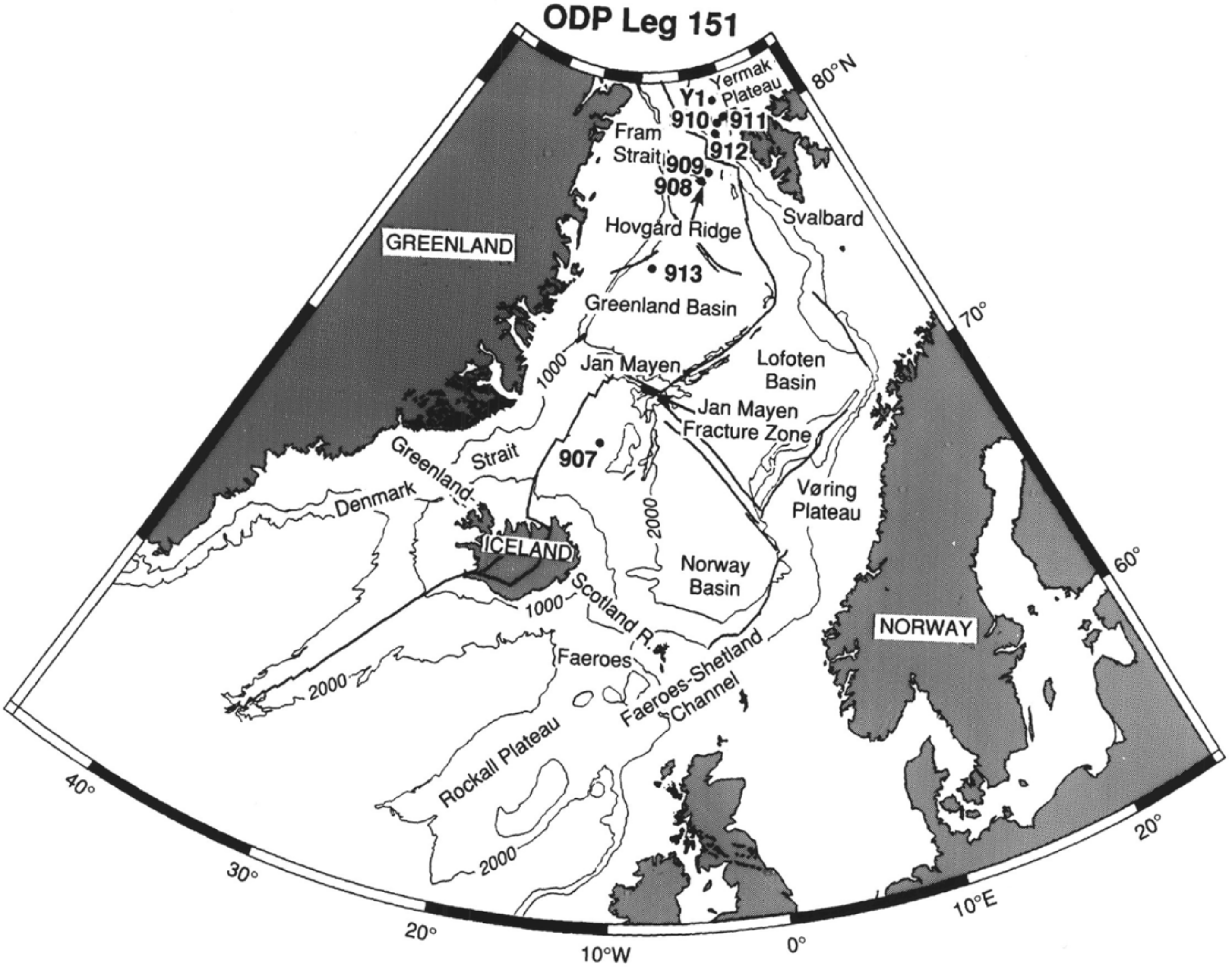

ODP Leg 151
Yermak Plateau
80°N
Y1
910
911
912
909
908
Fram Strait
Svalbard
Hovgard Ridge
GREENLAND
913
Greenland Basin
70°
Lofoten Basin
Jan Mayen
Jan Mayen Fracture Zone
1000
Greenland
Strait
Denmark
907
Vøring Plateau
2000
ICELAND
Norway Basin
60°
1000
Scotland R.
NORWAY
Faeroes
Faeroes-Shetland Channel
2000
Rockall Plateau
2000
40°
30°
20°
10°W
0°
10°E
20°

OCEAN DRILLING PROGRAM

LEG 151 PRELIMINARY REPORT

NORTH ATLANTIC ARCTIC GATEWAYS 1

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ABSTRACT

ODP Leg 151 drilled seven sites in the Norwegian-Greenland Sea and the Arctic Ocean, recovering over 3 km of core, which ranges in age from middle Eocene to Quaternary. Site 907 on the Iceland Plateau recovered a middle Miocene to Quaternary sequence overlying basement basalts with calcareous microfossils only in the upper Pliocene to Quaternary, but with a middle to upper Miocene biosiliceous-rich interval indicating high-productivity conditions. Site 908 in the Fram Strait documents a late Oligocene age for the biosiliceous-rich pre-rifted strata on the Hovgård Ridge microcontinent. Nearby Site 909 penetrated 1061.8 m into the Fram Strait basin, which acts as the corridor for deep-water flow between the Arctic Ocean and Norwegian-Greenland Sea, and recovered an upper Oligocene?/lower Miocene to Quaternary sequence high in organic matter and hydrocarbons but virtually absent of calcareous and siliceous microfossils. Sites 910, 911, and 912 on the Yermak Plateau consist of Pliocene to Quaternary glacio-marine sediments with abundant dropstones and high organic carbon content. An overcompacted zone in the upper 20 to 50 m at these sites may indicate ice-sheet loading on the plateau during past glacial advances. Ice-rafted dropstone occurrences are as old as late Miocene at Site 907 (6.4 Ma), and at least as old as 3.5 Ma in the Fram Strait and Yermak Plateau; however, relative increases in abundance occur consistently at about 2.5 Ma at most drill sites. Site 913 on the East Greenland Margin drilled a thick section of Pliocene to Quaternary glacio-marine sediments with abundant dropstones, overlying a middle Eocene to lower Oligocene and middle Miocene sequence of clays and silty clays. A biosiliceous-rich interval occurs in the upper Eocene to lower Oligocene.

INTRODUCTION

The Arctic and subarctic seas exert major influences on global climate and ocean systems. Understanding the causes and consequences of global climatic and environmental change is an important challenge for humanity. The high northern latitude oceans are of high relevance for this task, since they directly influence the global environment through the formation of permanent and seasonal ice covers, transfer of sensible and latent heat to the atmosphere, deep-water renewal, and deep-ocean ventilation, which control or influence both oceanic and atmospheric chemistry. Thus, any serious attempt to model and understand the Cenozoic variability of global climate must take into account these paleoenvironmental changes in the Arctic and subarctic deep-sea basins.

Leg 151 drilled a series of sites (Fig. 1) in four remote geographic, partly ice-covered locations (the northern gateway region, i.e., Yermak Plateau, Fram Strait, the East Greenland Margin, and the Greenland-Norway Transect, i.e., the Iceland Plateau) with the aim of reconstructing the temporal and spatial variability of the oceanic heat budget and the record of variability in the chemical composition of the ocean. Leg 151 also undertook a study of circulation patterns in the pre-glacial, relatively warm polar and subpolar oceans, and of the mechanisms of climatic change in a predominantly ice-free climatic system. In addition, the drilling recovered a collection of sequences containing records of biogenic fluxes ($CaCO_3$, opal, and organic carbon) and stable-isotopic carbon and oxygen records that will address aspects of facies evolution and depositional environments as well as the carbon cycle and productivity. The drilling approach focused on rapidly deposited sediment sequences to be used for high-resolution, Milankovitch-scale paleoclimatic analysis and rapid sub-Milankovitch-scale climate changes. The drill sites are arrayed as either broad north-south and east-west transects to monitor spatial paleoclimatic variability (i.e., Sites 907, 913, and the Fram Strait/Yermak Plateau sites) or closely spaced suites of cores across a range of depths to monitor vertical variability (i.e., Sites 910, 911, and 912 on the Yermak Plateau). Other approaches included sites drilled to better constrain the time of opening of Fram Strait, and sites placed to monitor downstream sedimentological effects of deep flow through narrow gateway constrictions (i.e., Sites 908 and 909).

The age and nature of basement rocks in several regions were also of interest; however, this objective was reached only at the Iceland Plateau (Site 907). Time constraints, pollution prevention and safety constraints, and ice conditions prevented basement from being reached in the East Greenland Margin, Fram Strait, and Yermak Plateau regions, respectively. The sites to the north of Svalbard (Sites 910, 911, and 912) also constitute the first drilling to be conducted in the Arctic Ocean proper.

Summary of Objectives

Cenozoic Paleoceanography of the Nordic Seas

1) To study the timing and history of deep and shallow water exchange between the Arctic Ocean and the Norwegian-Greenland Sea via the Fram Strait (northern gateway).

2) To study the timing and history of deep and shallow water inflow and outflow between the Norwegian-Greenland Sea and the North Atlantic across the Greenland-Scotland Ridge.

3) To investigate water-mass evolution, particularly addressing the initiation and variability of east-west and north-south oceanic fronts in surface waters, the initiation and variability of northern-source deep-water formation, and the history of vertical physical and chemical gradients.

