

Included in this group are sediments containing at least 30% silt and clay. Two subdivisions are recognized: the transitional siliceous sediments having at least 15% diatoms but less than 30% calcareous skeletons, and transitional calcareous sediments having at least 30% calcareous skeletons. The following rules apply for naming transitional biogenic sediments:

1. A transitional siliceous sediment is called muddy diatomaceous ooze if diatoms are more abundant than silt and clay; otherwise, it is called diatomaceous mud.
2. The transitional calcareous sediments are named according to their principal fossil types: marly foraminiferal ooze or marly nannofossil ooze. If the lesser biogenic component exceeds 15%, the sediment is called marly calcareous ooze.

Detrital Sediments

A. Terrigenous Detrital Sediments

Sediments in this group are classified according to their texture as defined by the standard size classes of sediment according to Friedman and Sanders (1978; Figs. 2-10 and 2-11). Sand/silt/clay ratios of the terrigenous fraction, based upon optical examination of smear slides, are presented on the core description logs. These ratios are used to assist in classification of terrigenous sediments. The following rules apply for sediments that are primarily composed of mixtures of sand, silt and clay:

1. The sediments are named after their major clastic component (end-member) if that component is greater than or equal to 70% (i.e., sand, silt, clay).
2. Sediments containing a mixture of silt and clay greater than or equal to 70% are called mud.
3. Sediments containing between 30% and 50% sand and between 50 and 70% mud, silt or clay are called sandy mud.
4. Sediments containing between 50% and 70% sand and between 30% and 50% mud are called muddy sand.
5. Sediments containing a minor component between 15% and 30% (e.g., diatoms or pebbles) should have a qualifier (e.g., diatomaceous muddy sand).

Pebbles are seldom encountered as a distinct sedimentary unit in marine sediments except in glacial marine sediments. The following rules apply to the naming of sediments that consist primarily of pebbles:

1. Sediments containing 70% or more pebbles are called pebbles.
2. Sediments containing between 50% and 70% pebbles and between 30% and 50% either mud or sand are called muddy pebbles or sandy pebbles, respectively.

Pebble units often contain finer matrix sediment, some or nearly all of which may be washed away during core retrieval or transportation. Removal of matrix sediment by washing is usually easily identified during core description. If the matrix sediment constitutes more than 10% of a pebble unit, the composition of the matrix is mentioned.

In graded sequences in which the size of the particles ranges from one textural class to another (e.g., silt to sand), the term graded clastics is used as the name of the unit. If the size of the particles ranges within one textural class, the unit is named according to its textural class (e.g., "sand, yellow gray (5Y 7/2), graded").

B. Glacial and Glaciomarine Sediments

Because SHALDRIL involves sampling glacial and glaciomarine deposits, a significant portion of the cored intervals will likely contain these poorly sorted deposits. The non-genetic classification used to classify glacial and glaciomarine deposits is as follows:

1. Diamicton- an unsorted mixture of gravel, sand and mud in more or less equal quantites, stratification and fossils are rare. Pebbles tend to be angular with striations.

2. Pebbly mud- mud containing dispersed pebbles in concentrations exceeding 30% by volume.
3. Gravel- sediments consisting of greater than 70% pebbles.

C. Volcaniclastics

This sediment group is classified according to the classification proposed by Fisher (1961, 1966). The nomenclature and the size limits are as follows:

Fine ash:	less than 63 μm
Coarse ash:	63 μm to 2 mm
Lapilli:	2 mm to 64 mm

As suggested by Fisher (1966), the term "volcanic" is not used as an adjective of ash or lapilli. The term "volcaniclastic" is used only for graded sequences where the particles size grades from ash to lapilli; thus, the name of the unit is graded volcaniclastics. In the case of graded sequences where the size of the particles ranges within one textural class, the unit is named according to its textural class (e.g., "coarse ash, brownish black (5YR 2/1) graded, well sorted").

Volcaniclastics that have biogenic or terrigenous components in excess of 15% will have a qualifier with the term "bearing" added to the qualifier (e.g., "diatom-bearing coarse ash"). The same term is also added to the qualifier of other groups of sediment if the unit contains more than 15% volcaniclastics (e.g., "ash-bearing diatomaceous ooze").

BIOSTRATIGRAPHY

Introduction

Shipboard biostratigraphic investigation of SHALDRIL cores included primarily two microfossil groups, diatoms and calcareous nannofossils. These were supplemented by radiolarians and silicoflagellates as appropriate.

Ages for all datum events were calibrated to the Geomagnetic Polarity Time Scale (GPTS) of Cande and Kent (1992, 1995) and the Cenozoic global chronostratigraphic compilation of Berggren et al. (1995). A new timescale for the Neogene has recently been proposed by Gradstein et al. (2004). The reversal ages of the GPTS, however, have not yet been revised to this new timescale, which prevents revision of the age calibrations for Southern Ocean biostratiraphic datum events. Future revision of age interpretations of SHALDRIL cores will likely include biostratigraphic age calibrations revised to the Gradstein et al. (2004) timescale.

Preliminary ages for SHALDRIL cores were assigned primarily based upon core-catcher samples. Samples from within the cores were examined when a refined age determination was necessary and time permitted. Correlations to standard chronostratigraphic frameworks will likely by further enhanced by shore-based studies of other microfossil groups (e.g. foraminfers and dinoflagellates), magnetostratigraphic data, and strontium-isotope stratigraphy.

Diatoms

Zonal Schemes

The goal of initial diatom work on SHALDRIL cores was to identify important marker datums and delineate zonal boundaries. Several extensive diatom biostratigraphic studies have been carried out for Cenozoic cores recovered in the Southern Ocean region (e.g. Schrader, 1976; Gersonde and Burckle, 1990; Baldauf and Barron, 1991; Harwood and Maruyama, 1992; Gersonde and Bárcena, 1998; Zielinski and Gersonde, 2002; Censarek and Gersonde, 2002). These studies have resulted in several proposed zonal schemes and numerous revisions. Currently, detailed and well-calibrated Southern Ocean zonal schemes exist for the Oligocene to Recent. The schemes utilized during the SHALDRIL cruise were drawn primarily from three sources: Zielinski and Gersonde (2002), Censarek and Gersonde (2002), and Harwood and Maruyama (1992). Figures 2-12 through 2-14 illustrate these zonal schemes, marker species datums, and age calibrations.

The Plio-Pleistocene diatom zonal scheme applied to SHALDRIL cores is that proposed by Zielinski and Gersonde (2002) for the southern regions of the Southern Ocean (Fig. 2-12). This zonal scheme relies primarily upon biostratigraphic data collected from cores in the Altantic sector of the Southern Ocean during Ocean Drilling Program (ODP) Leg 177 (Zielinski and Gersonde, 2002), but the datums used in this scheme have previously been well-established from biostratigraphic studies at many sites around the Southern Ocean.

One new feature of this revised scheme is the addition of the LO datums of Rouxia constricta and Rouxia leventerae in the middle and upper Pleistocene; these datums were recently recognized as biostratigraphically useful and used to refine the Pleistocene diatom zonation (Zielinski and Gersonde, 2002; Zielinski et al., 2002). The age calibrations for most diatom events in the Plio-Pleistocene interval are tied to magnetostratigraphic records and have relatively precise age calibrations. One zonal datum of uncertain age is the first occurrence datum (FOD) of F. barroni (4.2-4.6 Ma). A hiatus is present in many Southern Ocean sections in the 4.5 to 4.0 Ma interval, and this datum may also be diachronous across different latitudes/regions. In addition to the primary zonal datums, several other diatom datum events are biostratigraphically useful in the Plio-Pleistocene interval (Table 2-1). These events were utilized where possible for age assessment and of SHALDRIL cores.

The middle to upper Miocene diatom zonal scheme applied to SHALDRIL cores is a modified version of that proposed by Censarek and Gersonde (2002) for the southern regions of the Southern Ocean (Fig. 2-13). This zonal scheme relies upon biostratigraphic data collected from cores in the Altantic sector of the Southern Ocean during ODP Legs 113 and 177 (Censarek and Gersonde, 2002). Minor modifications to this zonation include: utilization of the first common occurrence datum (FCOD) of Actinocyclus ingens (16.1 Ma) for the base of the A. ingens-D.maccollumii Zone, the addition of the FOD of Thalassiosira torokina (9.0 Ma) and the FOD of Actinocyclus ingens var. ovalis (8.6-8.6 Ma) as subzonal markers in the A. kennettii-F. praecurta Zone, and the addition of the last occurrence datum (LOD) of Nitzschia miocenica (6.0-6.2 Ma) as a subzonal marker in the H. triangularus-F. aurica Zone (Fig. 2-13). In addition to the primary zonal datums, several other datum events are biostratigraphically useful in the middle to upper Miocene interval (Table 2-2).

The names of several Southern Ocean diatom zones in Miocene to Pleistocene interval have been changed to reflect recent taxonomic revisions. The former Pliocene-Pleistocene Nitzschia spp. zones have been changed to Fragilariopsis spp., following the taxonomic revisions of Gersonde and Bárcena (1998), Zielinski and Gersonde (2002), and Censarek and Gersonde (2002). The names of the former Nitzschia hustedtii-Nitzschia grossepunctata and Nitzschia hustedtii Zones in the Miocene have also been changed to the Denticulopsis simonsenii and Dent. simonsenii-Nitzschia grossepunctata Zones, respectively, in order to reflect taxonomic clarifications in the Denticulopsis group by Yanagisawa and Akiba (1990).

The lower Oligocene to lower Miocene diatom zonal scheme applied to SHALDRIL cores is a modified version of that proposed by Harwood and Maruyama (1992) (Fig. 2-14). This zonal scheme relies primarily upon biostratigraphic data collected from cores in the Indian sector of the Southern Ocean during ODP Leg 120 (Harwood and Maruyama, 1992). Age calibrations of several of the zonal datums utilized in this scheme were recently revised by Roberts et al. (2003) through detailed correlation to magnetostratigraphic records. Modifications made to the zonation originally proposed by Harwood and Maruyama (1992) include: the use of the FOD Rhizosolenia antarctica (33.2 Ma) as the only subzonal datum in the R. oligocaenica Zone, the use of the last common occurrence datum (LCOD) of Rocella vigilans var. A (~29.0 Ma) as a subzonal marker in the R. vigilans Zone, and the use of the FCOD of Thalassiosira praefraga (20.5 Ma) as the base of the T. praefraga Zone. In addition to the primary zonal datums, several other datum events are biostratigraphically useful in the lower Oligocene to lower Miocene interval (Tables 2-2 and 2-3). These events were utilized to refine and corroborate the age information indicated by the zonal datums.

A well-established Southern Ocean diatom zonal scheme for the middle to upper Eocene does not currently exist. Diverse diatom assemblages existed through this interval in both shelf areas and in open-ocean regions (e.g. Hajós, 1976; Gombos, 1983; Gombos and Ciesielski, 1983; Harwood and Bohaty, 2000), but very few datum events have been identified and chronostratigraphically calibrated. Several diatom, ebridian, and silicoflagellate datums that are presently identified as biostratigraphically useful in the middle to upper Eocene are listed in Table 2-3. This list will be further developed and zonal schemes will be constructed as more diatom work is completed in this time interval, allowing further age refinement of SHALDRIL cores. Cores from ODP Leg 189 on the Tasman Rise, in particular, will allow development of a middle-to-upper Eocene diatom zonal scheme for the Southern Ocean region.

The application of the standard Southern Ocean diatom zonal schemes to Antarctic-shelf sections is problematic. Antarctic-shelf diatom assemblages are typically very different than open-ocean assemblages, and many of the marker taxa that are biostratigraphically useful at deep-sea locations are either not present or are present in low abundance in coastal/neritic shelf assemblages. Consequently, refined zonal schemes for application in shelf areas are currently in development. To date, informal Antarctic-shelf zonal schemes have been proposed for the Oligocene to lower Miocene (Harwood et al., 1998; Scherer et al., 2000; Harwood and Bohaty, 2001) and for the upper Miocene to upper Pliocene (Winter and Harwood, 1997).

Although drilling has been limited in shelf areas, several sections provide reference data for shelf-diatom assemblages. Shelf sites located in the Ross Sea/McMurdo Sound area include: Deep Sea Drilling Project (DSDP) Leg 28 cores (McCollum, 1975; Steinhauff et al., 1987), the MSSTS-1 drillcore (Harwood, 1986), the CIROS-1 and CIROS-2 drillcores (Harwood, 1989; Winter and Harwood, 1997); the Ross Ice Shelf Project (RISP) cores (Harwood et al., 1989), the Dry Valley Drilling Project (DVDP) Drillcores 10 and 11 (Brady, 1979, 1981; Winter and Harwood, 1997), the Cape Roberts Project (CRP) drillcores CRP-1, CRP-2/2A, and CRP-3 (Harwood et al., 1998; Scherer et al., 2000; Harwood and Bohaty, 2001); and Eocene erratics collected from southern McMurdo Sound (Harwood and Bohaty, 2000). Reference material for the Prydz Bay region includes ODP Leg 119 and 188 cores (Baldauf and Barron, 1991; Barron and Mahood, 1993; and Mahood et al., 1993; Mahood and Barron, 1996; Whitehead and Bohaty, 2003) and outcrops from the region containing diatomaceous sediments (e.g. Pickard et al., 1988; Harwood et al., 2000; Whitehead et al., 2001). Shelf sections in the Antarctic Peninsula region are of particular relevance for SHALDRIL cores. Previous drilling of pre-Quaternary sections in this region, however, is limited to cores recovered during ODP Leg 178 (Winter and Iwai, 2002; Iwai and Winter, 2002).

One potential problem in the biostratigraphic study of glacially-influenced sediments is reworking. The degree of diatom reworking can be qualitatively assessed from abundance, preservation, and/or the presence of obviously older or allochthonous taxa within a younger assemblage. Some taxa typically reworked in Southern Ocean sediments include: Actinocyclus ingens, Denticulopsis dimorpha var. areolata, and Denticulopsis simonsenii; these taxa are both heavily silicified and very abundant in certain intervals, thus easily reworked and incorporataed into younger sediments. In sections where reworking was suspected, we preferentially relied upon first occurrence (FO) or first common occurrence (FCO) datums for biostratigraphic age constraint.

Diatom Preparation

Samples from SHALDRIL cores were prepared for diatom analysis using standard procedures. A smear or strewn slide was initially prepared for all samples and examined under the microscope. If necessary, the samples were further prepared using chemical treatment and/or sieving. The chemically treated samples were reacted in small beakers with 10% hydrochloric acid in order to remove the carbonate component, followed by 10% H_2O_2 to remove labile organic material. The samples were not heated during chemical treatment. Selected samples were also sieved at 10 microns using nylon screens. All samples were prepared using 20x40 mm cover slips and mounted using Norland Optical Adhesive #61 (refractive index = 1.56). The slides were examined on a Zeiss Axioscope Microscope at 400x and 1000x, with the higher power used mainly for taxonomic identification.

Relative diatom abundance was determined from smear or strewn slides of the unsieved preparations. The total relative abundance of diatoms (as a group) was determined at 400x magnification and was based on the average number of specimens observed per field of view. Several traverses were made across the coverslips, and abundance estimates were recorded (Table 2-1, Fig. 2-13) as follows:

A (Abundant)	= >10 valves per field of view
C (Common)	= 3-9 valves per field of view
F (Few)	= 1 to 2 valve(s) per field of view
R (Rare)	= 1 valve in 2-30 fields of view
T (Trace)	= Very rare fragments present
B (Barren)	= No diatom valves or fragments present

The qualitative abundance of individual diatom taxa was based on the number of specimens observed per field of view at 1000x (oil objective). Individual species abundance categories are listed below. Generally, one-quarter to one-half of the 20 mm x 40 mm coverslip was examined (40 mm = ~200 fields of view). After initial abundance determinations were made at 1000x, the slides were then routinely scanned at 400x to identify rare taxa.

A (Abundant)	= ≥ 2 valves per field of view
C (Common)	= 1 to 5 valve(s) in 5 fields of view
F (Few)	= □1 to 3 valve(s) in 20 fields of view
R (Rare)	= □1 to 2 valve(s) in 60 fields of view
X (Present)	= □ 1 valve or identifiable fragment per traverse of coverslip
r	= Rare occurrences of a taxon interpreted as reworked specimens.
d	= Rare occurrences of a taxon interpreted as downcore contamination

The degree of siliceous microfossil fragmentation often mirrors dissolution, but the two factors are not necessarily dependent (i.e., well-preserved samples can be highly fragmented). Preservation of diatoms, therefore, was qualitatively based on the degree of dissolution and was rated as follows:

G (Good)	= Slight to no dissolution
M (Moderate)	= Moderate dissolution
P (Poor)	= Severe effects of dissolution

In addition, the degree of fragmentation was also noted:

L (Low)	= Minimal fragmentation
M (Moderate)	= Frustules moderately fragmented
H (High)	= Frustules highly fragmented; very few complete valves present

Taxonomy

The diatom taxonomic concepts followed here are based primarily on descriptions and illustrations of taxa from Eocene to Recent sections in Antarctic and Subantarctic waters. Most biostratigraphic and taxonomic work in the Southern Ocean has been derived from deep-sea sections, and the following papers are the primary references in this pool of literature: Abbott (1974), McCollum (1975), Gombos (1977), Schrader (1976), Fenner et al. (1976), Akiba (1982), Ciesielski (1983), Gombos (1983), Gombos and Ciesielski (1983), Ciesielski (1986), Gersonde and Burckle (1990), Gersonde (1990, 1991), Fenner (1991), Baldauf and Barron (1991), Harwood and Maruyama (1992), Mahood and Barron (1996), Gersonde and Bárcena (1998), Zielinski and Gersonde (2002), Censarek and Gersonde (2002), Iwai and Winter (2002); Winter and Iwai (2003), and Bohaty et al. (2003).

In addition, an important supplement to the papers above are reports containing taxonomic descriptions and illustrations of coastal and neritic taxa, including Harwood (1986,1989), Bohaty et al. (1998), Harwood et al. (1998), Scherer et al. (2000), and Harwood and Bohaty (2000, 2001). Several reports from North Pacific cores and outcrops also provide taxonomic guidelines for Oligocene and Miocene diatom taxa, including: Schrader & Fenner (1976), Barron (1985a,b), Akiba (1986), Akiba and Yanagisawa (1986), Yanagisawa and Akiba (1990), Akiba et al. (1993), Yanagisawa (1995), Gladenkov and Barron (1995), Scherer & Koç (1996), Gladenkov (1998), Komura (1998), and Barron et al. (2004).

A number of Neogene diatom taxa from the Southern Ocean have recently been transferred from the genus Nitzschia to Fragilariopsis (Gersonde and Bárcena, 1998; Zielinski and Gersonde, 2002; Censarek and Gersonde, 2002). We have followed these revisions, with a few exceptions. Several Miocene and Pliocene taxa, including Nitzschia miocenia and Nitzschia reinholdii, are currently left assigned to Nitzschia, pending further SEM investigation of these taxa and establishment of morphological ties to Fragilariopsis.

For many Southern Ocean diatom taxa, intermediate or transitional forms often precede the first occurrence or follow the last occurrence of the "sensu stricto" forms. The precise placement of datum levels is therefore difficult in intervals where these evolutionary transitions occur. For example, transitional forms have been documented between Thalassiosira jacksonii and T. inura, Fragilariopsis aurica and F. barronii, Fragilariopsis praeinterfrigidaria and F. interfrigidaria, F. interfrigidaria and F. weaveri, and F. barronii and F. kerguelensis, all of which involve zonal marker taxa. In some cases, such as the F. aurica-F. barronii lineage, the transition take places over a short time interval (narrow stratigraphic interval) and the problem is seen only in expanded sections sampled at high resolution.

Stricter taxonomic divisions than currently defined for the above taxa are needed to further refine the Southern Ocean zonal scheme. Where possible, the zonal datum levels were identified by the first or last common appearance of "sensu stricto" forms in the biostratigraphic assessment of SHALDRIL cores.

Calcareous Nannofossils

Biostratigraphy

For Cenozoic sediments of the Antarctic-Peninsula region, the cosmopolitan nannofossil biostratigraphic schemes of Martini (1971) and Okada and Bukry (1980) were employed with major modifications. The absence of low- to mid-latitude marker species in the Southern Ocean necessitated the combination of many of the zones, particularly in the Neogene (Pospichal et al. 1992) (Fig. 2-12). Wei and Wise (1992) calibrated several useful Neogene high-latitude nannofossil datums to the paleomagnetic time scale (subsequently recalibrated with Berggren et al., 1995). About five useful zones were used for the austral high-latitude Neogene.

Higher resolution is possible for the Oligocene to mid-middle Eocene (Wise, 1983; Wei and Wise, 1990; Wei and Thierstein, 1991) (Fig. 2-15). Ages for key datum levels have been calibrated in the region of the Kerguelen Plateau against magnetostratigraphy by Wei (1992); these are indicated in bold type on Figure 2-15, where they are shown against the Berggren et al. (1995) time scale.

As noted by Wei (1992), biomagnetostratigraphic correlations at several Southern Ocean sites may show considerably different ages relative to those compiled from the mid latitudes by Berggren et al. (1985, 1995). Where such differences exist, we have chosen to use in most instances ages derived from the high-latitude calibrations against the magnetostratigraphy. As noted above, where such ages differ from those in the lower latitudes, in Figure 2-15 the high-latitude ages are shown in bold type following the corresponding datum level (similarly, high-latitude biostratigraphic datums are also indicated in bold type). For major differences in age assignment, arrows indicate where on the chart a datum has been repositioned for purposes of this cruise.

Methods

Smear slides were prepared for calcareous nannofossil study using standard techniques. Slides were examined using the light microscope, under crossed polarizers, transmitted light, and phase contrast light at 1000-1200x magnification. Preservation and abundance of calcareous nannofossil species vary significantly due to etching, dissolution, or calcite overgrowth. Preservation and abundance are as follows:

VG = very good preservation (no evidence of dissolution and/or overgrowth; no alteration of primary morphological characteristics, and specimens appear diaphanous; specimens were identifiable to the species level);

G = good preservation (little or no evidence of dissolution and/or overgrowth; primary morphological characteristics only slightly altered; specimens were identifiable to the species level);

M = moderate preservation (specimens exhibit some etching and/or overgrowth; primary morphological characteristics sometimes altered; however, most specimens were identifiable to the species level); and

P = poor preservation (specimens are severely etched or exhibit overgrowth; primary morphological characteristics largely destroyed; fragmentation had occurred; specimens could be identified at the species and/or generic level).

Six calcareous nannofossil abundance levels are as follows:

V = Very abundant (10-100 specimens per field of view)
A = Abundant (1-10 specimens per field of view)
C = Common (1 specimen per 2-10 fields of view)
F = Few (1 specimen per 11-100 fields of view)
R = Rare (1 specimen per 101-1000 fields of view)
B = Barren

Radiolarians

Zonation

Middle and high latitude Cenozoic radiolarian zones of Lazarus (1992), Abelmann (1992), and Takemura (1992) were applied to the SHALDRIL radiolarian material. Stratigraphic constraint of radiolarian events were based on examination of selected samples from core catchers.

The middle Miocene to Pleistocene zonation of Lazarus is based on the earlier schemes of Hays (1965), Chen (1975), Weaver (1976), Keany (1979), and Caulet (1991) and refined by Lazaras (1992) using sediments recovered on ODP Legs 119 and 120. The lower to middle Miocene zonation of Abelmann (1992) and the upper Eocene to upper Oligocene zonation of Takemura (1992) are based on radiolarian studies from ODP Legs 113 and 120. Biostratigraphically useful radiolarian datums from these zonations have been calibrated to the Berggren et al. (1995) geomagnetic polarity time scale.

Methods

To obtain radiolarians from core-catcher samples, about 10 cm^3 of sediment was disaggregated and boiled with 10% H_2O_2 and about 1% Calgon solutions followed by washing on a 63- m mesh sieve. Some samples were cleaned with 10% HCl when necessary. The residue was moved into a beaker, and a strewn slide made using a pipette. Norland-61 optical adhesive was used as a mounting medium.

Additional samples were taken from the cores, not at regular intervals, but from lithologies that are more likely to yield good radiolarian abundance and preservation. These samples were prepared onboard to help locate biostratigraphic events more accurately.

Overall radiolarian abundance was determined based on strewn slide evaluation at 10X, using the following convention:

A (abundant)	= >100 specimen per slide traverse
C (common)	= 50-100 specimen per slide traverse
F (few)	= 10-50 specimen per slide traverse
R (rare)	= <10 specimen per slide traverse
B (barren)	= No radiolarians in sample

Preservation was recorded as follows:

E (excellent)	= Nearly pristine, complete skeleton, lacking any indication of dissolution, recrystallization or breakage
G (good)	= Majority of specimens complete; minor dissolution, recrystallization and/or breakage
M (moderate)	= Minor but common dissolution, small amount of recrystallization or breakage of specimens
P (poor)	= Strong dissolution, recrystallization or breakage, many specimens unidentifiable

Silicoflagellates

Silicoflagellates are most commonly preserved in diatomites underlying modern or ancient ocean upwelling areas or in diatomites preserved by nearby volcanism. During the SHALDRIL cruise, silicoflagellates were observed generally as a in byproduct diatom or calcareous nannofossil preparations.

To determine the abundance of silicoflagellates, all specimens that consisted of more than half a skeleton were counted. The silicoflagellate zonation followed was that utilized by McCartney and Wise (1990) and McCartney and Harwood (1992). The compilation by Perch-Nielsen (1985) is also helpful.

PHYSICAL PROPERTIES

Introduction and General Objectives

Shipboard physical properties determinations provide a first look at variations in core material characteristics and may be correlated with core lithology and regional seismic data. The principal objectives of the physical properties measurement program are closely connected to the main scientific and operational goals. They can be grouped together as follows:

1. Providing comprehensive physical properties datasets, including those from electric resistivity (ER) probes, the magnetic susceptibility meter (MS), gamma-ray attenuation porosity evaluator [GRAPE], and Pwave logger [PWL].
2. Magnetic susceptibility was measured on whole-round sections along the length of the recovered core.

All instruments/apparatus used in the shipboard laboratory and principles of methods are described in Blum (1997). Measurements were made on whole and half linered sections of cores using the MST.

Sampling Strategy

Whole-core sections were scanned with the Multi-Sensor Track (MST) before being split. We then selected physical properties samples from the split cores. Where recovery permitted, we sampled every 5 to 10 cm depending on the sediment type. Final physical property measurements of the discrete samples are to be done on shore after the cruise. Using wet and dry weight volumes, water content, porosity, saturated bulk density and void ratios will be determined.

Core Measurements

Multisensor Track

The MST included three physical properties sensors (magnetic susceptibility meter, gamma-ray attenuation porosity evaluator [GRAPE], and Pwave logger [PWL]. Individual, unsplit core sections were placed on the MST, which automatically moved the section through the sensors on a fiberglass track. For some sites half-linered sections were run through the MST track. MST data were sampled at discrete intervals, with the sampling rate chosen to optimize data resolution and the time limitations of running each core section through the device. GRAPE data, compressional wave velocity, and magnetic susceptibility data were all logged at an interval of 1 cm and acquisition times of 5 s. Core sections were run through the MST after they had warmed to at least 16°C. GRAPE data are most reliable in undisturbed cores. Where cores were not filling the lines, disturbed, or fractured, we expect the GRAPE density to have a general lower value.

The PWL operates simultaneously with the GRAPE and transmits a 500-kHz P-wave pulse (2-μs wave period; 120 V) through the core. A pair of displacement transducers monitors the separation between the P-wave transducers. Data are collected at 1-cm intervals. The quality of the data was assessed by examining the arrival time and amplitude of the received pulse. Data with anomalously large travel times or low amplitudes were discarded. Magnetic susceptibility was determined on all sections at 1-cm intervals using the 1.0 (1 s integration time) range on the Bartington meter (model MS2C), which has a 63-88-mm coil diameter, depending on the core diameter. Magnetic susceptibility helps detect variations in magnetic properties caused by lithologic changes or alteration.

Electric Resistivity

The Middlebury electric resistivity (ER) probes consist of four (2 current, 2 potential) collinear and equally spaced (5 mm) electrodes in the Wenner configuration. We modified the basic configuration by having the probes in a horizontal plane. The ER probe is calibrated using saline solutions of known resistivity values. The probe is placed on the surface of the split core at 2-5 cm intervals with the probes aligned parallel to bedding. The voltage potential is measured and averaged for 1000 samples within a 5 second window. The voltage is then converted to resistance and using the calibration constants then to resistivity. The core resistivity values are then obtained for the entire length of the core.

UNDERWAY GEOPHYSICS

Underway geophysical data were collected during all transits. Data collection was organized and monitored by the shipboard science party. Data editing and processing was completed by the science party and by RPSC support staff.

Navigation

Navigation data was obtained from several different GPS systems which combined offer complete redundancy for navigational data. Two Seatex Seapath 200 systems operated as the primary navigational data and as the primary input into the differential positioning system (DP). These systems received DGPS corrections from a Fugro Starfix spot beam system. Two independent Fugro Starfix systems were also operating and receiving a GPS string. All GPS systems output a data string every 0.5 seconds while on DP. This output however has to be reduced to a 1 Hz data string for the collection of Chirp data.

Chirp Sub-Bottom Profiler

High-resolution seismic data were acquired with a Bathy 2000 hull-mounted chirp sonar system (echo-sounder or precision depth recorder). This chirp system emits a high-frequency, swept-frequency signal with a predominant frequency of 3.5 kHz. The data are recorded digitally and require minimal processing. Chirp profiles typically image the upper tens of meters of sediment beneath the seafloor with a vertical resolution of 2 m.

Multibeam Swath Bathymetry

Prior to drilling, multibeam swath bathymetry surveys were conducted around each drill site. These data were used to avoid areas where iceberg plowing and sediment gravity flows had disturbed the sea floor. Multibeam bathymetric data was collected with a hull-mounted Simrad EM120 swath profiler. This system operates at 12 kHz using 191 beams. For this work we have operated in equal distance mode, rather than equal angle. Ping editing was conducted manually aboard the ship to remove anomalous spikes. A corrective sound velocity was calculated after obtaining a temperature profile for each area using an expendable bathythermograph and a surface salinity measurement.

Seismic Data

In order to image the deeper subsurface and select drill sites, intermediate-resolution seismic surveys were conducted with one or two 50 in^3 generator injector (GI) airguns. Some surveys were collected with the airguns configured down to 50 in^3 for higher frequency data. Solid array streamer data were recorded digitally and were recorded on an Elics digital acquisition system. The data has an average stratigraphic resolution of ~ 10 m. Tuning problems resulted in a bubble pulse in the upper 10 to 20 milliseconds of some of the data. Chirp data are used to fill this gap.

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FIGURES

Figure 2-1. An example of numbered cores.

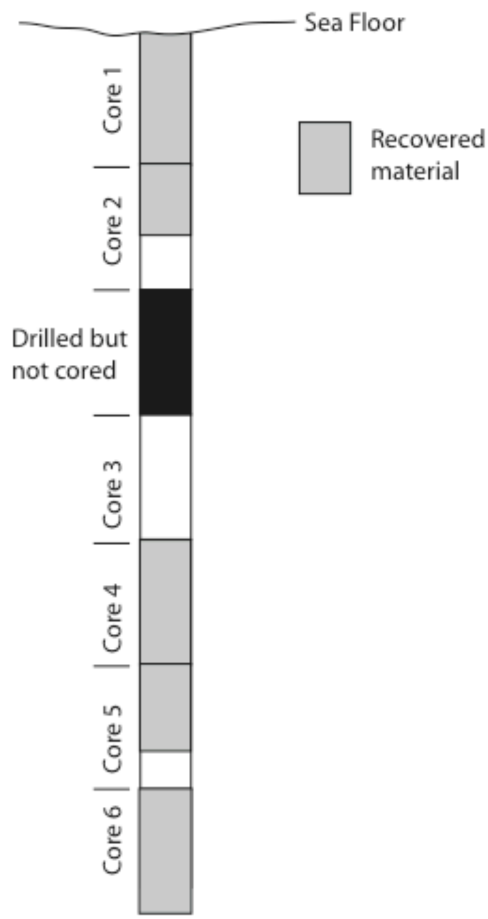


Figure 2-2. An example of numbered core sections.

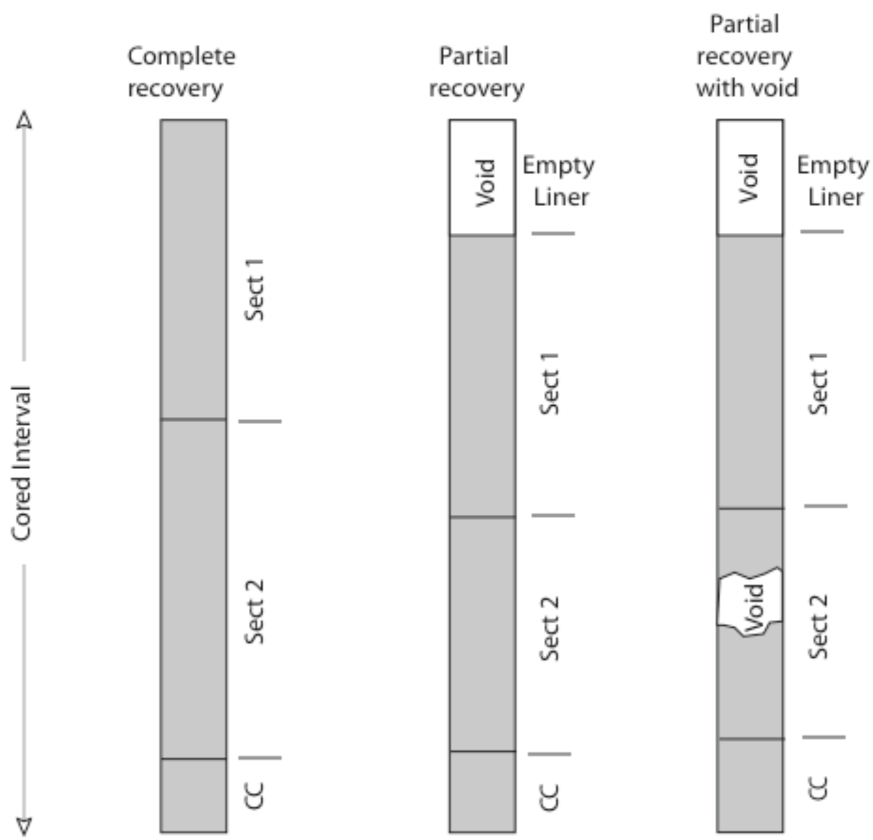


Figure 2-3. Deck layout and drill-core processing steps.

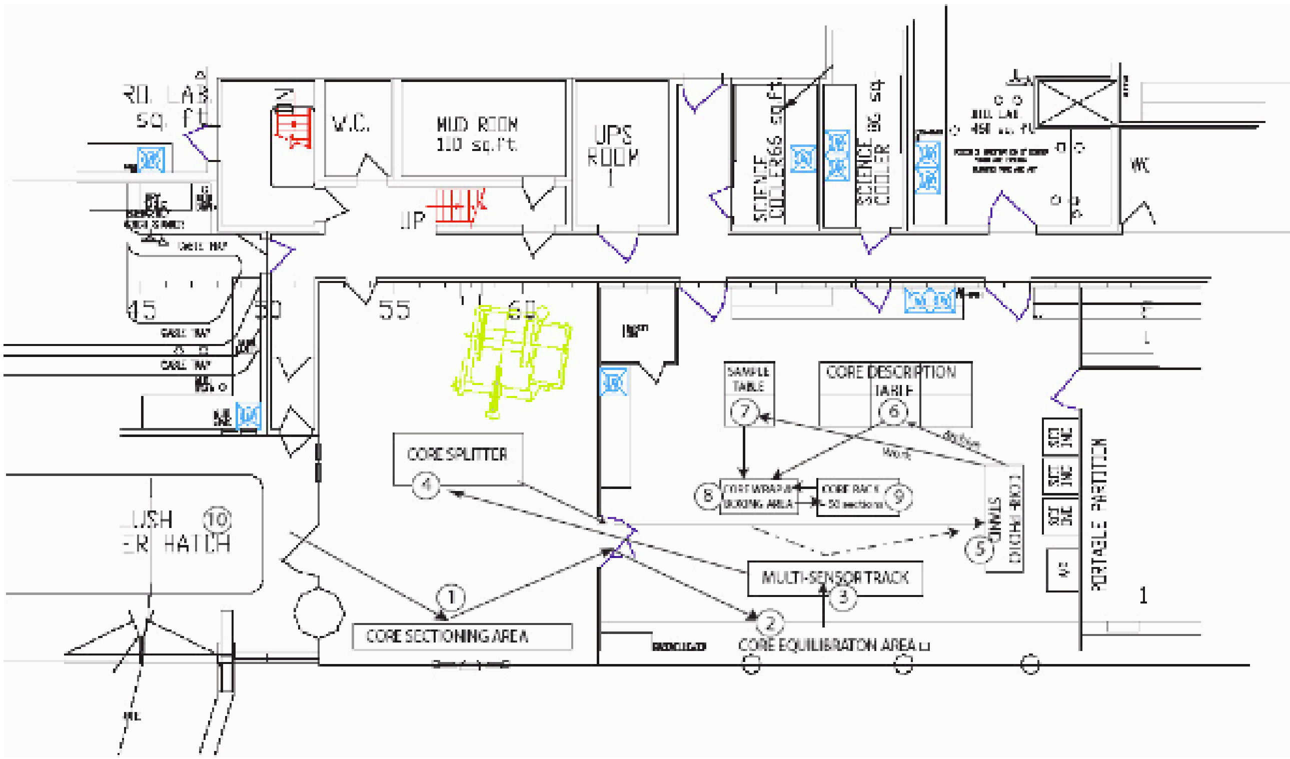


Figure 2-4. Deck layout and drill-processing steps (continued).

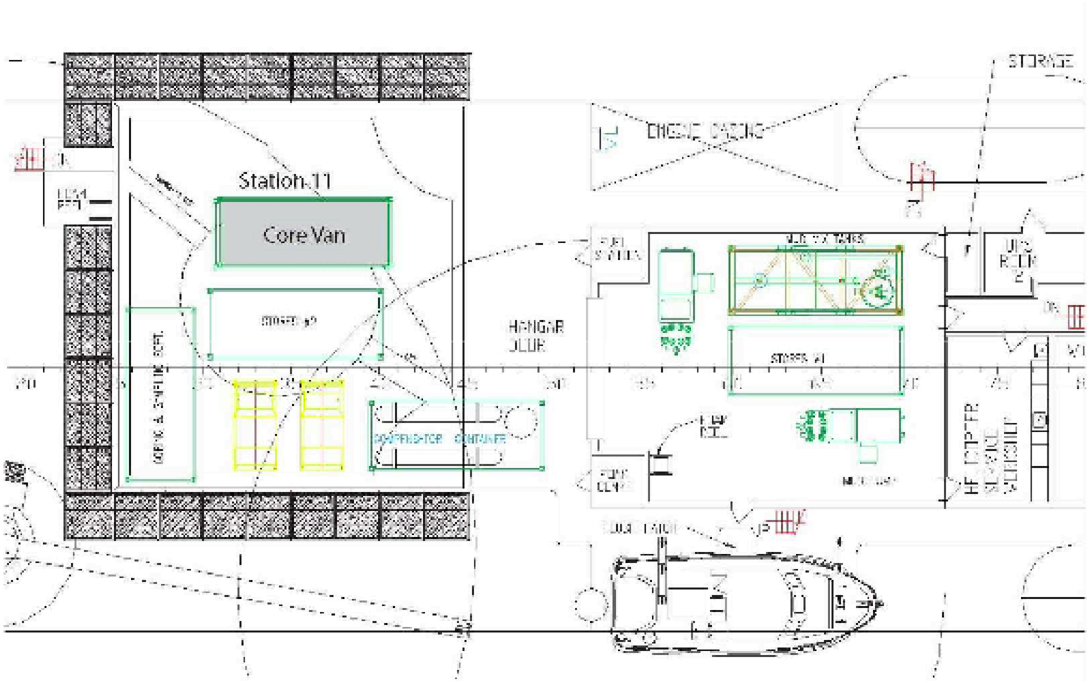


Figure 2-5. Example of the Core Log Spreadsheet.

SHALDRIL CRUISE NBP05-02, SITE 1 (Maxwell Bay)

Multibeam Water Depth: 488 m

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
1A	1	KC	0.00	2.71	2.71	2.71	2.71	0.00	0.00	2.71	100.0%	100.0%	1	0-150	94	1145	1
													2	150-279			
1B	1	E	0.00	2.50	2.50	2.05	2.05	0.00	0.00	2.05	82.0%	82.0%	1	0-104	95	0137	
													2	104-205			
1B	2	E	2.50	4.00	1.50	1.45	0.75	0.70	0.00	0.75	96.7%	50.0%	1	1-145		0230	
1B	3	E	4.00	6.50	2.50	2.61	1.37	1.24	0.00	1.37	104.4%	54.8%	1	0-150		0430	
													2	150-261			
1B	4	E	6.50	9.50	3.00	2.96	1.81	1.15	0.00	1.81	98.7%	60.3%	1	0-150		0625	
													2	150-296			
1B	5	E	9.50	12.50	3.00	2.95	1.66	1.29	0.00	1.66	98.3%	55.3%	1	0-150		0750	
													2	150-295			
1B	6	E	12.50	15.50	3.00	2.95	1.90	1.05	0.00	1.90	98.3%	63.3%	1	0-150		0937	
													2	150-295			
1B	7	E	15.50	17.50	2.00	1.73	1.63	0.10	0.03	1.61	86.5%	80.3%	1	0-23		1034	
													2	23-173			
1B	8	E	17.50	20.50	3.00	1.59	1.59	0.00	0.00	1.59	53.0%	53.0%	1	0-136		1152	
													2	136-159			
1B	9	E	20.50	23.50	3.00	2.40	2.20	0.20	0.06	2.14	80.0%	71.3%	1	0-90		1246	

Figure 2-6. Example of the Core Description Log for barrel sheets.

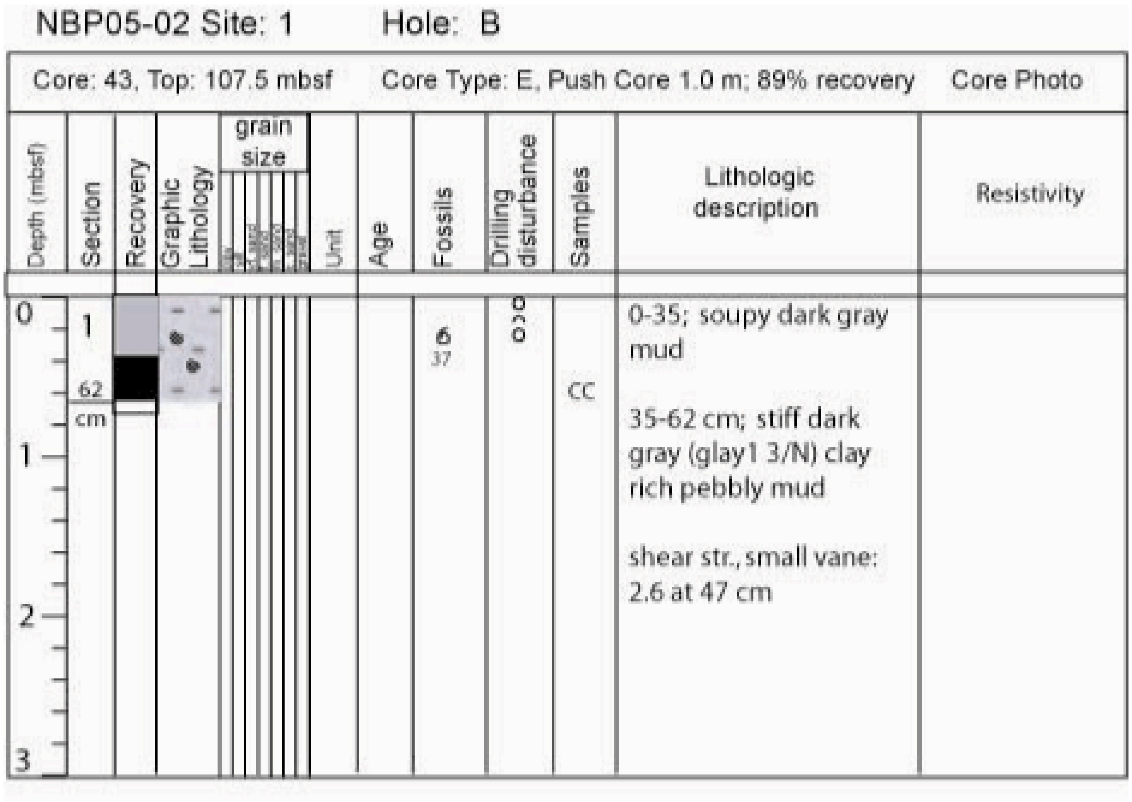


Figure 2-7. Lithologic symbols for barrel sheets.

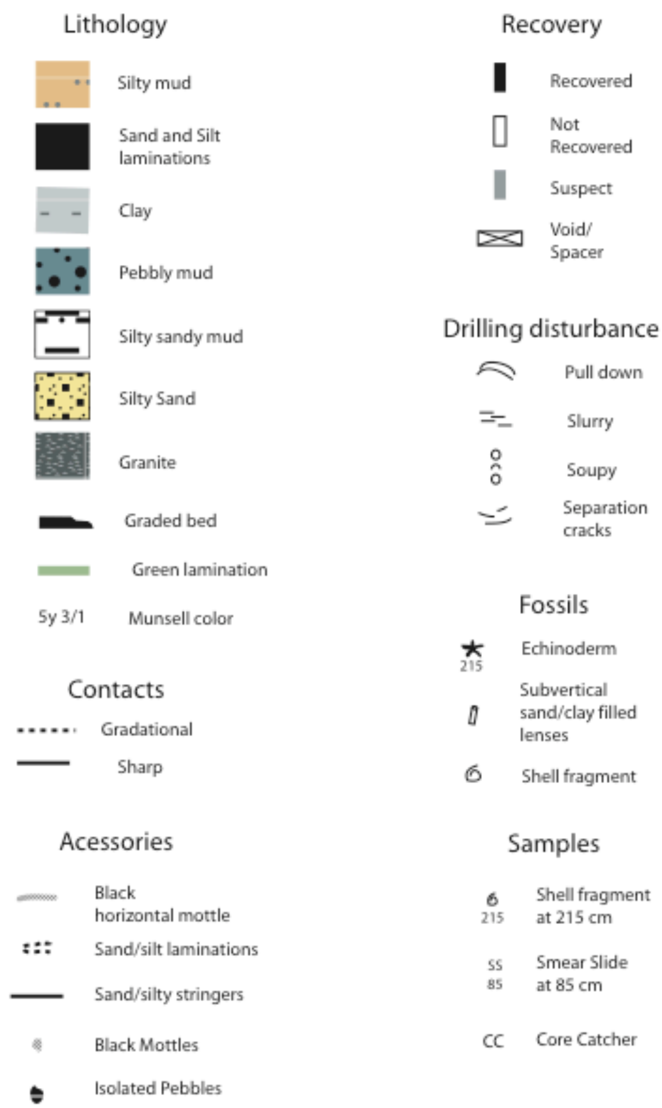


Figure 2-8. Arrangement of core boxes in the refrigerated van.

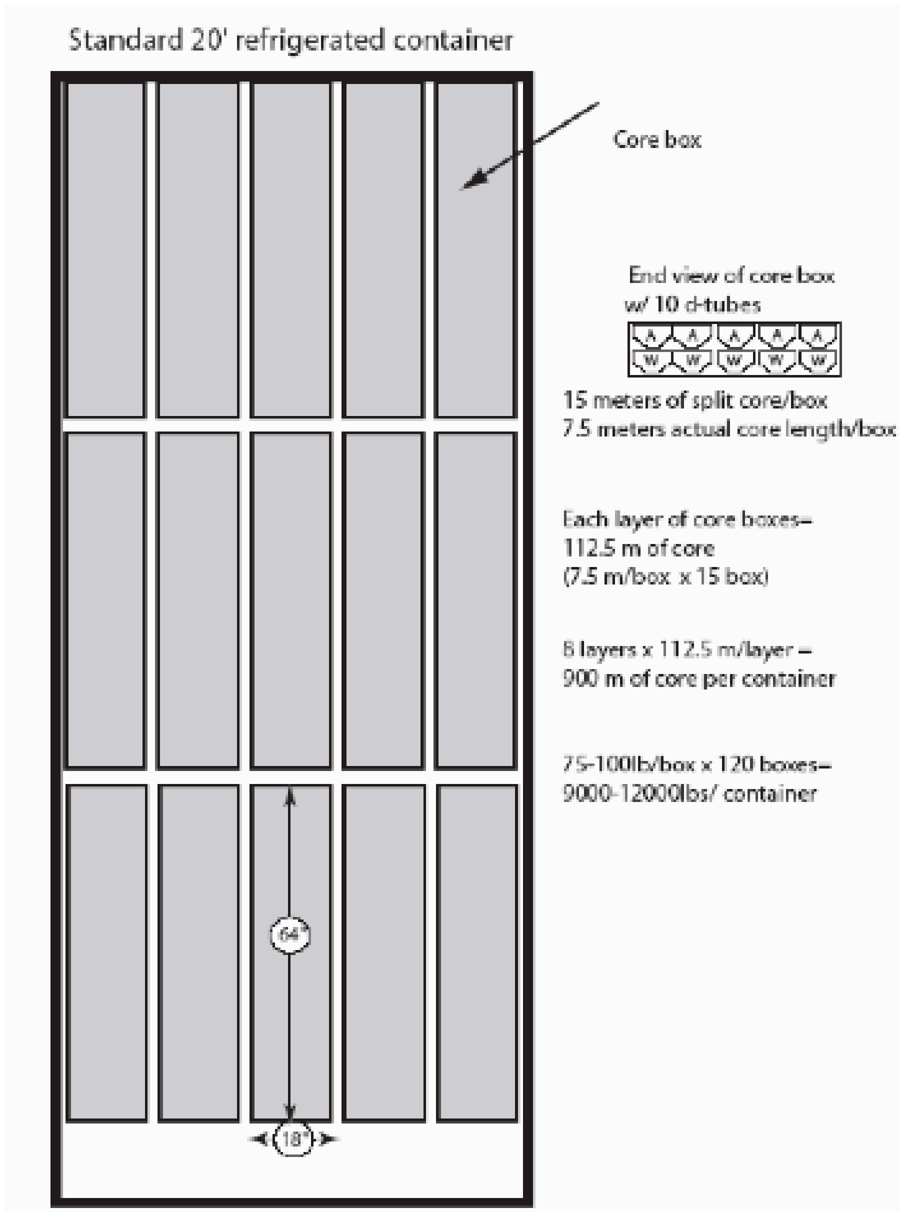


Figure 2-9. Classification scheme used for marine sediments.

