Integrated Ocean Drilling Program
Expeditions 303 and 306 Scientific Prospectus

North Atlantic Climate

Ice sheet–ocean atmosphere interactions on millennial timescales during the late Neogene–Quaternary using a paleointensity-assisted chronology for the North Atlantic

Documenting and monitoring bottom water temperature variations through time: installing a Cork at Site 642, Norwegian-Greenland Sea

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This IODP Scientific Prospectus is based on precruise Science Advisory Structure panel discussions and scientific input from the designated Co-Chief Scientists on behalf of the drilling proponents. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the science deliverables outlined in the plan presented here are contingent upon the approval of the IODP-USIO Science Services, TAMU, Deputy Director of Science Services in consultation with IODP-MI.

ABSTRACT

Integrated Ocean Drilling Program Expeditions 303 and 306 are based on two separate proposals (572-Full3 and 543-Full2/543-ADD) entitled "Ice sheet–ocean atmosphere interactions on millennial timescales during the late Neogene–Quaternary using a paleointensity-assisted chronology (PAC) for the North Atlantic" and "Installation of a CORK in Hole 642E to document and monitor bottom water temperature variations through time," now 2 and 4 years old, respectively. This prospectus updates information presented in the proposals based on site survey data and other operational refinements.

The objective of Proposal 572-Full3 is to place late Neogene–Quaternary climate proxies in the North Atlantic into a paleointensity-assisted chronology (PAC), a chronology based on a combination of geomagnetic paleointensity, stable isotope, and detrital layer stratigraphies. Proposed primary sites are located off Orphan Knoll (Newfoundland), on the Eirik Drift (southeast Greenland), on the southern Gardar Drift, and in the central Atlantic "ice-rafted debris (IRD) belt." Mean sedimentation rates are estimated to be in the range of 5–50 cm/k.y. at these sites. The advanced piston corer (APC), utilizing the drillover technique, may be expected to reach penetration depths of ~300 meters below seafloor, resulting in recovery of late Neogene to Quaternary climate records. Coring operations will likely be restricted to APC because of the inadequacy of extended core barrel (XCB) cores for high-resolution stratigraphy.

The objective of Proposal 543-Full2 is to place a CORK at Ocean Drilling Program Site 642 (Vøring Plateau) to document and monitor bottom water temperature variations through time. A 150 m casing string with reentry cone will be drilled into the surface sediment followed by installation of a thermister string and CORK.

SCHEDULE FOR EXPEDITIONS 303 AND 306

Expedition 303 and most of Expedition 306 are based on Integrated Ocean Drilling Program (IODP) drilling proposal number 572-Full3 (available at www.isas-office.jp/scheduled.html). One site to be occupied during Expedition 306 is based on proposal number 543-Full2 and 543-ADD. Following ranking by the IODP Scientific Advisory Structure, the expeditions were scheduled by the IODP Operations Committee for the research vessel *JOIDES Resolution,* operating under contract with the U.S. Implementing Organization (USIO). Expedition 303 is currently scheduled to depart St. Johns, Newfoundland (Canada), on 27 September 2004 and to end in Ponta Delgada, Azores Islands (Portugal), on 14 November 2004. In addition to time for travel to and from port, a total of 43 days is available for the operations described in this report for Expedition 303. At present, Expedition 306 is scheduled to depart Ponta Delgada, Azores Islands (Portugal), on 4 March 2005 and end in Reykjavik, Iceland, on 22 April 2005 (for the current detailed schedule, see iodp.tamu.edu/scienceops). Note, however, shifting Expedition 306 to a more ideal weather window will be under consideration at upcoming IODP science planning meetings. This shift in schedule is being considered as one possible scenario in an attempt to drill the Irminger Basin sites (see www.isas-office.jp/pdf/scheduled/572-Full3_Channell.pdf), which are excluded in the present weather window by request of the ship's operator. In addition to time for travel to and from port, a total of 45 days will be available for the drilling, coring, and installation of the subseafloor observatory described in this report for Expedition 306. Further details on the *JOIDES Resolution* can be found at iodp.tamu.edu/publicinfo/drillship.html.

INTRODUCTION

Expeditions 303 and 306 focus on placing late Neogene–Quaternary North Atlantic climate history into a paleointensity-assisted chronology (PAC). The nine primary drilling locations (Fig. F1) are known, either from previous Ocean Drilling Program (ODP)/Deep Sea Drilling Project (DSDP) drilling or from conventional piston cores, to have the following attributes:

- They contain distinct records of millennial-scale environmental variability (in terms of ice sheet–ocean interactions, deep circulation changes, or sea-surface conditions);
- They provide the requirements for developing a millennial-scale stratigraphy (through geomagnetic paleointensity, oxygen isotopes, microfossils, and regional environmental patterns); and
- They document the details of geomagnetic field behavior.

The ultimate objective is to generate a chronostratigraphic template for North Atlantic climate proxies to allow their export and correlation at a sub-Milankovitch scale.

Expedition 306 will include the installation of a CORK at ODP Site 642 (Vøring Plateau, Norwegian margin) to investigate the feasibility of reconstructing bottom water temperature histories at the decade to centennial timescale by making high-precision temperature-depth measurements. The objectives at Site 642 are summarized in "CORK Installation at ODP Site 642."

BACKGROUND

Geological Setting

The North Atlantic Ocean is undoubtedly one of the most climatically sensitive regions on Earth because the ocean-atmosphere-cryosphere system is prone to mode jumps that are triggered by changes in freshwater delivery to source areas of deepwater formation. During the last glaciation, these abrupt jumps in climate state are manifest by Dansgaard/Oeschger (D/O) cycles and Heinrich Events in ice and marine sediment cores, respectively. Given the paramount importance of the North Atlantic as a driver of global climate change, we propose to drill at nine key locations to extend the study of millennial-scale climate variability over the last few million years. What is the rationale for studying millennial-scale variability in the North Atlantic over the last few million years rather than just the last glacial cycle (recoverable by conventional piston cores)? Determining the long-term evolution of millennial-scale variability in surface temperature, ice sheet dynamics, and thermohaline circulation can provide clues to the mechanisms responsible for abrupt climate change. For example, the average climate state evolved toward generally colder conditions with larger ice sheets during the Pliocene–Pleistocene. This shift was accompanied by a change in the spectral character of climate proxies, from dominantly 41- to 100-k.y. periods between ~920 and 640 ka (Schmieder et al., 2000). Among the numerous questions to be answered are the following:

- When did "Heinrich Events" first appear in the sedimentary record of the North Atlantic?
- Are they restricted to the "100-k.y. world" when ice volume increased substantially?

Seismic Studies/Site Survey Data

Seismic data for positioning the Eirik Drift (LAB) sites and southern Gardar Drift (GAR) sites were collected during the *Knorr* KN166-14 cruise (principal investigator: Greg Mountain) in summer 2002. Seismic reflection profiles were collected with Lamont-Doherty's portable high-resolution acquisition system. This comprised a Price 135 standard cubic feet per minute compressor, two 45 in^3 generator injector air guns depth-controlled at 2.5 m and fired every 12.5 m along track, a 48-channel, 600 m solid Innovative Transducers Inc. streamer, also depth-controlled at 2.5 m, and onboard recording based on an OYO Instruments Data Acquisition System-1 and additional software for gunfire control and 1 ms sampling. Onboard as well as more elaborate onshore seismic processing was performed using Landmark's Promax software. A cruise of the *Hudson* in August 2001 (principal investigator: David Piper) obtained seismic reflection lines for Orphan Knoll (ORPH) proposed Sites ORPH2A and ORPH3A using a Huntec deep-towed sparker system augmented by single-channel seismic data (Toews and Piper, 2002).

SCIENTIFIC OBJECTIVES

"Climate"-Related Objectives

Stratigraphy is the fundamental backbone of our understanding of Earth's history, and stratigraphic resolution is the main factor that limits the timescale of processes that can be studied in the past. Sub-Milankovitch-scale climate studies face the challenge of finding a stratigraphic method suitable for correlation at this scale (see Crowley, 1999). Even under optimal conditions, chronologies based on $\delta^{18}O$ are unable to provide sufficient stratigraphic resolution. Within the North Atlantic region, recent improvements in stratigraphic resolution have resulted in a new understanding of the dynamics of millennial-scale climate variability over the last ~100 k.y. (e.g., van Kreveld et al., 2000; Sarnthein et al., 2001). These stratigraphies have utilized chronologies from the Greenland Summit ice cores (GRIP/GISP2) and the recognition of regional lithostratigraphic linkages such as Heinrich events and higher-frequency ice-rafted debris (IRD) layers, ash layers, and susceptibility cycles combined with planktonic/benthic $\delta^{18}O$, acceleration mass spectrometry (AMS) ^{14}C dates, and geomagnetic paleointensity data (e.g., Bond et al., 1992, 1993, 1999; McManus et al., 1994; Stoner et al., 1998, 2002; Voelker et al., 1998; Kissel et al., 1999; Laj et al., 2000).

The objective of these expeditions is to integrate paleointensity and paleoceanographic proxies and extend the North Atlantic millennial-scale stratigraphies over the last few million years, and into the late Miocene in the case of proposed Site IRD4A.

Understanding the mechanisms and causes of abrupt climate change is one of the major challenges in global climate change research today (see Clark et al., 1999, p. vii) and constitutes a vital initiative of the Initial Science Plan of IODP. Ideally, the best approach to this problem would be to collect records of climate variability from a dense geographic network of sites, but this is impractical in paleoceanographic research. In the absence of dense coverage, the most viable approach is to obtain long, continuous time series from key regions and compare the response and timing of climate change among sensitive regions. Here, we intend to develop PACs to establish the phase relationships among globally distributed millennial-scale records. Building global correlations on millennial timescales is an essential step to defining the underlying mechanisms of abrupt climate change.

A persistent ~1500 y cycle has been observed for the past 80 k.y. that is apparently independent of glacial or interglacial climate state (Bond et al., 1999). The millennial-scale cyclicity in the Holocene appears to be mirrored in the last interglacial (marine isotope Stage [MIS] 5e) and is defined by the same petrologic proxies in both interglacials. The presence of this cyclicity in interglacials, and the IRD petrology that defines it, indicates that the cyclicity does not reflect ice sheet instability or changes in calving of coastal glaciers, but rather changes in sources of drifting ice, driven by changes in the size and intensity of the subpolar cyclonic gyre (Bond et al., 1999). The Holocene cycles reflect a mechanism operating on at least hemispheric scale (Sirocko et al., 1996; Campbell et al., 1998; DeMenocal et al., 2000), indicating that the MIS 5e and Holocene cyclicities have a common origin, possibly related to solar forcing (Bond et al., 2001). The implication is that the 1500 y cycle may have been a dominant feature of the Earth's ocean-atmosphere climate over a very long time. How far back in time does the ~1500 y cycle extend? Do Dansgaard/Oeschger (D/O) cycles simply represent an amplification of this? Do distinct modes of variability persist through other glacial and interglacial intervals? If so, is the pacing always the same or does millennial-scale variability evolve during the late Pleistocene?

Recently published evidence from earlier interglacials (MIS 11 and 13) in both the subpolar and subtropical North Atlantic suggests that interglacial cyclicity at those times may have had a significantly longer pacing, on the order of 5000 y or more. The interglacial records from MIS 11 and 13 in Oppo et al. (1998) and McManus et al. (1999), for example, show rather sporadic events that, regardless of age model, cannot occur every 1500 y. Similarly, a MIS 11 record from ODP Site 1063 off Bermuda indicates large shifts in benthic $\delta^{13}C$ on the order of 5–6 k.y. (Poli et al., 2000). In contrast, data from MIS 11 at ODP Site 980 implies the presence of a 1–2 k.y. pacing (McManus et al., 1999), suggesting that the 1500 y cycle may be operating in MIS 11 and in other pre-MIS 5e interglacials. If this is true, then the interglacial climate variability may reflect a persistent, perhaps periodic, process operating continuously within the Earth's climate (rather than red noise resulting from a highly nonlinear climate system).

The best evidence for the 1500 y cycle during interglacials seems to be coming from IRD proxies that monitor changes in the subpolar gyre in the North Atlantic. Our proposed drilling sites are positioned to monitor such changes. In contrast to ODP Site 980 (Rockall Plateau), our proposed sites are located well within the main present-day routes of iceberg transport into the North Atlantic and thereby are well-suited to capturing faint interglacial signals in shifting ocean surface circulation. If we can connect the 1500 y cycle to paleointensity records, we will have a means of directly comparing both signals with climate records from well outside the North Atlantic.

Geomagnetic-Related Objectives

Understanding the changes in the ice sheet-ocean-atmosphere system that give rise to millennial-scale climate changes requires the precise long-distance correlation of ice cores and marine sediment cores. Geomagnetic paleointensity records from marine sediment cores have been shown to contain a global signal suitable for fine-scale correlation (see Meynadier et al., 1992; Guyodo and Valet, 1996; Channell et al., 2000; Stoner et al., 2000, 2002; Laj et al., 2000), at least for the last glacial cycle (Fig. F2).

Beyond the range of AMS ^{14}C dating, geomagnetic paleointensity data may provide the only viable means of sub-Milankovitch-scale long-distance correlation. Paleointensity records have been applied to stratigraphic correlation in the Labrador Sea for the last 200 k.y. (Stoner et al., 1998), throughout the North Atlantic for the last 75 k.y. (Laj et al., 2000), and for the Atlantic realm for the last 110 k.y. (Stoner et al., 2000). As variations in geomagnetic paleointensity control atmospheric production of ^{10}Be and ^{36}Cl isotopes, and the flux of these isotopes is readily measurable in ice cores, paleointensity records in marine cores provide an independent link between marine sediment and ice core records (e.g., Mazaud et al., 1994). The lows in paleointensity at ~40 and ~65 ka (Fig. F2) are readily identifiable as highs in ^{10}Be and ^{36}Cl fluxes (Baumgartner et al., 1998; Raisbeck et al., 1987) in the Vostok and GRIP ice cores, respectively. Frank et al. (1997) showed that 10^4–10^5 y variability in ^{10}Be production rate, as determined from globally distributed deep-sea cores over the last 200 k.y., can be matched to sediment paleointensity data. This observation and the similarity of globally distributed paleointensity records (Fig. F2) indicate that much of the variability in paleointensity records is globally correlative. The few high-resolution paleointensity records available beyond 200 ka also indicate that fine-scale features are correlative. For example, the paleointensity record for the MIS 9–11 interval (300–400 ka) from the Iceland Basin (ODP Sites 983 and 984) can be correlated to the sub-Antarctic South Atlantic (ODP Site 1089) at suborbital (millennial) scale (Stoner et al., 2002) (Fig. F3).

In addition to the practical use of magnetic field records for correlation of climate records, further drilling of high-sedimentation-rate drift sites will impact the "solid Earth" theme of IODP by documenting the spatial and temporal behavior of the geomagnetic field at unprecedented resolution. Such data are required to elucidate processes in the geodynamo controlling secular variation and polarity reversal of the geomagnetic field. Recently derived records of directional secular variation and paleointensity from drift sites (e.g., ODP Legs 162 and 172) have substantially advanced our knowledge of magnetic secular variation, magnetic excursions, and directional/intensity changes at polarity reversal boundaries (see Channell and Lehman, 1997; Channell et al., 1998, 2002; Lund et al., 1998, 2001a, 2001b). Numerous directional magnetic excursions have been observed within the Brunhes Chron at ODP Leg 172 drift sites (Lund et al., 1998, 2001a, 2001b) and in the Matuyama Chron at ODP Leg 162 sites (Channel et al., 2002). These excursions (or brief subchrons) correspond to paleointensity minima and have estimated durations of a few thousand years. From ODP Leg 162 records and records from the Pacific Ocean, it has been suggested that spectral power at orbital frequencies in paleointensity records may reflect a fundamental property of the geodynamo (Channell et al., 1998; Yamazaki, 1999) rather than climate-related contamination of paleointensity records (Guyodo et al., 2000).

There is no doubt that North Atlantic drift sites have revolutionized our understanding of the behavior of the geomagnetic field by providing Brunhes paleomagnetic records of unprecedented resolution. The records can now provide useful constraints for numerical simulations of the geodynamo (e.g., Glatzmaier and Roberts, 1995; Gubbins, 1999; Coe et al., 2000). As a result of these parallel advances, our understanding of the geomagnetic field is on the threshold of substantial progress.

The proposed drilling sites will provide high-resolution paleomagnetic records extending through the Matuyama Chron (to ~3 Ma). They will allow us to assess the temporal and spatial variability of the geomagnetic field in the Brunhes Chron and compare these records with reversed polarity records from the Matuyama Chron. Are the characteristics of secular variation different for the two polarity states? Are polarity transition fields comparable for sequential polarity reversals? Does the geomagnetic field exhibit a complete spectrum of behavior from high-amplitude secular variation to polarity reversals, which has not hitherto been documented due to lack of high-resolution records?

The non-axial-dipole (NAD) components in the historical field vary on a centennial scale, and this has been interpreted to indicate similar repeat times in the past (Hulot and Le Mouël, 1994; Hongre et al., 1998). If this is correct, paleointensity records from cores with sedimentation rates less than ~10 cm/k.y. are unlikely to record anything but the axial dipole field. On the other hand, standing NAD components have been detected in the 5 m.y. time-averaged field, although the distribution of these NAD features remains controversial (Kelley and Gubbins, 1997; Johnson and Constable, 1997; Carlut and Courtillot, 1998). Refinement of time-averaged field models as the paleomagnetic database is augmented will lead to a better grasp of how the non-zonal terms in the time-averaged field may influence paleointensity records.

RELATIONSHIP TO PREVIOUS NORTH ATLANTIC DRILLING

Two previous ODP legs to the North Atlantic recovered sequences that are continuous and have sedimentation rates high enough to study oceanic variability on sub-Milankovitch timescales. During Leg 162 four sites were drilled on sediment drifts south of Iceland. These sequences are yielding invaluable insight into the nature of millennial-scale climate variability in the North Atlantic (Raymo et al., 1998; McManus et al., 1999; Raymo, 1999; Flower et al., 2000; Kleiven et al., 2003). Similarly, during Leg 172 in the northwest Atlantic between ~30° and 35°N, sequences with high deposition rates that are suitable for millennial- and perhaps centennial-scale studies were recovered (Keigwin et al., 1998). Given the successes of Legs 162 and 172, why are additional sites needed in the North Atlantic? The sites proposed herein will augment those of Legs 162 and 172 in two fundamental ways. First, most of our sites are located in the North Atlantic “IRD belt,” where massive iceberg discharges are recorded by coarse layers of ice-rafted detritus that are depleted in planktonic foraminifers and have oxygen isotopic values indicative of reduced sea-surface salinities. Site 980 (from ODP Leg 162) does lie within the IRD belt, but it is located on its distal northeastern edge and, consequently, lacks the strong sea-surface response to millennial-scale IRD events that are so well displayed to the south and west. Second, the depth distribution of the proposed sites (2273–3884 meters below sea level [mbsl]) are ideal for monitoring millennial-scale changes in the production of North Atlantic Deep Water. Leg 162 sites span 1650–2170 mbsl and provide the intermediate-depth end-member for studies of the formation of Glacial North Atlantic Intermediate Water (GNAIW). Leg 172 drift sites provide a relatively complete depth transect spanning 1291–4595 mbsl. The sites proposed herein will unify the record of millennial-scale variability in the North Atlantic by bridging the “gap” between Legs 162 and 172. The sites will also expand the geographic range of sites needed to distinguish between latitudinal changes in the mixing zone between southern and northern source waters and changes due to vertical migration of water mass boundaries (Flower et al., 2000).

Data and modeling studies point to changes in the modes of NADW formation as one of the principal factors driving millennial-scale climate change in the high-latitude North Atlantic and Europe (for review, see Alley et al., 1999). The proposed sites are distributed so that they monitor the major deepwater end-members of NADW: Norwegian-Greenland Sea Water (GAR sites) and Labrador Seawater (LAB sites) as well as the final NADW mixture (ORPH sites). Alley et al. (1999) discussed three distinct modes of thermohaline circulation in the North Atlantic: modern (M), glacial (G), and Heinrich (H). The modern mode is marked by deepwater formation in the Nordic Seas and North Atlantic where the three end-members mix to form NADW. In the glacial mode, deepwater formation is suppressed in the Nordic Seas and GNAIW forms farther south in the North Atlantic. In the Heinrich mode, both deep- and intermediate-water formation is greatly reduced. Together with the depth transects drilled during Legs 162 and 172, the sites proposed here will permit monitoring deep- and intermediate-water formation during all three modes of formation.

DRILLING STRATEGY

The (high resolution) stratigraphic goals require high sedimentation rates (>5 cm/k.y.) at the chosen sites, as well as complete and undisturbed recovery of the stratigraphic sequence. The drilling strategy will consist of advanced piston coring (APC) in three or more holes at each site to ensure complete and undisturbed recovery of the stratigraphic section (Tables T1, T2). We propose to use the "drillover" strategy employed during ODP Leg 202 to maximize APC penetration. Traditionally, the depth limit of APC coring is controlled by the overpull required to retrieve the core barrel. In cases where the full APC stroke is achieved but excessive force is required to retrieve the core barrel (often the limit of APC penetration), the drillover strategy entails advance of the rotary bit to free the APC barrel. APC coring will terminate when the pressure gauge on the rig floor indicates that full APC stroke can no longer be achieved. Because of the pivotal role of magnetic studies in the objectives of the proposal, nonmagnetic core barrels will be used throughout.

Two factors influenced the decision to terminate holes at the limit of the APC, and therefore *not* to utilize extended core barrel (XCB) technique:

- The increase in drilling disturbance associated with the XCB, particularly in the upper part of the XCB section, has not been conducive to the generation of high-resolution PAC chronologies. Poor recovery and "biscuiting" are common in poorly consolidated lithologies recovered by XCB.
- At all locations, other than GAR sites, the deeper stratigraphic section has been sampled during previous DSDP or ODP drilling legs.

Penetration depths (using APC methods) will not exceed 400 meters below seafloor (mbsf). At North Atlantic sites with similar lithologies, the maximum penetration depth has been 250 mbsf. APC drilling over may increase this penetration to >300 mbsf. In the seismic sections accompanying this report, we mark 400 ms two-way traveltime (TWT) (~320 mbsf) as the maximum possible penetration depth. Note that several days for each expedition are not scheduled for operations to provide for appropriate weather contingency.