Cenozoic Evolution of Climate in High Northern Latitudes

1) To investigate the timing and development of polar cooling and the evolution of low to high latitude thermal gradients in the northern hemisphere.

2) To establish the temporal and spatial variation of sea-ice distribution, the glacial history of the circumarctic, Greenland, and Northern Europe, and the history of IRD sedimentation in the Arctic.

3) To investigate variations in climatic zonality and meridionality through time as response to tectonic forcing.

4) To establish the history of the higher frequency components of the climatic and glacial evolution of the Arctic and subarctic areas.

5) To identify ocean-atmosphere interactions associated with Northern Hemisphere deep-water formation and the interhemispheric couplings and contrasts in climatic evolution.

Sediment Budgets

1) To investigate fluxes of biogenic carbonate, opaline silica, organic matter, and nonbiogenic sediment components through time.

2) To study bathymetric variability through time of the CCD and lysocline.

3) To establish the spatial and temporal history of silica preservation.

4) To investigate Arctic and subarctic oceanic influence on global biogeochemical cycles.

RESULTS

Site 907

Site 907 (proposed site ICEP-1) is located on the eastern Iceland Plateau in the southwestern part of the Norwegian-Greenland Sea, in an area west of the extinct Iceland Plateau spreading axis on oceanic crust of around magnetic anomaly 6B age (approx. 22-24 Ma), and west of the Jan Mayen Ridge (a microcontinent which was originally part of the Greenland continental margin). Site 907 represents part of the western extension of a paleoenvironmental transect from the Norwegian (ODP Leg 104) to the Greenland continental margin, as well as one of the southern tie points of a north-south transect through the North Atlantic-Arctic gateways. Site 907 was also located on a relatively shallow part of the Iceland Plateau, providing access to an undisturbed, flat-lying, pelagic sediment sequence.

The site location had been selected at SP 400 of the ICEP1-89, Segment A multichannel seismic reflection line collected by the University of Bergen, Norway. The seismic line could be correlated with confidence to the reflection data collected on board *JOIDES Resolution* during site approach, which together with the 3.5-kHz record also established the undisturbed nature of the pelagic sedimentary sequence.

Our plans were to double or triple APC- and XCB-core this site to obtain a complete stratigraphic sequence of Neogene and Quaternary pelagic sediments and to reach basement. Hole 907A was APC-cored to 216.3 mbsf, where the core barrel bounced, indicating a hard interface. We then continued to XCB-core and achieved a total penetration of 224.1 mbsf; the last two cores were in basalt. After completion of Hole 907A a successful logging program was carried out. A medical emergency requiring the immediate evacuation of a sick crew member prevented us from drilling additional holes at this site.

Five sedimentary lithostratigraphic units (Fig. 2) were recognized at Site 907 (on top of the basalt encountered at 216.3 mbsf):

Unit I: (0-16.8 mbsf) This unit consists of Quaternary dark grayish brown to grayish brown clayey silts, silty clays, and foraminifer-bearing silty muds, with minor amounts of biosilica-bearing silty carbonate ooze. Most color boundaries are gradational because of the pervasive bioturbation. This unit is distinguished by the presence of biogenic calcareous material, primarily foraminifers. In addition to the biogenic components, the coarse fractions consist of quartz, feldspar, and mica, with little volcanic glass. Dropstones (=IRD) >1 cm are rare.

Unit II: (16.8-56.3 mbsf) This unit consists of Quaternary to Pliocene clayey silts and silty clays, characterized by the absence of biogenic carbonate and the abundance of silt- and sand-sized siliciclastic grains. The silts and clays are dark grayish brown to dark gray and gray and commonly massive, but some show faint mottling. Volcanic glass is rare, with a slight increase toward the bottom of this unit.

Unit III: (56.3-118.1 mbsf) This unit is characterized by Pliocene to upper Miocene clayey silts and silty clays, with biogenic silica, an increase in volcanic glass content, and a decrease in the percentages of quartz and feldspar. They are primarily dark olive gray, olive gray, and very dark gray. In addition to volcanic glass the coarse fractions consist of quartz, feldspar, mica, and accessory minerals. Dropstones are found throughout. With the exception of ash layers, all lithologic and color boundaries are gradational due to pervasive bioturbation. Two subunits can be defined: Subunit IIIA has interbedded nannofossil ooze and nannofossil silty clay, whereas Subunit IIIB does not.

Unit IV: (118.1-197.3 mbsf) This unit is characterized by upper to middle Miocene dark greenish gray to dark gray ash- and biosilica-bearing silty clays and clayey silts, with pervasive greenish gray color bands. Moderate to intensive bioturbation is present throughout, giving the sediments a mottled appearance and resulting in many gradational color and lithologic boundaries. Abundant ash layers ranging in thickness from 1 to 15 cm are common in the upper part of the unit; some ash layers are graded.

Unit V: (197.3-216.3 mbsf) This unit consists of middle Miocene dark olive gray clayey mud and silty clay, which is distinguished from Unit IV by its high quartz and clay and low biosilica contents. Mottling and color changes occur. Burrows are commonly filled with sand-sized volcanic glass.

The micropaleontological studies of the recovered sediment sequence at Site 907 demonstrated that it consists of Pliocene to Quaternary hemipelagic deposits, upper and middle Miocene biosiliceous oozes, and middle Miocene ash-rich muds. Siliceous microfossils in Core 907A-21H-CC have an age of 14 Ma, whereas dinoflagellates suggest an age not older than 16 Ma of Core 907A-23H-CC. Most major pelagic microfossil groups have contributed to a detailed biochronology, which is supported by an excellent magnetostratigraphy.

Calculated bulk sedimentation rates range from about 10-20 m/m.y. in the upper Miocene to Quaternary part of the drilled section to > 80 m/m.y. in the middle Miocene. Correlation to previous micropaleontological studies of DSDP Legs 38 and 94 and ODP Legs 104 and 105 proved difficult because of a number of factors: location of the new site under different water masses, better coring techniques, scarceness of calcareous materials, variable preservation of siliceous species, and high percentages of endemic species. Site 907 siliceous microfossil assemblages suggest highly productive surface waters during most of the Neogene, whereas the decline of the pelagic habitats as indicated by the increased presence of ice-rafted materials since the late Pliocene led to the deposition of overlying, mostly terrigenous sediments typical for the glacial depositional environments.

Geochemical measurements documented the scarceness of calcareous materials, which are, with the exception of a few thin nannofossil-rich zones in the Pliocene, restricted to the upper part of the Quaternary. Organic carbon contents were generally low, and the components are mostly of terrigenous origin. Shipboard physical property measurements and logging established the cyclic nature of most of the penetrated sediment column. The uphole increase in wet bulk density and decrease in porosity occur at roughly 55 mbsf, which coincides with the onset of major IRD deposition at about 2.6 Ma.

Extraordinarily high heat-flow values (observed by the Adara tool and confirmed by logging), together with a number of geochemical anomalies, point to the unexpected existence of hydrothermal fluid flow through the deeper part of the sampled sequence.

The sedimentary sequence rests on top of acoustic basement which consists of nearly aphyric basalts. Each of the recovered units is homogeneous and massive, distinguished by glassy tops and bottoms with abundant vesicles on either side of the glass. They indicate that the cooling units are pillow basalts.

In summary, Site 907 fulfilled its objectives insofar as we collected a more or less complete Neogene and Quaternary paleoenvironmental section as the southern part of the North Atlantic-Arctic gateway problem. However, it did not fulfill our expectations either of a particularly high stratigraphic resolution section or of extensive carbonate sedimentation in the Neogene and Quaternary on the Iceland Plateau.

Site 908

Site 908 (proposed site FRAM-2) was drilled on Hovgård Ridge, which marks the northern boundary of the Boreas Basin, and which blocks the deep southern Fram Strait with the exception of narrow channels that have developed between the Greenland continental margins in the west and the Svalbard continental margin in the east, where the northern end of the still active mid-ocean Knipovich Ridge is found. The site on top of Hovgård Ridge was drilled to determine the age and lithology of sediments in basins on the ridge crest to establish timing and sedimentary processes immediately postdating the opening of Fram Strait and the subsidence of the ridge. It was also planned as a shallow-water site to investigate the history of water-mass exchange between the Arctic Ocean and the Norwegian-Greenland Sea. The age of the sedimentary units on top of the ridge was unknown.

The drilling program consisted of double or triple APC- (to refusal) and XCB-coring of the sedimentary sequence to a depth of 360 mbsf. The available seismic reflection lines established the existence of a strongly stratified, almost 200-m-thick upper sequence of sediments limited by a strong reflector marking the existence of an erosional interface on top of a small sedimentary basin.

High gas concentrations and stiff sediments restricted APC coring to the upper 100 m, and the burned-out shoe of the XCB limited total depth of penetration to 344.6 mbsf. The coring program was then curtailed because of the difficult stratigraphy of the uppermost sediments, resulting from sparse microfossil age control, and the incomplete record of the entire sequence on top of Hovgård Ridge. The logging program was also limited because of the poor hole qualities around the unconformity due to rapid swelling of formations, even after reaming.

Two major lithologic units are distinguished, according to changes in composition, texture, and the occurrence of dropstones (Fig. 3). The boundary between lithologic Units I and II is placed at 185 mbsf, where the biosilica content sharply increases.