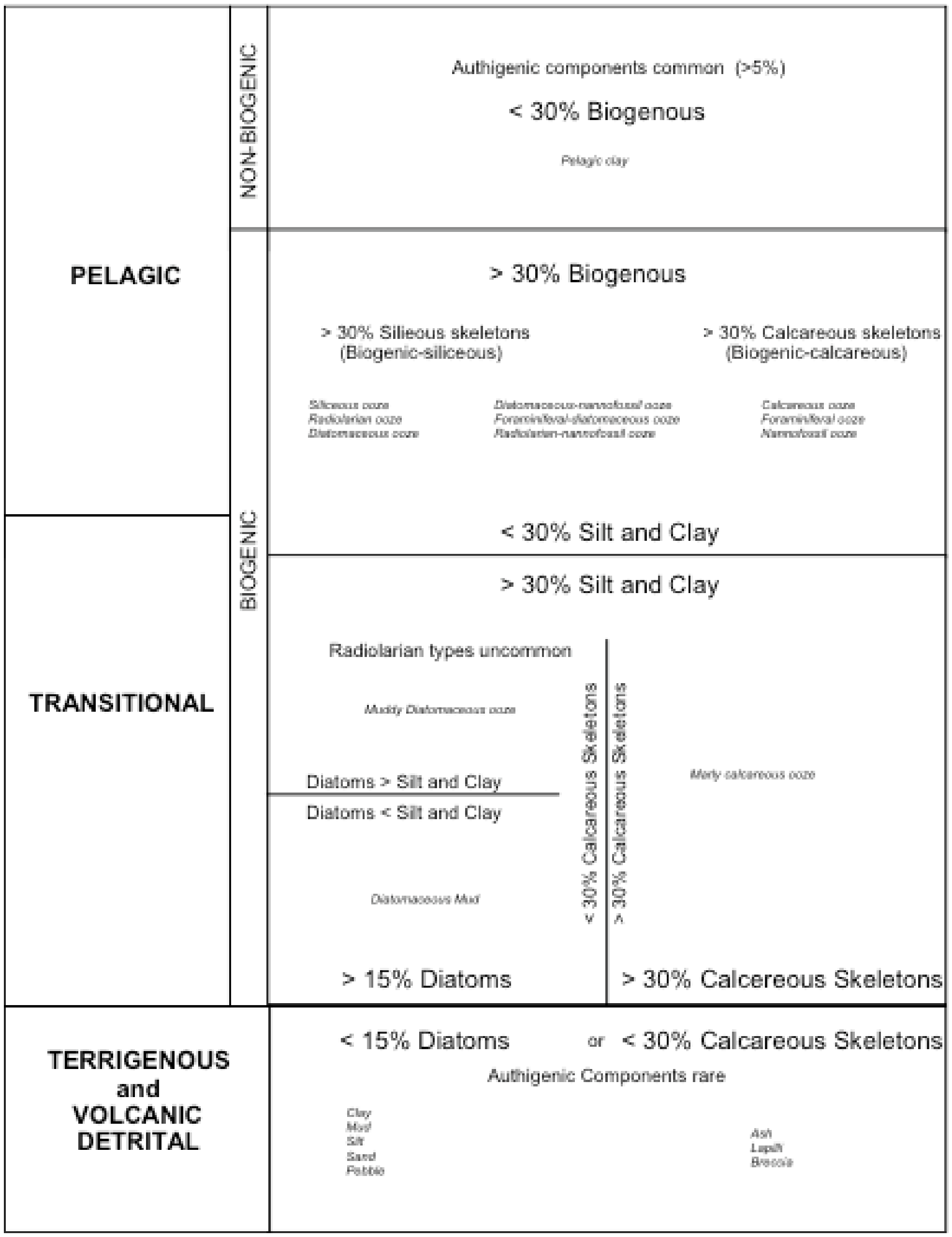


Figure 2-10. Classification of clastic sediments.

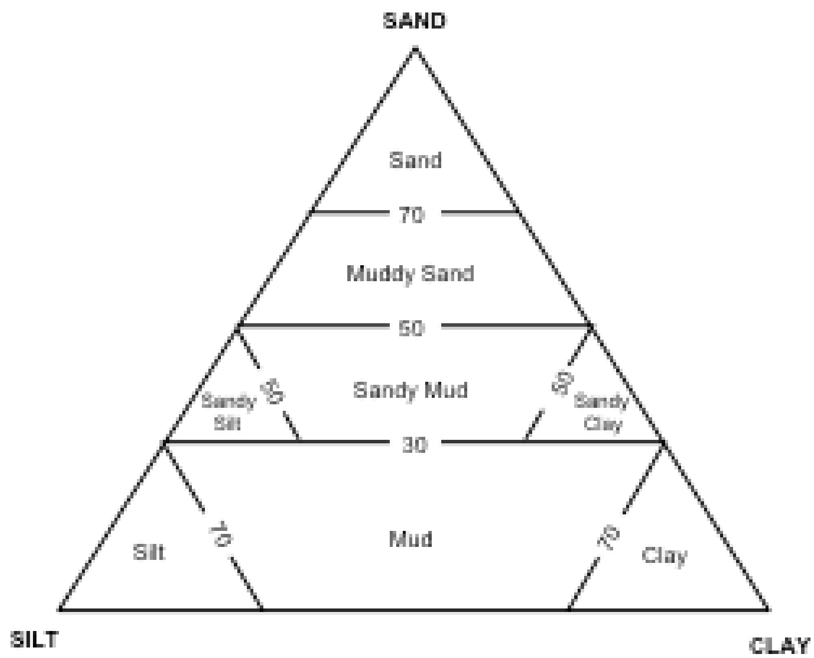
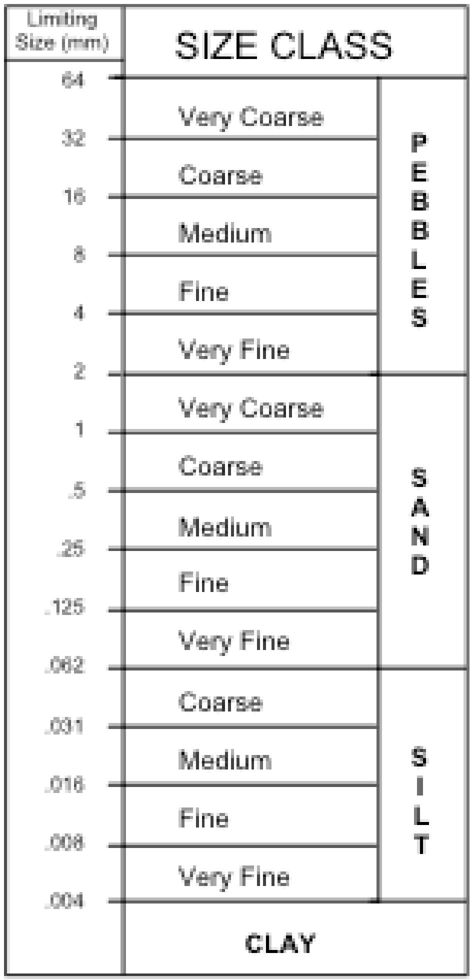


Figure 2-11. Standard size classes of sediments.



Standard size classes of sediment
(modified after Friedman and Sanders, 1978)

Figure 2-12. Plio-Pleistocene diatom zonal scheme applied to the sections recovered during SHALDRIL. This scheme was proposed by Zielinski and Gersonde (2002) and utilizes datums that are typically identified in southern areas of the Antarctic region. All ages are calibrated to the Berggren et al. (1995) time scale. Brackets represent FO or LO datums, and filled triangles represent FCO or LCO datums.

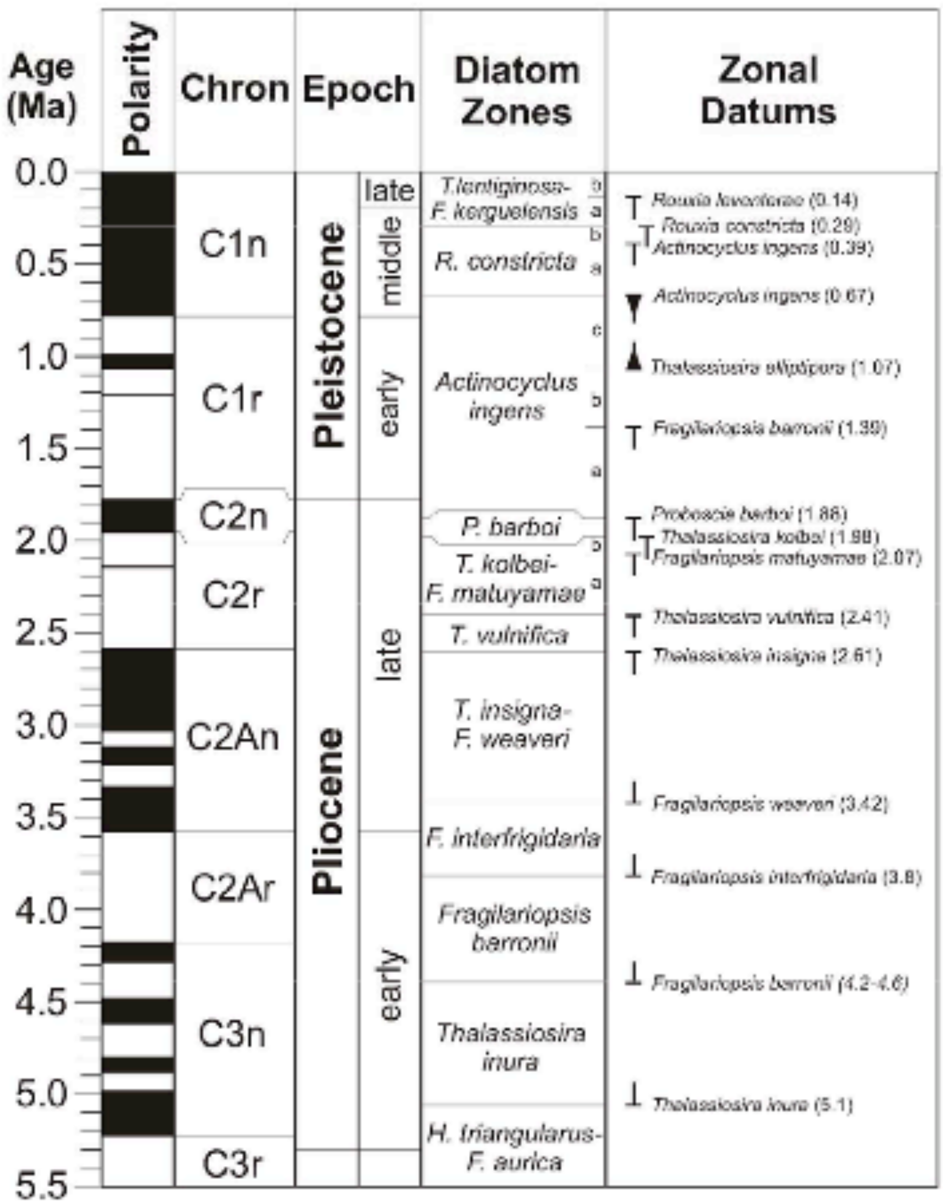


Figure 2-13. Middle to late Miocene diatom zonal scheme applied to sections recovered during SHALDRIL. This zonal scheme was proposed by Censarek and Gersonde (2002) and utilizes datums that are typically identified in southern areas of the Antarctic region. All ages are calibrated to the Berggren et al. (1995) time scale. Brackets represent FO or LO datums, and filled triangles represent FCO or LCO datums.

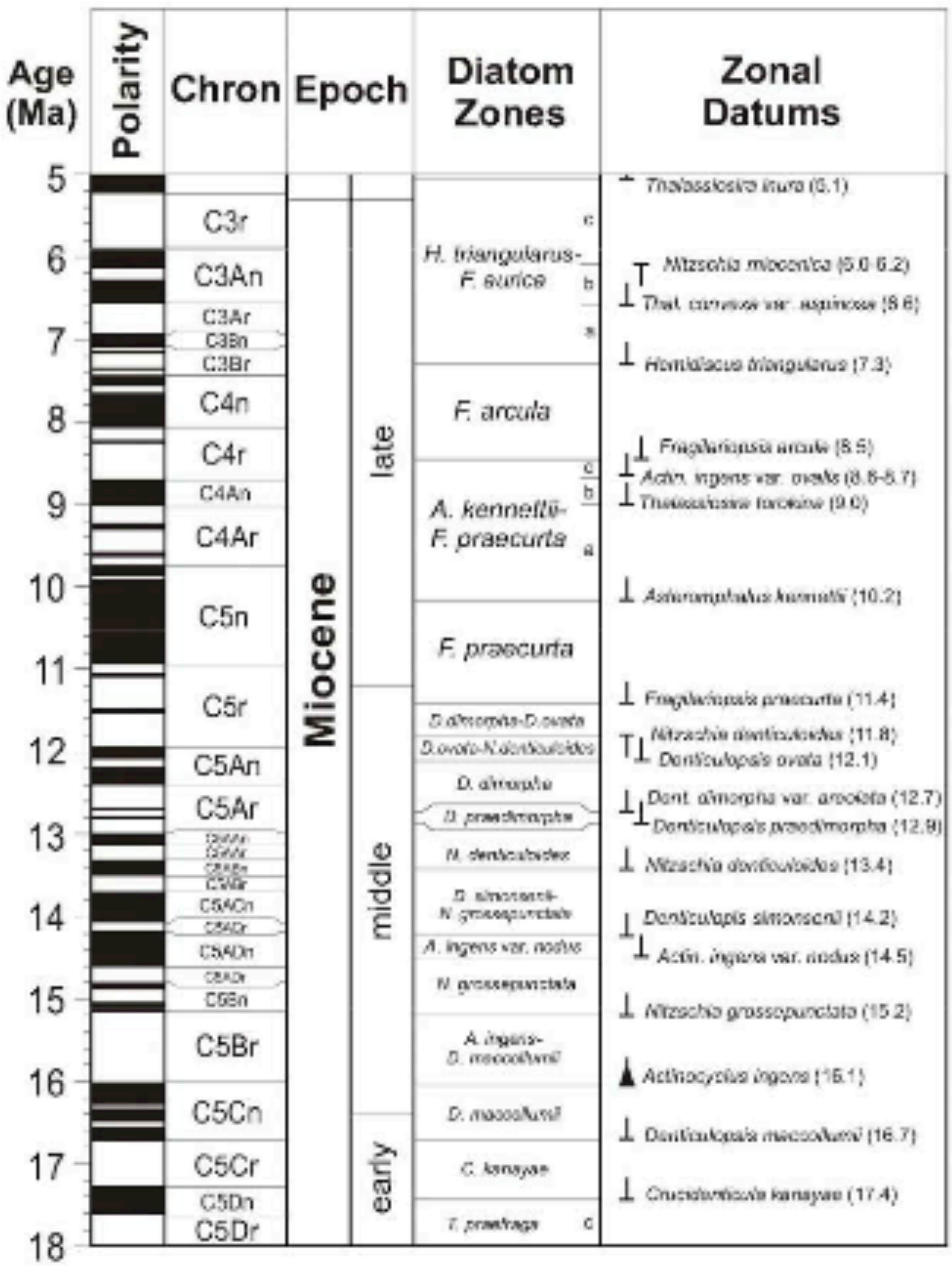


Figure 2-14. Oligocene to early Miocene diatom zonal scheme for the Southern Ocean. This zonal scheme represents a modified version of that proposed by Harwood and Maruyama (1992). All ages are calibrated to the Berggren et al. (1995) time scale. Brackets represent FO or LO datums, and filled triangles represent FCO or LCO datums.

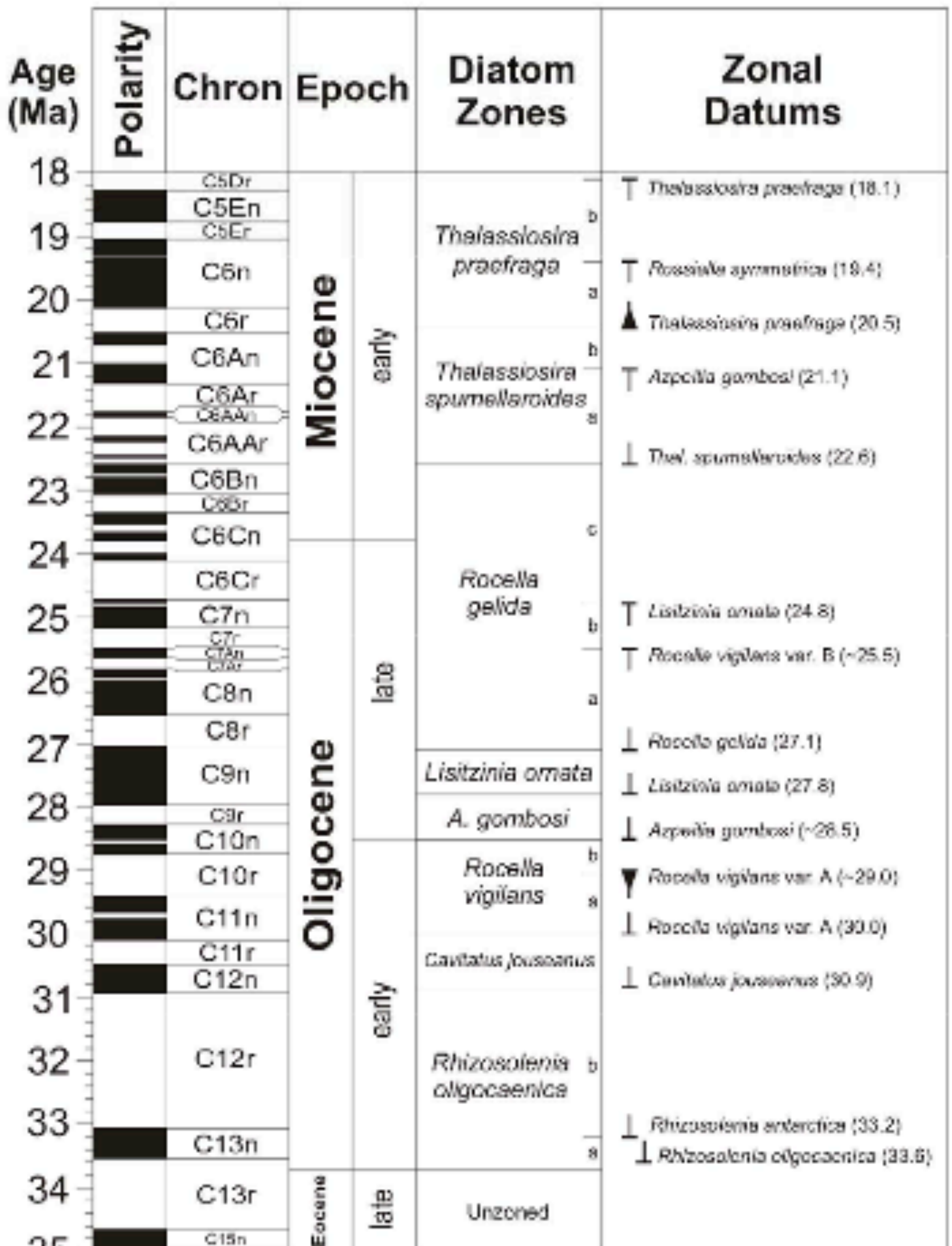


Figure 2-15. Holocene through middle Eocene time scale and calcareous nannofossil biostratigraphic datums applied to SHALDRIL NBP05-02 Sites 1-3 against those for planktonic foraminifers (modified from Berggren et al., 1995; Gradstein et al., 1994; Erba et al., 1995). High-latitude zonations used for SHALDRIL vs. low-latitude zonations are indicated under "SHALDRIL" and "Low Lat" respectively, for foraminfers and nannofossils. High-latitude biostratigraphic datum and age correlations are indicated in bold type under "Biostratigraphic Datums;" foraminiferal datums are underlined. Planktonic foraminifer zonations adopted from Berggren (1992a: Neogene Kerguelen); Stott and Kennett (1990: Antarctic Paleogene; modified by Huber, 1991, and Berggren, 1992b). Nannofossil zonations from Wise (1983: Antarctic Oligocene to mid-middle Eocene; modified by Wei and Wise, 1990; and Wei and Thierstein, 1991, and calibrated against magnetostratigraphy by Wei, 1992).

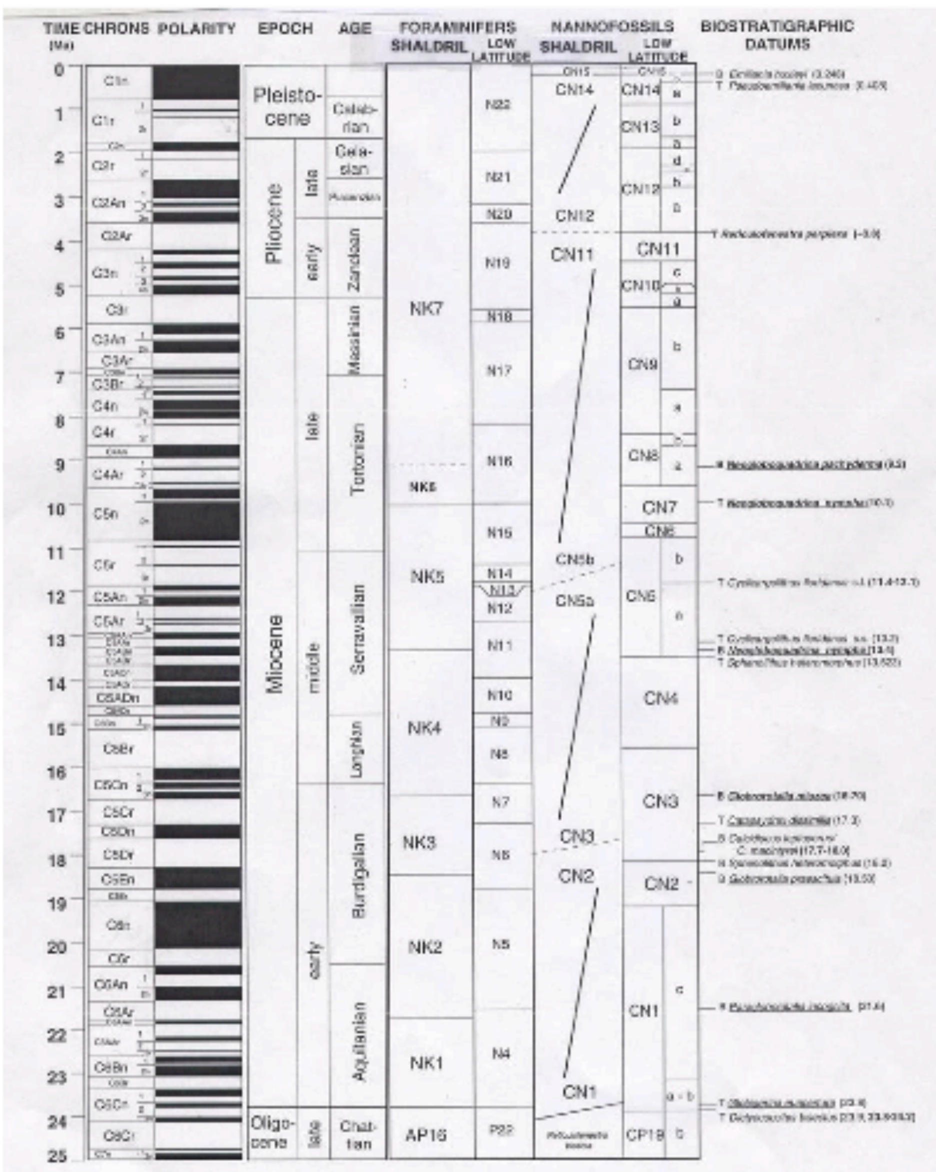


Figure 2-15 (cont.).

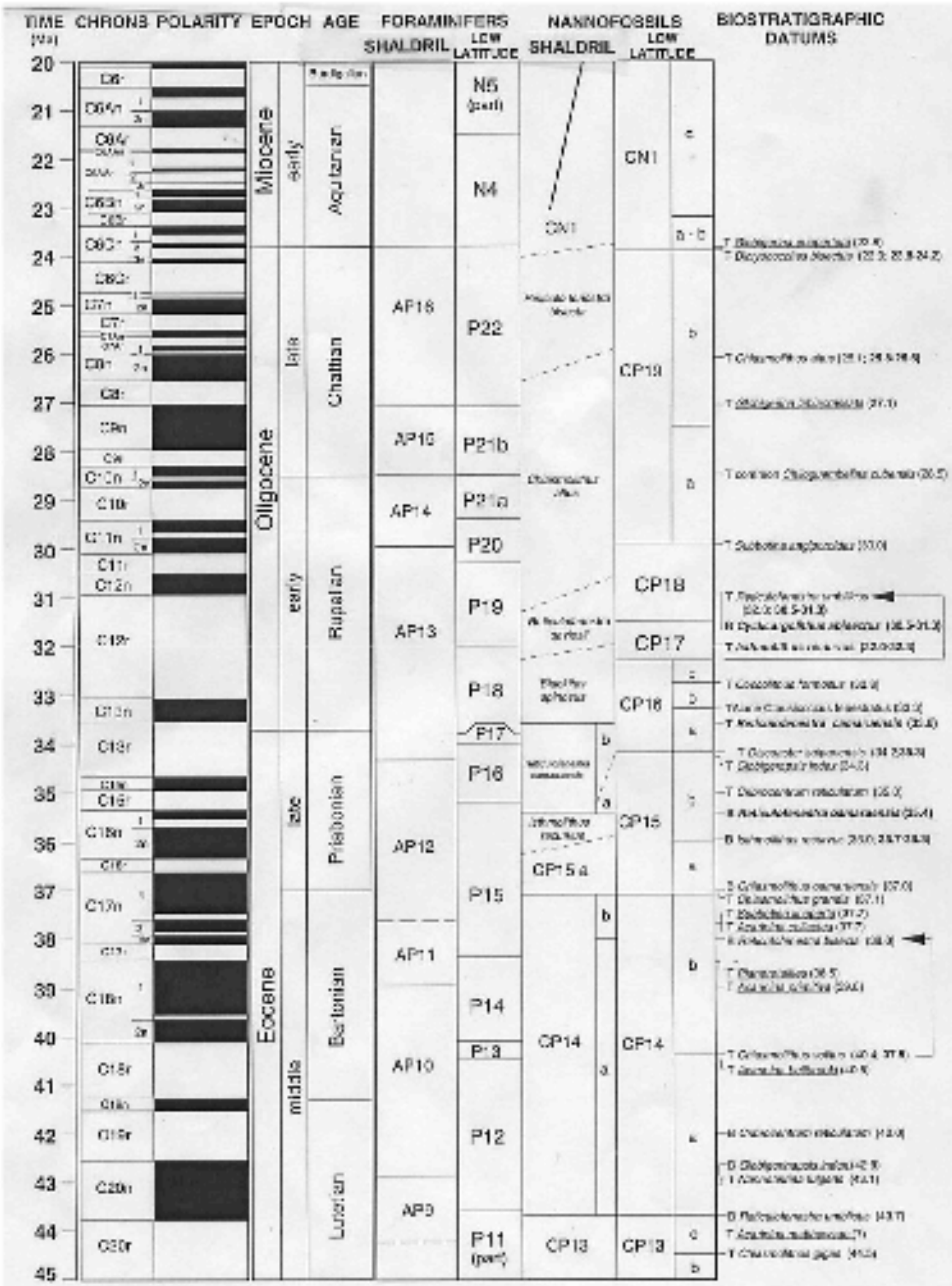


Table 2-1. Plio-Pleistocne diatom events and age calibrations for the Southern Ocean. All ages are calibrated to the Berggren et al. (1995) timescale, and zonal datums are labeled in bold type. Source references are as follows: Bu = Burkle et al. (1978), Cl = Ciesielshi (1983), F = Fenner (1991), BB = Baldauf and Barron (1991), HM = Harwood and Maruyama (1992), WH = Winter and Harwood (1997), MB = Mahood and Barron (1995), GB = Gersonde and Bárcena (1998), WI = Winter and Iwai (2002), ZG = Zielinski and Gersonde (2002), CG = Censarek and Gersonde (2002), Zet = Zielinski et al. (2002), WB = Whitehead and Bohaty, and S1 = Stickley et al. (2004a).

Event	Taxon	"Southern" Calibration				"Northern" Calibration				Other Calibrations	
		Upper Age (Ma)	Lower Age (Ma)	Average Age (Ma)	Source	Upper Age (Ma)	Lower Age (Ma)	Average Age (Ma)	Source	Age (Ma)	Source(s)
LOD	***Rouxia leventerae***	0.13	0.14	0.14	ZG, Zet	-	-	-	-	-	-
LOD	*Hemidiscus karstenii*	0.18	0.19	0.19	ZG	0.18	0.19	0.19	ZG	0.19	Bu
LOD	***Rouxia constricta***	0.28	0.30	0.29	Zet	0.28	0.30	0.29	Zet	-	-
LOD	***Actinocyclus ingens***	0.36	0.42	0.39	ZG	0.45	0.51	0.48	ZG	0.55	S1
FCOD	*Hemidiscus karstenii*	-	-	-	-	0.41	0.43	0.42	ZG	0.42	Bu, GB
LCOD	***Actinocyclus ingens***	0.64	0.70	0.67	ZG	0.56	0.64	0.60	ZG	0.66	C1, HM, GB
LOD	*Nitzschia reinboldii*	2.72	2.72	2.72	ZG	0.60	0.77	0.69	ZG	0.65 / 3.4	BB / HM
LOD	*Fragilariopsis fossilis*	-	-	-	-	0.70	0.99	0.85	ZG	0.9	Bu
LOD	*Thalassiosira elliptipora*	0.61	0.85	0.73	ZG	0.77	0.82	0.80	ZG	0.65-0.69	C1, HM
LOD	*Thalassiosira fasciculata*	0.81	0.87	0.84	ZG	0.76	0.87	0.82	ZG	0.75	GB
FCOD	***Thalassiosira elliptipora***	1.01	1.13	1.07	ZG	1.00	1.07	1.04	ZG	1.04-1.13	F, GB
LOD	*Actinocyclus* sp. F of ZG	1.20	1.42	1.31	ZG	1.20	1.42	1.31	ZG	-	-
LOD	***Fragilariopsis barronii***	1.36	1.41	1.39	ZG	1.26	1.48	1.37	ZG	1.30-1.35	HM, WH, GB
LOD	*Rouxia antarctica*	1.35	1.56	1.46	ZG	1.35	1.56	1.46	ZG	-	-
LOD	*T. tetraoestrupii* var. *reimerii*	1.32	1.60	1.46	ZG	1.35	1.48	1.42	ZG	1.6	MB
LOD	***Proboscia barboi***	1.82	1.94	1.88	ZG	1.82	1.94	1.88	ZG	1.7-1.8	F, C1, BB, GB
FOD	*Fragilariopsis kerguelensis*	2.04	2.34	2.19	ZG	1.93	1.93	1.93	ZG	3.2	HM
LOD	***Thalassiosira kolbei***	1.98	1.98	1.98	ZG	1.98	2.08	2.03	ZG	1.9	HM, WH, GB
LOD	***Fragilariopsis matuyamae***	2.07	2.07	2.07	ZG	2.07	2.12	2.10	ZG	2.1	GB
FOD	*T. tetraoestrupii* var. *reimerii*	2.43	2.66	2.55	ZG	2.43	2.66	2.55	ZG	2.4	MB
FOD	*Fragilariopsis matuyamae*	2.36	2.40	2.38	ZG	2.50	2.66	2.58	ZG	2.6	GB
FOD	*Actinocyclus* sp. F of ZG	-	-	-	-	1.84	2.34	2.09	ZG	-	-
FOD	*Rouxia constricta*	1.60	1.60	1.60	ZG	0.91	0.91	0.91	ZG	-	-
LOD	*Actinocyclus maccollumi*	2.31	2.76	2.54	ZG	2.31	2.76	2.54	ZG	1.7-2.8	HM
LOD	*Actinocyclus karstenii*	2.24	2.34	2.29	ZG	2.24	2.34	2.29	ZG	1.7-2.8	HM
LOD	***Thalassiosira vulnifica***	2.38	2.43	2.41	ZG	2.38	2.55	2.47	ZG	2.3-2.5	C1, BB, GB, WI
LOD	*Thalassiosira inura*	2.37	2.37	2.37	ZG	2.55	2.65	2.60	ZG	1.9	HM, WH
FOD	*Actinocyclus maccollumi*	2.50	3.30	2.90	ZG	2.50	3.30	2.90	ZG	2.80-3.10	HM
LOD	*Thalassiosira lentiginosa* var. *ovalis*	-	-	-	-	-	-	-	-	2.5	C1, HM
LOD	*Fragilariopsis praeinterfrigidaria*	2.55	3.30	2.93	ZG	2.55	3.30	2.93	ZG	3.7	HM
LOD	***Thalassiosira insigna***	2.55	2.66	2.61	ZG	2.55	2.66	2.61	ZG	2.5-2.7	C1, GB, WI
LOD	*Fragilariopsis weaveri*	2.54	2.66	2.60	ZG	2.54	2.66	2.60	ZG	2.8	C1
LOD	*Thalassiosira convexa*	2.56	2.64	2.60	ZG	2.56	2.64	2.60	ZG	-	-
LOD	*Thalassiosira striata*	1.80	3.50	2.65	ZG	1.80	3.50	2.65	ZG	2.4-3.2	HM, WH
LOD	*Fragilariopsis interfrigidaria*	2.58	2.96	2.77	ZG	2.58	2.96	2.77	ZG	2.7	HM
LOD	*Thalassiosira complicata*	2.92	3.31	3.12	ZG	2.92	3.31	3.12	ZG	3.2-3.5	HM
FOD	*Thalassiosira vulnifica*	3.20	3.21	3.21	WB	-	-	-	-	2.7-3.2	BB, HM, WI
LOD	*Fragilariopsis aurica*	-	-	-	-	3.37	3.37	3.37	ZG	3.7-4.2	HM
FOD	*Thalassiosira lentiginosa* var. *ovalis*	-	-	-	-	-	-	-	-	3.4	HM
FOD	***Fragilariopsis weaveri***	3.42	3.42	3.42	ZG	3.42	3.42	3.42	ZG	3.2-3.4	BB, HM, WB
FOD	*Thalassiosira insigna*	3.42	3.42	3.42	ZG	3.42	3.42	3.42	ZG	3.20-3.40	HM, WB
FOD	***Fragilariopsis interfrigidaria***	3.75	3.88	3.82	WB	3.80	3.80	3.80	ZG	3.7-3.8	BB, HM, WI
LOD	*Fragilariopsis arcula*	-	-	-	-	4.08	4.08	4.08	ZG	3.9-4.6	HM
FOD	***Fragilariopsis barronii***	4.15	4.16	4.16	WB	-	-	-	-	4.2-4.6	C1, BB, WI
FOD	*Thalassiosira striata*	-	-	-	-	-	-	-	-	4.5	HM
FOD	*Thalassiosira complicata*	-	-	-	-	-	-	-	-	4.5-4.7	HM
FOD	***Thalassiosira inura***	5.03	5.09	5.06	WB	-	-	-	-	4.8-5.0	BB, CG
FOD	*Fragilariopsis praeinterfrigidaria*	5.09	5.09	5.09	CG	-	-	-	-	-	-

Table 2-2. Miocene diatom events and age calibrations for the Southern Ocean. All ages are calibrated to the Berggren et al. (1995) timescale, and zonal datums are labeled in bold type. Source references are as follows: BB = Baldauf and Barron (1991), B = Barron (1992), HM = Harwood and Maruyama (1992), BI = Baldauf and Iwai (1995), YA = Yanagisawa and Akiba (1998), WI = Winter and Iwai (2002), CG = Censarek and Gersonde (2002), Bo = Bohaty et al. (2003), PM Pfuhl and McCave (2003), S1 = Stickley et al. (2004a), and Bet = Barron et al. (2004).

Event	Taxon	"Southern" Calibration				"Northern" Calibration				Other Calibrations	
		Upper Age (Ma)	Lower Age (Ma)	Average Age (Ma)	Source	Upper Age (Ma)	Lower Age (Ma)	Average Age (Ma)	Source	Age (Ma)	Source(s)
LOD	*Hemidiscus triangularus*	5.13	5.13	5.13	CG	6.43	6.43	6.43	CG	5.8	HM
FOD	*Thalassiosira tetraoestrupii* group	-	-	-	-	-	-	-	-	5.6-5.8	BB, HM
LOD	*Fragilariopsis donahuensis*	-	-	-	-	-	-	-	-	5.8	HM
LOD	*Nitzschia miocenica*	-	-	-	-	-	-	-	-	6.0-6.2	BB, BI
FOD	***Thalassiosira convexa* var. *aspinosa***	**6.58**	**6.58**	**6.58**	**CG**	**6.54**	**6.54**	**6.54**	**CG**	**6.7**	**B**
FOD	***Hemidiscus triangularus***	**7.30**	**7.30**	**7.30**	**CG**	**7.30**	**7.30**	**7.30**	**CG**	**6.2**	**HM**
LOD	*Denticulopsis crassa*	7.39	7.76	7.58	CG	7.51	7.51	7.51	CG	8.7	WI
FOD	*Fragilariopsis reinholdii*	-	-	-	-	7.96	8.23	8.10	CG	8.1 / 6.4	B / HM
FOD	***Fragilariopsis arcula***	**8.41**	**8.49**	**8.45**	**CG**	**7.40**	**7.40**	**7.40**	**CG**	**-**	**-**
FOD	*Actinocyclus ingens* var. *ovalis*	8.49	8.49	8.49	CG	8.70	8.70	8.70	CG	8.7	HM
FOD	*Thalassiosira torokina*	-	-	-	-	-	-	-	-	9.0	HM
FOD	***Asteromphalus kennettii***	**10.12**	**10.21**	**10.17**	**CG**	**10.30**	**10.31**	**10.31**	**CG**	**10.3**	**BB**
LOD	*Denticulopsis dimorpha* var. *areolata*	-	-	-	-	-	-	-	-	9.9-10.9	S1
LCOD	*Denticulopsis dimorpha* var. *areolata*	-	-	-	-	-	-	-	-	10.7	HM
LOD	*Denticulopsis ovata*	4.93	4.93	4.93	CG	10.50	10.60	10.55	CG	-	-
FOD	*Fragilariopsis aurica*	9.50	10.30	9.90	CG	6.94	6.94	6.94	CG	-	-
FOD	*Denticulopsis crassa*	9.70	10.12	9.91	CG	10.95	10.95	10.95	CG	-	-
FOD	***Fragilariopsis praecurta***	**11.40**	**11.43**	**11.42**	**CG**	**10.95**	**10.95**	**10.95**	**CG**	**-**	**-**
LOD	***Nitzschia denticuloides***	**11.78**	**11.82**	**11.80**	**CG**	**11.86**	**11.86**	**11.86**	**CG**	**11.5-11.8**	**HM, Bo**
FOD	***Denticulopsis ovata***	**12.11**	**12.11**	**12.11**	**CG**	**11.10**	**11.10**	**11.10**	**CG**	**-**	**-**
FOD	***Denticulopsis dimorpha* var. *areolata***	**12.73**	**12.74**	**12.74**	**CG**	**12.12**	**12.12**	**12.12**	**CG**	**12.2**	**BB**
LOD	*Crucidenticula nicobarica*	-	-	-	-	-	-	-	-	12.3	BB, HM
LOD	*Denticulopsis praedimorpha*	-	-	-	-	12.25	12.25	12.25	CG	-	-
LOD	*Actinocyclus ingens* var. *nodus*	-	-	-	-	-	-	-	-	12.5	HM
FOD	***Denticulopsis praedimorpha***	**12.81**	**12.92**	**12.87**	**CG**	**-**	**-**	**-**	**-**	**12.84**	**BB**
FOD	***Nitzschia denticuloides***	**13.48**	**13.38**	**13.43**	**CG**	**-**	**-**	**-**	**-**	**-**	**-**
FOD	***Denticulopsis simonsenii***	**14.18**	**14.30**	**14.24**	**CG**	**14.22**	**14.22**	**14.22**	**CG**	**14.2**	**BB, HM**
FOD	***Actinocyclus ingens* var. *nodus***	**14.18**	**14.80**	**14.49**	**CG**	**14.35**	**14.35**	**14.35**	**CG**	**14.4-14.5**	**HM, PM**
FOD	***Nitzschia grossepunctata***	**15.20**	**15.20**	**15.20**	**CG**	**-**	**-**	**-**	**-**	**-**	**-**
FCOD	***Actinocyclus ingens***	**14.80**	**17.30**	**16.05**	**GG**	**16.20**	**16.20**	**16.20**	**CG**	**16.2-16.3**	**BB, HM**
FOD	***Denticulopsis maccollumii***	**16.70**	**16.70**	**16.70**	**CG**	**-**	**-**	**-**	**-**	**16.6-16.7**	**HM**
FOD	***Crucidenticula kanayae***	**17.27**	**17.61**	**17.44**	**CG**	**-**	**-**	**-**	**-**	**17.7**	**BB**
LOD	***Thalassiosira praefraga***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**17.8-18.4**	**YA, HM**
LOD	*Asteromphalus symmetricus*	-	-	-	-	-	-	-	-	18.5	HM
LOD	***Rossiella symmetrica***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**19.4**	**HM**
FCOD	***Thalassiosira praefraga***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**20.3-20.8**	**HM, YA**
LOD	***Azpeitia gombosi***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**21.1**	**HM**
LOD	*Rocella gelida*	-	-	-	-	-	-	-	-	22.3 / 24.3	BB, HM / Bet
FOD	***Thalassiosira spumellaroides***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**22.6**	**HM**
FOD	*Thalassiosira praefraga*	-	-	-	-	-	-	-	-	22.67-22.94	Bet

Table 2-3. Eocene-Oligocene diatom events and age calibrations for the Southern Ocean. All ages are calibrated to the Berggren et al. (1995) timescale, and zonal datums are labeled in bold type. Source references are as follows: C2 = Ciesielski (1991), BB = Baldauf and Barron (1991), BH = Bohaty and Harwood (2000), R = Roberts et al. (2003) Sp = C. Stickley (pers. comm., 2003), S1 = Stickley et al. (2004a), S2 = Stickley et al. (2004b), Bet = Barron et al. (2004), and u = Bohaty unpublished data from ODP Sites 738, 744, and 748.

Event	Datum	Age (Ma)	Chron	Source(s)	Site(s)	Notes
LOD	***Lisitzinia ornata***	~24.8	C7n(?)	R	744	
LOD	***Rocella vigilans* var. B**	24.8-26.3	C7n to C8n	R	744, 748	
FOD	***Rocella gelida***	27.1	C9n/C8r boundary	R	744	
FOD	***Lisitzinia ornata***	27.8	C9n	R	744, 748	
FOD	*Rocella vigilans* var. B	27.6-27.8	C9n	R	744, 748	
FOD	***Azpeitia gombosi***	~28.5	C10n	HM, R	748	
FOD	*Cavitatus rectus*	28.51-28.65	C10n.1r to C10n.2n	Bet	1220 (eq. Pacific)	
LCOD	***Rocella vigilans* var. A**	~29.0	C10r	R, S1, S2	748, 1172	
FOD	***Rocella vigilans* var. A**	30.0	C11n.2n	R, S1, S2	748, 1172	
FOD	***Cavitatus jouseanus***	30.8-30.9	C12n	R	744, 748	
FOD	***Rhizosolenia antarctica***	33.2	C13n	R	748	
LOD	*Hemiaulus caracteristicus*	33.2-33.4	C13n	BB, S1, S2, u	744, 748, 1172	
LOD	*A. ammodochium* (double, loricate)	~33.3	C13n	BH	748	Ebridian
LOD	*Distephanosira architecturalis*	~33.5	base C13n	S1, S2, u	738, 744, 748, 1172	
LOD	*Micromarsupium anceps*	~33.5	base C13n	BH	748	Ebridian
FOD	***Rhizosolenia oligocaenica***	33.6-33.8	C13r	R	744, 748	
LCOD	*Naviculopsis constricta*	~34.7	C13r/C15n boundary	C2	703	Silicoflagellate
FOD	*Craniopsis octo*	~40	C18n to C18r	BH	748	Ebridian
LOD	*T. inconspicuum* var. *trilobata*	~40.5	C18r	HM, Sp	748, 1172	
LCOD	*T. inconspicuum* var. *trilobata*	~45	C20r	Sp	1172	

Chapter 3: Maxwell Bay
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SITE 1: MAXWELL BAY

A. BACKGROUND AND OBJECTIVES

The South Shetland Islands experience the warmest climate in Antarctica, which is manifest by tidewater glaciers with elevated equilibrium lines, rocky beaches, and meltwater streams emanating from tidewater glaciers. Maxwell Bay is the largest bay in the South Shetland Islands and has been the subject of marine geological investigations focused mainly on sedimentary processes active within the bay (Griffith and Anderson, 1989; Domack and Ishman, 1993). The subpolar bays of the South Shetland Islands differ from bays and fjords on the mainland in that they contain relatively thick post-glacial sediment fill consisting dominantly of terrigenous sediment, a product of the more temperate glacial setting (Griffith and Anderson, 1989). Griffith and Anderson (1989) speculated that the bays of the South Shetland Islands contain a sedimentary record of the most extreme temperature fluctuations in the Antarctic Peninsula region due to their relatively higher latitude location. Analysis of piston cores from the bay revealed the presence of carbonate material suitable for radiocarbon dating. However, the post-glacial fill of these bays is so thick (up to 120 meters) that conventional, and even jumbo piston coring, are unsuitable for sampling the thick sedimentary record. These thick post-glacial deposits may contain the best record of high-frequency climatic change and this is why Maxwell Bay was targeted as a drill site for the first leg of SHALDRIL. The cores at Site 1 were collected in 488 m of water and reached a maximum depth of 108.2 m (Fig. 3-A1).

B. OPERATIONS

Site 1 is located at 62° 16.931′ S, 58 45.230′ W in 488 m of water. The drill site is located within Maxwell Bay and thus receives some protection from wind and waves; its selection as the first SHALDRIL drill site was in part based on the desire to practice station keeping in these protected conditions.

The *Palmer* came onto the drill site position at 0930 on 04 April 2005 (all times are UTC). Dynamic positioning was begun at that point and the station was held until 1020 on 07 April 2005, a total of over 72 hours. During that time, the wind did increase to moderate levels but stayed under 25 knots on the whole. Seas increased while on station but also remained only moderate, under 1 m usually. Throughout the time on DP, the vessel held station very well. A danger watch circle was set with a radius of 48 m (10% of water depth) and a warning circle set at 24 m, 5% of the water depth, away from the drill site. The vessel never came close to crossing the warning circle. Overall, holding station so well is considered one of the major successes of the NBP0502 cruise.

A kasten core was taken prior to running the drill string. The sediment recovered in the kasten core (NBP0502-1A) was used to help determine recovery in the upper part of the drill core (see Physical Properties). Also, the time allotted to kasten coring allowed the vessel to practice DP prior to the drillers running pipe.

The soft sediments of the Maxwell Bay site were cored with the extended core barrel push sampler inside the API drill string. API drill pipe and collars were run to the sea floor in approximately 12 hours plus about 3 hours of set up time for drilling operations once the vessel was on site. Considering that all of the operations were being done for the first time, running pipe went remarkably smoothly.

Once sampling was begun, core was brought on board at regular intervals (Table 3-B1). Coring operations lasted for approximately 50 hours and the hole reached 108.2 mbsf (NBP0502-1B). Forty-three cores were obtained from the hole, with approximately 87% recovery. Only one core from Hole 1B, Core 19E, did not have any recovery (Table 3-B1). The total recovery was 101.13 m but this number includes some section with significant disturbance, gaps due to core expansion, and some overlap. The disturbed sections were typically interpreted as sediment that had been partially fluidized by the weight of the drill pipe sitting on the sediment in advance of the push sampler. Any sediment that appeared to be disturbed enough to call into doubt its stratigraphic integrity is counted as disturbed core rather than competent core. The corrected recovery was 88.17 m, which represents 81.5% recovery over the length of the core. The entire section was sampled with extended core barrel push samplers. The attempted push distance varied from 1.5 m to 3 m and the normal operating mode was to use a 2.5 m push.

C. LITHOSTRATIGRAPHY

NBP0502 Site 1 consists of a kasten core (NBP0502-1A) and a drill core (NBP0502-1B). NBP0502-1A consists of 2.71 m of dark greenish gray silty mud with intense black mottling and a few very fine to fine black sand laminations (Fig. 3-C1). NBP0502-1A generally duplicates the first push core (NBP0502-1B-1E) of the long drill core also collected at this site (NBP0502-1B). A detailed description of NBP0502-1B is illustrated in Figure 3-C2. Three distinct sedimentary units were sampled. The upper unit, Unit I, extends from 0 to 58.3 meters below sea floor (mbsf) and is a diatomaceous mud. This unit consists of mottled olive to dark grey mud with occasional olive green or black laminations, black sand layers, and rare pebbles. Sand layers commonly measure a few centimeters thick with sharp lower and gradational upper contacts. These layers are composed of silt to medium sand and generally fine upwards. The sands are volcaniclastics, dominated by glass with significant components of andesite and basalt. Bivalves are common throughout.

The second unit encountered is a clay-rich mud that ranges from approximately 58.3 to 105.2 mbsf with a gradational upper contact. This unit is characterized by alternating zones of homogeneous dark gray clay and silty mud, with abundant black sand layers and occasional pebbles. This unit is marked by a significant increase in terrigenous clay, silt, and sand layers along with a decrease in diatom abundance. Clay zones are nearly homogeneous with very little silt and rare sand lenses and olive green laminations rich in diatoms. Silt zones feature faint laminations, abundant mottling, and sharp contacts with clay zones. As in the upper unit, the black volcaniclastic sands and silts fine upwards and feature sharp lower and gradational upper contacts. Bivalves and echinoderms are common.

The third unit, Unit III, extends from approximately 105.2 to 108.2 mbsf and is a clay-rich diamicton. This unit is distinguished by a sharp increase in pebble abundance and a sharp increase in shear strength with no stratification or laminations. Pebbles are black volcanics encased in black sands and silts. This unit contains fractured shell (bivalve) and echinoderm fragments.

D. BIOSTRATIGRAPHY

Introduction

Drilling at the Maxwell Bay site was aimed at reconstructing the Holocene (post-LGM) climate history of the northern realm of the Antarctica Peninsula. The sediments of SHALDRIL Holes 1A and 1B are composed primarily of greenish-grey diatom-bearing silty clay and clayey silt. Initial shipboard paleontological work included sample preparations for diatoms, calcareous nannofossils, and radiolarians. The occurrence of benthic foraminifers was also noted in the radiolarian preparations. The goal of the initial biostratigraphic work was to provide age information and a preliminary paleoenvironmental assessment. The results of these initial investigations are described below.

Diatoms

Diatom-rich sediments were recovered in SHALDRIL Holes 1A and 1B. Diatom slides were prepared for one sample from Hole 1A, and forty samples were prepared from Hole 1B (Table 3-D1). Hole 1A is equivalent to upper ~3 meters of Hole 1B. The diatom abundance and assemblage notes given here will therefore focus primarily on samples from the thick section recovered in Hole 1B. Diatom samples were taken at an average sample spacing of ~2.5 m, or approximately one sample per core.