Drilling in the North Atlantic outside the optimal weather window (July–August) will require flexibility in the operations plan, which may be dictated by weather conditions. If Expedition 303 has to be modified due to poor weather conditions, sites from Expedition 306 may be substituted in the 303 operations program. Any Expedition 303 sites not drilled during that expedition will be transferred to the operations plan for Expedition 306.

PROPOSED DRILL SITES

Orphan Knoll (ORPH)

- ORPH2A (50°12.40′N, 45°41.22′W; water depth = 3539 m), at Core MD95-2024 is close to HU91-045-094P (P-094) (50°12.26′N, 45°41.14′W; water depth = 3448 m), MD99-2237 (50°11.93′N, 45°41.03′W; water depth = 3530 m), and DSDP Leg 12 Site 111 (50°25.57′N, 46°22.05′W; water depth = 1797 m).
- ORPH3A (50°9.984′N, 45°38.273′W; water depth = 3591 m).

Orphan Knoll is a seamount located between the Newfoundland continental slope and the Northwest Atlantic Mid-Ocean Canyon (NAMOC) (Fig. F4). Oceanic magnetic Anomaly 34 (Late Cretaceous) lies offshore to the east. Core HU90-045-094, collected by the *Hudson* (HU) in 1990, was located in a small channel east of Orphan Knoll within 1 km of a 30 m core (MD95-2024) collected during the 1995 *Marion Dufresne* (MD) (Images) campaign. An additional 30 m "calypso" piston core (MD99-2237) was collected nearby during the 1999 Images campaign.

The attraction of this region is that these MD and HU piston cores have provided the most detailed marine record of Laurentide Ice Sheet (LIS) instability over the last 110 k.y. in the form of rapidly deposited detrital layers intercalated in background hemipelagic sediments (Hillaire-Marcel et al., 1994; Stoner et al., 1995, 2000). The site is apparently well positioned to sample overflow deposits from the nearby NAMOC and is therefore a sensitive monitor of NAMOC activity and, hence, LIS instability. Drilling at this site will extend the record of LIS instability back beyond the last glacial cycle, allowing us to observe LIS instability in a variety of glacials and interstadial conditions, as well as in the "40-k.y. world" and the transition into the "100-k.y. world."

Drilled on the crest of Orphan Knoll in 1970, DSDP Site 111 lies ~36 km northwest of proposed Site ORPH2A. Site 111, located in 1797 m water depth, was drilled to 250 mbsf. The base of the Pleistocene was placed at 128 mbsf with 20 m of Pliocene overlying a series of unconformities between which lower Miocene, Eocene, and Mesozoic sediments were recovered.

Proposed Site ORPH2A is located at the site of cores MD95-2024 and HU91-045-094 (Fig. F5). A cruise of the *Hudson* in August 2001 obtained crossing seismic reflection lines for the proposed site using a Huntec deep-towed sparker system augmented by single-channel data (Toews and Piper, 2002). The ~200 ms TWT for the upper Quaternary sediment sequence at proposed Site ORPH2A is increased to ~300 ms TWT at proposed Site ORPH3A (Fig. F6). Correlation of reflectors to the HU and MD piston cores places the "pink" reflector at ~120 ka (Fig. F7). At proposed Site ORPH2A, ~5 km northeast from the scarp shown in Figure F7, the "pink" reflector is at ~30 ms TWT (Fig. F8). The Quaternary sedimentary section is expanded at proposed Site ORPH3A relative to ORPH2A.

Eirik Drift (LAB)

Primary sites

- LAB3A (58°2.169′N, 48°27.57′W; water depth = 3350 m), close to LA-5 and ODP Leg 105 Site 646 (58°12.559′N, 48°22.147′W; water depth = 3450 m); shotpoint (SP) 4000 on Line BGR-2.
- LAB6A (57°28.5078′N, 48°31.842′W; water depth = 3485 m); common depth point (CDP) 900 on KN166-14 Line 25a.
- LAB7A (58°14.2267′N, 45°38.5888′W; water depth = 2273 m); CDP 2550 on KN166-14 Line 19 and CDP 7435 on KN166-14 Line 24c.

Alternate sites

- LAB8A (58°28.525′N, 46°27.823′W; water depth = 2650 m); CDP 13975 on KN166-14 Line 25a.
- LAB8B (58°33.2271′N, 46°18.0404′W; water depth = 2556 m); CDP 15000 on KN166-14 Line 25a.

- LAB8C (58°30.346′N, 46°24.034′W; water depth = 2554 m); CDP 14375 on KN166-14 Line 25a.

Two holes were drilled at ODP Site 646 (Leg 105) on the northwest edge of Eirik Drift (Fig. F9) during October 1985. The penetration depths were 103.5 mbsf in Hole 646A and 777 mbsf in Hole 646B. Poor recovery (53% for Hole 646B) led to an incomplete record of the upper Miocene–Holocene sedimentary sequence. The sediments are silty clays in the upper Pliocene–Quaternary (0–188 mbsf), muddy sand and silty muds in part of the upper Pliocene (188–236 mbsf), and silty clay in the upper Miocene–upper Pliocene interval (236–766 mbsf). Thin-bedded detrital carbonate beds are present throughout the section and are of particular interest because they can be associated with LIS instability. Little significance was attached to these layers in the original studies of Site 646 sediments; however, we now know from nearby piston cores (e.g., HU90-013-013P) that these detrital layers correlate with Heinrich-type detrital layers in the North Atlantic IRD belt. One of the objectives of drilling at this site will be to place these detrital layers into a PAC and, hence, correlate them to similar layers at the other drill sites and to ice core records.

The Site 646 sediments carry a well-defined magnetization component resolved by alternating-field (AF) demagnetization. The Brunhes/Matuyama boundary was identified at 60 mbsf (Clement et al., 1989), indicating a mean Brunhes sedimentation rate of 7.7 cm/k.y. A complete magnetostratigraphy of the late Miocene–Holocene record was compromised by incomplete recovery and drilling disturbance, exacerbated by poor weather conditions. Planktonic oxygen isotope data (Aksu et al., 1989) are available from Site 646 sediments to MIS 23 (~900 ka).

The deeper-water proposed sites (LAB3A and LAB6A) are located south of ODP Site 646 (Fig. F9). Tracing of reflectors from Site 646 along seismic Line BGR-2 and KN166-14 Lines 21 and 25a indicates that proposed Sites LAB3A and LAB6A have expanded Pliocene–Quaternary sedimentation relative to Site 646. These deepwater sites are located below the Western Boundary Undercurrent (WBUC) and therefore are characterized by expanded interglacial sedimentation. The contrasting sedimentation between proposed Sites LAB3A, LAB6A, and LAB7A will allow us to document changes in the outflow of the WBUC (therefore in the production of NADW) during Pliocene–Quaternary time and also to reconstruct the deep-sea circulation patterns that prevailed during interglacial intervals. The composite record from the proposed sites will benefit from the contrasting sedimentation patterns, thereby maximizing the resolution of the composite record at this location.

Proposed Site LAB3A is located close to the LA-5 site (surveyed for ODP Leg 105) on Eocene oceanic crust. Proposed Site LAB3A lies at SP 4000 on seismic Line BGR-2 at 3350 m water depth (Fig. F10). Hudson (84-030) Line 14 passes through ODP Site 646 (Fig. F11) and crosses Line BGR-2 at SP 3900 (Fig. F10). KN166-14 Line 21 crosses Line BGR-2 at SP 3697 on Line BGR-2 (Fig. F12). The multichannel seismic (MCS) profile for KN166-14 Line 21 at the BGR-2 crossing is shown in Figure F13.

Maximum penetration at ODP Site 646 was 767 mbsf (reaching into the upper Miocene) in Hole 646B. At this site, reflector R1 (late Pliocene) lies at 236 mbsf and the base of the Pliocene (R2) at 480 mbsf (Fig. F11) (Arthur et al., 1989; Shipboard Scientific Party, 1987). We expect the sedimentary section at proposed Site LAB3A to be thicker than that at Site 646. APC coring was discontinued at Site 646 after recovery of Core 105-646B-14H (~130 mbsf) as pull-up was becoming “difficult” in poor weather conditions. We expect to achieve a maximum of ~ 300 mbsf using the APC drillover technique.

In the 767 m section recovered at Site 646, there was no evidence of gas pockets or expansion of sediment within core liners. Methane was not detected above 180 mbsf (within the zone of pore water sulfate depletion). Below 180 mbsf, methane occurrences were very sporadic, with three maximum values in the 25,000–30,000 ppm range for gas collected by vacutainer sampling the 300–400 mbsf depth range. Low organic carbon contents in the sediment (average ~0.35 wt%, mainly of terrigenous origin) (Stein et al., 1989) indicate little biogenic activity.

Proposed Site LAB6A is located at CDP 900 on KN166-14 Line 25a (Figs. F14, F15, F16) on Eocene oceanic crust at 3485 m water depth. Sedimentation rates are enhanced relative to proposed Site LAB3A, providing the opportunity to recover an expanded Pliocene–Quaternary section at sedimentation rates estimated to be ~50 cm/k.y., based on a provisional age model for a gravity core collected at the site during the KN166-14 cruise (Henderson and Wright, 2004).

Proposed Site LAB7A is located at the crossing of KN166-14 Lines 19 and 24c (Fig. F9) on Eocene oceanic crust at a water depth of 2273 m. MCS profiles for Line 19 (Fig. F17) and Line 24c (Fig. F18) indicate that this relatively shallow water site provides the opportunity to recover an expanded Pliocene–Quaternary section at sedimentation rates in excess of 15 cm/k.y. The 3.5 kHz profile is shown in Figure F19.

Alternate proposed Sites LAB8A, LAB8B, and LAB8C are located on KN166-14 Line 25a at CDPs 13975, 15000, and 14375, respectively (Figs. F20, F21). The objective here is to sample an expanded Pliocene–Quaternary sediment package at relatively shallow water depths (water depth = 2556 m at proposed Site LAB8B) and the mudwaves at proposed Sites LAB8A and LAB8C. Drilling in the mudwaves (Fig. F20) permits access to the older part of the sedimentary section by APC drilling. In addition, the results will provide important information on the sedimentary architecture of the mudwaves and, hence, on sedimentary evolution of the Eirik Drift.

Gardar Drift (GAR)

- GAR1B (56°21.882′N, 27°53.310′W; water depth = 2821 m), close to MD99-2253.
- GAR2A (53°3.40′N, 33°31.78′W; water depth = 3024 m), at HU91-045-080 near MD95-2017 (53°02.56′N, 33°31.51′W; water depth = 3100 m), NEAP18K (52°46′N, 30°21′W; water depth = 3275 m), and DSDP Leg 94 Site 611 (52°50.47′N, 30°18.58′W; water depth = 3195 m)

ODP Leg 162 (Sites 983 and 984) drilling in the Iceland Basin indicated that northern Gardar/Bjorn Drift sediments are devoid of major hiatuses, at least during the Quaternary. Sites 983 and 984 are located outside the main IRD belt (sensu Ruddiman, 1977) and do not contain a robust detrital carbonate (Heinrich layer) signal. We propose two sites in the southern part of the Gardar Drift (Fig. F1) where sedimentation rates are high (9–11 cm/k.y.) and yet close enough to the IRD belt to record the Heinrich-type detrital layers, which monitor ice sheet instability. The water depths at GAR1B and GAR2A (2820 and 3024 m) and the ability to derive a benthic stable isotope record from this region (see Chapman and Shackleton, 1999) will allow ice sheet–ocean interaction to placed on a benthic isotopic record. Carbon isotope data will allow high-resolution monitoring of NADW. ODP Leg 162 drift sites (Sites 980–984) are all at shallower water depths (<2000 m) and therefore monitor the intermediate water. At ODP Site 982, Venz et al. (1999) proposed that GNAIW production ceased during terminations and NADW production increased. There was apparently a time lag between the shutdown of GNAIW and the renewed production of upper NADW. ODP Site 607 presently provides the best monitoring of NADW (Raymo et al., 1992). One of the objectives of proposed Sites GAR1B and GAR2A is to provide NADW monitoring at higher resolution in the southern part of the Gardar Drift.

Proposed Sites GAR1B and GAR2A were surveyed from *Knorr* during summer 2002 using the Lamont-Doherty HiRes MCS system: dual 45/45 in^3 generator injector guns towed at 2 m, recording 48 channels, and then stacking the data 24-fold. Continuous hull-mounted 3.5 kHz sonograms and Hydrosweep bathymetry were also recorded during the survey and during transit between proposed Sites GAR1B and GAR2A.

On the crest of the Gardar Drift, sedimentation rates are ~11 cm/k.y. for a 33 m core (MD99-2253) collected by the *Marion Dufresne* in 1999 (56°21.78′N, 27°48.95′W; water depth = 2840 m). This is close to the location of proposed Site GAR1B (Fig. F22). It lies on oceanic crust close to Anomaly 10 (~30 Ma), and the total sediment thickness is ~600 m. The MD99-2253 piston core has a moderately high sedimentation rate (~9 cm/k.y. for the last glacial cycle) and well-defined planktonic $\delta^{18}O$ and geomagnetic paleointensity records. We present the Seabeam survey at proposed Site GAR1B (Fig. F23), the MCS track map (Fig. F24), the MCS profiles (Figs. F25, F26, F27), and the 3.5 kHz data (Fig. F28).

Proposed Site GAR2A is located at the site of Core HU91-045-080 (53°3.40′N, 33°31.78′W; water depth = 3024 m). It lies north of the Charlie Gibbs Fracture Zone and east of Reykjanes Ridge. It is located on oceanic crust close to Anomaly 5 (~10 Ma), and the total sediment thickness is ~600 m. The Seabeam survey (Fig. F29), the MCS track map (Fig. F30), the MCS profiles (Figs. F31, F32), and the 3.5 kHz data (Fig. F33) are presented.

IRD Belt (IRD)

Primary sites

- IRD1A (49°52.667′N, 24°14.287′W; water depth = 3884 m), at DSDP Leg 94 Site 609.
- IRD3A (41°0.068′N, 32°57.438′W; water depth = 3426 m), at DSDP Leg 94 Site 607.

Alternate site

- IRD4A (42°50.205′N, 23°5.252′W; water depth = 3542 m), at DSDP Leg 94 Site 608.

Proposed Site IRD1A is at DSDP Site 609. The site is an obvious candidate for drilling using modern techniques to recover a demonstrably complete record of the sediment sequence. DSDP Hole 609 penetrated to 400 mbsf and recovered an upper Miocene to Holocene sedimentary sequence comprising nannofossil ooze and chalk. Unfortunately, the present state of these cores, collected in 1983, is poor. This classic site must be redrilled for the high-resolution studies proposed here. The mean sedimentation rate at Site 609 was ~5.7 cm/k.y. *Vema* cruise 23 passed over the site. *Vema* single-channel seismic (SCS) data were augmented by crossing lines (Ch94) at the time of

DSDP drilling. The sediment thickness was estimated to be ~800 m. Our proposed penetration at proposed Site IRD1A (300 mbsf to within the upper Miocene) is less than the penetration in DSDP Hole 609 (400 mbsf); therefore, we believe that no further site survey data are required. The base of the Pliocene lies at ~295 mbsf and represents an attainable target depth for APC drilling.

Proposed Site IRD3A is placed at DSDP Site 607. Mean sedimentation rates at this location are 5–10 cm/k.y. for the last few million years. Two holes were drilled at this site during DSDP Leg 94 (June–August 1983) using the hydraulic piston corer (HPC). A 311 m section of foraminiferal-nannofossil ooze and nannofossil ooze was recovered. The rationale for reoccupying this site is essentially the same as that for DSDP 609. Together Sites 609 and 607 constitute benchmark sites for the long-term (millions of years) surface and deep ocean climate records from the subpolar North Atlantic. DSDP Leg 94 drilling of this site preceded the shipboard capability for construction of composite sections (and pass-through magnetometers for continuous measurement of magnetic parameters). Paleomagnetic data from this site indicate that the magnetic properties are optimal for recording the geomagnetic field. The present condition of existing DSDP cores, collected in 1983, does not permit the high-resolution studies proposed here.

At the site of core VM 30-97, located close to DSDP Site 607, Heinrich events are marked by the distinctive detrital carbonate signature, thereby providing a means of correlation to the other proposed sites. At this locality, antiphased patterns of ocean surface temperatures were found in core VM 30-97 for the 10–40 ka interval (Bond et al., 1999). The proposed redrilling of Site 607 will provide a long-term record of this apparent antiphase pattern that is beginning to emerge in the western North Atlantic. By placing the surface temperature signals into a chronological framework based on a combination of oxygen isotopic stratigraphy, detrital carbonate-bearing Heinrich events, and geomagnetic paleointensity, we expect to obtain an optimal reconstruction of the phasing of the temperature records. Penetration at Site 607 reached 311 mbsf (Hole 607A). We propose the same penetration depth, reaching upper Miocene sediments (base of Pliocene at ~240 mbsf).

At DSDP Site 608 (proposed Site IRD4A), the total penetration was 530 mbsf, reaching basaltic basement (capped by middle Eocene sediments) at 515 mbsf. The target at proposed Site IRD4A is the excellent upper Miocene section in the 140–260 mbsf interval. The base of Pliocene lies at ~140 mbsf and the base of the Miocene at ~410 mbsf.

LOGGING/DOWNHOLE MEASUREMENTS PLAN

The current operations plan for Expedition 303 includes downhole logging at the first proposed site, currently ORPH3A (alternatively, if a different site is drilled first then that site will be logged in place of ORPH3A). The two standard IODP tool string configurations will be deployed. The triple combination (triple combo) tool string logs formation resistivity, density, porosity, natural gamma radiation, and borehole diameter and will be run first, followed by the Formation MicroScanner (FMS)-sonic tool string, which provides an oriented 360° resistivity image of the borehole wall, logs of formation acoustic velocity, natural gamma ray, and borehole diameter. The Lamont-Doherty Earth Observatory (LDEO) high-resolution Multisensor Gamma Tool (MGT) will be deployed on the top of the triple combo tool string and run on a separate pass. Logging operations at additional sites and during Expedition 306 will take place based upon an assessment of the results from proposed Site ORPH3A. Preferred sites for logging during Expedition 306 (assuming the ideal operational plan) are IRD3A and one of the GAR sites.

Assessment of logging at additional sites will require consideration of multiple issues. The objectives of these cruises are intimately linked to obtaining complete recovery of the sedimentary section, requiring at least three, and possibly four holes at each site. Thus, there is an obvious impact when opting between these two operational activities for these cruises; when logging operations are in progress, core is not being acquired. In addition, because the base of the drill pipe must be securely in the hole during logging operations (typically 100 mbsf, but in some conditions somewhat shallower), the upper part of the sedimentary section is not logged.

On the other hand, logging data will assist in the construction of a robust stratigraphic framework for the site through detailed core-log integration. This will allow core data to be plotted on a true depth scale, thereby allowing an assessment of core expansion and identification of core gaps. Ensuring quality control of spliced core records is of fundamental importance to the success of this expedition and can only be fully achieved through comparison with logging data. Additionally, the high sedimentation rates expected at some of the proposed sites will allow the identification of Milankovitch cycles in much of the standard logging data (including natural gamma radiation, density, and porosity). Environmental changes occurring over millennial time periods will be identifiable in the FMS data. Obviously, the importance of logging data only increases if core recovery is less than ideal.

In summary, additional logging after the first site will entail evaluation by the science party of core and logging data quality and the impact of weather conditions on coring and logging operations, previous logging in the area, depth of coring penetration, and operational time constraints, all in light of the issues discussed above. This will likely be required on a site-by-site basis. Further details on logging tools and their applications can be found on the LDEO Borehole Research Group (BRG) Web site (www.ldeo.columbia.edu/BRG/).

SAMPLING STRATEGY

General Conditions

Shipboard and shore-based researchers should refer to the interim IODP Sample, Data, and Obligations policy posted on the Web at iodp.tamu.edu/curation/policy.html. This document outlines the policy for distributing IODP samples and data to research scientists, curators, and educators. The document also defines the obligations that sample and data recipients incur. Access to data and core sampling during Expeditions 303 and 306, or within the 1 y moratorium following the expeditions, must be approved by the Sample Allocation Committee (SAC). The SAC (composed of Co-Chief scientists, Staff Scientist, and IODP Curator on shore and curatorial representative on board ship) will work with the Shipboard Scientific Party to formulate a formal expedition-specific sampling plan for shipboard and postcruise sampling.

Shipboard scientists are expected to submit sample requests 2 months before the beginning of the expedition. Sample requests may be submitted at iodp.tamu.edu/curation/samples.html. Based on sample requests (shore based and shipboard), the SAC and Shipboard Scientific Party will prepare a working cruise sampling plan. This plan will be subject to modification depending upon the actual material recovered and collaborations that may evolve between scientists during the expedition. Modifications to the sampling plan during the expedition require the approval of the SAC.

All sample frequencies and sizes must be justified on a scientific basis and will depend on core recovery, the full spectrum of other requests, and the cruise objectives. Some redundancy of measurement is unavoidable, but minimizing the duplication of measurements among the shipboard party and identified shore-based collaborators will be a factor in evaluating sample requests.

Cruise-Specific Sampling

Shipboard sampling during both expeditions will be restricted to low-resolution sampling (e.g., biostratigraphic sampling). Samples for high-resolution studies (such as stable isotope investigations) will be carried out postcruise at a designated sampling party.

The Science Planning Committee (SPC) has advocated that the participants of Expeditions 303 and 306 be considered as a single scientific party. The ramification of this is that Expedition 303 and 306 participants may work on materials from either expedition, pending approval of individual sample requests by the SAC. Because Expedition 306 is scheduled to depart ~4 months after Expedition 303, staffing of the shipboard party for Expedition 306 will not have been completed prior to the date that Expedition 303 sails. Hence, developing an integrated sampling plan before the first expedition commences is not possible. As mentioned above, the bulk of the sampling for these expeditions will occur during postcruise sampling parties. Therefore, a more integrated plan can be developed prior to each sampling party. Expedition 303 participants will submit precruise sample requests in August 2004. Expedition 306 participants will submit sample requests for consideration by January 2005 prior to the Expedition 303 sampling party (tentatively scheduled for February 2005), which may necessitate modification of sample requests by Expedition 303 participants. Similarly, for the Expedition 306 sampling party (tentatively scheduled for late July 2005), sample requests from Expedition 303 participants will be considered at that time.