> Unit I: (0-185 mbsf) Except for a few intervals of foraminifer-bearing clayey or silty mud, which occur in the two uppermost cores, and three distinct ash layers, this unit consists entirely of Quaternary to Pliocene siliciclastic sediments. Textural changes define a general downward trend in dominant lithology from clayey or silty muds interbedded with minor clayey silts or silty clay, toward homogeneous silty clay. Three subunits can be distinguished on the basis of the occurrence of dropstones (mainly clastic sedimentary rocks), texture, and sedimentary structures.

> Unit II: (185-344.6 mbsf) Lithologic Unit II is distinguished by the appearance of biosilica and distinctly greater sediment lithification. The sediments consist primarily of upper Oligocene to early Miocene? dark olive gray to dark grayish brown silty clays. Diatoms are the dominant biogenic component and typically constitute 8%-20% of the bulk sediment. Sponge spicules and radiolarians are lesser biogenic components, together with few molluscan fragments. Bioturbation is pervasive.

Microfossils recovered reveal a discontinuous stratigraphic sequence of Pliocene to Quaternary and upper Oligocene to possibly lowermost Miocene sediments. An unconformity, clearly visible on the seismic reflection records and identified at the base of Core 908A-20X (187.1 mbsf), separates relatively unfossiliferous Pliocene and Quaternary hemipelagic from upper Oligocene diatom-rich muds. Miocene sediments are absent at Site 908, with the possible exception of lowermost Miocene diatom-rich muds in Cores 908A-21X and -22X (187.1-206.3 mbsf). Paleomagnetic studies have yielded an interpretable polarity stratigraphy in the upper 180 mbsf, whereas the magnetostratigraphic temporal control for the sediments below the unconformity at 187 mbsf remain very uncertain (but not incompatible with the established biostratigraphy).

The sediments of Unit I are representative of the glacial Pliocene and Quaternary depositional regime in the southern Fram Strait, with little documentation of the glacial and interglacial faunas and floras. Below Core 908A-20X the section is fossiliferous, consists of very dark gray mud(stones), and contains upper Oligocene siliceous microplankton (diatoms, rare radiolarians) and deep neritic benthic foraminifers. The entire section is also rich in terrestrial organic material. Methane increased at 90-100 mbsf, and the C1/C2 ratios decreased at 120 mbsf, but these were not considered a serious problem because they stabilized below 275 mbsf. This section of fully marine Oligocene sediments without indications of a sea-ice cover is at present unique for the Arctic and subarctic Northern Hemisphere.

Site 909

Site 909 (proposed site FRAM-1A) had been planned as the deep-water location in Fram Strait on a small abyssal terrace which is located immediately to the north of Hovgård Ridge. This terrace comprises the sill between the Arctic Ocean and the Norwegian-Greenland Sea and it is protected against the influx of turbidites by channels or depressions to the west (Hovgård Ridge and the channel between it and the Greenland continental margin), east (northern extension of the active mid-ocean Knipovich Ridge), and north (Molloy Deep). Shallow gravity cores from the terrace had demonstrated the existence of a hemipelagic fossiliferous sediment section with an undisturbed, easily-dateable upper Quaternary stratigraphy. Since the central part of the Fram Strait was ice-free, the westernmost of the locations proposed for the FRAM-1 site was selected.

Holes 909A (to 92.5 mbsf) and 909B (to 135.1 mbsf) were drilled earlier while waiting for the escort icebreaker *MSV Fennica* in mid-August. Penetration at Hole 909C was to 1061.8 mbsf, which was drilled when the advancing ice had intermittently driven us off all remaining sites on the Yermak Plateau, in early September. Recovery and sediment properties at this site were excellent, but at depth where well-defined bedding was observed, Hole 909C deviated by up to 25° from the vertical. The deep hole had to be abandoned due to safety considerations because of the stepwise increase of hydrocarbon concentrations near the bottom of the hole.

The drilled sediment section consists of gray to dark gray clays to silty clays to muds with varying amounts of sand and/or dropstones. Numerous subtle color changes follow bedding planes. Bioturbation is pervasive except in the lowermost part of the drilled sequence with "laminated" intervals, which are interrupted by several slumps. No volcanic ashes were observed.

The entire sedimentary sequence can be subdivided into three lithologic units, based on their texture, composition, and sedimentary structures (Fig. 4):

> Unit I: (0-248.8 mbsf) This unit consists of Quaternary to Pliocene gray to dark gray interbedded clays, silty clays, and clayey muds with varying amounts of dropstones with diameters of >1.0 cm. They are mostly rounded to subrounded clastic sedimentary -- in particular, black siltstones -- and crystalline rocks, rarely limestones. Coal fragments are conspicuous in many horizons. Dropstones do not occur beneath 240 mbsf. The upper 50 m contains minor calcareous nannofossils. Mono-sulfides and color banding occur throughout.
>
> Unit II: (248.8-518.3 mbsf) This unit consists of Pliocene to Miocene dark silty clays and clayey silts with common pyrite. Some of the clays are carbonate-rich. Bioturbation is light to moderate throughout. Fe sulfide concretions and diffuse pods occur sparsely. Nodular pyrite concretions and disseminated pyrite grains are common. Below 499 mbsf the silty clays are increasingly fissile and show some parting along planes, which may be related to foliation but are more likely related to original bedding. Bioturbation is minimal throughout intervals displaying layering, which varies from medium color bands to fine laminations. Mottled surfaces and millimeter- to centimeter-scale burrows attest to moderate to extreme bioturbation in poorly layered sediments. Carbonate clay consolidation increases with depth.
>
> Unit III (518.3-1061.8 mbsf) Based on sedimentary structures, this Miocene to Oligocene unit can be subdivided into two subunits. The upper subunit (518.3-923.4 mbsf) consists of dark gray silty clays, clayey silts, and muds, and some is carbonate bearing; it is also characterized by meter-scale intervals of bioturbated layers and laminations. The lower subunit (923.4-1061.8 mbsf) comprises dark gray silty clays, clayey silts, and clayey and silty muds which are characterized by several intervals of commonly folded and

otherwise deformed bedding. Disseminated pyrite and glauconite are common, and benthic foraminifers and worm tubes occur.

Microfossil assemblages comprise mostly palynomorphs as well as agglutinated benthic foraminifers. Dinoflagellates suggest a nearly complete Miocene section. Other microfossil groups are virtually absent, with the exception of rare calcareous nannofossils in the upper 50 m and from 700 mbsf to the base. Calcareous nannofossils in Core 909C-102R give a basal age of latest Oligocene to early Miocene, in agreement with dinoflagellate ages. The benthic foraminifers, however, suggest an older age (early Oligocene), indicating unusual diachrony of this group, possibly caused by the migration of benthic habitats. Siliceous microfossils were virtually absent, but dissolved silica in pore waters in the upper part of the section was present in high enough quantities to suggest their original presence. However, in the lower part of the section, dissolved silica was so low that the original sediments must have been opal-free.

The paleomagnetic record is good in the Pliocene and Quaternary, where the Brunhes, Matuyama, Gauss, and perhaps Gilbert chrons can be identified, including their major subchrons, and sedimentation rates of 50-80 m/m.y. are suggested for the upper 300-400 mbsf. Below this level, many clear magnetozone boundaries can be identified, but their correlation to the geomagnetic polarity time scale remains problematic at the present time.

Site 909 was the first site on Leg 151 to be drilled that displayed disruption due to gas. Organic carbon values are relatively high throughout, with maximum values of 1.5%-2.6% in the lowermost 60 m of the site. At about 450 mbsf, besides abundant methane, higher hydrocarbons also started to occur in minor amounts. Due to the drastic two-step increase in propane, butanes, pentanes, and hexanes at about 1020 and 1050 mbsf, as well as the occurrence of strong light yellow fluorescence in the lowermost two cores, drilling was terminated.

Despite the high gas concentrations, a long and good-quality data set of physical properties has been obtained. Compaction effects are not complete even at the base of Hole 909C. The physical-property profiles appear stepped in places, as bulk density values are seen to increase dramatically over very short depth intervals, often coinciding with lithostratigraphic boundaries. Physical property measurements are supported by a successful logging program. The average velocity in

Hole 909C was 2.02 km/s. The total Hole 909C drilled is equivalent to 1.023 s TWT. The acoustic basement reflector is probably about 140 m below the terminal depth.

Site 910

Site 910 (proposed site YERM-4) is located in 556 mbsl on the central inner Yermak Plateau. Its objectives were to study the Neogene evolution and glacial history of the Arctic, to investigate the history of influx of North Atlantic waters into the Arctic Ocean, and to form the shallow member of a bathymetric transect of depth gradients of sediment properties and accumulation. Owing to very stiff and sticky surface sediments, attempts to APC- and XCB-core the site did not result in satisfactory recovery, so we were forced to switch to the RCB mode relatively early, with a marked improvement in recovery below 150 mbsf.