Qualitative estimates of total diatom abundance, preservation, and abundance of individual taxa in SHALDRIL Holes 1A and 1B are recorded in Table 3-D1. In general, well-preserved and diverse diatom assemblages are present in the upper part of Hole 1B from Cores 1B-1E through 24E (0 to ~64 mbsf). Below this level (Cores 1B-25E through 43E, ~64 to 109 mbsf), diatom abundance and preservation are highly variable (Fig. 3-D1), although moderately well-preserved diatoms are present in most samples. Samples characterized by low diatom abundance and high fragmentation in the lower part of section appear to be correlated with increased silt content. This trend is consistent with a general downcore coarsening of grain size noted in visual core descriptions and smear slide observations (Fig. 3-C2).

With the exception of rare occurrences of extinct taxa that are interpreted to be reworked, all diatom taxa observed throughout Hole 1B are modern (extant) species (Table 3-D1). The presence of fully modern assemblages lends support to a presumed

Holocene age for the drill core. Diatom biostratigraphy, however, cannot differentiate between the Holocene and the late Pleistocene. The absence of *Rouxia leventerae* in all samples indicates an age younger than 140 Ka (Marine Isotope Stage 6) for the entire section. The absence of *Rouxia constricta* further corroborates this age interpretation, indicating an age younger than 290 Ka (MIS 8).

Extinct diatom taxa interpreted as reworked are rare in the upper part of Hole 1B (above ~69 mbsf). Increased reworking is noted from Core 1B-26E (~69 mbsf) to the bottom of the section (Table 3-D1), corresponding to an increase in silt content of the sediments. The reworked taxa range in age from the early Miocene to the late Pleistocene. The range of *Thalasiosira praefraga* is restricted to the early Miocene, indicating that sediments as old as early Miocene have been reworked and incorporated into Holocene sediments of Maxwell Bay. No extinct taxa typical of upper Pliocene to middle Pleistocene strata were observed (e.g., *Rouxia leventerae* and *Thalassiosira elliptipora*), further suggesting reworking of primarily lower Miocene to lower Pliocene material.

Qualitative estimates for the abundance of individual diatom taxa in SHALDRIL Hole 1B are recorded in Table 3-D1. The assemblages are dominated by *Chaetoceros* spp., *Thalassiosira antarctica, Fragilariopsis kerguelensis, Fragilariopsis curta, Cocconeis* spp., and *Eucampia antarctica* var. *antarctica*. Taxa of secondary abundance include *Thalassiosira gracilis, Fragilariopsis angulata, Rhizosolenia* spp., and *Eucampia antarctica* var. *recta*. Several of these taxa are illustrated in Plate 3-D1. Qualitative abundance data reveal substantial changes in diatom assemblage composition through the section. Significant downcore variation was noted in the abundance of *Chaetoceros* spp., *Eucampia antarctica* var. *antarctica*, *Rhizosolenia* spp., and *Thalassiosira antarctica* (Table 3-D1). These observations suggest that the diatom assemblages are recording significant variation in the long-term climatic evolution of outer Maxwell Bay.

A complex paleoecological signal is evident in most samples from SHALDRIL Hole 1B, as taxa with different ecological affinities occur together within samples. For example, cold-water, sea-ice related taxa such as *F. curta* and *T. antarctica* co-occur in abundance with more open-water, oceanic taxa such as *F. kerguelensis*. This mixing of ecological groups is most likely a reflection of significant seasonal variation in local sea-ice cover, sea-ice thickness, sea surface temperatures, nutrient supply, and/or stratification. Both chemical and physical changes in the upper water column can result in seasonal successions/blooms of different diatom taxa in the plankton. Some taxa thrive near the retreating sea-ice edge, while others thrive in relatively open water after sea ice has dispersed in late spring/summer. These seasonal changes in diatom assemblage composition (and bloom events) are blurred in the sedimentary record, particularly in highly bioturbated sediments, as encountered here.

Initial qualitative abundance estimates of SHALDRIL Hole 1B diatoms show that the diatom assemblages are comparable to those reported from the Holocene section recovered at Ocean Drilling Program Site 1098 in the Palmer Deep basin. Taylor and

Sjunneskog (2002, Fig. 4) report a similar combined occurrence of taxa such as *F. curta, T. antarctica,* and *F. kerguelensis* throughout the Palmer Deep sequence.

Without quantitative diatom data from SHALDRIL Hole 1B, it is difficult to evaluate downcore assemblage changes in a paleoenvironmental context. One simple indicator of climatic change is the "*Eucampia* index" employed by Leventer et al. (2002) for samples from the Palmer Deep section. The application of this proxy is relatively new and has not been widely applied. It is based on changes in the average morphology of *Eucampia antarctica* valves. Two ratios can be used to track these morphological changes. One is the ratio of symmetrical to asymmetrical intercalary valves (the S/A ratio). This ratio effectively represents the proportion *Eucampia antarctica* var. *recta* of relative to *E. antarctica* var. *antarctica*. *Eucampia antarctica* var. *recta* is a variety that forms straight chains with symmetrical valves, and *E. antarctica* var. *antarctica* is a variety that forms curved chains with asymmetrical valves (Plate 3-D1). In plankton samples, *E. antarctica* var. *antarctica* is distributed in more northerly waters than *E. antarctica* var. *recta* (Fryxell, 1991). The S/A ratio may therefore reflect temperature changes, where a higher abundance of *E. antarctica* var. *antarctica* (and lower S/A ratio) indicates warmer temperatures. The second ratio that tracks changes in *Eucampia antarctica* morphology is the ratio of terminal to intercalary valves. Terminal valves are characterized by "pointy" elevations, and intercalary valves are characterized by "flat-topped" elevations (see Plate 3-D1). The ratio of terminal to intercalary valves (the T/I ratio) is a reflection of chain length; longer chains possess more intercalary valves. It is thought that average chain length is determined by duration of the growing season, which is directly related to duration of sea-ice cover and thickness. Although the terminal valves of the two varieties of *E. antarctica* cannot be distinguished (Fryxell, 1991), decreases in the T/I ratio are thought to reflect the formation of longer chains and presumably longer growing season and reduced sea-ice cover. Therefore, the *Eucampia* morphological ratios appears to be useful as a relative indicator of both temperature and sea-ice conditions.

Significant downcore variation in *Eucampia* S/A and T/I ratios is observed in SHALDRIL Hole 1B (Table 3-D2, Fig. 3-D1). These preliminary data represent *Eucampia* counts from twenty-eight samples, with fifty to one hundred specimens counted per sample for all samples except for Sample 1B-41E, 91 cm (Table 3-D2). Both ratios show similar trends. Relatively high S/A and T/I ratios characterize the uppermost section of the hole (0 to ~30 mbsf). Decreased ratios occur in the middle interval between~30 and 76 mbsf, and relatively high, but variable, ratios are recorded in the lowermost interval (~76 to 109 mbsf). In general, minimum values for both ratios occur between 30 and 57 mbsf. Taken at face value, these ratios qualitatively indicate an interval of variable temperatures and sea-ice conditions in the lowermost section at ~105 to 76 mbsf. Warming and decreased sea-ice influence are indicated for the overlying interval between ~30 and 76 mbsf, with peak warming in the interval between ~30 and 57 mbsf. A return to cool conditions with increased sea-ice is indicated for the upper interval between 0 and ~30 mbsf. These interpretations should be taken as very preliminary until a further high-resolution quantitative diatom analysis is performed and corroborated with other diatom assemblage data.

The decrease in the *Eucampia* S/A and T/I ratios in the middle interval of Hole 1B results from a significant increase in abundance of *Eucampia antarctica* var. *antarctica* (Fig. 3-D1). *Eucampia antarctica* var. *antarctica* is characterized by a both a longer chain length than *E. antarctica* var. *recta* and asymmetrical intercalary valves, thus affecting both of the ratio indices. The abundance of *E. antarctica* var. *antarctica* between Cores 1B-12E and 21E (~31 to 57 mbsf) represents a striking change in diatom assemblage composition. A similar acme of *E. antarctica* var. *antarctica* is recorded from 18 to 28 meters composite depth (mcd) in the Palmer Deep section and represents deposition during the mid-Holocene climatic optimum (Taylor and Sjunneskog, 2002; Sjunneskog and Taylor, 2002). Development of a radiocarbon-based age model for SHALDRIL Hole 1B will determine whether a correlation exists between the *E. antarctica* var. *antarctica* acme events in these two sections.

One possible piece of supporting data for warming in the middle section of Hole 1B is the very rare occurrence of *Azpeitia tabularis* in samples from Cores 1B-10E, 12E, 14E, and 20E (Table 3-D1). The presence of this taxon may indicate warmer sea-surface temperatures between ~25 and 52 mbsf. *Azpeitia tabularis* is typically found in more northerly areas of the Southern Ocean and is believed to be an indicator of increased temperature at southerly sites (Zielinski and Gersonde, 1997).

The sediments recovered in SHALDRIL Hole 1B are heavily bioturbated (see Lithostratigraphy) and very few laminated horizons were observed during initial shipboard core description (Fig. 3-D1). One lamination, however, was observed in Core 1B-17E, and several were described in Core 1B-41E (see "Lithostratigraphy"). "Toothpick" smear slide preparations were made from laminated horizons at 1B-17E-1, 215 cm (44.65 mbsf), 41E-1, 13 cm (103.83 mbsf), 41E-1, 68 cm (104.38 mbsf), and 41E-1, 70 cm (104.40 mbsf). All laminations sampled were dominated by *Chaetoceros* resting spores. Similar *Chaetoceros*-dominated laminations were recognized in Palmer Deep sediments, as well as in other Holocene cores from the Antarctic Peninsula region (Leventer et al., 1996; 2002). These horizons have been interpreted as single events representing spore sedimentation after spring blooms at the sea-ice edge (Leventer et al., 2002).

In addition to abundant *Chaetoceros* resting spores, the laminated layers at 103.83 mbsf (Sample 1B-41E-1, 13 cm) and 104.38 mbsf (Sample 41E-1, 68 cm) also contain abundant small, needle-shaped calcite crystals. The origin of this carbonate material is uncertain.

Silicoflagellates

Silicoflagellate occurrence and abundance was recorded during examination of the diatom smear slides from SHALDRIL Hole 1B. *Distephanus speculum speculum* was noted in all samples from Hole 1B (Table 3-D1). Very rare five-sided and "pseudofibulid" variants of *Ds. speculum speculum* were also noted in several samples (Table 3-D1).

Calcareous Nannofossils

Smear slides were prepared for calcareous nannofossils at ~2.5 m intervals through SHALDRIL Hole 1B. Most samples are barren of calcareous nannofossils, except for the sporadic occurrence of rare specimens of *Thoracosphaera* sp. cf. *T. heimii* (a calcareous dinoflagellate). *Thoracosphaera* specimens occur at several levels within the section, and a consistent occurrence is recorded in seven adjacent samples between ~37 and 46 mbsf (Table 3-D3). *Thoracosphaera* spp. have been interpreted as warmer-water indicators in Antarctic Quaternary sediments (Villa and Wise, 1998), hence their occurrence between ~37 and 46 mbsf may strengthen inferences of a warm interval within the Holocene suggested by changes in the diatom assemblages.

Radiolarians & Foraminifers

Thirty core-catcher samples were processed for radiolarians from SHALDRIL Site 1. These included samples from Cores 1A-1KC and Cores1B-3E to 6E, 8E to 12E, 17E, 18E, 20E to 23E, 25E to 27E, 30E to 31E, 33E to 35E, and 38E to 43E. Samples were sieved at 63 microns and smear slides of the sieved fractions were made using Norland optical adhesive. Radiolarians are rare to very rare in all samples examined, except for Samples 1B-21E-CC and 41E-CC that contain radiolarians in higher abundance. Most slides contained only one to five radiolarian tests, except for Samples 21E-CC and 41E-CC that contain 20 to 30 specimens. Most tests were fair to moderately well preserved. All specimens are typical modern cold-water radiolarians. These include *Antarctissa denticulata, Antarctissa strelkovi, Lithelius nautiloides, Theocalyptra davisiana, Theocalyptra* sp., *Actinomma* sp., and a number of Spumellarian species too poorly preserved to be clearly identified.

In addition to radiolarians, rare to few benthic foraminifers were observed in core catcher samples from Cores 5E, 17E, 22E, 23E, 26E, 27E, 41E, and 43E.

Summary

All indications suggest that the section recovered in SHALDRIL Hole 1B is Holocene in age, but diatom biostratigraphy can only constrain the age to younger than 140 Ka. The sediments are diatom-rich, and examination of radiolarian preparations indicate that benthic foraminifers are also common throughout the drillcore. Both microfossil groups will be useful for further studies seeking to gain insight into Holocene paleoclimatic changes in Maxwell Bay. Preliminary investigation of diatom assemblages in Hole 1B shows significant change through the core, suggesting long-term variation in sea-ice conditions and sea-surface temperature. Quantitative analysis of the diatom assemblages is required to further illuminate these changes.

E. PHYSICAL PROPERTIES

Introduction

The objective of the physical properties program at Site 1 was to aid in the interpretation of stratigraphic and geophysical data from Maxwell Basin. Holes 1A and 1B differed in their depth and coring method. Hole 1A was a 2.71 m kasten core and Hole 1B was a extended core barrel push core that reached 108.2 mbsf.

Measurements were made by three methods; MSCL track which sampled every cm and recorded magnetic susceptibility and GRAPE data, electric resistivity probe and discrete sampling. Depending on the coring technique, some of the methods varied.

The kasten core had electric resistivity measurements made every 2 cm. Discrete samples (normally 5 cc, using a syringe sampling system) were made but were not processed onboard. These samples were stored in weighed vials and kept in the cooler until transport. The core was scraped down 4 cm and a half-split liner obtained an archive sample in the unsampled region. This half-split liner was run through the MSCL track and obtained magnetic susceptibility data at 1 cm intervals.

Electrical Resistivity

Hole 1B had electric resistivity measurements and discrete samples taken at a 5 cm resolution. Downhole variations in electric resistivity correlate with changes in sediment lithology. Core disturbances are readily observed in the resistivity and have been removed. Overall downhole trend of increased resistivity correlates with decreased porosity due to compaction. The electrical resistivity profile between NBP0502-1A-KC and NBP0502-1B-1E shows a loss of approximately 18 cm for the push core.

Multi-sensor Core Logging

Due to technical difficulties with the MSCL track (see Appendix 3-H1), Sections NBP05-02 1B-1E through NBP05-02 1B-12-2 were run on split liners. Sections NBP05-02 13E-1 to NBP05-02 43E-1 were run on whole linered cores. Data obtained from the MSCL track includes only magnetic susceptibility and gamma ray counts. The GRAPE unit was not calibrated so only counts per second were obtained and will be converted at a later time. The p-wave logger was malfunctioning and no reliable data could be obtained. Subsequently the split liners were rerun on the MSCL track to obtain a consistent magnetic susceptibility profile for this hole but the reported values have not been calibrated for loop size or half-liner size. Initial evaluation of the data showed that some spurious data was being captured beyond the end of each measured core section. Additionally, we noticed that the magnetic susceptibility sensors were occasionally recording erroneous negative values. These values were removed from the analyses.

Concluding Discussion

Minimal interpretation can be made at this time. The sediment lithology and depth of burial are likely responsible for the physical state of the sediments recovered in

Maxwell Bay. The cores from this site will need to be rerun on split cores at ARF once the cores arrive at the facility and the MSCL is repaired and calibrated properly.

F. SEISMIC STRATIGRAPHY

Two seismic surveys were conducted in Maxwell Bay by the Rice University group. The first was conducted in 1986, as part of the USCGC Glacier Deep Freeze 86 cruise. A single line was collected along the axis of the bay using a 4.0 to 4.6 kJ EG&G sparker array and single channel hydrophone streamer. Later, in 1991, a seismic survey of the bay was conducted from the R/V *Polar Duke* using a Hamco 100 cubic inch water gun and Teledyne single channel streamer. These data show acoustically laminated sediments ponded within three mini-basins in the lower half of the bay. The sediment fill in the southern-most minibasins is upwards of 150 milliseconds thick (Fig. 3-F1).

During the SHALDRIL cruise, a chirp sonar and swath bathymetry survey was conducted in Maxwell Bay to make sure that the drill site was not situated near sidewall slumps or debris flows (Fig. 3-A1). The site was selected within the center of the southern minibasin (Fig. 3-F2) where sediment thickness was estimated to be 100 meters. No noticeable breaks (hiatuses) in the basin fill are noted, which indicates continuous deposition since the last glacial maximum.

G. SITE SUMMARY

Site 1 (62° 16.931′ S, 58 45.230′ W, water depth 488 m) was located in the center of the southern-most mini basin of outer Maxwell Bay on King George Island. The intent was to recover a high-resolution Holocene section deposited above the calcium carbonate compensation depth in a region of the peninsula that is experiencing the largest warming in the last century.

A 108.2 m sequence (82% overall recovery) was recovered containing a modern assemblage of diatoms suggesting that the entire site is Holocene in age. Three sedimentary units were observed. Unit I (0 – 58.3 mbsf) is a diatomaceous mud containing volcaniclastic sand layers having sharp to gradational lower contacts. This unit contains a well-preserved and diverse diatom assemblage. Unit II (58.3 – 105.2 mbsf) is alternating dark gray clay layers with silty mud layers. This unit has low diatom abundance with high fragmentation. There is an increase in terrigenous material and decrease in diatom abundance within this unit. Unit III (105.2 – 108.2 mbsf) is a clay-rich diamicton. This unit has variable diatom abundance and preservation.

A small outwash fan occurs at the mouth of Maxwell Bay and records the maximum ice advance in the region. The clay-rich diamicton at the base of the sequence records the maximum glacial advance in the bay. The sequence above the diamicton records gradual warming and associated retreat of ice from the bay. Based on specific diatom indices (T/I and S/A – see Biostratigraphy), the middle section of Site 1 (30 – 57 mbsf) may have cored through the mid-Holocene climatic optimum. This seems to also be suggested by the calcareous nannofossil data as well. Diatom assemblages further suggest that the lower units of the site record variable temperature and sea ice conditions. However a more detailed biostratigraphy is needed to verify this interpretation. Calcareous material occurs throughout the cored interval, so this site should yield a robust radiocarbon stratigraphy.

H. APPENDICES

Appendix 3-H1. Multi-Sensor Core Logging Operational Issues

Several operational issues surfaced during the initial shipboard use of the MSCL. Prior to its initial operational use, both hardware and software problems were encountered as the MSCL failed to operate during testing prior to Site 1. Before leaving the Antarctic Research facility, the logger was operating according to specifications. Because the MSCL is by its construction a very complex and fragile piece of equipment, damage in transit was suspected, but no physical damage was found. However, after these initial problems were encountered, a loose connection was found and repaired. A message kept appearing as the MSCL was operated, indicating that the computer and the logger were not communicating.

With the help of shipboard computer support personnel, two different versions of the MSCL Geotek software, v 6.1 and v6.2, were reloaded to see if this solved the operational problem. It didn't. Next, the MSCL was connected to a different onboard computer to see if a hardware problem with the MSCL equipment was the problem. This too failed to solve the problem with the MSCL. At this point a Raytheon technician was engaged to help. First, the connecting cables between the computer and the logger were swapped but to no effect. Thinking that a problem with the computer serial port was likely, things were again rewired and there finally was a signal from the computer to the logger and it started to function. However, the calibration software for the P-wave was corrupted, the gamma-ray calibration curve was missing, so only magnetic susceptibility and raw gamma-ray counts were obtained.

Presently, the Geotek MSCL being utilized on SHALDRIL is seven years old and is showing its age, both from a hardware and software perspective. The computer is still running on the Windows 98 operating system and the software versions are no longer supported by Geotek.

If this equipment is to be used on further shipboard operations in the future, these issues need to be rectified by a total upgrade of the system, including the camera system, and a contract should be established with Geotek to regularly test and service the equipment. A MSCL specialist from Geotek may need to be brought on-site to set-up and check out the equipment prior to shipboard operations.

Appendix 3-H2. Lithologic Logs

Appendix 3-H2 follows the figures and contains the detailed lithologic logs from Hole NBP0502-1B.

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FIGURES

Figure 3-A1. Multibeam swath bathymetry mosaic for Maxwell Bay showing the Site 1 location.

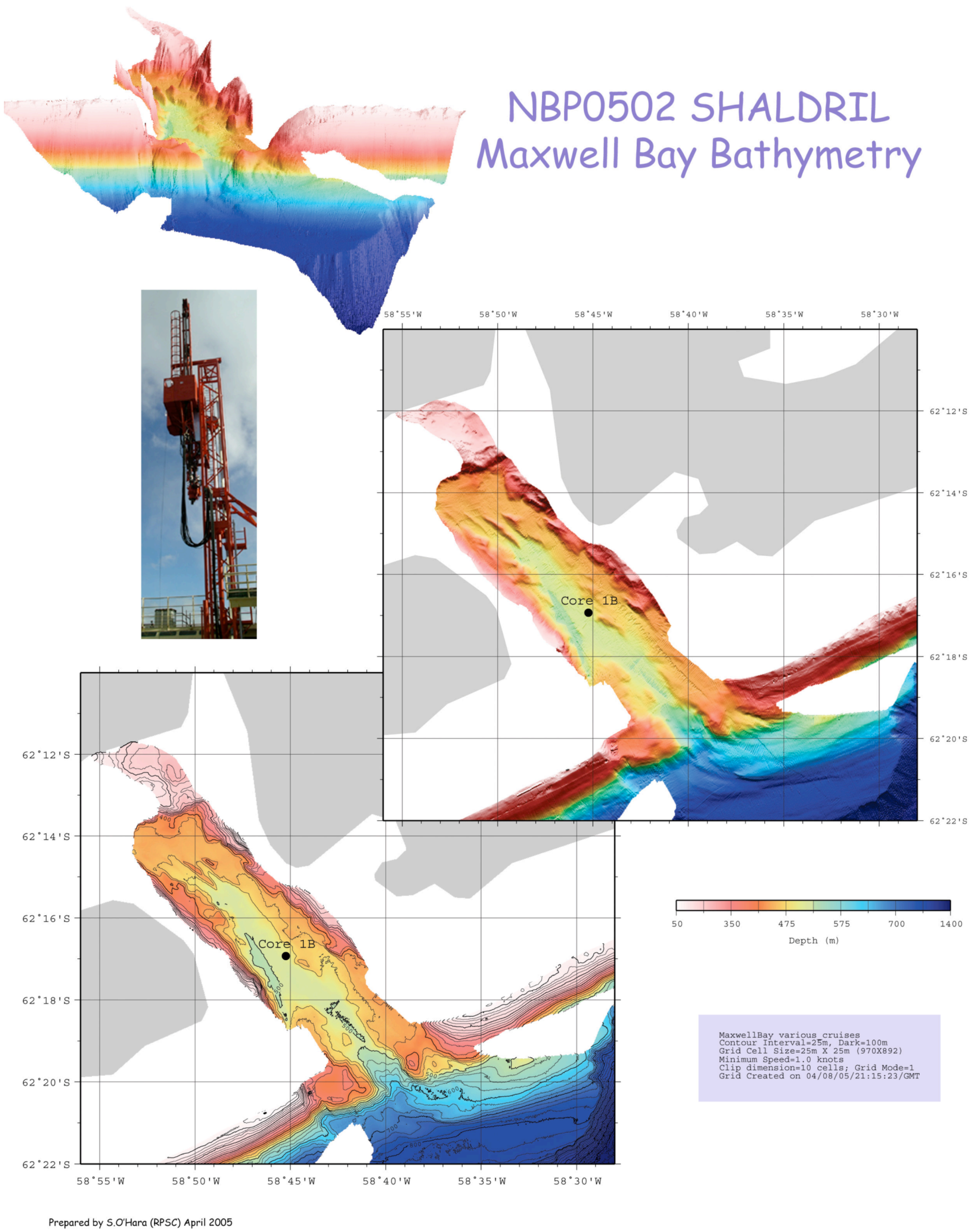


Figure 3-C1. Lithologic log of kasten core NBP0502-1A-KC.

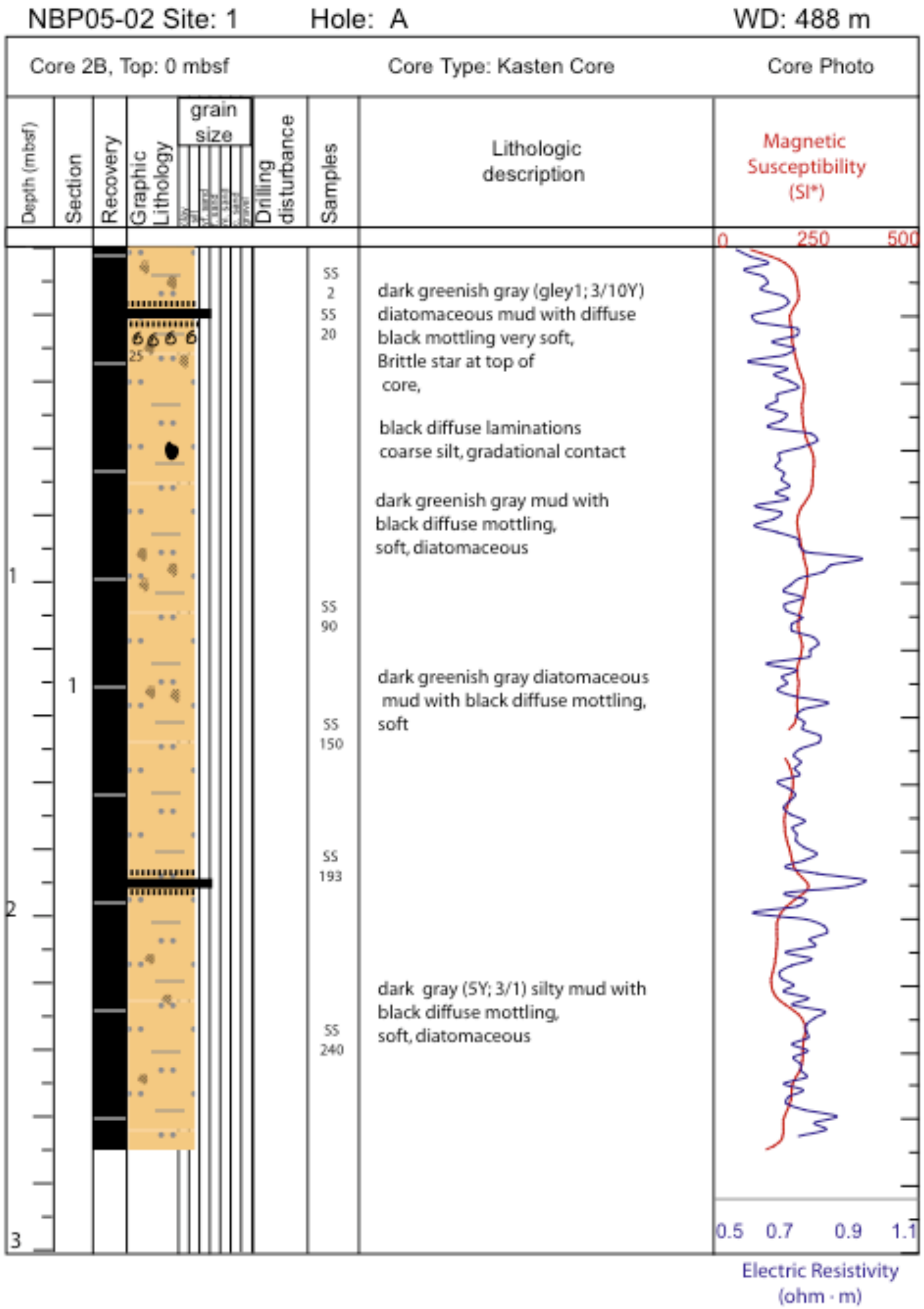


Figure 3-C2. Summary lithologic log of drill core NBP0502-1B.

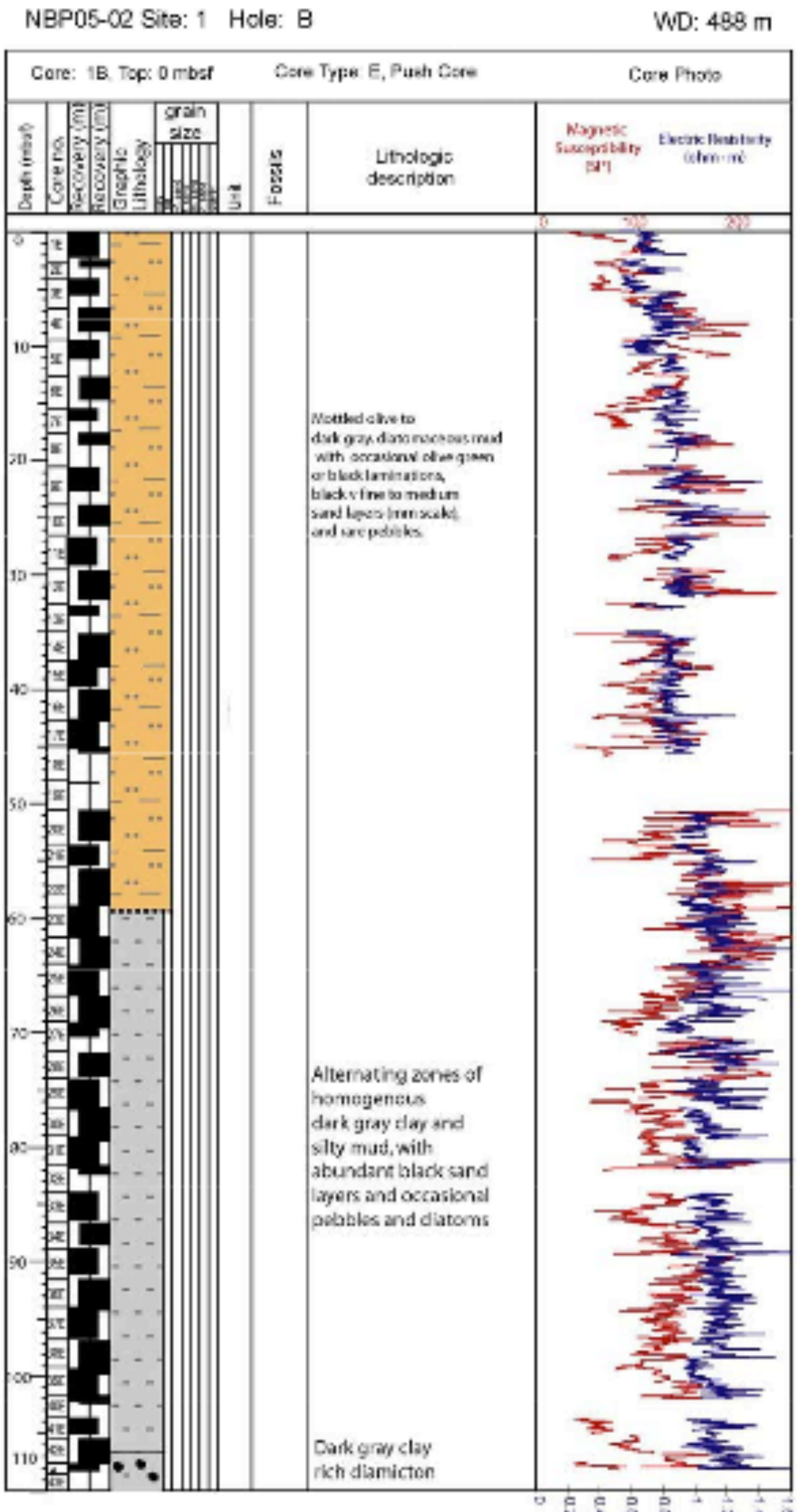


Figure 3-D1. Selected diatom data from SHALDRIL Hole 1B. (A) Qualitative total diatom abundance. (B) Diatom preservation. (C) Qualitative estimates of *Eucampia antarctica* var. *antarctica* abundance. (D and E) Stratigraphic variation in *Eucampica antarctica* morphologies. "S/A" is the ratio of symmetrical intercalary valves to asymmetrical intercalary valves. "T/I" is the ratio of terminal valves to intercalary valves. The S/A ratio is a qualitative indicator of temperature, with higher values indicating colder temperatures. The T/I ratio is a qualitative indicator of sea-ice cover and/or thickness, with higher values indicating more sea-ice cover. Note that the S/A ratios are plotted on a log scale. (F) Stratigraphic position of *Chaetoceros*-dominated laminations.

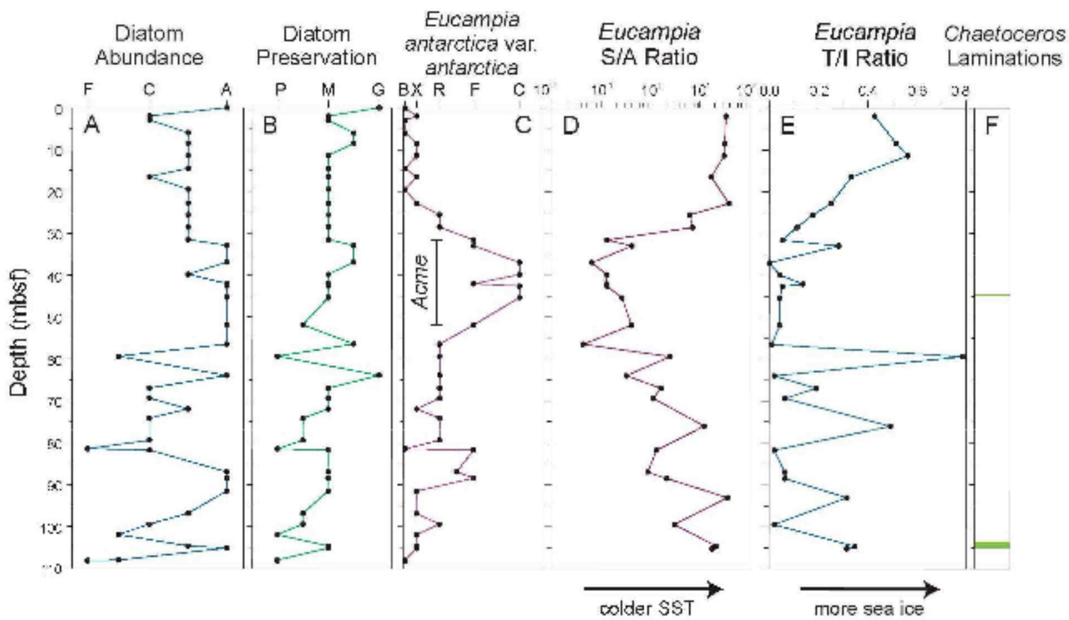


Figure 3-F1. Seismic line SS-E-2 in Maxwell Bay showing the Site 1A hole location.

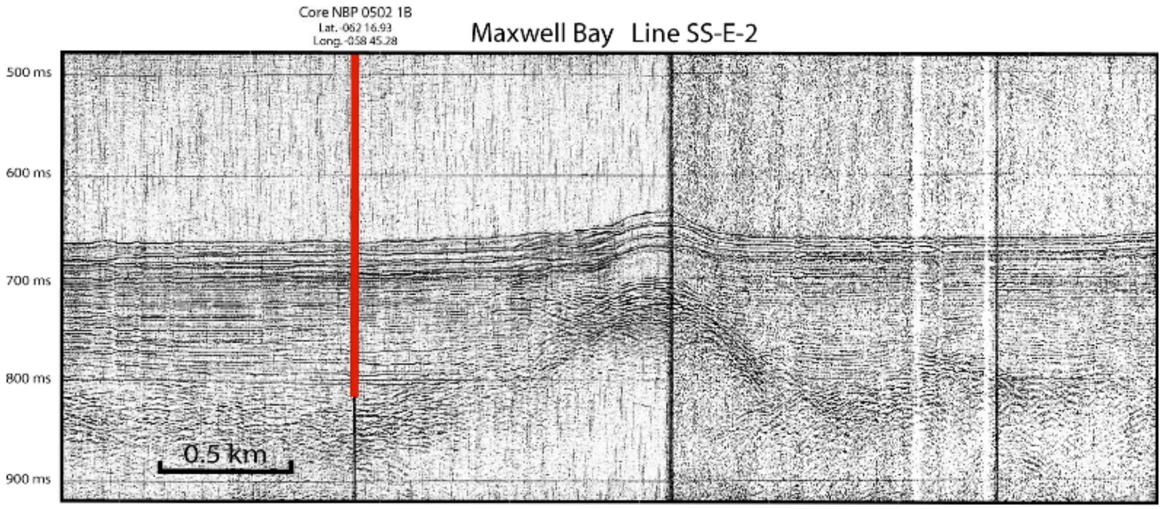


Figure 3-F2. Chirp data from the NBP0502 cruise showing the layered sediments penetrated with the Site 1 cores.

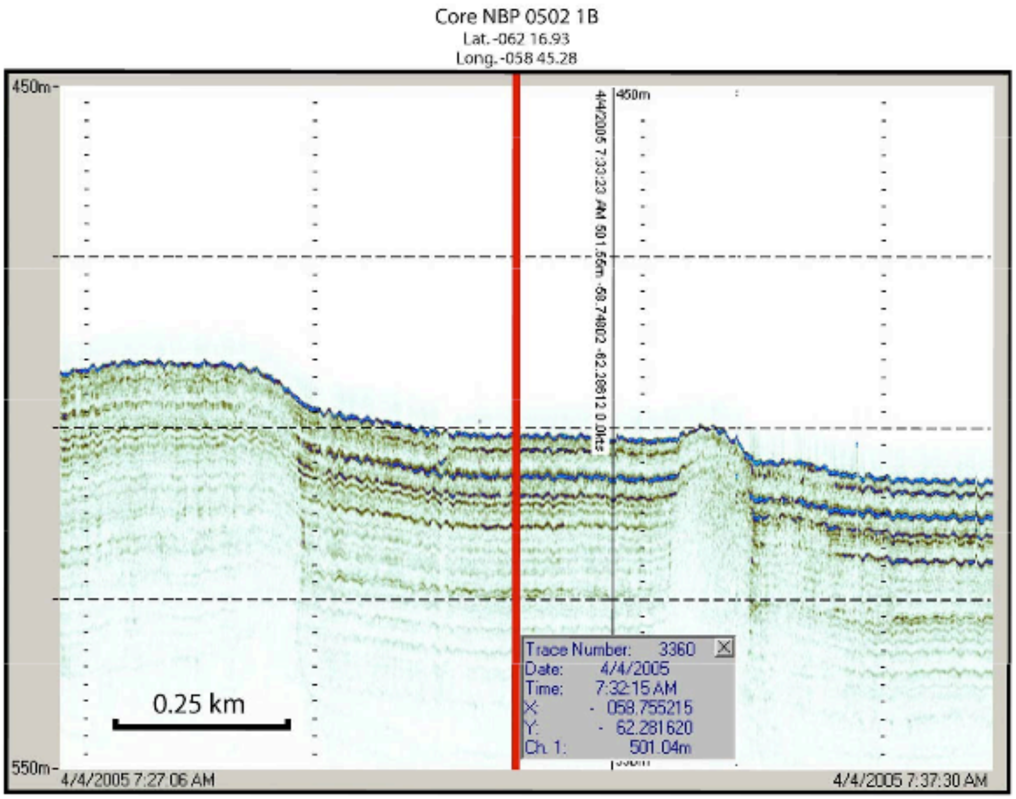


Plate 3-D1. Selected diatom taxa from SHALDRIL Hole 1B. All specimens are illustrated at the same scale, and the scale bar in the lower right corner represents 20 microns. (A-D) *Eucampia antarctica* var. *recta*. A. Articulated terminal and intercalary valves, Sample 1B-29E-2, 204 cm. B. Intercalary valve, Sample 1B-29E-2, 204 cm. C. Intercalary valve in valve view, Sample 1B-29E-2, 204 cm. D. Terminal valve, Sample 1B-29E-2, 204 cm. (E-L) *Eucampia antarctica* var. *antarctica.* E. Articulated terminal and intercalary valves, Sample 1B-29E-2, 204 cm. F-G, I-J. Articulated intercalary valves, Sample 1B-14E-2, 190 cm. H. Terminal valve, Sample 1B-14E-2, 190 cm. K-L. Intercalary valves in valve view, Sample 1B-14E-2, 190 cm. Note asymmetry of *Eucampia antarctica* var. *antarctica* in both valve and girdle views. (M and P). *Thalassiosira antarctica* var. *antarctica*, Sample 1B-29E-2, 204 cm. (N) *Asteromphalus hookeri*, Sample 1B-14E-2, 190 cm. (O) *Cocconeis* sp., Sample 1B-14E-2, 190 cm. (Q) *Thalassiosira gracilis* var. *expecta*, Sample 1B-14E-CC. (R) *Fragilariopsis angulata*, Sample 1B-24E-CC. (S) *Fragilariopsis curta*, Sample 1B-14E-CC. (T) *Rhizosolenia antennata* var. *semispina*, Sample 1B-24E-CC. (U) *Actinocyclus actinochilus,* Sample 1B-14E-2, 190 cm. (V) *Thalassiosira lentiginosa*, Sample 1B-14E-2, 190 cm. (W) *Actinocyclus ingens*, Sample 1B-29E-2, 204 cm (reworked specimen).

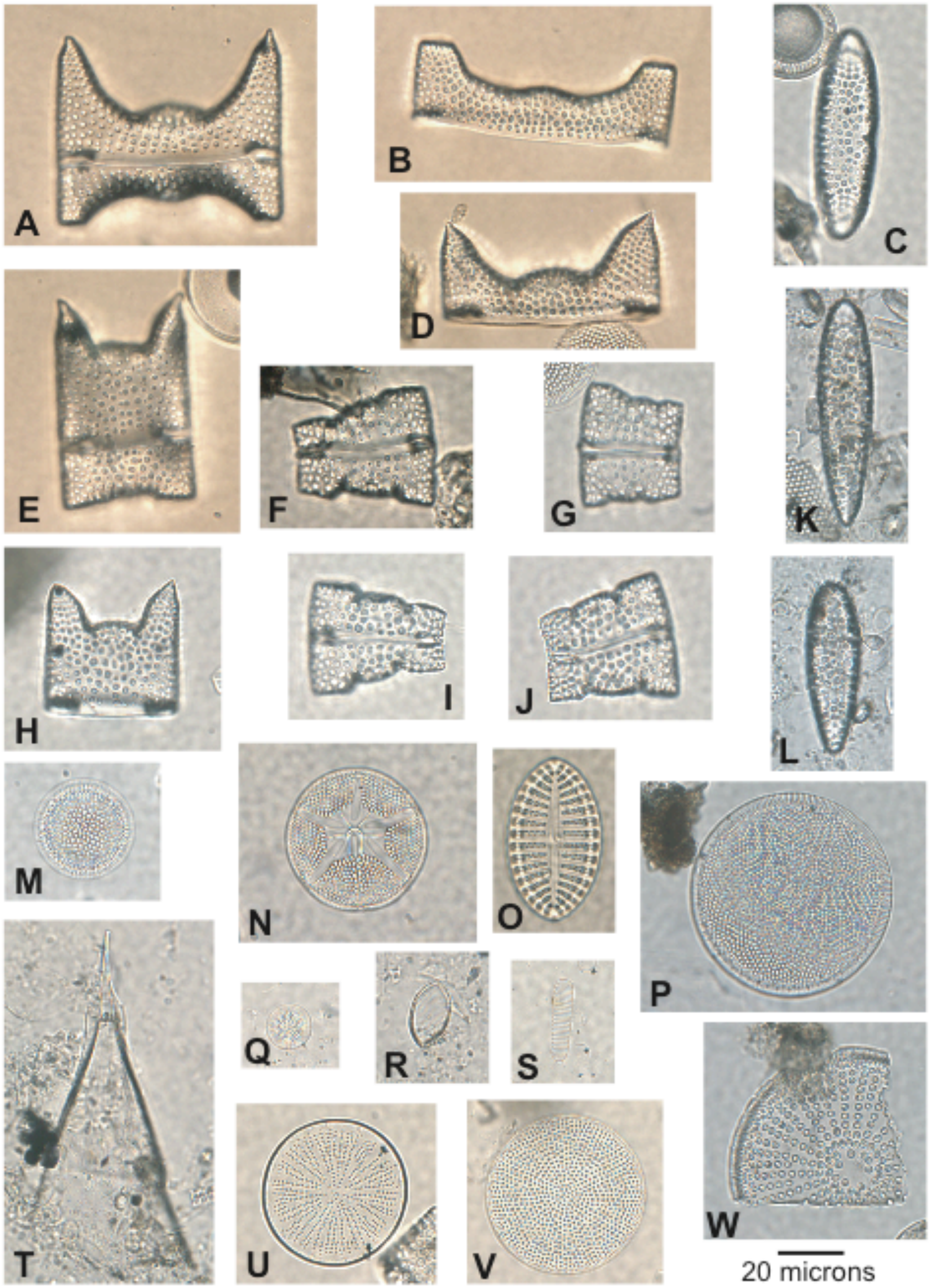

A
B
C
D
E
F
G
K
H
I
J
L
M
N
O
P
T
Q
R
S
U
V
W
20 microns

Table 3-B1. Drilling and coring recovery log for holes 1A and 1B.

SHALDRIL CRUISE NBP05-02, SITE 1 (Maxwell Bay)

Multibeam Water Depth: 488 m

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
1A	1	KC	0.00	2.71	2.71	2.71	2.71	0.00	0.00	2.71	100.0%	100.0%	1	0-150	94	1145	1
													2	150-279			
1B	1	E	0.00	2.50	2.50	2.05	2.05	0.00	0.00	2.05	82.0%	82.0%	1	0-104	95	0137	
													2	104-205			
1B	2	E	2.50	4.00	1.50	1.45	0.75	0.70	0.00	0.75	96.7%	50.0%	1	1-145		0230	
1B	3	E	4.00	6.50	2.50	2.61	1.37	1.24	0.00	1.37	104.4%	54.8%	1	0-150		0430	
													2	150-261			
1B	4	E	6.50	9.50	3.00	2.96	1.81	1.15	0.00	1.81	98.7%	60.3%	1	0-150		0625	
													2	150-296			
1B	5	E	9.50	12.50	3.00	2.95	1.66	1.29	0.00	1.66	98.3%	55.3%	1	0-150		0750	
													2	150-295			
1B	6	E	12.50	15.50	3.00	2.95	1.90	1.05	0.00	1.90	98.3%	63.3%	1	0-150		0937	
													2	150-295			
1B	7	E	15.50	17.50	2.00	1.73	1.63	0.10	0.03	1.61	86.5%	80.3%	1	0-23		1034	
													2	23-173			
1B	8	E	17.50	20.50	3.00	1.59	1.59	0.00	0.00	1.59	53.0%	53.0%	1	0-136		1152	
													2	136-159			
1B	9	E	20.50	23.50	3.00	2.40	2.20	0.20	0.06	2.14	80.0%	71.3%	1	0-90		1246	

Table 3-B1 (cont.).

													2	90-239			
1B	10	E	23.50	26.50	3.00	2.35	1.95	0.40	0.05	1.90	78.3%	63.3%	1	0-85		1335	
													2	85-235			
1B	11	E	26.50	29.50	3.00	2.35	2.35	0.00	0.02	2.33	78.3%	77.7%	1	0-83		1420	
													2	83-233			
1B	12	E	29.50	32.50	3.00	2.55	2.55	0.00	0.18	2.37	85.0%	79.0%	1	0-105		1505	
													2	105-255			
1B	13	E	32.50	35.00	2.50	0.61	0.61	0.00	0.00	0.61	24.4%	24.4%	1	0-61		1855	
1B	14	E	35.00	37.50	2.50	3.00	3.00	0.00	0.25	2.75	120.0%	110.0%	1	0-150		2004	
													2	150-300			
1B	15	E	37.50	40.00	2.50	2.60	2.60	0.00	0.20	2.40	104.0%	96.0%	1	0-150		2100	
													2	150-260			
1B	16	E	40.00	42.50	2.50	2.60	2.60	0.00	0.04	2.56	104.0%	102.4%	1	0-150		2146	
													2	150-261			
1B	17	E	42.50	45.00	2.50	2.76	2.76	0.00	0.09	2.67	110.4%	106.8%	1	0-150		2251	
													2	150-276			
1B	18	E	45.00	48.00	3.00	0.89	0.89	0.00	0.05	0.84	29.7%	28.0%	1	0-89	96	0910	2
1B	19	E	48.00	50.50	2.50	0.00	0.00	0.00	0.00	0.00	0.0%	0.0%	1			0950	
1B	20	E	50.50	53.50	3.00	2.97	2.97	0.00	0.53	2.44	99.0%	81.3%	1	0-150		1050	3
													2	150-300			
1B	21	E	53.50	56.50	3.00	3.00	3.00	0.00	0.36	2.64	100.0%	88.0%	1	0-150		1145	
													2	150-300			
1B	22	E	56.50	59.00	2.50	2.90	2.90	0.00	0.48	2.42	116.0%	96.8%	1	1-140		1240	
													2	140-290			
1B	23	E	59.00	61.50	2.50	2.95	2.95	0.00	0.41	2.54	118.0%	101.6%	1	0-145		1315	
													2	145-295			
1B	24	E	61.50	64.00	2.50	3.00	3.00	0.00	0.22	2.78	120.0%	111.2%	1	0-150		1410	
													2	150-300			
1B	25	E	64.00	66.50	2.50	2.85	2.85	0.00	0.30	2.55	114.0%	102.0%	1	0-150		1440	
													2	150-300			
1B	26	E	66.50	69.00	2.50	2.89	2.89	0.00	0.33	2.56	115.6%	102.4%	1	0-139		1529	
													2	139-289			
1B	27	E	69.00	71.50	2.50	2.28	2.98	0.70	0.27	1.31	91.2%	52.4%	1	0-150		1603	
													2	150-298			
1B	28	E	71.50	74.00	2.50	2.67	2.67	0.26	0.15	2.26	106.8%	90.4%	1	0-150		1705	
													2	150-267			
1B	29	E	74.00	76.50	2.50	2.98	2.98	0.00	0.44	2.54	119.2%	101.6%	1	0-150		1743	

Table 3-B1 (cont.).

