OCEAN DRILLING PROGRAM

LEG 152 PRELIMINARY REPORT

EAST GREENLAND MARGIN

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SCIENTIFIC REPORT

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ABSTRACT

The principal objectives of Leg 152 were to sample the basalts of the seaward-dipping reflector sequences (SDRS) on the continental margin of southeast Greenland and in the adjacent Irminger Basin. The leg aimed to achieve deep penetration (400 m) at one site on the featheredge of the SDRS and another deep site in the center of the sequence. Drilling of the cover sediments was aimed at recording the subsidence history of the margin and the paleoceanographic development of this part of the North Atlantic. Four sites (914-917) were drilled on the shelf in 500 m of water, and two on the continental rise in 1868 m (Site 918) and 2088 m (Site 919). Deep penetration (779 m) into the earliest basalts of the SDRS was achieved at Site 917, recording the nature of some of the earliest volcanism and the nature of the breakup unconformity and immediate substrata. Three lava series were identified, an Upper Series of picrites and high Mg-basalts, a Middle Series of dacites and evolved basalts and a Lower Series of basalts and rare olivine basalts. The middle and Upper Series are separated by thin fluvial sandstones. Flow thicknesses decrease systematically upsection. All three series appear to be derived by melting of a normal MORB-like depleted upper mantle. Contamination of the lavas by continental lithosphere was recognized in the trace element composition (high Ba, K, Sr) of the two lower series.

Further basalt drilling at Site 918 showed that a MORB source was the source of all the magmatic melts during SDRS eruption. No evidence was found to implicate the presence of a chemically less depleted mantle plume, similar to that underlying the modern Icelandic hotspot, although the presence of large volumes of magma and picritic basalts clearly indicates the need for a thermally anomalous mantle source. Weathering horizons and intercalated sediments demonstrate that the lavas were erupted in a subaerial environment. Penetration of the basal breakup unconformity moreover indicates that the Greenland crust had been stretched, subsided and then uplifted into a subaerial environment prior to SDRS volcanism. Eruption rates were very high, with the whole 150-km-wide SDRS apparently having been produced during magnetic Chron 24r (latest Paleocene to early Eocene), spanning only 2.7 m.y. Gradual thermal cooling of the margin has resulted in gradual subsidence since that time. Sites 914-917 have remained at shelf depths probably due to buoyant underlying continental crust, while Site 918 subsided rapidly, as it lies east of the sharp ocean-continent transition. An influx of terrigenous turbidites in the Irminger Basin during the late

Oligocene may reflect both a fall in eustatic sea level and the start of (flexural) uplift of the Greenland margin. Ridge-push from the Reykjanes Ridge may have instigated the uplift and is seen in the shape of boreholes measured by caliper logging tools. Development of glauconitic hardgrounds within middle Miocene chalks indicates a start to the flow of the cold North Atlantic Deep Water (NADW) at 13-11 Ma into the Irminger Basin over the subsiding Iceland-Greenland Ridge. Microfauna suggest a warm climate up to this time. The first occurrence of ice-rafted debris is in marine silts of 7 Ma (late Miocene). The provenance of dropstones clearly points to a previously unrecorded early glaciation of southern Greenland. The date predates other estimates of North Atlantic glaciation by about 3-4 Ma and may indicate that the later widespread North Atlantic glaciation nucleated in this area.

INTRODUCTION

Divergent rifted margins are among the most prominent topographic features on our planet. One type of divergent rifted margin that was discovered barely 10 years ago, the so-called volcanic rifted margin, is now recognized as perhaps the most common style developed along the Atlantic margins. This style has also been identified along stretches of the Antarctic margins and around the Indian Ocean.

Leg 152 represents the second in an eight-leg program, proposed by the NARM-DPG, to investigate rifted margins and is the first leg to address processes at volcanic rifted margins by drilling six sites along a transect at 63°N, southeast Greenland (Figs. 1 and 2).

The southeast Greenland transect is located approximately 600 km south of the original center of the ancestral Iceland hotspot in a region of apparent structural simplicity, with a well-understood, simple plate kinematic history. Breakup took place within cratonic lithosphere, forming two conjugate margins, one in southeast Greenland and the other represented by the Rockall-Hatton margin, previously drilled by Deep Sea Drilling Project (DSDP) Leg 81 (Roberts, Schnitker, et al., 1984). This transect of a total of six sites (914-919; Fig. 2) was designed to constrain a number of different features of the margin including the timing of break-up, the nature of the lithospheric deformation, magmatic processes, flexural deformation rates, emplacement mechanisms, geochemical and volumetric trends in the magmatism, spreading rates prior to formation of the first oceanic magnetic isochrons, syn- and post-constructional subsidence of the volcanic carapace, and the post-breakup subsidence of the spreading ridge. Sites 914-917 on the East Greenland Shelf (Fig. 2) sampled, through deep basement penetration (approximately 800 m), the initial volcanism and underlying basement, while Site 918 sampled the central part of the high-production volcanic phase in an area of interpreted steady-state wedge formation. Site 919 was a shallow penetration site aimed at recovering an expanded section of the Pliocene to Holocene for detailed biostratigraphic and magnetostratigraphic studies. Lack of time prevented further deepening at this site to investigate the Paleogene sediments and the nature of the basaltic basement at this oceanward end of the seaward-dipping reflector sequences.

Figure 3 shows an interpreted multichannel seismic line across the East Greenland volcanic rifted margin. Landward of the drill sites the Precambrian basement is penetrated by a narrow zone of dikes. Seaward, the volcanic basement is characterized by baselap-free, seaward-dipping, and offlapping lava-flow units (seaward-dipping reflector sequence, SDRS); and a seaward zone of seafloor-spreading crust generated at increasing water depth. This peculiar structure has caused an intense debate on the emplacement mode and crustal heritage of the SDRS (Hinz, 1981; Mutter et al., 1982; Smythe, 1983; Roberts, Schnitker, et al., 1984; Larsen and Jacobsdottir, 1988; Eldholm et al., 1989). There is now a general consensus, however, that the kinematic model for crustal accretion in Iceland (Palmason, 1973, 1980) can qualitatively explain the structure as a continuous process of igneous crustal accretion emanating from a central linear.

Several models attempt to explain the formation of large volumes of magma at rifted plate margins. These range from catastrophic plume "impact" models, where a plume ascending from the lower mantle impacts and initiates magmatism when it hits the base of the lithosphere (Richards et al., 1989), through the more passive plume "incubation" models, whereby a large plume head slowly incubates beneath a lithospheric cap (Kent et al., 1992) and releases melt only when the lithosphere is stretched (White and McKenzie, 1989). Other models imply no role for a plume, for example, the broad thermal anomalies of Anderson et al. (1992) and the convective overturn model of Mutter et al. (1982).

These different models are not mutually exclusive, and components of several or all of them may contribute to the formation and petrological characteristics of viscous remanent magnetization

(VRM). Some of the key differences between the models are the degree of temperature anomaly within the asthenosphere, the shape and life length of the temperature anomaly and the role of "passive" plate drag and associated mechanical thinning of the lithosphere in the process of melting of the asthenosphere and the excessively strong generation of magmatic melts.

Sites drilled during Leg 152 will be used to investigate these variables by examining in detail the temporal evolution of the magmatism from its start (Site 917) through to its excessive phase (Site 918).

DRILLING OBJECTIVES

Leg 152, drilling the East Greenland Shelf and adjacent Irminger Basin had the following goals:

- To constrain the timing of, and tectono-magmatic variation across, an archetypal seaward-dipping reflector sequence (SDRS).
- To determine and constrain volcanic emplacement mechanisms and investigate the nature of underplating.
- To evaluate the relationship between the Iceland plume and the southeast Greenland volcanic rifted margin.
- To understand the subsidence and oceanographic history of the Irminger Basin, Arctic bottom water overspill across the Iceland-Greenland Ridge, and the glaciation history of southern Greenland.

SITE 914

Site 914 (proposed site EG63-1A) is located on the East Greenland Shelf (Figs. 2 and 4), approximately 60 km from the coast. The site was selected to penetrate a representative sequence of Quaternary and Tertiary sediments commensurate with deep penetration (400 m) of the featheredge of the seaward-dipping reflector sequences (SDRS). The primary objectives of this site are the Quaternary and Holocene glacial history of the margin, the Paleogene sedimentation and subsidence history, and the composition, age and eruption environment of the SDRS.

It was originally intended that proposed site EG63-1 would include a cased, multiple reentry hole for deep basement penetration. However, a firm, 120-m-thick layer of glacial diamicton with dropstones led to severe drilling difficulties, and three holes were required. Failure to reach basaltic basement led to Site 914 being abandoned in favor of sites to the WNW (Sites 915, 916 and 917), where the basement is at a shallower level.

The upper part of the succession cored in Holes 914A and 914B (Fig. 5) comprises Holocene glaciomarine sandy silt and mud with dropstones (lithologic Subunit IA; 0 to 5 mbsf), Quaternary compacted diamicton (Subunit IB; 5 to 14 mbsf), and glaciogenic sediment with gravel clasts, the matrix of which was not recovered (Subunit IC; 14 to 158.5 mbsf). The interval 158.5 to 187.2 mbsf was not recovered, but according to the seismic record, it is also of glaciogenic origin. A 5-cm-thick ash-bearing layer occurs at interval 152-914A-1H-1, 30-35 cm. The dropstones comprise a variety of lithologic types, including basalt, granite gneiss, and quartzite, and range in size from sand grains to cobbles of at least the width of the core.

Lithologic Unit II (187.2 to 245.0 mbsf; base not recovered) is characterized by massive, greenish black sandy silts, which have been extensively bioturbated. Detrital grains include quartz, plagioclase, amphiboles, pyroxene, garnet, mica, lithic fragments of basalt, and wood. The presence of a zeolite, phillipsite, indicates alteration of volcanic glass by seawater. Calcareous sandstones occur in Unit II. They contain glauconite and a variety of biogenic detritus, indicating a marine origin for the sediment. Overall, the fine grain size and bioturbation in Unit II suggest a mid- to outer-shelf environment of deposition. The sandy interbeds indicate increased current activity, perhaps related to storms.

Lithologic Unit II has been dated by nannofossils as latest Eocene to early Oligocene (32-35 Ma). Benthic foraminifers indicate paleo-water depths of between 100 and 250 m for the lithologies in Unit II.

A detailed study of benthic and planktonic foraminifers has been carried out in order to provide a biostratigraphic framework for bulk density measurements in Core 152-914A-1H. These fluctuations may be related to climatically induced changes in depositional environment. The benthic foraminifer assemblage indicates a transition from a glacial to an interglacial environment in the upper 30 cm of the recovered sediments. Multi-sensor track (MST) data from the top part of Unit I reveal marked changes in all properties at depths of 2.1 and 5 mbsf. These changes within the Quaternary sediments include a rapid increase in bulk wet density, magnetic susceptibility, and natural gamma with depth. Locally, the diamictons show high shear strengths, consistent with subglacial compaction.

Core 152-914A-1H was analyzed for paleomagnetic properties; below this core, recovery was minimal, and most intervals showed excessive drilling disturbance. The core is of normal polarity. Correlation with the Brunhes Chron is proposed. Paleomagnetic data were obtained from four cores in Hole 914B (Cores 152-914B-13R, and -15R to -17R). Core 152-914B-15R carries a reverse polarity magnetization. Core 152-914B-16R and the upper part of Core -17R (down to Section 152-914B-17R-3, 75 cm) are also reversely magnetized. The lower part of Core 152-914-17R carries a normal polarity remanence. Biostratigraphic data suggest that the reverse polarity remanence of Cores 152-914B-15R and -16R probably represents a partial record of Chron C12r. Nannoplankton data from Core 152-914B-17R indicate an age range of 32 to 35 Ma. Thus, the downhole transition from reverse to normal polarity in Core 152-914B-17R may represent either the reversal between Chrons C12r and C13n, or Chrons C13r and C15n.

Principal Findings at Site 914

(i) The presence of diamicton confirms that wet-based glaciers advanced to at least this point on the shelf, some 60 km east of the present ice sheet. The tephra found in the uppermost part of the core will enable us to determine whether the advance predates the latest (Weichselian) glaciation.

(ii) The benthic and planktonic foraminifers in the Quaternary and Holocene sediments illustrate changes in climatic conditions during glacial and interglacial periods.

(iii) The oldest sediment recovered at this site is of latest Eocene-early Oligocene age, and confirms that marine shelf conditions existed at that time. Benthic foraminifers indicate water depths of between 100 and 250 m at that time, thus providing a datum point for the subsidence study of the margin.

(iv) A marked hiatus exists between the lower Oligocene strata and the Quaternary glaciomarine deposits.

SITE 915

Site 915 is located on the East Greenland Shelf, approximately 58 km from the Greenland coast (Figs. 2 and 4). After an unsuccessful attempt to reach basement at Site 914, *JOIDES Resolution* was moved to an alternate site on the shelf, some 3 km to the NW. Seismic profiles indicate that glacial sediment cover is thinner at this site than at Site 914. The primary objectives of this site are the same as at Site 914, namely: Quaternary and Holocene glacial history of the margin, the Paleogene sedimentation and subsidence history, and the composition, age and eruption environment of the seaward-dipping reflector sequences (SDRS).

Three lithological units have been recognized in the cored section (Fig. 6). The recovery of Unit I, glaciomarine muds and sands with dropstones, was very poor. Nevertheless, the unit was divided into two subunits. Subunit IA (0-2.2 mbsf) is Pleistocene to Holocene glaciomarine silty sand and silty mud with dropstones. A short length of compacted diamicton was recovered at the base of the subunit. Subunit IB (2.2-93.7 mbsf) is presumed to be a diamicton with gneiss, basalt, metasediment and granitic pebbles and cobbles. No matrix was recovered from this subunit. The age is presumed to be Quaternary, on the basis of stratigraphic position and lithological correlation with other areas.

Unit II (93.7 to 187.1 mbsf) comprises late Eocene volcaniclastic silty sandstone and sandy siltstone with interbeds of calcareous mudstone and sandstone. The unit has been divided into three subunits. Subunit IIA (93.7 to 148.8 mbsf) is predominantly black and dark gray in color, and heavily bioturbated. It comprises siltstone, minor calcareous siltstone, and mudstone. The major source for most of the sediment was volcanic, but there is a significant contribution from the Precambrian metamorphic terranes of Greenland. Plant fragments are scattered through the subunit. Subunit IIB (148.8-168.0 mbsf) is a dusky red and laminated volcaniclastic clayey silt with sand. The primary source material for this subunit was probably lateritized basalt. Subunit IIC (168.0 to 187.1 mbsf) is lithologically similar to Subunit IIA. Sedimentary facies and benthic foraminifers are consistent with Unit II having been deposited in shallow water at shelf or upper slope depths.

Unit III (187.1-189.3 mbsf) comprises a heterolithic conglomerate with gravel, sands and silts. The clasts in the conglomerate are predominantly basalt, and the unit overlies a red, weathered basalt. The unit was probably deposited in a subaerial environment, possibly an alluvial fan.

The igneous succession (189.3-209.4 mbsf) consists of two basalt units: an upper, 1.05-m-thick, highly oxidized basalt flow, and 4 m of slightly altered, vesicular basalt. The two flows are separated by several basalt cobbles, indicating that they are not contiguous. This is confirmed by shipboard XRF trace element data, which show that the upper flow has higher abundances of Zr, Y, TiO_2 and Ni than the lower flow. The lower basalt contains glomerocrysts of olivine, plagioclase and pyroxene. The composition of the basalts, especially the high Zr/Nb ratios, indicates derivation from a depleted, mid-ocean-ridge basalt mantle source. Alteration is restricted to clay, zeolite and chlorophaeite(?) linings in vesicles, and about 5% clay in the groundmass.

Nannofossils confirm a Quaternary (<1.7 Ma) age for lithologic Subunit IB; a late Eocene age for Subunit IIA, and a late middle Eocene age for Subunit IIC. An age could not be obtained for Unit III, although it is inferred to be early Eocene on the basis of its stratigraphic position and association with the subaerial lava sequences. Planktonic foraminifers are consistent with these ages. Benthic foraminifers indicate a paleo-water depth of less than 250 m for Subunit IIA.

Paleomagnetic data were obtained from seven cores in Hole 915A. Core 152-915A-16R carries a normal polarity magnetization. Biostratigraphic data do not permit a firm correlation to the geomagnetic time scale; the magnetozone could represent Chrons C15n or C16n-1n or C16n-2n. Cores 152-915A-18R through -22R are all reversely magnetized. Cores 152-915A-21R and -22R are both of middle Eocene age (38-41 Ma), and correlation with Chron C18r is tentatively proposed. The reverse polarity remanence in Cores 152-915A-18R to -20R probably records the same chron. Core 152-915A-24R through the upper part of the volcanic basement is reversely magnetized. Stratigraphic arguments, based on the age of the magnetic anomalies in this area, suggest a Chron C24r age.

Interstitial water samples were taken from the core from Hole 915A. A decrease in dissolved chloride was observed as the basement was approached, suggesting that fresh, low-chloride water from layers within the basalt discharge into the sediments. Monitoring of hydrocarbons C1 to C3 showed no significant amounts of gases in the sediments at Site 915. Elevated yields of organic C are probably due to wood fragments. Carbonate contents are between 0% and 5%, with values up to 38% in strongly cemented sandstones.

The diamictons recovered at Site 915 are heavily consolidated, with shear strengths greater than the range covered by hand-held penetrometers. This suggests that these sediments have been in contact with ice sheet(s) on the East Greenland Shelf. At greater depths at Site 915 (about 30 m above basement) thin, strongly lithified volcanic sandstone beds have, through synthetic seismic modeling, enabled detailed correlation between the core and the seismic data.

Principal Findings at Site 915

(i) Drilling at Site 915 demonstrated the presence of basaltic basement beneath sediments of late middle Eocene age.
(ii) The basalt has been extensively weathered, probably in a subaerial environment, and the immediately overlying sediments (Unit III) appear to be alluvial in origin.
(iii) The predicted age of the basalts (early Eocene) is considerably older than the sediments, and this will require confirmation by Ar-Ar dating of the basalt; suitable feldspar-rich basalt has been recovered.
(iv) The recovery of Eocene sediments will provide important data for studies of the subsidence history of the shelf.
(v) The presence of diamicton confirms that wet-based glaciers advanced to at least this point on the shelf, some 55 km east of the present ice sheet.

SITE 916

Site 916 (proposed site EG63-1B) is located on the East Greenland Shelf, approximately 50 km from the coast (Fig. 2). This site was selected to penetrate a representative sequence of Quaternary and Tertiary sediments, commensurate with deep penetration of the featheredge of the seaward-dipping reflector sequences (SDRS). The primary objectives of this site are the Quaternary and Holocene glacial history of the margin, the Paleogene sedimentation and subsidence history, and the composition, age and eruption environment of the SDRS.

Unit I (0 to 60.4 mbsf maximum thickness) comprises glaciomarine sediments and diamicton (Fig. 7). Very poor recovery of this unit means that it is not possible to obtain an accurate thickness from the recovered core. The base of the unit is set at 60.4 mbsf, the depth to the base of the last core in which diamicton debris was recovered. Below 60.4 mbsf and above the top of Unit II at 78.6 mbsf there is no recovery and this depth interval is accordingly not attributed to a lithological unit. Unit I has been subdivided into three subunits. The upper subunit (IA; 0 to 15.1 mbsf) consists of gravel-sized fragments of basalt, dolerite, gabbro, and metamorphic rocks. The middle subunit (IB; 15.1 to 33.2 mbsf) is a compact, heterolithic diamicton, and is interpreted as a lodgment till, deposited by a thick, grounded ice sheet. Clasts include metamorphic and igneous rocks. Only gravel was recovered from Subunit IC (33.2 to 60.4 mbsf). The lower part of the diamicton gives a Quaternary age, based on foraminifers.

Unit II (78.6 to 96.7 mbsf) is dominated by volcaniclastic sandy silt with interbeds of silty sand. Basalt is the dominant volcanic clast in these rocks. Siderite-rich layers form distinct light-colored beds 1 to 10 mm thick. Episodic deposition is recorded by fining-upward sequences, cross-beds, channeling and load casts. We found well-preserved fragments of wood and rootlets in Section 152-916A-14R-1. The absence of marine microfauna, and the abundance of woody fragments, indicate that the sediments were deposited in a nearshore environment, but it is not possible to tell if the unit was marine, lagoonal, brackish or lacustrine. Future shore-based studies may resolve this question. It has not been possible to assign a firm age to Unit II, but it is tentatively dated as being of Eocene age, based on lithological correlation from Site 915.

Unit III (96.7 to 101.7 mbsf, TD) is a volcanic breccia with olivine-rich basalt present as in situ layers or large clasts of local origin. The breccia may represent a lahar or volcanic mud flow. The olivine in the basalt is replaced by iddingsite. Preliminary XRF trace element analyses give a high Zr/Nb ratio (>25) and high Ni content (>300 ppm); the data are consistent with a primitive MORB-like composition. Bedding planes dip at 10° to 30° throughout Lithologic Unit II and Unit III, and the core is normal faulted in several places. This is consistent with observations of the seismic profiles, which indicate a normal fault in the vicinity of Hole 916A. A 20-cm-wide zone of hydrothermal alteration in Unit III (Section 916A-15R-2; 97.5 mbsf) is also consistent with faulting.