The 507.4-m-thick sequence recovered at Site 910 consists of very firm, nearly homogeneous silty clays and clayey silts, predominantly very dark gray. It is highly consolidated in the surface layers. Sediment texture and mineral components exhibit variations of 20%-30% throughout the sequence, but show few major trends (Fig. 5). Dropstone frequency reaches 1-3 dropstones per meter recovered in Cores 910C-1R to -22R (0-208.7 mbsf), whereas frequencies are less than 1 per meter in Cores 910C-23R to -53R (208.7-507.4 mbsf). The drilled sequence comprises a single silica-rich lithologic unit, which is subdivided into three subunits, based on dropstone frequency and variations in siliciclastic abundance. Reworked siliceous microfossils, episodic occurrences of mollusc fragments, and wood fragments have been observed at a number of intervals. In general, carbonate values are low, varying between 1.5% and 6%, and organic carbon values are relatively high throughout (0.7%-1.4%). The recovered sequence suggests variations in the siliciclastic influx to the Yermak Plateau throughout the time interval documented in these cores, and an increase of ice-rafting at approximately 208.7 mbsf, possibly an indicator of the intensification of Northern Hemisphere glaciation.

The sediments are glacial-marine throughout and mostly devoid of siliceous microfossils, but Cores 910C-17R through -20R contain reworked diatoms, silicoflagellates, and radiolarians. Silica in the interstitial waters is substantially lower than at other sites, which appears to reflect equilibrium with diagenetic opal phases.

The biostratigraphy of this site is based on calcareous nannofossils and planktonic foraminifers. The upper part of Hole 910C, down to 64.2 mbsf, contains Quaternary microfossils, but the position of the Quaternary/Pliocene boundary is not clear because of the poor core recovery in the upper part of the holes. The occurrences of small specimens of the calcareous nannofossil *Gephyrocapsa* and the foraminifer *Neogloboquadrina* dextral in Sample 910C-11R-CC indicate that the Quaternary/Pliocene boundary may be situated close to this zone. Below 112.4 mbsf the nannofossil assemblages change abruptly and are dominated by Pliocene species. The unusually consistent occurrence of benthic foraminifers in the entire sequence provides a basis for ecologic and oceanographic interpretations of the bottom conditions. Benthic foraminifers indicate a Pacific influence below Core 910C-38R. Terrestrial plant material and palynomorphs are common throughout the section. Dinoflagellates are represented only by rare reworked Cretaceous taxa.

The shipboard paleomagnetic studies of Site 910 cores did not yield accurate temporal constraints for the stratigraphic section, although APC coring in Holes 910A and 910B allowed us to assign the upper 25 mbsf of the sedimentary column to the Brunhes. In Hole 910C, drilled with the RCB, poor recovery in the upper 150 mbsf prevented any useful interpretation of the magnetostratigraphy for that interval. When *JOIDES Resolution* was driven off location at Site 912 by encroaching ice, Hole 910D was drilled to study physical properties of the overconsolidated glacial Quaternary and Pliocene sediments. Recovery of the upper 150 m was improved.

Methane contents were high throughout (10,000-100,000 ppm, based on headspace). Significant amounts of ethane and propane occurred below 300 mbsf. C1/C2 ratios show a consistent, but "normal" decrease with increasing depth (i.e., temperature).

The outstanding geotechnical properties of this site with its highly overconsolidated upper part of the penetrated sequence resulted in our decision to devote a dedicated D hole to an in-depth post-cruise study of the physical properties. The drilled sequence could be subdivided into two geotechnical units, determined by the marked increase in shear strength observed at 19 mbsf in Hole 910A and between 9 and 18 mbsf in Hole 910C. Sharp increases in sediment strength (from <100 kPa to >300 kPa) and wet bulk density (from 1.7 g/cm^3 to 2.2 g/cm^3), and a sharp decrease in porosity (from 50% to 35%) between 0 and 20 mbsf, indicate that the shallow sediments are overconsolidated. Below 150 mbsf, where core recovery is better, the sediments show more normal distributions of index properties and strength. The overconsolidation of shallow sediments at this site may result from ice-loading.

Site 911

Site 911 (proposed site YERM-3) is located in the shallow southern part of the Yermak Plateau, at a moderate distance northeast of Site 910. It was intended to drill a thick blanketing sequence of Neogene and Quaternary sediments whose upper part we hoped to study for the glacial history of the Arctic Ocean, the influx of Atlantic surface water into the Arctic, and as a shallow member of a bathymetric transect which had the aim of studying depth gradients in sediment accumulation. Three holes were drilled, the first to a maximum depth of 505.8 mbsf.

The sediments recovered at Site 911 (Holes 911A, 911B, and 911C) consist primarily of unlithified, homogeneous very dark gray clayey silts and silty clays of Quaternary and Pliocene age. Silty mud and clayey mud appear as minor lithologies in layers which commonly have a very dark gray or very dark olive gray color. In general, biogenic particles are rare. Slight to intensive bioturbation is present throughout the entire sequence. A single lithologic unit has been defined, which can be subdivided into two subunits, primarily based on variations in dropstone abundances (Fig. 6).

> Subunit IA: (0-380.4 mbsf) This Quaternary to Pliocene subunit is distinguished by an increase in dropstone abundance to peak values of about six per core, with siltstones, sandstones, and shales as dominant lithologies, and coal fragments, plutonic rocks, and limestones as minor lithologies.
>
> Subunit IB: (380.4-505.8 mbsf: Pliocene). By comparison with Subunit IA, Pliocene Subunit IB is defined by a smaller content of dropstones. Between Cores 911A-41X and -49X only one or no dropstones have been found. Below this level, significant amounts of dropstones have been found only in Core 911A-52X. The dropstones are also smaller in diameter (average 1.3 cm) and consist mostly of plutonic rocks and sand/siltstones.

The three holes recovered a Quaternary and Pliocene sequence of ice-rafted sediments with scattered calcareous microfossils. Glacial sediments contain rare to common Quaternary and Pliocene benthic and planktonic foraminifers and calcareous nannofossils. The boundary between the Pliocene and Quaternary is recognized only in the deepest hole, Hole 911A, between the final occurrence of the planktonic foraminifers *Neogloboquadrina atlantica* sinistral (Pliocene) in Core 911A-43X (409.3 mbsf) and the first occurrence of *N. pachyderma* sin. (Quaternary) in Core 911A-37X (351.9 mbsf). Calcareous nannofossil data support this stratigraphic interpretation. Siliceous microfossils are absent, with the exception of rare recrystallized and reworked specimens. Reworked planktonic and benthic foraminifers, probably ice-rafted, occur in the lower part of Hole 911A. Sedimentation rates at Site 911 ranged from 170 m/m.y. in the Pliocene and pre-Jaramillo to about 100 m/m.y. during the last million years. The high Quaternary and Pliocene sedimentation rates are similar to those of the other sites at the Yermak Plateau.

A total of three Schlumberger tool strings were run at Hole 911A: the quad combination (sonic, induction, litho-density, natural gamma-ray), the formation microscanner (FMS), and the geochemical logging tool. The interval logged (107-476 mbsf) covers lithologic Subunits IA and IB. There are no major lithological variations described downhole, a feature reflected in the downhole natural gamma-ray activity log, which has cyclicity but no major trends. Several of the recorded logs exhibit a cyclic nature, most prominently the resistivity logs. Preliminary spectral analyses defined spectral power in the 40-ky and 100-ky bands, reflecting known Milankovitch frequencies.

Physical-property measurements have been made on materials from Holes 911A and 911B only. Both holes exhibited evidence of the presence of relatively high amounts of gas and of drilling disturbances (biscuiting) in the deep parts of the sequences, so the information was limited. The concentration of headspace methane is high throughout the sedimentary section. Based on the physical-property measurements, five geotechnical units can be defined, which mainly reflect the downcore variability of bulk densities. Sediments in the top 50 m show some evidence for overcompaction, similar to but of less magnitude than those at Site 910.

Site 912

Site 912 (proposed site YERM-2A) is located on the shallow southwestern edge of the Yermak Plateau. It was selected to study trends in Neogene and Quaternary sediment accumulation on the Yermak Plateau and to investigate the glacial history of the Arctic gateway. It had been planned for penetration through a thick sedimentary section of Quaternary and Neogene age with evidence for the glacial history of the Arctic and the history of the North Atlantic (West Spitzbergen Current) water influx into the Arctic. It was also to be an intermediate member of a depth transect.

When arriving at the planned location, which was easily verified by seismic reflection profiling during the approach, sea ice was detected at a sufficient distance to begin drilling operations. However, while APC-coring the first hole the ice edge advanced rapidly, forcing us to abandon drilling operations and to pull back to close to the seafloor. After the ice edge had settled down for a while, we renewed our efforts by starting a second APC-hole, which to our dismay also had to be abandoned after a few cores, this time permanently because of the eastward-advancing ice.

Hole 912A reached 145.4 mbsf, and Hole 912B only 39.5 mbsf. Toward the end of Leg 151 an additional attempt to return to Site 912 led to drilling Hole 912C with the aim of RCB-coring the deeper part of the section; however, this hole (with very low recoveries) also had to be abandoned after reaching 209.1 mbsf, owing to advancing ice. The stratigraphic record of this site, therefore, is too short to have reached all scientific objectives.