													2	150-298			
1B	30	E	76.50	79.00	2.50	3.00	3.00	0.00	0.27	2.73	120.0%	109.2%	1	0-150		1829	
													2	150-297			
1B	31	E	79.00	81.50	2.50	2.97	2.97	0.00	0.04	2.93	118.8%	117.2%	1	0-150		1920	4
													2	150-298			
1B	32	E	81.50	84.00	2.50	0.51	0.51	0.00	0.00	0.51	20.4%	20.4%	1	0-51		2011	
1B	33	E	84.00	86.50	2.50	2.98	2.98	0.00	0.21	2.77	119.2%	110.8%	1	0-150		2050	
													2	150-298			
1B	34	E	86.50	89.00	2.50	2.97	2.97	0.00	0.06	2.91	118.8%	116.4%	1	1-150		2136	
													2	150-297			
1B	35	E	89.00	91.50	2.50	2.56	2.56	0.00	0.11	2.45	102.4%	98.0%	1	0-150		2211	
													2	150-256			
1B	36	E	91.50	94.00	2.50	2.97	2.97	0.00	0.23	2.74	118.8%	109.6%	1	0-150		2315	
													2	150-297			
1B	37	E	94.00	96.50	2.50	3.00	3.00	0.00	0.28	2.72	120.0%	108.8%	1	0-150		2355	
													2	150-300			
1B	38	E	96.50	99.00	2.50	2.95	2.95	0.00	0.06	2.89	118.0%	115.6%	1	0-150	97	0031	
													2	150-295			
1B	39	E	99.00	#####	2.50	2.97	2.97	0.00	0.12	2.85	118.8%	114.0%	1	0-150		0125	
													2	150-297			
1B	40	E	#####	#####	2.20	0.49	0.49	0.00	0.00	0.49	22.3%	22.3%	1	N/A		0203	5
1B	41	E	#####	#####	1.50	1.45	1.45	0.00	0.04	1.41	96.7%	94.0%	1	0-145		0249	
1B	42	E	#####	#####	2.30	2.80	2.80	0.00	0.00	2.80	121.7%	121.7%	1	0-150		0325	
													2	150-280			
1B	43	E	#####	#####	0.70	0.62	0.62		0.00	0.62	88.6%	88.6%	1	0-62		0430	
											Site	1C					
											TD=	108.2					
											Recovery Total			101.13 m		0.935 %	
											Recovery Corrected			88.17 m		0.815 %	

1) Live brittle star at top of core
2) Recovered and logged via MSCL 124 cm, but only saved 89 cm;
top part with drilling slurry discarded
3) Started using double core catchers
4) bottom 2.40-2.97 m = soupy texture, likely disturbed
5) No usable recovery; i.e., "back-wash" material

Table 3-D1. Stratigraphic occurrence and relative abundance of diatom taxa in SHALDRIL Holes 1A and 1B.

Cruise	Hole	Core	Section	Top Interval (cm)	Bottom Interval (cm)	Depth (mbsf)	Diatom Abundance	Preservation	Fragmentation	Diatoms - Planktonic	*Actinocyclus actinochilus*	*Amphora* spp.	*Asteromphalus hyalinus/parvulus*	*Asteromphalus hookeri*	*Azpeitia tabularis*	*Chaetoceros bulbosum*	*Chaetoceros* spp. (vegetative cells & resting spores)	*Corethron criophilum* (valves & spines)	*Coscinodiscus* spp. (large)	*Dactyliosolen antarcticus* (girdle bands)	*Eucampia antarctica* var. *antarctica*	*Eucampia antarctica* var. *recta*	*Fragilariopsis angulata*	*Fragilariopsis curta*	*Fragilariopsis cylindrus*	*Fragilariopsis kerguelensis*	*Fragilariopsis obliquecostata*	*Fragilariopsis pseudonana*	*Fragilariopsis ritscheri*	*Fragilariopsis separanda*	*Fragilariopsis sublinearis*	*Fragilariopsis vanheurckii*	*Hyalodiscus* spp.	*Odontella weissflogii*	*Paralia* spp.	*Porosira* spp.	*Proboscia alata*	*Rhizosolenia* spp.	*Stellarima microtrias*	*Synedropsis* spp.	*Thalassionema nitzschioides*	*Thalassiosira antarctica* var. *antarctica*	*Thal. gracilis* var. *gracilis/expecta*	*Thalassiosira lentiginosa*	*Thalassiosira oliverana*	*Thalassiosira tumida*	*Thalassiosira/Detonula* spp.
Hole 1A																																															
NBP0502	1A	1KC	CC	-	-	2.71	C	M	M		R		R				C-A	R	X	R-F		R	F-C	F-C	R	F-C	X		R-F							X		F		R		F-C	R-F	R			R
Hole 1B																																															
NBP0502	1B	1E	1	0	0	0.00	A	G	L-M		R		X	X			C-A	R	X	R		R	F	F	F	F	X		F	R		X						R	R	R		F	F-C	X	X		X
NBP0502	1B	1E	2	195.5	200.5	1.98	C	M	M		X						A	X	X	R-F	X	R	F	F	R	F-C			R	X								R				F	F-C		X		X
NBP0502	1B	2E	1	45.5	50.5	2.98	C	M	M		X		X	X			C		X	R		R	F	F-C	R-F	F			R		X					X		X				F-C	R	R			X
NBP0502	1B	3E	2	198.5	200.5	6.00	C-A	M-G	L-M		X						A			R		R	F		R	F-C	X		R	R						X		R	X	X		F	R	X			
NBP0502	1B	4E	2	200	200	8.50	C-A	M-G	L-M		X		X				A		X		X	R-F	F	F	R	F	X		R	R						X		F-C	X			R-F	F	X			X
NBP0502	1B	5E	2	191	191	11.41	C-A	M	M-L		X	X					A	X		R	X	R-F	F-C		X	F	X		R							R		R		X		F-C	R	R			R
NBP0502	1B	6E	2	200	200	14.50	C-A	M	M-L		R			X			A		R	R		R	R	F-C	R	F-C	X		R	X						R		R	X	R-F		F	F	X			R
NBP0502	1B	7E	2	100	100	16.50	C	M	H		X			X			C-A		X	X	X	R	R	F		F-C	R		X			X						R				F	R	R			R
NBP0502	1B	8E	1	101	101	19.51	C-A	M	L-M		X					X	VA			R		R-F	R-F	F	X	F	X	X	R							X		R	R	X		F-C	R	X			
NBP0502	1B	9E	2	231	251	22.81	C-A	M	M		R			X			C		R	R-F	X	R-F	F-C	F-C	X	F-C	R-F		X		X							X	X	X		F-C	F	R			R-F
NBP0502	1B	10E	2	204	201	25.51	C-A	M	M		X	X		X	X		VA		X	R	R	F-C	F	F-C	R	C			R	X	X		X		X			X	X	R	X	F-C	F	X			R
NBP0502	1B	11E	2	201	201	28.51	C-A	M	M		R		X			X	VA			F	R	F	F	F-C	X	F-C	X		X			X				X		X	X	R		F-C	R-F	R			F
NBP0502	1B	12E	2	204	201	31.51	C-A	M	M						X		A	X	X-R	R	F	R-F	F	F	X	F-C			X	X		R				X		R	X	X		F	F	R	X		R
NBP0502	1B	13E	1	41	41	32.91	A	M-G	M		R		X				A		R	R-F	F	F	R-F	F-C		F-C	X		X							X	X	F-C				F	F	X	X		X
NBP0502	1B	14E	2	190	190	36.98	A	M-G	M		X		X		R		C-A			R	C	R	F-C	F-C	X	F-C			X	X		X						R		X		R-F	F	X			
NBP0502	1B	15E	2	232	232	39.82	C-A	M	M-H		R		X				A		R	R	C	R	F-C	F		F-C	X		X									R-F	X			F	R	R			X
NBP0502	1B	16E	2	204	201	42.01	A	M	M-H				X			X	C-A		R		F	R	F	F	F	F-C	X		R									R	X	R-F		F	R-F	R	X		R
NBP0502	1B	17E	2	6	6	42.56	A	M	M-H		X						A				C	R	F	F-C	R	F-C			X	F-C		X				X		X	R			F-C	F	R	X	X	F
NBP0502	1B	18E	1	30	30	45.38	A	M	M		R						A		R	R	C	R	F	F-C	R	F	R		X	X	X	R				X		F-C	X	X	?	F-C	R	X			F
NBP0502	1B	20E	1	140	140	51.98	A	P-M	H		R				X		C			R	F	R	F	F		F-C	A		R		X				X	X			X			C	F	R	X		F
NBP0502	1B	21E	CC	-	-	56.58	A	M-G	M		X		X	X		X	VA		X	X	R	F-C	F	F-C		F-C			X			F-C				X		X	R	X		F		X		X	
NBP0502	1B	22E	CC	-	-	59.48	F-C	P	H		X			X			F		X	R	R	F	F	F	X	F			X			R			X			F		X		F-C	F	R			X
NBP0502	1B	24E	CC	-	-	64.08	A	G	L-M		R						A			F	R	R	F	F	R	F-C	X		X		X	F				X		C-A	X			F		R-F		X	X
NBP0502	1B	25E	CC	-	-	67.08	C	M	H		X						C	X	R		R	R-F	R	F	X	F			R							X		R		R		F	R	R		X	X
NBP0502	1B	26E	CC	-	-	69.38	C	M	H		R						C		X	R	R	R-F	R-F	F	X	F			X		X	R						F		R-F		F		X		X	X
NBP0502	1B	27E	CC	-	-	71.98	C-A	M	M-H		X						F-C	X	X	R-F	X	R	F	F	R	F	R		X			F			X	X	X	X		F		F-C					X
NBP0502	1B	28E	CC	-	-	74.17	C	P-M	H		X	X					C			R	R	X		F	R	F			X									X		R		F	X			X	X
NBP0502	1B	30E	CC	-	-	79.47	C	P-M	H		X						F			R	R	R		X	X	F					X	F			X		X	X	X	R		F	X	X		X	F
NBP0502	1B	31E	CC	-	-	81.58	F	P	H								F		X	X		X	X	F	X	F	X								R			R		X	X	R	X				X
NBP0502	1B	32E	1	28	28	81.78	C	M	H		X						C		X	R	F	F		F	X	F			X	R		F				X		R		F		F	R				X
NBP0502	1B	33E	CC	-	-	86.98	A	M	M		X						A		R		R-F	R-F		F-C		F	X		R			F		X	X			F	X	R	X	F	R				X
NBP0502	1B	34E	CC	-	-	88.47	A	M	H		X						C		X		F	X		F		X				X							X	F		F		F					X
NBP0502	1B	35E	CC	-	-	91.58	A	M	M-H		R						F		X		X	R	X	F	R	R-F			X			F			X		R	R		F		F		X			X
NBP0502	1B	37E	2	280	280	96.98	C-A	P-M	H		X						C	X			X	R		F	F	F											X	R	X		X	F	R	X		X	X
NBP0502	1B	38E	CC	-	-	99.45	C	P-M	H		X					X	C		X	X	R	F	R	R		R	R		R						X		X	R		F	X	F	X	X			
NBP0502	1B	39E	CC	-	-	101.97	F-C	P	H		X						F-C		X	X	X	R	X	F	X							F						X		R	X	F	R	X			X
NBP0502	1B	41E	1	92	92	104.62	C-A	M	M		X					X	A		X		X	R	X	F-C	X		R		F			F-C				X		X		F		F					X
NBP0502	1B	41E	CC	-	-	105.15	A	M	M-H		X	X					A		X		X	R	X	F-C	R	R-F	R					F		X	X	X	X	R	X	R-F		C					X
NBP0502	1B	42E	CC	-	-	108.00	F-C	P	H		R-F						F		X			R	X	F	F	F			R			F						X	X			F	R				X
NBP0502	1B	43E	CC	-	-	108.12	F	P	H		R						F		X			R	X	F	X	R			X			F				X			X	X		F	R				X

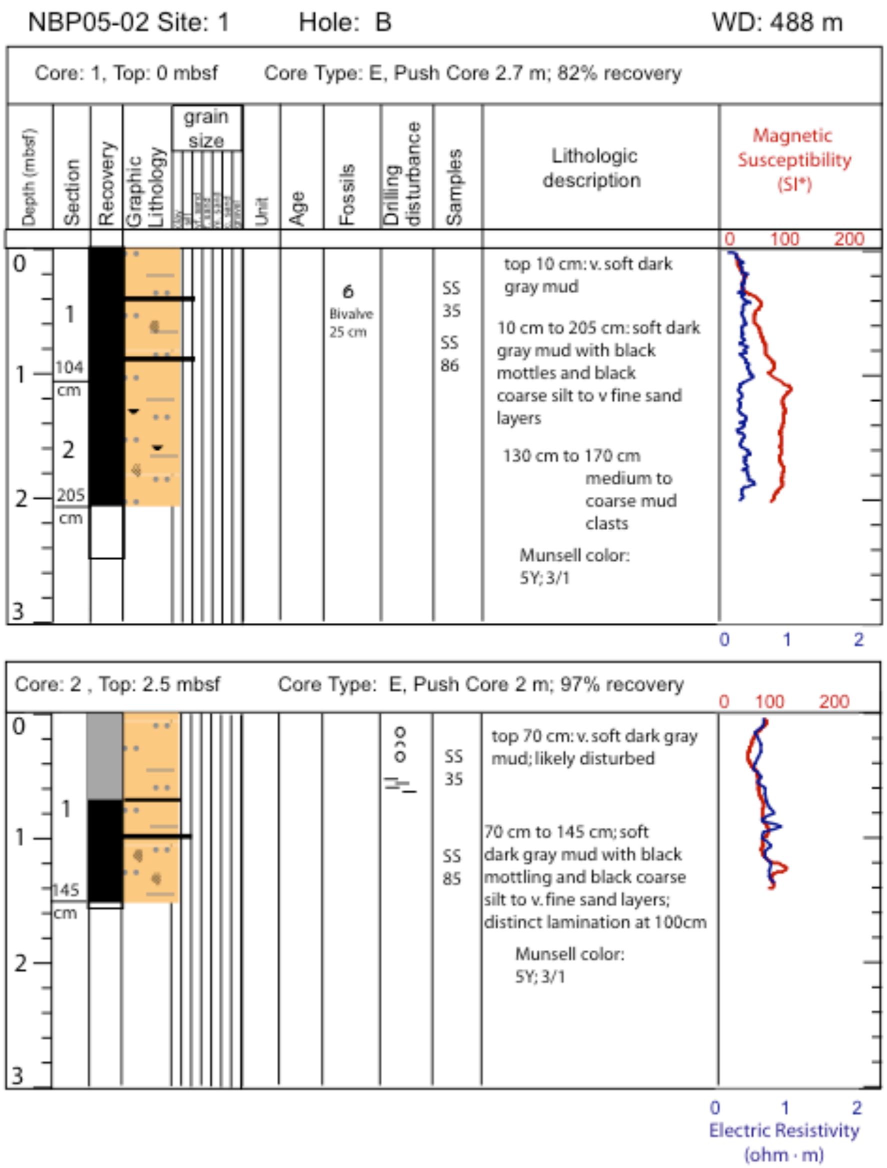
Table 3-D2. *Eucampia antarctica* counts from SHALDRIL Hole 1B.

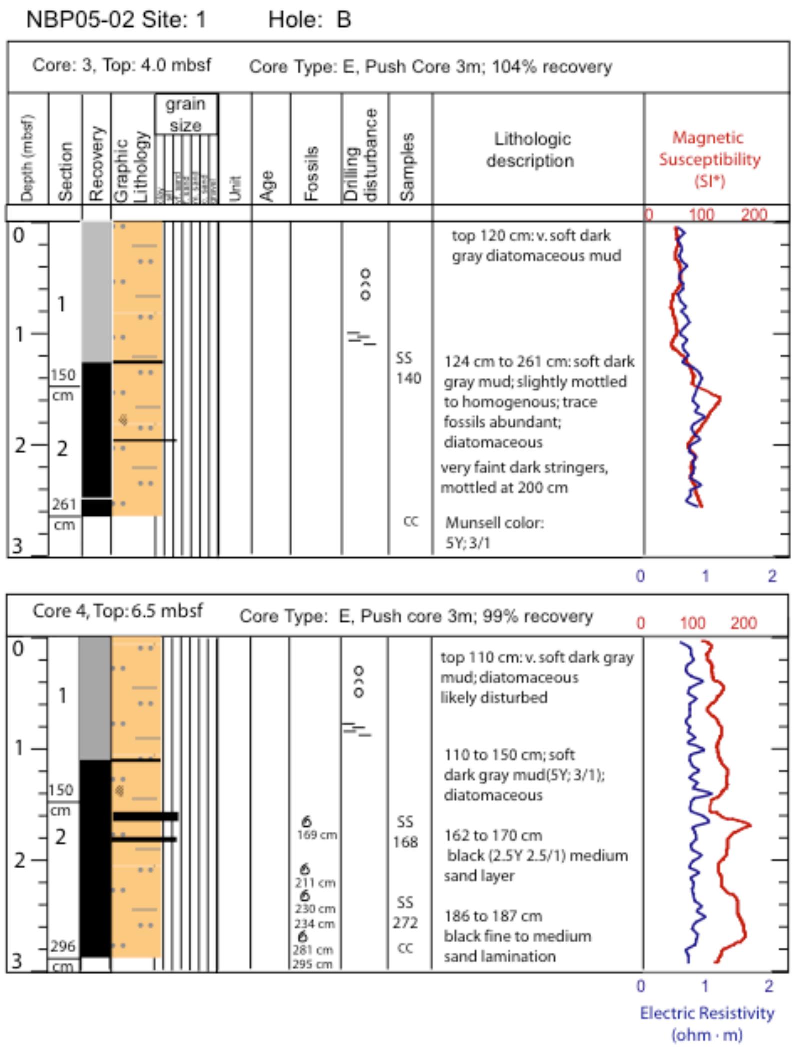
Cruise	Hole	Core	Section	Top Interval (cm)	Bottom Interval (cm)	Depth (mbsf)	Preparation(s)	*Eucampia antarctica* var. *recta* (intercalary)	*Eucampia antarctica* var. *antarctica* (intercala	*Eucampia antarctica* (terminal)	Total	Terminal/Intercalary	Symmetric Intercalary/Asymmetric Intercalary
NBP0502	1B	1E	2	195.5	200.5	1.98	smear	34	1	15	50	0.43	34.0
NBP0502	1B	4E	2	200	200	8.50	smear	32	1	17	50	0.52	32.0
NBP0502	1B	5E	2	191	191	11.41	smear	31	1	18	50	0.56	31.0
NBP0502	1B	7E	2	100	100	16.50	smear	34	2	12	48	0.33	17.0
NBP0502	1B	9E	2	231	231	22.81	smear	39	1	10	50	0.25	39.0
NBP0502	1B	10E	2	201	201	25.51	smear	44	7	9	60	0.18	6.3
NBP0502	1B	11E	2	201	201	28.51	smear	79	11	10	100	0.11	7.2
NBP0502	1B	12E	2	201	201	31.51	smear	11	84	5	100	0.05	0.1
NBP0502	1B	13E	1	41	41	32.91	smear	23	55	22	100	0.28	0.4
NBP0502	1B	14E	2	190	190	36.90	smear	6	94	0	100	0.00	0.1
NBP0502	1B	15E	2	232	232	39.82	smear	11	85	4	100	0.04	0.1
NBP0502	1B	16E	2	201	201	42.01	smear	10	78	12	100	0.14	0.1
NBP0502	1B	17E	2	6	6	42.56	smear	11	84	5	100	0.05	0.1
NBP0502	1B	18E	1	30	30	45.30	smear	20	76	4	100	0.04	0.3
NBP0502	1B	20E	1	140	140	51.90	smear	14	34	2	50	0.04	0.4
NBP0502	1B	21E	CC	-	-	56.50	smear	4	95	1	100	0.01	0.0
NBP0502	1B	22E	CC	-	-	59.40	smear	20	8	22	50	0.79	2.5
NBP0502	1B	24E	CC	-	-	64.00	smear	12	37	1	50	0.02	0.3
NBP0502	1B	25E	CC	-	-	67.00	smear	26	16	8	50	0.19	1.6
NBP0502	1B	26E	CC	-	-	69.39	smear	25	22	3	50	0.06	1.1
NBP0502	1B	29E	2	201	201	76.01	smear	62	5	33	100	0.49	12.4
NBP0502	1B	32E	1	28	28	81.78	smear	28	21	1	50	0.02	1.3
NBP0502	1B	33E	CC	-	-	86.98	smear	22	25	3	50	0.06	0.9
NBP0502	1B	34E	CC	-	-	88.47	smear	32	15	3	50	0.06	2.1
NBP0502	1B	36E	2	154	154	93.04	smear, >10	37	1	12	50	0.32	37.0
NBP0502	1B	38E	CC	-	-	99.45	smear	37	12	1	50	0.02	3.1
NBP0502	1B	41E	1	92	92	104.62	smear	22	1	8	31	0.35	22.0
NBP0502	1B	41E	CC	-	-	105.15	smear	36	2	12	50	0.32	18.0

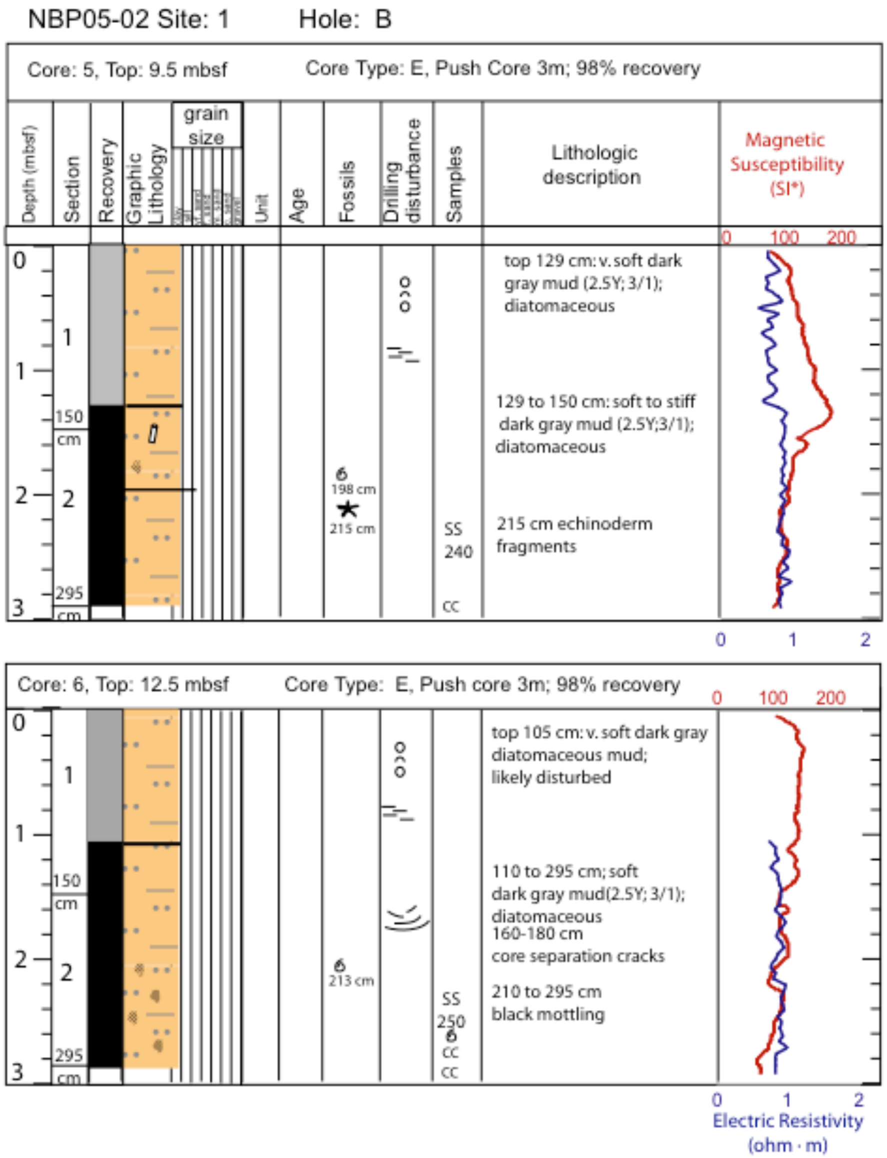
Table 3-D3. *Thoracosphaera* occurence in SHALDRIL Hole 1B. Values represent number of specimens observed, and dashes indicate examined samples in which no *Thoracosphaera* were found.

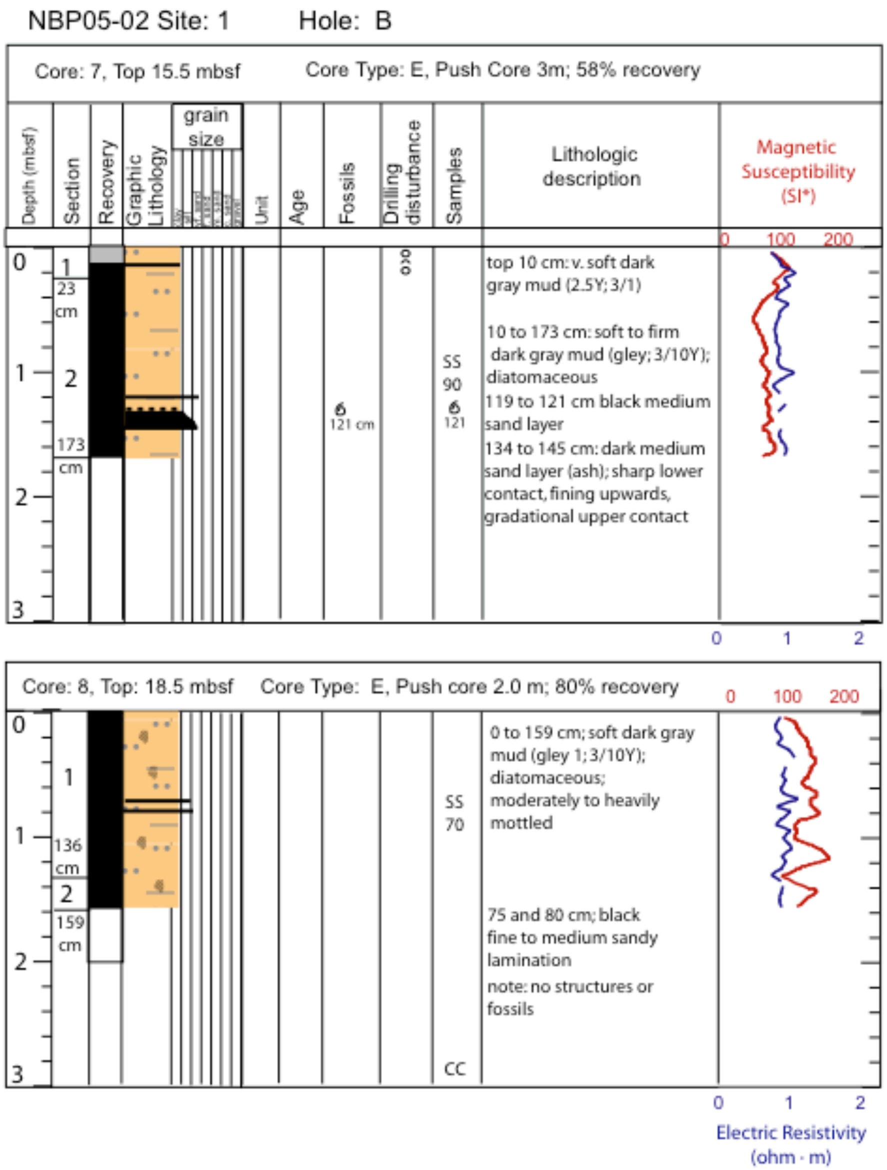
Cruise	Hole	Core	Section	Top Interval (cm)	Bottom Interval (cm)	Depth (mbsf)	*Thoracosphaera* sp.	*Thoracosphaera* sp. cf. *T. heimii*
NBP0502	1B	1E	1	0	0	0.00	-	-
NBP0502	1B	1E	2	195.5	200.5	1.98	-	-
NBP0502	1B	2E	1	295.5	300	4.47	-	-
NBP0502	1B	3E	1	140	140	5.40	-	-
NBP0502	1B	3E	2	199.5	200.5	6.00	-	-
NBP0502	1B	4E	1	2	3	6.53	-	-
NBP0502	1B	4E	2	291	291	9.41	1	-
NBP0502	1B	5E	2	191	191	11.41	2	-
NBP0502	1B	7E	2	100	100	16.50	-	-
NBP0502	1B	9E	2	231	231	22.81	-	-
NBP0502	1B	10E	2	101	101	24.51	-	1
NBP0502	1B	10E	2	201	201	25.51	-	-
NBP0502	1B	11E	2	201	201	28.51	-	-
NBP0502	1B	12E	2	201	201	31.51	-	-
NBP0502	1B	13E	1	41	41	32.91	-	-
NBP0502	1B	14E	2	190	190	36.90	1	1
NBP0502	1B	15E	2	232	232	39.82	2	-
NBP0502	1B	16E	2	201	201	42.01	1	1
NBP0502	1B	17E	2	6	6	42.56	3	-
NBP0502	1B	17E	CC	-	-	45.26	-	4
NBP0502	1B	18E	1	30	30	45.30	1	-
NBP0502	1B	18E	CC	-	-	45.89	-	1
NBP0502	1B	20E	1	140	140	51.90	-	-
NBP0502	1B	20E	CC	-	-	53.47	-	1
NBP0502	1B	21E	CC	-	-	56.50	-	-
NBP0502	1B	22E	CC	-	-	59.40	-	-
NBP0502	1B	24E	CC	-	-	64.00	-	-
NBP0502	1B	25E	CC	-	-	67.00	-	-
NBP0502	1B	26E	CC	-	-	69.39	-	-
NBP0502	1B	28E	CC	-	-	74.17	-	-
NBP0502	1B	30E	CC	-	-	79.47	-	1
NBP0502	1B	31E	CC	-	-	81.50	-	-
NBP0502	1B	32E	1	28	28	81.78	-	-
NBP0502	1B	33E	CC	-	-	86.98	1	-
NBP0502	1B	35E	CC	-	-	91.56	-	-
NBP0502	1B	38E	CC	-	-	99.45	-	-
NBP0502	1B	39E	CC	-	-	101.97	-	-
NBP0502	1B	41E	CC	-	-	105.15	-	-
NBP0502	1B	42E	CC	-	-	108.00	1	-
NBP0502	1B	43E	CC	-	-	108.12	-	-

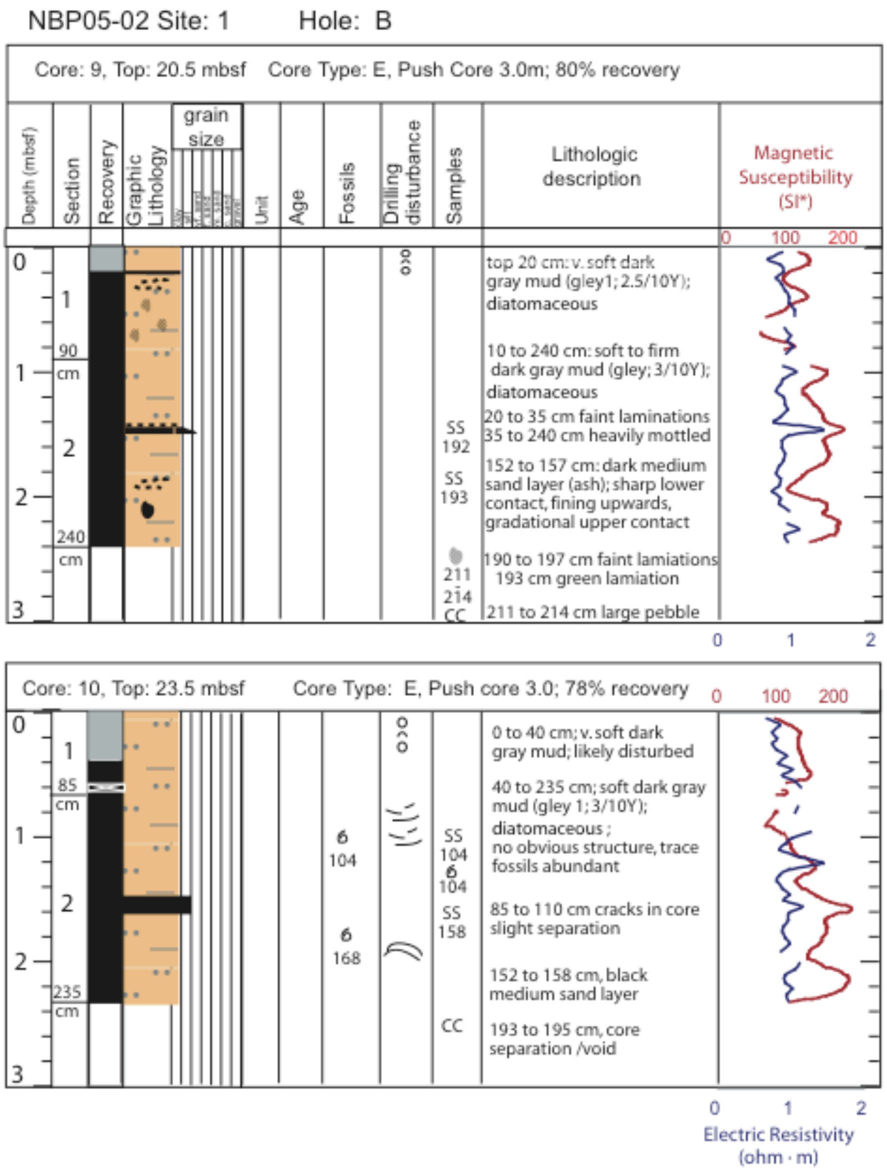
APPENDIX 3-H2. LITHOLOGIC LOGS

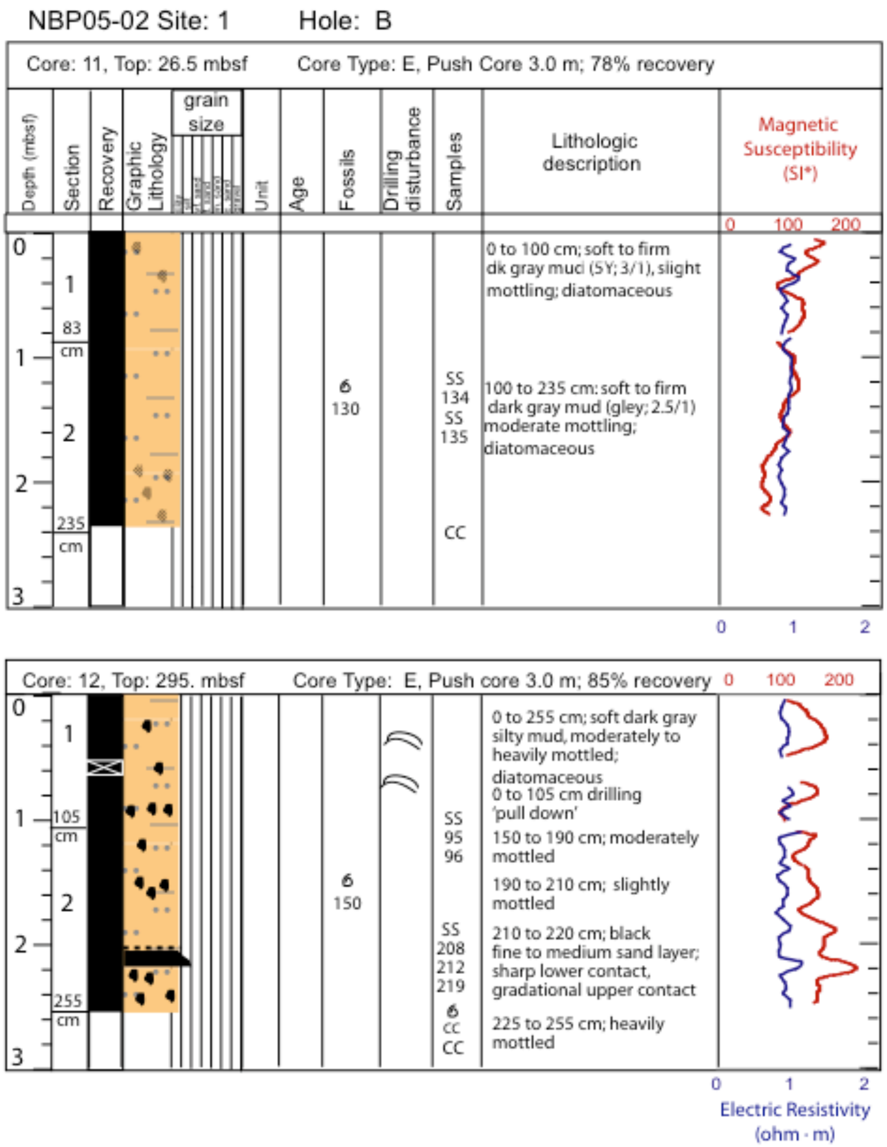


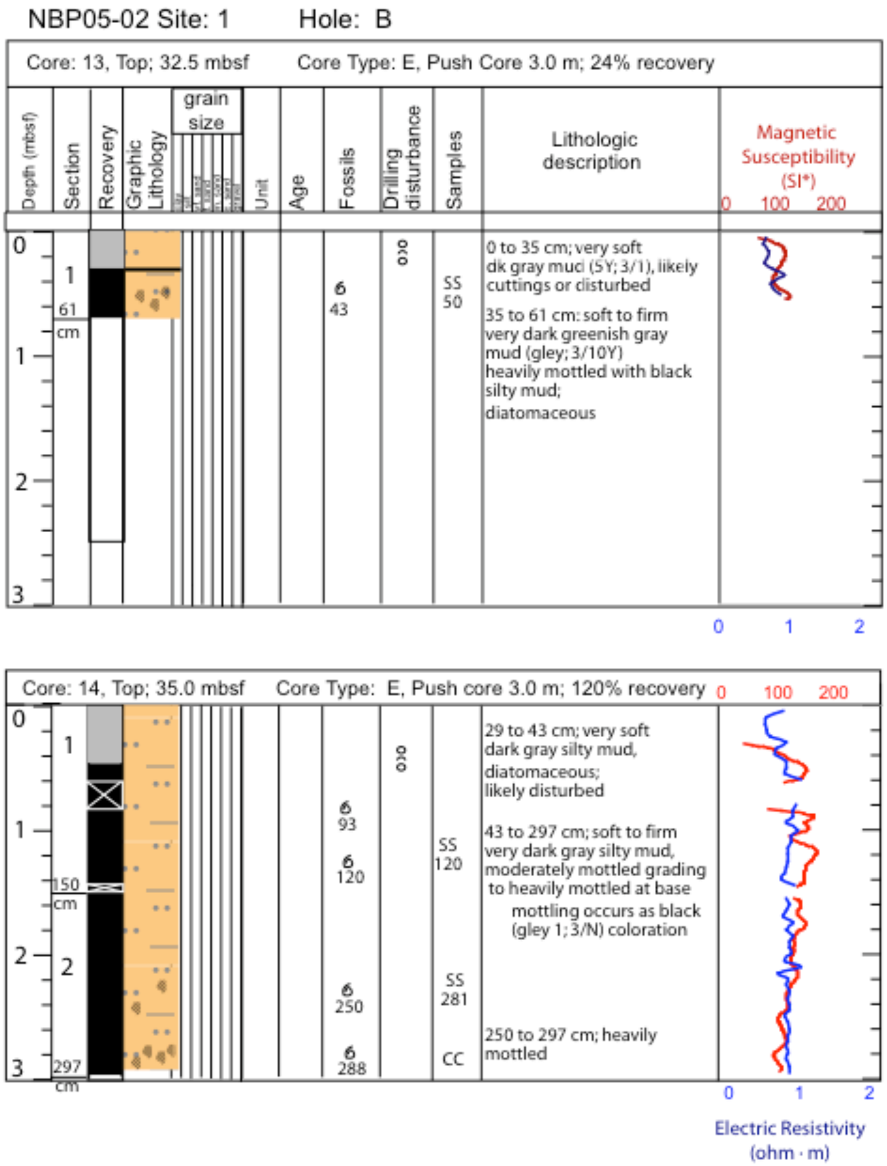

NBP05-02 Site: 1 Hole: B
Core: 3, Top: 4.0 mbsf
Core Type: E, Push Core 3m; 104% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
top 120 cm: v. soft dark gray diatomaceous mud
124 cm to 261 cm: soft dark gray mud; slightly mottled to homogenous; trace fossils abundant; diatomaceous
very faint dark stringers, mottled at 200 cm
Munsell color: 5Y; 3/1
SS 140
CC
150 cm
261 cm
0 1 2
Core 4, Top: 6.5 mbsf
Core Type: E, Push core 3m; 99% recovery
0 100 200
top 110 cm: v. soft dark gray mud; diatomaceous likely disturbed
110 to 150 cm; soft dark gray mud(5Y; 3/1); diatomaceous
162 to 170 cm black (2.5Y 2.5/1) medium sand layer
186 to 187 cm black fine to medium sand lamination
169 cm
211 cm
230 cm
234 cm
281 cm
295 cm
SS 168
SS 272
CC
150 cm
296 cm
0 1 2
Electric Resistivity (ohm · m)

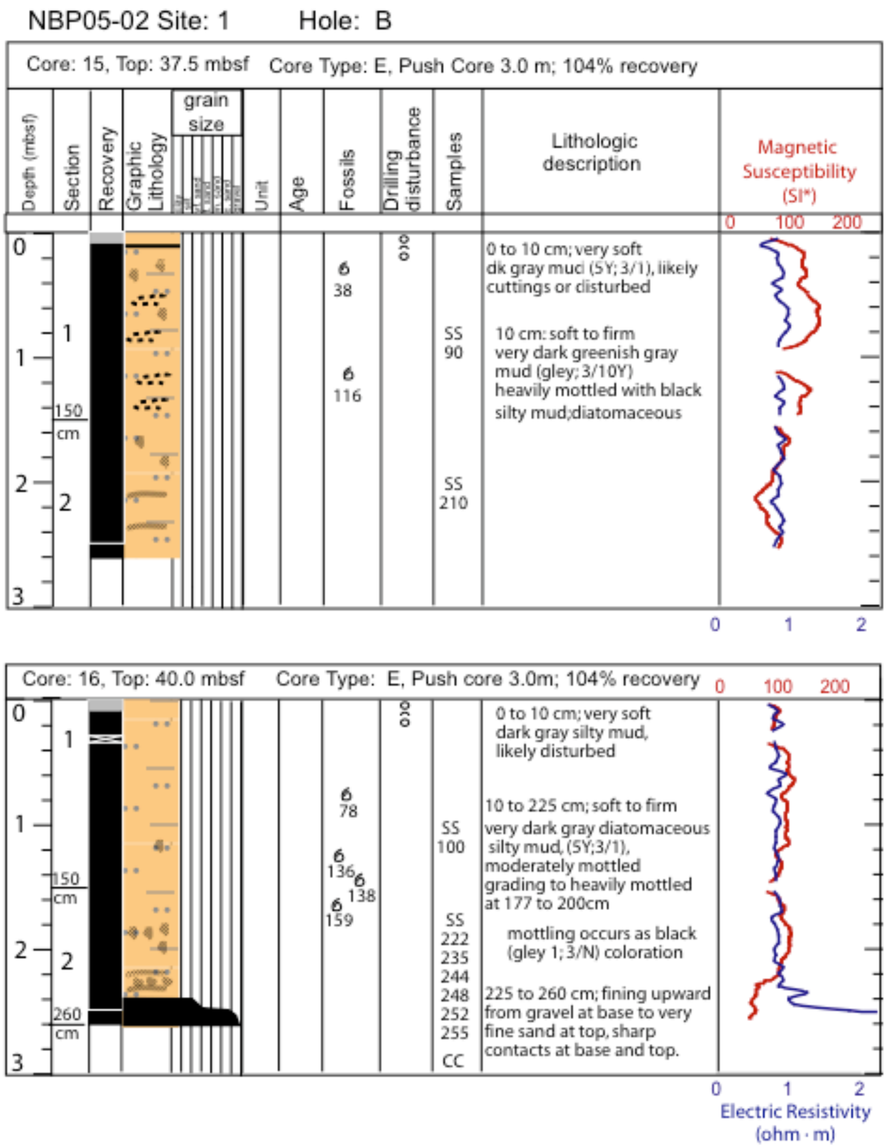

NBP05-02 Site: 1 Hole: B
Core: 5, Top: 9.5 mbsf
Core Type: E, Push Core 3m; 98% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
top 129 cm: v. soft dark gray mud (2.5Y; 3/1); diatomaceous
129 to 150 cm: soft to stiff dark gray mud (2.5Y;3/1); diatomaceous
215 cm echinoderm fragments
198 cm
215 cm
SS 240
CC
150 cm
295 cm
Core: 6, Top: 12.5 mbsf
Core Type: E, Push core 3m; 98% recovery
top 105 cm: v. soft dark gray diatomaceous mud; likely disturbed
110 to 295 cm; soft dark gray mud(2.5Y; 3/1); diatomaceous
160-180 cm core separation cracks
210 to 295 cm black mottling
213 cm
SS 250
CC
CC
Electric Resistivity (ohm · m)

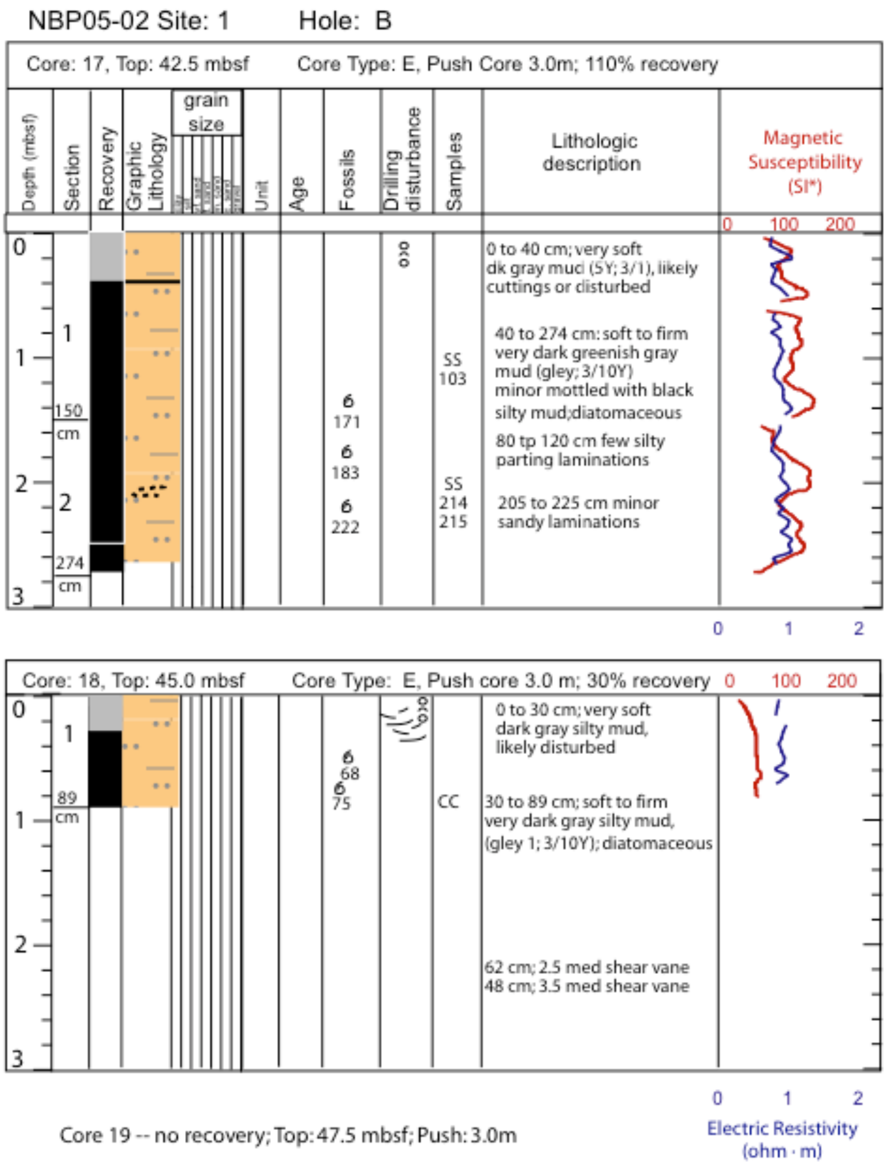

NBP05-02 Site: 1 Hole: B
Core: 7, Top 15.5 mbsf
Core Type: E, Push Core 3m; 58% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
top 10 cm: v. soft dark gray mud (2.5Y; 3/1)
10 to 173 cm: soft to firm dark gray mud (gley; 3/10Y); diatomaceous
119 to 121 cm black medium sand layer
134 to 145 cm: dark medium sand layer (ash); sharp lower contact, fining upwards, gradational upper contact
23 cm
173 cm
121 cm
SS 90
121
Core: 8, Top: 18.5 mbsf
Core Type: E, Push core 2.0 m; 80% recovery
0 to 159 cm; soft dark gray mud (gley 1; 3/10Y); diatomaceous; moderately to heavily mottled
75 and 80 cm; black fine to medium sandy lamination
note: no structures or fossils
136 cm
159 cm
SS 70
CC
Electric Resistivity (ohm · m)

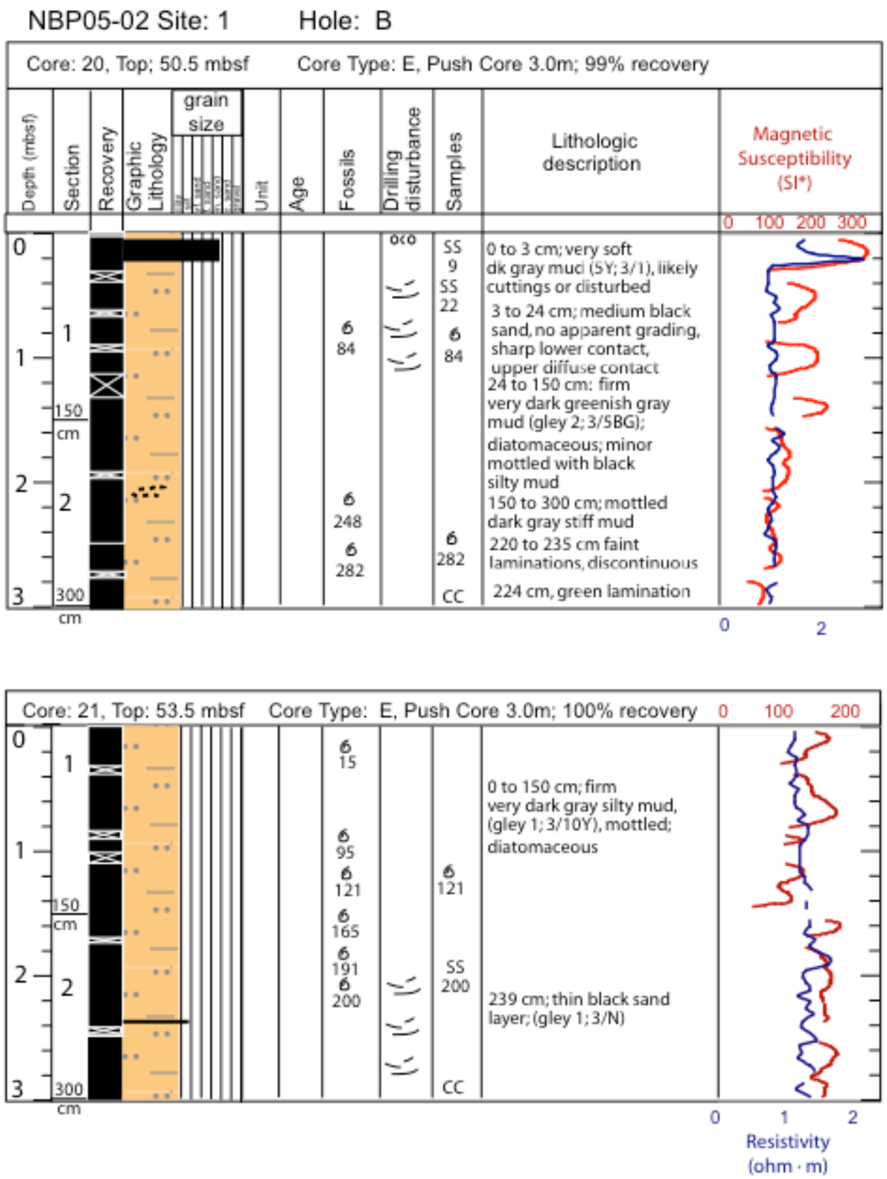

NBP05-02 Site: 1 Hole: B
Core: 9, Top: 20.5 mbsf Core Type: E, Push Core 3.0m; 80% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
top 20 cm: v. soft dark gray mud (gley1; 2.5/10Y); diatomaceous
10 to 240 cm: soft to firm dark gray mud (gley; 3/10Y); diatomaceous
20 to 35 cm faint laminations
35 to 240 cm heavily mottled
152 to 157 cm: dark medium sand layer (ash); sharp lower contact, fining upwards, gradational upper contact
190 to 197 cm faint lamiations
193 cm green lamiation
211 to 214 cm large pebble
SS 192
SS 193
211
214
CC
90 cm
240 cm
0 1 2
Core: 10, Top: 23.5 mbsf Core Type: E, Push core 3.0; 78% recovery
0 100 200
0 to 40 cm; v. soft dark gray mud; likely disturbed
40 to 235 cm; soft dark gray mud (gley 1; 3/10Y); diatomaceous; no obvious structure, trace fossils abundant
85 to 110 cm cracks in core slight separation
152 to 158 cm, black medium sand layer
193 to 195 cm, core separation /void
SS 104
104
SS 158
CC
104
168
85 cm
235 cm
0 1 2
Electric Resistivity (ohm · m)