CORK INSTALLATION AT ODP SITE 642

Introduction

The northern North Atlantic is the primary deep ventilator of the oceans, and it is now recognized that production of deep water in this area is intimately related to the global climate (Broecker et al., 1985; Dickson, 1997; Woods et al., 1999). Changes in the production of NADW may be the result of, or lead to, regional or global climatic changes. Unfortunately, there is a lack of long-term observations and those that do extend back in time are concentrated at the surface or near surface. Hydrographic time series from the North Atlantic, though sparse and sporadic, show natural variability on timescales of decades to centuries (Wunsch, 1992). The few observations that exist for the deep ocean show variability on similar timescales and at large spatial scales. Oceanographic observations indicate that the thermohaline structure of the North Atlantic has changed over the past 20–30 y and the presence of significant variations in bottom water temperature (BWT) (Roemmich and Wunsch, 1984; Antonov, 1993).

Background

It is hypothesized that subbottom temperature-depth profiles can be used to construct BWT histories at timescales on the order of decades to a century. The conductive thermal regime of oceanic crust comprises the superposition of two processes: the outward flow of heat from the Earth's deep interior and perturbations to the deep regime by changes of BWT at the seafloor.

The latter effects operate on a relatively short timescale (decades, centuries, and millennia), whereas the former process operates on a geologic timescale, with secular changes taking place over millions of years. In the context of the short-term BWT perturbations, the outward flow of heat from the interior is seen as a quasi-steady-state process. Because oceanic sediments have a low thermal diffusivity, changes in BWT diffuse slowly downward by conduction, perturbing the background thermal regime. These measurable anomalies are a direct thermophysical consequence of BWT variations and, as such, are a straightforward measure of temperature, not a proxy. Resolution analysis indicates that 100 y of temperature change is potentially recoverable from high-precision temperature-depth logs in boreholes 200 m deep. If this hypothesis is correct and because ocean bottom sediments continuously record changes in BWT, it is theoretically possible to reconstruct BWT histories anywhere in the ocean.

ODP Site 642 (Fig. F1) represents an ideal candidate to test this hypothesis for two reasons. It is located near Ocean Weather Ship Station (OWS) Mike, which has been in continuous operation over the last 50 y. Weekly temperature and salinity measurements at depths greater than 2000 m have been made since 1948 (Gammelsrød et al., 1992). These measurements represent the longest homogeneous time series from the deep ocean. They will be used to check the efficacy of our measurements and analysis as well as to provide a direct test of our hypothesis. Site 642 is located on the eastern margin of the Norwegian Sea (Fig. F1), a climatically sensitive area that records the changing hydrographic character and horizontal exchange of deep water from the Greenland Sea, Arctic Ocean, and Norwegian Sea. As such, BWT histories will yield insight into the complex interplay between these important water masses.

Scientific Objectives

The primary objectives of this study are to

- Document the ability to recover BWT histories from temperature-depth profiles. The possibility to reconstruct BWT histories with sufficient resolution creates the potential for transects of such measurements across climatologically important gateways such as Reykjanes Ridge.
- Reconstruct BWT histories at Site 642. How large have these variations been? How far back in time can we reliably estimate BWT histories?
- Isolate perturbations in the subsurface temperature profile resulting from variations in BWT histories. Are observed temperature perturbations to the background thermal field in fact due to variations in BWT?

Proposed Research

To capture thermal transients associated with temporal variations in BWT, we will install a borehole observatory in a new 150 mbsf hole close to Site 642, consisting of a CORK (which will seal the borehole from the overlying ocean), thermistor string, data logger to make and record the temperature measurements, and a seal below the temperature string to ensure against formation fluids entering the borehole interval where the measurements are made. This configuration allows high-precision temperature measurements as a function of both depth and time. High-precision temperature measurements will be made at two timescales: in quick succession and over longer time intervals. Averaging a quick succession of temperature measurements is an effective way to reduce instrumental and environmental noise. Temperature measurements with an appropriate length of time between them can be used to directly monitor the propagation of transient temperatures (Chapman and Harris, 1992).

Casing and CORK Installation Plan

At 6712.7°N, 255.8˚E (water depth = 1289 m) near Hole 642E, operations will begin with a jet-in test followed by drilling in to 150 mbsf of 10¾ inch casing and reentry cone. The bottom of the cased hole will be sealed with a bridge plug, and then the CORK and thermistor string will be installed (Table T2).

Logging/Downhole Measurements Plan

The current operational plan for the new hole at Site 642 precludes a logging program. However, it is highly desirable to have a downhole record of temperature from Hole 642E to assess current background thermal conditions in the region. A high priority, if time and operations allow, will be to produce a vertical temperature profile, using a tool such as the Davis-Villinger Temperature Probe (DVTP) or the Lamont high-temperature tool.

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Table T1. Expedition 303 operations plan and time estimate.

Site	Location (lat/long)	Water depth (mbsl)	Operations description	Transit (days)	Drilling (days)	Logging (days)
St. John's, Newfoundland			Sea Voyage from St John's to ORPH3A: 317 nmi @ 10.0 kt	1.3		
ORPH3A (Canada)	50°09.984′N, 45°38.273′W	3591	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		7.2	
			Log: triple combo and FMS-sonic.			0.8
			Transit from ORPH3A to LAB7A: 486 nmi @ 10.0 kt	1.9		
LAB7A (Denmark)	58°14.227′N 46°38.589′W	2273	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.5	
			Transit from LAB7A to LAB3A: 59 nmi @ 10.0 kt	0.2		
LAB3A (Denmark)	58°02.169′N 48°27.57′W	3350	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
			Transit from LAB3A to LAB6A: 34 nmi @ 10.0 kt	0.1		
LAB6A (Denmark)	57°28.508′N 48°31.842′W	3485	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
			Transit from LAB6A to IRD1A: 969 nmi @ 10.0 kt	3.9		
IRD1A (International)	49°52.667′N 24°14.287′W	3884	3X APC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.9	
Ponta Delgada			Sea Voyage from IRD1A to Ponta Delgada, Azores: 757 nmi @ 10.0 kt	3.2		
			Subtotal:	10.6	32.4	0.8
			Total operating days:	43.8		

Alternate sites*						
IRD3A (International)	41°0.068′N 32°57.438′W	3426	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
IRD4A (International)	42°50.205′N 23°05.252′W	3542	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements		6.8	
LAB8A (Denmark)	58°28.525′N 46°27.823′W	2650	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.9	
LAB8B (Denmark)	58°33.227′N 46°18.04′W	2556	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.5	
LAB8C (Denmark)	58°30.346′N 46°24.034′W	2554	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
ORPH2A (Canada)	50°12.40′N 45°41.22′W	3539	3X APC to 200 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		4.8	
GAR2A (International)	53°03.400′N 33°31.780′W	3024	3X APC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.0	
GAR1B (International)	56°21.882′N 27°53.310′W	2821	3X APC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.0	

Notes: APC = advanced piston coring. * = all Expedition 306 primary sites are listed as alternates for Expedition 303.

Table T2. Expedition 306 operations plan and time estimates.

Site	Location (lat/long)	Water depth (mbsl)	Operations description	Transit (days)	Drilling (days)	Logging (days)
Ponta Delgada			Sea Voyage from Ponta Delgada to IRD3A: 416 nmi @ 10.0 kt	1.7		
IRD3A (International)	41°0.068′N, 32°57.438′W	3426	3X APC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.6	
			Transit from IRD3A to ORPH2A: 766.5 nmi @ 10.0 kt	3.2		
ORPH2A (Canada)	50°12.40′N, 45°41.22′W	3539	3XAPC to 200 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		4.8	
			Transit from ORPH2A to GAR2A: 483.2 nmi @ 10.0 kt	2.0		
GAR2A (International)	53°03.400′N 33°31.780′W	3024	3XAPC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.0	
			Transit from GAR2A to GAR1A: 278.5 nmi @ 10.0 kt	1.2		
GAR1B (International)	56°21.882′N 27°53.310′W	2821	3XAPC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.0	
			Transit from GAR1A to Site 642:1031.6 nmi @ 10.0 kt	4.3		
Site 642 (Norway)	67°12.70′N 02°55.80′W	1288	Install reentry cone with 150 m 10 3/4 inch casing and CORK with thermistor string.		4.8	
Reykjavik			Sea Voyage from Site 642 to Reykjavik, Iceland: 657.7 nmi @ 10.0 kt	2.7		
			Subtotal:	15.1	27.5	
			Total operating days:	43.3		

Site	Location (lat/long)	Water depth (mbsl)	Alternate sites*	Transit (days)	Drilling (days)	Logging (days)
IRD-1A (International)	49°52.667′N 24°14.287′W	3884	3X APC to 300 mbsf. Drillover stuck core barrels. Tensor orientation on all APC cores. Four Adara measurements.		6.9	
IRD-4A (International)	42°50.205′N 23°05.252′W	3542	3X APC to 300 mbsf. Drillover stuck core barrels to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.8	
LAB-7A (Denmark)	58°14.227′N 46°38.589′W	2273	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.5	
LAB-3A (Denmark)	58°02.169′N 48°27.57′W	3350	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
LAB-6A (Denmark)	57°28.508′N 48°31.842′W	3485	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
LAB-8A (Denmark)	58°28.525′N 46°27.723′W	2703	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.9	
LAB-8B (Denmark)	58°33.227′N 46°18.04′W	2556	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		5.5	
LAB-8C (Denmark)	58°30.346′N 46°24.034′W	2618	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		6.4	
ORPH-3A (Canada)	50°09.98′N 45°38.27′W	3591	3X APC to 300 mbsf. Drillover stuck core barrels. to extend APC depth. Tensor orientation on all APC cores. Four Adara measurements.		7.2	

Notes: APC = advanced piston coring. * = all Expedition 303 primary sites are listed as alternates for Expedition 306.

Figure F1. Location of proposed drill sites. Blue circles = primary sites planned for Expedition 303, red circles = primary sites planned for Expedition 306, and open circles = alternate sites.

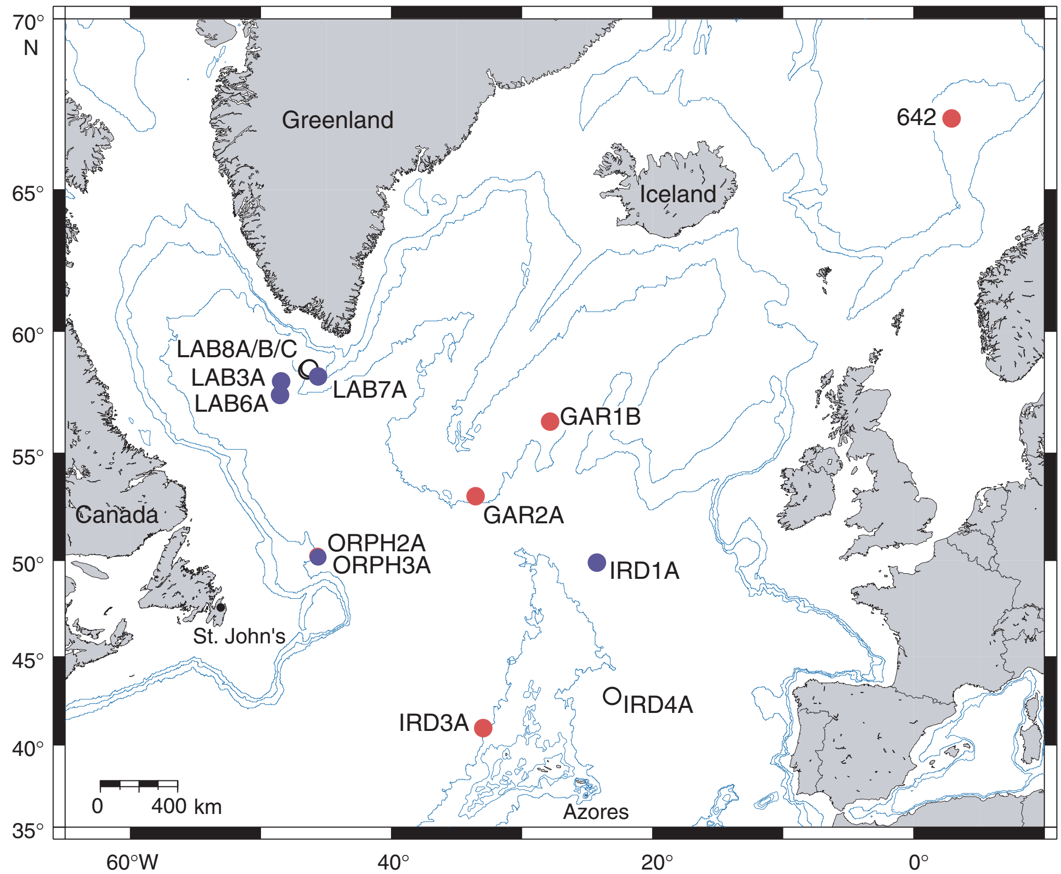


Figure F2. Geomagnetic paleointensity and cosmogenic isotope records on the GISP2 official chronology of Meese et al. (1994) and Bender et al. (1994). A. ^{10}Be flux from the GISP2 ice core (Finkel and Nishiizumi, 1997) and ^{36}Cl flux from the GRIP ice core (Baumgartner et al., 1998). B–G. Geomagnetic paleointensity records: (B) MD95-2024, Orphan Knoll, proposed Site ORPH2A (Stoner et al., 2000); (C) MD95-2009 (Faeroe-Shetland Ridge) (Laj et al., 2000); (D) North Atlantic ODP Site 983 (Channell et al., 1997); (E) Mediterranean stack (Tric et al., 1992); (F) Somali Basin (Meynadier et al., 1992); (G) Core 21-PC02 (subantarctice South Atlantic) (Channell et al., 2000). H. ^{10}Be flux from the Vostok Ice Core (Mazaud et al., 1994; Meese et al., 1994). I. Sint-200 paleointensity composite (Guyodo and Valet, 1996). Shading represents detrital layers on MD95-2024 (ORPH2A).

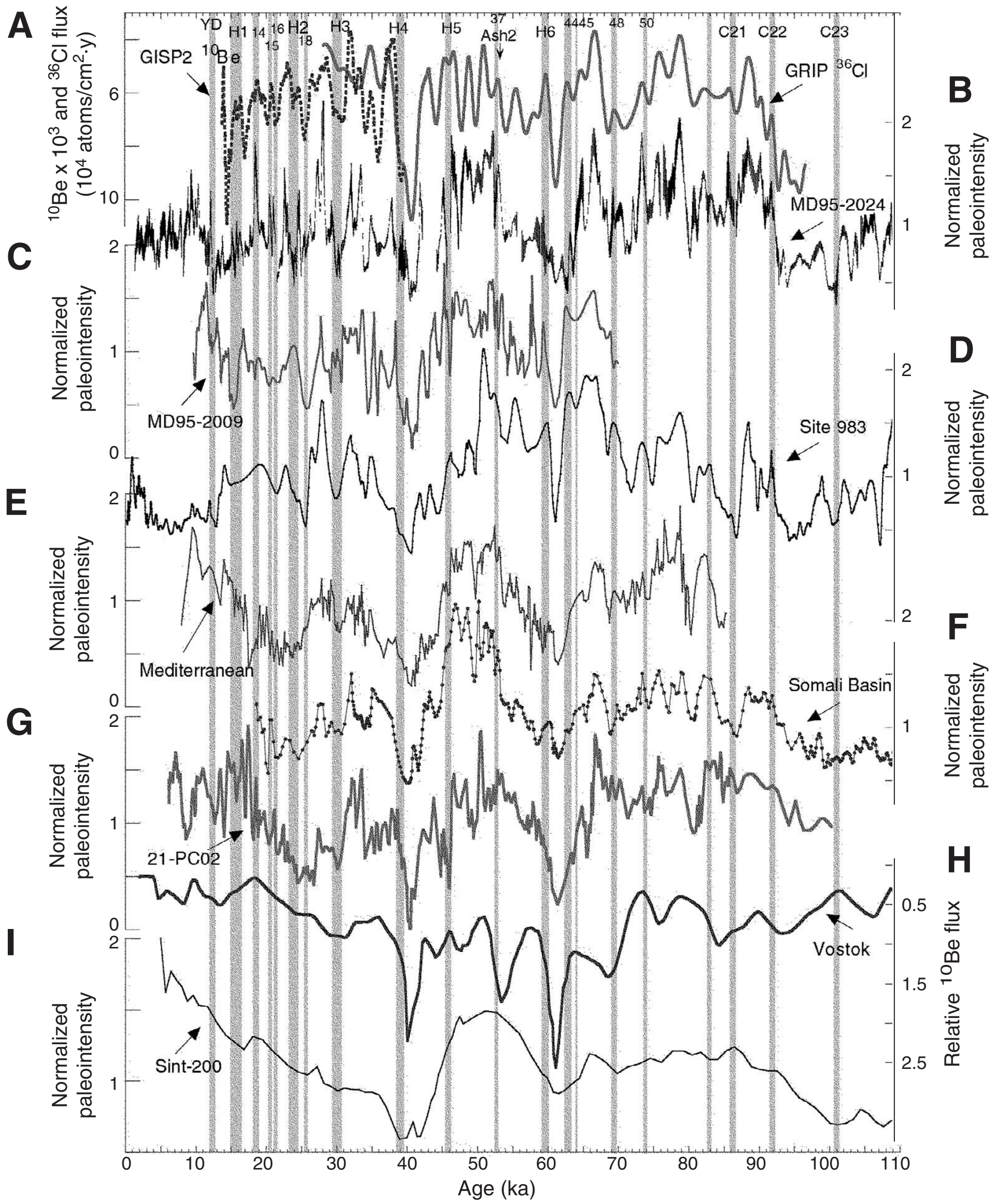


Figure F3. Benthic oxygen isotope and geomagnetic paleointensity records for the 320–400 ka interval based on correlation of the paleointensity records. A. $\delta^{18}O$ reference curve. B, E. North Atlantic ODP Site 983 benthic $\delta^{18}O$ (*C. wuellerstorfi*) and paleointensity, respectively (Channell et al., 1997, 1998). C, F. North Atlantic ODP Site 984 benthic $\delta^{18}O$ (*C. wuellerstorfi*) and paleointensity, respectively (Channell et al., 1998; Channell, 1999). D, G. ODP Site 1089 benthic $\delta^{18}O$ and paleointensity, respectively (Stoner et al., 2003.

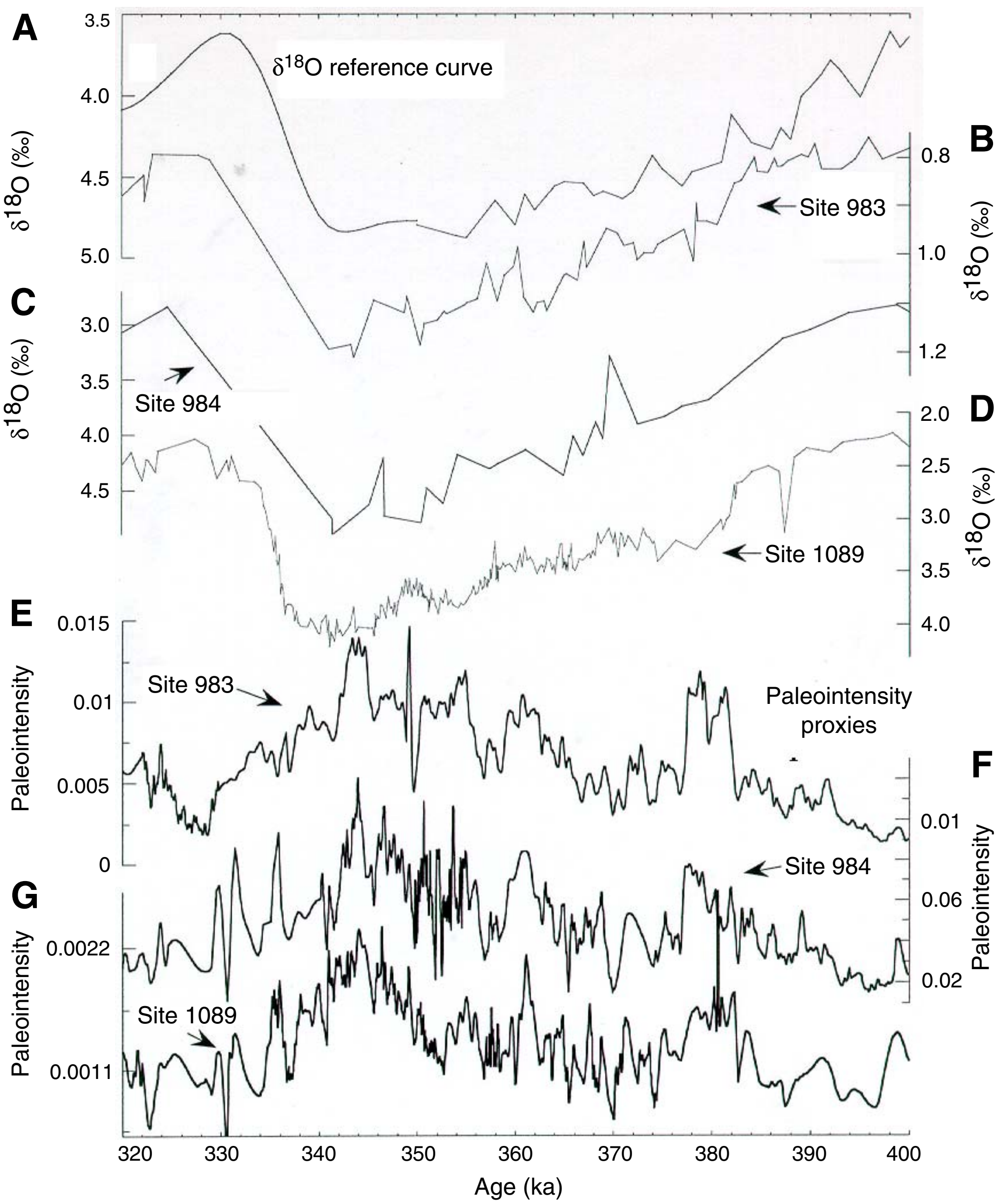


Figure F4. Location of Orphan Knoll (from Toews and Piper, 2002).