Sediments recovered at Site 912 are predominantly very dark gray, unlithified, slightly to moderately bioturbated silty clays and clayey silts of Quaternary to Pliocene age (Fig. 7). Faint color banding, possibly of diagenetic origin, is present in intervals throughout. Sediment texture and mineral abundances exhibit variations of approximately 20%-30% throughout the sequence, but no major trends occur. A single lithologic unit was defined at Site 912, based on the relative uniformity in sediment type, texture, and mineralogy. The unit is characterized by higher abundances and greater sizes of dropstones as compared to Sites 910 and 911 on the inner Yermak Plateau. Most of the dropstones consist of silt-, sand-, and mudstones, but metamorphic and igneous rocks are also common. Two lithologic subunits were defined on the basis of changes in dropstone abundance, with the Subunit IA/IB boundary placed at 40 mbsf (within the Quaternary). The uphole increase in dropstone abundance at about 40 mbsf indicates an enhancement of glacio-derived sediment transport potentially related to an intensification of Northern Hemisphere glaciation. Minor differences in dropstone lithologies between the subunits could indicate slight changes in ice circulation and source areas.

Three holes recovered a Quaternary and Pliocene sequence of ice-rafted sediments with scattered occurrences of calcareous microfossils. Siliceous microfossils are absent, with the exception of rare reworked diatoms and silicoflagellates, rare and poorly preserved radiolarians, and rare diatoms indicative of uppermost Pliocene to lower upper Quaternary. Dinoflagellates are rare and non-age diagnostic; terrestrial palynomorphs are common throughout. Ice-rafted *Inoceramus* prisms are found in Pliocene sediments.

The magnetostratigraphic results yield a fairly robust age vs. depth model, which is consistent with biostratigraphic age determinations. Owing to poor core recovery, it was not possible to estimate Pliocene linear sedimentation rates. Pre-Jaramillo sedimentation rates vary from 80 to 100 m/m.y., but they decrease to about 30 m/m.y. during the last 1 m.y. of deposition.

The physical properties allowed a subdivision of the sequence into three geotechnical units. The upper one (G-I, to 8 mbsf) comprises highly variable but generally low-bulk-density and high-porosity silty clay without dropstones. Geotechnical Unit G-II (8-50 mbsf) consists of silty clay to mud with variable amounts of dropstones and increased but highly variable bulk densities as well as inversely related trends in water content and porosity. In Geotechnical Unit G-III (below 50 mbsf) recovery is reduced, but physical properties appear more constant. The recovered sediments suggest a hemipelagic, glacio-marine depositional environment, the dominant proportion of the material being relatively fine-grained.

Site 913

Site 913 (proposed site EGM-2) is located in the deep Greenland Basin on crust slightly older than magnetic anomaly 24B; it is the northernmost of the drill sites planned along the East Greenland Margin.

The original scientific objectives were aimed at describing the onset and evolution of the East Greenland Current, monitoring the deep-water formation in the Greenland Basin, and deciphering the history of the input of coarse ice-rafted debris. Two holes were drilled, Hole 913A to APC- and XCB-core the upper part of the sedimentary sequence, and Hole 913B to RCB-core the deeper part of the sequence to reach basement. The poor recovery of the upper part of the drilled sequence has prevented fulfillment of most of the previously defined scientific objectives, but after penetrating a several-hundred-meter-thick sequence of Quaternary and Pliocene glacio-marine sediments with large ice-rafted components, we succeeded in reaching Oligocene to Eocene fossiliferous pelagic deposits. These deposits contain a rich variety of lithologies documenting a stratigraphic interval which had not been covered on previous DSDP and ODP legs. Throughout the entire sedimentary section of the site, headspace methane concentrations were very low.

Sediments in Hole 913A and the shallow part of Hole 913B (to 307.2 mbsf) are, in large part, glacially influenced. They consist of interbedded lithologies with a variety of textures (from clay to silty clay and clayey mud to silty sand) with 2%-6% carbonate and 0.1%-1% organic carbon. Although the colors are not monotonous, they are limited to dark grays, dark grayish browns, and olive grays. Beds are of decimeter- to meter-scale thickness and are generally massive. Coarse particles are common throughout, and sand and gravel layers occur as deep as 164 mbsf. Individual dropstones are particularly prevalent in the upper 131 mbsf. They are obviously many times larger than core-barrel diameter. Their lithology is diverse and includes a variety of sedimentary (quartz sand-, silt-, and limestones), igneous (gabbros, granites), and metamorphic (quartzites, amphibolites, gneisses, and schists) lithologies. Crystalline rocks are predominant, in contrast with the Yermak Plateau and Fram Strait sites, where fine-grained clastic sedimentary rocks are most common. Siliciclastics dominate these shallow sediments, but planktonic and benthic foraminifers constitute up to 40% in specific layers; nannofossils are a trace component.

Siliciclastics are still present in sediments recovered below several washed intervals (375.2-509.9 mbsf), but are not dominant. Carbonate values are usually <1%, except in selected thin zones where they rise to 10%-23%. Organic carbon concentrations reach only 0.1%-0.5% (the exception being a value of 2.7% in Core 913B-27R). Alteration products such as zeolites are more important, as are siliceous microfossils. Diatoms and radiolarians both occur in concentrations as great as 20%. Total biosilica reaches concentrations above 50%, the sediments thus constituting siliceous oozes. Particle size generally decreases, and silty clays and clays prevail. Layers within the deeper part of the section are typically of millimeter to centimeter thickness. Bedding styles consist of fine, continuous, sharp laminations no thicker than 1 mm to diffuse, discontinuous, gradational layers as thick as 10 cm. Burrows and other traces are absent from some packets of laminae, while mottled interfaces, cross-cutting burrows, and determinable traces such as *Chondrites* characterize the less well-defined intervals. Perhaps the most distinctive aspect of these deeper sediments is the riotous color schemes associated with them. A full palette of greens characterizes the highly bioturbated zones. The laminated intervals are even more exotic, mixing the full range of greens with a stunning array of hues, including blues, browns, violets, tans, and yellows.

Four lithologic units were defined (Fig. 8):

Unit I: (0-3.2 mbsf) Sediments consist of Quaternary interbedded clays, silts, and sand, and biocarbonate-bearing clay and silty mud. There are surprisingly few dropstones.

Unit II (3.2-378.7 mbsf) is divided into two subunits. Subunit IIA (3.2-143.8 mbsf) consists of Quaternary to Pliocene interbedded clayey mud and silty mud with minor gravelly or gravel-bearing layers, defined by the presence of abundant large dropstones of various lithologies. Subunit II B (143.8-378.7 mbsf) comprises middle Miocene to Pliocene predominantly silty clay, clayey silt, and silty mud, with very few dropstones.

Unit III (378.7-770.3 mbsf) is divided into four subunits. Subunit IIIA (378.7-462.0 mbsf) consists of middle Miocene to late Miocene interbedded, massive and laminated silty clay and clay which at intervals is slightly bioturbated and can contain Mn concretions. Subunit IIIB (462.0-490.7 mbsf) contains early Oligocene to late Eocene biosilica-bearing clay, biosiliceous to silty clay, and clayey and silty siliceous ooze with layers of dusky to bright greens, blues, and purples. Subunit IIIC (490.7-674.1 mbsf) consists of middle Eocene to early Oligocene massive and laminated clays, minor silty clays, and muds. They contain rare microfossils.

Subunit IV (674.1-770.3 mbsf) comprises middle Eocene laminated clays, silty clays, and massive silty clays, as well as clayey and silty muds in fining-upward sequences. In the lower part, some layers of well-cemented calcareous sandstone and siltstone have been penetrated; their presence is the probable cause of the reduced recoveries from the bottom of Hole 913B.

The uppermost sequence at Site 913 consists of poorly recovered Quaternary to Pliocene sediments containing planktonic and benthic foraminifers and nannofossils to a depth of 288.4 mbsf. Sediments in the interval 288.4-375.2 mbsf are either barren of microfossils or of indeterminate age due to poor recovery. Diatoms, radiolarians, and benthic foraminifers recovered at 423.5 mbsf suggest an age of middle to early late Miocene for the overlying washed section. Sediments at 471.6 to 490.7 mbsf comprise lower Oligocene to upper Eocene radiolarians, diatoms, and benthic foraminifers; radiolarians and diatoms are particularly well preserved and abundant through the upper part of this interval, providing a first look at a Paleogene siliceous sequence along the East Greenland margin. Diatoms are absent with the exception of pyritized forms at 558.1 mbsf. Radiolarians are reduced, but continuous from 490.7 to 558.1 mbsf, and co-occur with sporadic appearances of *Bolboforma* and planktonic and benthic foraminifers. Combined data from 500.3 to 558.1 mbsf indicate middle to upper Eocene sediments. Samples from 548.8 to 587.1 mbsf are barren of microfossils with the exception of agglutinated benthic Eocene foraminifers at 567.7 mbsf. The lower part of the hole has been marred by poor recoveries, but sediments are fossiliferous, and, based on agglutinated foraminifers and *Bolboforma*, seem to belong to the middle Eocene, several million years younger than oceanic basement under Site 913.

Shipboard magnetostratigraphic studies are inconclusive due to poor recovery and very low NRM intensities.

Measured bulk densities from the glacial marine sediments of this site range from 1.95 to 2.1 g/cm^3 but decrease to values of 1.8 to 1.45 g/cm^3 as sediments become finely laminated farther below and the amount of diatoms present in the sediments increases. Compressional velocities measured on the sediment from this laminated interval show typical thin-bedded anisotropic behavior (12% *P*-wave anisotropy). Along the bedding planes, the velocities are 1750 m/s. The lowered density in the biosiliceous material relative to the glacial marine sediments may partially explain the increased velocities.