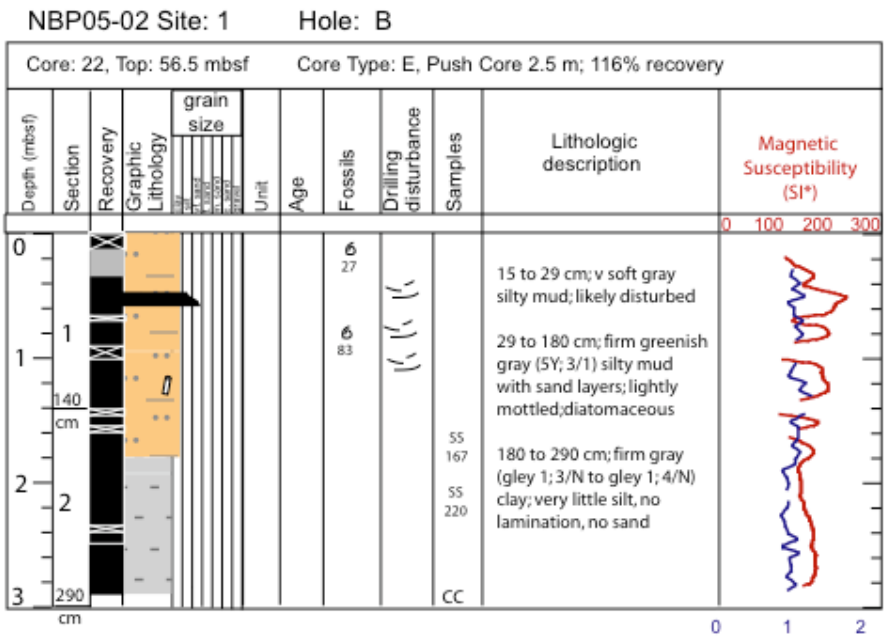

NBP05-02 Site: 1 Hole: B
Core: 11, Top: 26.5 mbsf
Core Type: E, Push Core 3.0 m; 78% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
83 cm
235 cm
130
SS 134 SS 135
CC
0 to 100 cm; soft to firm dk gray mud (5Y; 3/1), slight mottling; diatomaceous
100 to 235 cm: soft to firm dark gray mud (gley; 2.5/1) moderate mottling; diatomaceous
0 1 2
Core: 12, Top: 295. mbsf
Core Type: E, Push core 3.0 m; 85% recovery
105 cm
255 cm
150
SS 95 96
SS 208 212 219
CC
CC
0 to 255 cm; soft dark gray silty mud, moderately to heavily mottled;
diatomaceous
0 to 105 cm drilling 'pull down'
150 to 190 cm; moderately mottled
190 to 210 cm; slightly mottled
210 to 220 cm; black fine to medium sand layer; sharp lower contact, gradational upper contact
225 to 255 cm; heavily mottled
Electric Resistivity (ohm · m)

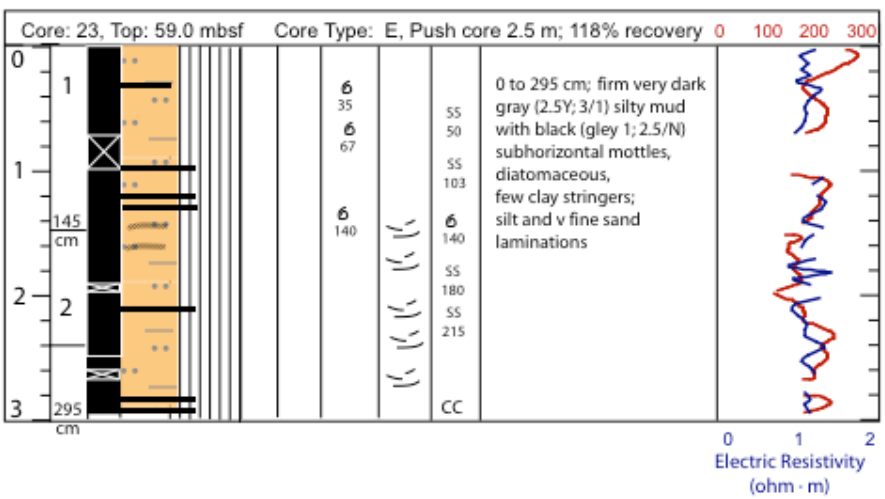

NBP05-02 Site: 1 Hole: B
Core: 13, Top; 32.5 mbsf Core Type: E, Push Core 3.0 m; 24% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
61 cm
SS 50
43
0 to 35 cm; very soft dk gray mud (5Y; 3/1), likely cuttings or disturbed
35 to 61 cm: soft to firm very dark greenish gray mud (gley; 3/10Y) heavily mottled with black silty mud; diatomaceous
Core: 14, Top; 35.0 mbsf Core Type: E, Push core 3.0 m; 120% recovery
150 cm
297 cm
93
120
250
288
SS 120
SS 281
CC
29 to 43 cm; very soft dark gray silty mud, diatomaceous; likely disturbed
43 to 297 cm; soft to firm very dark gray silty mud, moderately mottled grading to heavily mottled at base
mottling occurs as black (gley 1; 3/N) coloration
250 to 297 cm; heavily mottled
Electric Resistivity (ohm · m)
0 1 2

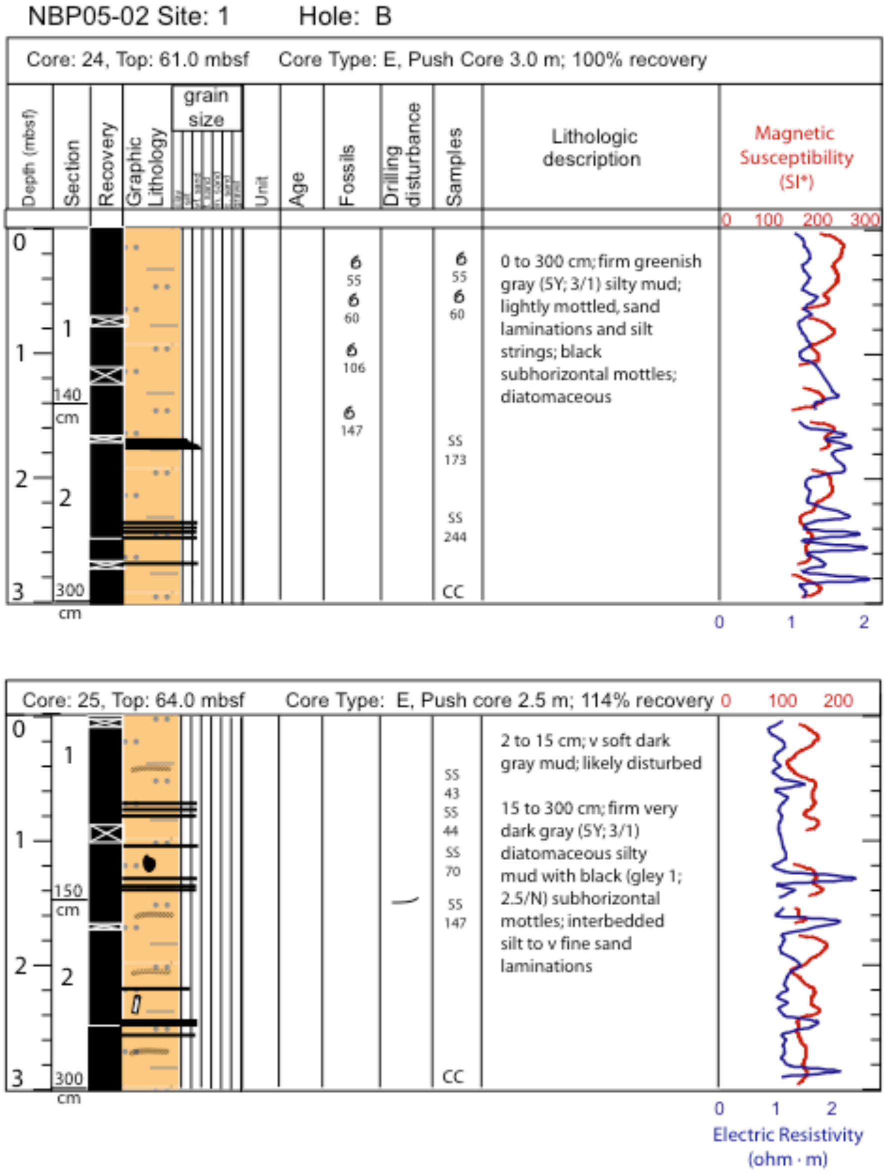

NBP05-02 Site: 1 Hole: B
Core: 15, Top: 37.5 mbsf Core Type: E, Push Core 3.0 m; 104% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0 to 10 cm; very soft dk gray mud (5Y; 3/1), likely cuttings or disturbed
10 cm: soft to firm very dark greenish gray mud (gley; 3/10Y) heavily mottled with black silty mud;diatomaceous
38
116
SS 90
SS 210
150 cm
0 1 2
Core: 16, Top: 40.0 mbsf Core Type: E, Push core 3.0m; 104% recovery
0 100 200
0 to 10 cm; very soft dark gray silty mud, likely disturbed
10 to 225 cm; soft to firm very dark gray diatomaceous silty mud, (5Y;3/1), moderately mottled grading to heavily mottled at 177 to 200cm
mottling occurs as black (gley 1; 3/N) coloration
225 to 260 cm; fining upward from gravel at base to very fine sand at top, sharp contacts at base and top.
78
136
138
159
SS 100
SS 222 235 244 248 252 255
CC
150 cm
260 cm
0 1 2
Electric Resistivity (ohm · m)

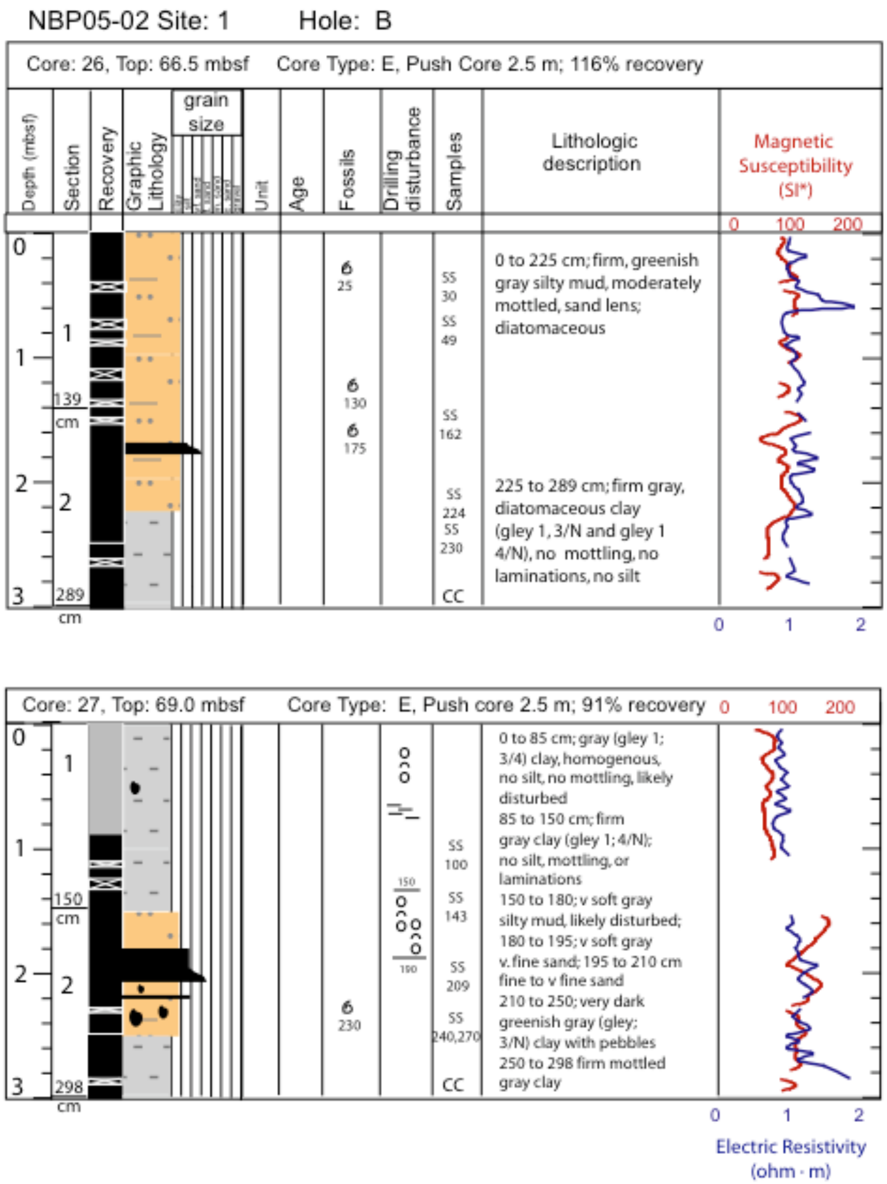

NBP05-02 Site: 1 Hole: B
Core: 17, Top: 42.5 mbsf Core Type: E, Push Core 3.0m; 110% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0 to 40 cm; very soft dk gray mud (5Y; 3/1), likely cuttings or disturbed
40 to 274 cm: soft to firm very dark greenish gray mud (gley; 3/10Y) minor mottled with black silty mud; diatomaceous
80 tp 120 cm few silty parting laminations
205 to 225 cm minor sandy laminations
SS 103
SS 214 215
171
183
222
150 cm
274 cm
Core: 18, Top: 45.0 mbsf Core Type: E, Push core 3.0 m; 30% recovery
0 to 30 cm; very soft dark gray silty mud, likely disturbed
30 to 89 cm; soft to firm very dark gray silty mud, (gley 1; 3/10Y); diatomaceous
62 cm; 2.5 med shear vane
48 cm; 3.5 med shear vane
68
75
CC
89 cm
Core 19 -- no recovery; Top: 47.5 mbsf; Push: 3.0m
Electric Resistivity (ohm · m)
0 1 2

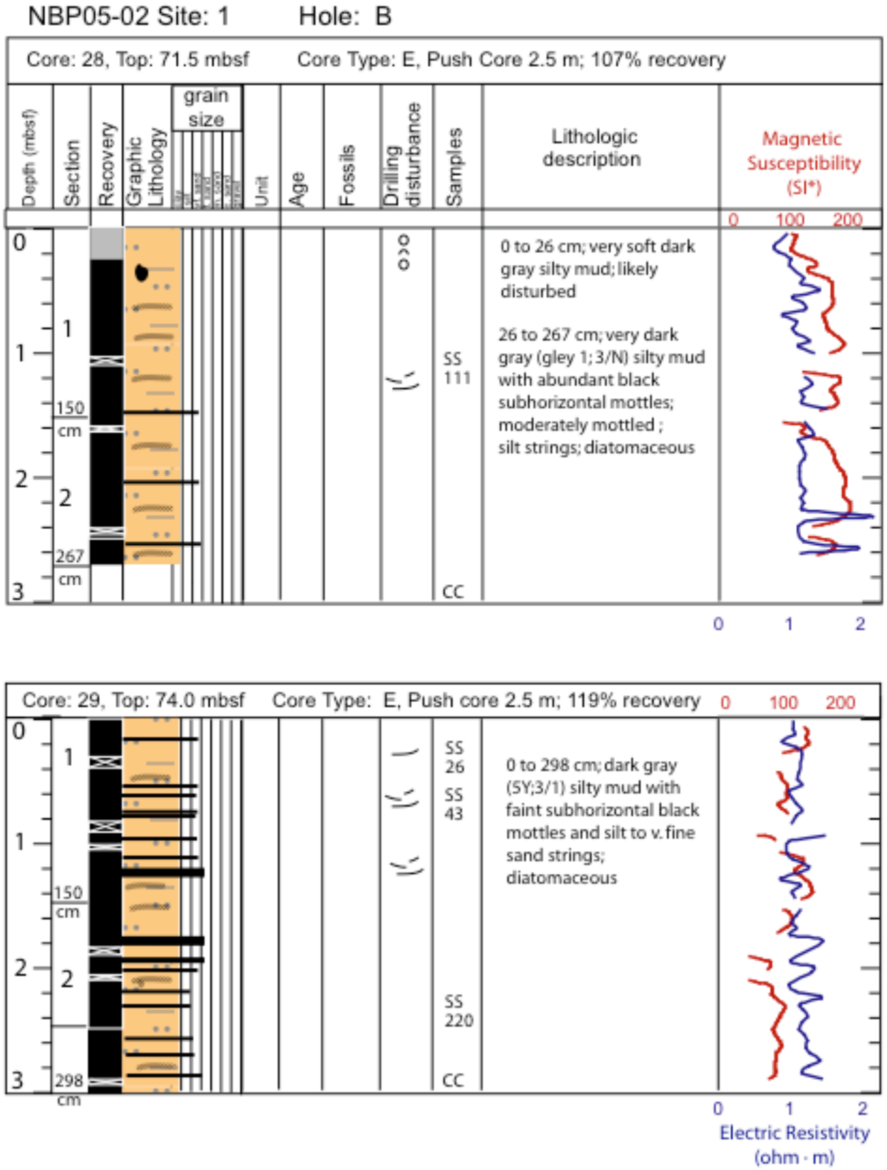

NBP05-02 Site: 1 Hole: B
Core: 20, Top; 50.5 mbsf
Core Type: E, Push Core 3.0m; 99% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200 300
0 to 3 cm; very soft dk gray mud (5Y; 3/1), likely cuttings or disturbed
3 to 24 cm; medium black sand, no apparent grading, sharp lower contact, upper diffuse contact
24 to 150 cm: firm very dark greenish gray mud (gley 2; 3/5BG); diatomaceous; minor mottled with black silty mud
150 to 300 cm; mottled dark gray stiff mud
220 to 235 cm faint laminations, discontinuous
224 cm, green lamination
SS 9
SS 22
84
248
282
CC
150 cm
300 cm
Core: 21, Top: 53.5 mbsf
Core Type: E, Push Core 3.0m; 100% recovery
0 100 200
0 to 150 cm; firm very dark gray silty mud, (gley 1; 3/10Y), mottled; diatomaceous
239 cm; thin black sand layer; (gley 1; 3/N)
15
95
121
165
191
200
SS 200
CC
Resistivity (ohm · m)
0 1 2

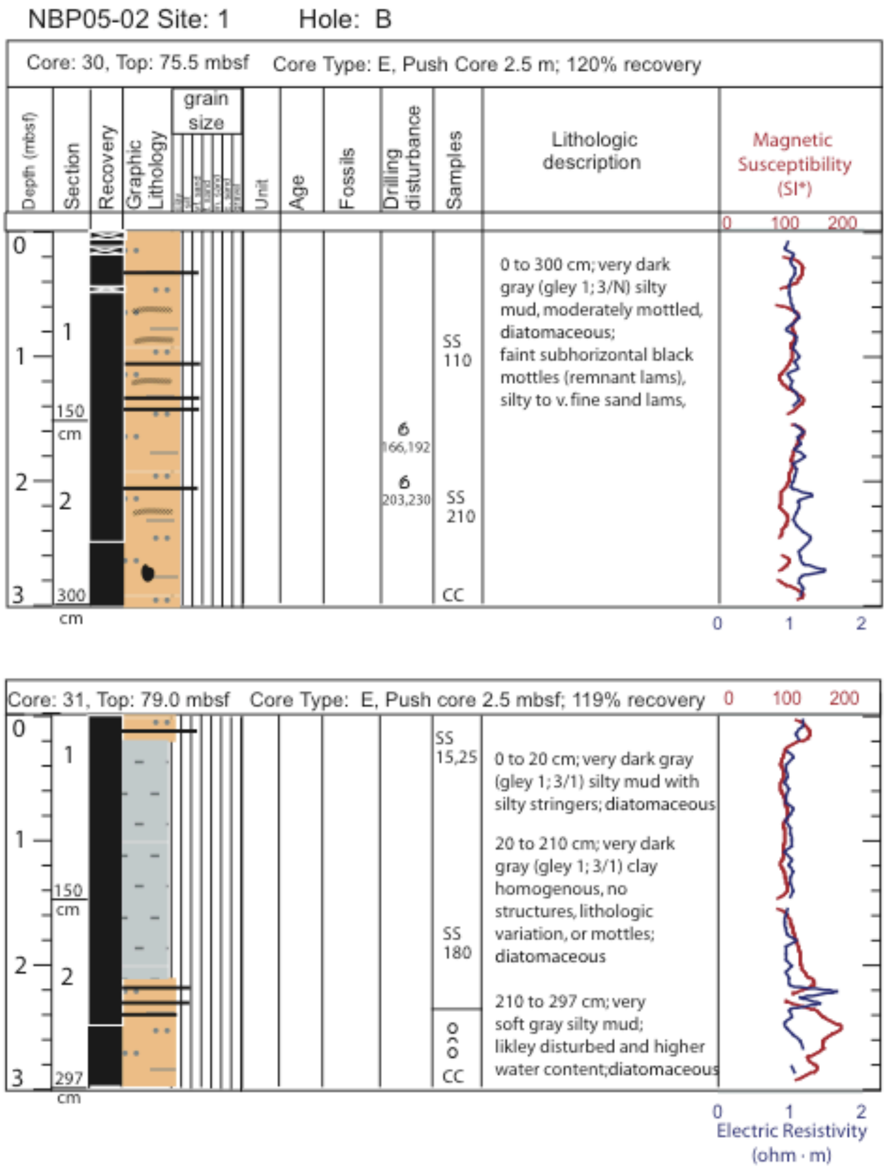

NBP05-02 Site: 1 Hole: B
Core: 22, Top: 56.5 mbsf Core Type: E, Push Core 2.5 m; 116% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200 300
15 to 29 cm; v soft gray silty mud; likely disturbed
29 to 180 cm; firm greenish gray (5Y; 3/1) silty mud with sand layers; lightly mottled;diatomaceous
180 to 290 cm; firm gray (gley 1; 3/N to gley 1; 4/N) clay; very little silt, no lamination, no sand
140 cm
290 cm
SS 167
SS 220
CC
0 1 2

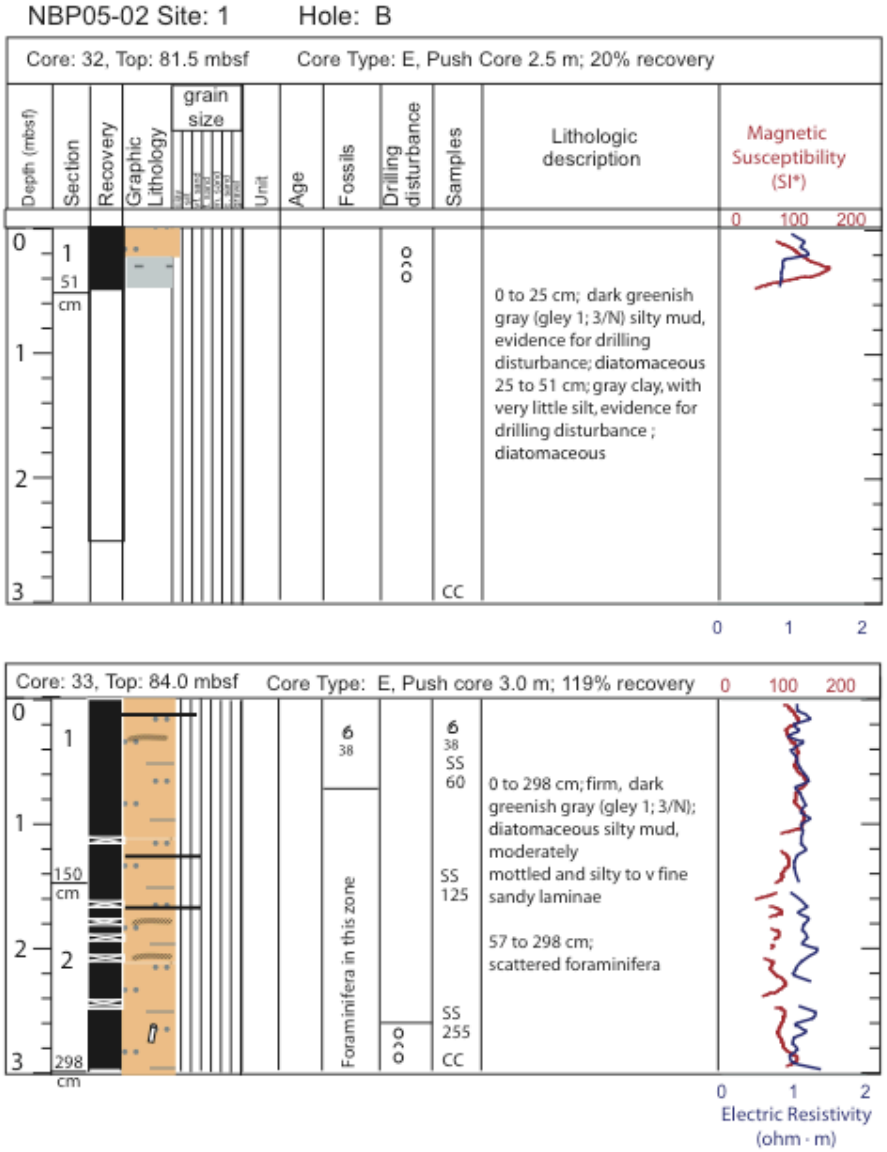

Core: 23, Top: 59.0 mbsf Core Type: E, Push core 2.5 m; 118% recovery
0 100 200 300
0 to 295 cm; firm very dark gray (2.5Y; 3/1) silty mud with black (gley 1; 2.5/N) subhorizontal mottles, diatomaceous, few clay stringers; silt and v fine sand laminations
145 cm
295 cm
SS 50
SS 103
SS 180
SS 215
CC
0 1 2
Electric Resistivity (ohm · m)

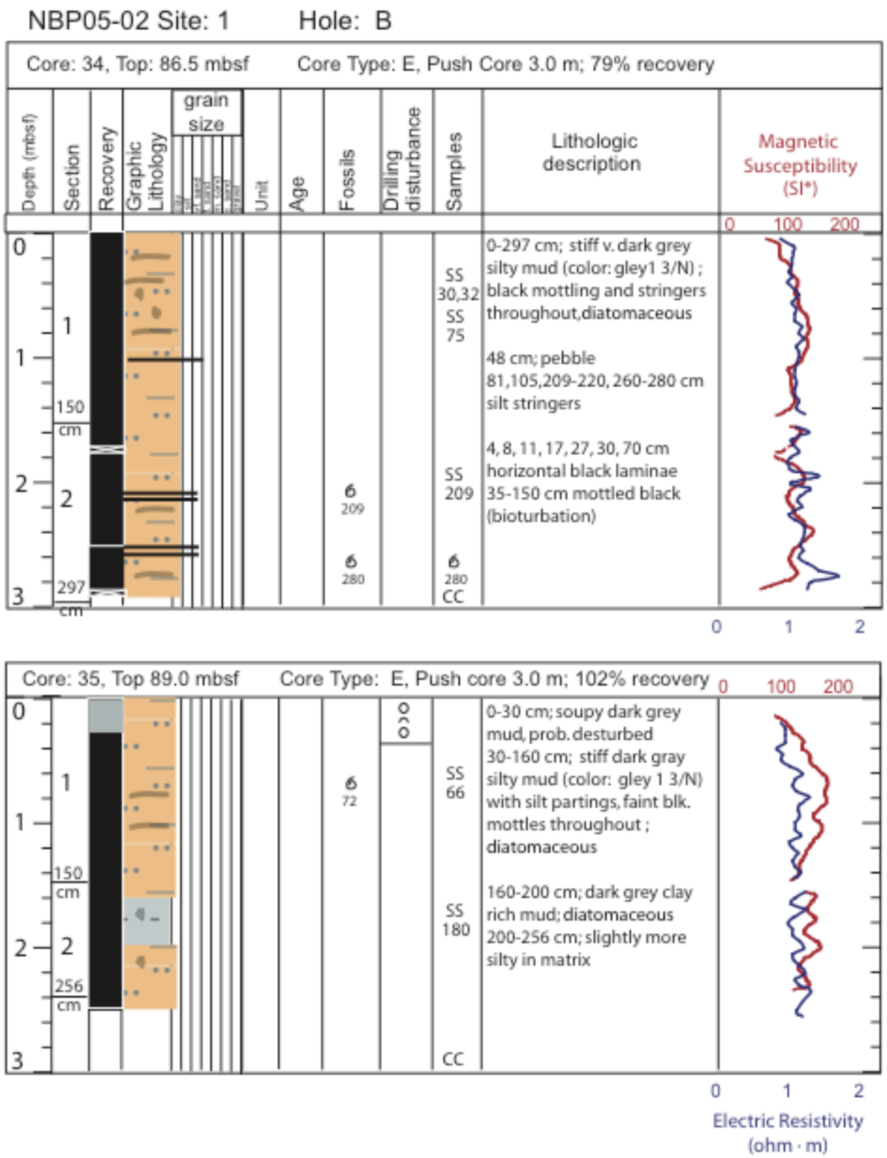

NBP05-02 Site: 1 Hole: B
Core: 24, Top: 61.0 mbsf Core Type: E, Push Core 3.0 m; 100% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200 300
140 cm
300 cm
0 to 300 cm; firm greenish gray (5Y; 3/1) silty mud; lightly mottled, sand laminations and silt strings; black subhorizontal mottles; diatomaceous
55
60
106
147
SS 173
SS 244
CC
Core: 25, Top: 64.0 mbsf Core Type: E, Push core 2.5 m; 114% recovery
0 100 200
150 cm
300 cm
2 to 15 cm; v soft dark gray mud; likely disturbed
15 to 300 cm; firm very dark gray (5Y; 3/1) diatomaceous silty mud with black (gley 1; 2.5/N) subhorizontal mottles; interbedded silt to v fine sand laminations
SS 43
SS 44
SS 70
SS 147
CC
0 1 2
Electric Resistivity (ohm · m)

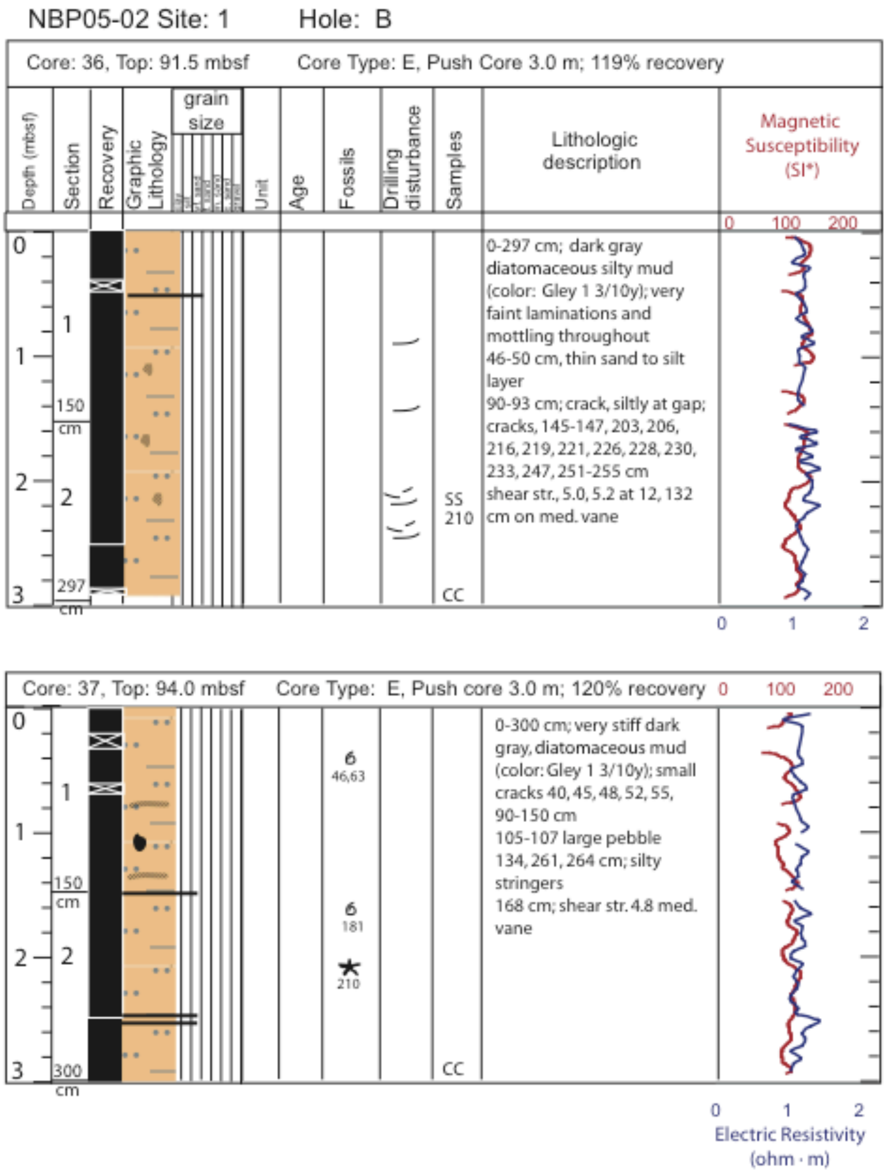

NBP05-02 Site: 1 Hole: B
Core: 26, Top: 66.5 mbsf Core Type: E, Push Core 2.5 m; 116% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0 to 225 cm; firm, greenish gray silty mud, moderately mottled, sand lens; diatomaceous
225 to 289 cm; firm gray, diatomaceous clay (gley 1, 3/N and gley 1 4/N), no mottling, no laminations, no silt
139 cm
289 cm
SS 30
SS 49
SS 162
SS 224
SS 230
CC
0 1 2
Core: 27, Top: 69.0 mbsf Core Type: E, Push core 2.5 m; 91% recovery
0 to 85 cm; gray (gley 1; 3/4) clay, homogenous, no silt, no mottling, likely disturbed
85 to 150 cm; firm gray clay (gley 1; 4/N); no silt, mottling, or laminations
150 to 180; v soft gray silty mud, likely disturbed;
180 to 195; v soft gray v. fine sand; 195 to 210 cm fine to v fine sand
210 to 250; very dark greenish gray (gley; 3/N) clay with pebbles
250 to 298 firm mottled gray clay
150 cm
298 cm
SS 100
SS 143
SS 209
SS 240,270
CC
Electric Resistivity (ohm - m)

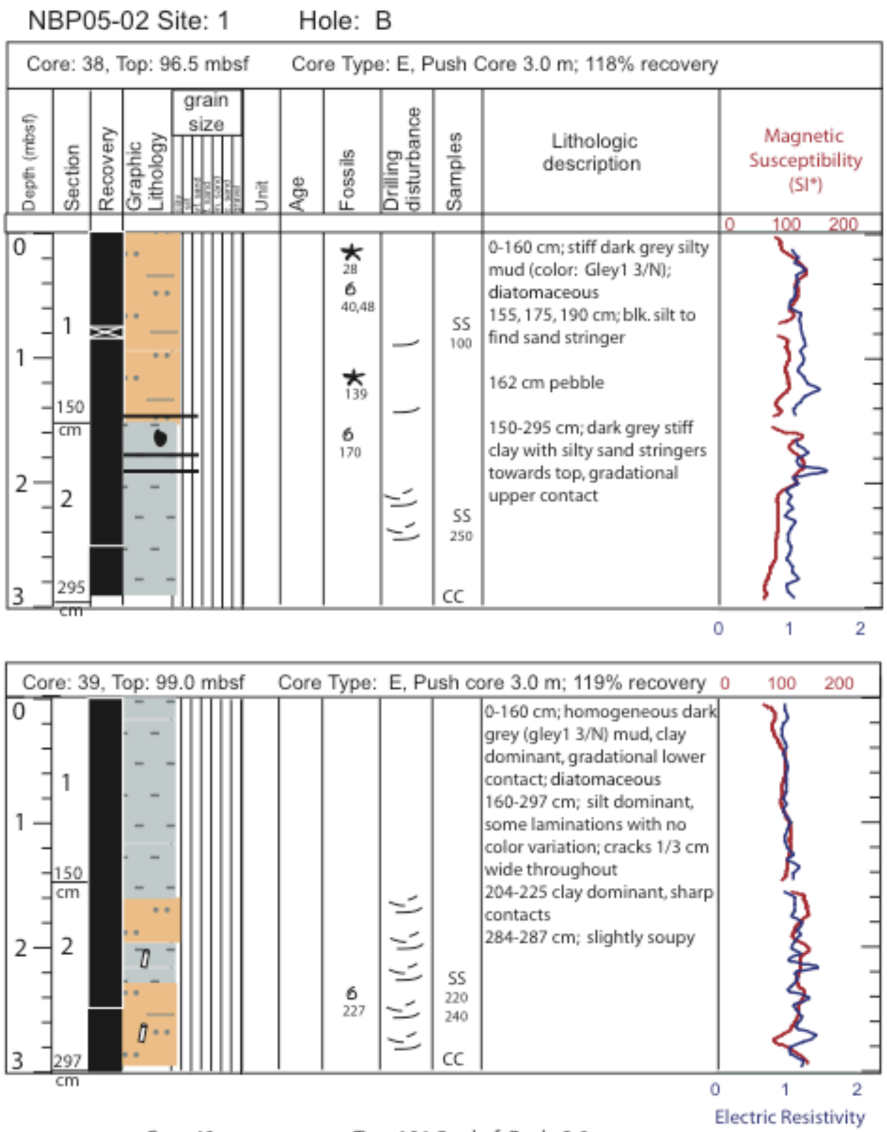

NBP05-02 Site: 1 Hole: B
Core: 28, Top: 71.5 mbsf Core Type: E, Push Core 2.5 m; 107% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0 to 26 cm; very soft dark gray silty mud; likely disturbed
26 to 267 cm; very dark gray (gley 1; 3/N) silty mud with abundant black subhorizontal mottles; moderately mottled ; silt strings; diatomaceous
SS 111
CC
150 cm
267 cm
0 1 2
Core: 29, Top: 74.0 mbsf Core Type: E, Push core 2.5 m; 119% recovery
0 100 200
SS 26
SS 43
SS 220
CC
0 to 298 cm; dark gray (5Y;3/1) silty mud with faint subhorizontal black mottles and silt to v. fine sand strings; diatomaceous
150 cm
298 cm
0 1 2
Electric Resistivity (ohm · m)


NBP05-02 Site: 1 Hole: B
Core: 30, Top: 75.5 mbsf Core Type: E, Push Core 2.5 m; 120% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
150 cm
300 cm
SS 110
SS 210
CC
166,192
203,230
0 to 300 cm; very dark gray (gley 1; 3/N) silty mud, moderately mottled, diatomaceous; faint subhorizontal black mottles (remnant lams), silty to v. fine sand lams,
0 1 2
Core: 31, Top: 79.0 mbsf Core Type: E, Push core 2.5 mbsf; 119% recovery
0 100 200
150 cm
297 cm
SS 15,25
SS 180
CC
0 to 20 cm; very dark gray (gley 1; 3/1) silty mud with silty stringers; diatomaceous
20 to 210 cm; very dark gray (gley 1; 3/1) clay homogenous, no structures, lithologic variation, or mottles; diatomaceous
210 to 297 cm; very soft gray silty mud; likley disturbed and higher water content; diatomaceous
0 1 2
Electric Resistivity (ohm · m)

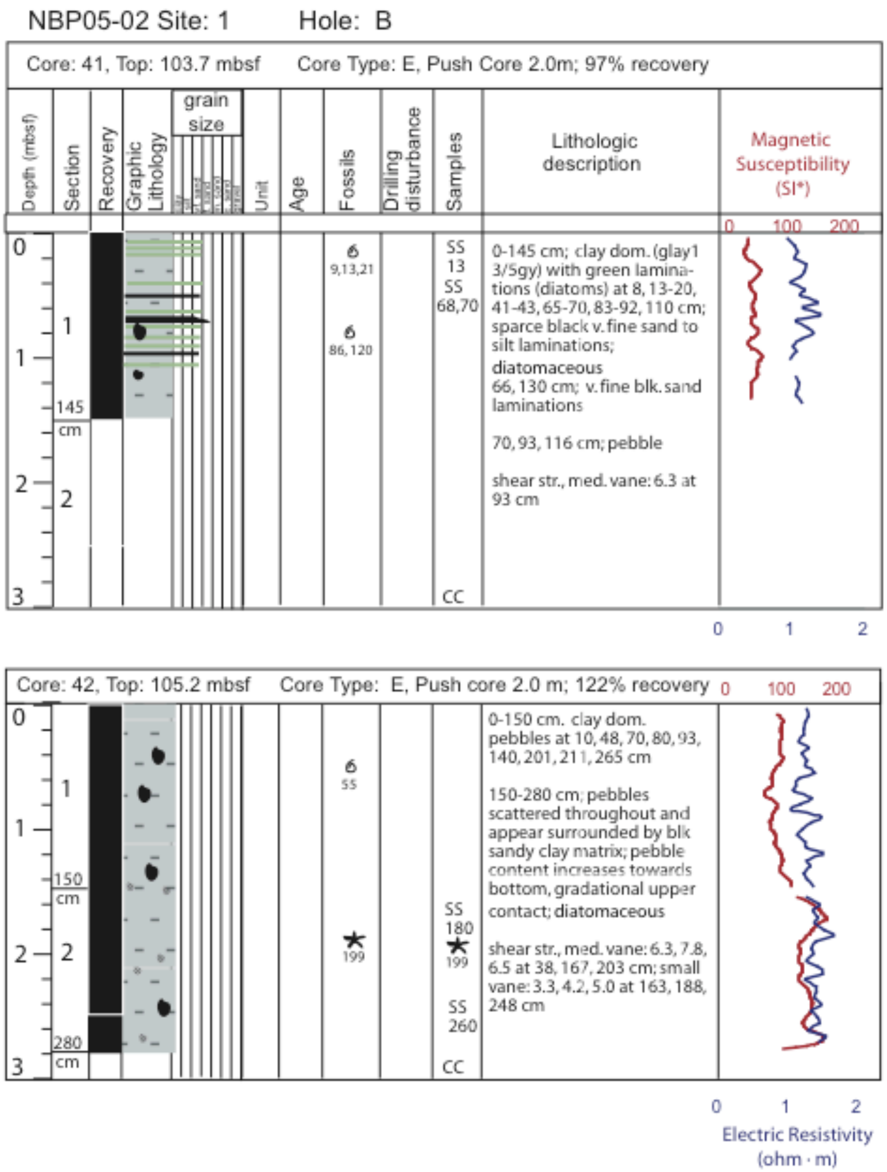

NBP05-02 Site: 1 Hole: B
Core: 32, Top: 81.5 mbsf Core Type: E, Push Core 2.5 m; 20% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0
1
2
3
1
51 cm
CC
0 to 25 cm; dark greenish gray (gley 1; 3/N) silty mud, evidence for drilling disturbance; diatomaceous
25 to 51 cm; gray clay, with very little silt, evidence for drilling disturbance ; diatomaceous
0 1 2
Core: 33, Top: 84.0 mbsf Core Type: E, Push core 3.0 m; 119% recovery
0 100 200
150 cm
298 cm
38
SS 60
SS 125
SS 255
CC
Foraminifera in this zone
0 to 298 cm; firm, dark greenish gray (gley 1; 3/N); diatomaceous silty mud, moderately mottled and silty to v fine sandy laminae
57 to 298 cm; scattered foraminifera
0 1 2
Electric Resistivity (ohm · m)

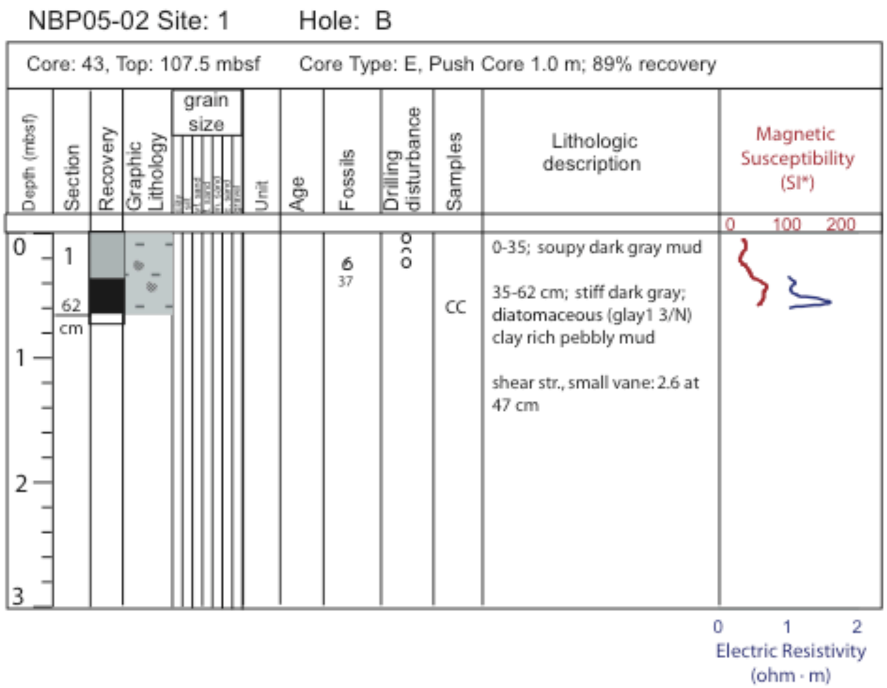

NBP05-02 Site: 1 Hole: B
Core: 34, Top: 86.5 mbsf
Core Type: E, Push Core 3.0 m; 79% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0-297 cm; stiff v. dark grey silty mud (color: gley1 3/N); black mottling and stringers throughout, diatomaceous
48 cm; pebble
81,105,209-220, 260-280 cm silt stringers
4, 8, 11, 17, 27, 30, 70 cm horizontal black laminae
35-150 cm mottled black (bioturbation)
SS 30,32
SS 75
SS 209
280
CC
150 cm
297 cm
Core: 35, Top 89.0 mbsf
Core Type: E, Push core 3.0 m; 102% recovery
0-30 cm; soupy dark grey mud, prob. desturbed
30-160 cm; stiff dark gray silty mud (color: gley 1 3/N) with silt partings, faint blk. mottles throughout; diatomaceous
160-200 cm; dark grey clay rich mud; diatomaceous
200-256 cm; slightly more silty in matrix
SS 66
SS 180
CC
72
150 cm
256 cm
Electric Resistivity (ohm · m)


NBP05-02 Site: 1 Hole: B
Core: 36, Top: 91.5 mbsf Core Type: E, Push Core 3.0 m; 119% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0-297 cm; dark gray diatomaceous silty mud (color: Gley 1 3/10y); very faint laminations and mottling throughout
46-50 cm, thin sand to silt layer
90-93 cm; crack, siltly at gap; cracks, 145-147, 203, 206, 216, 219, 221, 226, 228, 230, 233, 247, 251-255 cm
shear str., 5.0, 5.2 at 12, 132 cm on med. vane
SS 210
CC
Core: 37, Top: 94.0 mbsf Core Type: E, Push core 3.0 m; 120% recovery
0-300 cm; very stiff dark gray, diatomaceous mud (color: Gley 1 3/10y); small cracks 40, 45, 48, 52, 55, 90-150 cm
105-107 large pebble
134, 261, 264 cm; silty stringers
168 cm; shear str. 4.8 med. vane
Electric Resistivity (ohm · m)



Core 40-- no recovery; Top: 101.5 mbsf; Push: 2.0m


NBP05-02 Site: 1 Hole: B
Core: 41, Top: 103.7 mbsf Core Type: E, Push Core 2.0m; 97% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0-145 cm; clay dom. (glay1 3/5gy) with green laminations (diatoms) at 8, 13-20, 41-43, 65-70, 83-92, 110 cm; sparce black v. fine sand to silt laminations;
diatomaceous
66, 130 cm; v. fine blk. sand laminations
70, 93, 116 cm; pebble
shear str., med. vane: 6.3 at 93 cm
9,13,21
86, 120
SS 13 SS 68,70
CC
145 cm
0 1 2
Core: 42, Top: 105.2 mbsf Core Type: E, Push core 2.0 m; 122% recovery
0 100 200
0-150 cm. clay dom. pebbles at 10, 48, 70, 80, 93, 140, 201, 211, 265 cm
150-280 cm; pebbles scattered throughout and appear surrounded by blk sandy clay matrix; pebble content increases towards bottom, gradational upper contact; diatomaceous
shear str., med. vane: 6.3, 7.8, 6.5 at 38, 167, 203 cm; small vane: 3.3, 4.2, 5.0 at 163, 188, 248 cm
55
199
SS 180
199
SS 260
CC
150 cm
280 cm
0 1 2
Electric Resistivity (ohm · m)


NBP05-02 Site: 1
Hole: B
Core: 43, Top: 107.5 mbsf
Core Type: E, Push Core 1.0 m; 89% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
0
1
2
3
1
62 cm
37
CC
0-35; soupy dark gray mud
35-62 cm; stiff dark gray; diatomaceous (glay1 3/N) clay rich pebbly mud
shear str., small vane: 2.6 at 47 cm
0 1 2
Electric Resistivity (ohm · m)

Chapter 4: Herbert Sound
Table of Contents

SITE 2: HERBERT SOUND

A. BACKGROUND AND OBJECTIVES

Herbert Sound is a large fjord located on the northern side of James Ross Island. The mouth of the sound empties into Prince Gustav Channel (Fig. 4-A1). It is the largest fjord on the south side of the Antarctic Peninsula and is subject to colder and dryer conditions than fjords that have been studied on the northern side of the Antarctic Peninsula.