Sections 152-916A-4R-2 and -5R-1 from lithologic Subunit IB show normal magnetization. No biostratigraphic data are available for these cores; Core 152-916A-9R, however, yielded a Pleistocene age. Correlation with the Brunhes Chron is proposed. Sedimentary rocks from lithologic Units II and III also show normal polarity magnetization, but no biostratigraphic data are available for these units; thus a magnetochron assignment is not possible for these cores.

No significant amounts of methane (C1) or ethane (C2) were detected in the entire sediment column of Hole 916A. Total organic carbon values for the sediments range from 0 to 57 wt%, reflecting the variation in the amount of plant debris. Carbon/nitrogen (C/N) ratios show values higher than 12 for the siltstones and the brown coals, which is characteristic of terrigenous organic material. In addition, the organic matter contains mainly type III kerogen and is provisionally interpreted as having a terrigenous provenance, although this interpretation has to be treated with caution until the contribution from thermal maturation and aquatic algal material is fully assessed. Deposition under anaerobic conditions in the aquatic environment prevented the decomposition of the organic material, as indicated by well-preserved plant fossils and authigenic pyrite crystals found in the sediments.

Principal Findings at Site 916

(i) Basaltic basement occurs at the depth predicted by the sharp reflector observed on seismic profiles.

(ii) The basalt was emplaced as a lava flow and probably weathered in a subaerial environment.

(iii) The basement is overlain by sediments with high volcaniclastic and organic matter components, and were deposited in either a nearshore, a lagoonal, or a lacustrine environment.

(iv) Although it was not possible to determine the age of the lower sedimentary units, it is anticipated that they will yield diagnostic microfossils (e.g., palynomorphs) during shore-based studies. These will be required to determine the minimum age of the last volcanic rocks and the subsequent subsidence history of the margin.

(v) As with Sites 914 and 915, the presence of diamicton confirms that wet-based glaciers advanced to at least this point on the shelf, some 53 km east of the present ice sheet.

SITE 917

Site 917 (proposed site EG63-1B) is located on the East Greenland Shelf, approximately 50 km from the coast. The site was selected to penetrate deeply into the featheredge of the seaward-dipping reflector sequences (SDRS). The primary objectives at this site are a determination of the Paleogene sedimentation and subsidence history; the composition, age and eruption environment of the SDRS; and the nature of the rock types beneath the SDRS.

Lithologic Unit I (Fig. 8) is a thin layer (0-28.7 mbsf; 3.2 m recovered in Cores 152-917A-1R to -3R) of Quaternary, glaciomarine silt with dropstones, and a gravel of probable glaciomarine origin. The compacted diamicton recovered at Sites 914-916 to the east is absent from the thin Quaternary succession cored at this site.

The Quaternary rocks unconformably overlie Unit II (28.7-37.7 mbsf; Core 152-917A-4R): upper middle Eocene (CP14A), dark-gray, marine, micaceous sandy siltstones with a high content of volcanic glass and basalt fragments. The benthic foraminiferal assemblage within Unit II indicates a paleo-water depth of less than 200 m.

A basal volcaniclastic conglomerate (Unit III: Core 917A-5R and -6R; 37.7 to 41.9 mbsf) lies between Unit II and the basaltic flows. Volcaniclastic sandstones are found intercalated with the basalts in Section 917A-22R-1 (183.0 mbsf), and thin clay-rich zones occur throughout the volcanic sequence. These, like Unit III, are barren of calcareous nannofossils, indicating that they were not deposited under open marine conditions.

Hole 917A reached basaltic basement at 41.9 mbsf. A total of 91 flow units, plus 1 intrusive sheet, have been recognized in the recovered core. The volcanic succession has been divided into three stratigraphic series: an Upper (41.9 to 183.4 mbsf), Middle (184.1 to 376.7 mbsf) and Lower Series (376.7 to 821.06 mbsf). The Upper and Middle Series are separated by a thin (67 cm recovered; 183.4 to 184.1 mbsf) fluvial sandstone interval. The lavas of the Upper Series are predominantly olivine basalts and picrites; those of the Middle Series are more evolved basalts and dacites; and the Lower Series comprises basalts with scattered olivine basalts. Pyroclastic units occur within the Middle Series at 188.0 and 375.0 mbsf.

The entire sequence was erupted subaerially, as evidenced by the common presence of red, oxidized flow tops and fewer reddened soil horizons. Strongly vesicular horizons are present. Hyaloclastite breccia at the base of two flows may have been caused by lava flowing into shallow water or over a wet substrate. Morphologically, both aa and pahoehoe flow types are present, with the more massive aa flows predominating in the Middle and Lower Series. Flow thickness tends to increase downhole; the average flow thicknesses are 4.2 m (Upper Series), 8.1 m (Middle Series), and 12.7 m (Lower Series). Several flows exceed 30 m in thickness, and one is more than 50 m thick.

The lavas are slightly to strongly altered. The distribution of zeolites is not systematic, but the assemblage indicates that the temperature did not exceed 120°C. Zeolites are scarce in the Middle Series, due perhaps to the increased silica content of these lavas. Calcite is a late-stage alteration mineral and may be associated with fracturing associated with tilting of the lava pile. The lower 280 m of the volcanic sequence is highly fractured and faulted; one fault (at 576.5 mbsf) is marked by a mylonite zone. Structures within the basalts and intercalated sediments indicate that the lavas dip at approximately 25° relative to the drill core; this is consistent with the seismic profiles that show a seaward dip. Geopetal structures in half-filled amygdules, however, consistently show a shallower dip of about 5°, suggesting that hydrothermal activity continued after regional flexuring.

The Upper Series lavas are predominantly olivine basalts and picrites; the main phenocryst phase is olivine. The sequence of phenocryst phases in the Middle and Lower Series is olivine, olivine + plagioclase, olivine + plagioclase + augite (=B1 magnetite), plagioclase + augite + magnetite (in the dacite). Three dacite flows at the base of the Middle Series contain basalt xenoliths, some with lobate margins, and disequilibrium phenocryst assemblages. These suggest that magma mixing has occurred. The dacites are not peraluminous.

The majority of the lavas have high Zr/Nb ratios (18 to 50), although six flows from the Middle and Lower Series have ratios less than 15. The high Zr/Nb ratios are comparable with values for depleted mid-ocean-ridge basalt (MORB), indicating derivation from a MORB-like source. The Upper Series also has low Ba contents and low Ba/Zr ratios, similar to MORB. The Lower and Middle Series, however, have high Ba/Zr ratios, indicating interaction between the magmas and continental lithosphere. The Upper Series lavas show no evidence for such contamination.

The decrease in the thickness of lava flows, together with the increasing predominance of primitive, picritic and olivine basalts in the Upper Series, is consistent with the evolution of the magmatic plumbing system, whereby initially the magma has long residence times in large magma bodies, to a situation where the magma travels rapidly through the crust and is erupted with minimal fractionation.

Underlying the lavas is a thin layer of quartzose, coarse-grained sandstone of possible fluviatile origin (lithologic Unit V; 821.06 to 821.20 mbsf) of unknown age. Beneath the sandstone we encountered steeply inclined, low-grade metamorphic, carbonaceous, pyrite-bearing mudstones and sandstones (lithologic Unit VI; 821.2 to 874.9 mbsf). Poorly preserved fossils, possibly foraminifers, indicate a marine origin. Trace fossils *(Chondrites)* also indicate deep water (outer shelf?) conditions; bottom conditions may have been euxinic. The petrography and bulk-rock composition indicate that the rock is, at least in part, of volcanic (basaltic) origin. The steep inclination of the bedding (30° to vertical, with some beds showing overturning) may be related to tilting and slumping associated with pre-SDRS rifting. The age and affinities of this unit are unknown, although there are some similarities to known onshore exposures of Paleocene sediments, such as the Ryberg and Vandfaldsdalen Formations in Kangerdluqssuak, East Greenland.

In Hole 917A, paleomagnetic whole-core measurements were obtained only from Core 152-917A-4R, which carries a reverse polarity. Nannoplankton data from this core indicate a CP14a age (middle Eocene); the reverse polarity remanence could represent either Chron C18r or C19r. Paleomagnetic data were obtained from 76 discrete samples, from 65 of the igneous units. All samples carry a reverse polarity remanence. Stratigraphic arguments, based on the age of the magnetic anomalies in this area, suggest correlation with Chron C24r (upper Paleocene to lower Eocene), but this must await confirmation by shore-based radiometric dating.

Excellent recovery of the basaltic basement has resulted in the generation of a significant data base for all the physical properties measurements. MST data are effective at showing large-scale downhole variation. The natural gamma plots appear to pick out the gross downcore geochemical trends established by ship-based XRF analysis, and confirmed by the downhole logging. The division between the three series of the basalts is particularly clear, with the Upper Series having a mean natural gamma of approximately 400 total counts, compared with about 500 to 600 total counts for the Middle and Lower Series.

Over 100 thermal conductivity measurements have been made on sedimentary and igneous units. For the soft sediments, full-spaced thermal conductivity measurements range between 1.2 and 1.7 W/m°C. Hard-rock samples were measured non-destructively, using the half-spaced method. Average thermal conductivity for unaltered basalts ranges between 1.8 and 2.1 W/m°C. There is a broad negative correlation between degree of alteration and thermal conductivity.

Hamilton Frame P-wave velocity measurements showed a wide range (3.0-5.5 km/s) of values in the basalts, varying significantly from one flow to another. Velocities of alteration zones and laterites are as low as 2.5 km/s.

There are no organic or inorganic results to report for this site.

The Formation Microscanner (FMS) and Quad-Combo logging tools were successfully deployed in Hole 917A, despite failure of the temperature sonde. The FMS tool provided high-quality image data in the interval 595.0 to 165.0 mbsf. The differential caliper data show an elliptical hole, with the maximum stress direction along 105°, which is approximately normal to the margin. The synthetic seismogram shows good correlation with the site-survey seismic data. There are also good correlations between the natural gamma, velocity, resistivity and caliper logging data and the physical and chemical measurements made on the recovered core. For example, it is possible to clearly distinguish the boundary between the Middle and Lower Series of lavas, to distinguish the evolved lavas, and to identify individual units, especially from the FMS image.

Principal Findings at Site 917

(i) Lava sequence recovered at Site 917 could be readily divided into three series, based on the flow morphology, thickness and geochemistry. All lavas appear to have been erupted subaerially.
(ii) Trace element chemistry suggest continental crustal contamination of the Lower and Middle Series. The more picritic Upper Series are derived by simple asthenospheric melting. There is no evidence of any involvement of a chemically undepleted source, such as that sourcing the modern Iceland volcanism.

(iii) Pre-volcanic sediments of Unit VI are strongly tilted and may suggest large degrees of extension and block rotation prior to eruption of the seaward-dipping lavas. The sand of Unit V indicates uplift and subaerial erosion prior to eruption.

SITE 918

Site 918 is located near the center of the seaward-dipping reflector sequences on the upper continental rise of the SE Greenland Margin, approximately 130 km from the Greenland coast. The site was selected to study the age and emplacement environment of the SDRS, the history of the East Greenland glaciation, the subsidence history of the Irminger Basin, and the early formation of the North Atlantic Deep Water.

The 1194.7-m-thick sedimentary section (Figs. 9 and 10) has been divided into five lithologic units. Lithologic Unit I (0-600.0 mbsf; Holocene to Miocene) is predominantly dark gray silt with both volcanogenic and continentally derived components. It has been divided into five subunits, depending on the presence of turbidites and the proportion of ice-rafted debris.

Unit II (600.0 to 806.5 mbsf; upper Miocene to lower Miocene) is 288.5 m thick, composed of nannofossil chalk and silt, and is moderately to heavily burrowed. Common micritic and glauconitic hardgrounds occur at the base and top of this unit. The silt bands contain a mixed suite of minerals derived from both volcanic and continental terrains.

Unit III (806.5-1108.2 mbsf; lower Miocene to upper Oligocene) comprises sand, silt and nannofossil chalk, and has been divided into two subunits. Subunit IIIA comprises interbedded sand beds and nannofossil chalk; Subunit IIIB comprises massive, quartz-rich turbiditic sands which are intermittently heavily bioturbated. Dolomite is a common constituent in the lower subunit, and there is an increase in glauconite downcore. A layer of unconsolidated gravel occurs at the base of Unit III.

Unit IV (1108.2-1157.9 mbsf; middle to lower Eocene) is 49.7 m thick and comprises interbeds of nannofossil chalk and volcaniclastic silt with nannofossils.

Unit V (1157.9-1189.4 mbsf; lower Eocene) is 31.5 m thick and consists of glauconitic sandy silt with interbeds of calcareous sand.

Sample 152-918D-95R-CC (1183 mbsf) yielded a few specimens of nannofossils, which did not allow a useful age determination but did indicate that the sediment was deposited in open marine conditions. Planktonic foraminifers indicate that warm surface water conditions prevailed in the early and middle Miocene, but that cool surface water conditions persisted throughout the middle-late Miocene. Warm surface water recurred during the basal late Miocene. Lower Eocene benthic foraminifers from Samples 152-918D-92R-CC and -93R-CC indicate a paleo-water depth between 75 and 200 m for the interval between 1160 and 1168 mbsf.

Eighteen age-control points were good enough for use in constructing an age vs. depth diagram and for calculation of sedimentation rates for the sedimentary sequence at Site 918. The sedimentation rate for the Pleistocene-Holocene interval is about 8 cm/k.y., which is comparable with that estimated for Site 914 on the continental shelf. The Pliocene has a very high sedimentation rate (20 cm/k.y.), which testifies to the significant contribution of ice-rafted material during that time. The Miocene has a sedimentation rate of about 2 cm/k.y. Another interval with high sedimentation rates is the upper Oligocene turbidite sequence (5 cm/k.y.). An unconformity lies between the upper Oligocene and middle Eocene. A very low sedimentation rate (0.4 cm/k.y.) characterizes the middle and lower Eocene interval.

Basalt was first encountered in Core 152-918D-93R at 1168.2 mbsf. Although only 2.8 m was recovered, this unit could be as much as 12 m thick. It comprises dark gray, holocrystalline basalt with glomerocrysts of plagioclase and clinopyroxene, and less than 1% olivine microphenocrysts. Secondary alteration is restricted to slight clay development in the mesostasis and in the rims of olivines. Compositionally, the rock is an evolved tholeiite, with 5.1% MgO and 66 ppm Ni, and 3 w % TiO_2. The high Zr/Y (6.7) and low Zr/Nb (6.5) ratios of this basalt indicate affinities with Icelandic tholeiites. The unit may represent a sill or a flow; there were no recovered contacts. Below this unit there is a further 9.3 m of sedimentary rocks, above the main basaltic basement.

Hole 918D reached basaltic basement at 1188.5 mbsf. Deep (17.7 m), subaerial weathering has affected the top three flow units, which have been completely oxidized and altered to clay. The first rock preserving any original mineralogy was encountered at 1206.0 mbsf (Core 152-918D-98R-2, 65 cm). From there to the bottom of the hole (at 1302.3 mbsf), 18 flow units were identified. The upper units were separated by altered basaltic breccia, which was generally severely disturbed by drilling and, in places, reduced to gravel. The breccia is, therefore, of indeterminate origin although some of it may be hyaloclastite.

With depth, the proportion of breccia decreases and is last seen beneath Unit 12 at 1264.8 mbsf. Units 13 to 19 are separated by reddened flow tops where these are preserved. No evidence for submarine eruption was found, although the upper flow units may have been erupted into shallow water or across a wet substrate.

All of the flow units consist of aphyric tholeiite with very little mineralogical or compositional variation. They contain 7.1% to 8.8% MgO, 70 to 84 ppm Ni and are highly depleted in incompatible elements (K_2O < 0.1%, Nb < 3 ppm). High Zr/Nb ratios (16 to 30), and low Zr/Y ratios (1.6 to 2.2) are similar to depleted mid-ocean-ridge basalts. Low Ba, K_2O and Sr are consistent with derivation from a depleted MORB source.

Hole 918A reveals a detailed record of normal and reverse magnetozones. The normal polarity sediments in the interval between 152-918A-1H-1, 0 cm, and -7H-3, 60 cm, have been correlated mainly with the Brunhes Chron; the predominantly reversely magnetized interval below this is correlated with the Matuyama Chron. There may be a marked hiatus in the sedimentary record between these two events that has led to the omission of the Jaramillo event. The interval 152-918A-10H-3, 30 cm, to -11H-6, 90 cm, is tentatively correlated with the Olduvai event, and the interval 152-918A-16H-1, 0 cm to -18H-4, 150 cm, contains normal polarities associated with the Réunion events. For much of the succession in Hole 918D, and particularly the Miocene, firm magnetochron assignments are not possible. The problem is compounded by low core recovery. Lower Eocene (CP9b-CP10) sediments immediately overlying basement are reversely magnetized and are correlated with Chron C24r. All of the measured basalts from the volcanic basement were erupted during a period of reversed magnetic polarity. From the biostratigraphic evidence, the polarity event is likely to be Chron C24r, but radiometric data are needed to confirm this.

Monitoring of light hydrocarbons C1 to C3 showed a significant increase of methane up to 80,000 ppm in the sediments from about 80 to 470 mbsf. Above and below this interval very low values occur. This increase is consistent with a zone of low quantities of sulfate and indicates methane generation due to the decay of organic matter rather than migration from lower parts of the sequence. The content of organic matter within the sediments is low. The correlation between organic carbon and the organic carbon/nitrogen ratios indicates a marine background sedimentation, with frequent supply of terrigenous organic matter causing enhanced organic carbon values. Carbonate contents vary between 0 and 10 wt% in the upper 600 mbsf and increase dramatically (up to 40 wt%) in the lower parts of the succession.

Initial results from the interstitial water chemistry reveal that:
(i) Concentrations of dissolved chloride in the upper 100 mbsf indicate a maximum at about 50 mbsf, most likely caused by a remnant of higher seawater salinities during the glacial maximum.
(ii) Concentrations in calcium, magnesium and chloride show extremes in their concentration/depth profiles at about 550 mbsf, related to the alteration of volcanic matter at this level.
(iii) Below 825 mbsf, i.e., in the zone characterized by the occurrence of sandy and silty deposits, chloride concentrations drop as much as 5% below seawater values. Some of these lower chloride fluids may have undergone lateral transport along sand zones.

The water sampling and temperature probe was deployed in Hole 918A with two successful runs for temperature and three successful runs for interstitial water. Temperatures at 142 and 198 mbsf suggest a linear gradient in the top 200 m of Site 918, with a gradient of 5.6°C/100 m and a heat flow of 75±8 mW/m^2. This heat flux is similar to other observations in the Irminger Basin.

Based principally on MST and index property data, twelve mechanical units can be defined for Site 918. Few of the boundaries between these units correspond with the lithological units described above, but MST and discrete property measurements do reveal and corroborate detailed sedimentary features such as glauconitic hardgrounds, diamictons, and fining-upward sequences. GRAPE bulk density data, natural gamma and magnetic susceptibility measurements are particularly useful for detecting these features. There is a range of mean thermal conductivity in the sediments from 1.1 to 1.70 W/m°C. In the basalts, thermal conductivity ranges from 1.5 to 1.8 W/m°C.

Principal Findings at Site 918

(i) Dropstones in glaciomarine sediments indicate that ice-rated debris was being deposited in the Irminger Basin as early as 7.0 Ma (late Miocene)

(ii) Glauconitic hardgrounds in chalks suggest that strong erosive bottom water flow of the North Atlantic Deep Water, overspilling the Iceland/Greenland Ridge was affecting the Greenland continental rise area at 11-13 Ma.

(iii) Eruption of the seaward-dipping basalt lavas was subaerial. Subsidence below sea level, following strong weathering, took place in the early Eocene.

SITE 919

The sediment column at Site 919 is assigned to one lithologic unit, which is at least 147 m thick (Figs. 11 and 12). The dominant lithology comprises clay and silt in various proportions, and nearly 200 distinct beds or packages of beds were identified in the sediment sequence. Many of the beds show fining-upward and sharp basal contacts, indicating deposition from turbidity currents. Other beds have more irregular contacts and more poorly-sorted interiors, which may result from deposition from melting icebergs and subsequent reworking by mass flow and bottom currents on the seafloor. Dropstones occur throughout the sediment column, but they are smaller and less common than those found at the other Leg 152 sites.

A variety of detrital grains occurs in these sediments; quartz is ubiquitous. Commonly associated with quartz are amphibole, clinopyroxene and opaque minerals. Other minerals include garnet, epidote and sphene. Volcanic glass is a common constituent. Most of the mineral grains probably originated in Greenland, and the volcanic detritus in Iceland. Discrete air-fall volcanic ash layers occur at nine places in the cores.

Weak seismic reflectors in the upper part of the sediment column at this site cannot be correlated with layers or structures in the observed cores.