SUMMARY AND CONCLUSIONS

During the Arctic summer of 1993, *JOIDES Resolution,* accompanied by the Finnish icebreaker *MSV Fennica,* recovered the first scientific drill cores from the eastern Arctic Ocean, including material which records the earliest history of the connection between the North Atlantic and Arctic oceans, the onset of glacial climate in the Arctic and the inception of abundant sea-ice formation and sediment ice rafting, and evidence for massive ice caps on the Arctic Ocean margin during certain glaciations.

The oldest sediments recovered, middle Eocene at Site 913, contain the highest abundances of terrigenous organic matter recovered during Leg 151 and indicate the close proximity of a continental source during this initial phase of seafloor spreading in the Greenland Basin. Episodes of laminated sediment deposition suggest a lack of infaunal activity and bioturbation during the middle Eocene. The dissolved-silica level is extremely low, suggesting an absence of biosiliceous deposition and hence indicates a restricted basin or basins receiving nutrient-depleted surface water over shallow sills, well above the mid-water nutrient maxima common in modern oceans. During this time, Fram Strait remained closed to deep-water flow. Productivity increased throughout the middle Eocene, and Site 913 remained below the CCD.

At Site 913, there was a renewed influx of terrigenous organic carbon in the late Eocene, coinciding with the first appearance of preserved biogenic silica. Upsection, the sediments display vivid shades of blue, purple, and green and the preservation and abundance of siliceous microfossils increases. The siliceous intervals were formed during times of high productivity, resulting in high sedimentation rates and high abundances of marine organic carbon. Nevertheless, ventilation of the deep waters was poor, resulting in lamination and probably causing the accumulation of CO_2 in deep water, which dissolved carbonate.

The late Oligocene to earliest Miocene interval from Site 908 on the Hovgård Ridge suggests moderately well-mixed oceanic conditions in the Norwegian-Greenland Sea. The sediments record relatively high but variable surface-water productivity, well demonstrated by the most highly variable organic carbon of any Leg 151 site (0.75% to 2.0%). High productivity is also indicated by the abundance of siliceous microfossils. This site was below the CCD during this time, and the intermediate waters were poorly ventilated. Extensive bioturbation suggests at least intermediate bottom-water oxygen levels, but thin, poorly bioturbated and laminated intervals suggest episodes of very low oxygen content. Laminated-sediment intervals continued until about the middle/late Miocene boundary (Site 907, Site 909, Site 913) and provide evidence for restricted circulation in the early Miocene Greenland-Norwegian Sea. Deep-water flow from the Arctic or production in the Nordic Seas did not occur before this time.

The late Miocene time interval is represented only at two sites. Site 909 is characterized by a paucity of microfossils, while Site 907 is rich in siliceous microfossils, which began prior to the middle/late Miocene boundary but ended by about 7 Ma, suggesting that deep-water formation began to better mix the Nordic Seas, but that true North Atlantic Deep Water (NADW) was not formed until the latest part of the Miocene. The disappearance of anoxic indicators marks the start of deep mixing in the Greenland Basin, while the presence of siliceous production on the Iceland Plateau shows that the southern part of the Nordic Seas still had net upward transfers of nutrients from deeper waters to the surface, unlike modern conditions. The gradient from north to south reflects either the beginning of inflow of Arctic deep waters into the Nordic Seas or the development of a strong temperature gradient in surface waters and the beginning of basinal deep-water formation in the north.

At all sites, the Pliocene and Quaternary interval is marked by evidence of ice, with significant quantities of dropstones appearing near the late Miocene/Pliocene boundary, with a marked increase at about 2.5 Ma.

Pliocene and Quaternary sediments on the Yermak Plateau at the southern edge of the Arctic Ocean are extremely thick, deposited either by the melting of a sediment-laden pack ice transported to the region by Arctic surface circulation or during interglacials as ice melted from a massive Barents Sea ice sheet or an ice cap centered on Svalbard. The former scenario seems more likely, because the melting ice edge now supports high productivity, which could cause the observed high levels of marine organic carbon deposition. The summer edge of Arctic pack ice must then have been near the Yermak Plateau for most of the Plio-Pleistocene interval.

Site 910 was marked by a highly overconsolidated interval, beginning at about 25 m depth in the sediment column. No such interval was found at the deeper water Site 912 (south) or Site 911 (north). At Site 912, sedimentary evidence of the ice sheet was recorded for the same time interval. The consolidated interval was traced along the Yermak Plateau with seismic reflection profiles. This consolidation possibly indicates that an ice lobe of the Barents ice sheet reached well out to sea in the late Pleistocene and was grounded on the top of the Yermak Plateau. These event(s) may have occurred prior to the last glacial maximum at 18 ka. Evidence for the extension of the Barents ice sheet westward will provide important constraints for Pleistocene ice models.

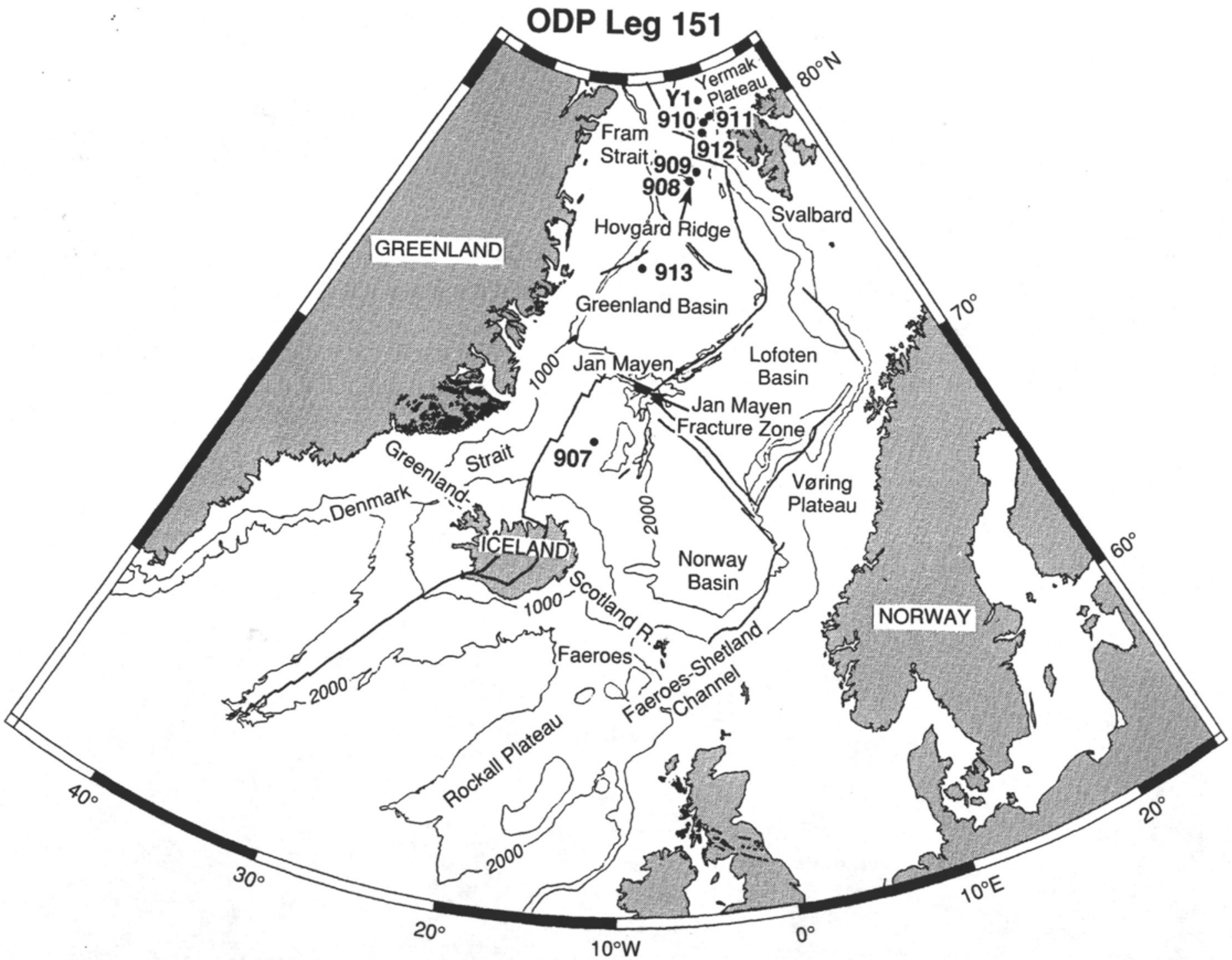


Figure 1. Location of Leg 151 drill sites. Y1 = proposed site YERM-1.