Herbert Sound was selected as a back-up site for acquiring a Holocene stratigraphic section because it is located near the James Ross Basin work area and provides protection from storms. Marine geological data acquired during a 1991 cruise of the R/V *Polar Duke* showed the sound to contain up to 30 meters of Holocene sediments. A number of piston cores collected during that same cruise were later studied as part of an undergraduate research project at Rice University (Maher et al., 2004). This work showed that sediments within the sound contain carbonate material for radiocarbon age dating and preliminary analyses yielded a radiocarbon database that extends back to approximately 8,000 years.

B. OPERATIONS

Site NBP0502-2 is located at 63° 58.259′ S, 57° 45.511′ W at a water depth of 359 m. The site, located in Herbert Sound on the northwest side of James Ross Island, was selected as an alternate drilling site because of its protection from the wind and proximity to the primary drilling targets. Strong winds in the northwestern Weddell Sea did not allow drilling operations to begin at the primary sites and thus the Herbert Sound alternate was drilled.

Two kasten cores were taken in Herbert Sound. The first kasten core overpenetrated the sediment and did not recover the sediment-water interface. This is most likely due to running the winch at too high a speed (~40 m/min) as the corer reached bottom. The second kasten core was lowered more slowly (~10 m/min) and recovered the sediment-water interface. Both kasten cores had full (>3 m) barrels.

Drilling in Herbert Sound was conducted much like in Maxwell Bay. The *Palmer* went onto DP without difficulty. The winds in Herbert Sound remained under 25 knots throughout the time on station. Wind directions were variable in Herbert Sound, partially a function of multiple glaciers entering the enclosed sound. This did not affect the ability of the *Palmer* to hold station.

Hole NBP0502-2C reached a total depth of 10.5 m. Because soft Holocene sediments were the target, extended push sampling was planned. In part to test all of the sampling tools available, the Shelby tube with a liner was used for this site. The one exception to this is Core NBP0502-2C-2E, since the second core run always was to be a

1.5 m push and the only Shelby tube sampler available is 2.5 m. Overall, recovery at this site (73%) is slightly lower than that at Maxwell Bay. Despite this, the Shelby tube is considered to be a good option for coring in very soft sediments and will continue to be considered as an option for soft sediments.

Core NBP0502-2C-5E reached hard material at 10.5 m. Because the weather had cleared at the primary sites, Site 2 was abandoned rather than attempting to run a hammer sampler or drill through the obstacle.

C. LITHOSTRATIGRAPHY

NBP0502 Site 2 consists of three cores including two kasten cores and one drill core. The first kasten core overpenetrated, and a second kasten core was taken (Hole 2B). Hole 2B consists of 3.0 m of soft, dark olive gray silty mud with some very fine to fine black sand laminations and black/brown mottling (Fig. 4-C1). The kasten core generally duplicates the first push core (Core 2C-1E) of the long drill core also collected at this site (Hole 2C). Detailed descriptions of Hole 2C are presented in Figure 4-C2 and Appendix 4-H1. Three distinct sedimentary units were sampled. The upper unit (Unit I) extends from 0.0 to 8.2 mbsf and is a diatomaceous mud. This unit consists of mottled olive to dark gray mud with occasional olive green or black laminations and some pebbles. Bivalves are common throughout. Unit II is a clay-rich mud that ranges from approximately 8.2 to 8.4 mbsf. The clay layer is nearly homogeneous with very little silt and common sand lenses. Unit III extends from approximately 8.4 to 9.91 mbsf and is a clay-rich diamicton. This unit is distinguished by a sharp increase in pebble abundance, a sharp decrease in shear strength, and no stratification or laminations. The decrease in shear strength may correspond to increased drilling disturbance near the bottom of the core. Pebbles are black volcanics encased in black sands and silts. Shear strength measurements taken throughout the core show a general increase down core (App. 4-H1).

D. BIOSTRATIGRAPHY

Introduction

NBP0502 Site 2 is located on the north side of James Ross Island in Croft Bay, Herbert Sound, Antarctica. Two kasten cores (Holes 2A and 2B) were taken at the site, and one longer core was attempted with the Seacore drill rig (Hole 2C). Hole 2C was drilled to a sub-bottom depth of 10.5 mbsf. The site was chosen with the goal of recovering Holocene sediments with a push-corer tool and then sampling underlying Cretaceous strata with the rotary drill bit. The hole was terminated in the upper glacial till unit. Initial shipboard paleontological work included sample preparations for diatoms, calcareous nannofossils, and radiolarians.

Diatoms

Diatom smear slides were prepared for five samples from Hole 2C (Table 1-D2). Samples from Cores 2C-1E, 2E, and 3E contain abundant and well-preserved diatoms, but samples from Cores 2C-4E and 5E are barren. All taxa observed in the upper three samples of the section are modern (extant) taxa. The assemblages are dominated by *Chaetoceros* resting spores and *Thalassiosira antarctica* var. *antarctica*, with secondary abundances of *Fragilariopsis curta* and *Fragilariopsis vanheurckii* (Table 1-D2). These taxa are all associated with the sea-ice environment and are commonly found in plankton-net samples from near the sea-ice edge.

Laminations were observed in Cores 2C-2E and 3E (see Lithostratigraphy). "Toothpick" samples were taken from laminations at 2.86 mbsf (Sample 2C-2E-1, 36 cm) and 5.37 mbsf (Sample 2C-3E-1, 37 cm). Both laminations are dominated by *Chaetoceros* resting spores, but also contain a significant abundance of *Thalassiosira antarctica* var. *antarctica*.

In comparison to Holocene diatom assemblages recovered at Site 1 in Maxwell Bay, the assemblages from Site 2 are indicative of colder conditions with more sea-ice influence. *Fragilariopsis kerguelensis,* for example, is common component of the Hole 1B assemblages, whereas this taxon was not observed in Hole 2C. *Fragilariopsis kerguelensis* is typically found in the warmer, more northerly waters of the Polar Frontal Zone area.

Calcareous Nannofossils

Nannofossil smear slides were prepared and examined for five core-catcher samples from Hole 2C. All samples examined were essentially barren of calcareous nannofossils. Samples 2C-1E-CC, 3E-CC, and 4E-CC contained very rare specimens (~2 per slide) of *Thoracosphaera* sp., (a calcareous dinoflagellate). Additionally, a few extremely rare specimens of reworked Cretaceous nannofossils were observed in Samples 2C-4E-CC and 2C-5E-CC. These specimens included *Watznaueria* cf. *W. barnesae* and *Arkhangelskie* cf. *cymbiformis*. Cretaceous strata crop out on nearby James Ross Island, thus the presence of reworked Cretaceous nannofossils is not unexpected. A range chart was not compiled for this site due to the extremely rare occurrence of calcareous nannofossils.

Radiolarians

Four samples were examined for radiolarians from Hole 2C. Samples 2C-1E-CCand 2E-CC contain well-preserved radiolarian tests, few to common in abundance. All specimens are typical modern cold-water radiolarians, and the assemblages are dominated by *Antarctissa denticulata, Antarctissa strelkovi,* and a number of unidentified spumellarian species. Core-catcher samples from Cores 2C-4E and 5E are barren of radiolarians.

In addition to radiolarians, rare benthic foraminifers were observed in the core-catcher sample from Core 2C-3E.

E. PHYSICAL PROPERTIES

The objective of the physical properties program at Site 2 was to aid in the interpretation of stratigraphic and geophysical data from Herbert Sound at Croft Bay. Holes 2A, 2B and 2C differed in their depth and coring method. Hole 2A was a 3.05 m kasten core that did not recover the sediment-water interface. Hence, Hole 2B obtained a 3 m kasten core that had the sediment-water interface at the very top. Hole 2C was a push core that reached 10.5 mbsf.

Measurements were made by three methods: MSCL track (which sampled every cm and recorded magnetic susceptibility and GRAPE data), electric resistivity probe, and discrete sampling. Depending on the coring technique, some of the methods varied.

Electric resistivity measurements were made every 2 cm in both Holes 2A and 2B. Discrete samples (normally 5 cc, using a syringe sampling system) were made only on Hole 2B and were not processed onboard. These samples were stored in weighed vials and kept in the cooler until transport. The core was scraped down 4 cm and a half-split liner obtained an archive sample in the unsampled region. This half-split liner was run through the MSCL track to obtained magnetic susceptibility data at 1-cm intervals. Due to the highly diatomaceous sediment, the magnetic susceptibility readings were under 10 SI* and thus correlation between cores was not achievable using this technique. However, the electric resistivity measurements allowed correlation between the three cores.

Electric resistivity measurements and discrete samples were taken at a 5-cm resolution in Hole 2C. Data obtained from the MSCL track includes magnetic susceptibility and gamma ray counts. The GRAPE and magnetic susceptibility unit are not calibrated so these cores will be rerun at a later time. Downhole variations in electric resistivity vary slightly but larger excursions can be related to more compacted sandier layers. Core disturbances are readily observed in the resistivity and have been removed. A large excursion at the base of the hole is correlated with a highly compacted diamicton.

Due to limited recovery, minimal interpretation can be made at this time. The sediment lithology is most likely responsible for the physical state of the sediments recovered in Herbert Sound.

F. SEISMIC STRATIGRAPHY

High-resolution seismic data were acquired within Herbert Sound using a 15 cubic inch water gun and single channel streamer (Fig. 4-F1). The survey revealed a draping unit that is up to 30 meters thick within the deeper portions of the sound. Chirp 3.5 kHz data collected during the SHALDRIL cruise highlight the Holocene strata (Fig. 4-F2). A number of large slumps and debris flows occur along the steep flanks of the sound. These Holocene deposits rest directly on older strata with dipping reflectors that are interpreted as Cretaceous volcaniclastic deposits similar to those strata that can be see in the steep cliffs flanking the fjord (Fig. 4-F3).

G. SITE SUMMARY

Site 2 (63° 58.259′ S, 57° 45.511′ W, water depth 359 m) is located just south of a glacial trough in Croft Bay of Herbert Sound on the northern side of James Ross Island. In a sheltered region, we tested the drilling capabilities of penetrating through unconsolidated Holocene sediment into the underlying lithified Cretaceous volcaniclastic, deltaic bedrock.

Two kasten cores (each recovered ~3m) sampled diatomaceous silty mud containing distinct bivalve layers at 0.2 and 2.2 mbsf. A 10.5 m sequence (73% overall recovery) was sampled. Three sedimentary units were identified. Unit I (0.0 – 8.2 mbsf) is a diatomaceous mud containing bivalves throughout along with several distinct bivalve horizons. This unit contains abundant and well-preserved diatoms and radiolarians down to 6.5 mbsf. The diatom assemblages are indicative of colder and more extensive sea-ice conditions than found in Maxwell Bay (Site 1). Below 6.5 mbsf, the core is barren of diatoms and radiolarians. Unit II (8.2 – 8.4 mbsf) is a homogeneous clay-rich sediment with few silt or sand layers. Unit III (8.4 – 9.9 mbsf) is a clay-rich diamicton. This unit has a sharp increase in pebble abundance and shear strength. Magnetic susceptibility and electric resistivity measurements show peaks associated with sandy layers and a large increase at Unit III that corresponds to the diamicton contact. There is a sharp increase in pebble count in Unit III. There are a few reworked Cretaceous calcareous nannofossils at 8.4 mbsf and 10.2 mbsf that most likely originated from underlying strata.

The Holocene section in Herbert Sound is more condensed than that observed in Maxwell Bay. The thickness of the Holocene appears to be ~ 6.5 meters in comparison to the 100+ meters sampled at Site 1. It appears that this site has been proximal to sea ice throughout. Whether this site experienced warming during the mid-Holocene is presently unclear; further biostratigraphic work and dating will help elucidate the Holocene paleoclimatic history of the area. The clay-rich diamicton records the last glacial advance in this bay. After reaching the diamicton, the weather conditions improved at our primary sites in the Weddell Sea and it was deemed important to abandon the hole and move to Site 3.

H. APPENDIX

Appendix 4-H1. Lithologic Logs

Appendix 4-H1 contains the detailed lithologic logs from Hole NBP0502-2C and follows the figures.

REFERENCES

Maher, J., Wellner, J.S., and Anderson, J.B., 2004. Seismic and Sediment Data From Herbert Sound, Northwestern Weddell Sea, Indicate a Long-Lived Holocene Ice Canopy. American Geophysical Union Annual Meeting, San Francisco, CA.

FIGURES

Figure 4-A1. Multibeam swath bathymetry mosaic for Herbert Sound showing the Site 2 location.

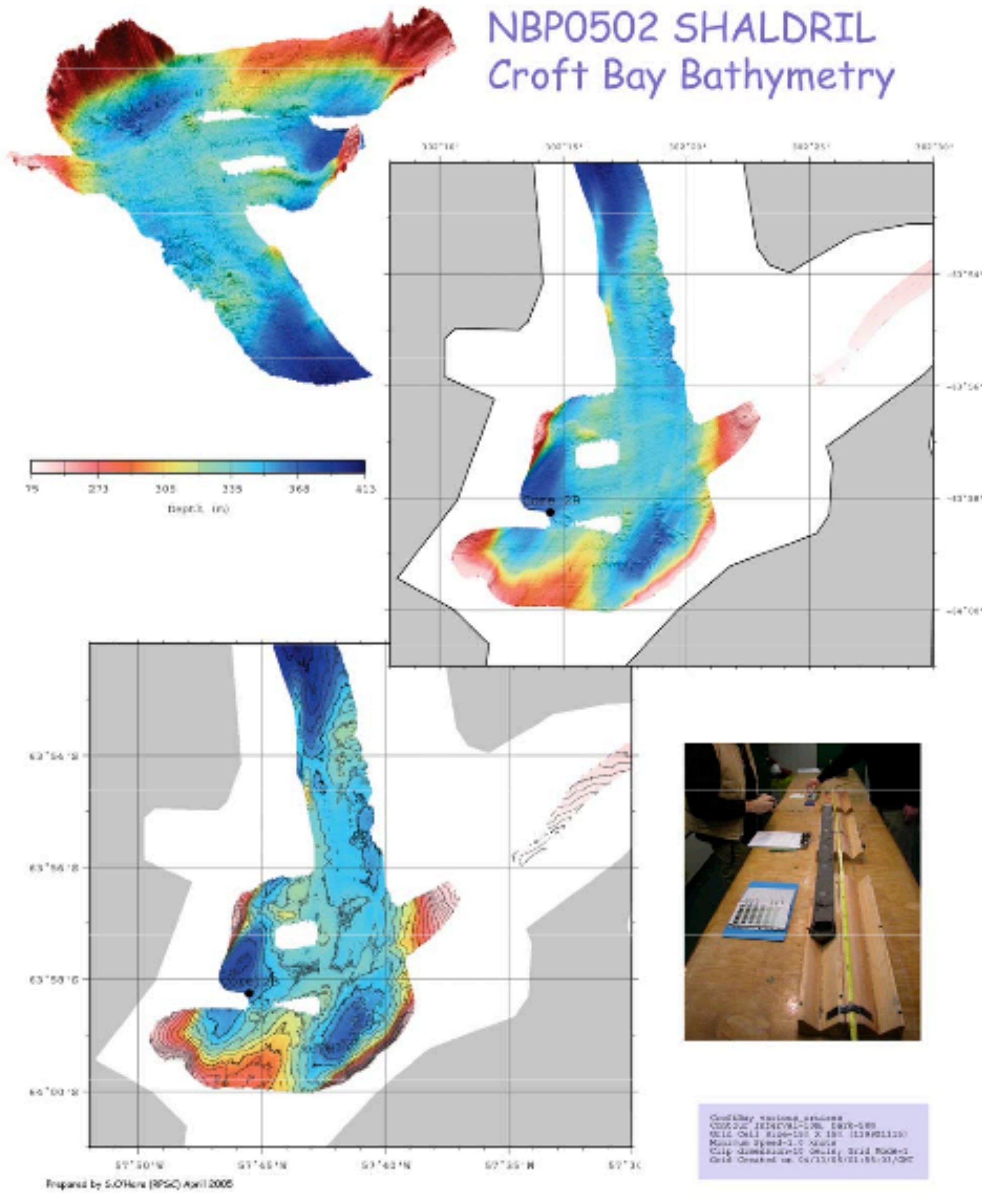


Figure 4-C1. Lithologic log of kasten core NBP0502-2B-KC.

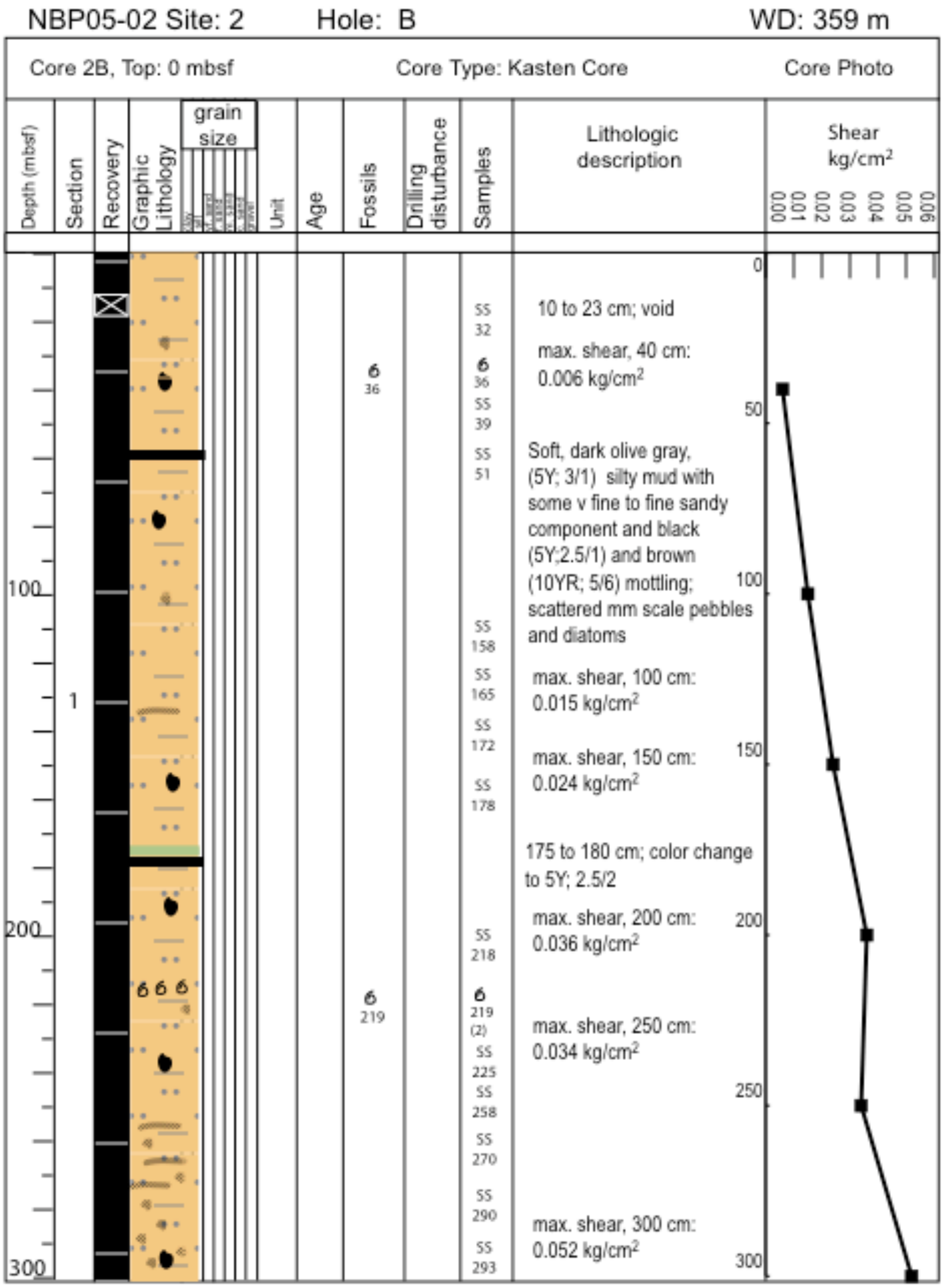


Figure 4-C2. Summary lithologic log of drill core NBP0502-2C.

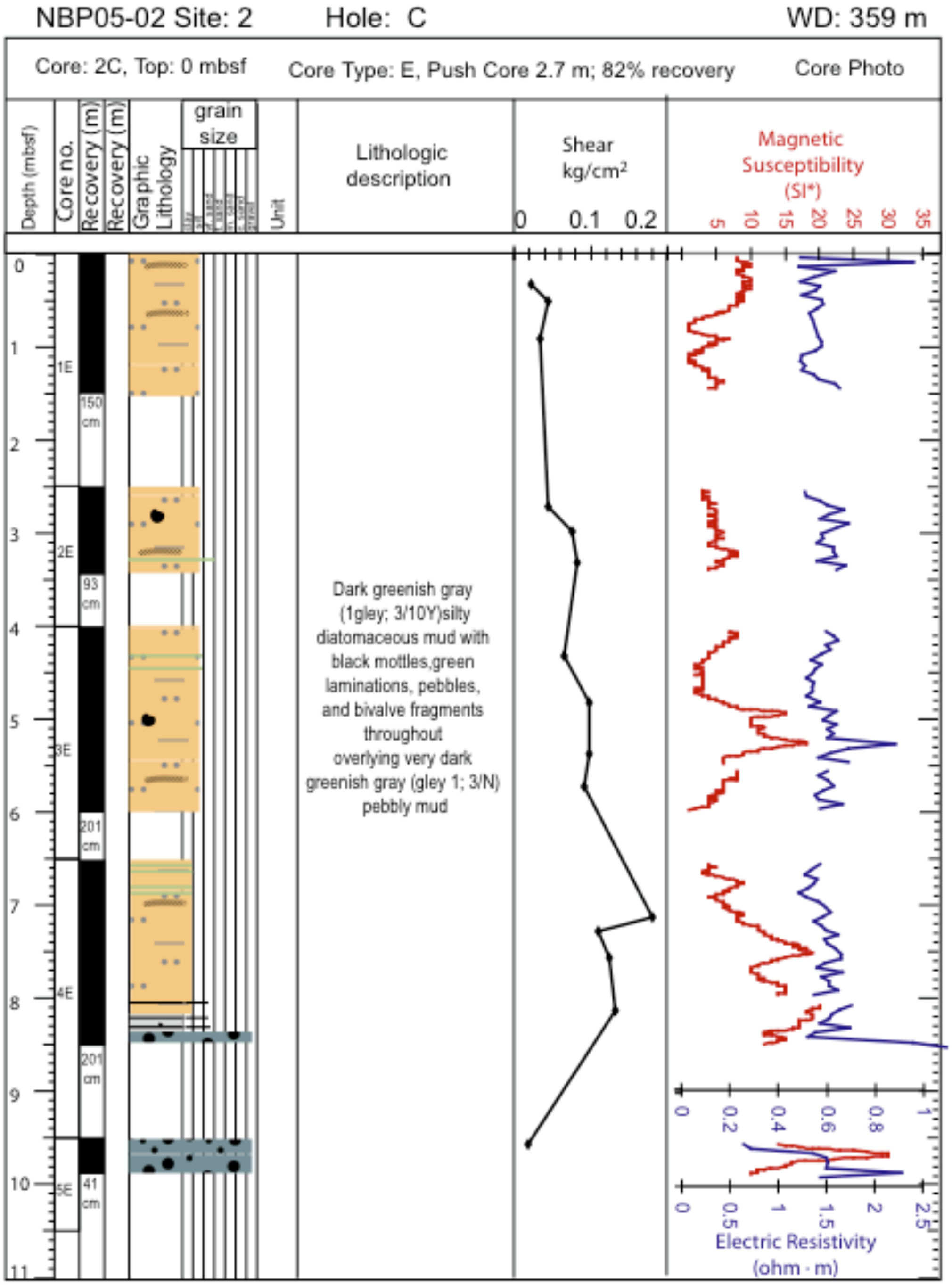


Figure 4-F1. Seismic line PD91-40A in Herbert Sound.

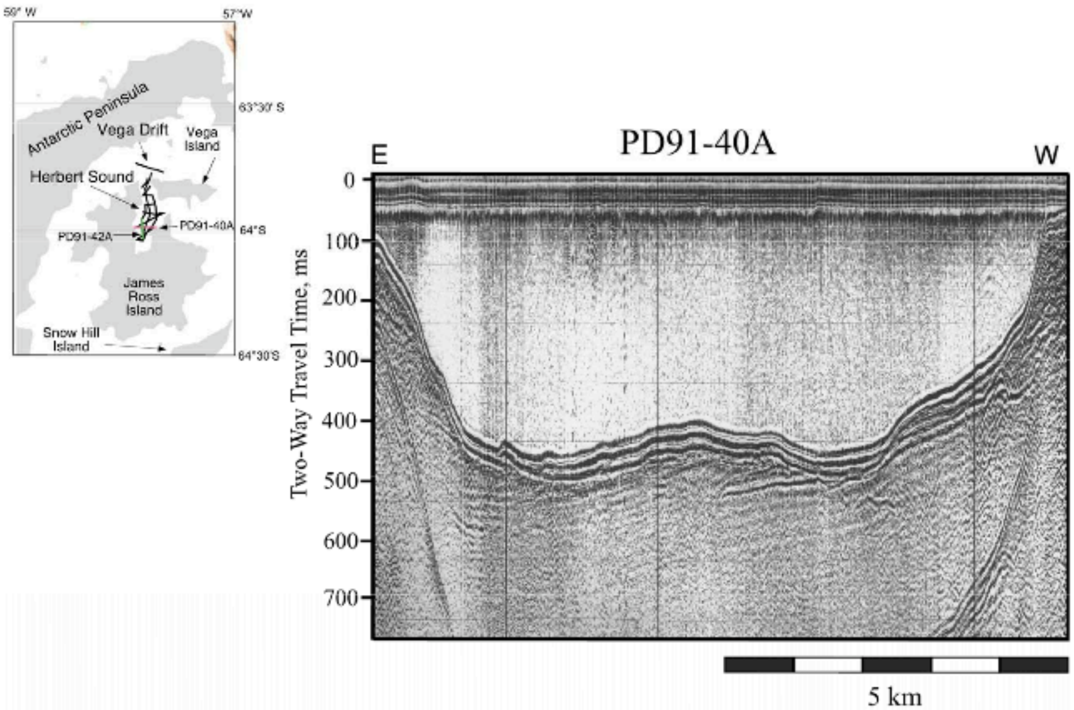


Figure 4-F2. Chirp data from the NBP0502 cruise showing the Site 2 core location.

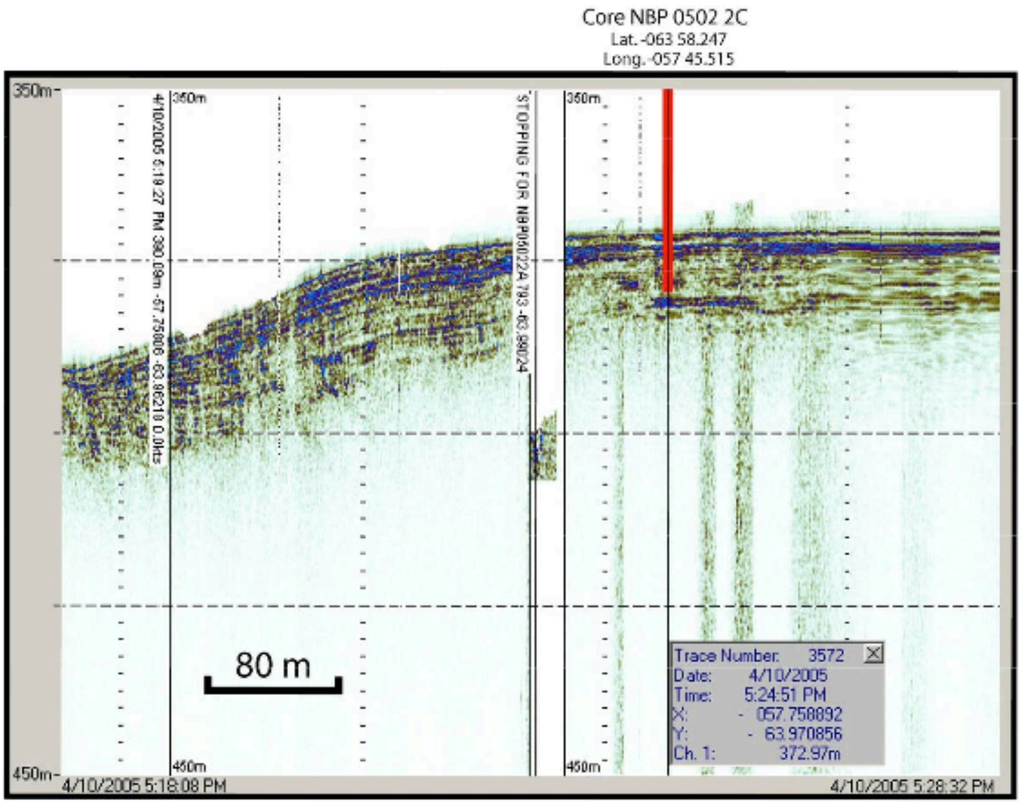


Figure 4-F3. Dipping Cretaceous volcaniclastic strata on James Ross Island. (Photo by A. Injac.)

Table 4-B1. Drilling and coring recovery log for Site 2.

SHALDRIL CRUISE NBP0502, SITE 2 (Herbert Sound)

Multibeam Water Depth: 359 m

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
2A	1	KC	0.00	3.09	3.09	3.09	3.09	0.00	0.10	2.99	100.00%	96.76%	1	150	100	1819	1
													2	156			
													1	150			
													2	128			
													3	28			
2B	1	KC	0.00	3.01	3.01	3.01	3.01	0.00	0.13	2.88	100.00%	95.68%	1	150	100	1911	
													2	156			
2C	1	E	0.00	2.50	2.50	2.50	1.50	1.00	0.20	1.30	100.00%	52.00%	1	150	101	243	2
2C	2	E	2.50	4.00	1.50	1.50	0.93	0.00	0.00	1.50	100.00%	100.00%	1	93	101	324	
2C	3	E	4.00	6.50	2.50	2.50	2.01	0.00	0.04	2.46	100.00%	98.40%	1	150	101	359	
													2	151			
2C	4	E	6.50	9.50	3.00	2.00	2.01	0.00	0.00	2.00	66.67%	66.67%	1	150	101	445	3
													2	151			
2C	5	E	9.50	10.50	1.00	0.41	0.41	0.00	0.00	0.41	41.00%	41.00%	1	41	101	530	

Site	2C		
TD=	10.5		
Recovery Total		8.91 m	0.849 %
Recovery Corrected		7.67 m	0.73 %

1) 2 archives of kasten core made, one set has 2 sections, one set has 3 sections
2) Disturbed material from top of core not saved, top of competent material marked as top of interval
3) Pushed only 2 m before hitting hard material, core represents 100% recovery of top 2 m of section, then 1 m drilled out

Table 4-D1. Stratigraphic occurrence and relative abundance of diatom taxa in SHALDRIL Holes 2C, 3A, 4A, 6A, 6C, 6D, and 6E.

Hole	Core	Section	Top Interval (cm)	Bottom Interval (cm)	Depth (mbsf)	Diatom Abundance	Preservation	Fragmentation
Hole 2C								
2C	1E	CC	-	-	1.30	A	G	L-M
2C	2R	1	36	36	2.86	A	G	L
2C	3R	CC	-	-	3.97	A	G	L
2C	4E	CC	-	-	8.51	B	-	-
2C	5E	CC	-	-	9.91	B	-	-
Hole 3A								
3A	1R		cuttings		4.90	C	M-P	M-H
3A	2R		cuttings		5.11	B	-	-
3A	4R		cuttings		9.50	B	-	-
3A	5R		cuttings		14.58	B	-	-
3A	6R		cuttings		17.08	F	P	H
3A	8H		cuttings		17.50	B	-	-
3A	14R		cuttings		28.74	T	P	H
Hole 4A								
4A	1KC	CC	-	-	8.48	F	P	H
Hole 6A								
6A	1KC	1	14	14	8.14	C	P	H
Hole 6C								
6C	3PH		cuttings		~4.0	A	M-G	L
Hole 6D								
6D	1KC	CC	-	-	2.95	C	M-P	H
Hole 6E								
6E	4R	CC	-	-	18.00	C	P	H
6E	6R	CC	-	-	13.00	C	M	M
6E	8R	CC	-	-	28.00	C	M	M

Diatoms - Planktonic

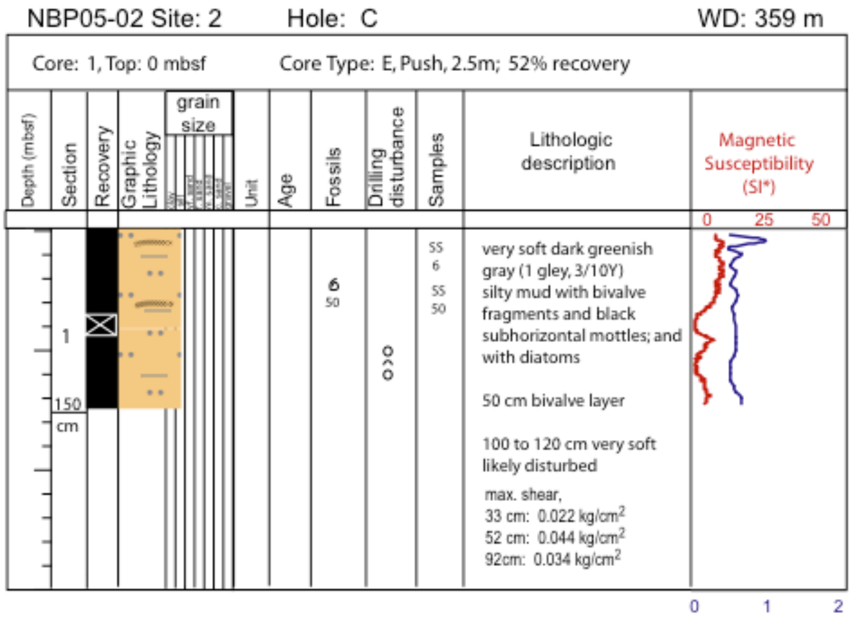
Hole	Core	Depth (mbsf)	*Actinocyclus actinochilus*	*Asteromphalus hyalinus/parvulus*	*Asteromphalus hookeri*	*Chaetoceros bulbosum*	*Chaetoceros* spp. (vegetative cells & resting spores)	*Corethron criophilum* (valves & spines)	*Coscinodiscus* spp. (large)	*Dactyliosolen antarcticus* (girdle bands)	*Eucampia antarctica* var. *antarctica*	*Eucampia antarctica* var. *recta*	*Fragilariopsis angulata*	*Fragilariopsis curta*	*Fragilariopsis cylindrus*	*Fragilariopsis longissima*
Hole 2C																
2C	1E	1.30	X				VA					X		F-C	F	
2C	2R	2.86	R			X	VA					X		F		
2C	3R	3.97	R				VA	X			X	X		C	F	
2C	4E	8.51														
2C	5E	9.91														
Hole 3A																
3A	1R	4.90	R				A	R	X			X		F		
3A	2R	5.11														
3A	4R	9.50														
3A	5R	14.58														
3A	6R	17.08	X				F	X	X					F		
3A	8H	17.50														
3A	14R	28.74	X				X					X				
Hole 4A																
4A	1KC	8.48	R				F	X	X	X		X		X		R
Hole 6A																
6A	1KC	8.14	X				F			X	X	R	R	F	R	F
Hole 6C																
6C	3PH	~4.0	R				VA	X				F	R	C	R	R-F
Hole 6D																
6D	1KC	2.95					C			X		R	F	F	R	C
Hole 6E																
6E	4R	18.00					C			X	X	F	R	R	X	C
6E	6R	13.00	X	X			A			X	F	R	R	F	X	C
6E	8R	28.00	R		X		A		X		R	F		C	X	C

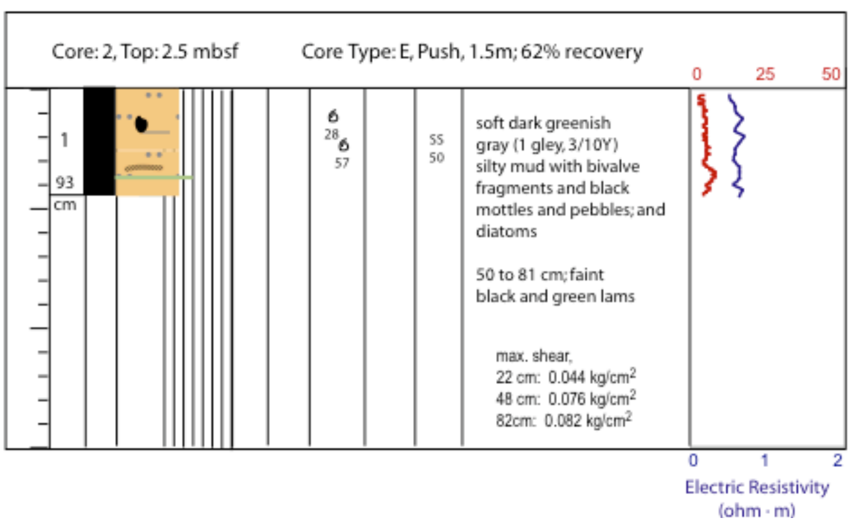
Hole	Core	Depth (mbsf)	*Fragilariopsis obliquecostata*	*Fragilariopsis ritscheri*	*Fragilariopsis separanda*	*Fragilariopsis sublineata*	*Fragilariopsis vanheurckii*	"*Melosira*" sp. (large)	*Odontella weissflogii*	*Paralia* spp.	*Porosira* spp.	*Proboscia alata*	*Rhizosolenia* spp.	*Stellarima microtrias*	*Thalassiosira* spp.	*Thalassionema nitzschioides*	*Thalassiosira antarctica* var. *antarctica*	*Thal. gracilis* var. *gracilis/expecta*	*Thalassiosira lentiginosa*	*Thalassiosira oliverana*	*Thalassiosira tumida*	*Thalassiothrix/Trichotoxon* spp.
Hole 2C																						
2C	1E	1.30	X	X			F				X			X	R		C-A					
2C	2R	2.86	R	R-F			R-F				R				X		C					
2C	3R	3.97	X	R		X	F								R-F		C					
2C	4E	8.51																				
2C	5E	9.91																				
Hole 3A																						
3A	1R	4.90	X	X		X	R		X		X	X	X		X		C					X
3A	2R	5.11																				
3A	4R	9.50																				
3A	5R	14.58																				
3A	6R	17.08	X				X				X						F	X				
3A	8H	17.50																				
3A	14R	28.74					X		X	X	X						R					
Hole 4A																						
4A	1KC	8.48	X				X		X	X	X		X	X			R	X		X	X	X
Hole 6A																						
6A	1KC	8.14	R	X			R		X		X	X	R	X	F		F	F	X	R		X
Hole 6C																						
6C	3PH	~4.0	X	R			C	X	R		R	X	R		F	X	C		X		R	X
Hole 6D																						
6D	1KC	2.95	X	F			R	X	X	R			R	X	X	X	C	F	X			X
Hole 6E																						
6E	4R	18.00	R	R	R		R	X	X				R	X	F		F	F			X	X
6E	6R	13.00		R	X		F	X	X		X		R	X	R		F	F	R		X	X
6E	8R	28.00	F	R			F		R		X				R		C	R	R		X	

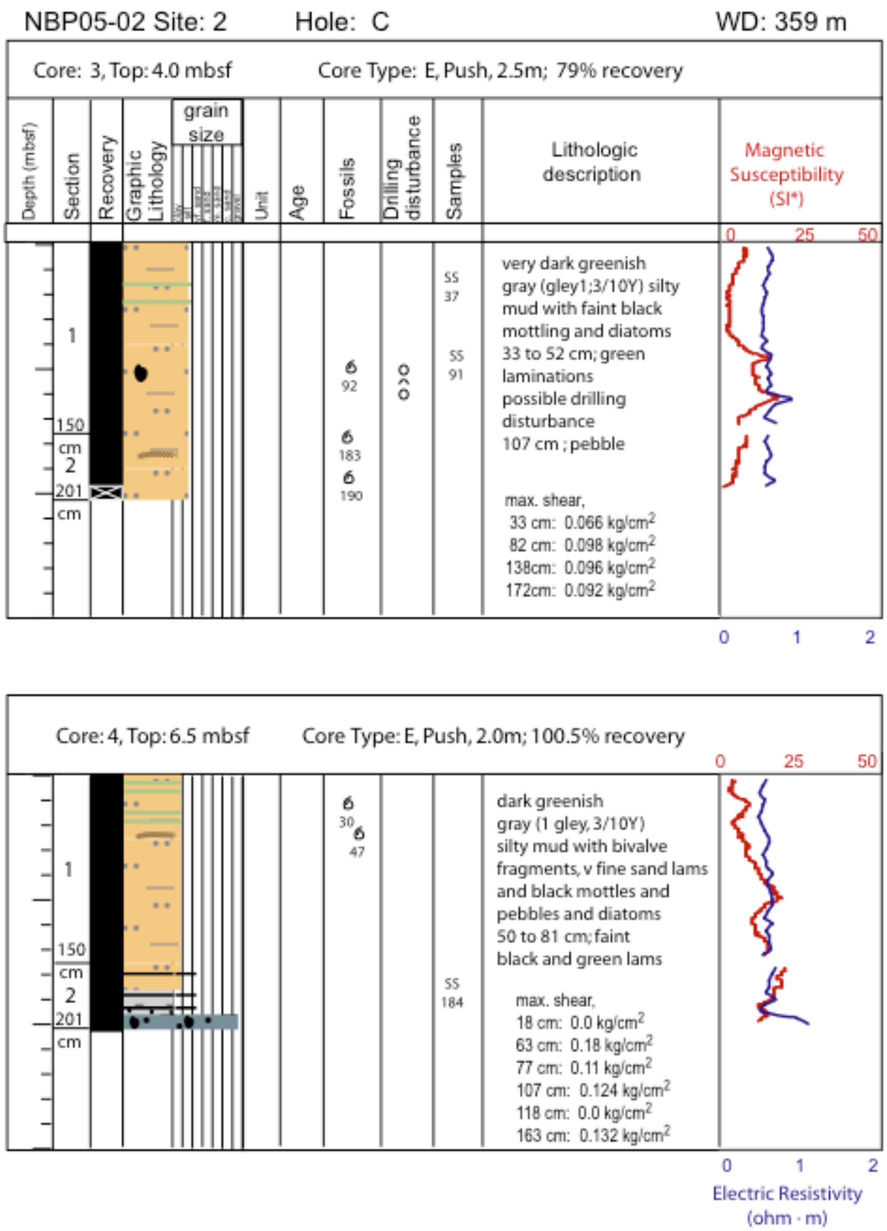
Diatoms - Benthic / Sea-ice Benthic; Diatoms - Reworked; Silicoflagellates

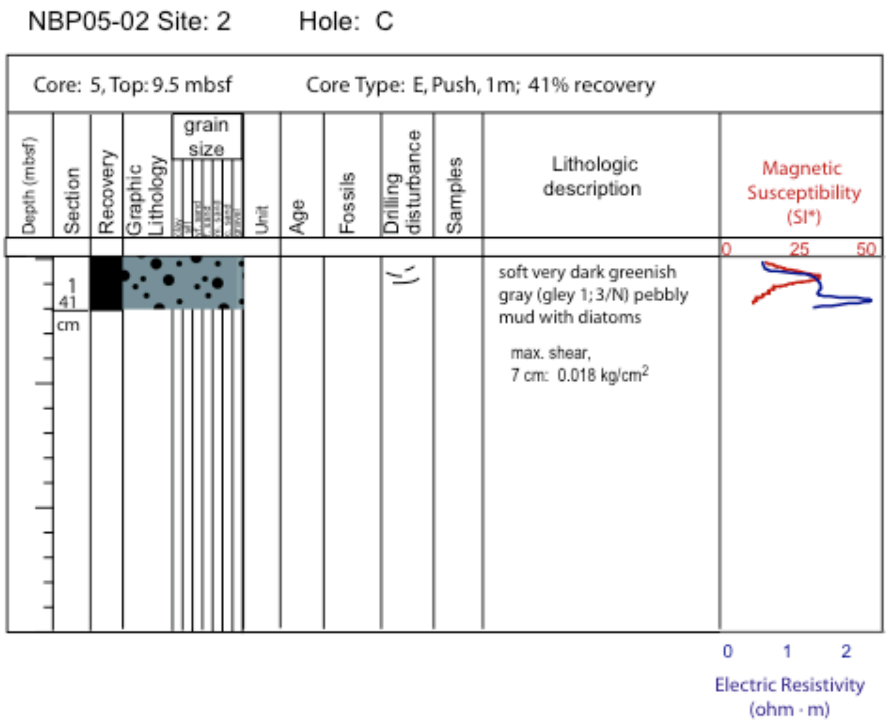
Hole	Core	Depth (mbsf)	*Achnanthes* spp.	*Amphora* spp.	*Cocconeis* spp. (several taxa)	*Grammatophora* spp.	*Navicula directa*	*Navicula* spp. (small)	*Nitzschia* spp.	*Pinnularia quadratarea*	*Pinnularia* spp.	*Pleurosigma* spp.	*Pseudogomphonema* spp.	*Actinocyclus ingens*	*Denticulopsis* spp.	*Coscinodiscus* sp. A (of Harwood, 1986)	*Stephanopyxis* spp.	*Trinacria excavata*	*Distephanus speculum speculum*
Hole 2C																				
2C	1E	1.30			R			X	X	X			X						X
2C	2R	2.86			R		X	R		X			X						
2C	3R	3.97			R			R	X	X			X						X
2C	4E	8.51																	
2C	5E	9.91																	
Hole 3A																				
3A	1R	4.90		X	R								X	r			r	r	
3A	2R	5.11																	
3A	4R	9.50																	
3A	5R	14.58																	
3A	6R	17.08						X											
3A	8H	17.50																	
3A	14R	28.74			X				X					r			r		
Hole 4A																				
4A	1KC	8.48		X	X		X								r	r	r(?)		
Hole 6A																				
6A	1KC	8.14	R	X	F	R		F	X										
Hole 6C																				
6C	3PH	~4.0	X		F			X	X				R						
Hole 6D																				
6D	1KC	2.95	R	X	F			X		X		X	X						
Hole 6E																				
6E	4R	18.00	X		F		X	R			X		X						R
6E	6R	13.00	X		F			X											X
6E	8R	28.00	R		F			X	X				X						X

APPENDIX 4-H1. LITHOLOGIC LOGS






NBP05-02 Site: 2
Hole: C
WD: 359 m
Core: 3, Top: 4.0 mbsf
Core Type: E, Push, 2.5m; 79% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 25 50
1
150 cm
2
201 cm
92
183
190
SS 37
SS 91
very dark greenish gray (gley1;3/10Y) silty mud with faint black mottling and diatoms
33 to 52 cm; green laminations
possible drilling disturbance
107 cm ; pebble
max. shear,
33 cm: 0.066 kg/cm2
82 cm: 0.098 kg/cm2
138cm: 0.096 kg/cm2
172cm: 0.092 kg/cm2
0 1 2
Core: 4, Top: 6.5 mbsf
Core Type: E, Push, 2.0m; 100.5% recovery
0 25 50
1
150 cm
2
201 cm
30
47
SS 184
dark greenish gray (1 gley, 3/10Y) silty mud with bivalve fragments, v fine sand lams and black mottles and pebbles and diatoms
50 to 81 cm; faint black and green lams
max. shear,
18 cm: 0.0 kg/cm2
63 cm: 0.18 kg/cm2
77 cm: 0.11 kg/cm2
107 cm: 0.124 kg/cm2
118 cm: 0.0 kg/cm2
163 cm: 0.132 kg/cm2
0 1 2
Electric Resistivity (ohm · m)


NBP05-02 Site: 2
Hole: C
Core: 5, Top: 9.5 mbsf
Core Type: E, Push, 1m; 41% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0
25
50
1
41
cm
soft very dark greenish gray (gley 1; 3/N) pebbly mud with diatoms
max. shear, 7 cm: 0.018 kg/cm2
0
1
2
Electric Resistivity (ohm · m)

Chapter 5: Seymour Island
Table of Contents

SITE 3: SEYMOUR ISLAND

A. BACKGROUND AND OBJECTIVES

The James Ross Basin lies within a back-arc terrain that is associated with the Cenozoic magmatic arc located along the Antarctic Peninsula (Elliot, 1988; Macdonald and Butterworth, 1990). A complete onshore stratigraphic record of the Cretaceous through Eocene occurs on James Ross and Seymour Islands. Neogene strata are not exposed on the islands but have been imaged offshore as a seaward dipping succession. Using intermediate-resolution seismic profiles, a seismic stratigraphic framework has been developed for the offshore strata (Anderson et al., 1992). The oldest stratigraphic unit, Unit S5, is inferred to be of late Eocene through Oligocene in age. The late Eocene-Oligocene is a transition from greenhouse to icehouse conditions and is associated with neritic faunal decline. Though well documented in low to mid latitudes (both in marine and terrestrial settings), very little is known about shallow-water biotas in high latitudes. These offshore dipping strata contain a record of the climatic and paleobiological changes that occurred while this region of Antarctica developed a subpolar climate and subsequently became glaciated. The older part of the succession was targeted as our third drill site.

B. OPERATIONS

Site 3 (64° 10.283′ S, 56° 16.335′ W, water depth 323 m, Fig. 5-B1) is located in the western most Weddell Sea, approximately 15 km east of Seymour Island. The intent was to sample off-lapping strata that have tentatively been assigned an Eocene age. The seas were calm and sea-ice conditions were suitable for drilling when the site was first reached. Sea-ice cover was approximately 6 to 8 tenths cover but much of the ice was soft and an ice-free area about 500 m west of the intended drill site was selected for drilling. Iceberg concentrations were relatively small, with an average of 6 to 12 icebergs located within 1 kilometer of the ship at the time the vessel went on station. Winds were between 5 and 10 knots.

The vessel arrived on location at 2105 hrs on 11 April 2005. The drill string was lowered and the core barrel run in, but the pipe had to remain suspended while the ship maneuvered around an iceberg.

The Paleogene drilling objective is located approximately 20 m below a till layer (Figure 5-B2). In order to reach the Paleogene section before ice or weather forced a move, the fastest means to get through the till was employed. With the tools at hand, rotary drilling with a standard 5-m core barrel in place was considered to be the most expedient means of accomplishing this task. Collecting samples in the till was secondary to the goal of penetrating the unit.

The first interval of 4.91 m drilled smoothly in 1 hr 25 min, but returned no usable sample in the core barrel. Cores 3A-2R and –3R penetrated only 20 cm and 80 cm respectively in about the same amount of time. At that point a push core barrel was run in to clear the hole (no core number given); although penetration was 1.59 m, no sediment was recovered. Drilling for Cores 4R-6R advanced the hole 10 m to 17.5 mbsf in about five hours, recovering only two loose bag samples.

At this point, it was suspected that the bit was jammed by rock, therefore the hammer sample barrel was deployed three times in succession over the next hour and a half. Each barrel was hammered repeatedly, and each time the cutter head upon retrieval showed deep gouges. Penetration of an additional 3.24 m was achieved with only one bag sample recovered after the second attempt.