The nannofossils recovered from Hole 919B indicate that the oldest sediments are of late Pliocene age. An extended Quaternary sequence (about 93.5 m) has been recovered from Hole 919A. Planktonic assemblages are abundant and well preserved throughout; temperate to warm water conditions are indicated by increased species diversity and a range of warm-water species in the Pliocene sediments. Siliceous microfossils, such as radiolarians and sponge spicules, are generally common to abundant. The location of the boundary between nannofossil Zones CN14 and CN13, the Pliocene/Pleistocene boundary, is in Core 152-919B-6H, between 120 and 125 mbsf.

The interval 152-919A-1H, 0 cm, to 919B-6H-2, 35 cm, is dominantly of normal polarity, with two intervals showing reversed and/or mixed polarity records. Below 152-919B-6H-2, 35 cm (121 mbsf), the sediments are reversely magnetized. The uppermost normal polarity event is correlated with the Brunhes Chron. However, the lowest part of the normal event is close to or within the Pliocene/Pleistocene boundary, suggesting that it must be the normal part of the Matuyama event. This implies that the reversed polarity section of the upper part of the Matuyama event is missing. This implies in turn that an unconformity, of the order of a million years, exists in the sequence. No evidence for such a hiatus can be seen, either in the lithostratigraphy or in the MST records.

Seventy-two samples were analyzed for total organic carbon (TOC), nitrogen and sulfur, and inorganic carbon. Calcium carbonate content ranges from 0% to about 10%, with its concentration controlled by the abundances of planktonic foraminifers. TOC, total nitrogen and total sulfur abundances are very low. Total organic carbon/total nitrogen ratios indicate that the organic matter is predominantly marine in origin. However, the low TOC means that these ratios should be used cautiously. Methane concentrations are high in the lower part of the sediment column, ranging from 400 to 20,000 ppm in the interval 85 to 147 mbsf. In the upper part of the column, methane is close to the detection limit of the equipment. The methane distribution curve is similar to that in the upper part of the curve determined at Site 918.

Dense sampling of the interstitial pore waters of Pleistocene sediments was carried out to further define the signal of increased seawater salinity and to sharpen the boundary between the sulfate reduction and the methane production zones. Similar studies were carried out at Site 918, but in less detail. There is a well-developed chloride maximum of about 572 mM at about 50 mbsf. In the depth interval 20 to 90 mbsf, the concentration-depth profile for sulfate is essentially linear toward the base of the sulfate reduction zone. This suggests transport by diffusive exchange within this depth interval. Methane levels are kept low, presumably by the action of sulfate-reducing bacteria.

MST and other physical properties measurements were made on all of the cores from Site 919, with the exception of Cores 152-919B-1H and -2H, which were analyzed by MST only. On the basis of the MST data, all of the sediments were grouped in one mechanical unit, which was subdivided on the basis of bulk density and P-wave velocity into three subunits. The boundary between Subunits M1a and M1b (152-919A-7H-1, 150 cm; 67 mbsf) is marked by an increase in P-wave velocity from 1525 to 1550 m/s. MST data are more variable in Subunit M1c than in M1b; in several respects M1a and M1c are similar. There is no evidence from the MST data to support the existence of an unconformity between about 120 and 125 mbsf, as inferred by the magnetobiostratigraphic data.

Principal Findings at Site 919

(i) An expanded Quaternary-Pliocene section provides a complete biostratigraphic and magnetostratigraphic section of this time interval, during which ice-rafting of debris from East Greenland was common.

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FIGURE CAPTIONS

Figure 1. Map of the North Atlantic region, showing the location of dipping reflector sequences, basalt and sill complexes, and Sites 914-919 drilled during Leg 152. Thin gray lines define seafloor magnetic anomalies. The seaward-dipping reflectors along the EG63 transect were all erupted during Chron 24r times. NAVP = North Atlantic Volcanic Province.

Figure 2. Bathymetry (in meters) of the southeast Greenland Shelf and continental slope, showing the location of Sites 914-919. Bathymetric data are from GEBCO 1:1,000,000 series (Deutches Hydrographisches Institut, Sheet 2).

Figure 3. Seismic line of the southeast Greenland transect drilled during Leg 152, showing location of Sites 914-919. Data is from seismic line GGU 81-08 of the Greenland Geological Survey.

Figure 4. Sites 914-917 are located at the landward featheredge of the SDRS wedge where it onlaps to down-flexed continental basement. Penetration of >800 m into the SDRS wedge was achieved at Site 917. Units are seismic stratigraphic units, correlated with lithological data from the drill sites.

Figure 5. Site 914 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age.

Figure 6. Site 915 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age. Igneous stratigraphic units are not displayed due to their small thickness.

Figure 7. Site 916 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age.

Figure 8. Site 917 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age. Ni content is displayed to demonstrate the chemical integrity of the Lower, Middle and Upper Series. Data were derived from shipboard XRF analyses. Igneous stratigraphic units are not

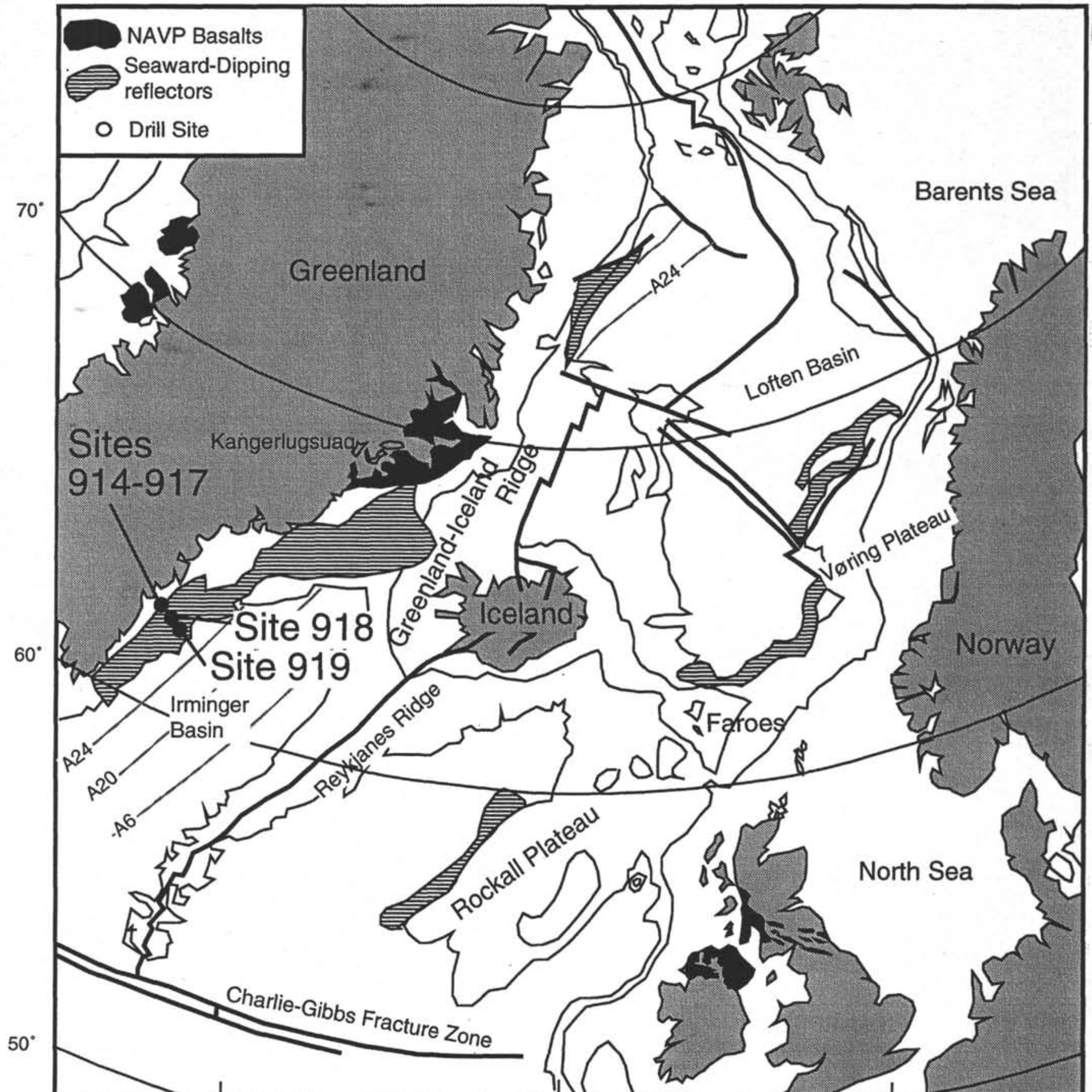
displayed due to their small thickness. Lithostraigraphic Units III and V are not marked due to their small thickness. They occupy depths 37.7 to 41.9 mbsf and 821.06 to 821. 20 mbsf respectively.

Figure 9. Site 918 is located within the central part of the approximately 100-km-wide SDRS wedge. Basement penetration of 100 m was achieved. Seismic stratigraphic sequences correlated from sequences on the shelf. Seismic Stratigraphic Sequences 1 and 2 are Quaternary, Subsequence 3A is Miocene to Pliocene, Subsequence 3B is Oligocene and Sequence 4 is Eocene. Data is from Greenland Geological Survey seismic line EG92-14.

Figure 10. Site 918 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age. Igneous stratigraphic units are not displayed due to their small thickness.

Figure 11. Site 919 is located on the eastern limit of the approximately 100-km-wide SDRS wedge. Penetration of 147 m was achieved within the Plio-Pleistocene. Reflectors marked on the seismic line represent surfaces of gentle onlap and possible hiatus. Stratigraphic sequences defined at Site 918 and on the shelf could not be identified at Site 919, as they were not penetrated by drilling operations.

Figure 12. Site 919 simplified stratigraphic log, including graphic lithology, stratigraphic units, and age.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Seaward-Dipping reflectors
Drill Site
Barents Sea
Greenland
Loften Basin
Sites 914-917
Kangerlugsuaq
Greenland-Iceland Ridge
Vøring Plateau
Iceland
Site 918
Site 919
Norway
Irminger Basin
Faroes
Reykjanes Ridge
Rockall Plateau
North Sea
Charlie-Gibbs Fracture Zone
A24
A20
A6
70°
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50°
30°
15°
0°

Figure 1

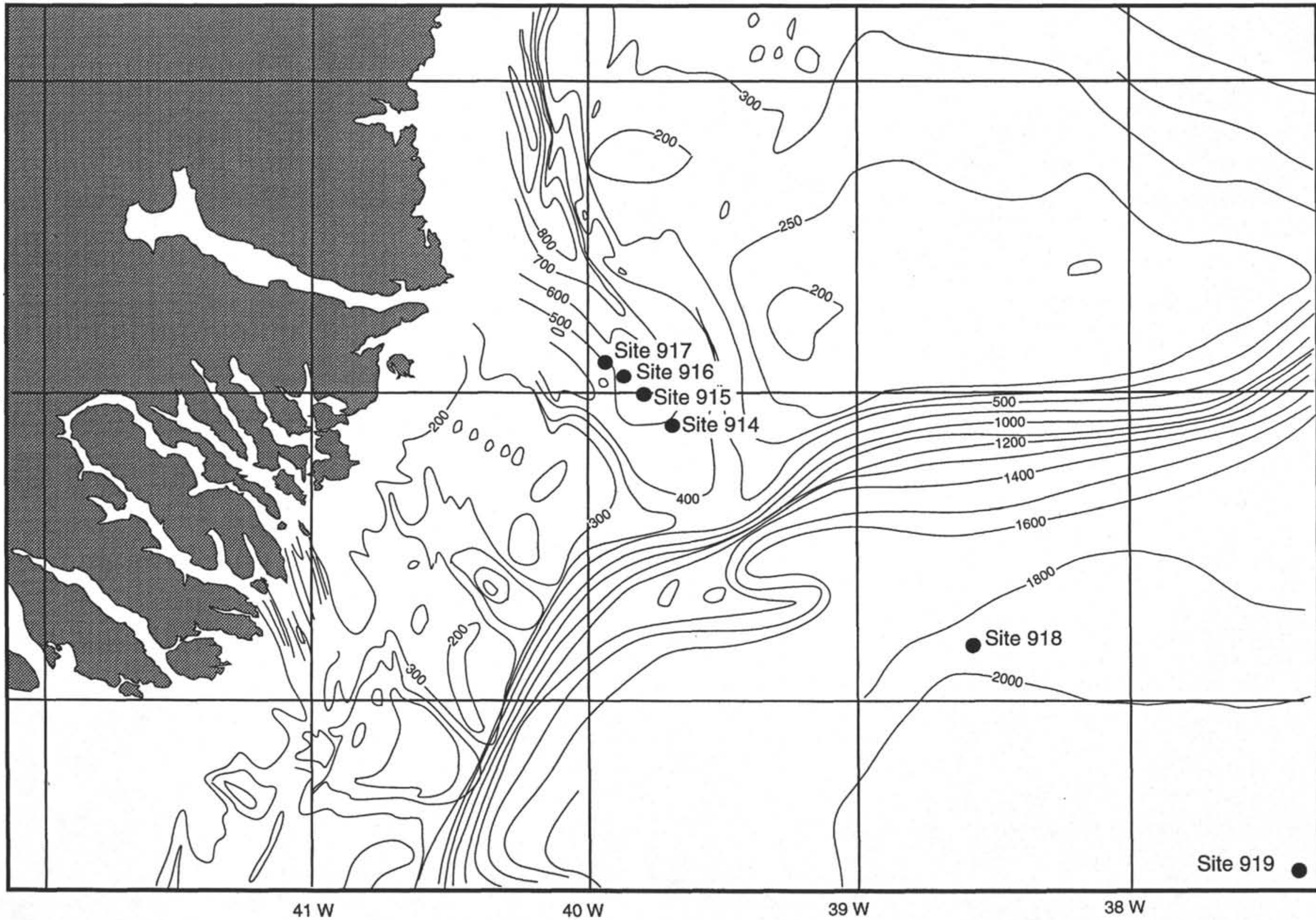
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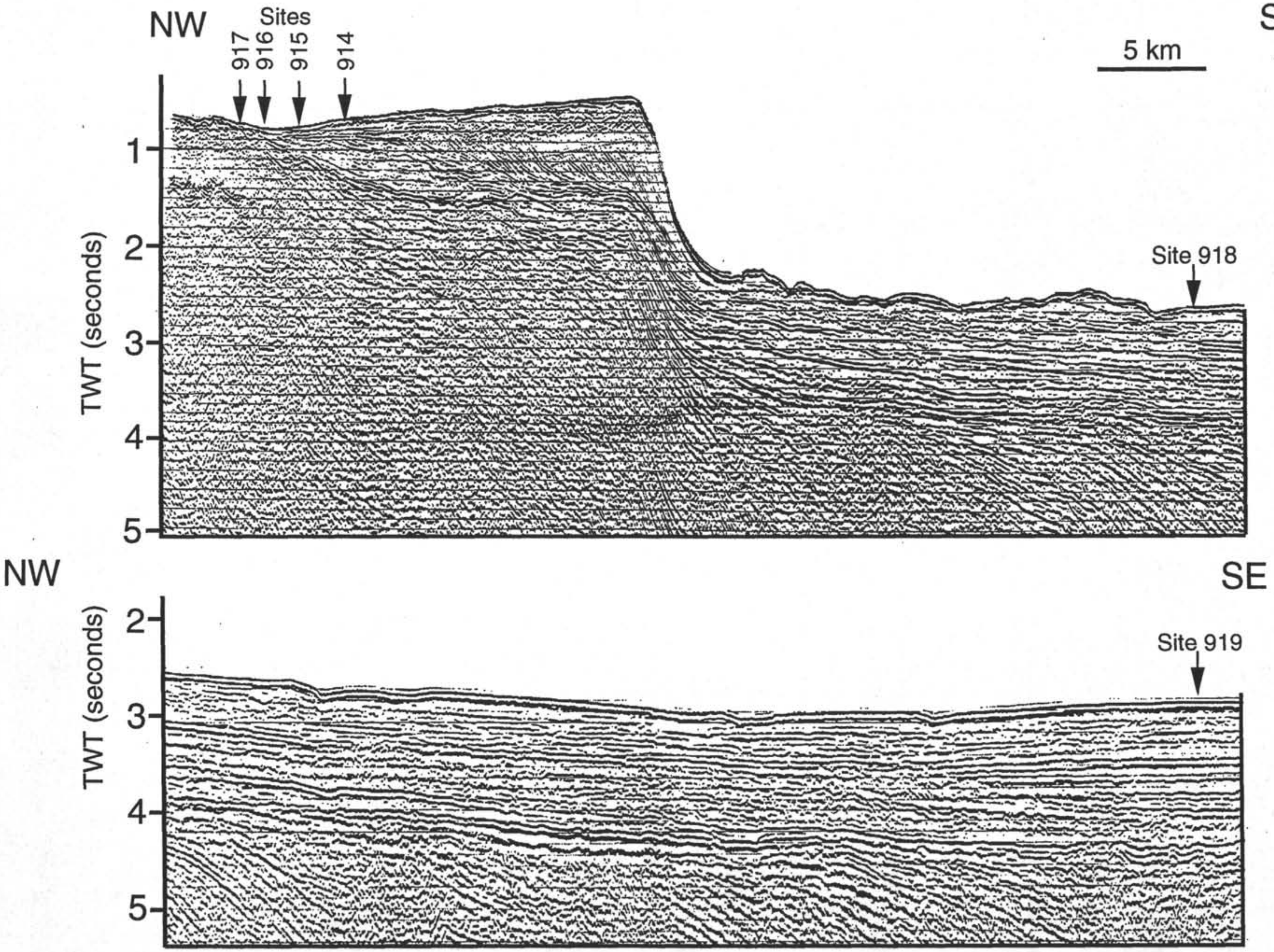
Figure 2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Site 919