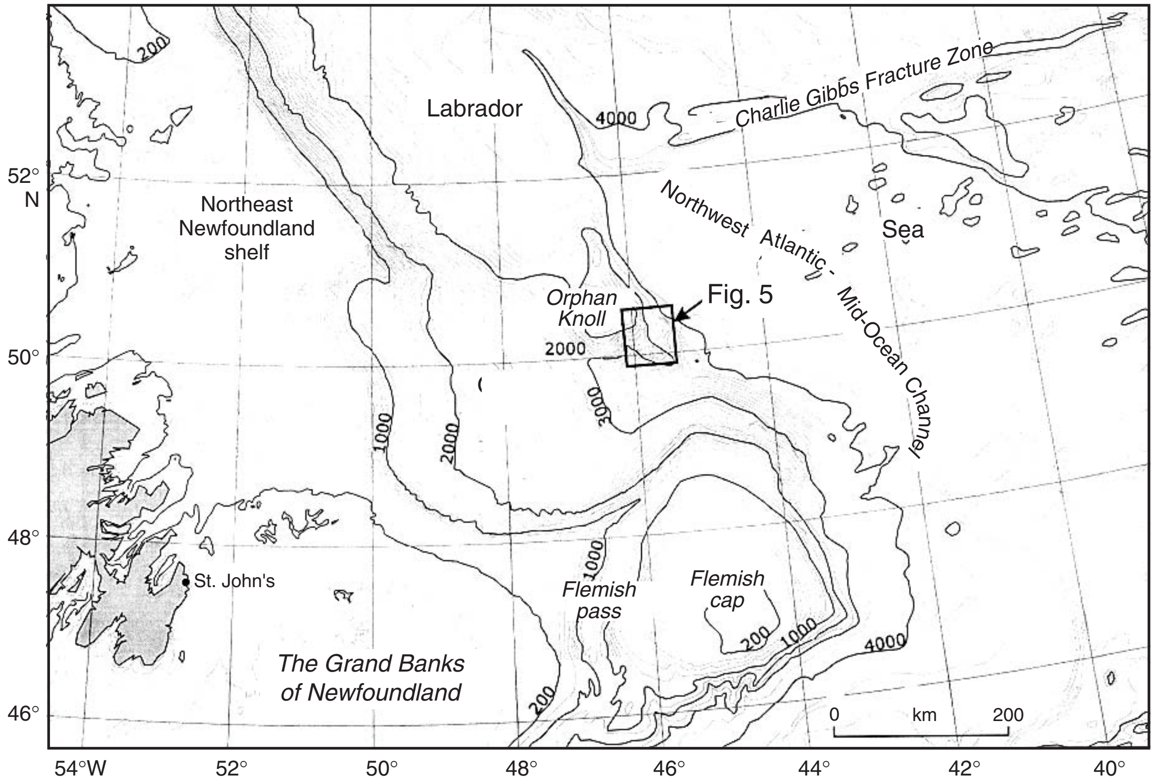


Figure F5. Bathymetric map of southeast part of Orphan Knoll showing location of piston cores, ship's track for site survey data acquisition, and the seismic reflection profile in Figure F7. The location of piston core HU91-045-094 coincides with the location of proposed Site ORPH2A (from Toews and Piper, 2002).

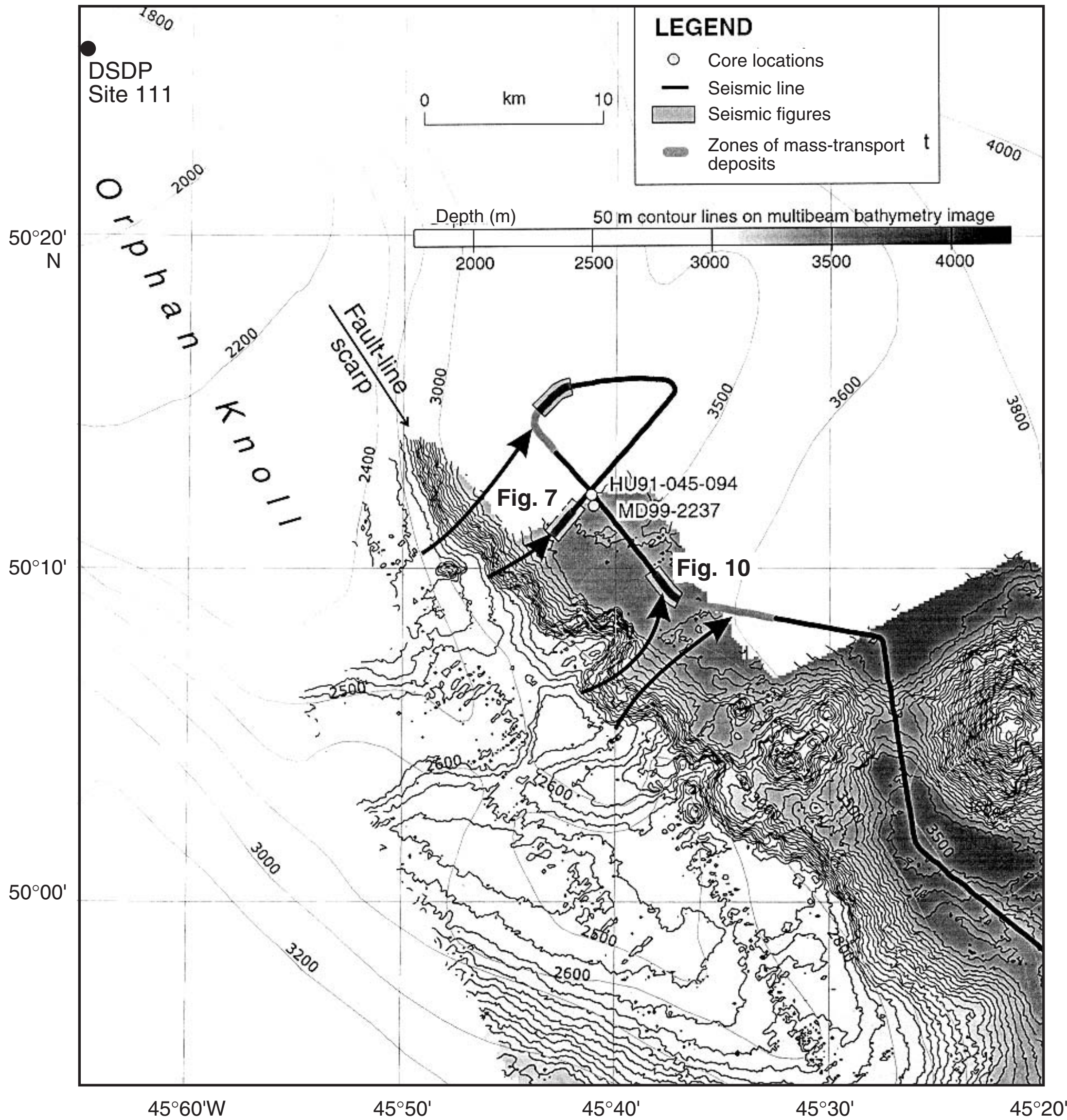


Figure F6. Proposed Sites ORPH2A and ORPH3A located on air gun profile.

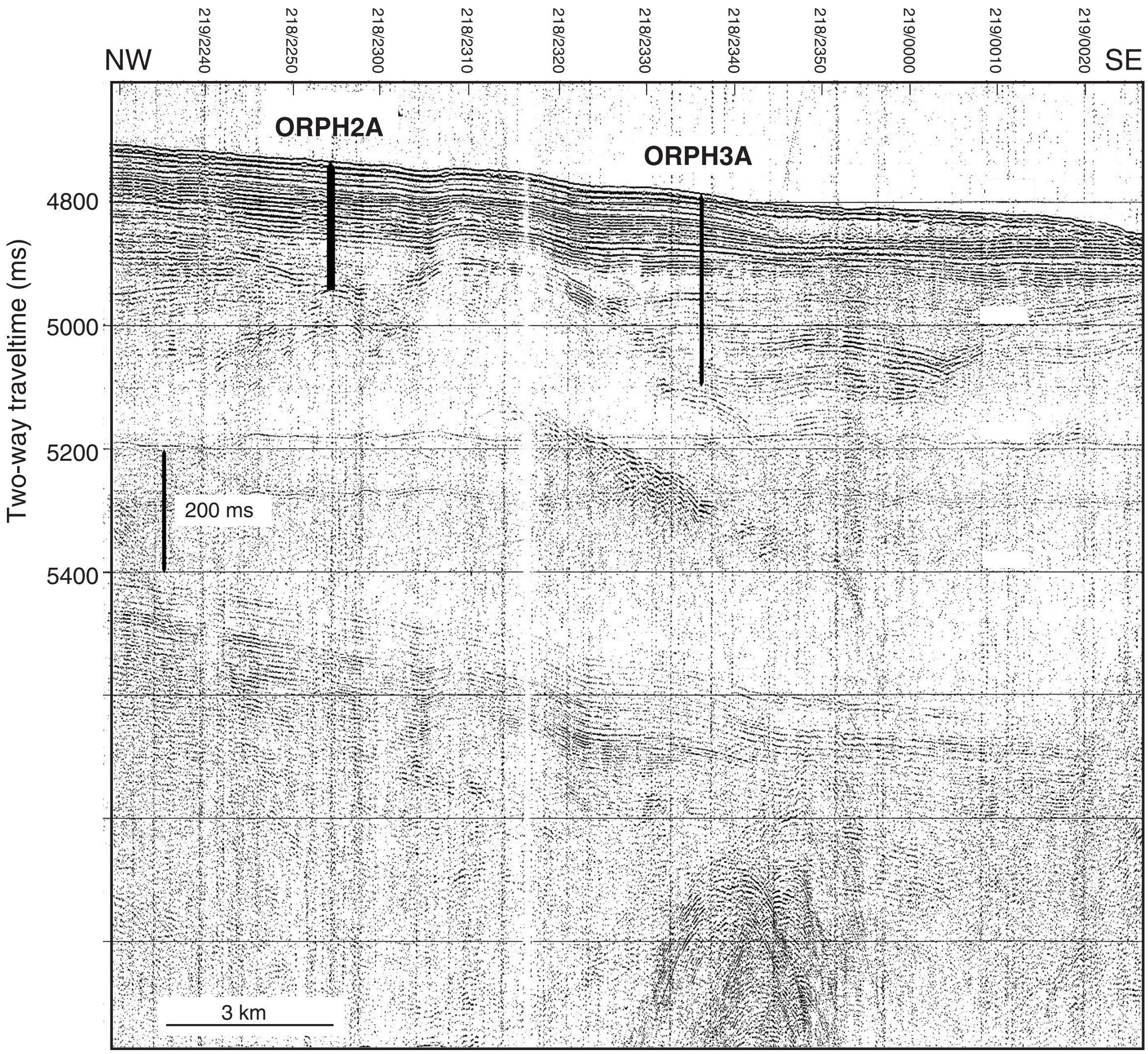


Figure F7. Huntec sparker profile showing type section for the seismic stratigraphy and the moat at the base of the fault scarp. Reflector labeled "pink" has an age of 120 ka based on correlation to piston cores. Proposed Site ORPH2A lies ~5 km northeast of the scarp. Location of seismic section is shown on Figure F5 (after Toews and Piper, 2002).

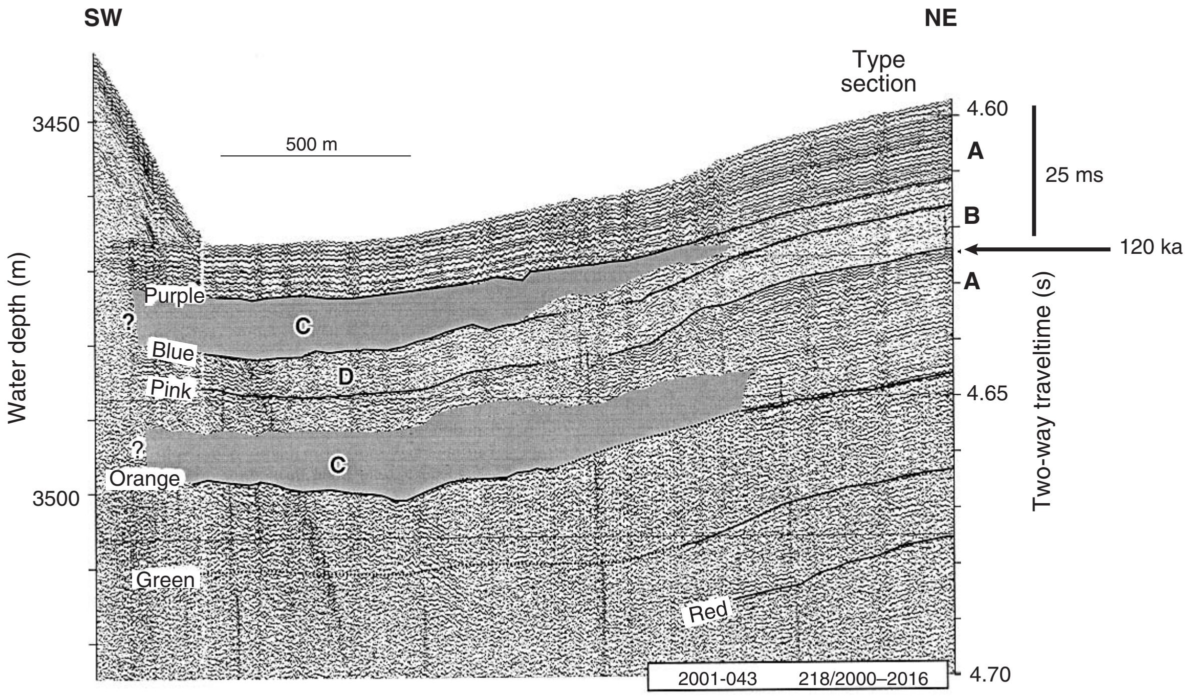


Figure F8. Huntec sparker profile at proposed Site ORPH2A.

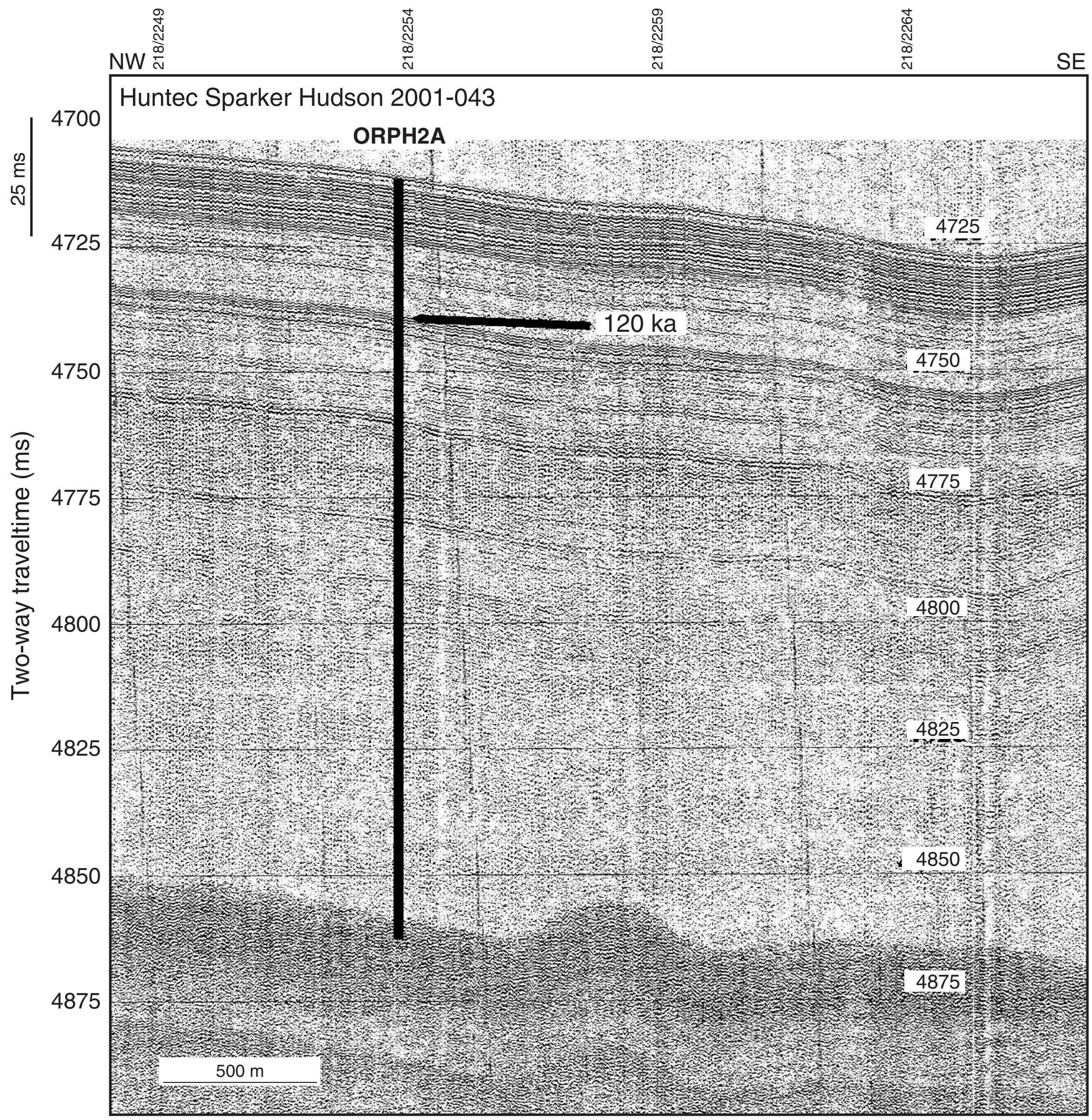


Figure F9. Location of LAB sites. Seismic Lines BGR-1, BGR-2, and lines from cruise KN166-14 are shown.

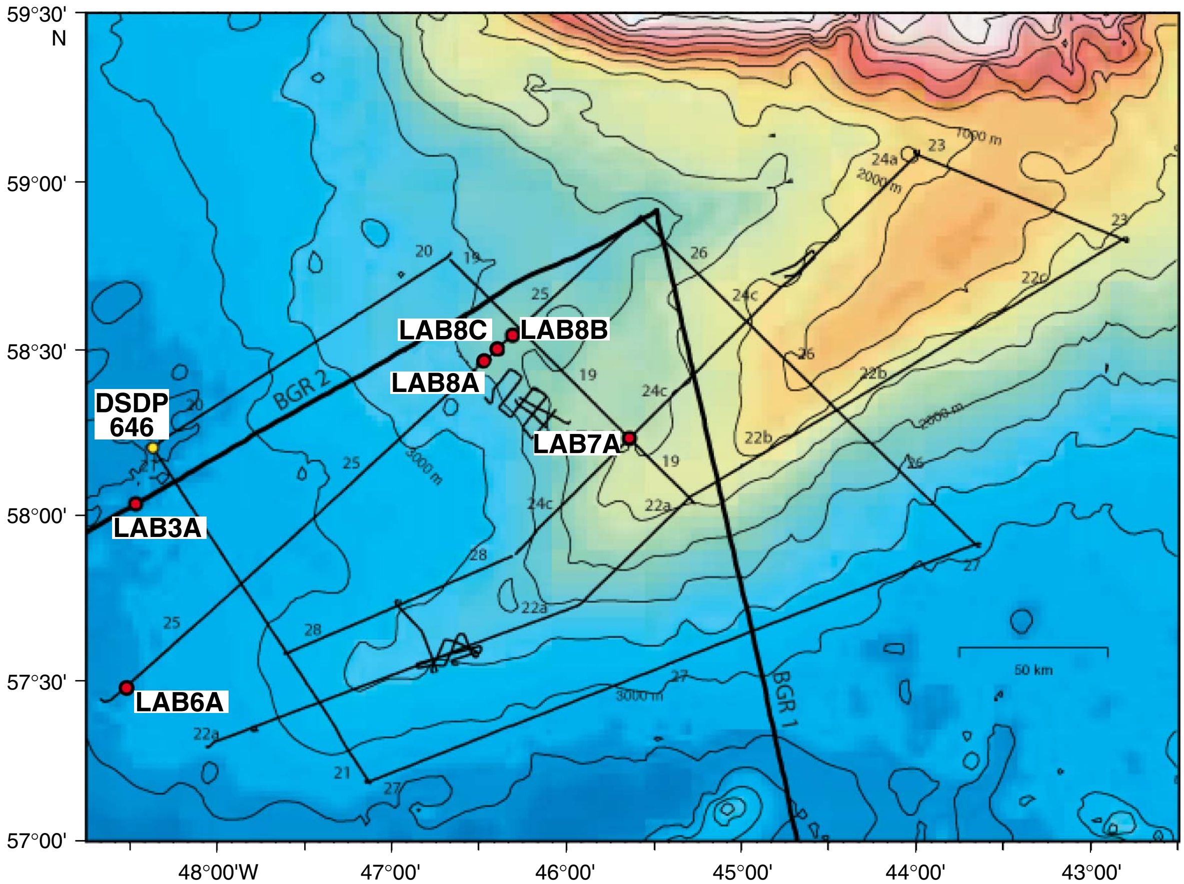


Figure F10. Proposed Site LAB-3A on seismic Line BGR-1. Hudson Line 14 from cruise HD84-30 and KN166-14 Line 21 connect this line to ODP Site 646 (see Fig. F9).