The next interval from 20.74 mbsf was drilled, at which point strong resistance was encountered as indicated by up to 4 tons of bit weight, high torque, and mud pressure. Upon recovery, it was found that there was no trace of mud on the core catcher. As something was impeding the flow of mud, the string was pulled back up hole about 3 m and the hammer tool was again deployed in an attempt to clear the bit of suspected cobbles (Core 3A-11H).

As a test to determine if the bit had been cleared, the extended core barrel (Core 3A-12E) was run in to see if it would lock into place. It did not, but returned with a damaged cutter head, so something was clearly blocking the way. The hammer tool was then redeployed (Core 3A-13H) in another attempt to clear the bit. This tool eventually broke.

Still at 20.74 mbsf, the drillers determined that there could be a potential problem with the bit and that further drilling without inspection would probably be futile. Also, ice conditions were worsening. The captain advised that station keeping would continue for no more than 24 hours as a large concentration of sizable icebergs were entering the 3-mile surveillance circle, on course toward the ship. Under these circumstances, the hole was abandoned without sampling the Paleogene.

Upon recovery of the drill string, a crowbar was used to pry two tightly packed, fist-sized cobbles out of the throat of the drill bit. In addition, a fist-sized, cohesive ball of stiff sediment was recovered. The bit itself was undamaged, and the four roller cones were all functional. It was now clear that the problem was the presence of cobbles in the hole that were just a bit too large to enter the core barrel but which had not been broken up or pushed aside by the drilling tools. The short time window allocated us at this site by the ice conditions did not allow a second chance to overcome the drilling obstacles. By the time we had pulled the pipe, all of the sites along the entire transect had been occluded by ice moving up from the south, and there was no returning to any of them this season. We had no choice at this point than to head north.

Although the drilling target was not reached, much was learned from Site 3. First, the problem of cutting through the till has forced a re-evaluation of how to plan for this in the future. While penetration of 20.74 m in till was achieved in just over 24 hours, there is room for improvement for the next cruise. In order to attempt to address some of these issues, it was decided that sampling diamicton would be the focus of the rest of the 2005 SHALDRIL test cruise.

On two occasions, the ship was intentionally maneuvered up to 25 m from the hole to avoid ice and then brought back onto station without impeding the drilling operation. The ship handling side of the operation, as well as the performance of the drill rig in adverse conditions, was impressive at this site.

C. LITHOSTRATIGRAPHY

No samples from Hole 3A were taken without severe drilling disturbance. Very little recovery was achieved as a total of ten small bags of sediment and no core were retrieved from the hole (Fig. 5-C1). All the samples bear a very close resemblance and appear to be from the same lithologic unit. The samples are all dark gray diamicton, with grain sizes ranging from clays to large cobbles up to centimeters in scale. Most of grains are basaltic, with a few quartzose grains interspersed. The grains are sub-angular to sub-rounded.

D. BIOSTRATIGRAPHY

Introduction

NBP0502 Site 3 is located to the northeast of Seymour Island, Antarctica. The site is located along a sequence of dipping strata off Seymour Island and was chosen with the goal of 1) penetrating a veneer of Quaternary glacial tills, and 2) sampling underlying Paleogene sediments. Hole 3A was drilled at the site with the Seacore drill rig to a sub-bottom depth of 20.74 mbsf, but the till layer was not successfully penetrated. Initial shipboard paleontological work included sample preparations for diatoms and calcareous nannofossils.

Diatoms

Diatom smear slides were prepared for seven samples of drill cuttings from Hole 3A (Table 4-D1). Diatoms are common in the uppermost sample at 4.90 mbsf. Diatoms are otherwise rare to barren in all samples below this level. All taxa observed in the section are modern (extant) taxa, with the exception of the presence of very rare extinct taxa that are interpreted as reworked (Table 4-D1). A sample of cuttings from the lowermost section of the hole at 20.74 mbsf was sieved with a mesh opening of 10 microns in order to search for rare specimens of reworked taxa. No diatom taxa characteristic of the Eocene or Oligocene were observed in this sample, which may be expected if material from the underlying strata had been reworked into the tills.

Calcareous Nannofossils

Nannofossil smear slides were prepared and examined for seven samples of drill cuttings recovered from Hole 3C. All samples examined are barren of calcareous microfossils with the exception of one specimen of *Braarudosphaera bigelowii* observed in mud that was adhearing to the outside of the bit when it was retrieved on deck. The bit had penetrated to 20.74 mbsf, but the mud could have been derived from any level within the hole. This specimen, although well preserved, may be reworked from older strata, as *B. bigelowii* is not presently found in Southern Ocean waters of this latitude. This taxon however, ranges from the Cretaceous to Recent, thus the age of any possible reworked material cannot be determined.

E. PHYSICAL PROPERTIES

No usable material suitable for physical property measurements was recovered from this site.

F. SEISMIC STRATIGRAPHY

Anderson et al. (1992) and Sloan et al. (1995) used intermediate-resolution seismic data to conduct a seismic stratigraphic analysis of the continental shelf in the northern part of the James Ross Basin. These authors divided the stratigraphic succession into five seismic units and mapped these units around the northwestern margin of the basin. The oldest unit, Unit S5 is inferred to be of late Eocene age based on along-strike correlation to onshore strata (Fig. 5-F1). A prominent onlap surface separates S5 from S4 and is correlated to the 30 Ma lowstand surface of Haq et al. (1987). A shelf-wide unconformity and change in seismic facies marks the stratigraphic boundary between S4 and S3 (Fig. line PD91-35). Units S5 and S4 follow the curvature of the basin, whereas the younger units (S3 through S1) prograde directly offshore, toward the west. Unit S3 is tentatively assigned an early-middle Miocene age, based on the assumption that initial glaciation of the shelf corresponded with glaciation of the shelf on the northern side of the Antarctic Peninsula. A change from progradational to aggradational stratal architecture marks the boundary between S2 and S1. Based on correlations to similar stratal staking patterns around West Antarctica, Unit S1 is assigned a Plio-Pleistocene age. The drill sites selected for SHALDRIL were chosen to test this seismic stratigraphic model and to add chronostratigraphic constraints to units and bounding surfaces.

G. SITE SUMMARY

Site 3 is located off Seymour Island in the James Ross Basin. A penetration depth of 20.74 m (0% effective recovery) into compacted Quaternary diamicton was obtained at this site. As part of the demonstration of the Seacore drilling capabilities, the primary drilling target was the Paleogene seaward dipping stratigraphic section that lay below that diamicton. Sampling the Quaternary, therefore, was only of secondary concern. Although the primary target was not reached, the *Palmer*'s dynamic positioning system was given a rigorous test for holding station in ice. The ship performed admirably in these difficult circumstances and exceeded expectations.

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FIGURES

Figure 5-B1. Bathymetry around Site 3. Because of the ice cover, only limited multibeam data was able to be collected.

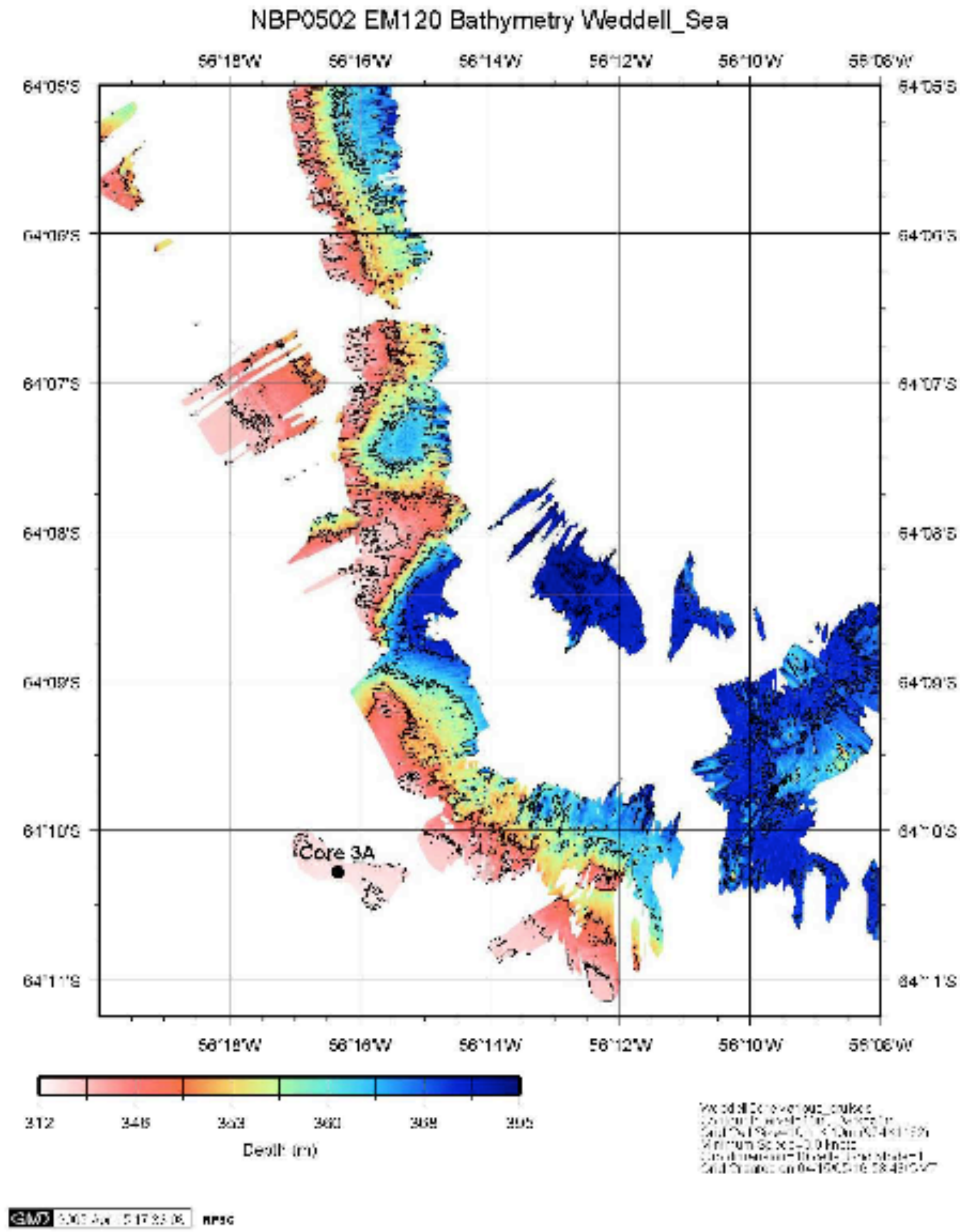

Figure 5-B2. Chirp 3.5 kHz data collected during NBP0502 showing at least 20 m of sediments above the last glacial maximum unconformity.

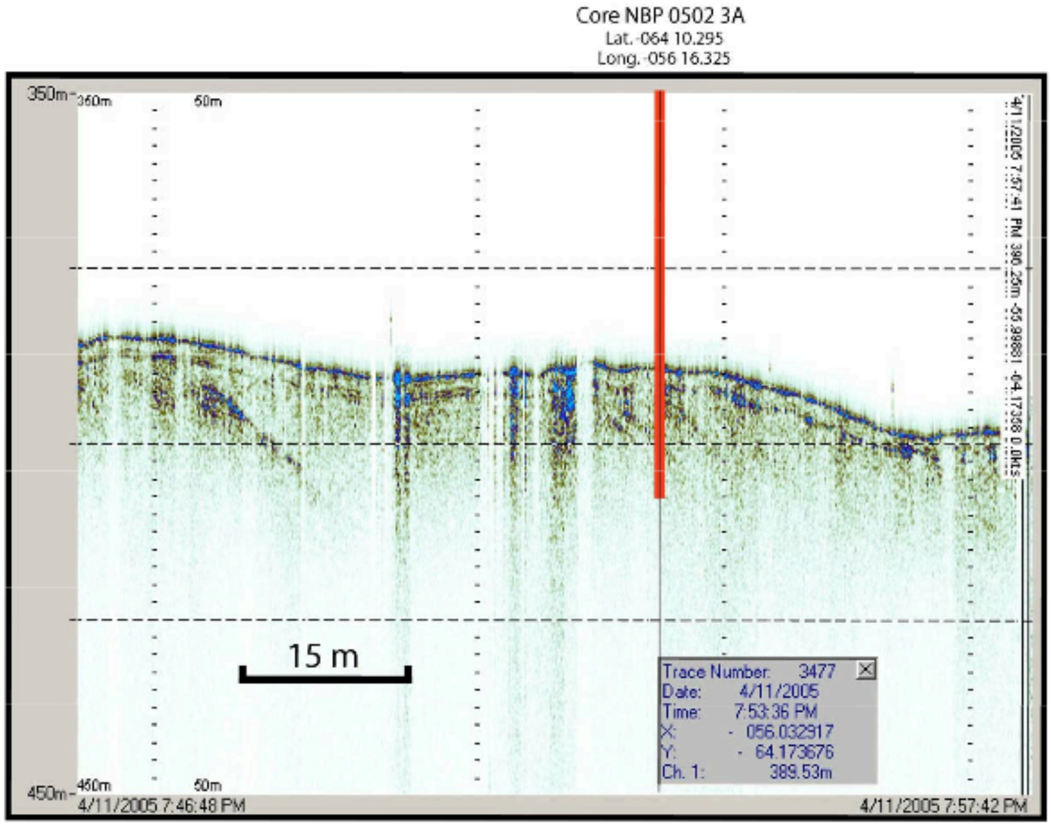

Figure 5-C1. Lithologic log for Core NBP0502 3A.

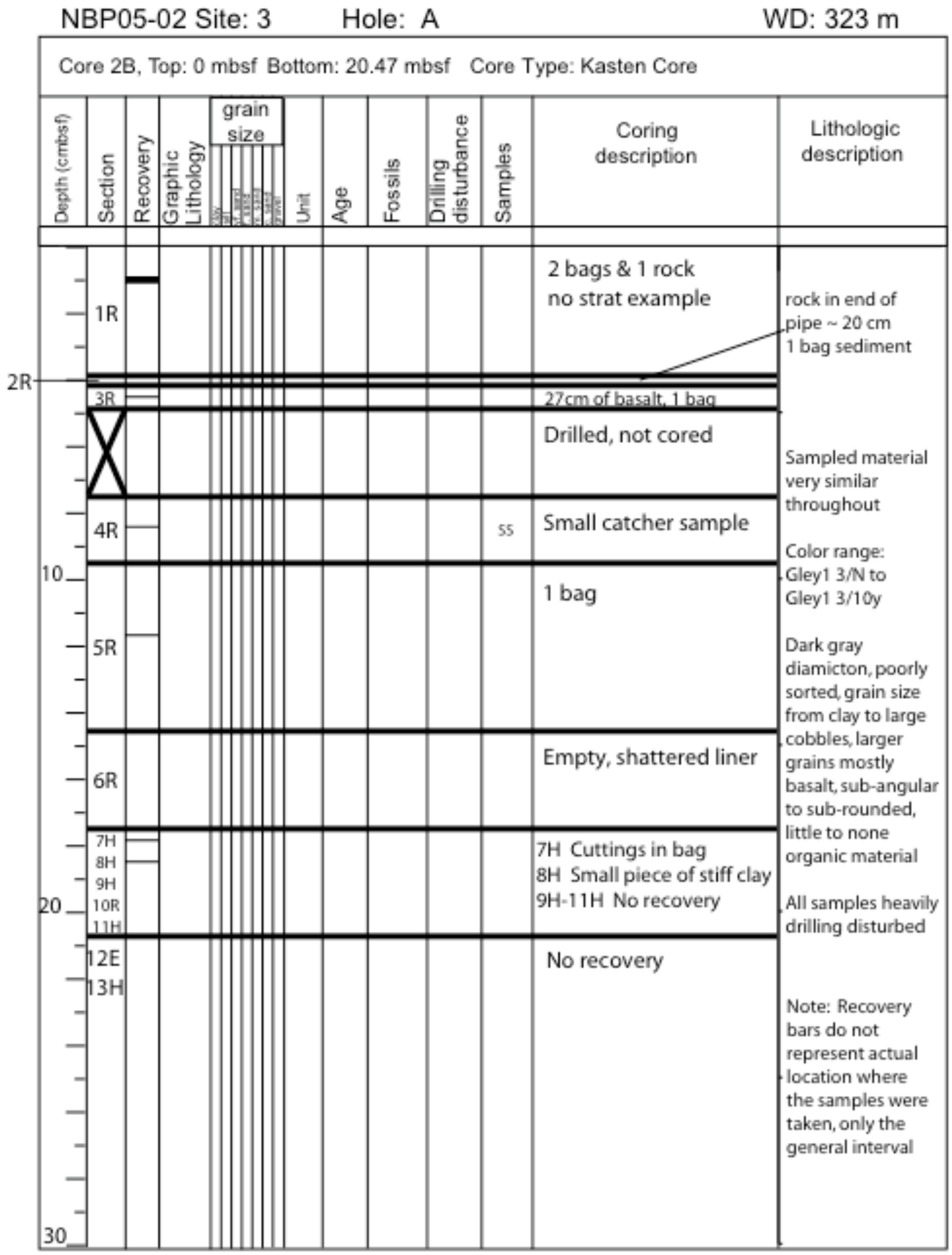

Figure 5-F1. Seismic line PD91-28 with site NBP0502 3A marked.

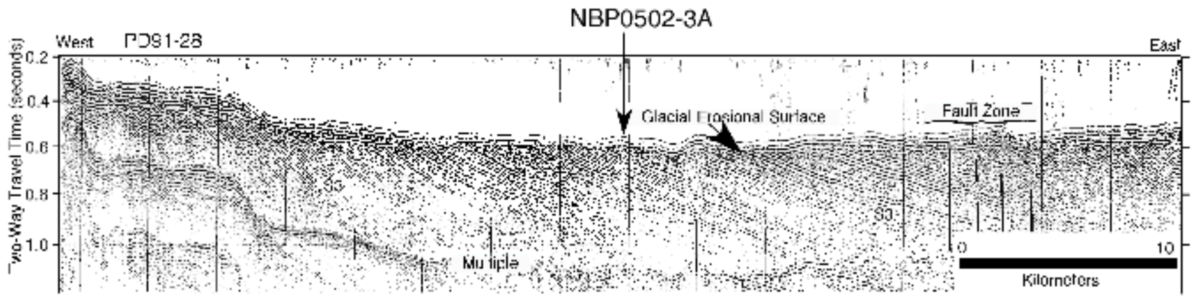

Figure 5-F2. Seismic line PD91-35.

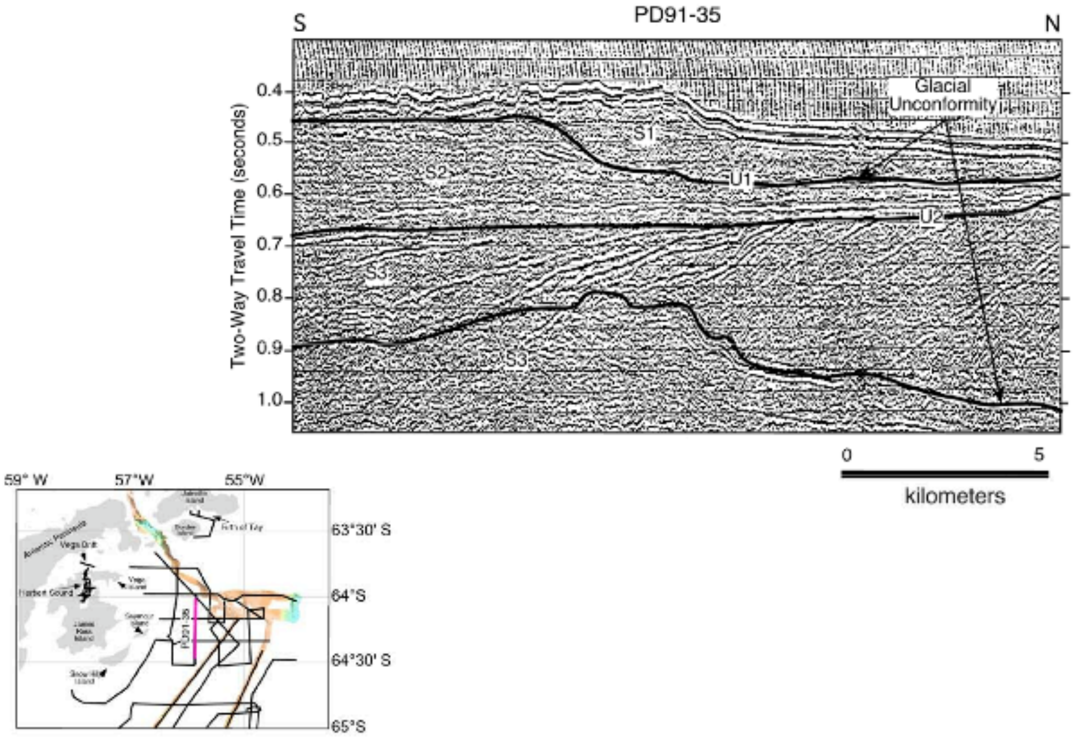

Table 5-B1. Drilling and coring log for Site 3.

SHALDRIL CRUISE NBP0502, SITE 3 (Seymour Island)
Multibeam Water Depth: 359 m

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
3A	1	R	0	4.91	4.91	0	0	0	0	0	0	0			101	430	1
3A	2	R	4.91	5.11	0.2	0	0	0	0	0	0	0			101	550	2
3A	3	R	5.11	5.91	0.8	0	0	0	0	0	0	0			101	730	2
3A		R	5.91	7.5	1.59	0	0	0	0	0	0	0			101	845	3
3A	4	R	7.5	9.5	2	0	0	0	0	0	0	0			101	1015	2
3A	5	R	9.5	14	5	0	0	0	0	0	0	0			101	1225	2
3A	6	R	14.5	17.5	3	0	0	0	0	0	0	0			101	1350	
3A	7	H	17.5	17.5	0	0	0	0	0	0	0	0			101	1600	
3A	8	H	17.5	17.5	0	0	0	0	0	0	0	0			101	1655	2
3A	9	H	17.5	17.5	0	0	0	0	0	0	0	0			101	1830	
3A	10	R	17.5	20.74	3.24	0	0	0	0	0	0	0			101	2030	
3A	11	H	17.5	17.5	0	0	0	0	0	0	0	0			101	2120	
3A	12	E	20.74	20.74	0	0	0	0	0	0	0	0			101	2315	
3A	13	H	20.74	20.74	0	0	0	0	0	0	0	0			102	20	4

Site	3A		
TD=	20.74		
Recovery Total		0 m	0 %
Recovery Corrected		0 m	0 %

1) Two ziplocks
2) One ziplock
3) No recovery at all, frozen mud valve, #4 repeated (although should have been given its own number)
4) Three ziplocks
10 bags total

Chapter 6: Bransfield Basin
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SITE 4: BRANSFIELD BASIN

A. BACKGROUND AND OBJECTIVES

The Bransfield Basin is an extensional basin that lies between the South Shetland Islands and the Antarctica Peninsula. The basin is approximately 100 km wide, and rifting is believed to have initiated at 2 Ma (Weaver et al., 1982; Gonzalez-Ferran, 1985, 1991) or in the early Pliocene (Jeffers et al., 1991). Regardless of the timing or causal mechanism for the formation of the basin, the associated rifting produced three subbasins, each with differing tectonic history. The central subbasin, extending from Trinity Peninsula to South Shetland Shelf, has a rifted sequence that is draped by prograding drift that terminates into trough mouth fans in the basin on the peninsula side. The southern side of the basin contains strata that are believed to span much of the Tertiary, although the older strata have been intensely deformed. Back-up sites on the narrow shelf of the south side of the basin are intended to provide chronostratigraphic constraints on the age of stratigraphic units in the region.

B. OPERATIONS

Site NBP0502-4 is located at 62° 58.4982′ S, 58° 13.1368′ W in 544 m of water (Fig. 6-B1). Dynamic positioning was achieved easily when arriving on site and a kasten core (Hole 4A) was recovered. The core is 48 cm in length including the intact core catcher sample (Table 6-B1). API drill string was run almost to the mudline. However, before coring operations could begin the wind and, more importantly, the heave increased dramatically. The *Palmer* was able to hold station. However, the heave compensation of the rig was close to maximum working conditions. If coring operations were already underway, the site may have been continued. But, it was decided to not start a hole under these conditions.

C. LITHOSTRATIGRAPHY

Hole NBP0502-4A sampled two distinct lithologic units (Fig. 6-C1). Unit I, which extends from 0.00 to 0.15 mbsf, consists of dark greenish gray, poorly sorted sandy silt, with sub-angular grains ranging in size up to several cm. The cobble lithology is dominantly basalt and gneiss. The contact between Unit I and Unit II is at 0.15 mbsf and is a sharp boundary. Unit II, which extends from 0.15 to 0.48 mbsf, consists of a very dark greenish gray, very fine sandy mud with scattered pebbles throughout but no cobbles. The grains are angular and poorly sorted.

D. BIOSTRATIGRAPHY

Introduction

NBP0502 Site 4 is located in the northeastern region of Bransfield Strait, south of King George Island. One short (0.48 m) kasten core (Hole 4A) was taken at the site. Initial shipboard paleontological work on the kasten core included sample preparations for diatoms and calcareous nannofossils.

Diatoms

A diatom smear slide was prepared for one sample from Hole 4A (Sample 4A-1KC-CC; 0.48 mbsf). Diatoms are poorly preserved in the sample but relatively common. The assemblage consists of both modern (extant) taxa and extinct, reworked taxa (Table 4-D1). Large, heavily-silicified fragmented and complete valves of *Stephanopyxis* spp. are a relatively common component of this assemblage. *Stephanopyxis* spp. are typically abundant in Eocene to Miocene assemblages from the Antarctic shelf. The absence of *Hemiaulus* spp. and *Pyxilla* spp. (heavily-silicified taxa that are common in Eocene and lower Oligocene strata on Antarctic shelf) in the Hole 4A assemblage suggests that the reworked material is late Oligocene in age or younger. The rare occurrence of *Coscinodiscus* sp. A (of Harwood, 1986) and *Denticulopsis* spp. may further narrow the age of the reworked material to late Oligocene to middle Miocene.

Calcareous Nannofossils

A nannofossil smear slide was prepared for one sample from Hole 4A (Sample 4A-1KC-CC). This slide is barren of calcareous nannofossils, except for very rare specimens of *Thoracosphaera*.

E. PHYSICAL PROPERTIES

Physical property measurements at Site 4 were limited to a very short kasten core (Hole NBP0502-4A). Total core recovery was 48 cm, including the core catcher that remained intact. The sediment-water interface was preserved as several live brittle stars were observed and sampled. Electric resistivity and magnetic susceptibility were run on the small section though results were nondescript. Electric resistivity measurements were made every 2 cm. Discrete samples (normally 5 cc, using a syringe sampling system) were made and were not processed onboard. These samples were stored in weighed vials and kept in the cooler until transport. The core was scraped down 4 cm and a half-split liner obtained an archive sample in the unsampled region. This half-split liner was run through the MSCL track to obtain magnetic susceptibility data at 1-cm intervals. Due to the limited recovery, no interpretation can be made at this time.

F. SEISMIC STRATIGRAPHY

Seismic stratigraphic studies of the Bransfield Basin were conducted by Jeffers and Anderson (1990), Banfield and Anderson (1995) and Prieto et al. (1998). These studies provided the seismic stratigraphic framework used to select drill sites in the

Bransfield Basin. In addition, seismic data were collected at this location during the NBP0502 cruise. These data, using two 50 cubic inch air guns and a single channel ITI streamer, were collected to help constrain the alternate drill sites. The data were shot during weather that did not permit drilling in the Weddell Sea. The data are of high quality but did not yield new drill sites that are better than those that had been previously selected using the 1991 data.

Four seismic stratigraphic units occur on the southern margin of the Bransfield Basin. These are tentatively correlated to seismic stratigraphic units in the offshore Seymour Island area, although this correlation is very tenuous. The drill sites in the Bransfield Basin were intended to provide chronostratigraphic constraints on the age of sequences within the basin. This would allow examination of the same scientific problems outlined for the offshore Seymour Island area.

Since only a kasten core was obtained at this site, the objectives described above were not met. However, the kasten core can be used for Holocene studies. The seismic data used for previous stratigraphic studies does not show the detail of the Holocene sediments (Fig. 6-F1), but the Chirp data obtained on this cruise highlight that section (Fig. 6-F2).

G. SITE SUMMARY

A kasten core at Site NBP0502-4 sampled approximately 5% or less of the soft sediment sitting above the last glacial maximum unconformity (Fig. 6-F2). Aside from studies of the very recent changes in the Bransfield Basin, this site may not be extremely useful. However, a valuable lesson was learned about the dynamic positioning system and the heave compensation system. It is now clear that the *Palmer* will be able to maintain station in heave beyond that which is acceptable for drilling.

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FIGURES

Figure 6-B1. Multibeam swath bathymetry of the Bransfield Basin around Site 4.

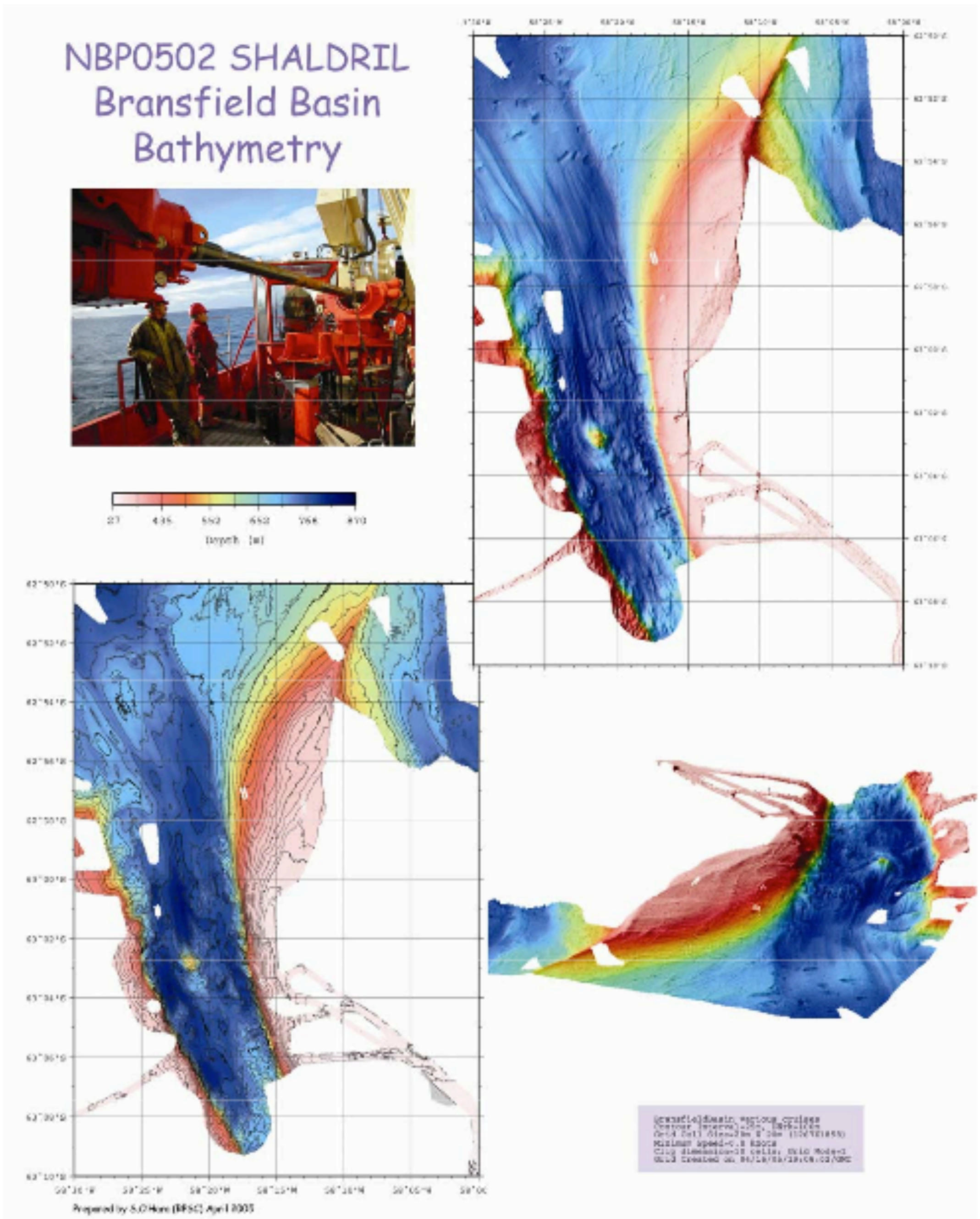

Figure 6-C1. Lithologic log of core NBP0502-4A-KC.

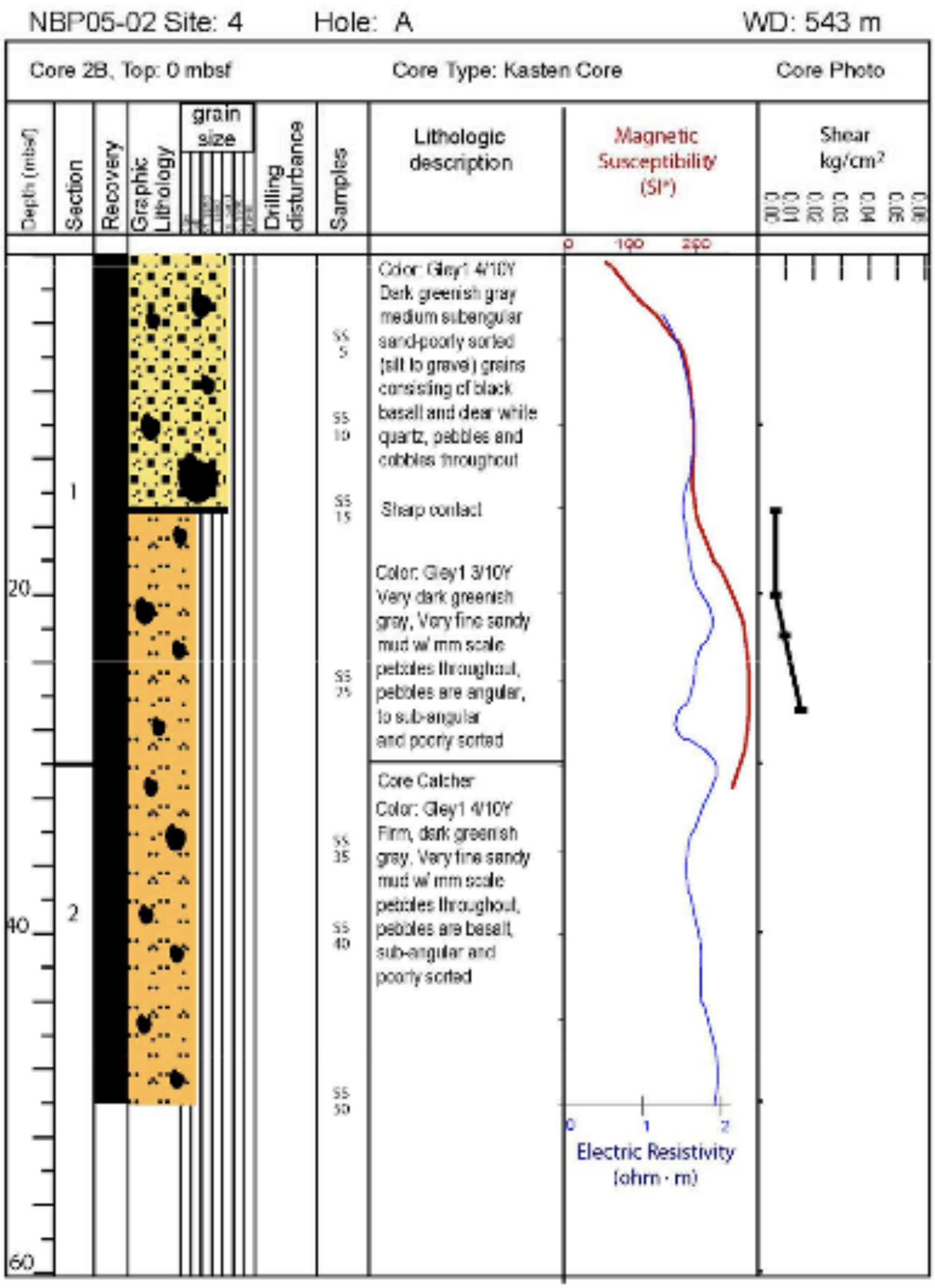

Figure 6-F1. Seismic line PD91-20A showing the location of Core NBP0502-4A-KC.

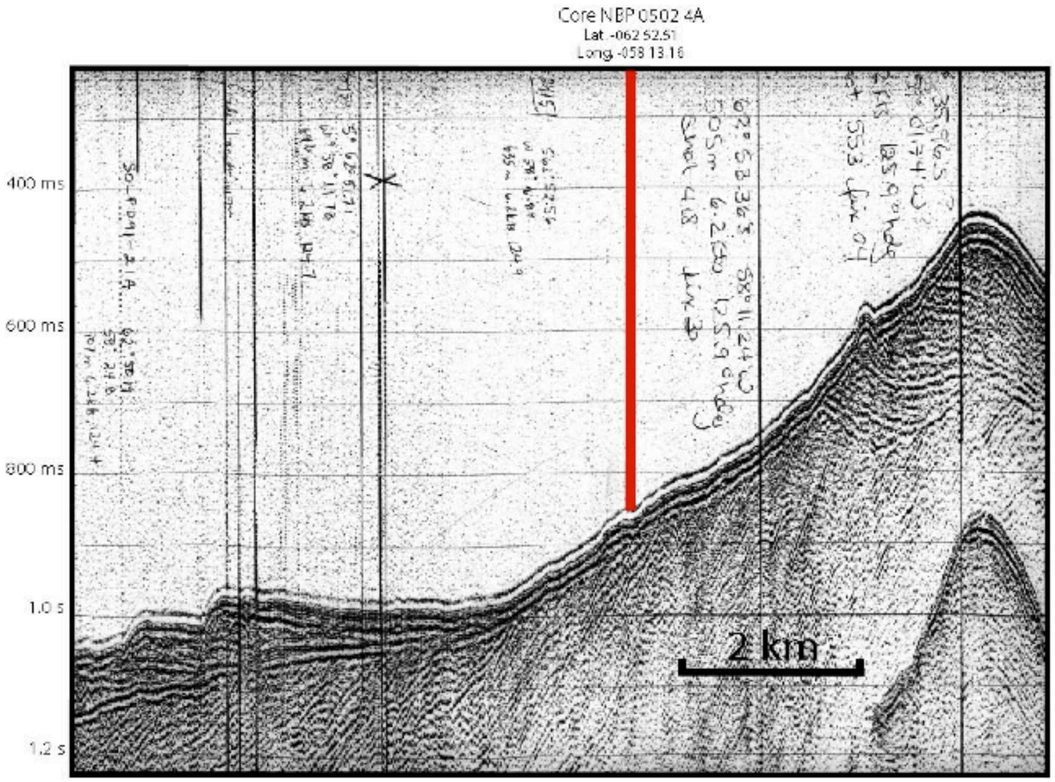

Figure 6-F2. 3.5 kHz Chirp data from NBP0502 showing the location of Core NBP0502-4A-KC.

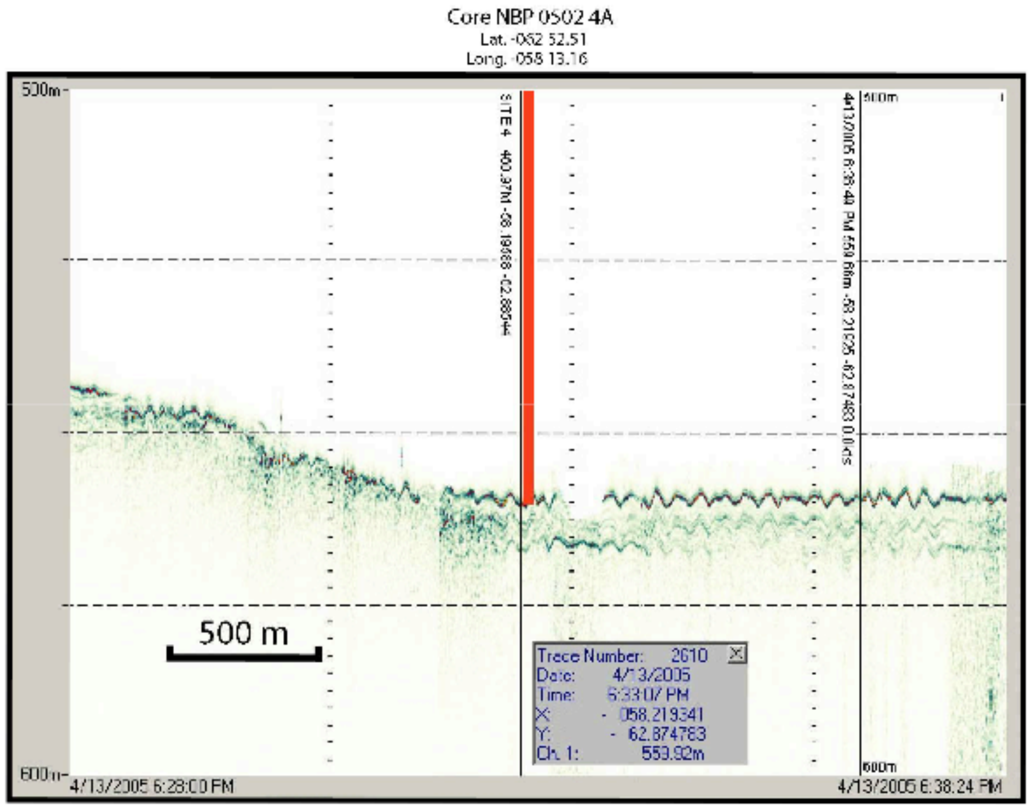

Table 6-B1. Coring recovery from Site 4.

SHALDRIL CRUISE NBP0502, SITE 4 Bransfield Basin

Multibeam Water Depth 542

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
4A	1	K	0	0.48	0.48	0.48	0.48	0	0	0.48	100%	100%	1	0-30	103	1949	
													2	30-48			1

1) Section 2 from core catcher

SITE 5: HUGHES BAY

Site 5 was drilled in Hughes Bay (64° 19' S, 61° 20' W) in 468 m of water (Fig. 7-1). The purpose of the site was to test the new "advance inner bit" or push rod manufactured on board in order to better penetrate the till. This bit was designed with the intention of improving the rate at which we were able to penetrate through the stiff till encountered throughout the cruise. The tool consisted of a non-rotating rod that extended beyond the drill bit. Conceptually, the rod was supposed to push cobbles away from the drill bit and prevent them from jamming the rotating bit.

Based on cores from PD91, the expected bottom was a thin mud layer overlying compacted diamicton. Two holes were attempted. No kasten core was attempted and no recovery was made in the two drill core attempts (Table 7-1). The bottom hole assembly became stuck during both attempts. While this lack of success meant that the "advance inner bit" design was not exactly right, the attempt taught the SHALDRIL party that an inner-bit system could help to advance the drill bit. Plans for new sampling tools for the 2006 SHALDRIL cruise will hopefully include an inner-bit system.

FIGURES

Figure 7-1. Multibeam swath bathymetry of Hughes Bay with the location of NBP0502 Site 5 drilling attempt marked.

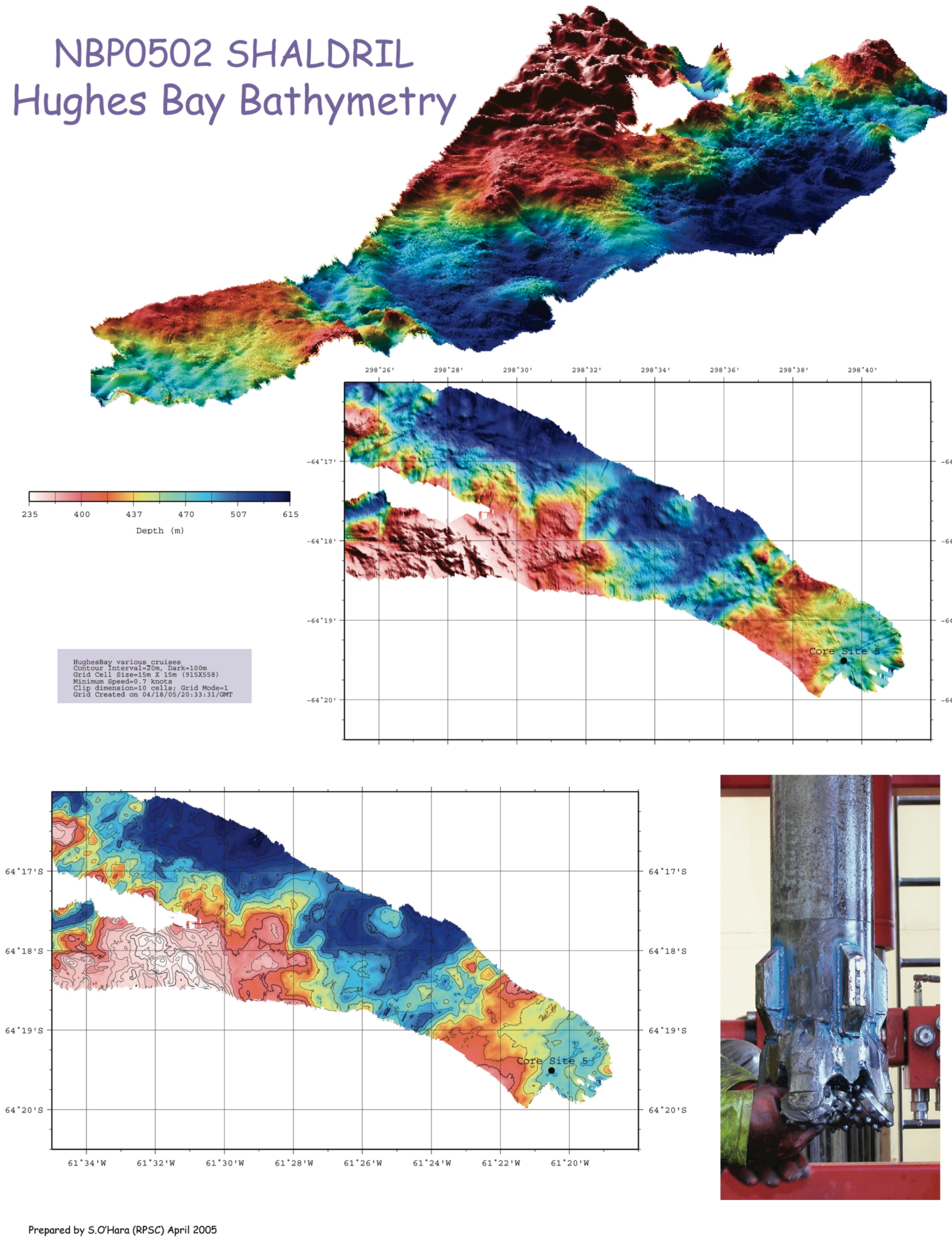

Table 7-1. Drilling attempts and recovery at NBP0502 Site 5.

SHALDRIL CRUISE NBP0502, SITE 5 (Hughes Bay)

Multibeam Water Depth 468 m

Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
5A		*	0	1	0	0	0	0	0	0	0	0					
5B		*	0	2.5	0	0	0	0	0	0	0	0					

*) Testing new advance inner bit; nothing recovered, bit stuck.

Site		
TD=		
Recovery Total	0 m	##### %
Recovery Corrected	0 m	##### %

Chapter 8: Lapeyrère Bay
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SITE 6: LAPEYRÈRE BAY

A. BACKGROUND AND OBJECTIVES

Lapeyrère Bay is one of two fjords on the east side of Anvers Island, in the Palmer Archipelago. Lapeyrère Bay experiences colder conditions and higher precipitation than at Hughes Bay (Site 5) and Maxwell Bay (Site 1). Fed by a large outlet glacier, Iliad Glacier, the bathymetry of Lapeyrère Bay consists of a long glacial trough with local flank highs (Fig. 8-A1). This site was selected because it provided shelter from strong winds and because piston cores from the area had previously sampled ~6 m of pebbly mud. Seismic data collected in the fjord during the 1985 Deep Freeze cruise showed acoustically laminated sediments in the deepest part of the bay, at depths below 600 meters. The site is located on the northern flank of the bay in 382 meters of water on a lobate feature that is interpreted as a glacial outwash fan (Fig. 8-A1).

The primary objective for this site was to test the piggyback system for sampling pebbly glacial marine sediments.

B. OPERATIONS

The final site for the NBP0502 SHALDRIL cruise was selected in large part to escape the weather. Drilling operations were not able to continue at Hughes Bay due to increased wind and heave. Thus, Lapeyrère Bay was selected because of the protection Anvers Island would provide from the wind.

Dynamic positioning was again achieved without difficulty. A kasten core was taken after arriving on station in order to capture the sediment-water interface. The drillers wanted to characterize the surface sediments before drilling. The piggyback system used for the first SHALDRIL cruise employs a clump weight that is placed on the seafloor. The clump weight should ideally be placed in locations with some soft sediment, so that it can be partially buried and thus not tip over, but not so much soft sediment that it could become entirely buried. While maybe somewhat softer than ideal, the kasten core indicated that the location was acceptable for deploying the piggyback system and putting the clump weight on the seafloor.

Hole NBP0502-6B was the first hole attempted using the piggyback system. The clump weight and API pipe were successfully run to the seafloor. The inner piggyback string, the HQ string, was run about 250 m into the water. At that point, the HQ string broke. It was eventually recovered by running additional HQ string to retrieve the piece but by that time the string had sunk 28 m into the sediment. The reasons for this break in the HQ string were not apparent. The vessel had not moved off station during the time the break occurred. One theory about what caused the break was that the clump weight had moved down slope slightly, causing a bend in the API pipe for which the more rigid HQ string could not compensate. Thus, a location with less seafloor relief was sought for Hole 6C.

Since no problems were presumed with the API string, the vessel moved to Hole 6C with the API string and clump weight raised just above mudline. The HQ string was successfully run and two core runs were made reaching a depth of 3.4 m, although no core was recovered. During the third core run, the HQ string broke near the ship's hull. The string sank about 20 m in soft sediment and was retrieved using the fishing tool. Again, the ship did not lose position. Because a flatter site had been selected, the possibility that seafloor slope was a factor was ruled out. After two inexplicable breaks in the HQ string, piggyback operations were terminated. The broken pieces of the HQ string will be sent for metallurgical analysis, and at this time the HQ sting used is suspected to contain unacceptable flaws. All drill string was brought on board after the second break but no other problems were identified.

The vessel relocated to a third position where a second kasten core was taken. Following the kasten core, the API pipe was run and extended push sampler cores were taken. Eight push cores with about 40% recovery brought the hole to 20-m depth. The recovery was much lower than other sites where soft sediment was cored. Much of the sediment recovered appeared to have been extremely disturbed and fluidized. This may be due to the API string resting on the intervals to be cored on a few occasions while problems were addressed.