Figure 3

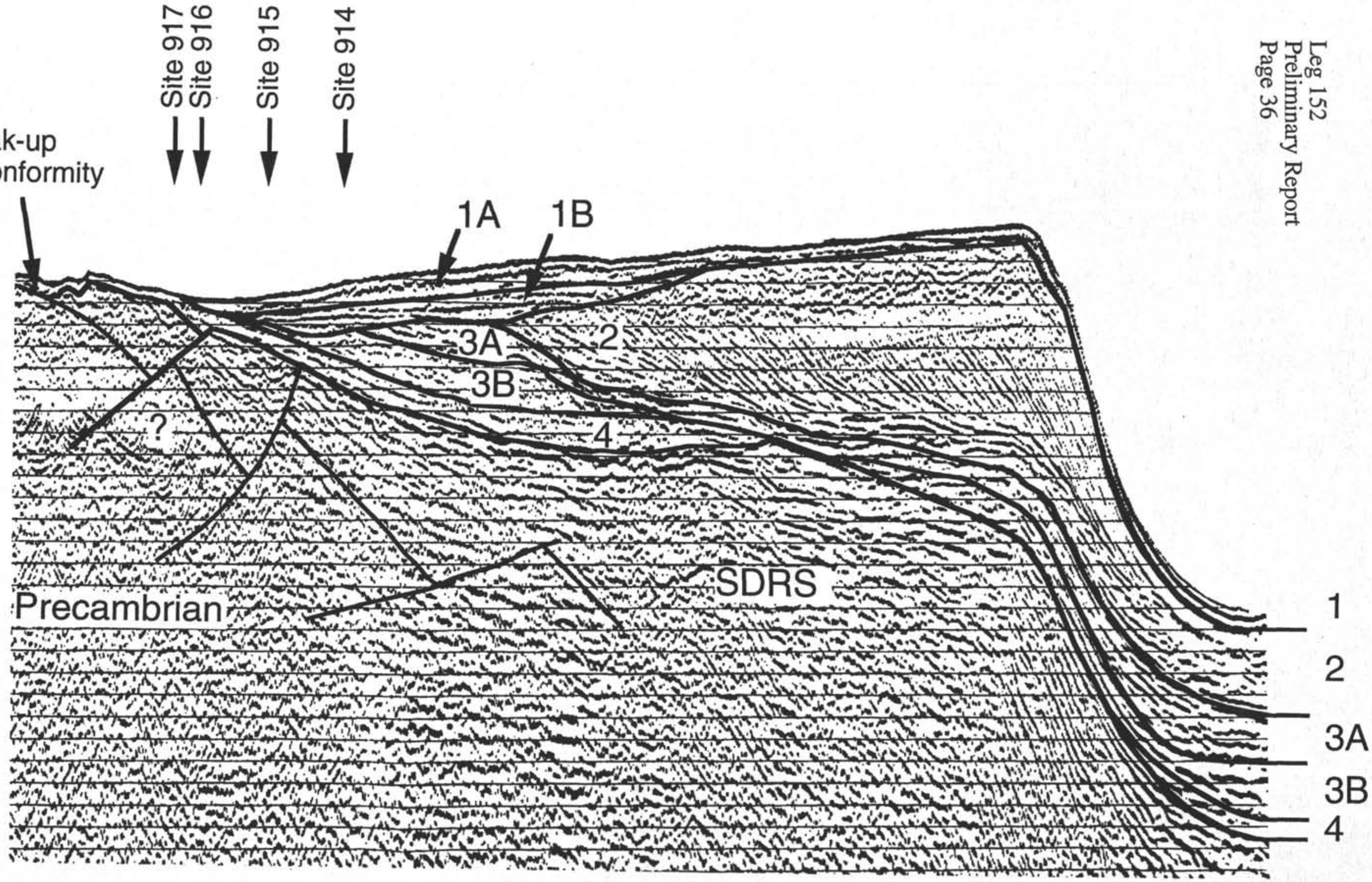
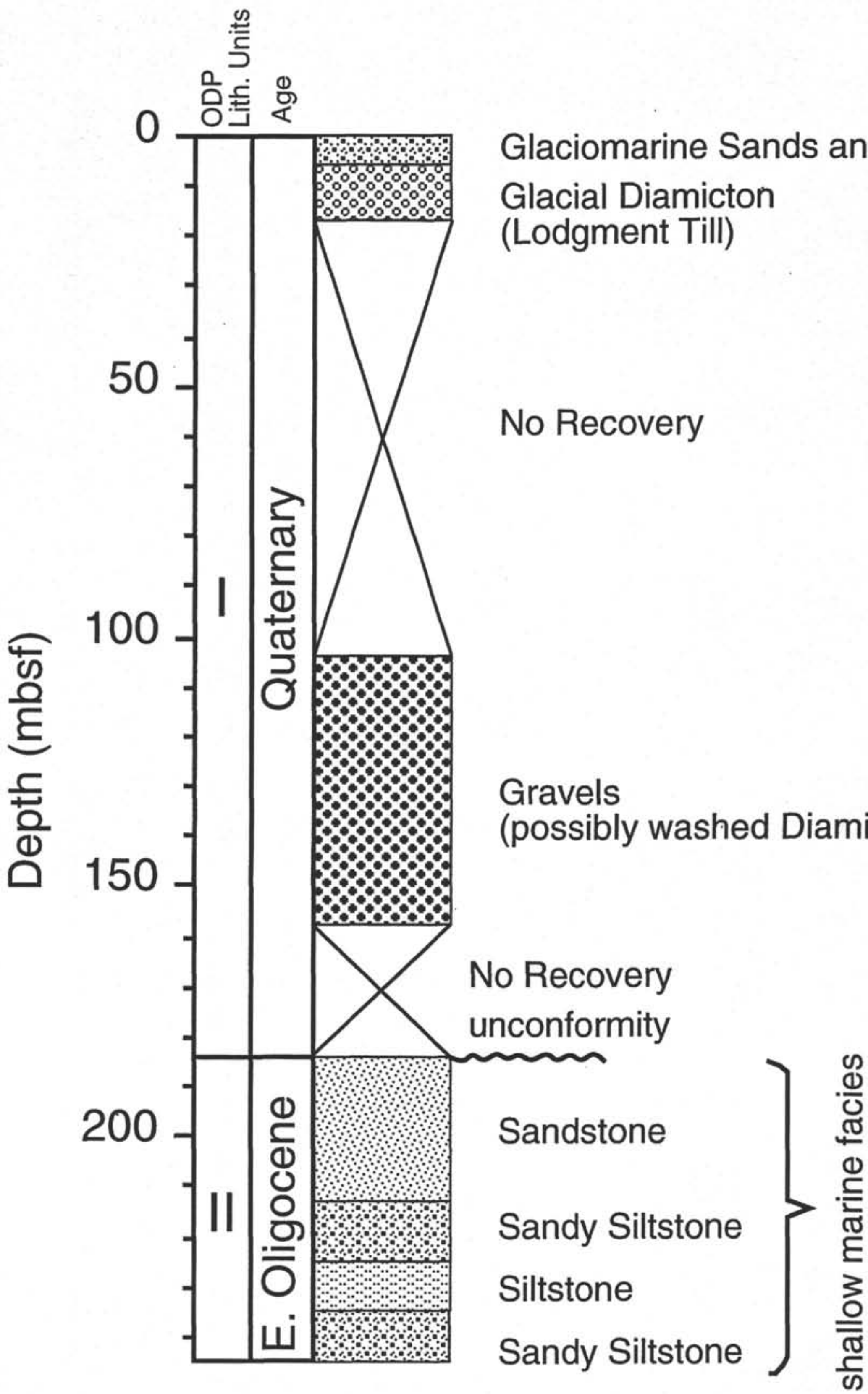

Site 917
Site 916
Site 915
Site 914
Break-up unconformity
1A
1B
2
3A
3B
4
?
SDRS
Precambrian
1
2
3A
3B
4

Figure 4



Site 914

Figure 5

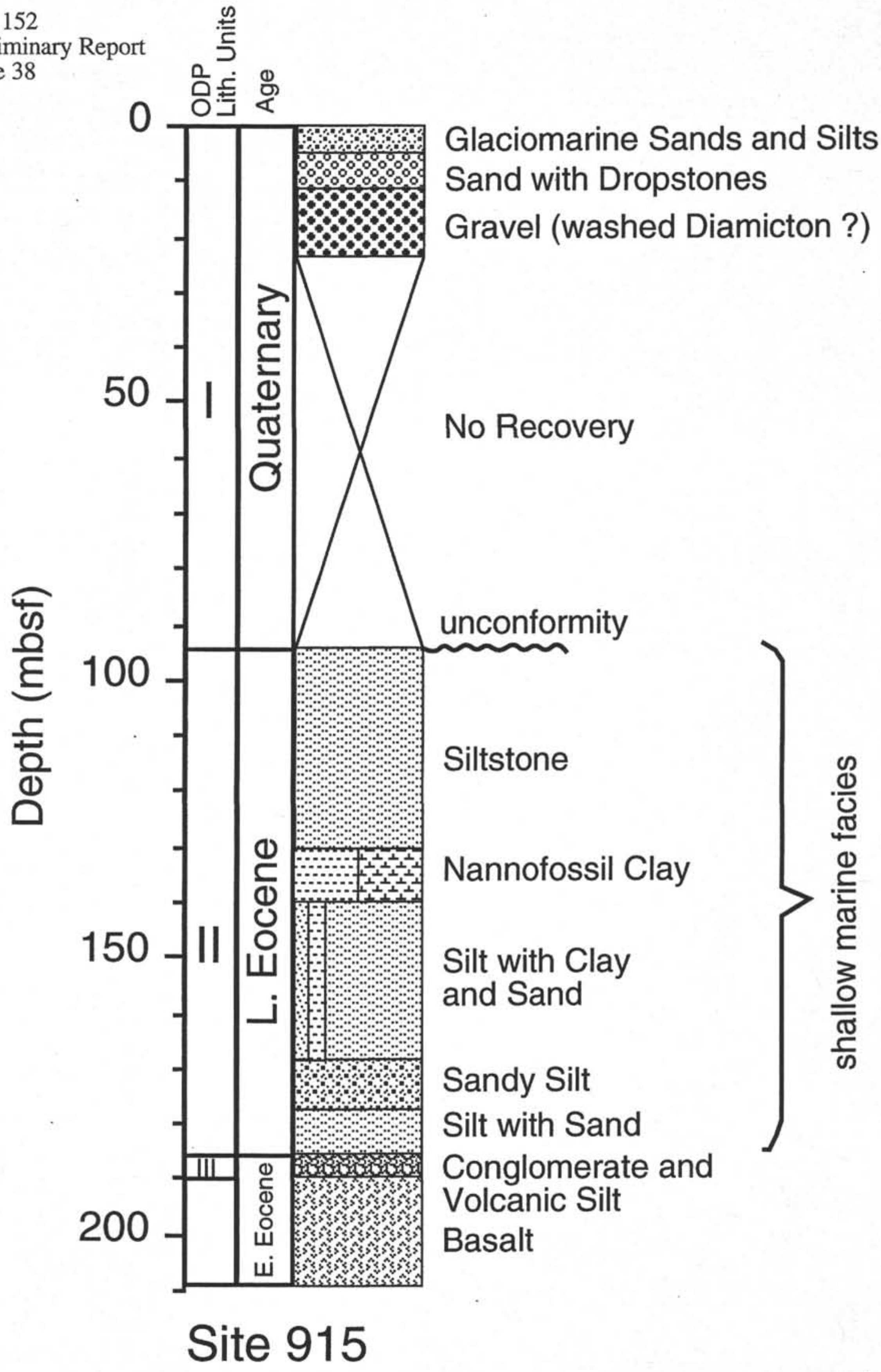

ODP Lith. Units
Age
0
50
100
150
200
Depth (mbsf)
I
II
III
Quaternary
L. Eocene
E. Eocene
Glaciomarine Sands and Silts
Sand with Dropstones
Gravel (washed Diamicton ?)
No Recovery
unconformity
Siltstone
Nannofossil Clay
Silt with Clay and Sand
Sandy Silt
Silt with Sand
Conglomerate and Volcanic Silt
Basalt
shallow marine facies
Site 915

Figure 6

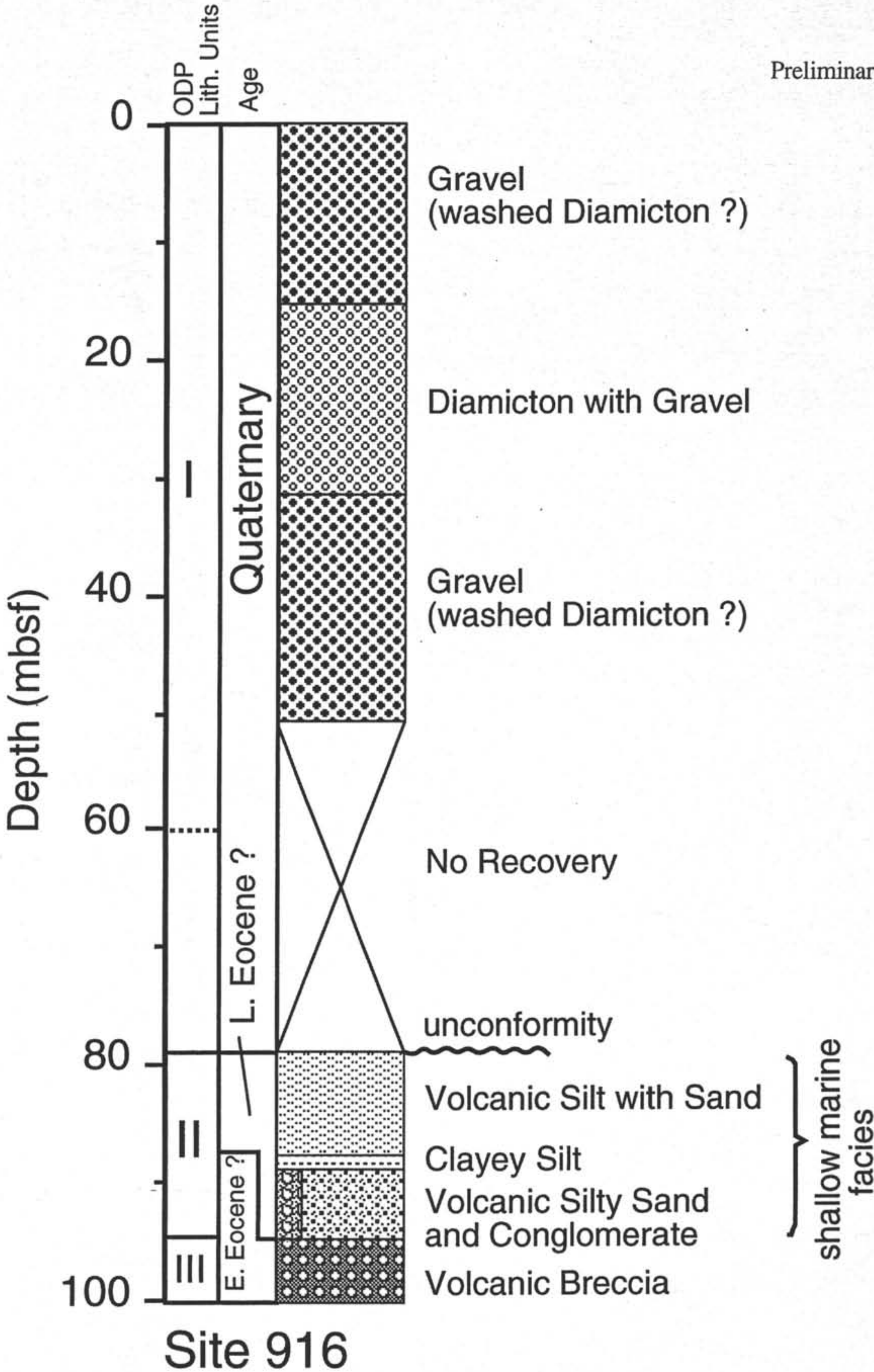

ODP Lith. Units
Age
Depth (mbsf)
0
20
40
60
80
100
I
II
III
Quaternary
L. Eocene ?
E. Eocene ?
Gravel
(washed Diamicton ?)
Diamicton with Gravel
Gravel
(washed Diamicton ?)
No Recovery
unconformity
Volcanic Silt with Sand
Clayey Silt
Volcanic Silty Sand
and Conglomerate
Volcanic Breccia
shallow marine
facies
Site 916

Figure 7

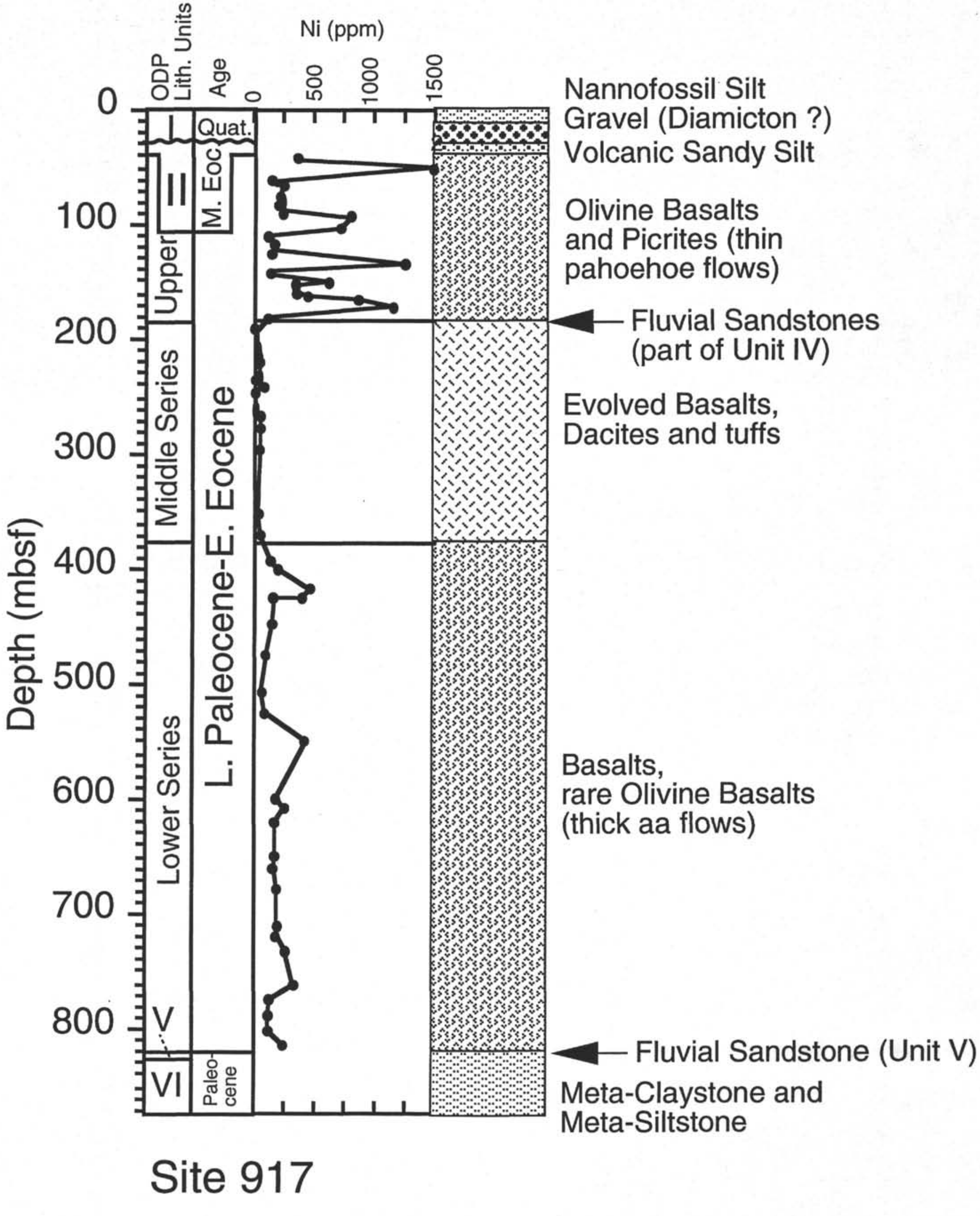

ODP Lith. Units
Age
Ni (ppm)
0
500
1000
1500
0
100
200
300
400
500
600
700
800
Depth (mbsf)
Quat.
I
II
M. Eoc
Upper
Middle Series
Lower Series
V
VI
L. Paleocene-E. Eocene
Paleo-cene
Nannofossil Silt
Gravel (Diamicton ?)
Volcanic Sandy Silt
Olivine Basalts and Picrites (thin pahoehoe flows)
Fluvial Sandstones (part of Unit IV)
Evolved Basalts, Dacites and tuffs
Basalts, rare Olivine Basalts (thick aa flows)
Fluvial Sandstone (Unit V)
Meta-Claystone and Meta-Siltstone
Site 917

Figure 8

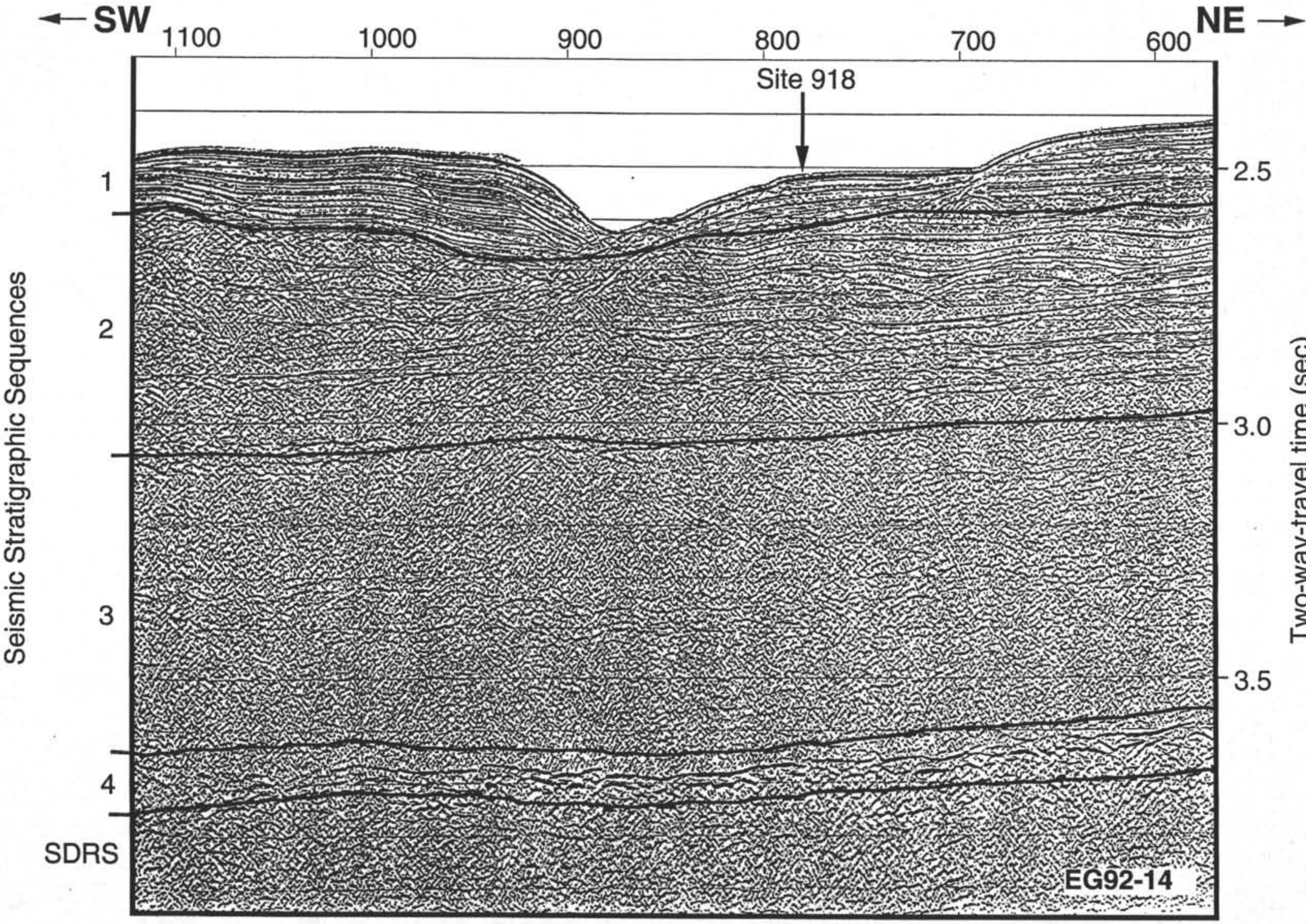

SW
NE
1100
1000
900
800
700
600
Site 918
Seismic Stratigraphic Sequences
1
2
3
4
SDRS
Two-way-travel time (sec)
2.5
3.0
3.5
EG92-14