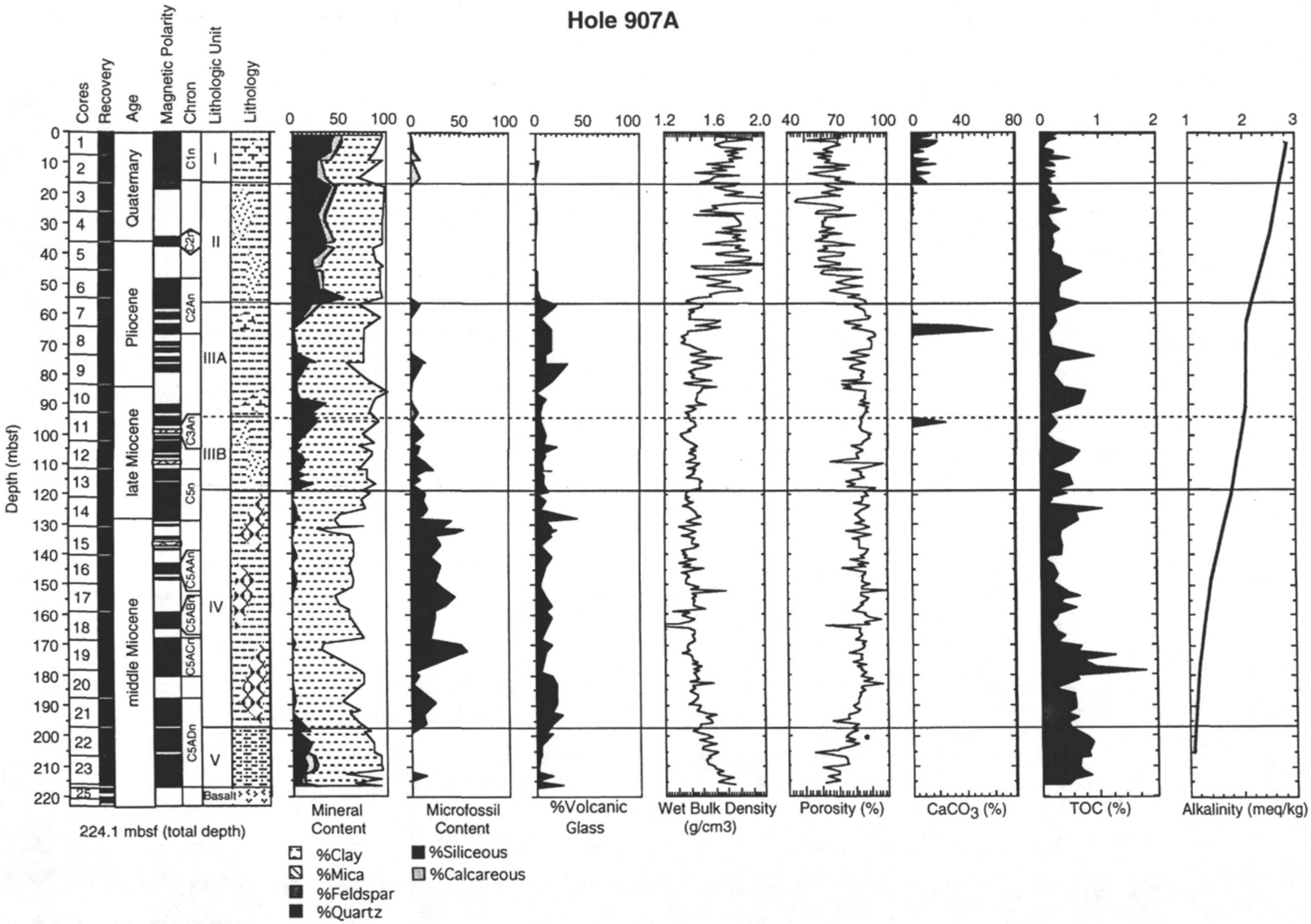


Figure 2. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 907.

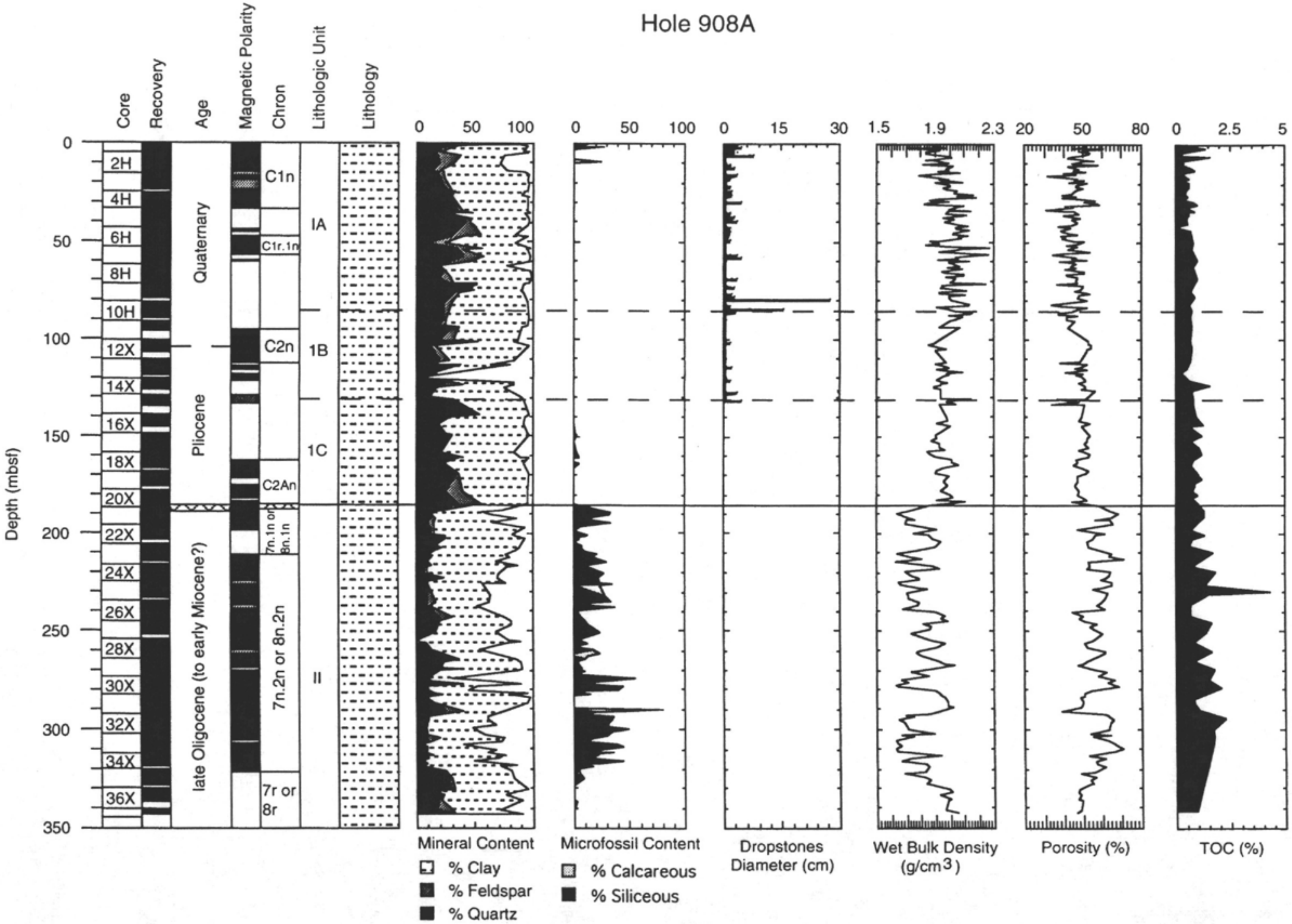


Figure 3. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 908.