The final push sample encountered something quite hard that could not be sampled with the extended core barrel. The sampling tool was therefore switched to obtain a rotary core. Drilling with the API string was extremely slow, but progress was made. After a couple hours of drilling, a 0.13-m core of granite was recovered. Because of the weathering pattern on the side of the sample, it is assumed that a large granite boulder was drilled, not the bedrock. Either way, the ability to core hard rock was demonstrated.

Hole 6E was terminated by an unplanned excursion from the drill site. Winds picked up gradually while on DP, but there was a sudden increase to gusts of about 40 knots. Just as discussions began about the potential need to terminate drilling, the *Palmer* was blown off station by over 140 m. The drillers pulled pipe up above the mudline as quickly as possible. Once the movement had been stopped, the drillers were able to recover the rest of the pipe. No damage was found and all equipment was recovered. See the cruise summary chapter for a full discussion of dynamic positioning on the *Palmer*.

C. LITHOSTRATIGRAPHY

NBP0502 Site 6 consists of two kasten cores and one drill core. The lithostratigraphy of these cores is illustrated in Figures 8-C1, 8-C2, and 8-C3. The first kasten core (Hole 6A) recovered 29 cm of greenish gray mud with very small-sized pebbles (several mm) scattered throughout. The average pebble size increases gradationally towards the bottom of the core, and there is a very slight color change to lighter greenish-gray towards the bottom. This core had occasional black mottling and was otherwise relatively homogeneous. The second kasten core (Hole 6D) recovered 293 cm of greenish gray sandy mud with very small pebbles scattered throughout. Similar to Hole 6A, this core is generally homogenous and composed of a small but significant amount, perhaps 1-2%, of pebbles and/or coarse sand.

The vast majority (0-20 mbsf) of sediments recovered in Hole 6E (Figure 8-C3) were dark greenish-gray mud with very fine sand and mm-sized pebbles scattered throughout, similar to the kasten cores. The drill cores had abundant black mottling and very few sand layers. The lithology of the pebble-sized clasts included granites and basalts. Low shear strengths from 5.0 to 7.4 m likely reflect that that section of core was somewhat disturbed in the drilling process. At the base of Hole 6E, a 13-cm interval of granite was obtained between 20.0 and 20.3 m.

D. BIOSTRATIGRAPHY

Introduction

NBP0502 Site 6 is located in Lapeyrère Bay on the north side of Anvers Island, western Antarctic Peninsula. Two kasten cores (Holes 6A and 6D) were taken at the site, and three longer cores were attempted with the Seacore drill rig (Holes 6B, 6C, and 6E). The kasten cores from Holes 6A and 6D recovered 0.29 m and 2.93 m of sediment, respectively. Hole 6E was the most successful Seacore hole and was drilled with the push-core tool to a sub-bottom depth of 20.03 mbsf. Initial shipboard paleontological work included sample preparations for diatoms, calcareous nannofossils, and radiolarians.

Diatoms

Diatom smear slides were prepared for five samples from Holes 6C, 6D, and 6E (Table 4-D1). Diatoms are abundant and moderately-to-well preserved, and a similar diatom assemblage is present in all samples. All diatom taxa observed are modern (extant) species. The assemblages are dominated by *Chaetoceros* resting spores, *Thalassiosira antarctica* var. *antarctica*, and *Fragilariopsis kerguelensis*, with secondary abundances of *Cocconeis* spp., *Eucampia antarctica* var. *recta*, *Fragilariopsis curta*, *Fragilariopsis vanheurckii*, and *Thalassiosira gracilis* (Table 4-D1). The assemblage represents a mixed ecological signal that results from seasonal changes at the site, reflecting both significant sea-ice influence (e.g., *F. curta* and *T. antarctica)* and more open-marine conditions (e.g., *F. kerguelensis*). Similar assemblages were observed in the Holocene section recovered in Maxwell Bay (SHALDRIL Hole 1B).

Calcareous Nannofossils

Nannofossil smear slides were prepared and examined for several samples from Holes 6D and 6E. Samples from both holes yielded rare abundance of calcareous nannofossils. The diversity of calcareous nannofossils remained unchanged from previous SHALDRIL sites. However, abundance and preservation was highest at this location. The assemblage consists of two species of *Thoracospheara*, a calcareous dinoflagellate. Specimens identified as *Thoracosphaera* sp. cf. *T. heimii* and *Thoracosphaera* sp. are present in Samples 6D-1KC, 0-2 cm, 6D-1KC-CC, 6E-4E-CC, and 6E-8E-CC.

Preliminary counts of *Thoracospheara* specimens were made for all samples examined from Hole 6D and 6E (Table 8-D1). Unusually abundant specimens were observed in Sample 6E-6E-CC; seventeen *Thoracosphaera* sp. and ten *Thoracosphaera* sp. cf. *T. heimii* were observed in this sample (Table 8-D1). Relatively abundant *Thoracospheara* in samples from Site 6 may indicate the influence of warmer, more northerly waters. This observation is consistent with the common occurrence of the diatoms *E. antarctica* var. *antarctica* and *F. kerguelensis* (Table 4-D1).

Radiolarians

One sample was examined for radiolarians from Hole 6D. The sample was taken from the bottom of the kasten core (Sample 6D-1KC-CC) and has a well preserved, low diversity radiolarian assemblage, few to common in abundance. All specimens are typical modern cold water radiolarians. These include *Antarctissa denticulata*, *Antarctissa strelkovi*, *Lithelius nautiloides, Cycladophora davisiana, Spongothrocus glacialis,* and a number of unidentified spumellarian species. In addition to radiolarians, well-preserved benthic foraminifera are abundant in the core-catcher sample.

E. PHYSICAL PROPERTIES

Introduction

Physical properties at Site 6 were used to assist in the interpretation of the stratigraphic and geophysical data from Lapeyrère Bay of Anvers Island. Of the five holes drilled at Site 6, only Holes 6A, 6D and 6E had adequate recovery for physical property analyses. Hole 6A is a 0.29 m kasten core that recovered the sediment/water interface but had little penetration. Hole 6D, taken ~500 meters laterally from Hole 6A, obtained a 2.9 m kasten core but did not recover the sediment-water interface. Hole 6E was a push core that reached 20.3 mbsf. As at the other sites, measurements were made by three methods: MSCL track (which sampled every cm and recorded magnetic susceptibility and GRAPE data), electric resistivity probe, and discrete sampling. Depending on the coring technique, some of the methods varied.

The kasten core recovered from Hole 6A is 0.29 m in length, including intact core-catcher material. Electric resistivity and magnetic susceptibility were run on the small section at 2-cm intervals. Discrete samples (normally 5 cc, using a syringe sampling system) were taken but not processed onboard. These samples were stored in weighed vials and kept in the cooler until transport. The core was scraped down 4 cm and a half-split liner obtained an archive sample in the unsampled region. This half-split liner was run through the MSCL track to obtained magnetic susceptibility data at 1-cm intervals and gamma-ray counts. Due to the limited recovery, no interpretation can be made at this time.

The kasten core recovered in Hole 6D is 2.93 m in length, and electric resistivity and discrete measurements were made every 2 cm. As with the previous kasten cores, the core was scraped down 4 cm and a half-split liner obtained an archive sample in the unsampled region. This half-split liner was run through the MSCL track to obtained magnetic susceptibility data at 1-cm intervals.

Electric resistivity measurements and discrete samples were taken at a 10-cm resolution in Hole 6E. Hole 6E core liners were run on the MSCL at 1-cm intervals. After splitting then discrete and electric resistivity measurements were made at a 10-cm interval. Data obtained from the MSCL track includes magnetic susceptibility and gamma ray counts.

All magnetic susceptibility and GRAPE data will need to be calibrated back at Antarctic Research Facility (ARF) at Florida State University (FSU) and only relative trends can be assessed at this time.

Electric Resistivity and Magnetic Susceptibility

Electric resistivity and magnetic susceptibility show downcore variability in all cores from Site 6. For Hole 6D, electric resistivity has some variability with small peaks that correlate with relative MS peaks at 48, 102, 172, and 196 cm. There is no visual correlation with changes in lithology, indicating that these peaks may be related to ice-rafted debris not visible at the liner surface. The magnetic susceptibility curve shows a 100 SI* drop between the archive core liners. There is no explanation at this time for this drop, as there is very little coring disturbance in the kasten core. This drop may be related to problems the MSCL has had throughout the cruise, and these results should only be used as a relative measure of magnetic susceptibility for these cores (and those at previous sites).

Hole 6E results are speculative but show some consistent patterns. Electric resistivity increases downcore showing the effects of compaction. Though the core recovery was marginal and many sections showed coring disturbance, there is a correlation of peaks of both magnetic susceptibility and electric resistivity with pebbles throughout the core. Data from Sections 6E–6E-1 and –6E-2 (Fig. 9-C-X) clearly show the effect of coring disturbance on magnetic susceptibility. The disturbed section shows approximately 80 SI* lower values than the background levels observed for the entire core.

Concluding Discussion

Due to limited recovery, minimal interpretation can be made for the sections recovered at Site 6. The sediment lithology does not vary greatly within these cores, and both the electric resistivity and magnetic susceptibility measurements are close to background levels. Small to large deviations from these background profiles are usually associated with pebbles observed within the core. Core sections in which magnetic susceptibility was run prior to splitting have lower values than average values for those sections with extreme coring disturbance. All cores will be rerun on the MSCL at the ARF at FSU once the MSCL track is repaired and calibrated.

F. SEISMIC STRATIGRAPHY

Seismic data were collected in Lapeyrère Bay during DF85. The data were acquired using a 4 kJ sparker and a single-channel streamer. Seismic data collected in Lapeyrère Bay show strong reflectors overlying acoustic basement (Fig. 8-F1; Griffith and Anderson, 1989). The chaotic and hummocky surface at the base of the outer basin slope suggest amalgamated slumps. The inner bay is characterized by acoustically laminated sediments (Griffith and Anderson, 1989). The drill site is located in the inner bay in the more laminated section (Fig. 8-F2).

G. SITE SUMMARY

Located in Lapeyrère Bay on Anvers Island of the Palmer Archipelago, five holes were attempted at Site 6, but sediment was recovered only from three holes (Holes 6A, 6D and 6E). All sites are located within less than 500 meters of each other. Hole NBP0502-6D and NBP0503-6E are at ~ 64^o 23.5143′ S, 63^o 14.9917′ W, water depth 390 meters. In this sheltered region, we tested the piggyback drilling capabilities of the drill rig in a bay that consisted of a glacial outwash fan overlying bedrock.

Hole NBP0502-6A is a short kasten core that showed that this site was dominated by sandy mud with pebbles scattered throughout. The piggyback system was first attempted at this location, Hole 6B, but failed. The drill string was lifted and moved less than 400 m to Hole 6C. While stringing the HQ pipe, the pipe separated again and this hole was abandoned. Hole 6D was located about 500 m to the southwest of Hole 6C, and a 2.93 m pebbly sandy mud was sampled with a kasten core. Hole 6E was a 20.3 m push and rotary core which recovered very similar material as the kasten cores until a granite boulder was reached at 20.0 mbsf. Diamond bit drilling recovered 13-cm length of granite. All cores contain a diatom assemblage that is similar to Maxwell Bay (Site 1) and are moderately-to-well preserved and abundant. This diatom assemblage gives a mixed ecological signal reflecting both open marine and sea-ice conditions. The calcareous nannofossils found near the bottom of the core (NBP0502-6E 6E-CC) indicate the influence of warmer waters.

H. APPENDIX

Appendix 8-H1. Lithologic Logs

Appendix 8-H1 contains the detailed lithologic logs from core NBP0502-6E and follows the figures.

REFERENCES

Griffith, T.W., and Anderson, J.B., 1989. Climatic control of sedimentation in bays and fjords of the northern Antarctic Peninsula. *Marine Geology*, 85: 181-204.

FIGURES

Figure 8-A1. Multibeam swath bathymetry of Lapeyrère Bay showing Site 6.

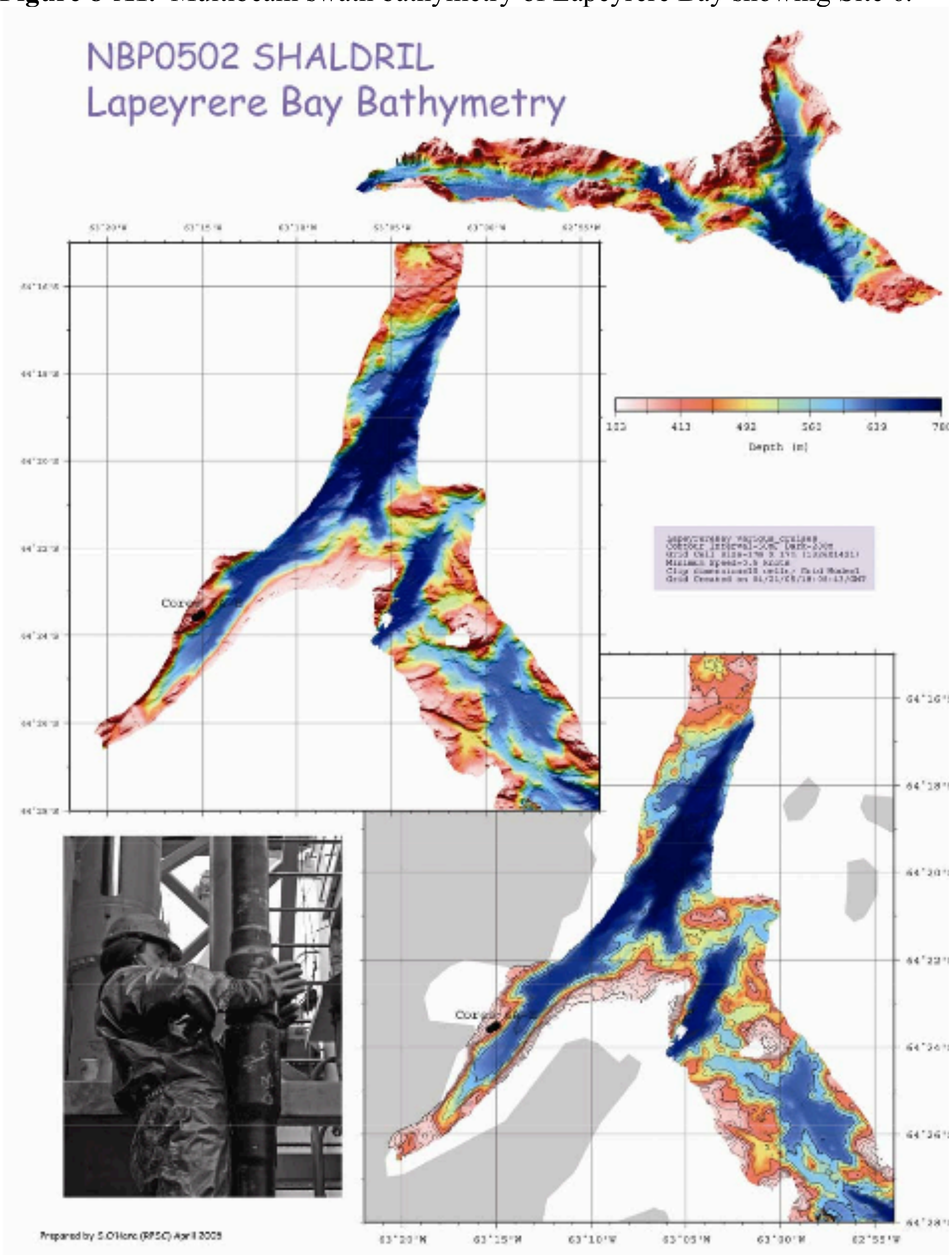


Figure 8-C1. Lithologic log of kasten core NBP0502-6A-KC.

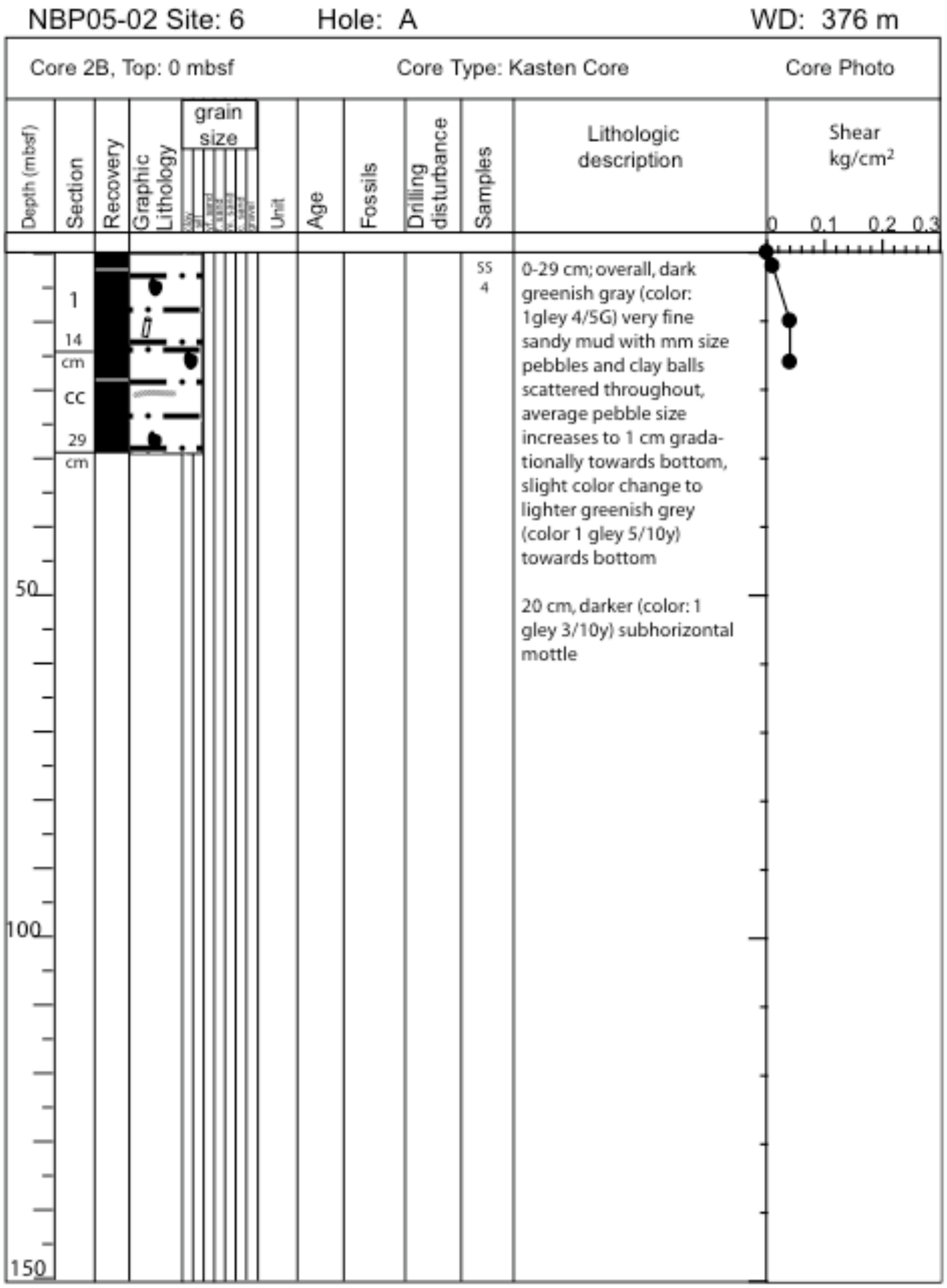


Figure 8-C2. Lithologic log of kasten core NBP0502-6D-KC.

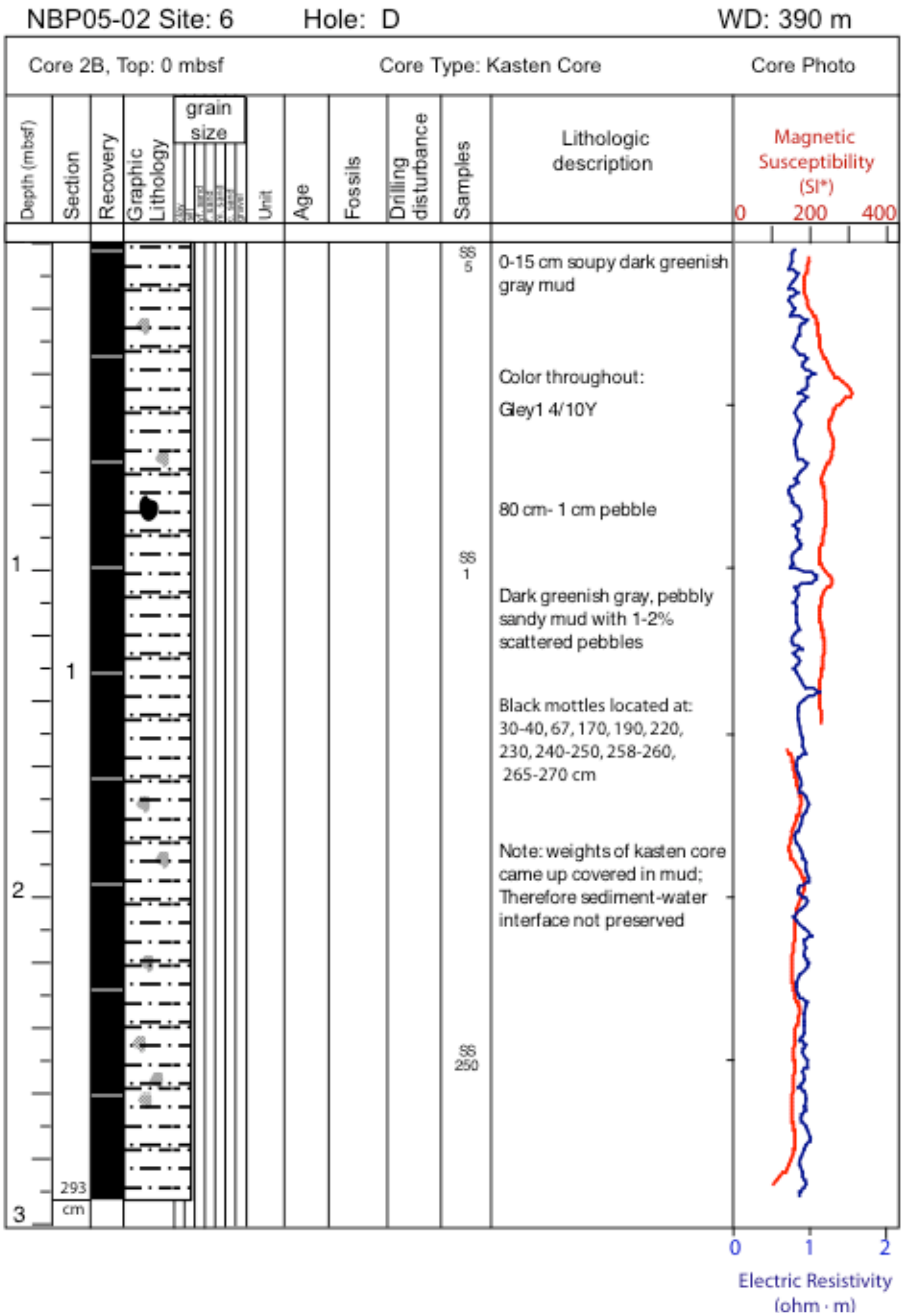


Figure 8-C3. Lithologic log of drill core NBP0502-6E.

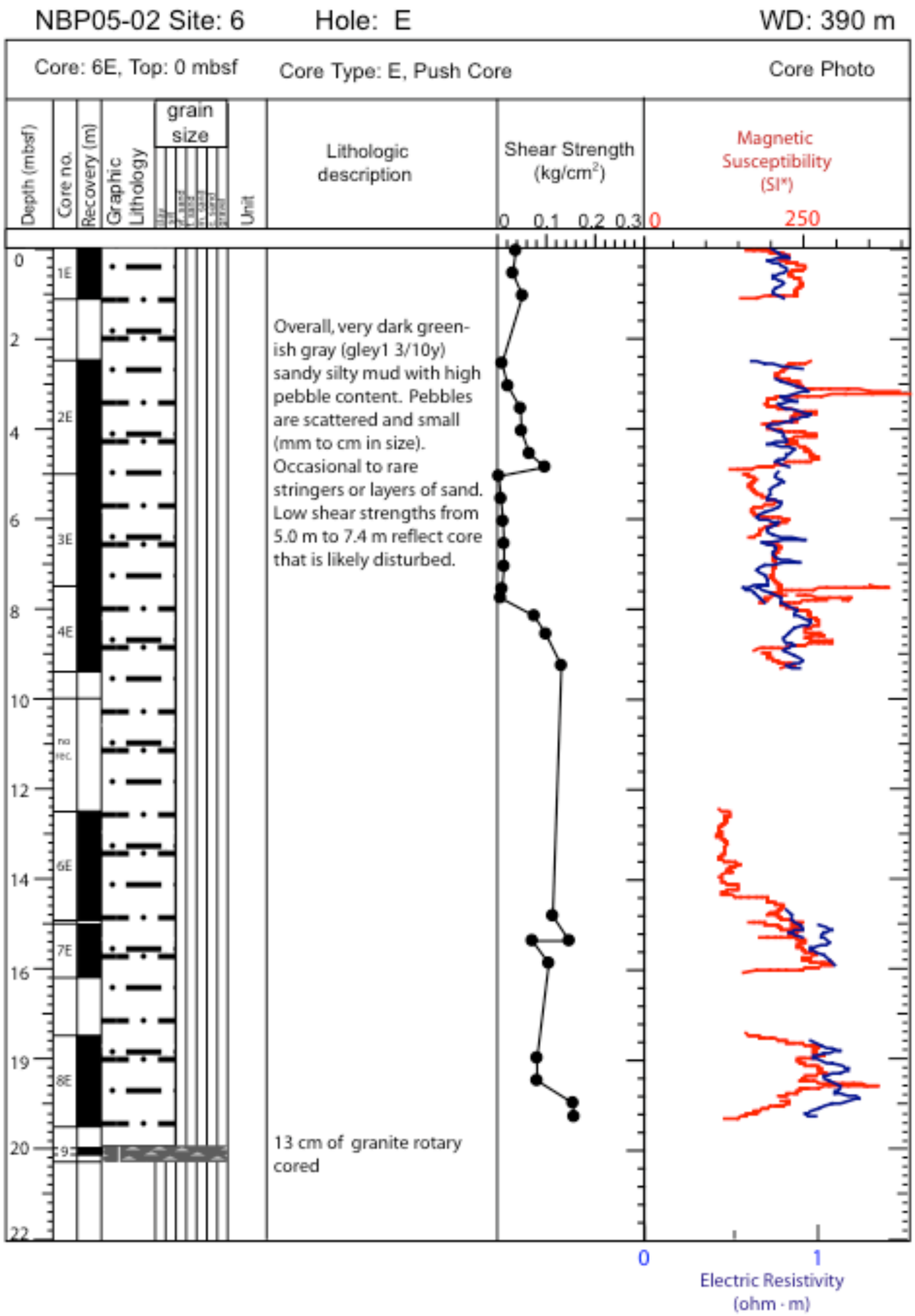


Figure 8-F1. Seismic line G6 from Lapeyrère Bay (from Griffith and Anderson, 1989). The Site 6 drill sites are close to Core 131.

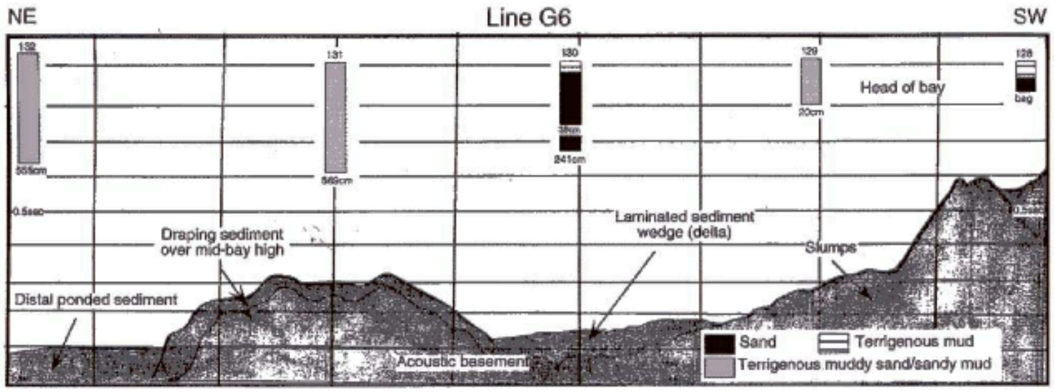


Figure 8-F2. Chirp 3.5 kHz data showing NBP0502 Site 6A.

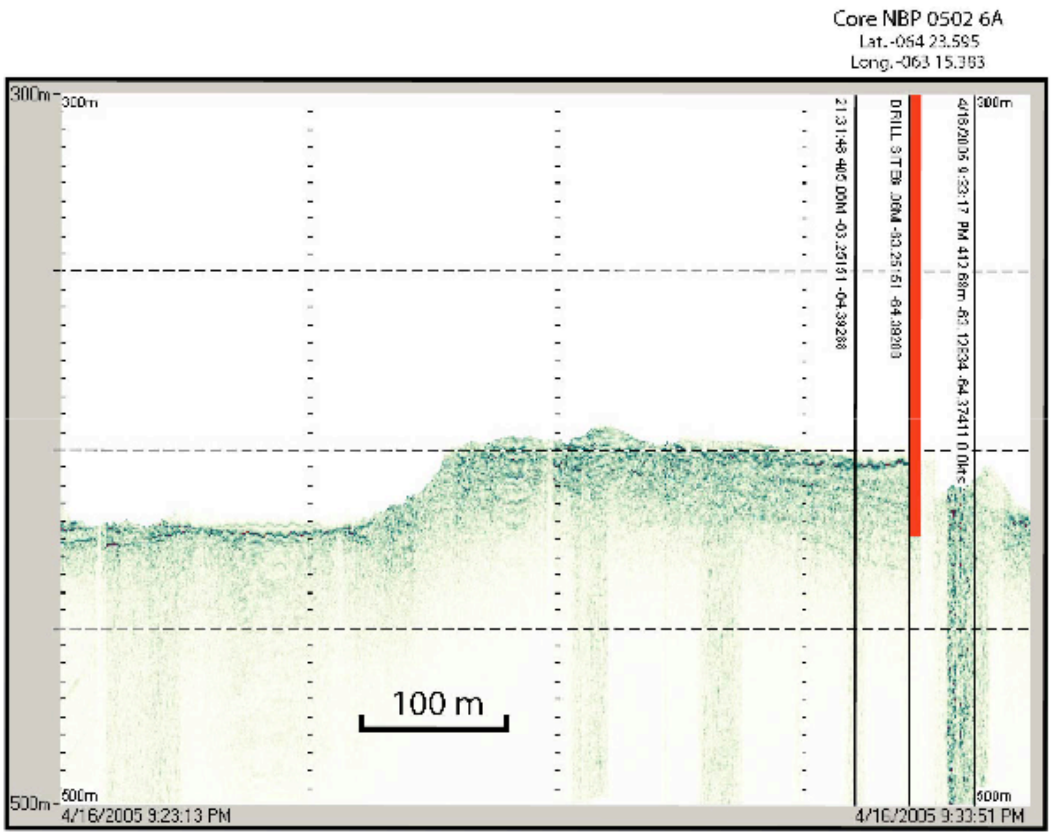


Table 8-B1. Drilling and coring log of Site 6.

SHALDRIL CRUISE NBP0502, SITE 6 (Lapeyrere Bay)
Multibeam Water Depth 388

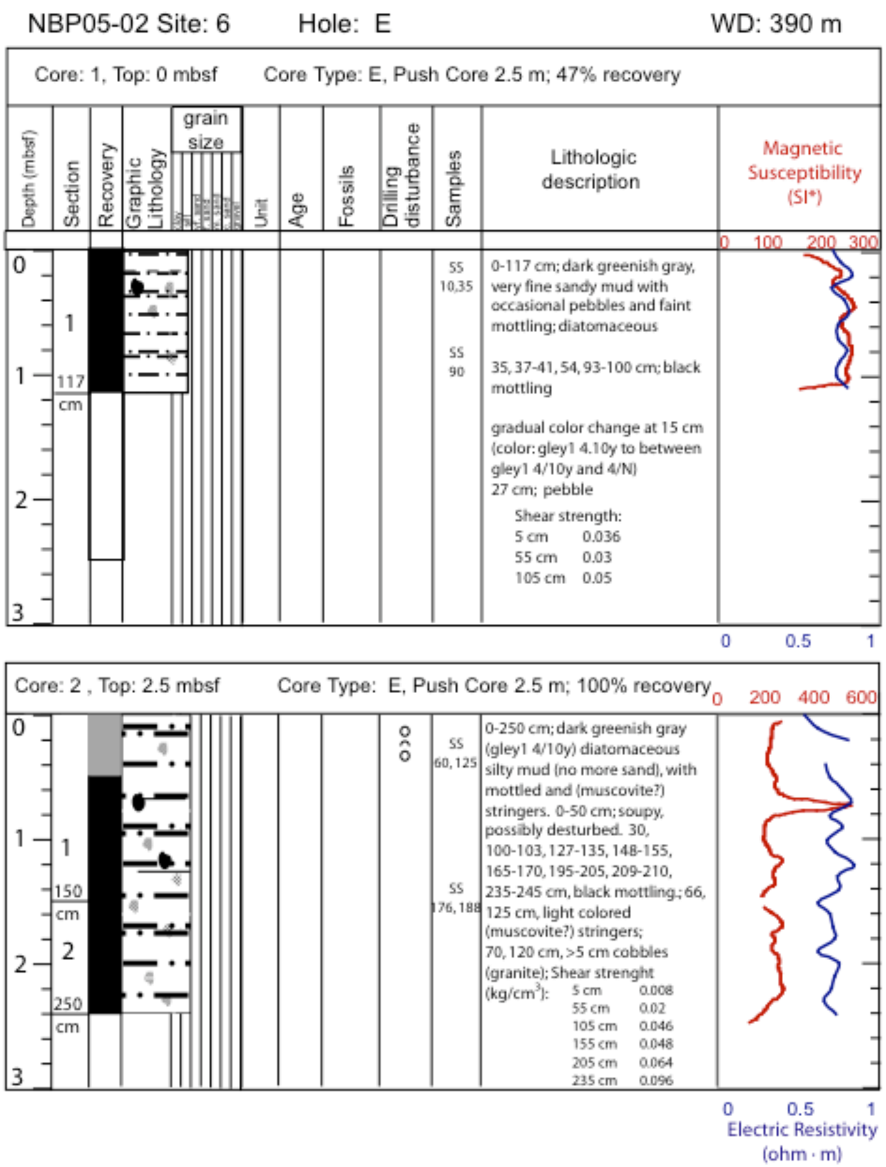
Station Number/Hole	Core Number	Core Type	Top (mbsf)	Bottom (mbsf)	Interval Cored ("push distance") (m)	Recovery: total (m)	Recovery: competent (m)	Recovery: disturbed (m)	Gaps (m)	Recovery Corrected (m)	Total Recovery (%)	Recovery Corrected (%)	Section Number	Section Lengths (cm)	Date (JD)	Time on Deck (GMT)	Comments
6A	1	KC	0	0.29	0.29	0.29	0.29	0	0	0.29	100%	100%	1	15	106	2300	
													2	14			
6B	1	PB	0	0	0	0	0	0	0	0	0%	0%			107		1
6C	1	PB	-1.6	1.4	3										108	1833	2
6C	2	PB	1.4	3.4	2	0	0	0	0	0	0%	0%			108	1942	
6C	3	PB	3.4	6.4	3	0	0	0	0	0	0%	0%	1	150	108	2100	3
													2	79			
6D	1	KC	0	2.93	2.93	2.93	2.93	0	0	2.93	100%	100%	1	150	109	1300	
													2	143			
6E	1	E	0	2.5	2.5	1.17	1.17	0	0.3	1.14	47%	46%	1	117	109	1615	
6E	2	E	2.5	5	2.5	2.5	2.5	0	0	2.5	100%	100%	1	150	109	1652	
													2	252			
6E	3	E	5	7.5	2.5	3	3	0	0	3	120%	120%	1	150	109	1737	
													2	150			
6E	4	E	7.5	10	2.5	1.9	1.55	0.35	0	1.55	76%	62%	1	150	109	1848	
													2	40			
6E	5	E	10	12.5	2.5	0	0	0	0	0	0%	0%			109	1918	4
6E	6	E	12.5	15	2.5	2.95	1	1.95	0.03	0.97	118%	39%	1	150	110	2025	5
													2	145			
6E	7	E	15	17.5	2.5	1.2	1.2	0	0	1.2	48%	48%	1	120	110	2125	6
6E	8	E	17.5	20	2.5	1.97	1.92	0	0.05	1.87	79%	75%	1	150	110	2200	7
													2	47			
6E	9	R	20	20.3	0.3	0.13	0.13	0	0	0.13	43%	43%			110	2235	8
											Site						
											TD=	20.3					
											Recovery Total			8.57	m	42%	
											Recovery Corrected			8.19	m	40%	

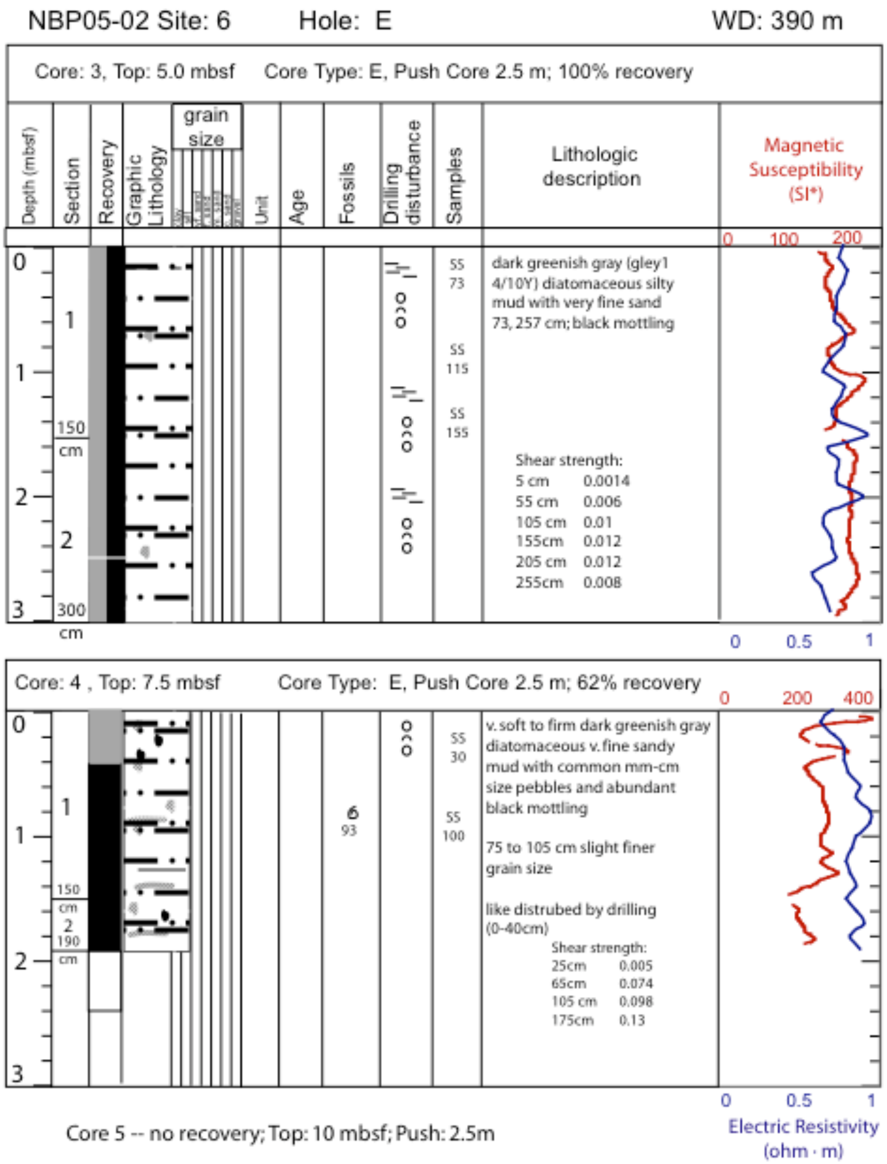
1) HQ pipe broke near bottom of water column and sunk 28 m into soft sediment.
2) First core run really just cleaning out pipe and retrieved slurry.
3) HQ pipe broke near hull and sank 20 m into soft sediment. Core recovered and saved but not opened. It is from the HQ string after it broke and could represent anywhere from 3.4 m to 20 m. Highly disturbed.
4) "Full recovery" turned out to be almost entirely water held in by clay plugs. Maybe jammed by part of core dropped in last run?
5) Core fairly fluidized again, gravel stuck in top of barrel.
6) Tool allowed to fall under own weight, reducing fluidization.
7) Better core, fluidization has been reduced.
8) Very slow drilling; piece of granite cored and bagged (probably a boulder, not outcrop.)

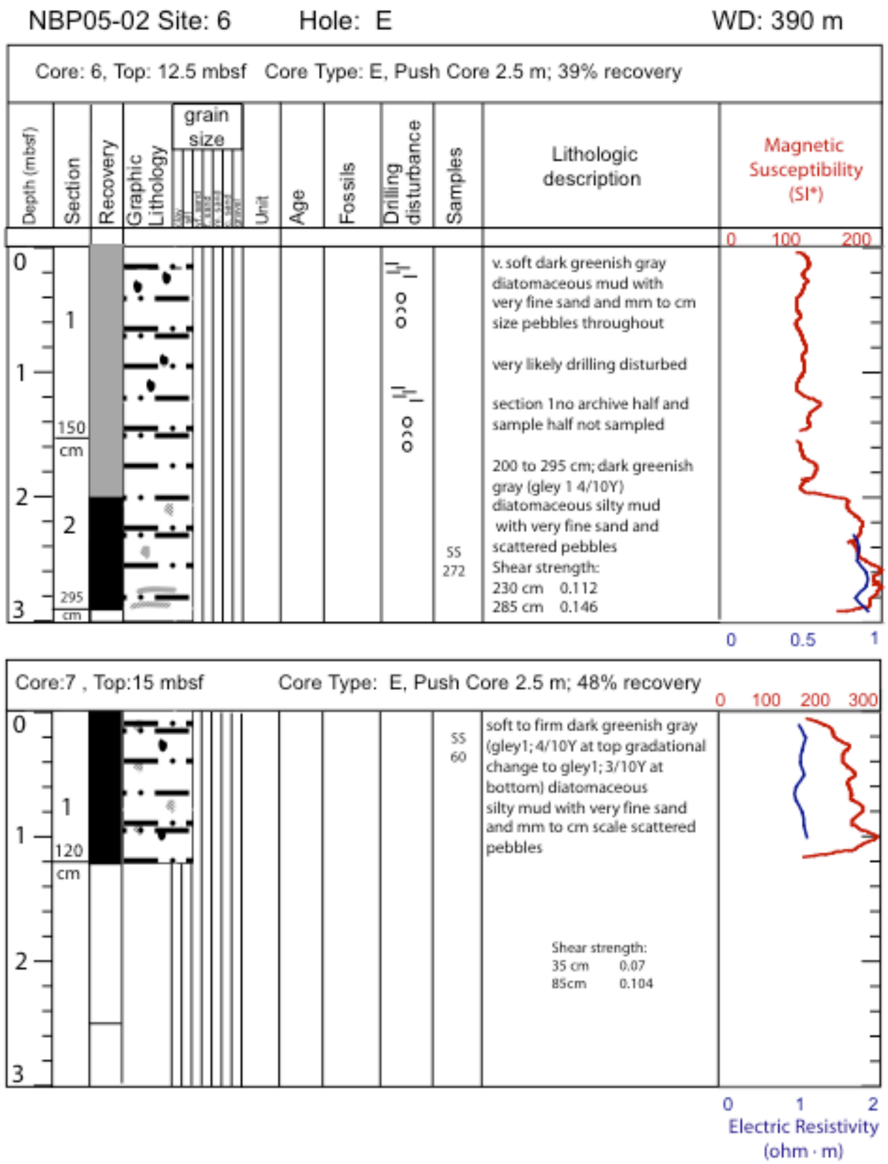
Table 8-D1. *Thoracosphaera* occurrence in SHALDRIL Holes 6D and 6E. Values indicate number of specimens observed during examination of one smear slide.

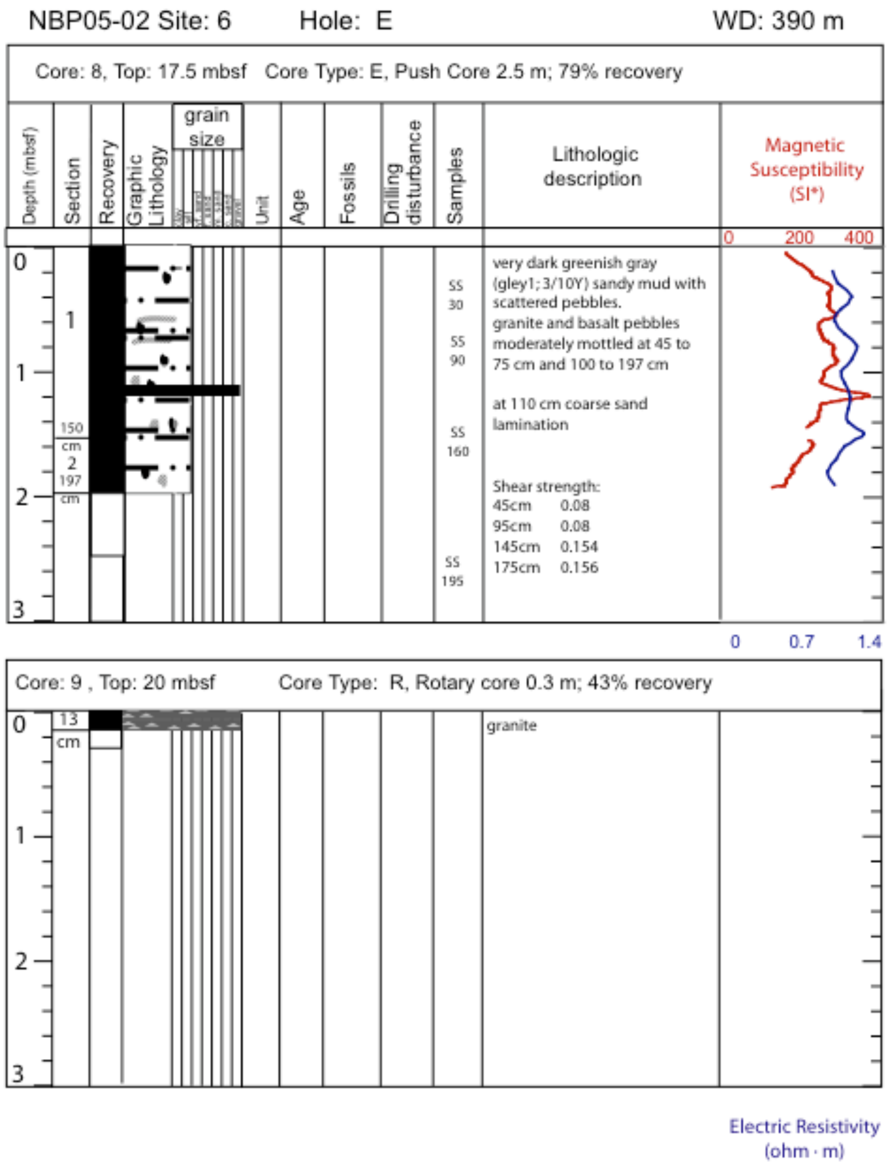
Hole	Core	Section	Top Interval (cm)	Bottom Interval (cm)	Depth (mbsf)	*Thoracosphaera* sp.	*Thoracosphaera* sp. cf. *T. heimii*
Hole 6D							
6D	1KC	1	0	2	0.01	2	1
6D	1KC	CC	-	-	2.95	4	3
Hole 6E							
6E	4E	CC	-	-	10.00	4	4
6E	6E	CC	-	-	15.00	17	10
6E	8E	CC	-	-	20.00	5	4

APPENDIX 8-H1. LITHOLOGIC LOGS




NBP05-02 Site: 6
Hole: E
WD: 390 m
Core: 3, Top: 5.0 mbsf
Core Type: E, Push Core 2.5 m; 100% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
dark greenish gray (gley1 4/10Y) diatomaceous silty mud with very fine sand 73, 257 cm; black mottling
Shear strength:
5 cm 0.0014
55 cm 0.006
105 cm 0.01
155cm 0.012
205 cm 0.012
255cm 0.008
Core: 4 , Top: 7.5 mbsf
Core Type: E, Push Core 2.5 m; 62% recovery
v. soft to firm dark greenish gray diatomaceous v. fine sandy mud with common mm-cm size pebbles and abundant black mottling
75 to 105 cm slight finer grain size
like distrubed by drilling (0-40cm)
Shear strength:
25cm 0.005
65cm 0.074
105 cm 0.098
175cm 0.13
Core 5 -- no recovery; Top: 10 mbsf; Push: 2.5m
Electric Resistivity (ohm · m)


NBP05-02 Site: 6
Hole: E
WD: 390 m
Core: 6, Top: 12.5 mbsf Core Type: E, Push Core 2.5 m; 39% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 100 200
v. soft dark greenish gray diatomaceous mud with very fine sand and mm to cm size pebbles throughout
very likely drilling disturbed
section 1no archive half and sample half not sampled
200 to 295 cm; dark greenish gray (gley 1 4/10Y) diatomaceous silty mud with very fine sand and scattered pebbles
Shear strength:
230 cm 0.112
285 cm 0.146
SS 272
150 cm
295 cm
0 0.5 1
Core:7 , Top:15 mbsf
Core Type: E, Push Core 2.5 m; 48% recovery
0 100 200 300
soft to firm dark greenish gray (gley1; 4/10Y at top gradational change to gley1; 3/10Y at bottom) diatomaceous silty mud with very fine sand and mm to cm scale scattered pebbles
Shear strength:
35 cm 0.07
85cm 0.104
SS 60
120 cm
0 1 2
Electric Resistivity (ohm · m)


NBP05-02 Site: 6
Hole: E
WD: 390 m
Core: 8, Top: 17.5 mbsf Core Type: E, Push Core 2.5 m; 79% recovery
Depth (mbsf)
Section
Recovery
Graphic Lithology
grain size
Unit
Age
Fossils
Drilling disturbance
Samples
Lithologic description
Magnetic Susceptibility (SI*)
0 200 400
very dark greenish gray (gley1; 3/10Y) sandy mud with scattered pebbles.
granite and basalt pebbles
moderately mottled at 45 to 75 cm and 100 to 197 cm
at 110 cm coarse sand lamination
Shear strength:
45cm 0.08
95cm 0.08
145cm 0.154
175cm 0.156
SS 30
SS 90
SS 160
SS 195
150 cm
2
197 cm
0 0.7 1.4
Core: 9 , Top: 20 mbsf Core Type: R, Rotary core 0.3 m; 43% recovery
13 cm
granite
Electric Resistivity (ohm · m)