Figure 9

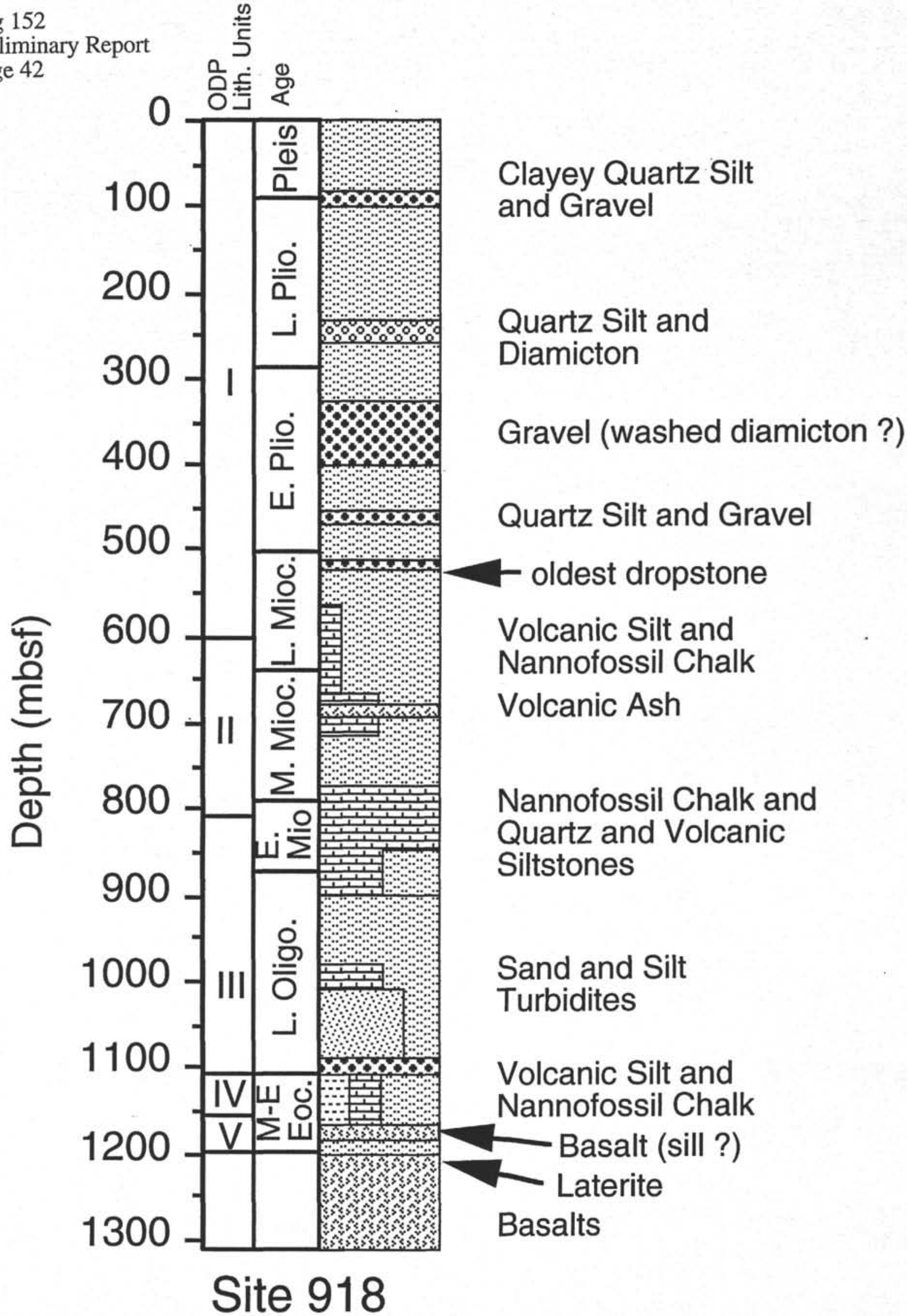

ODP Lith. Units
Age
Depth (mbsf)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
I
II
III
IV
V
Pleis
L. Plio.
E. Plio.
L. Mioc.
M. Mioc.
E. Mio
L. Oligo.
M-E Eoc.
Clayey Quartz Silt and Gravel
Quartz Silt and Diamicton
Gravel (washed diamicton ?)
Quartz Silt and Gravel
oldest dropstone
Volcanic Silt and Nannofossil Chalk
Volcanic Ash
Nannofossil Chalk and Quartz and Volcanic Siltstones
Sand and Silt Turbidites
Volcanic Silt and Nannofossil Chalk
Basalt (sill ?)
Laterite
Basalts
Site 918

Figure 10

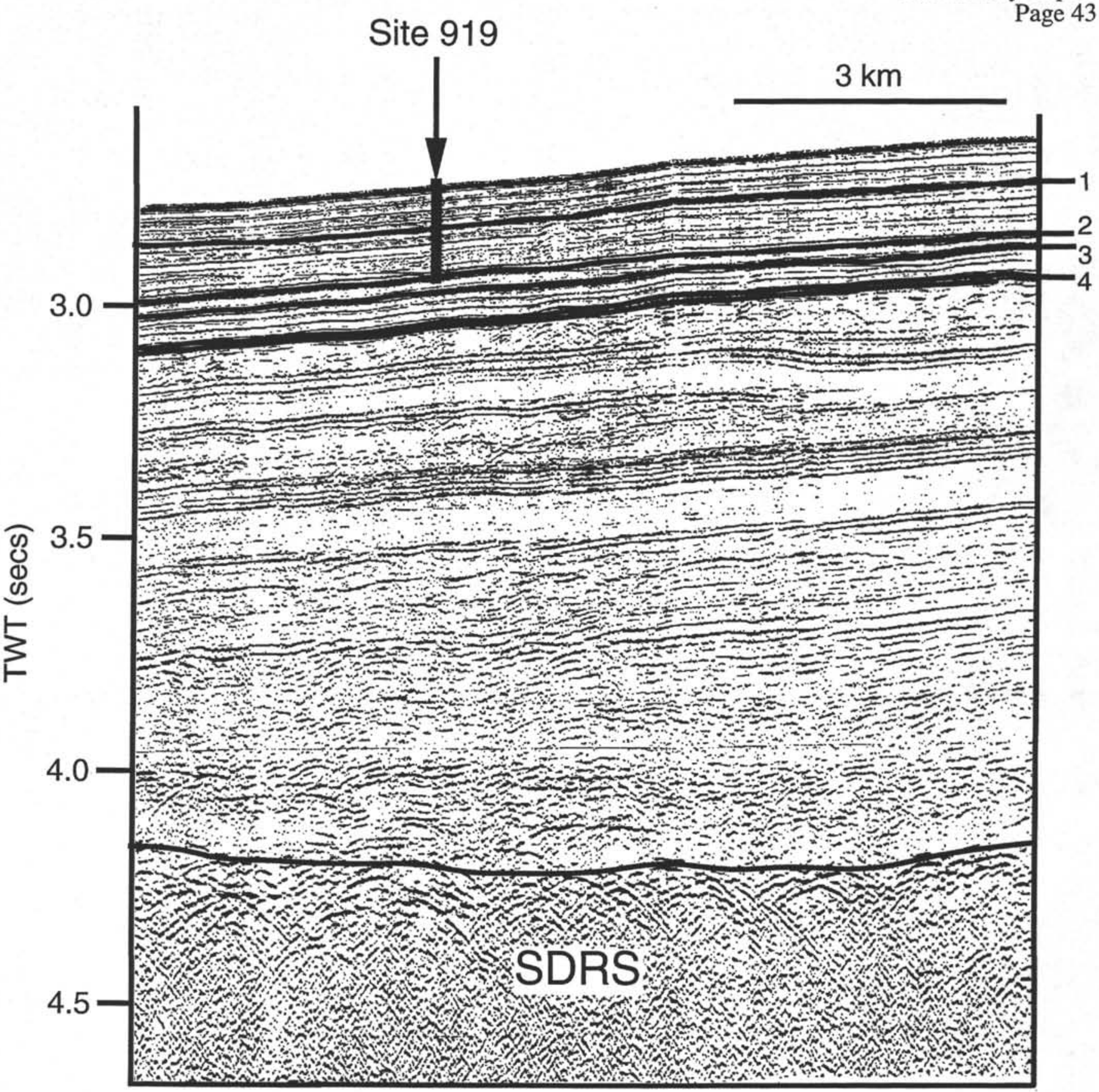
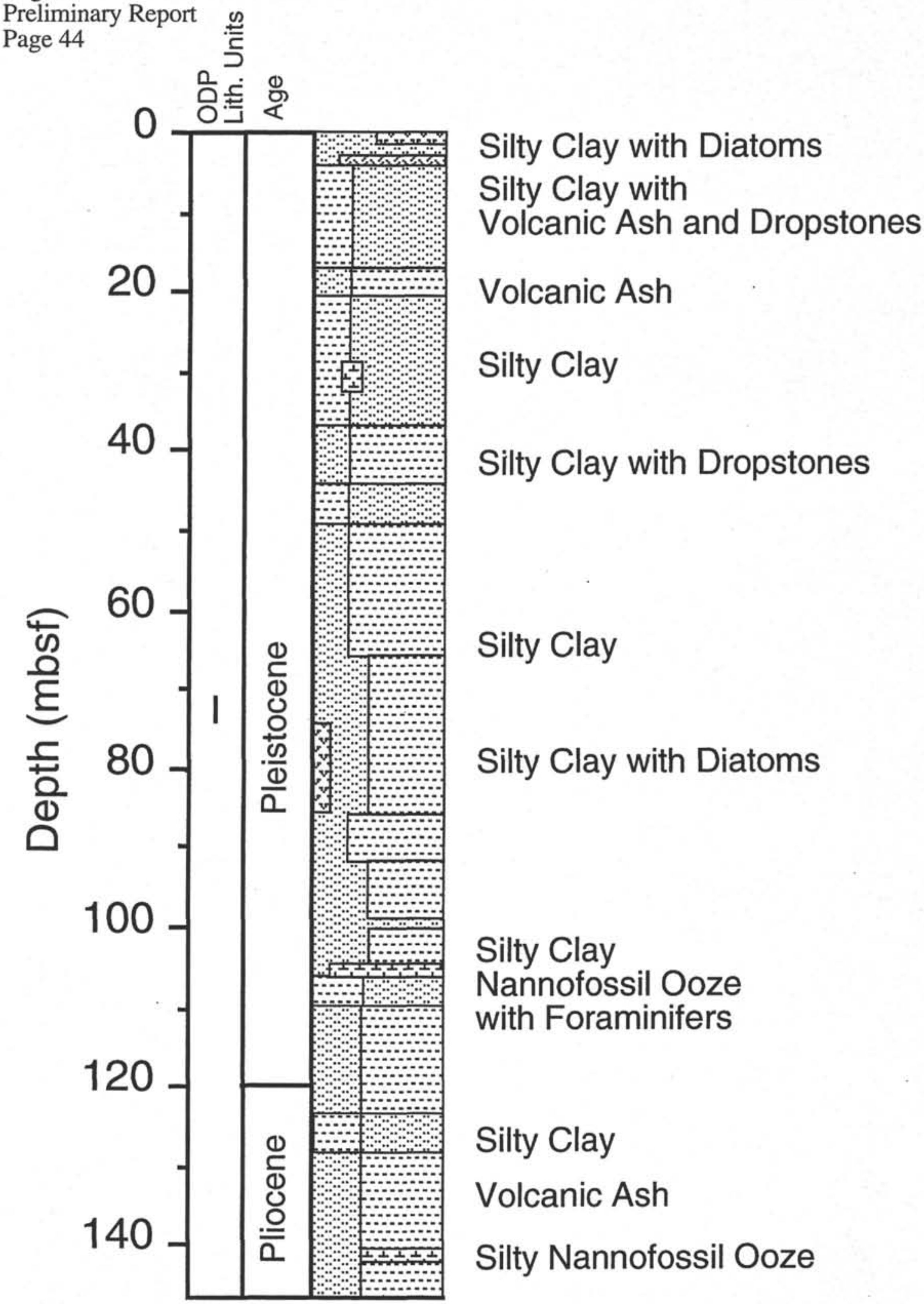


Figure 11



Site 919

Figure 12

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 152 were:

Operations Superintendent: Ron Grout

Development Engineer: Bill Rhinehart

Schlumberger Engineer: Karl Pohl

REYKJAVIK PORT CALL

ODP Leg 152 began when *JOIDES Resolution* arrived at Sundahofn Pier 411, Reykjavik, at 0700 hr on September 24, 1993. The port call was relatively light in terms of logistical and repair activities. In addition to the routine air and ocean freight, there were technical support personnel to service the Kappabridge and XRF equipment. Incoming Operations shipments of note included 10 RBI (5-C4 and 5-C7) RCB bits and the Drill Quip 20"16" running tool.

The vessel took on 1519.8 MT of fuel, 860 gallons of turbine-grade oil, and 953 MT of potable/drilling water. The time-determining item for this port call was the replacement of the number two and three crown sheave bearings, a job which lasted until the evening of September 29. The auxiliary seawater cooling lines were also cleaned out during the port call.

The port shaft seal, which was found to be leaking during Leg 151, was inspected by divers in the port. No visible reason could be found for the leaking seal. The decision was made to load up with additional turbine grade oil (860 gallons) and continue the cruise as scheduled. The last line was away at 1230 on September 28, and the vessel sailed for the first site.

TRANSIT TO SITE 914

When the *JOIDES Resolution* had cleared Reykjavik harbor, a course was set nearly due west for the operating area. The weather initially was clear and cold with occasional showers, which toward the evening hours turned to snow flurries. Gentle eight foot swells from the SSW caused a gradual three to four degree roll. By the next day, the swell had abated, and the remaining transit was accomplished in calm seas and overcast skies.

At 0500 on September 30 the ship slowed to five knots to deploy seismic gear and conduct a short survey. At 0726, a Datasonics beacon (Model 354B, 16 kHz, sn 758), modified to operate at a reduced source level (199 db), was deployed. After the seismic gear was retrieved, the ship returned to location and was positioning on site by 0900.

SITE 914

The initial site of Leg 152 was on the continental margin of Southeast Greenland approximately 23 nmi offshore and in approximately 530 m of water. The plans called for an advanced piston corer/extended core barrel (APC/XCB) hole to refusal, followed by a rotary core barrel (RCB) hole, which was to be extended 50 m into basement. The sediment was estimated to be 420 m thick, and the ambitious basement objective called for coring 400 m into basalt. The third hole of this site called for a cased reentry cone emplacement. The logging was to be in two stages. The first log would be deployed in the pilot hole in sediment, with the second planned solely for basement.

Upon coming on location, the crew was greeted with a spectacular view of the southeast coast of Greenland illuminated by the rising sun. A caravan of large icebergs was observed heading south at different speeds calculated to range between one and three knots. The icebergs appeared to be following a north-south channel, which was about 12 nmi W of location. There were also several large icebergs grounded with one large iceberg stuck on the sea bed in 215 m of water about 10 nmi from the ship.

Hole 914A

The precision depth recorder (PDR) indicated that the corrected water depth, adjusted to sea level was 533.4 m. A used RBI 11 7/16" C-3 bit was lowered to 529.8 m, and the first APC core was "shot" at 1430 on September 30. The seafloor depth was established at 533.8 m of direct pipe measurement (DPM), based upon the recovery of 5.01 m of clay laden sediment. APC coring was abruptly halted when the second core did not effect a full stroke. When the core barrel was retrieved, the liner was found to be shattered, indicating a high impact landing on firm sediment. After the core was dug out of the core barrel, it was found to measure some 6.6 m.

Instead of employing the advance by recovery method to record the progress, the amount of penetration was recorded at one meter based upon the fact that the washing down of the interval cored with 2H indicated a very hard zone after only one meter of penetration. Apparently, when the core barrel was retracted, it sucked in clay from the surrounding sediments.

XCB coring was initiated but was terminated after two cores, which succeeded in recovering only 0.3 m of glacial till while penetrating 12.6 m in a lethargic four hours. The BHA was retrieved and the hole terminated when the bit cleared the rig floor at 2200 on September 30.

Hole 914B

After a call to TAMU/ODP, management approved drilling to 100 m to be followed by continuous RCB coring, and an RCB bottom hole assembly (BHA) was made up with a bit release. The pipe was run in the hole, and Hole 914B was spudded with a center bit in place at 0130 on October 1. After drilling ahead for 14 1/2 hours at an average rate of penetration (ROP) of 8.6 m/hr, the core barrel was dropped and coring initiated at 93.8 mbsf at 1500 on October 1. During the drilling operation, a 10-bbl high-viscosity mud sweep was made after every connection. There were no hole problems drilling through the glacial till.

RCB coring advanced to 139.5 mbsf through glacial material with very low recovery with a 10-bbl high viscosity slug pumped after every connection.. At 116 mbsf, an extra 20-bbl high viscosity pill was circulated when a probable plugged bit caused the pressure to temporarily rise to 1000 psi. It was felt that the bit would clear itself, and after the next core, the pressure did return to 400-800 psi. ROP for this interval ranged from 18 m/hr to 37 m/hr.

A problem arose with the drill string when the bit was at 187.2 mbsf, immediately after making a connection. After lifting the pipe off the slips, it was found that the drill string could not be lowered down the hole. With both knobbies and a newly added joint of pipe in the derrick, working the pipe upward was not possible, as the compensator was locked. In addition, no movement down the hole was possible, as the drill string was stuck by the formation. Rotation was possible with erratic high torque (300-400 amps). During this operation, circulation was maintained.

The ship was offset 165 feet forward, forcing the pipe connection to lower to the slip level. The connection was then broken, a joint of pipe removed, and the pipe pulled up approximately 10 m. After an additional 20-bbl high viscosity pill was circulated, the pipe was successfully worked free. The joint of pipe which had been laid down was added once more to the drill string, and coring proceeded.

By 0500 on October 2, a storm from the north, which had started the previous evening, had built to sustained winds of 38-40 knots with gusts to 60 knots. Although the sea/swell was 10-14 feet, operations continued. As coring advanced down the hole, the weather deteriorated. By the time coring reached a depth of 245.0 mbsf, the storm had begun to push the vessel to the operational limit. The winds had now reached a sustained 50 knots with frequent gusts exceeding 70 knots. The seas reached 25 feet, causing the ship to roll three to five degrees with pitch between two and five degrees. Eight engines were on-line producing an average of 8 MW with peak loads exceeding 10.8 MW. The dynamic positioning system (DP) was commanding 80% of available power merely to hold station. Large waves impacting the vessel caused an immediate horizontal offset of 100 feet (18% of water depth), which required the overloaded power plants to increase output to the thrusters in order to move the vessel over location. The heave compensator was also frequently fully stroked out and at the limit of its operational capability. The decision was made to terminate operations and pull out of hole (POOH) and wait for the storm to abate. The storm lasted though the evening with no loss of wind strength. At the height of the storm, the seas were 40-60 feet with green water breaking over the bow.

At 1030 on October 3, the storm had lessened to allow the BHA to be pulled to the surface. Although the original bit still looked like new with only 16 hours rotation time, another new C-4 bit was made up, the MBR replaced, and three more drill collars added to the BHA to anticipate the additional weight on bit required in coring basalt. By 1445 the same day, the BHA was run down to 339.8 m. The original plan was to try to reenter the Hole 914B even though no free-fall funnel (FFF) had been deployed. When the surge though the moon pool proved too rough to launch the vibration-isolated television camera (VIT), it was decided that it would be better to offset the vessel 5 m east, spud a new hole and drill down to 225 mbsf to resume coring.

Hole 914C

After a total of 22 hours waiting on weather, operations again resumed at Site 914 at 1845, when the pipe was lowered to 508.8 m. Hole 914C was spudded with the RCB and center bit at 2000 on October 3. While drilling down in Hole 914B had been relatively free of hole problems, Hole 914C required many short trips and extra mud flushes to keep the hole open. The hole was drilled to 224 mbsf and the center bit retrieved. On dropping the first core barrel at 1915 on October 5, circulation was immediately lost, and the drill string could not be rotated. The core barrel was picked up a few feet, which allowed a limited amount of circulation (80 spm and 1000 psi). A 20-bbl high viscosity pill was circulated without any effect. Frequent overpulls of 100,000 pounds (100 Kips) were not effective in freeing the drill string. During one of the overpulls, the ship heaved with the swell and added an additional overpull so that the string was subjected to a total of 260 Kips over the 240 Kips of string weight (500 Kips total weight). The drill string came immediately free, and the pump pressure quickly dropped to 200-300 psi with 80 spm.

After pulling back to 204.0 mbsf, the pipe was lowered to 209.0 mbsf and found an apparent 15.0 m of fill. The core barrel was retrieved and the center bit dropped. No pressure change was observed, indicating a successful landing of the inner barrel. The drill string was picked up approximately 10 m, after the wireline had been run in and picked up the inner barrel. The center bit was again run, but did not land at bit level as expected. Instead, it landed at the bottom of the hole at 209 mbsf. This strongly suggested that the bit was no longer on the end of the drill string. There was no choice but to pull out of the hole (POOH) and inspect the damage. A FFF was not deployed because of the high probability that the bit was missing. This was confirmed when the BHA arrived on deck at 1200 on October 3. The bit and mechanical bit release (MBR) were missing, and it appeared that the bit release had been forced apart from the dogs, which were still mounted in the top connector. Left in the hole were the bit, bit seal, lower support bearing, float valve, and the bit disconnect.