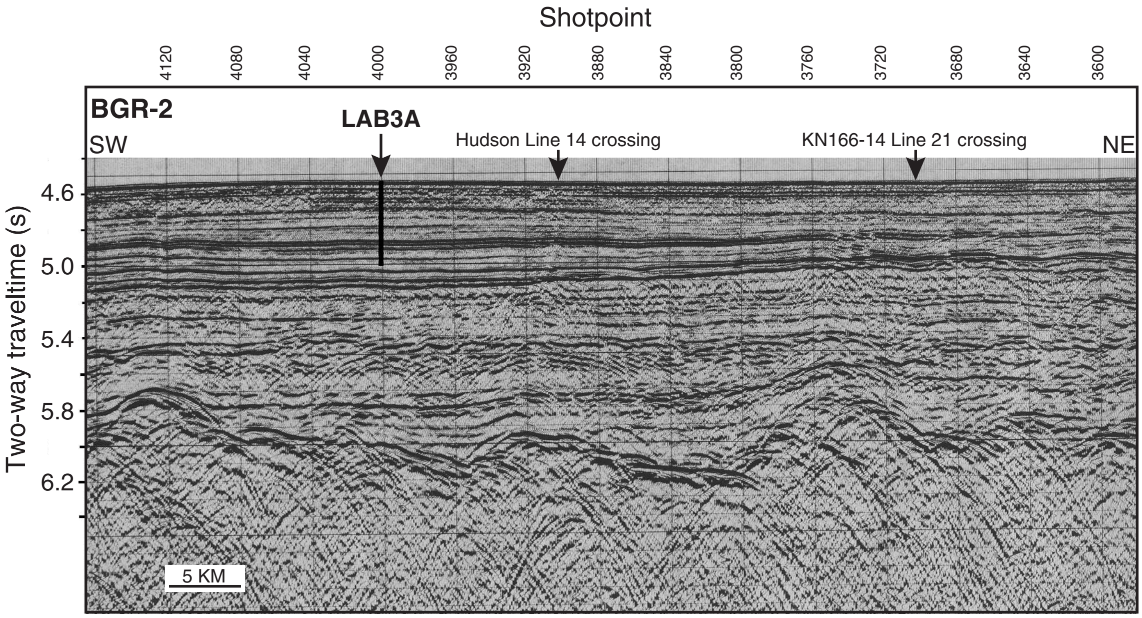


Figure F11. Hudson Line 14 (cruise HD84-30) that crosses ODP Site 646 and Line BGR-2 (see Figs. F9, F10) (from Arthur et al., 1989).

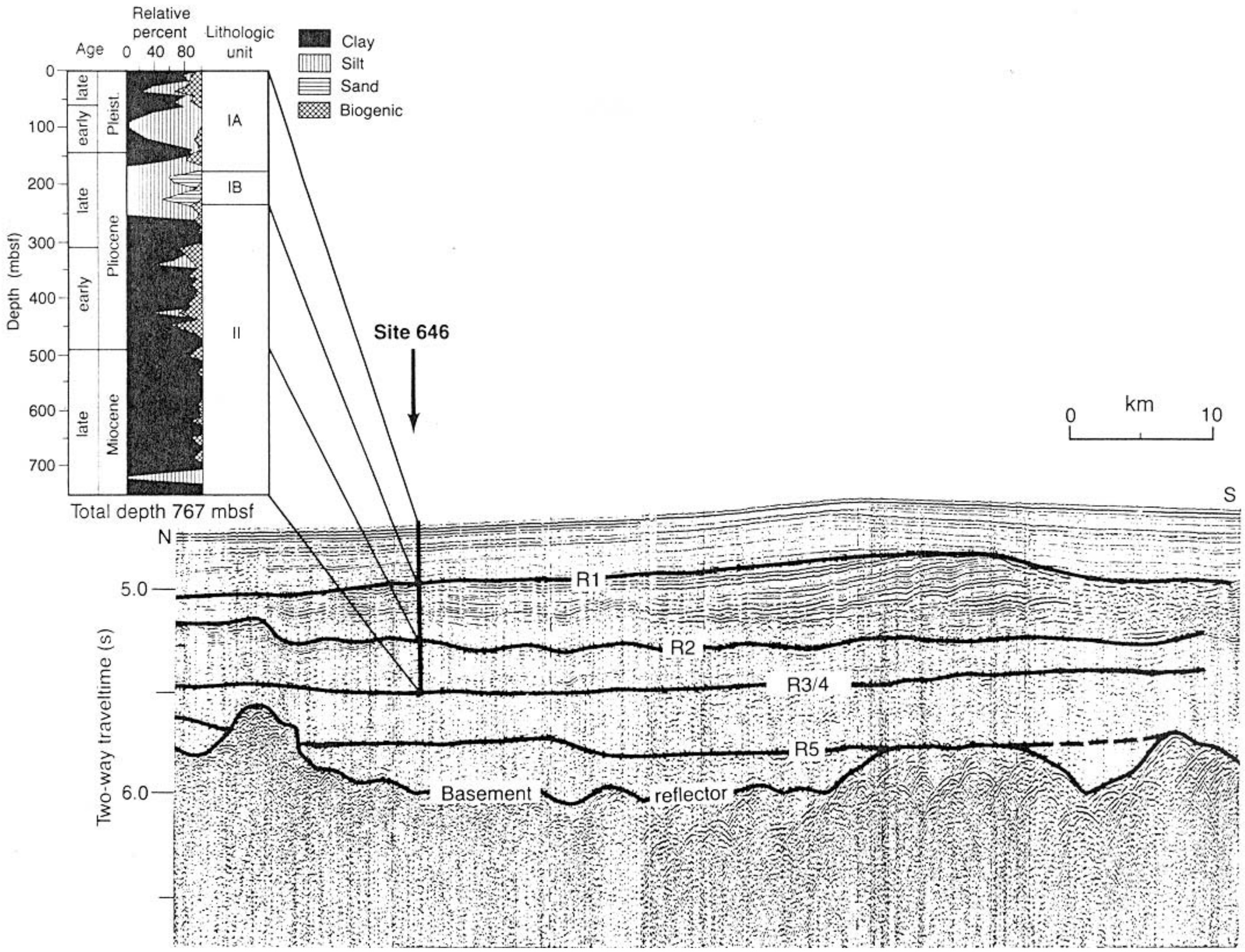


Figure F12. Track map for crossing of BGR-2 and KN166-14 Line 21.

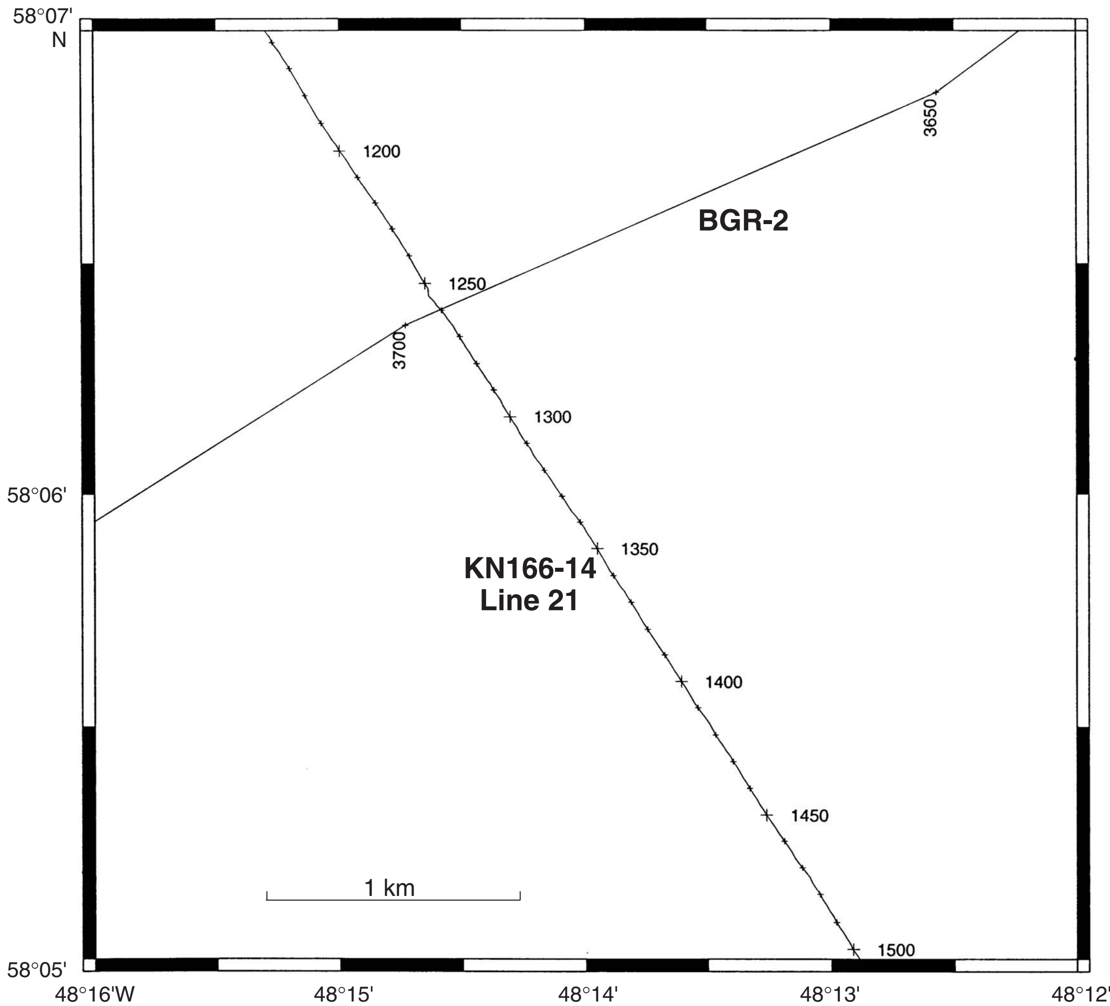


Figure F13. KN166-14 Line 21 showing the BGR-2 crossing.

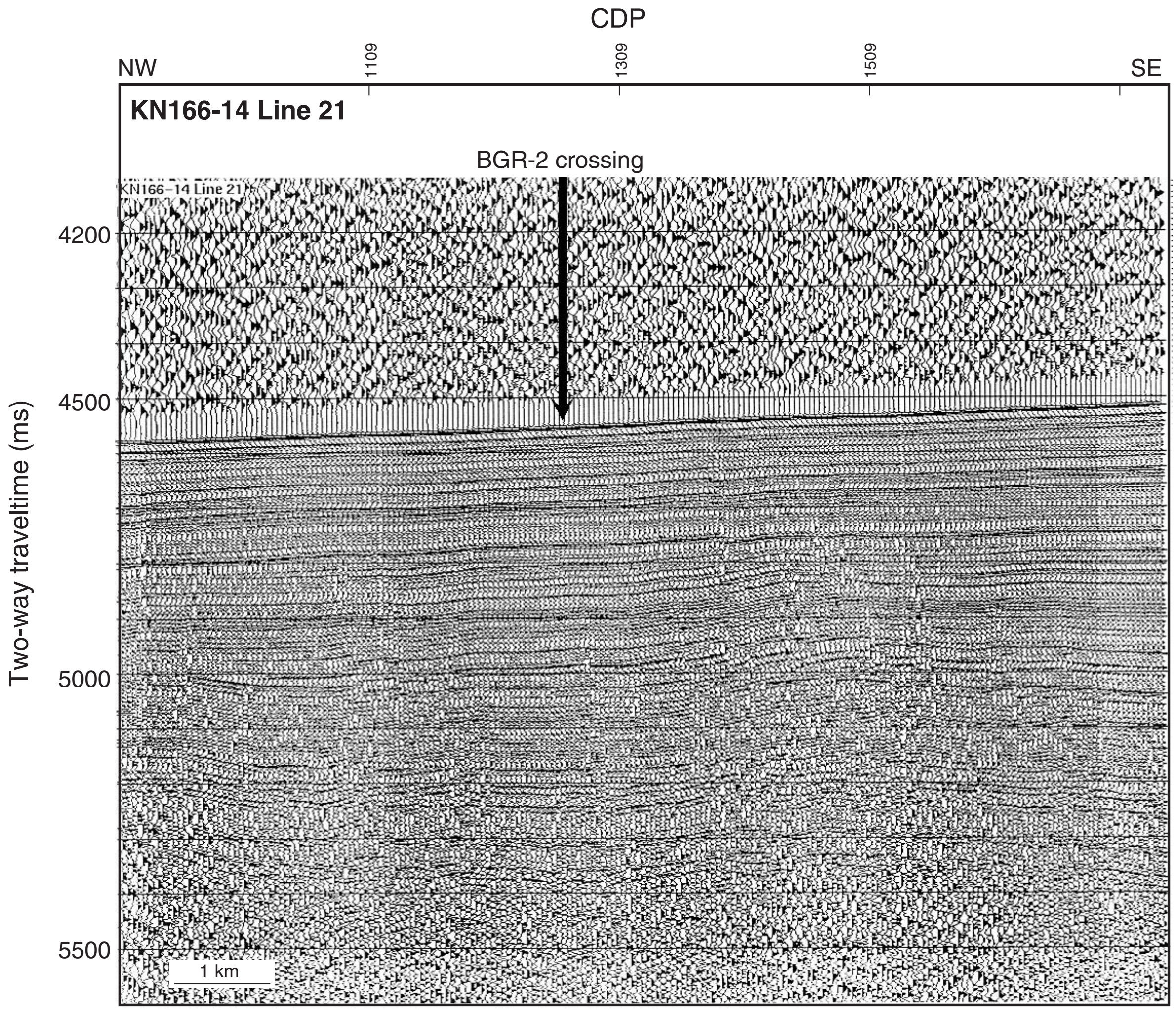


Figure F14. Track map for KN166-14 Line 25a showing location of proposed Site LAB-6A at CDP 900
.

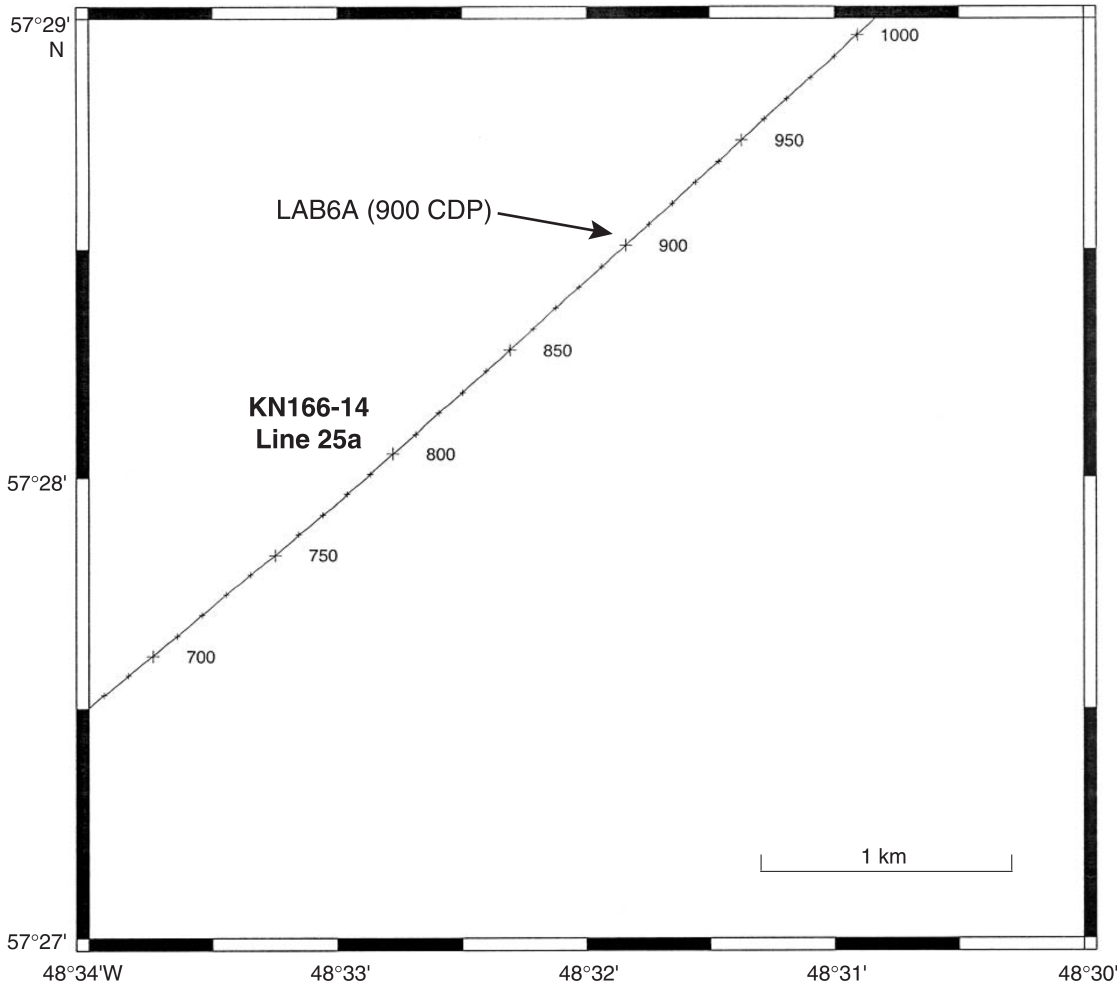


Figure F15. Proposed Site LAB-6A located on KN166-14 Line 25a (see Fig. F9).

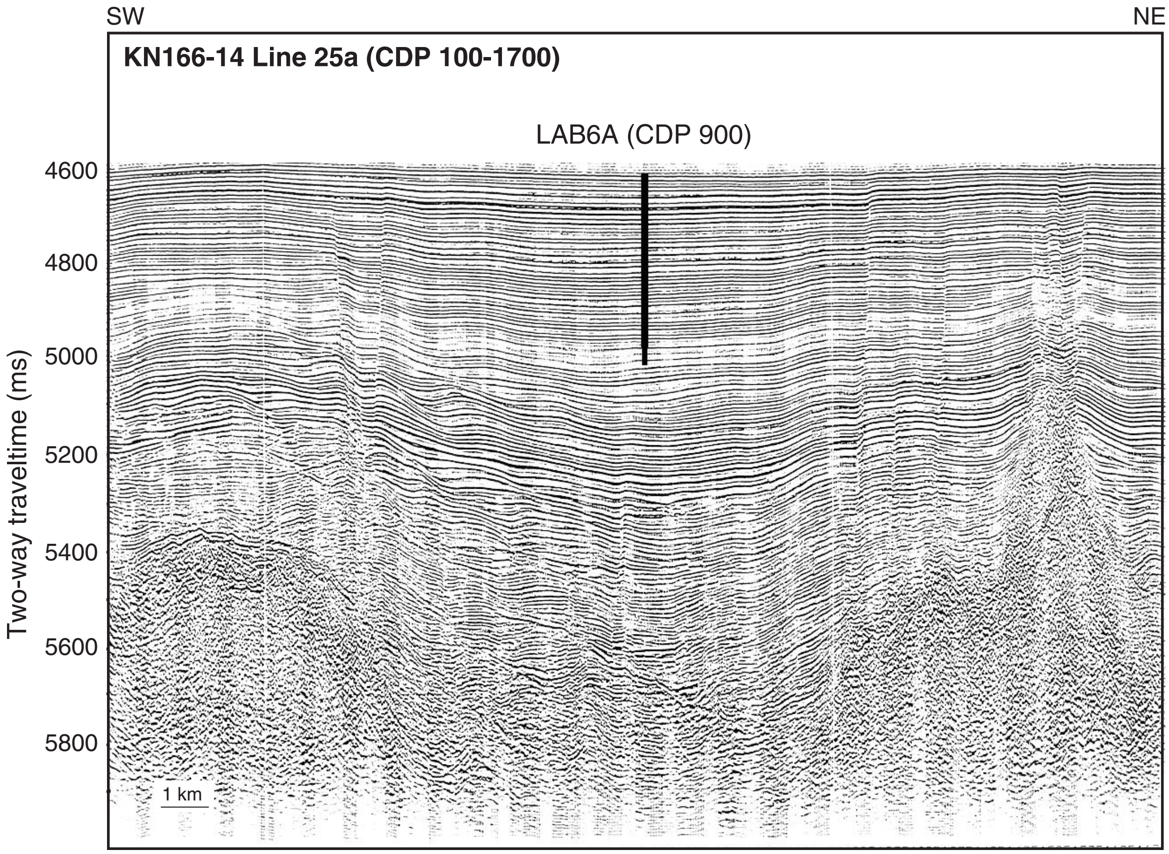


Figure F16. Proposed Site LAB-6A on KN166-14 Line 25a (3.5 kHz).

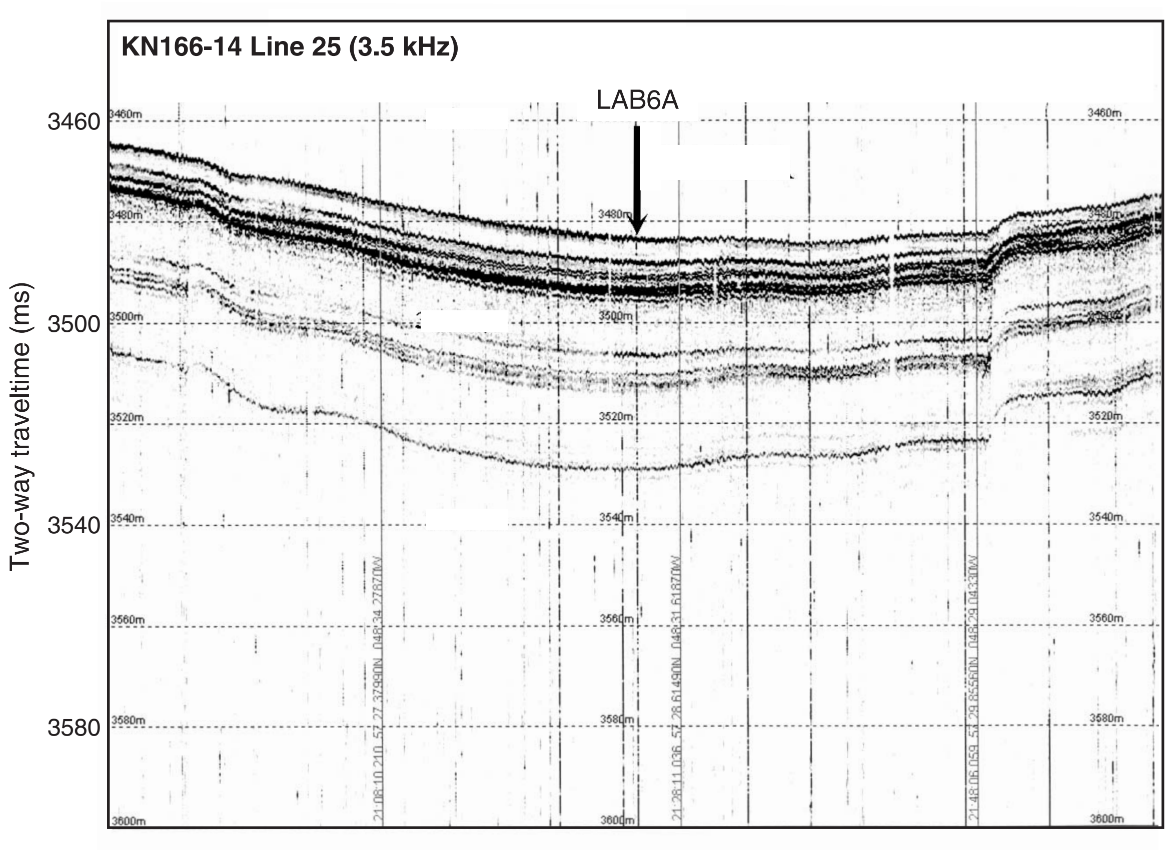


Figure F17. Proposed Site LAB-7A on KN166-14 Line 19.