The site was abandoned in favor of moving approximately two nmi WNW, where the glacio-marine sediments were thinner and the basement closer to the mudline. The beacon was turned off as the vessel moved off location in case a return to the site was necessary. It was expected that the ship would make a quick stop here to pick up the beacon at the conclusion of operations in the area.

SITE 915

Hole 915A

At 0130 on October 5, the vessel was offset to the new location in dynamic positioning (DP) mode. At 0030, the Site 914 beacon was turned off, and the first beacon on Site 915 was dropped at 0215. A second beacon was deployed when the first beacon auto-released almost immediately upon hitting the mud line. The SEDCO Electrical Superintendent was convinced that the beacon had been released by the precision depth recorder (PDR) pulses, which are very strong at a depth of only 500 m. At 0237, the second beacon was deployed.

After the vessel had stabilized on location, an RCB BHA, without a bit release, was lowered. A rotary core barrel (RCB) mud line core was obtained by gently lowering the drill string and observing the heave compensator action. The compensator action indicated that weight was taken at a depth of 532.7 m. This was considered the official depth of this site.

RCB coring commenced at 0500 on October 5 and advanced to 206.4 mbsf (Core 152-915A-25R). After the core barrel was withdrawn, flow-back from the pipe indicated that the flapper was jammed open, probably by a basaltic fragment. A chisel bit deplugger was dropped and recovered, and the flow-back ceased. Following the dropping of the core barrel for Core 152-915A-26R, the bit was lowered to the bottom of the hole, and coring resumed. Immediately, torquing of 200-400 amps was evident. It was assumed that the basaltic fragment cleared with the chisel deplugger had dropped a large chunk of hard rock on the bottom of the hole. After working the bit for four hours in an attempt to grind down this material, only 3 m was advanced down the hole. With only 32 hours on the bit, preparations were made for a bit trip. The core barrel was retrieved, containing only a 0.04 m chunk of basalt.

A free fall funnel (FFF) was made up and dropped at 1155 on October 7. The vibration-isolated television camera (VIT) was run in the hole and verified that the FFF was upright on the bottom. The BHA was pulled out of the hole, and the bit arrived on deck at 1415. Examination of the bit indicated that all four cone and four core guides were missing. It was inferred that what had been assumed to be a basaltic fragment was either part of the core guides, or a cone which had dropped off after the core barrel had landed. The large amount of metal in the hole thwarted any further coring of this hole. The vessel was offset in DP mode approximately 2.2 km north to Site 916 (EG63-1B). The beacon was turned off and left in place to facilitate a return to the site if that should be necessary.

SITE 916

Hole 916A

After the ship was offset to site survey location EG63-1B, a Benthos shallow water beacon was deployed (Model 210 LP, 14.5 kHz, 190 db, sn 44656) at 1615 on October 7. A backup beacon (Datasonics, Model 354B, 16.5 kHz, sn 763) was deployed at 1730. After the ship stabilized over the beacon, a rotary core barrel (RCB) bottom hole assembly (BHA), with a new C-4 RBI bit, and without a mechanical bit release (MBR), was run in and spudded Hole 916A at 1830 on October 7. The depth of the water was determined to be 513.7 m.

RCB coring advanced to 101.7 mbsf by 0345 on October 9. Although the bit had accumulated only 23 hours, it was felt prudent to pull the bit and investigate its condition after the premature failure of the same type bit at Hole 915A. A second free fall funnel (FFF) was prepared and launched at 0530 on October 9. The vibration-isolated television camera (VIT) was deployed and verified that the FFF was upright.

Reentry Number 1

A new RBI C-7 bit was affixed to the BHA, and an extra three drill collars were added to improve deep basement coring. At 1330 on October 9, the FFF was entered. The bit encountered a hard bridge at 6.8 mbsf and for the next three hours attempted to wash and ream past this obstruction. This effort was hampered by the inability of adding more than 5 Kips weight on bit (WOB) because the BHA was still above the mud line. After advancing only to 13.8 mbsf in this period, the effort to reenter the hole was abandoned. The BHA was then tripped to the surface. The BHA was subjected to a wet particle inspection to ensure that none of the connections were cracked as a result of the unsupported spud-in attempt. The bit arrived on deck at 2330 on October 9.

SITE 917

Transit and Hole 917A (EG63-1B)

The Datasonics beacon was recalled and retrieved from Site 916, and the vessel offset in dynamic positioning (DP) mode to a new location approximately 0.5 nmi NW of Site 916. According to the seismic record, this area contained a thinner layer of glacio-marine sediment overlying a thin sandstone layer, which in turn covered basalts. After the vessel stabilized on location, the precision depth recorder (PDR) depth relative to the dual elevator stool (DES) on the rig floor was measured at 517.0 m. A new RBI C-4 (medium hard) bit was fitted to the bottom hole assembly (BHA) and the drill pipe run in the water. When the rotary core barrel (RCB) spudded Hole 917A at 0400 hr on October 10, it established the water depth relative to driller's datum at 508.1 m.

After the first four cores penetrated glacial till and sediment in approximately 15 hours, the bit contacted basalt at 42 mbsf. Surprisingly, the rate of penetration (ROP) increased from 2.3 m/hr to 4.3 m/hr as the basalt was penetrated with Core 152-917A-5R. RCB coring then advanced routinely through basalt and highly altered basalt to a depth of 322.3 mbsf. During the coring of this basalt, the ROP frequently exceeded 5 m/hr and on two occasions attained 10 m/hr (Cores 152-917A-29R and -32R). On reaching this depth, the core bit had accumulated 68.7 hours of rotation and appeared to be in excellent shape as indicated by uniform torque indications, exceptionally high ROP, and the recovery of full diameter cores. The bit had penetrated 280 m of basalt with an average ROP of 5.1 m/hr.

Prudence dictated that after such an accumulation of rotating hours, it would be wise to recover the bit, inspect it, and then replace the bit with a hard formation type cutting structure. At 1015 hr on October 14, the 30-foot knobby was laid down and the bit pulled up to 91.1 mbsf. During this trip up the hole, very little drag was encountered, suggesting that the hole was in excellent condition. The vibration-isolated television (VIT) camera was deployed and lowered to inspect the condition of the top of the hole at the mud line. This inspection revealed that the effluent from the hole had settled uniformly around the top of the hole, making a neat sediment pile, which was snug up to the outside of the drill pipe. It had been expected that the top of the hole might have been eroded into a large saucer-shaped depression, which would have made the detection of the free fall funnel (FFF) difficult. Fortunately, this was not the case. The VIT was retrieved.

Reentry Number 2

The third FFF of Leg 152 was made up and deployed at 1507 hr. The bit was then pulled out of the hole (POOH) and was on deck at 1700 hr on October 14, where it was found to be in excellent condition, considering that the bit had accumulated 69 hours of rotating time in penetrating 280 m of basalt. The cutting structure of the bit was almost in new condition, with no chipped or missing inserts. The jets were not plugged, and the cone bearings were still snug. The bit gauge indicated that the bit was just 1/16 of an inch under gauge. Based upon the condition of the first bit, it was felt that 70 hours rotation was a reasonable expectation of bit life for coring in this basalt.

At this time, operations were interrupted for two hours for the routine task of cutting and slipping 115 feet of drilling line. A new RBI C-7 (hard formation) bit was made up as a mechanical bit release (MBR), the VIT deployed, and the drill string positioned for reentry by 2120 hr. At 2126 hr, the bit reentered the FFF and contacted a hard bridge at 18 mbsf. Before rotating the drill string, the VIT was retrieved, and at 2215 hr, washing and reaming operations were initiated from 18 mbsf to 100 mbsf. Approximately one hour after reaming, the bit was able to advance to the bottom of Hole 917A without the need of rotation. RCB coring resumed in the early morning hours of October 15.

RCB coring advanced from 322.3 mbsf to 663.2 mbsf (Cores 152-917A-44R to -84R) in 74.4 rotating hours. During this interval, 340.9 m basalt was cored and 182.50 m recovered (53.5%). The average ROP was 4.6 m/hr, with a high of 12.0 m/hr recorded between 350.3 mbsf to 355.3 mbsf. Half interval cores (approximately 5 m) were obtained in zones where highly fractured basalt was encountered to increase the possibility of recovery.

At 1530 hr on October 19, the top drive was set back and the bit POOH to the surface after the VIT had been deployed and used to verify that the FFF was still visible. The bit was on deck at 1945 hr. Inspection of the used bit verified that the interval of 70 hours was prudent and the type (C-7) was appropriate for coring this highly altered basalt. After the MBR was replaced, the BHA was run to 510.6 m preparatory to reentering the FFF. At this time, operations were terminated as a very large iceberg was approaching location. This iceberg was measured on radar to be approximately 900 m long by 400 m wide and moving in the vessel's direction at 1.4 knots. The iceberg passed the vessel heading south with the closest point of approach (C.P.A.) measured at 4.8 nmi to the west of location. The height was estimated to be between 60 and 80 m. A rough calculation of the displacement exceeded 93 million tons.

Reentry Number 3

After a two hour delay waiting for the iceberg to pass, the bit reentered the FFF at 0025 hr, October 22. The bit encountered the same bridge at 18 mbsf that was experienced on the first bit change. The top drive was kept in place, as it was necessary to wash and ream back to the bottom of the hole because many small bridges were encountered on the way to the bottom of the hole. The frequent washing and reaming protracted the time required to set the bit on the bottom. At 1200 hr, after a chisel deplugger had been dropped and retrieved to ensure that the throat of the bit was clear, coring once again resumed in Hole 917A.

After coring from 663.2 mbsf to 723.4 mbsf (Cores 152-917A-85R to -91R), operations had to be halted as another iceberg was tracked heading toward location. The top drive was set back and the bit POOH to 393 mbsf. From 1115 hr to 1200 hr on October 21, the vessel waited for this large iceberg to pass location. The iceberg passed west of location with a C.P.A. of 2.5 nmi. At 1200 hr the top drive was picked up and the bit washed and reamed to bottom, where 1 m of fill was detected. After a chisel deplugger had been dropped and retrieved to ensure that the bit throat was clear, coring resumed at 1445 hr on October 21. RCB coring advanced with excellent recovery to 807.6 mbsf by 1930 hr on October 22. A drift survey was conducted at 798 mbsf and found that the hole angle deviated from the vertical by four degrees.

During the early hours of October 22, a strong west wind blowing off the Greenland icecap (a local Katabatic wind called a Piteraq in Greenlandic) drove land-locked ice offshore and toward and past the vessel's location. During the afternoon, many growlers, bergy bits, icebergs, and brash ice were observed in close proximity to the vessel. By evening, one large bergy bit, estimated at 10 m wide and 3 m high, maintained a steady track toward the vessel. By 1930 hr, operations were terminated as once more the bit was POOH to a standby position in Hole 917A while the bergy bit was observed. As the bit was being POOH to the standby depth, the bergy bit continued to follow a course with a computed C.P.A. to the location of 0.1 nmi. Safety indicated that the hole had to be vacated, and this was done when the bit cleared the seafloor at 2050 hr. The vessel was offset to an ice-free position 2 nmi NE of location. The bergy bit was tracked by radar and observed to cross directly over Hole 917A. Due to heavy ice concentrations of bergy bits of undetermined size passing location during darkness, the vessel remained off site until the ice cleared the area.

Reentry Number 4

While standing-by for the ice to clear location, the bit was pulled to the surface and another new C-7 bit affixed to the BHA. The MBR was also changed. The vessel re-occupied location at 0530 on October 23, shortly after which the bit reentered the hole at 1100 hr. After retrieving the VIT, the bit was rotated past the ledge at 18 mbsf. Hole 917A was then washed and reamed from 18 mbsf to 249 mbsf. The top drive was set back and the drill pipe run in with stands until a bridge was encountered at 509 mbsf, which required that the top drive be picked up. After the hole was washed and reamed from 509 mbsf to 807 mbsf, the chisel deplugger was dropped and retrieved. RCB coring resumed in Hole 917A at 1845 hr on October 23. At 0300 hr local time, Core 152-917A-103R (826.9 mbsf to 831.5 mbsf) was recovered, containing well lithified dark greenish gray, laminated volcaniclastic siltstone and sandstone. Coring in Hole 917A had apparently effected a complete penetration of the featheredge of the basaltic seaward dipping reflector sequences (SDRS) of the East Greenland margin. Coring continued in this sedimentary material until 2115 hr on October 24. The total depth of the Hole was 874.9 mbsf, of which 775.6 m was basalt.

The hole was flushed with a 40 bbl high-viscosity mud pill. The MBR shifting tool was run in on the wireline and shifted the sleeve and dropped the bit at 2230 hr. The MBR was reset with the second wireline run, and by 2330 hr on October 24 the pipe was being pulled up to logging depth.

Logging Operations

The pipe was pulled up to 109.0 mbsf and run down to 124.0 mbsf. After rigging up the Schlumberger equipment, the first log was deployed at 0200 hr. The Formation MicroScanner (FMS) was run in the hole and contacted an obstruction at 664 mbsf, which was 211 m above the TD. The tool logged the hole up from 664.0 mbsf to 171.0 mbsf and obtained a good profile of the hole. The deviation of the hole was measured to be between five and six degrees. The calipers indicated that there is a north-south elongation of the hole and that numerous cavities exist in the lower part of the borehole wall in the proximity of 556 mbsf, as well as the region between 587 mbsf to 581 mbsf. The first log was completed by 0700 hr on October 25.

The second log run was a Quad Combo without the compensated neutron tool (CNT). The tool was run in the hole at 0700 hr and contacted an obstruction at 573.0 mbsf (302 m above the TD). The hole was logged from this depth up to 181.0 mbsf. After the tool was rigged down at 1730 hr, the drill pipe was run in the hole in an attempt to clear the bridges, preventing the logging tools from measuring the bottom of the hole.

The drillpipe was advanced down the hole in stands to a depth of 775 mbsf, where further advance was not possible without rotation. The top drive was picked up, but circulation was not possible due to an apparent blockage in the drill pipe. After several attempts at clearing the obstruction with high pump pressure and a wireline run of the chisel deplugger, the logging program was terminated and the pipe pulled out of the hole.

The bit was on deck at 0100 hr on October 26. Nearly 50 meters of the BHA was found to be filled with fine-grained basalt cuttings, which had been inhaled while attempting to use the BHA to clear the bridges at the bottom of the hole. After the BHA had been cleared of detritus, the drilling equipment was secured and the beacon recalled. Because of the presence of small bergy bits in the area, which could not be seen on radar, the vessel cautiously offset from location in DP mode toward Sites 915 and 914 to retrieve beacons before sailing to proposed site EG63-2 (Site 918).

SITE 918

Hole 918A

After a short 3.5 kHz seismic survey of the area, a beacon (Datasonics Model 354B, 15 kHz, 208 db, sn 754) was dropped on location at 1100 on October 26. The vessel came about and was lowering thrusters and hydrophones over location by 1130. The advanced piston core/extended core barrel (APC/XCB) bottom hole assembly (BHA) was made up with a non-magnetic drill collar and a used RBI C-3, 11 7/16" bit. The BHA was run in the hole, and at 1615, the first APC core was shot. The core recovered 1.81 m of clayey silt and established the mud line at 1868.5 mbsl. The corrected precision depth recorder reading (PDR) normalized to driller's datum was 1877.0 m.

APC coring advanced through clay and silt, peppered with gravel and glacial dropstones, to a refusal depth of 171.3 mbsf (Core 152-918A-19H). The APC-cored section recovered 171.48 m or 101.3% of the interval cored. The cores were oriented starting with Core 152-918A-4H, and there were successful water sampling/temperature probe (WSTP) runs at 49.3 mbsf, 96.8 mbsf, 152.3 mbsf, and 190.9 mbsf. Biogenic methane was present in concentrations as high as 85,000 ppm and was responsible for some core expansion. Ethane was detected at a level of 1 ppm.

The XCB core barrel was dropped, and XCB coring advanced from 171.3 mbsf to 332.7 mbsf. The interval cored was 161.4 m long with 86.8 m recovered (53.8%). The XCB system was able to penetrate the soft formation readily, but the increasing presence of glacial dropstones jammed liners, core catchers, and cutting shoes. In addition, seven XCB cutting shoes were destroyed as a result of trying to core the soft sediment littered with very hard glacial clutter. At a depth of 332.7 mbsf, XCB coring was terminated due to the poor recovery and ineffectiveness of the XCB system in recovering these sediments. At 0600 on 28 October, the pipe was pulled to the surface, with the bit clearing the mud line at 0715. After the vessel was offset 10 m south, Hole 918B was initiated.

Hole 918B

The first core barrel taken in Hole 918B recovered 6.85 m and established the mud line for Hole 918B at 1868.2 mbsl. A total of three piston cores were obtained from this hole. The second core barrel was bent by dropstones and was just barely able to be retracted into the outer barrel. The third core barrel became stuck and had to be worked for several minutes before it could be freed and retrieved. At this juncture, this hole was terminated and the bit pulled to the surface. The bit cleared the seafloor at 1200.

Jet-In Test

The vessel was offset 10 m NE, and a jet-in test was conducted. The bit was set on bottom with approximately 5 Kips weight on bit (WOB). The mud pump was set to 40 strokes per minute (spm). It took an hour and a half to advance the bit to 39.3 mbsf.

Hole 918C

The vessel was not offset for the third attempt at another APC hole. The bit was washed down to 25.8 mbsf and the first core obtained. The second piston core fired but did not advance as indicated by the lack of a bleeddown of pressure in the pipe. The core barrel was retrieved with a piece of basalt jammed into the cutting shoe. With time expiring for the unplanned APC hole, operations were terminated and the bit pulled to the surface. At 2130 on 28 October, the bit was on deck.

Hole 918D

Because more than the allotted time was expended in operations at the last site, the rotary core barrel (RCB) pilot hole was combined with the reentry hole. The plan was to wash in a reentry cone with 33 m of 16" casing, unlatch the paddle running tool, and drill ahead to 253.2 mbsf, where RCB coring would be resumed. Coring would then proceed into basement without setting the 11 3/4" casing. If an additional string of casing were required, then the hole would be opened with a 14 3/4" drill bit and the casing installed.

After a reentry cone was assembled and moved into the moon pool, the BHA with the paddle running tool (PRT) was made up with two joints of 16" casing and a Texas pattern running shoe (33 m). The hanger was picked up, and the PRT was then made up to the casing and cone.

At 0600 on 29 October, the reentry cone and 33 m of 16" casing were run to bottom. After two hours of jetting in, the PRT shifting tool was run down by wireline and released the PRT bushing from the BHA. The drilling assembly was then drilled ahead to 253 mbsf with a center bit. A 10-barrel high-viscosity mud pill was circulated after every third connection. At 2000 on 29 October, a core barrel was dropped and coring initiated. After coring from Cores 152-918D-1R to -3R

(253.3-279.9 mbsf), and recovering only 0.60 m of glacial till, a center bit deplugger was dropped on the core barrel for Core 152-918D-4R, and the bit was drilled ahead another 41.1 m, where coring again was resumed.

RCB coring then advanced from 324.0 to 696.1 mbsf with a 10-barrel high-viscosity mud pill circulated before every connection. At 0615 on 1 November, coring was interrupted for a wiper trip. The pipe was pulled in stands up to 288 mbsf with no overpull experienced. The pipe was run down to 667 mbsf, where 30 m of fill was encountered. The top drive was picked up and the hole washed and reamed to bottom, after which a 15-barrel high-viscosity mud pill was circulated. One tight spot was observed at 628 mbsf (40 K overpull) during washing and reaming.

Reentry Number 5

RCB coring resumed at 1200 on 1 November and cored from 696.1 to 898.1 mbsf (Cores 152-918D-44R to -64R) until 2300 on 2 November. By this time, the bit had accumulated 34.4 hours in penetrating nearly 900 m of sediment laced with dropstones. The Hole was flushed with a 20-barrel high-viscosity mud pill, and the top drive was set back in preparation for pulling out of the hole for a bit change. The pipe was pulled to the surface without any tight spots being observed. The bit cleared the seafloor at 0055 and was on deck at 0500 on 3 November. The bit was inspected and graded at 5,2,BT,N,CT,M,E,1/16,HR.

The old bit, the PRT, and two head subs were laid down, and a new RBI C-4 RCB bit and an additional outer core barrel (OCB) were added to the BHA. The BHA was run into the hole, and by 0950 on 3 November, a small vibration isolated television (VIT) camera survey was conducted to find the cone. At 1020, the bit entered the cone after passing over Hole 918C. The VIT was retrieved, and the bit was run into the hole to 857 mbsf, where the top drive was picked up. The center bit was dropped, and the Hole was washed and reamed from 884 to 884 mbsf. Approximately 12 m of soft fill was washed away.

RCB coring resumed at 1500 on 3 November. Rotary coring advanced from 898.1 to 1108.2 mbsf (Cores 152-918D-65R to -86R) through an interval characterized by turbidites with very rapid penetration rates (typically 5-10 minutes per core) and low recovery (202.5 m cored, 18.04 m recovered; 8.9%). The formation then firmed up as volcanic sandstone and siltstone were penetrated. The rate of penetration (ROP) gradually decreased from 23.0 m/hr to 11.5 m/hr in the interval from 1108.2 to 1165.8 mbsf (Cores 152-918D-87R to -92R). A drift survey was conducted at 1146.5 mbsf and measured the hole angle to be a little less than three degrees.

What was initially thought to be basaltic basement was penetrated in the interval 1165.8 to 1180.4 mbsf (Cores 152-918D-93R and -94R). The basalt was fresh and very hard and required 150 minutes of rotation to penetrate 5.0 m (ROP of 2.0 m/hr). Having thought basement was reached (it was later discovered to be a sill), coring was interrupted to conduct a wiper trip.

The pipe was pulled up to 1127 mbsf with the top drive attached. The top drive was set back, and the pipe was then pulled in stands to 259 mbsf. There was between 40-50 Kips of drag observed when the bit was pulled from 1175 to 1089 mbsf. After the bit reached 259 mbsf, the wiper trip was stopped for an hour while 115 feet of drilling line was slipped and cut.

By 1400 on 5 November, the pipe was run into the hole and contacted a hard bridge at 847 mbsf. The circulating head was made up, and an attempt made to wash through this bridge. When this failed to move the bridge, the top drive was picked up and a center bit dropped. The hole was washed and reamed from 847 to 915 mbsf. The center bit was retrieved, the top drive set back, and the pipe was then advanced into the hole by adding a stand of pipe at a time. At 1069 mbsf, another bridge was contacted, and again the top drive was picked up and a center bit dropped.

The hole was washed and reamed from 1069 to 1079 mbsf. During this operation, the hole packed off and the pump pressure rose to 1500 psi with only 40 SPM. Two 20-barrel high-viscosity mud pills were circulated, and washing and reaming continued to the bottom of the Hole, where 10 m of fill was found and cleared. When the wireline was run in to retrieve the center bit, the core barrel could not be unseated. A 20-barrel slug of 12 pounds per gallon (ppg) mud was circulated, and attempts continued to release the core barrel.

After two hours of unsuccessful efforts at retrieving the barrel, it was decided to pull out of the hole and inspect the cause of the problem. The pipe was pulled up to 1145 mbsf, where the top drive was set back. The pipe was pulled out of the hole, with the bit clearing the seafloor at 0530 on 6 November. The bit was on deck at 0845.

The core barrel was found to be locked into the OCB by very fine sand. The sanded-in OCB with core barrel was laid down, and a new OCB picked up. Also picked up was a new, very hard formation bit (Smith F9CB), which was a more appropriate tool to penetrate the very hard basalt recovered in the last core.

Reentry Number 6

The BHA was run in to 1805 m, after which the VIT camera was deployed. The VIT camera and bit were lowered to 1874 m, and a search conducted to find the reentry cone. During this time, a Force 10 storm was in progress. Although the storm did not seriously affect operations, it did extend the period before the bit was in position over the cone. After a 2.5 hour VIT survey, the bit reentered the cone at 2025 on 6 November.

The VIT was retrieved, and the pipe was run to a depth of 1030 mbsf before the formation took weight and the top drive was required. The interval from 1030 to 1180 mbsf was washed and reamed, with a center bit being deployed, followed by the circulation of a 50-barrel high-viscosity mud flush. After seven hours of washing and reaming, a core barrel was dropped and RCB coring resumed on Hole 918D at 0700 on 7 November.

RCB coring advanced from 1180.4 to 1271.9 mbsf into weathered, rubbly basalt with clay and altered volcaniclastic sediments. After a piece of basalt jammed in the core catcher during Core 152-918D-102R (1233.3-1240.5 mbsf) and resulted in 2.01 m of recovery, the switch was made to retrieving the core barrel for half cores. A 20-barrel high-viscosity mud pill was circulated after every full-core interval. While cutting Core 152-918D-109R (1266.9-1271.9 mbsf), the torque increased to 400 amps and became erratic. The ROP slowed to 1.7 m/hr from a previous interval ROP of 3.8 m/hr. The bit had accumulated 36.2 rotating hours by this juncture, and prudence indicated that the BHA be pulled and the condition of the bit inspected. A 50-barrel high-viscosity mud pill was pumped to flush the hole, and the top drive set back, after pulling the drill pipe to 1021 mbsf. The pipe was then pulled up in stands. The bit was on deck at 0030 on 10 November. An inspection of the bit indicated that it was in very good condition, except for the fact that one of the four nozzles was missing. The bit rotating on the missing nozzle may have been responsible for the erratic torque.

A new RBI C-7 bit was made up with a non-magnetic drill collar and run into the Hole. The C-7 bit was selected because it had a slightly more aggressive cutting structure than the F9 and consequently is considered better able to penetrate rapidly through the rubbly basalt. The pipe was run to 1826.8 mbsl, where operations were discontinued awaiting the passage of an iceberg.

At 1500 on 9 November, a large iceberg was observed visually north of location. It was detected on radar at 1630 approximately 12 nmi north and drifting on an erratic southeasterly course at 0.8 knots. The iceberg was tracked though the night and early morning hours as it approached location. As time passed, the iceberg grew smaller on the radar screen as it neared the vessel, and it was assumed that it was melting and breaking apart into smaller bergy bits. Ironically, these could be more dangerous, since they are difficult to pick up on radar. Tracking of the ice was also made difficult by heavy seas. Suddenly at 0400 on 10 November, at four nmi from the vessel, the berg disappeared from the radar. In view of the large initial size of the berg, it was feared that there may have been several bergy bits of dangerous proportions bearing down on location. Reentry operations were suspended from 0400 to 0800 until a bergy bit was observed through the darkness directly east of the vessel at approximately 0.5 nmi.

Reentry Number 7

The VIT camera was deployed, and the pipe lowered to 1874 m. The vessel was positioned over the cone, and the bit reentered the hole at 1015 after a 25-minute search. Following retrieval of the VIT camera, the pipe was run-in to 847 mbsf, where the formation took weight. The top drive was picked up, and from noon until midnight on November 10, the bit had to be washed and reamed to bottom. Some of the washing and reaming required using the center bit, and a 50-barrel high-viscosity mud pill was circulated at 1214 mbsf and at 1270 mbsf. Basalt coring resumed at midnight and advanced from 1271.9 to 1310.1 mbsf (Cores 152-918D-110R to -113R) by 1800 on 11 November.

At 1400 on 11 November, numerous icebergs began appearing north of the site and were observed drifting south toward location. Many of these were bergy bits, which were not detectable by radar. By 1800, the number of visible icebergs raised serious concern for the safety of the vessel. Coring operations were terminated, and the bit pulled out of the Hole (POOH).

When the evening weather forecast from DMI arrived, it indicated that the winds were predicted to gradually diminish over the next 72-hour period. It was expected that as the winds abated, the icebergs would quickly melt in the warmer surface water (4-6°C). During the evening the deck crew used spotlights to observe the sea immediately in front of the vessel to detect any small chunks of ice. At midnight, a bergy bit (3 m high by 6 m long) was detected moving toward location. As the bergy bit approached within one cable (1/10 of a nmi), the vessel was offset in dynamic positioning (DP) mode 200 m to starboard. After the bergy bit passed directly over location, the vessel returned to the original coordinates.

The bit was pulled to the surface and was on deck at 2315 on 11 November. Although the bit was in nearly new condition after only 10.8 hours of rotation, a new C-7 bit was picked up to extend the coring period of what was assumed to be the last bit used on this hole. A mechanical bit release (MBR) mechanism was also affixed in order to drop the bit outside the cone and reenter to log. While the vessel was standing by waiting for daylight and the icebergs to clear the area, the new bit was lowered to 1852.8 mbsl.

Reentry Number 8

At 0900 on 12 November, the VIT camera was deployed, and at 1027 the eighth reentry of Leg 152 was accomplished. The reentry operation was hampered by another Force 10 storm, which made the vessel difficult to position over the hole. The reentry was also made more difficult by a sediment plume, which was in the area surrounding the reentry cone. The plume appeared to be emanating from the cone. The shipboard inorganic geochemist, Joris Gieskes, later viewed a video recording of the reentry and considered that the hole could have penetrated an underground aquifer, so that what was observed was truly emanating from the hole.

The drill pipe was run in with stands to 240 mbsf, where the formation took weight. The pipe was pulled up to 232 mbsf and the VIT camera retrieved. At 1400, an attempt was made to slack off the pipe in order to lower to 240 mbsf, with no effect. When the pipe could not be lifted without exceeding the safe overpull limit, the top drive was picked up and circulation was established. The pipe could not be rotated and was firmly trapped by the hole.

For an hour and a half, the pipe was worked with overpulls ranging from 150 to 300 Kips. Finally, the pipe came free at 1515. The pipe was POOH using the top drive as far as 120 mbsf. After the top drive was set back, the pipe was POOH. The bit cleared the seafloor at 1650. It was decided that APC/XCB coring on proposed site EG63-3 would be more fruitful than attempting to reclaim Hole 918D. Before securing operations on Site 918, the BHA was inspected, and two drill collars were laid down. One collar was discovered to have a cracked pin, and the other had a zip-lift groove out of tolerance. Both beacons released upon command but were lost in the darkness and heavy swell. At 0100 on 13 November, the thrusters and hydrophones were secured, and the vessel was put under way to proposed site EG63-3.

Operations in Hole 918D had obtained 113 cores, while penetrating 1012.8 m of sediment and basement with 25.1 percent recovered (297.3 m was drilled). The main basaltic sequence was encountered at 1188.5 mbsf and was cored to a depth of 121.6 m, with 58.7 m (48.3%) recovered. A total of four bits were used (a fifth was deployed but not used) with a total of 93.9 hours of rotating time. In retrospect, if a second string of casing had been run in this hole, it would have needed to have case the entire sediment section (nearly 1200 m) because the most unstable part of the Hole was the lower 200 m, which was composed of poorly consolidated and unconsolidated turbidite sands and gravels.

SITE 919

At 0215 on 13 November, the vessel was under way at 6.4 knots to proposed site EG63-3. Two extra personnel were assigned to ice watch on the bridge wings to ensure that any ice in the water would be avoided. Both spotlights were used and swept the area in front of the vessel during the 40 nmi transit to the site. The vessel changed course once to avoid a large bergy bit.

Hole 919A

At 0800 on 13 November a beacon was dropped on location (354B, 16.5 kHz, sn 763) during the short precision depth recorder (PDR) survey of the area. By 0915, the thrusters and hydrophones were lowered, and the vessel was positioning over the beacon. From 0915 until 1045 steam hoses had to be used to defrost the APC core barrels in the shucks. Although antifreeze had been added to the storage shucks, no one had anticipated wind chills to minus 30°C, which had frozen the core barrels in place. The backup beacon (354B, 16 kHz, sn 752) was deployed at 1030 when the initial beacon transmissions changed to half pulse rate.

A standard advanced piston core/extended core barrel (APC/XCB) bottom hole assembly (BHA) was made up with a new Security S86F bit and run into the hole to 2085.2 mbsl. At 1615, Hole 919A was spudded with the first APC, which recovered 8.02 m of clayey silt. This established the mud line depth at 2088.2 mbsl. The precision depth recorder (PDR) had measured a depth of 2104.4 m.

After APC coring advanced 0-93.5 mbsf (Cores 152-919A-1H to -10H), the core barrel for Core 152-919A-11H would not seat in the landing shoulder. Inspection of the cutting shoe showed that the shoe was brinelled in, suggesting a hard landing on the flapper. The only remaining option was to trip the BHA and inspect the lockable float valve (LFV). Operations in Hole 919A had cored 93.5 m and recovered 93.59 m (100.1%). The cores had been oriented, starting with 152-919A-4H.

The bit cleared the mud line at 0230 and was on deck at 0545 on 14 November. Inspection of the LFV discovered that the flapper hinge had parted and that the flapper was tightly jammed in the mouth of the LFV. The LFV was replaced, and the bit run into the hole.

Hole 919B

After the vessel was offset 10 m south, APC coring resumed. At 1030, the first mud line core of Hole 919B was obtained and established the mud line depth at 2097.3 m (DPM). APC coring advanced from 0 to 18.7 m (Core 152-919B-1H to -2H) and recovered 18.67 m. The interval from 18.7 to 90.0 mbsf was washed ahead with a center bit, and coring resumed. APC coring advanced from 90.0 to 147.0 mbsf (Cores 152-919B-3H to -8H) and recovered 58.61 m (103%), with Cores 152-919B-3H and below being oriented.

Meanwhile an iceberg and a bergy bit, which had been closely watched, encroached on the "Yellow" warning zone at 1.6 nmi and 2.1 nmi respectively. Coring operations were stopped while the bit was pulled out of the hole (POOH) to 112.7 mbsf using the top drive. The top drive was set back, and the ice was observed as it approached location. After waiting only 30 minutes, it was clear as the ice entered the "Red" warning zone that both bergs were headed directly at the vessel location. The bit was then pulled above the mud line.

At 1840, the vessel was offset in DP to starboard approximately 200 m. Both the iceberg and the bergy bit drifted directly over the location of Hole 919B. Meanwhile, a third iceberg (Number 84 of the leg) was also being plotted and gave an indication of drifting over location. Concurrently with the appearance of the third iceberg, the weather began to deteriorate. By midnight of 14 November, the winds were blowing at 42 knots from the north with gusts up to 52 knots, and the barometer began to fall rapidly (981.0 mb by midnight).

The early morning hours of 15 November were spent attempting to observe the iceberg with spotlights through the spray, growing swell, and snow as it approached location. At 0145, the iceberg passed within 0.4 nmi of location, and the vessel repositioned itself 10 m east of Hole 919B. A total of 8.5 hours was spent waiting on these three icebergs. This time does not include the tripping in and out of the hole related to ice movements.

Hole 919C

The center bit was dropped, and Hole 919C was spudded at 0145 on 15 November and washed ahead to 60.1 mbsf. The plan was to wash ahead to 140 mbsf and resume APC coring, but this was thwarted as the weather worsened to storm force. At 0415, the pipe was pulled above the mud line, and waiting on weather began. Shortly after this, the storm deteriorated to Force 12 with sustained winds of 60 knots and gusts to 75 knots. The seas were 40-60 feet, and green water was frequently breaking over the bow. Acoustics were constantly being lost due to cavitation. The main propellers were overspeeding as the stern of the vessel would break the surface. The lowest barometric pressure of the leg was recorded at 970.8 mb.

At 0730, a green wall of water cleared the main deck and passed around and over the bridge and slammed against the starboard lifeboats and sprayed the drill floor. The starboard weather station was lost during this wave. The vessel was unable to hold location but was able to maintain a heading into the wind as the vessel was carried south.

A meeting was convened the morning of 15 November with the Co-chiefs, the ODP Operations Superintendent, the SEDCO Drilling Superintendent, and the Captain to the discuss the viability of staying in this area. All agreed that the constant presence of icebergs and the difficulty in detecting same in the growing dark hours and on radar, coupled with more frequent and intense storm activity, had made operations in the area unacceptably dangerous.

By 1400 on 15 November, the weather had improved to gale force, and the opportunity was taken to trip the pipe to the surface. The storm had taken the vessel 9 nmi south of the location of Hole 919C. By 2130 on 15 November, the BHA was broken into individual drill collars and laid down and the vessel cautiously headed south. It was considered too dangerous to return to location to retrieve the two beacons.

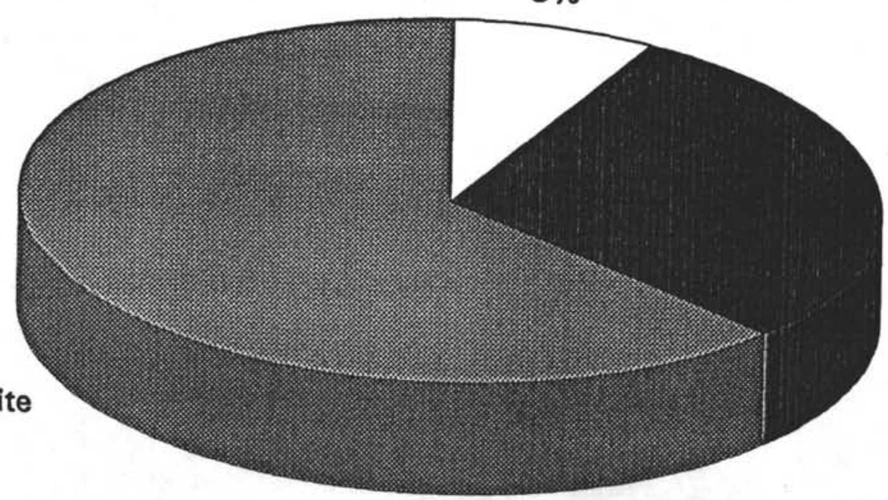
TRANSIT TO ST. JOHN'S

The vessel sailed at reduced speed through calm seas throughout 16 November. A Force 12 storm hit on the morning of 17 November with sustained winds of 60 knots and gusts to 80 knots (highest recorded during the leg) from 265 degrees. Green water broke over the bow regularly and one wave inundated the bridge deck and damaged the starboard spotlight and carried away the EPIRB beacon and lifering stored on the starboard wing. There was a considerable amount of ship motion, and pitch and roll angles of ten degrees were common.

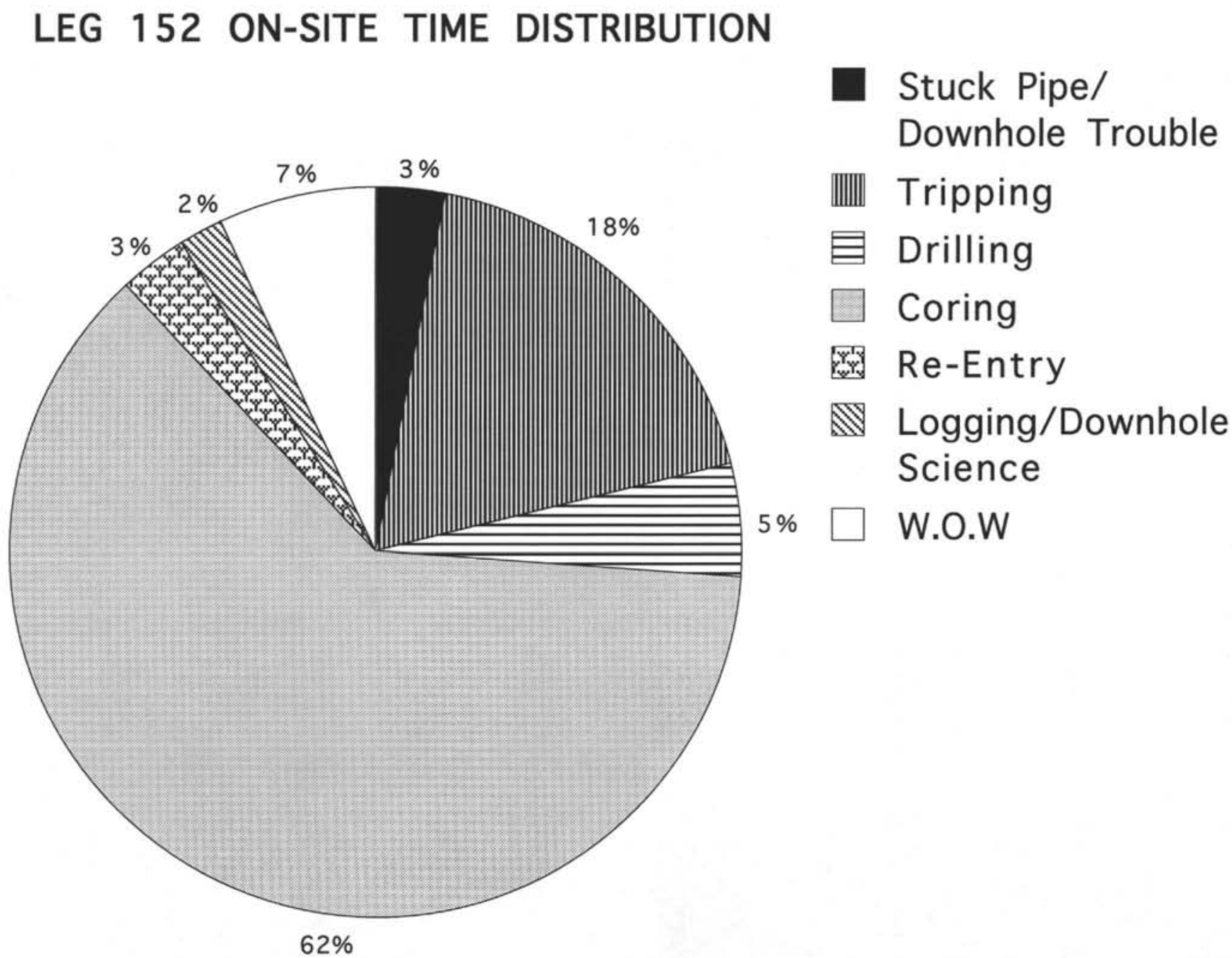
Numerous icebergs were also spotted visually and on radar throughout 17 November and were reported to the Canadian Ice Patrol in St. John's. The storm prevailed into the morning of 18 November and gradually improved through the day.