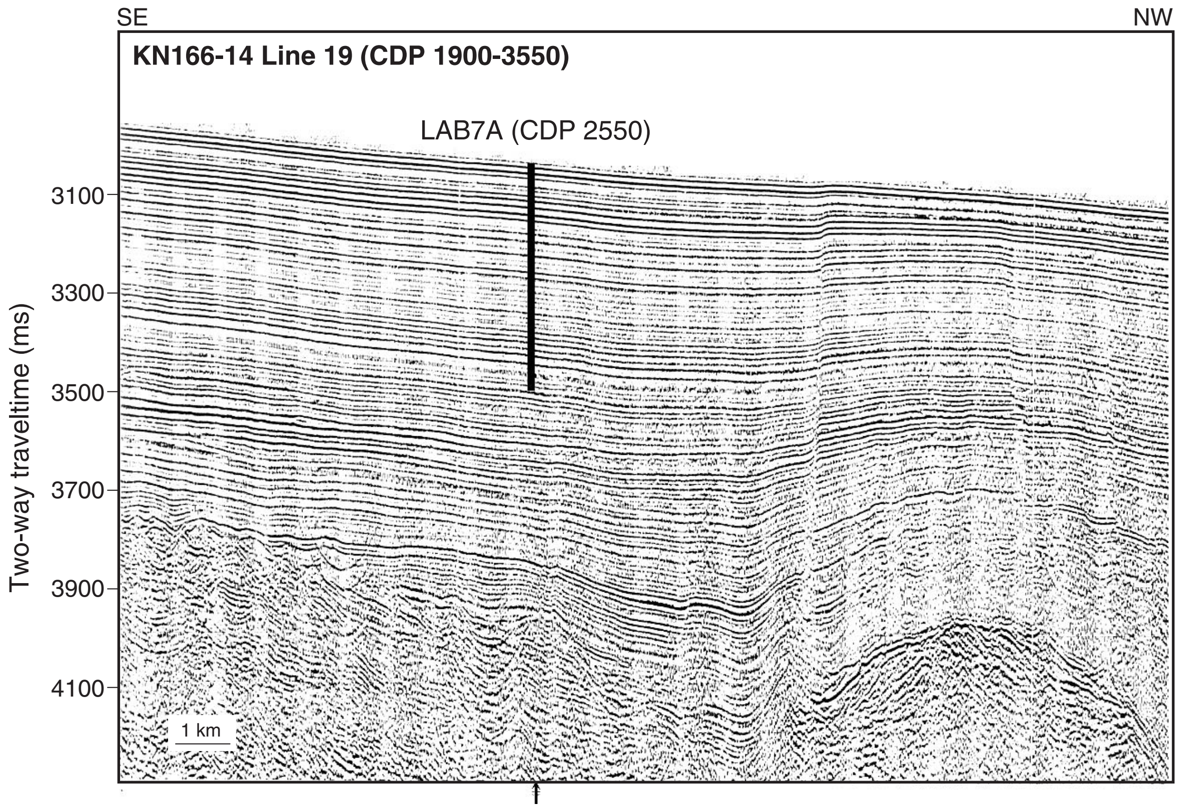


Figure F18. Proposed Site LAB-7A on KN166-14 Line 24c.

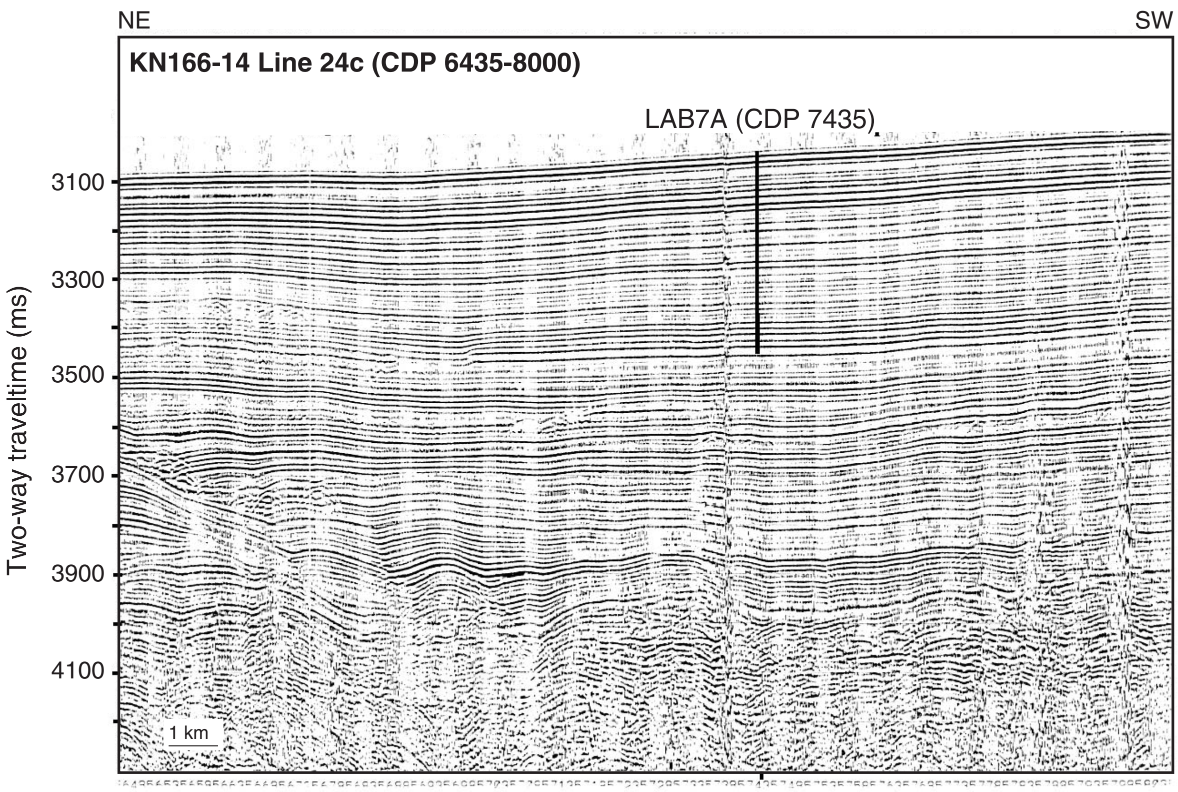


Figure F19. Proposed Site LAB-7A on 3.5 kHz data, KN166-14 Line 19.

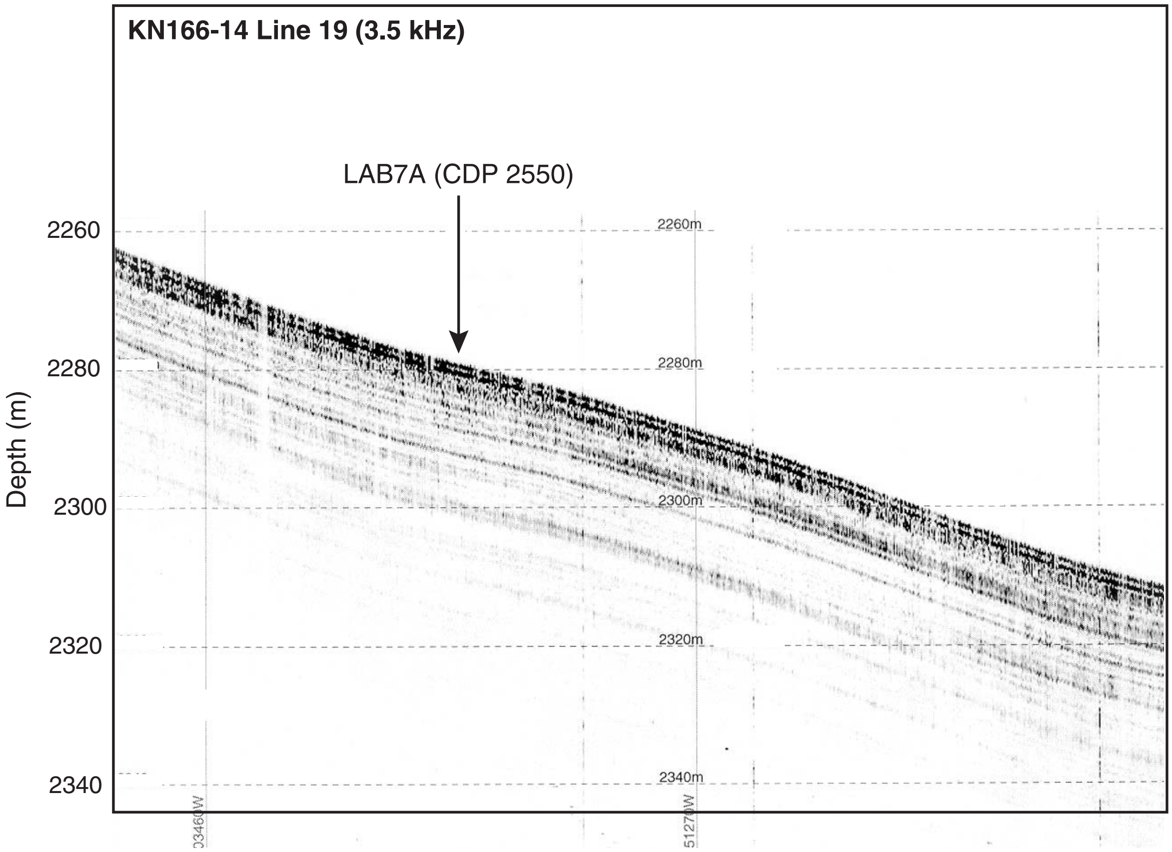


Figure F20. Proposed Sites LAB-8A, LAB-8B, and LAB-8C on KN166-14 Line 25a.

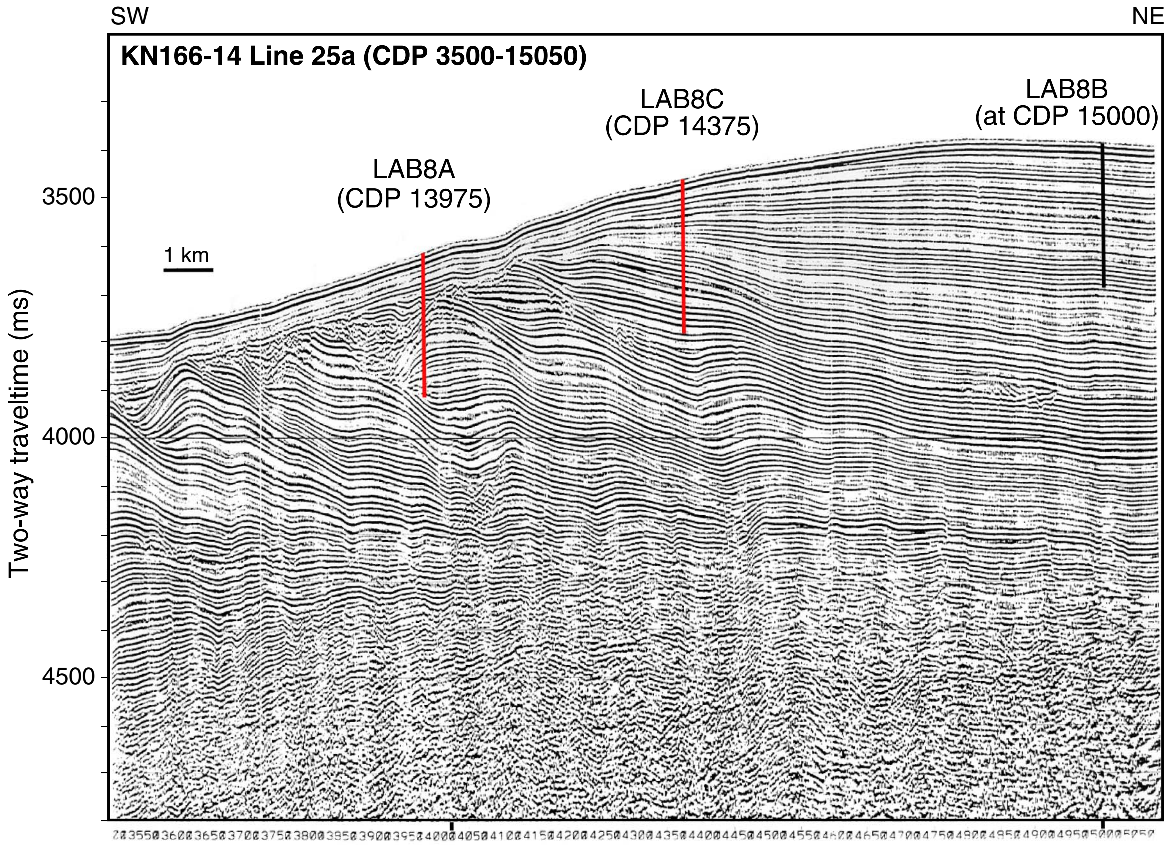


Figure F21. Proposed Site LAB-8B on KN166-14 Line 25a (3.5 kHz).

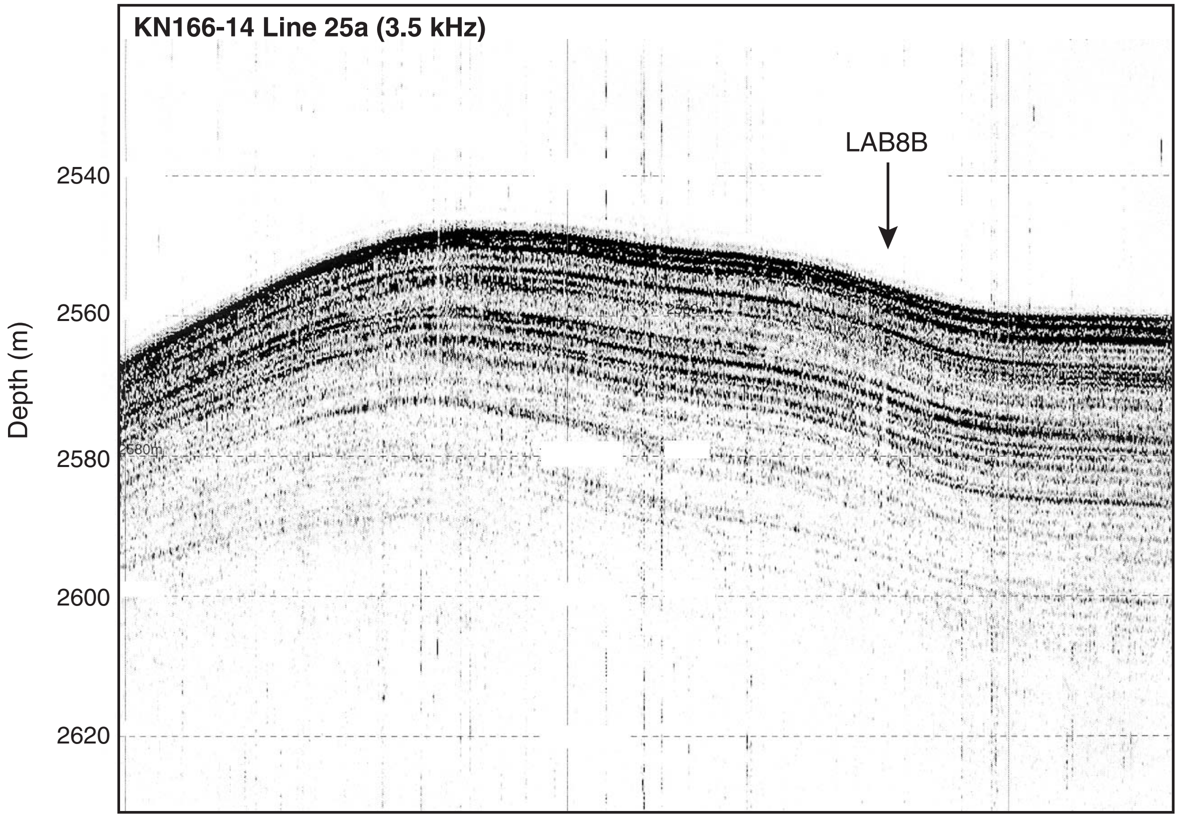


Figure F22. Location of proposed Site GAR-1B and piston core MD99-2253.

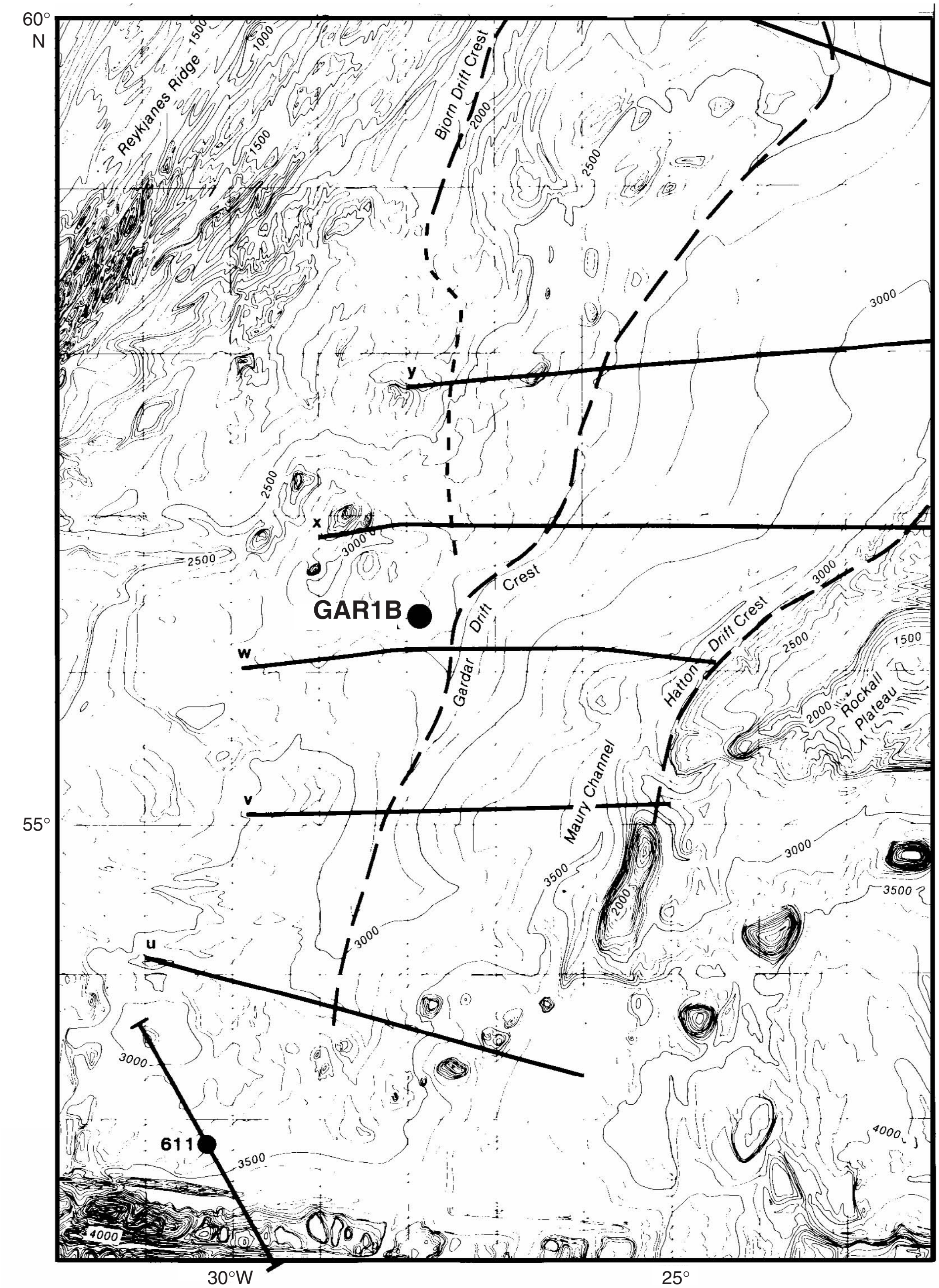


Figure F23. Proposed Site GAR-1B Seabeam survey KN166.-14

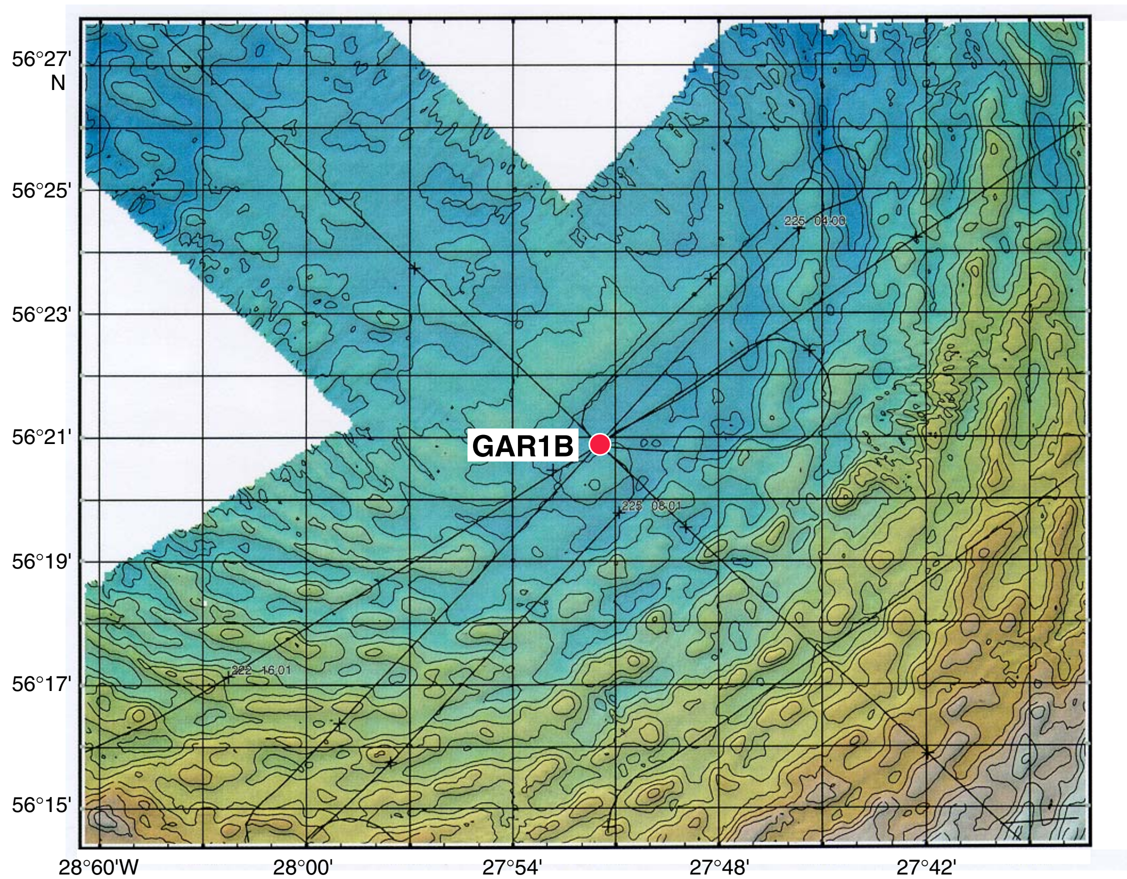


Figure F24. Track map (with CDPs) for MCS site survey of proposed Site GAR-1B.