TOTTIME.XLC
11/22/93
12:09 PM

LEG 152
TOTAL TIME DISTRIBUTION



Total days of leg =59.2


LEG 152 ON-SITE TIME DISTRIBUTION
Stuck Pipe/ Downhole Trouble
Tripping
Drilling
Coring
Re-Entry
Logging/Downhole Science
W.O.W
3%
18%
5%
62%
3%
2%
7%

OCEAN DRILLING PROGRAM
LEG 152
OPERATIONS RESUME

	days
Total Days (24-SEPT-93 to 22-NOV-93)	59.2
Total Days in Port	4.2
Total Days Underway	9.1
Total Days on Site	45.9

	days
Stuck Pipe/Downhole Trouble	1.4
Tripping	8.1
Drilling	2.1
Coring	28.1
Re-Entry	1.3
Logging/Downhole Science	1.0
W.O.W.	3.2
Other	0.7
Fishing & Remedial	0.0
Repair Time (ODP)	0.0
Development Engineering	0.0
Repair Time (Contractor)	0.0
Casing and Cementing	0.0

Total Distance Traveled (nautical miles)	1643.9
Total Miles Transited:	1612.5
Average Speed Transit (knots):	7.6
Total Miles Surveyed:	31.4
Average Speed Survey (knots):	2.7
Number of Sites	6
Number of Holes	13
Total Interval Cored (m)	2905.9
Total Core Recovery (m)	1256.8
% Core Recovery	43.3
Total Interval Drilled (m)	772.3
Total Penetration	3678.2
Maximum Penetration (m)	1310.1
Maximum Water Depth (m from drilling datum)	2099.5
Minimum Water Depth (m from drilling datum)	519.0

OCEAN DRILLING PROGRAM
SITE SUMMARY
LEG 152

HOLE	LATITUDE	LONGITUDE	WATER DEPTH (mbsl)	NUMBER OF CORES	INTERVAL CORED (meters)	CORE RECOVERED (meters)	PERCENT RECOVERED (percent)	DRILLED (meters)	TOTAL PENETRATION (meters)	TIME ON HOLE (hours)	TIME ON SITE (days)
914A	63*27.738N	39*43.489W	533.2	4	18.6	11.88	63.9%	0.0	18.6	14.50	0.60
914B	63*27.737N	39*43.482W	533.2	17	151.2	17.78	11.8%	93.8	245.0	37.25	1.55
914C	63*27.736N	39*43.479W	533.2	0	0.0	0.00	0.0%	224.0	224.0	61.25	2.55
		(EG63-1) TOTALS:		**21**	**169.8**	**29.66**	**17.5%**	**317.8**	**487.6**	**113.00**	**4.71**
915A	63*28.285N	39*46.909W	533.1	26	209.4	32.84	15.7%	0.0	209.4	60.00	2.50
		(EG63-1C) TOTALS:		**26**	**209.4**	**32.84**	**15.7%**	**0.0**	**209.4**	**60.00**	**2.50**
916A	63*29.137N	39* 48.664W	512.3	15	101.7	18.56	18.2%	0.0	101.7	55.25	2.30
		(EG63-1B) TOTALS:		**15**	**101.7**	**18.56**	**18.2%**	**0.0**	**101.7**	**55.25**	**2.30**
917A	63*29.500N	39*49.665W	508.1	110	874.9	454.88	52.0%	0.0	874.9	383.50	15.98
		(EG63-1B) TOTALS:		**110**	**874.9**	**454.88**	**52.0%**	**0.0**	**874.9**	**383.50**	**15.98**
918A	63*5.569N	38*38.336W	1868.5	38	332.7	260.28	78.2%	0.0	332.7	44.25	1.84
918B	63*5.568N	38*38.339W	1868.2	3	25.8	25.48	98.8%	0.0	25.8	4.75	0.20
918C	63*5.575N	38*38.328W	1868.2	2	9.6	9.64	100.4%	25.8	35.4	9.50	0.40
918D	63*5.572N	38*38.334W	1868.5	113	1012.8	254.62	25.1%	297.3	1310.1	364.75	15.20
		(EG63-2) TOTALS:		**156**	**1380.9**	**550.02**	**39.8%**	**323.1**	**1704.0**	**423.25**	**17.64**
919A	62*40.208N	37*27.611W	2088.2	10	93.5	93.59	100.1%	0.0	93.5	21.67	0.90
919B	62*40.201N	37*27.618W	2086.0	8	75.7	77.28	102.1%	71.3	147.0	12.92	0.54
919C	62*40.198N	37*27.625W	2086.0	0	0.0	0.00	0.0%	60.1	60.1	26.83	1.12
		(EG63-3) TOTALS:		**18**	**169.2**	**170.87**	**101.0%**	**131.4**	**300.60**	**61.42**	**2.56**
		LEG 152 TOTALS:		**346**	**2905.90**	**1256.83**	**43.3%**	**772.30**	**3678.20**	**1096.42**	**45.68**

TECHNICAL REPORT

The following ODP Technical and Logistics personnel were aboard *JOIDES Resolution* for Leg 152 of the Ocean Drilling Program:

Laboratory Officer:	Brad Julson
Senior Marine Laboratory Specialist:	Don Sims
Marine Computer Specialists/System Managers:	John Eastlund
	Barry Weber
Marine Electronics and Downhole Tool Specialists:	Roger Ball
	Eric Meisner
Marine Laboratory Specialist/Photography:	Barry Cochran
Marine Laboratory Specialist/Curatorial Representative:	Lorraine Southey
Marine Laboratory Specialist/Yeoperson:	Michiko Hitchcox
Marine Laboratory Specialists/Chemistry:	Chieh Peng
	Philip Rumford
Marine Laboratory Specialist/X-ray:	Mary Ann Cusimano
Marine Laboratory Specialist/Thin Section:	"Gus" Gustafson
Marine Laboratory Specialist/Underway Geophysics:	Robert Kemp
Marine Laboratory Specialist/Physical Properties:	Taku Kimura
Marine Laboratory Specialist/Paleomagnetics:	Monica Sweitzer
Marine Laboratory Specialist/Storekeeper:	John Dyke

INTRODUCTION

Drilling off Greenland in the late fall and early winter is quite difficult due to the rough weather conditions. September and October were considerably better than expected, although we experienced a Force 12 storm shortly after arriving at Site 914 in September. Waves as high as 40-60 ft and wind gusts of 75-90 kt were recorded. November, however, lived up to expectations, with almost constant gales and storms. The constant presence of icebergs and the difficulty in detecting them in the growing dark hours, even using radar, coupled with more frequent and intense storm activity, finally made operations in this area unacceptably dangerous toward the end of the leg.

There were frequent storms of Force 10, which hampered coring and complicated reentry operations. The last few days at Site 919 were characterized by high winds and low temperatures, along with blowing snow and spray. The very low wind-chill factor (-29°C) resulted in icing on exposed metal surfaces, as well as the stripping and peeling of external paint throughout the vessel. Icebergs were a continual problem. Operations were delayed while waiting on icebergs to pass on several occasions. Spotlights were employed to detect ice too small to be seen on radar.

Weather forecasts were received from the Danish Meteorological Institute, together with satellite photos of the ice coverage. The Lockheed weather system also was extremely helpful in receiving satellite weather information for our area of operations.

PORT CALL: REYKJAVIK

The ship arrived in port the morning of September 24, 1993. The oncoming technical crew moved aboard, and the crossover commenced. The liquid nitrogen dewars were refilled during the first day. Cores and freight were unloaded the following day. Later, the oncoming air and surface freight was brought aboard and distributed. There were also 3 days of tours by the Geological Society of Iceland, Danish VIPs and members of the JOIDES Technology and Engineering Development Panel (TEDCOM). The port call went smoothly due to the efficiency of the local dock workers. The ship sailed on September 28, 1993.

Underway Geophysics

Underway watches were begun as soon as *JOIDES Resolution* left port. The magnetometer sensor was deployed, and the 3.5 kHz and 12 kHz precision depth recorders (PDR's) were used on the transit. On approach to the first site (914), the seismic survey used an 80 inch water gun and a 200 inch water gun. Other moves between sites were made in dynamic positioning (DP) mode with GPS for navigation and the PDR's for depth control. Due to ice and sea conditions the magnetometer was not pulled behind the ship on the last line. Fleet angle sensor arm swivels on the Dynacon brand cable level winds used on the port magnetometer and starboard seismic winches were replaced with smaller-profile ones fabricated on board. This appears to have solved the jamming problems noted on previous legs. New seismic signal cables have been run overhead from a junction box installed over each winch to the geophysics lab. A jumper cable drops from the junction box through a protective conduit and connects to the winch slip rings. A new armored coaxial cable was run for the sonobuoy antenna. With the rough seas, the fantail at two different times was flooded, filling drawers on the workbench with saltwater. The contents were dried. A lot of effort was put into getting the Doppler sonar to work correctly. Although significant gains were made repairing it, it was not operating at 100%, and a service representative will attend the St John's port call. AGCNav was well received by the scientists and the ship's officers. The visual feedback of the ship's position is a great aid in providing accurate site surveys.

Physical Properties Laboratory

The changes to the MST track from last leg were helpful this leg. We had few breakdowns this leg, even with full, heavy APC cores. We did have an optical encoder problem that was eliminated by swapping out the encoders. A new GRAPE source was installed last leg, and a new detector was installed this leg. The new detector has a separate high voltage lead and a signal lead. The new source and detector produced much higher counts. The values for the GRAPE standards had to be adjusted accordingly for the new source. These values were changed in the GRSTART.DAT file. However, gamma radiation leaking from the new GRAPE source is now problematic in that it affects the natural gamma's counts even thought the source is well shielded. Apparently gamma rays are traveling at right angles and being detected by the natural gamma detector. The strength of the gamma radiation is so low as not to pose a safety hazard.

New "full space" thermal conductivity standards were received. These are small cylinders of different types of ceramics. We did not have anything strong enough to drill a small, deep hole, and these will be finished on shore. The two thermal conductivity boxes worked well. There is a switch now to choose which box the user wants to use.

The hard-rock bath was insulated with styrofoam to stabilize the water temperature. Another pair of transducers was installed on the Digital Sediment Velocimeter (DSV) in the transverse direction. The vane shear was automated last leg, and a number of problems were noticed this leg, especially with the optical encoders. Because the vane shear will not be needed next leg, we will send it home to change out the optical encoders.

The scientists used the new 4D data program to record the index properties data.

Magnetics Laboratory

There was a service call for the Kappabridge by Frantisek Juranek of Geofyzika. He replaced two circuit boards in the instrument. The instrument would still not communicate with the computer. Frantisek felt that the problem was in the interface box, which he took back with him for further analysis. Even though the instrument is on a metal ship, he suggested changing out the metal shelves for wooden shelves.

The problem of flux jumps was partially resolved this leg. One type of flux jump was isolated down to spikes in the power line from other machines used in the core lab. Because of the grounding used in the labstack, these spikes could have been passed from other machines. The other type of flux jump was reduced significantly by changing the inductors in the squid boxes. The correct inductors reduced the flux jumps by orders of magnitude.

One of the scientists wrapped each core in plastic wrap to keep down the dirt and magnetic noise in the cryomagnetometer. Some of the scientists also recommended a different style and manufacture of sample cubes.

Core Laboratory

In anticipation of the extreme cold, tarpaulins wind breaks were installed to cover the catwalk area for handling purposes. A large rubber mat was laid out over the grating to keep the wind from blowing up from below. In addition, non-skid mats, as well as salt, were used to keep ice from building up on the catwalk. A hose was run from a hot water faucet in the core lab in order to keep the core catcher inspection area and catwalk clean. Since the temperature did not rise above the freezing point for long periods of time, an air system was used to blow out the lines in order to keep the water from freezing in the hose. At one point the drain pipe froze solid, and it was necessary to use a propane torch to deplug this line. Extreme cold often obligated the use of hacksaws to cut the cores into sections, since normal core cutters caused the liners to shatter. Inside the core lab, a core rack extension was assembled to provide the extra space needed to due to the extra time required for the cores to warm up to room temperature.

The LASENTEC grain size analyzer was used regularly this leg, and the scientists had confidence in the data for the silts and clays, but felt that the instrument underestimates the sand-sized components. The UV light case used for curing smear slides prepared with Norland Optical mounting media was modified. The mounting media would not cure, and the problem was resolved by moving the shelf closer to the UV light.

A new tool called a "sonic welder" was tested to spot-weld dividers onto core liners during hard-rock drilling. The tool was not used because of the extremely high-pitched noise it produced and the fact that this electrical device could not be used in a wet environment.

Thin-Section Manufacture

Because of the excellent recovery of basalt in particular, demand for thin sections of basalt, as well as the glacial dropstones in the sedimentary cover, was high.

Chemistry Laboratory

There was an extensive pore water program, as well as an organic geochemistry study. Sediment samples were squeezed for interstitial water and were compared to water samples obtained from the WSTP tool. A complete suite of tests was run on the pore water using the Atomic Absorption Spectrometer (AA), Dionex and Spectrophotometer. A new Brinkman Titrino titration instrument was installed this leg. A program for the instrument was telexed to the ship. This instrument is intended to automate the chlorinity analyses. A pore water sample was to be diluted, and the instrument was to be able to titrate the sample automatically. Method development was started, but more development is necessary. Methods for the Dionex, the AA and the Titrino were carefully inspected and tested for accuracy and precision by the head of the Shipboard Measurements Panel (SMP), who was sailing as shipboard inorganic chemist.

A supplemental ship's airline was plumbed for the air-driven valves used on several of the instruments. This will reduce the amount of high quality air needed from the new Jun air compressor. A Syquest drive was installed on a PC to aid in backing up the calibration and other important data files. We hope to purchase the software to have this done automatically. A sequence was developed to interface the Rock-Eval with the chemstations. This sequence will allow automated uninterrupted analyses of the data from the Rock-Eval on the chemstation. The chemstation stores the data in a form which can easily be modified by the users. A new 6-way valve was installed during the leg on the Rock-Eval.

X-Ray Laboratory

A service representative from Fisons was at the Reykjavik port call to perform maintenance on the XRF machine. The goniometers were aligned, and the crystals cleaned. The high voltage calibration of the LiF200-Sc was adjusted. Both goniometers were zeroed, and the position calibrations were run to check the crystals on both detectors. Both goniometers were then recalibrated.

XRF analysis was extremely important this leg to determine the nature of the basalts and direct the drilling strategy. Samples were analyzed for both major and trace elements. Major element analyses were performed on pressed pellets. Trace element ratios of Nb/Zr, as well as TiO_2 and Ni, were important for determining the origins of the flows.

The XRD was used during the leg. The counts on the XRD tube were low, and the tube was changed out. The new tube gave the same counts for quartz. Modifications were performed on the amplifier card in order to remove spikes observed in the diffractograms. The spare card was also modified.

The Mac on the weighing station was upgraded to a Mac IIci.

Computer Facilities

The most significant event to affect the computer facilities on board *JOIDES Resolution* during Leg 152 was the shutdown of the VAX-11/750's. Tape drives were installed on the MicroVAX 3500's, and the LXY printers had serial/parallel converters installed, which means that all peripherals have now been removed from JAXVAX. The VAX-11/750's will be left on board until the Barbados port call at the end of Leg 153 to make sure that nothing has been overlooked. All the xyplex-related software from the VAXcluster system disks was removed. Four 32 MB memory cards were installed in the MicroVAX 3500's. The VAX software licenses were updated for another year.

New equipment was received for the different labs. A Mac IIci showed up unexpectedly for the minispin instrument in the Magnetics lab. A Mac IIsi was donated from the ODP Operations Department for use with the gas monitoring program, OPSGAS. The Mac IIsi has a larger screen and color, so the operations manager can view the gas results from the chemistry lab over the network in real time.

Two Mac Centris 650's were received, one for the physical properties lab, and one in the system manager's office that will hopefully be used as a server. We received a new copy of Adobe Illustrator 5.0 for the Yeoperson. We received a new Apple color scanner. It was installed in the user room and came with OFOTO, a color graphic scanning package as well as Omnipage Pro for text scanning. The weighing program in the X-ray lab was moved to a Mac IIci. A Mac TCP program was installed on many of the Mac's to allow these Mac's to connect to the VAX over the ethernet and reduce the need for serial connections. Additional memory cards were received and installed for the Mac's, PC's and laserwriters. We received two new Apple Laserwriter PRO630's and an Apple Laserwriter IIg to upgrade our existing old printers, as well as to expand our Ethernet capable printers.

The Alisashare volume Mac warehouse was split up. The Mac-related files were moved to Scratch A, and the PC/VAX related files were moved to a newly created Alisashare volume called PCwarehouse.

Near the end of Leg 151, the Unix kernel on the Sun Station, Balboa, was accidentally deleted, making the workstation unusable. We were able to restore everything by connecting the 8 mm drive and Balboa's external disc to Lamont's IPX and then copying our Unix kernel from the 8 mm backup to the external drive. The Sun Station, Balboa, was soon up and running again.

Core and Sample Curation

Sampling was not particularly heavy, but it was challenging. Ash samples were requested by many sedimentologists. The small amount recovered made it difficult to sample these layers easily with so many people. There was a large whole round sampling program. Many physical property whole rounds were taken for a consolidation study. The rest of the whole rounds were taken for a high resolution pore water study. There was excellent recovery in the hundreds of meters of basalt drilled. This was one of those rare occasions where the depth of the hole exceeded the depth of the water. High recovery in shallow water pushed the limits of the technical staff in handling the labor intensive hard-rock cores. This is also the first time in a while that there were back to back sites that recovered cores in the triple digits. A piece of wood was recovered and removed from the core to be saved in a nitrogen environment for future studies.

At the bottom of Site 917, after drilling through hundreds of meters of basalt, we recovered 8 cores of sediment. This interesting material was photographed at a very high resolution and will be further sampled later.

Downhole Measurements

The WSTP was run four times in Hole 918A. Water and temperature data were collected on each run. The ADARA tool was run once in Hole 918C, and temperature collected. The tools were not run more often due to the hostile presence of dropstones falling into the hole and formation conditions.

The multi-shot tool was used twice for drift measurements.

The tensor tool was used for orientation of APC cores. The tool worked well in Hole 918A until there was a battery or "unarmed" error. This tool will be sent back for testing to determine the cause of the problem. Another of these tools also suffered damage from shear pin shearing, and it too will be sent back for repairs. Two NiCad battery packs and a custom charging unit were received at the start of this leg. These packs are intended eventually to replace the expensive, disposable alkaline packs currently used. A series of tests was run on the batteries, and it was noted that at least three full cycles are needed to gain an effective charge. Cycle times were extended up to 21.5 hours, with only 2 hours needed to recharge the batteries.

Paleontology Lab/Microscopes

The paleontology lab was not heavily used during this leg. We installed a new centrifuge. An inventory of all of the sieves was completed and sent to the beach. During Leg 152, one of the sedimentologists requested that a video monitor display be installed from one of the scopes in the core lab to allow smear sections to be viewed in real time. The sedimentologists found this setup useful. A microscope was also set up for another scientist for photomicrography of thin sections at near 1:1 magnification.

Photo Lab

Operations were routine except for the extra photo paper purchased in port to augment our supply. Routine maintenance was performed on much of the equipment.

Library

The paleontological reprints have been removed from the library and sent to shore to be bound into volumes to be returned and placed in the paleontology lab and the library. The library was heavily used.

Miscellaneous

The conditions of the equipment in the labs was reported to ODP every 2 weeks in Lab Status Reports. A program is being written to simplify this reporting.

The Marine Emergency Technical Squad (Mets) met and trained with the SEDCO crew each week during the ship's fire and boat drill.

The H_2S safety monitoring equipment was inventoried and tested. Some of the units were sent back for new sensors, repair and maintenance.

Six officers from the Danish Navy Frigate *THETIS* came aboard and were given a tour of the vessel while we were on site.

LAB STATISTICS: LEG 152

General Statistics

Sites: 6
Holes: 13
Cored Interval (m): 2905.90
Core Recovered (m): 1256.83
Percent Recovered: 43.3
Total Penetration (m): 3678.20
Time on Site (Days): 45.68
Number of Cores: 346
Number of Samples: 7283

Samples Analyzed

Inorganic Carbon ($CaCO_3$): 432
Total Carbon (NCHS): 411
Water Chemistry (the suite includes pH, Alkalinity, Sulfate, Calcium, Magnesium, Chlorinity, Potassium, Silica, Lithium): 64
Pyrolysis Evaluation (Rock Eval and GHM): 69
Gas Samples: 131
Thin Sections: 127
XRF: 111
XRD: 67
MST Runs: 1259
Cryomagnetometer Runs: 889
Cubes: 91
Oriented Cores: 28
Physical Properties Velocity: 1069
Thermal Conductivity: 365
Index Properties: 776

Under Way Geophysics

Bathymetry (NM): 1526
Magnetics (NM): 1485
Seismic Survey (NM): 18
XBT's launched: 63

Downhole Tools

WSTP: 4
ADARA: 1