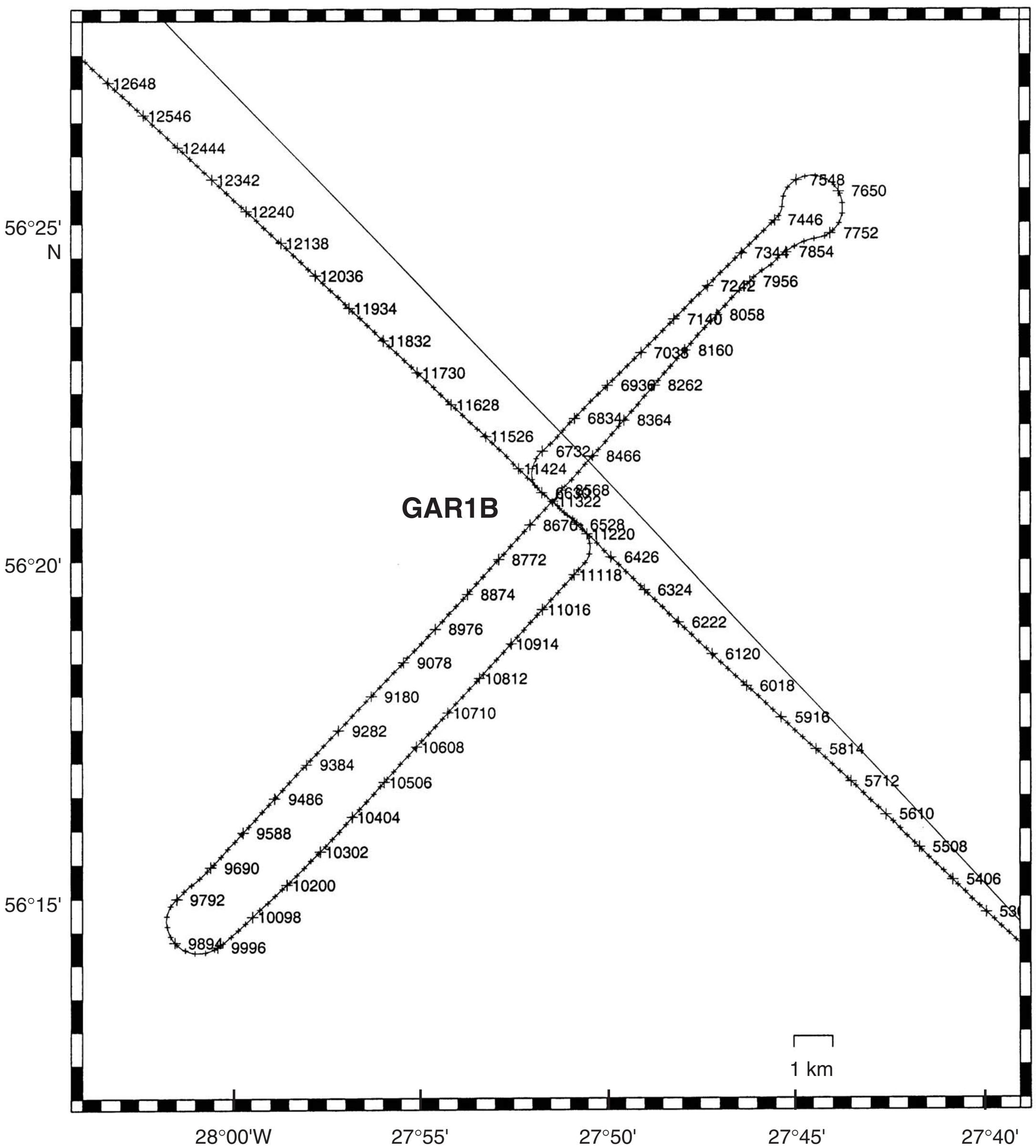


Figure F25. MCS profile at proposed Site GAR-1B (see Fig. F24 for track map).

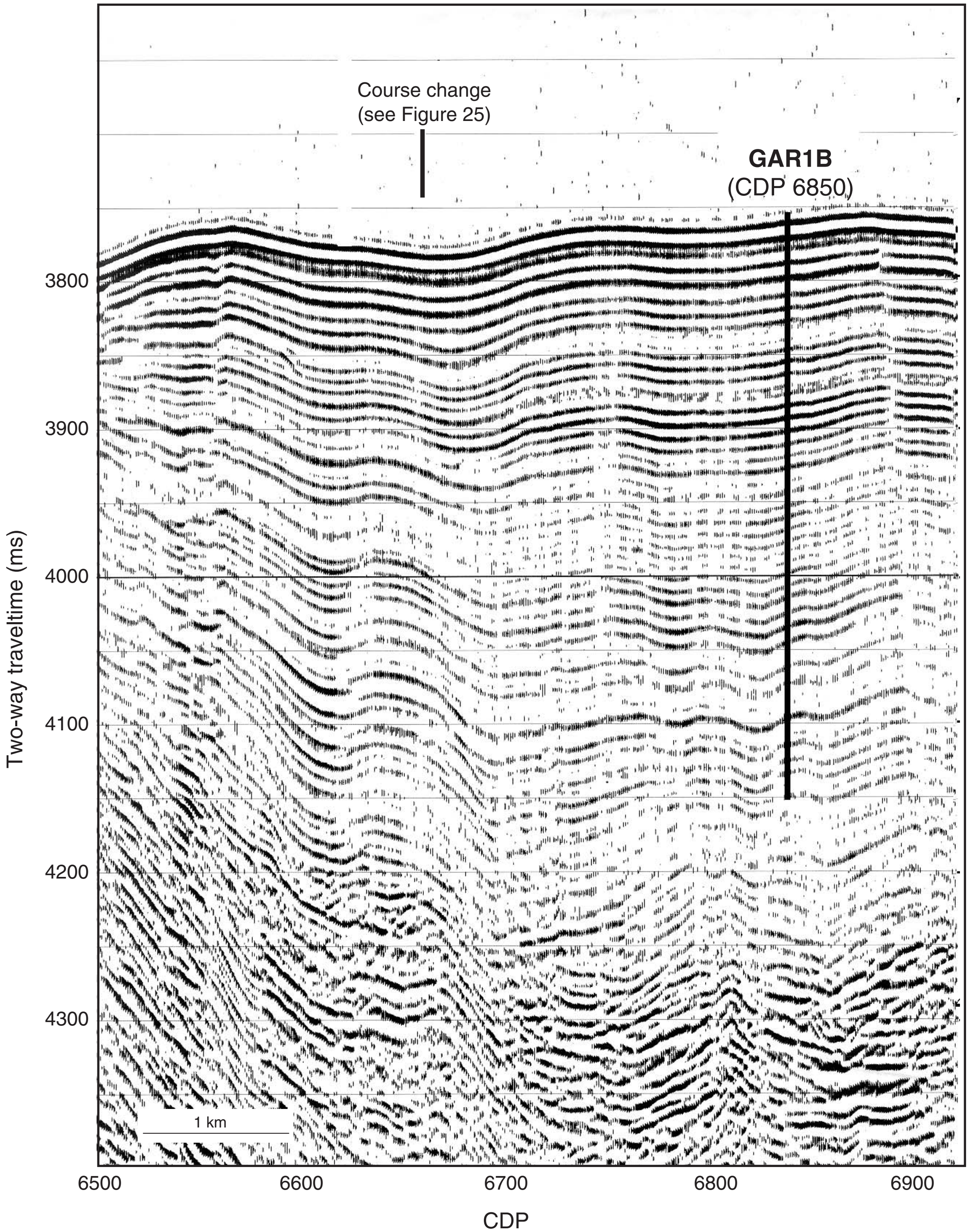


Figure F26. MCS profile at proposed Site GAR-1B (see Fig. F24 for track map).

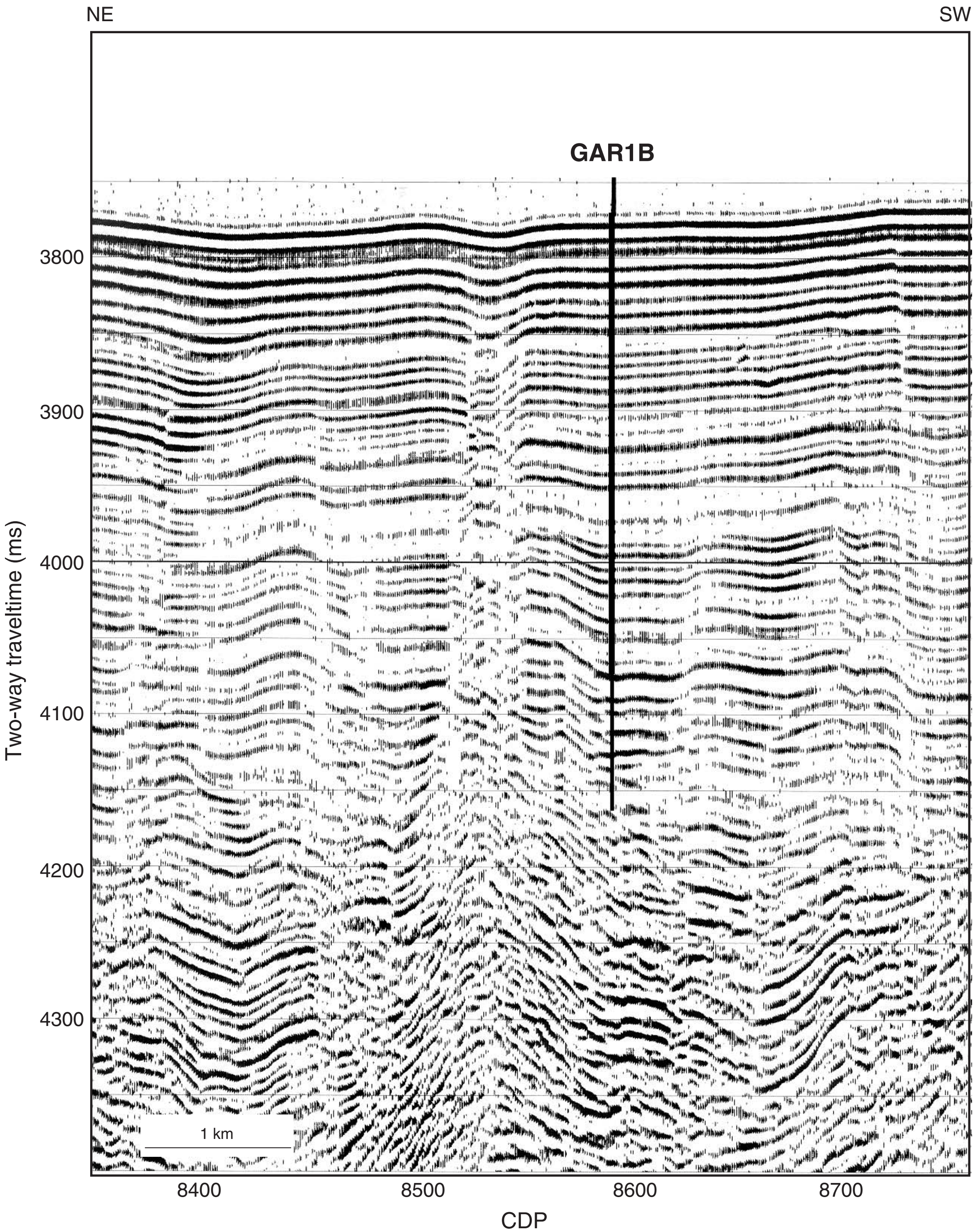


Figure F27. MCS profile at proposed Site GAR-1B (see Fig. F24 for track map).

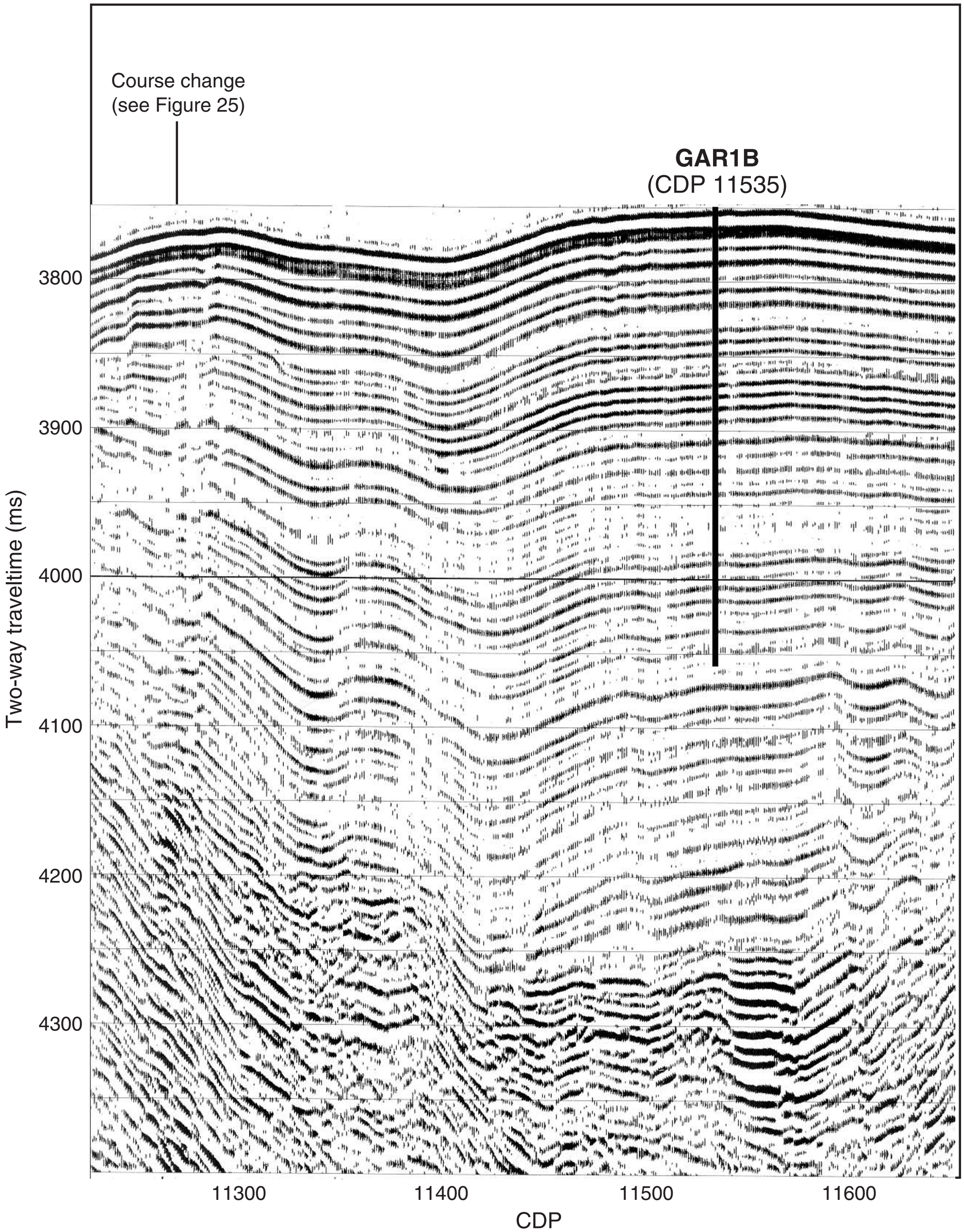


Figure F28. 3.5 kHz data at proposed Site GAR1B.

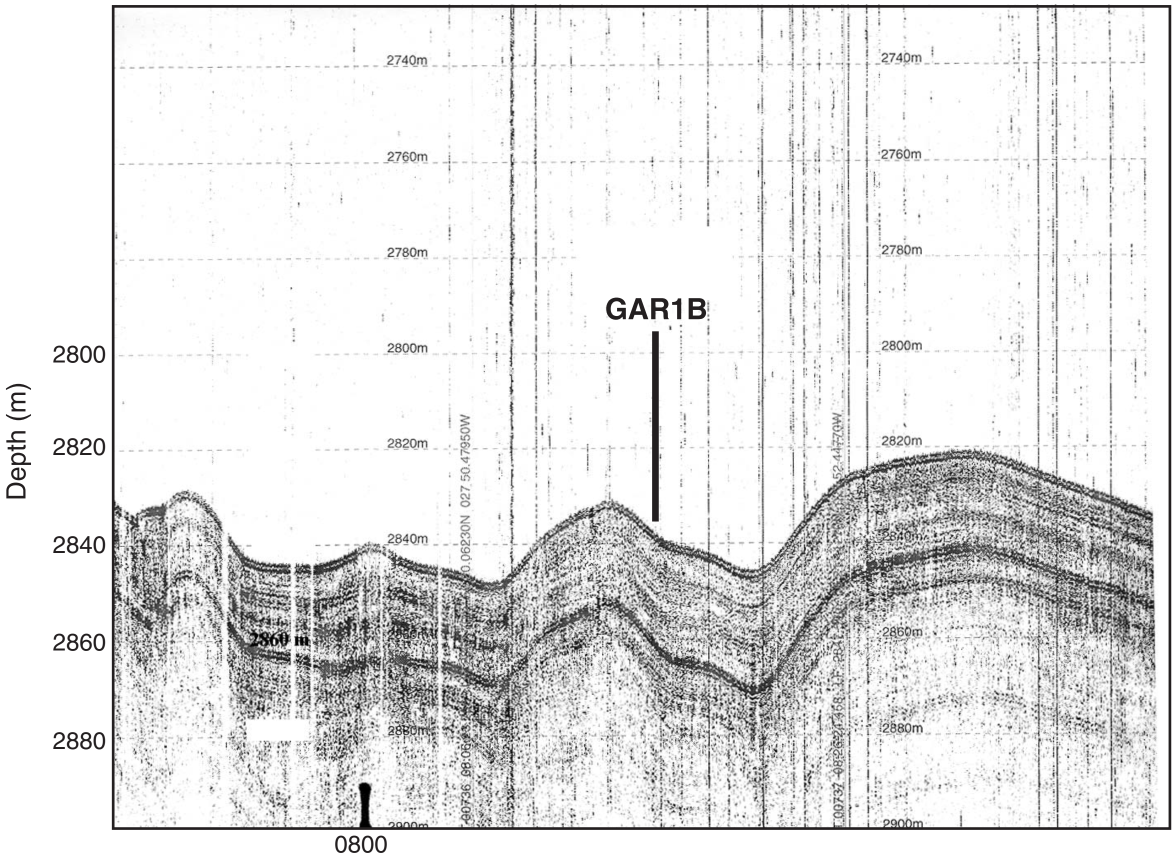


Figure F29. Proposed Site GAR-2A Seabeam survey KN166.-14

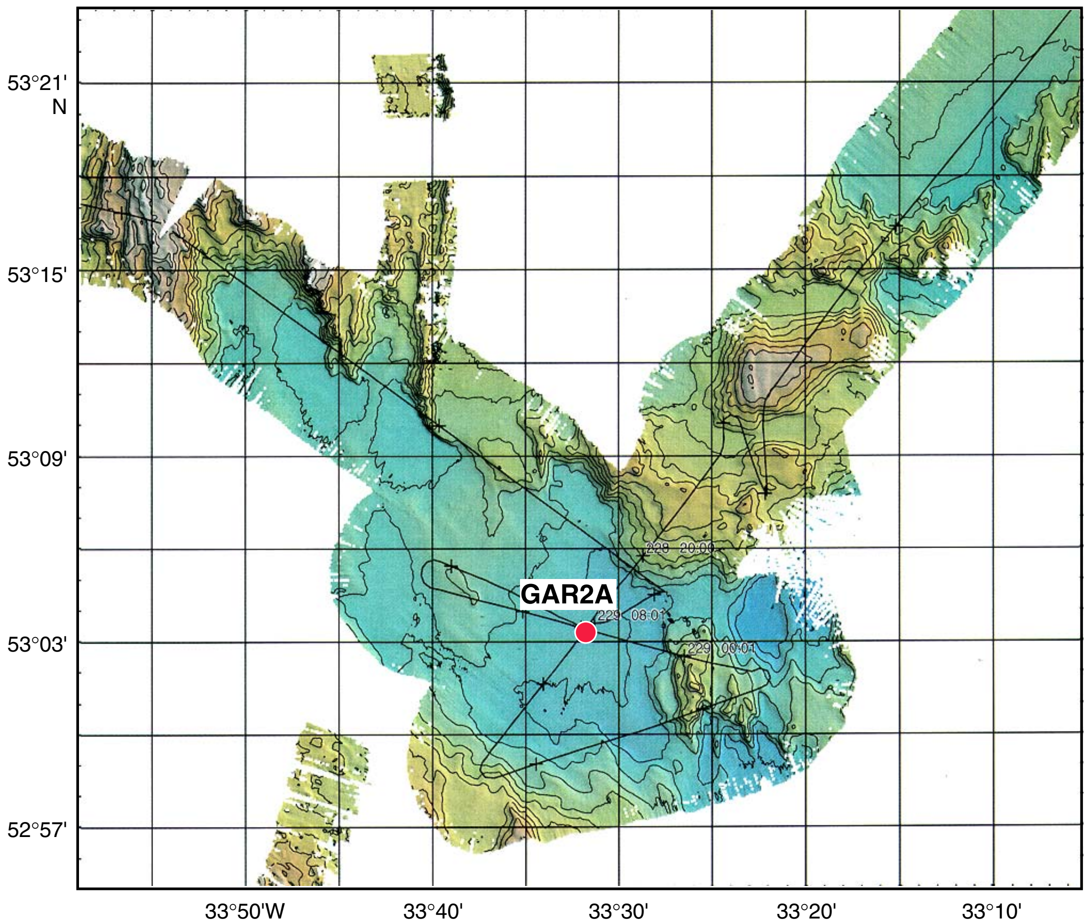


Figure F30. Track map (with CDPs) for MCS site survey of proposed Site GAR-2A.

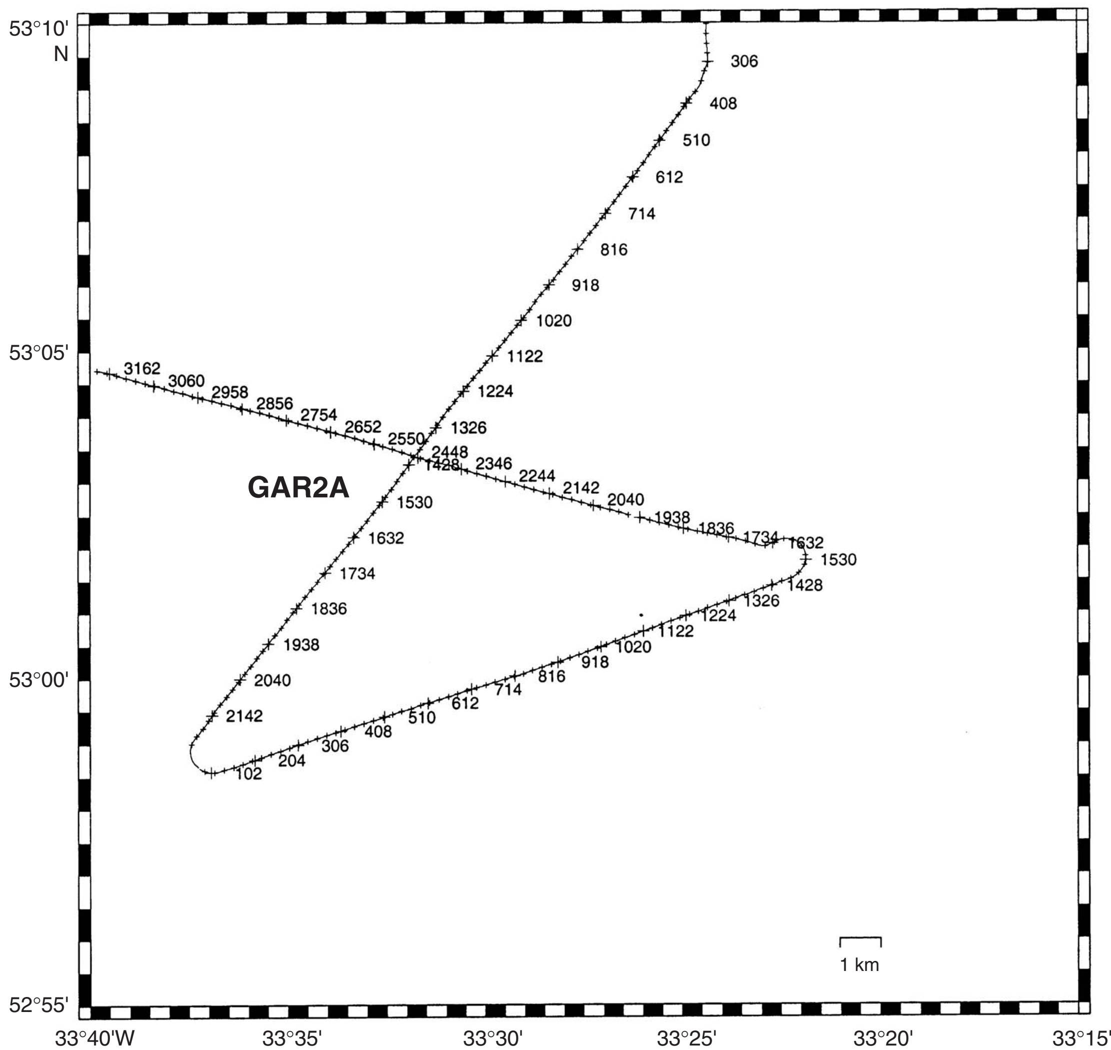


Figure F31. MCS profile across proposed Site GAR-2A.

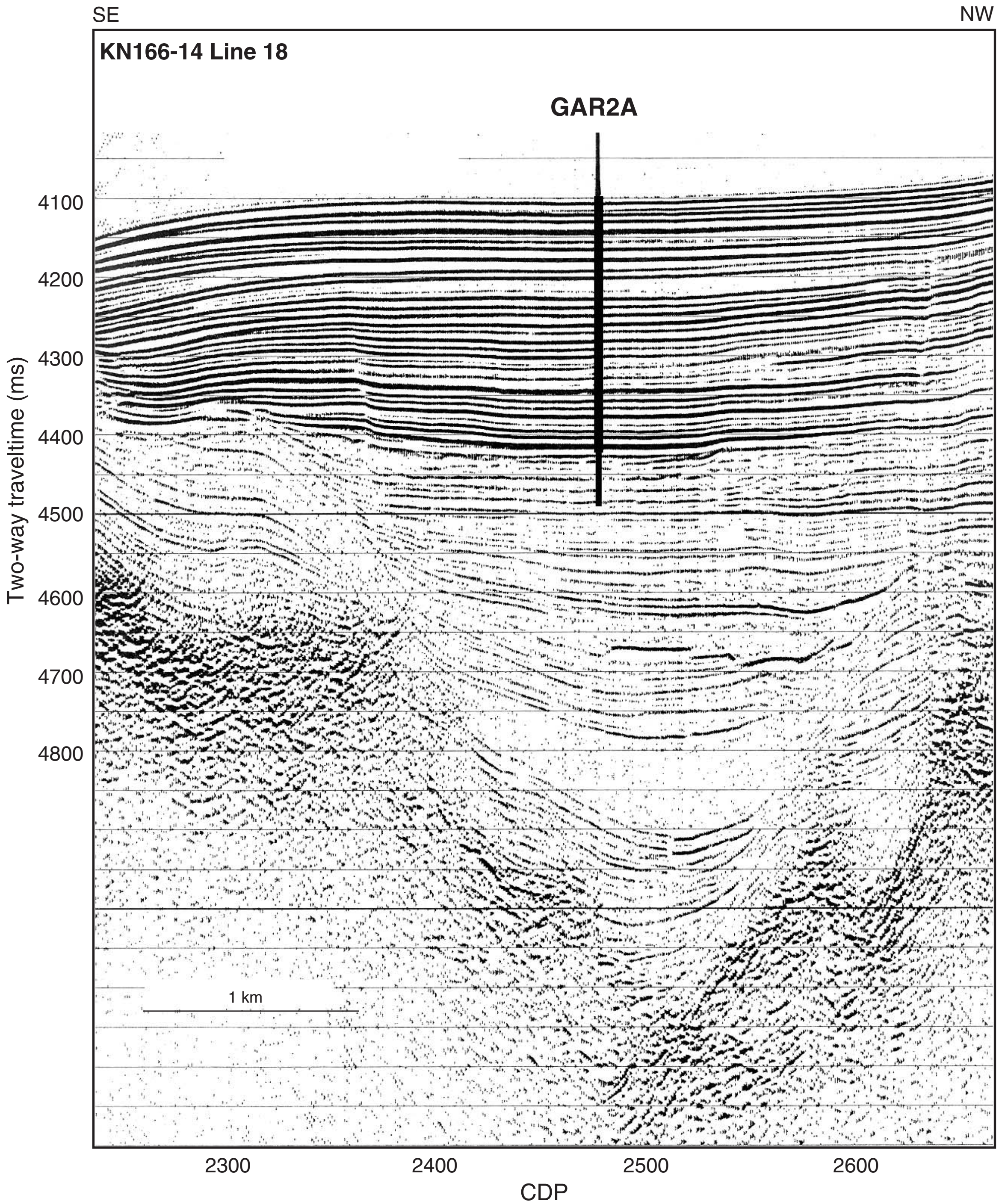


Figure F32. MCS profile across proposed Site GAR-2A.

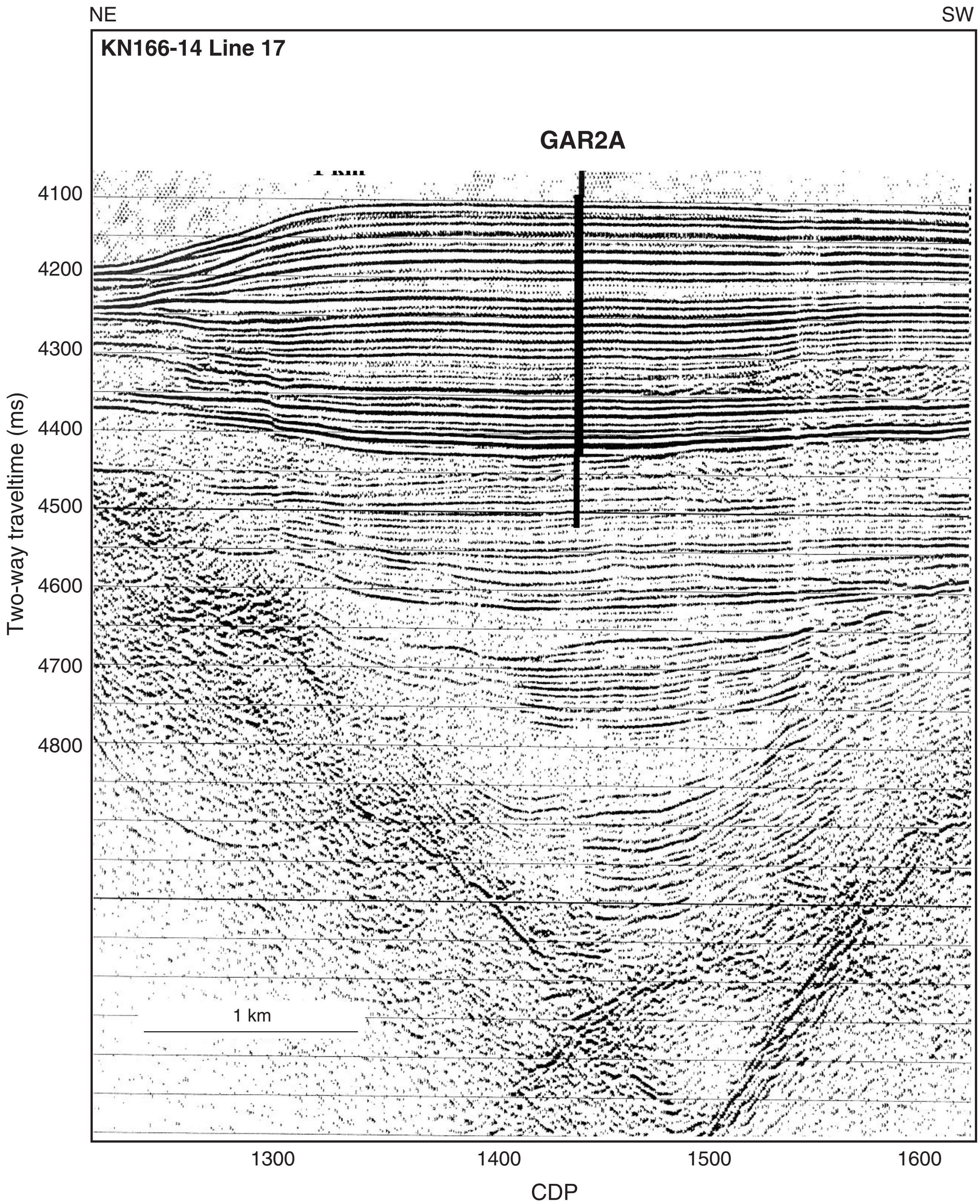
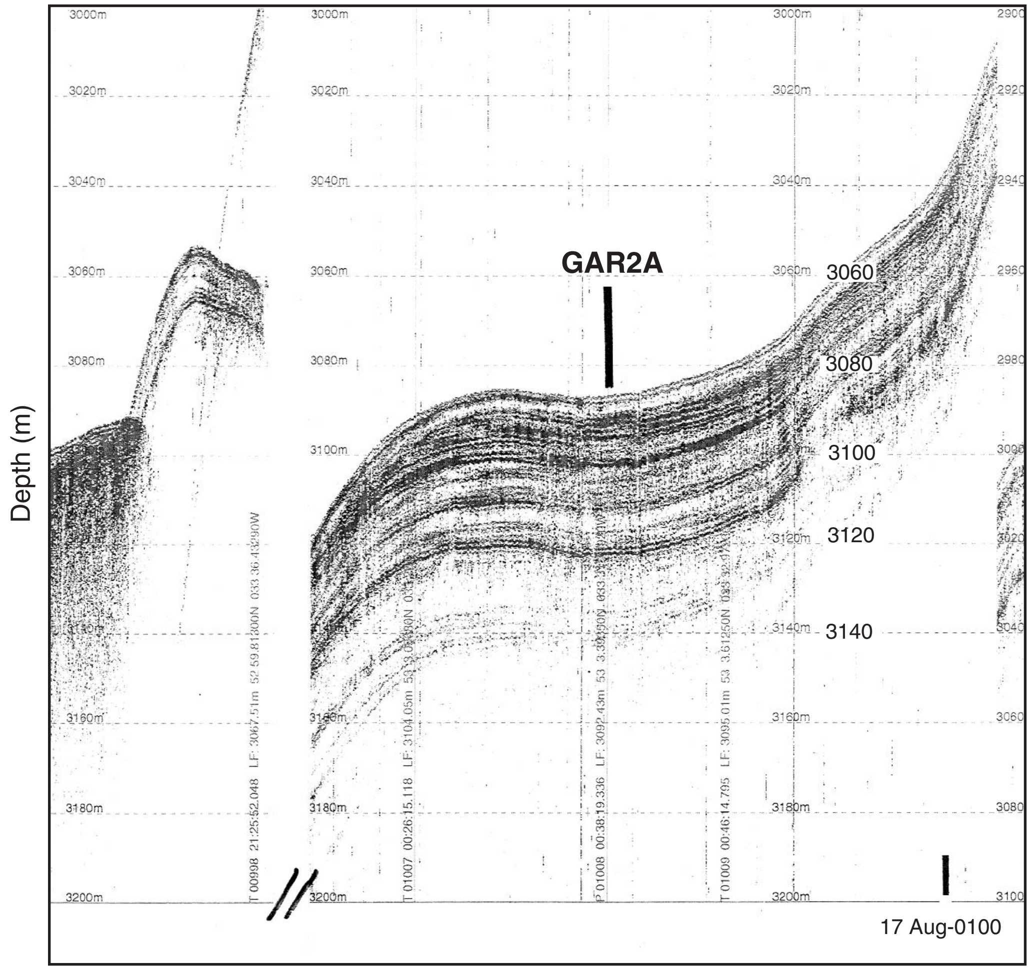


Figure F33. 3.5 kHz data for proposed Site GAR-2A.



SITE SUMMARIES

Site: ORPH2A

Proposed site:	ORPH2A
Priority:	Primary (subject to results from ORPH3A coring)
Position:	50°12.4′N, 45°41.22′W
Water depth (m):	3539
Target drilling depth (mbsf):	200
Approved maximum penetration	200
Survey coverage:	• *Hudson* cruise 2001/043, Huntec Lines 1–6 • Time: 6 August 2001 (JD = 218) at 22.53 • Track map–Fig. **F5** • Seismic profiles–Figs. **F6, F8**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. Such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	None
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: ORPH3A

Proposed site:	ORPH3A
Priority:	Primary
Position:	50°09.984′N, 45°38.273′W
Water depth (m):	3591
Target drilling depth (mbsf):	300
Approved maximum penetration (mbsf):	300
Survey coverage:	• *Hudson* cruise 2001/043, Huntec Lines 1–6 • Time: 6 August 2001 (JD = 218) at 23.53 • Track map–Fig. **F5** • Seismic profile–Fig. **F6**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. Such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	Triple combo, FMS-sonic
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB3A

Proposed site:	LAB3A
Priority:	Primary
Position:	58°02.169′N, 48°27.57′W
Water depth (m):	3350
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• Line BGR-2 (shotpoint 4000) • Track map–Fig. **F9** • Seismic profile–Fig. **F10**
Objective:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drill over
Logging program:	To be determined
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB6A

Proposed site:	LAB6A
Priority:	Primary
Position:	57°28.508′N, 48°31.842′W
Water depth (m):	3485
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• Line 14, KN166-14 Line 25a (CDP 900) • Track map–Fig. **F14** • Seismic profiles–Figs. **F15, F16**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	None
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB7A

Proposed site:	LAB7A
Priority:	Primary
Position:	58°14.227′N, 46°38.589′W
Water depth (m):	2273
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 24c (CDP 7435) at crossing with KN166-14 Line 19 (CDP 2550) • Track map–Fig. **F10** • Seismic profiles–Figs. **F17, F18, F19**)
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB8A

Proposed site:	LAB8A
Priority:	Secondary
Position:	58°28.525′N, 48°27.823′W
Water depth (m):	2650
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 25a (CDP 13975) • Track map–Fig. **F10** • Seismic profiles–Fig. **F20**)
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB8B

Proposed site:	LAB8B
Priority:	Secondary
Position:	58°33.227′N, 46°18.04′W
Water depth (m):	2556
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 25a (CDP 15000) • Track map–Fig. **F10** • Seismic profiles–Figs. **F20, F21**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: LAB8C

Proposed site:	LAB8C
Priority:	Secondary
Position:	58°30.346′N, 46°24.034′W
Water depth (m):	2554
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 25a (CDP 14375) • Track map–Fig. **F10** • Seismic profile–Fig. **F20**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Silty clay

SITE SUMMARIES (CONTINUED)

Site: GAR1B

Proposed site:	GAR1B
Priority:	Primary
Position:	56°21.882′N, 27°53.31′W
Water depth (m):	2821
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 19 (CDP 11534) • Track map–Fig. **F24** • Seismic profiles–Figs. **F25, F26, F27, F28**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Foraminifer-nannofossil ooze

SITE SUMMARIES (CONTINUED)

Site: GAR2A

Proposed site:	GAR2A
Priority:	Primary
Position:	53°3.4′N, 33°31.78′W
Water depth (m):	3024
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• KN166-14 Line 17 (CDP 1433) • KN166-14 Line 18 (CDP 2477) • Track map–Fig. **F30** • Seismic profiles–Figs. **F31, F32, F33**
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Foraminifer-nannofossil ooze

SITE SUMMARIES (CONTINUED)

Site: IRD1A

Proposed site:	IRD1A
Priority:	Primary
Position:	49°52.667′N, 24°14.287′W
Water depth (m):	3884
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• Redrill DSDP Site 609 • CH-94 (20 July 1983) • Vema 23 (20 October 1966)
Objective:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Foraminifer-nannofossil ooze

SITE SUMMARIES (CONTINUED)

Site: IRD3A

Proposed site:	IRD3A
Priority:	Primary
Position:	41°0.068′N, 32°57.438′W
Water depth (m):	3426
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	Redrill DSDP Site 607 CH-94 (20 July 1983) Vema 23 (28 May 1973)
Objectives:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Foraminifer-nannofossil ooze

SITE SUMMARIES (CONTINUED)

Site: IRD4A

Proposed site:	IRD4A
Priority:	Secondary
Position:	42°50.205′N, 23°5.252′W
Water depth (m):	3542
Target drilling depth (mbsf):	300
Approved maximum penetration	400
Survey coverage:	• Redrill DSDP Site 608 • CH-94 (12 July 1983) • Discovery 33 and 54
Objective:	Establish late Neogene–Quaternary intercalibration of geomagnetic paleointensity, isotope stratigraphies, and regional environmental stratigraphies, and in so doing develop a millennial-scale stratigraphic template. such a template is required for understanding the relative phasing of atmospheric, cryospheric, and oceanic changes that are central to our understanding of the mechanisms of global climate change on orbital to millennial timescales.
Drilling program:	3X APC to refusal with drillover
Logging program:	To be determined
Nature of rock anticipated:	Foraminifer-nannofossil ooze

SITE SUMMARIES (CONTINUED)

Site: 642

Proposed site:	642
Priority:	Primary
Position:	67°12.7′N, 2°55.8′E
Water depth (m):	1289
Target drilling depth (mbsf):	150
Approved maximum penetration	N/A
Survey coverage:	MCS BGR-1 and NH-1 for Site 642, Leg 104
Objectives:	• Document ability to recover bottom water temperature (BWT) histories from temperature depth profiles in marine sediments. • Reconstruct BWT histories at Site 642. • Directly isolate perturbations in subsurface temperature profiles resulting from variations in BWT histories.
Drilling program:	• Drill in reentry cone and casing to ~150 mbsf. • Set bridge plug. • Install thermistor string.
Logging program:	None
Nature of rock anticipated:	Muds, sandy mud, minor nannofossil and diatom ooze

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