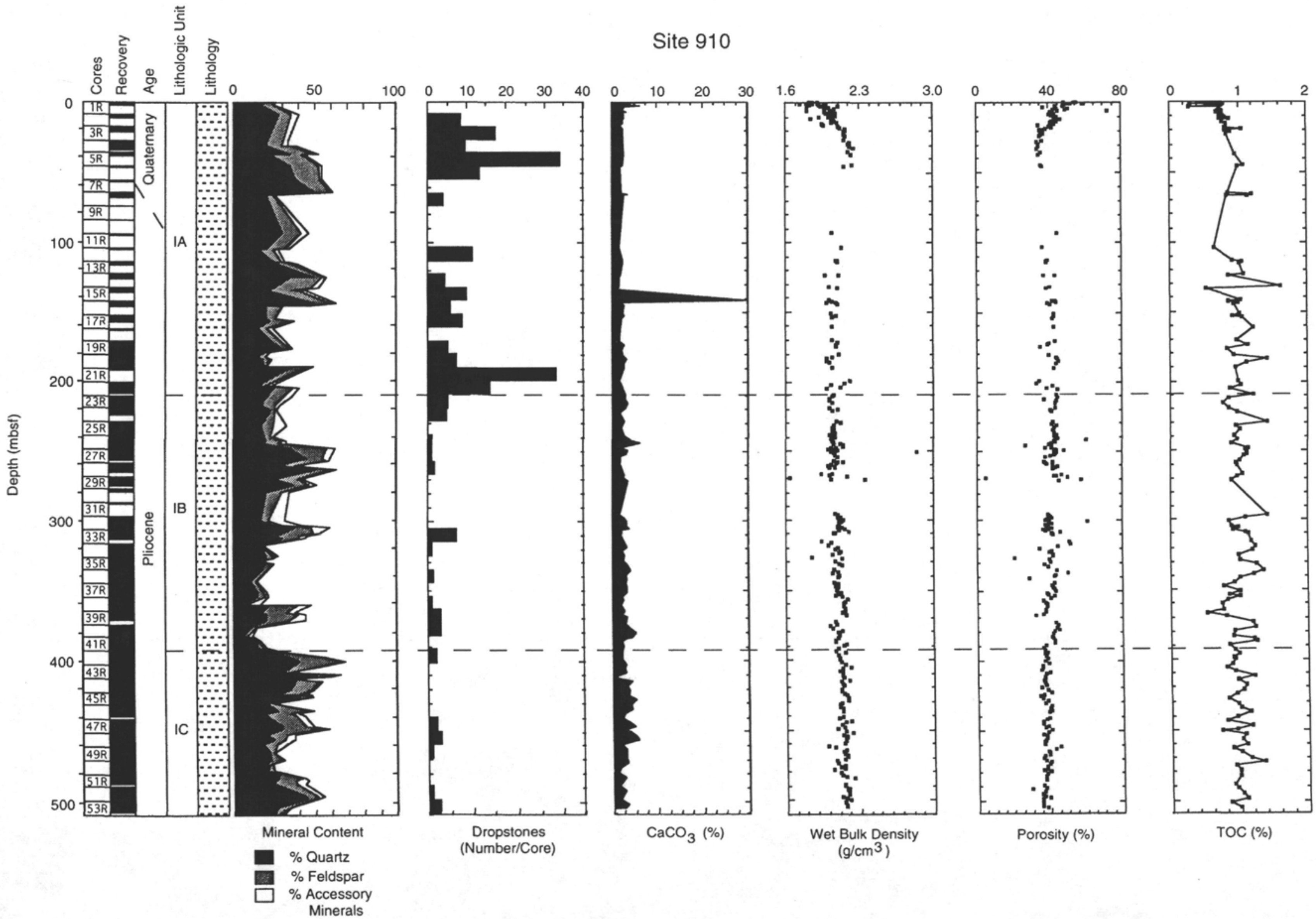


Figure 5. Summary of core recovery, age, lithologic units, sediment components, physical properties, and chemistry of Site 910.

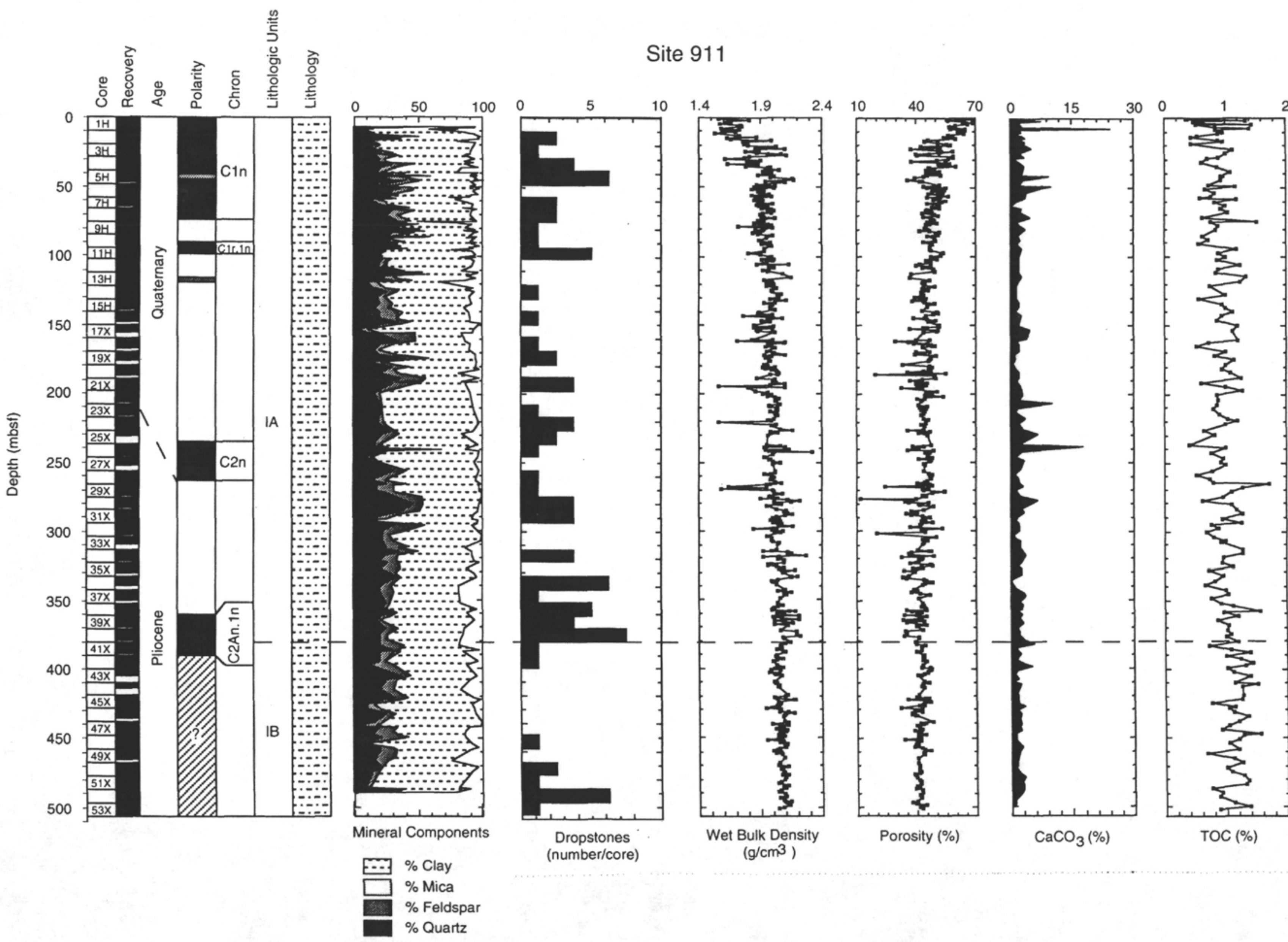


Figure 6. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 911.

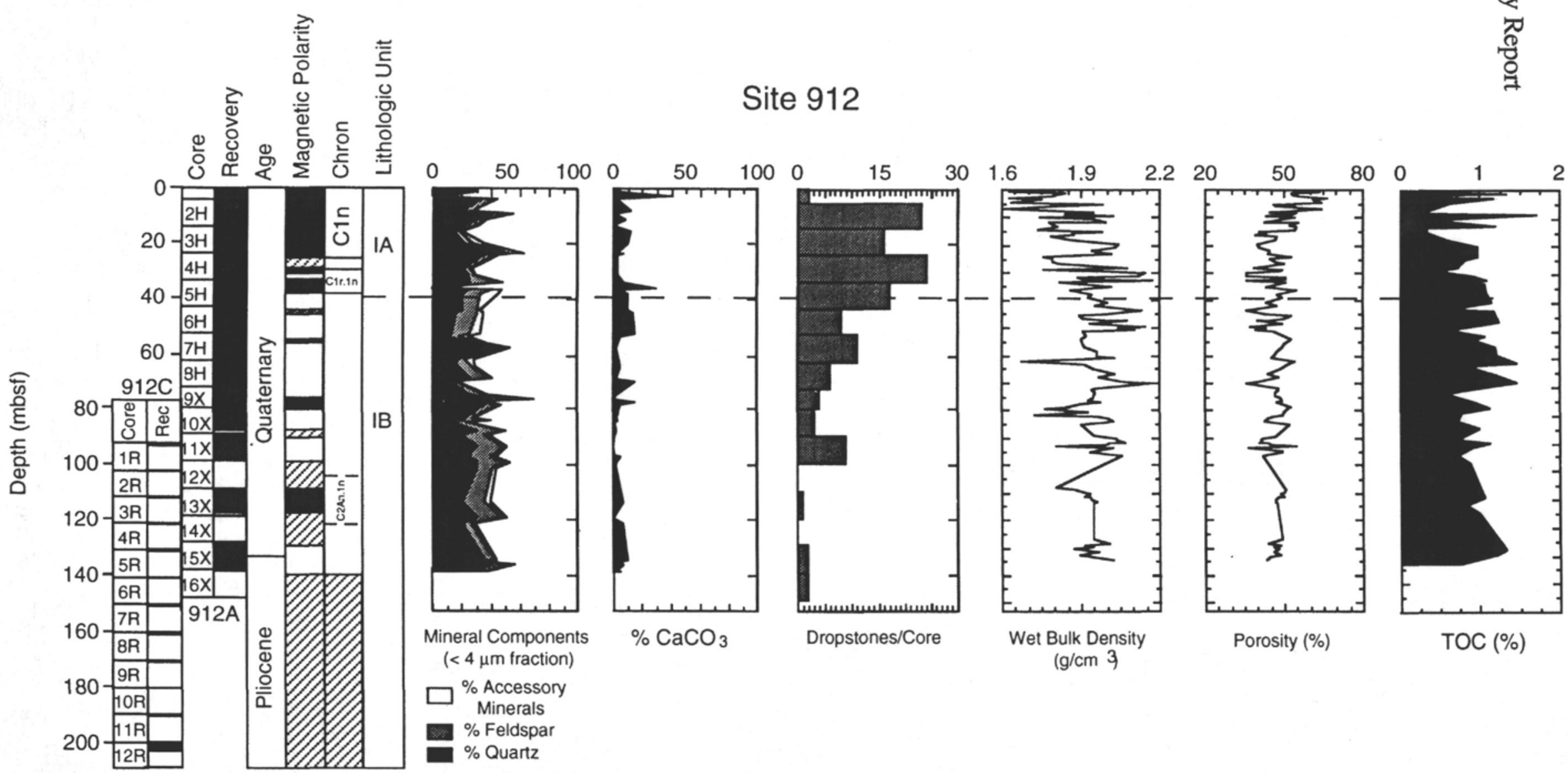


Figure 7. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 912.

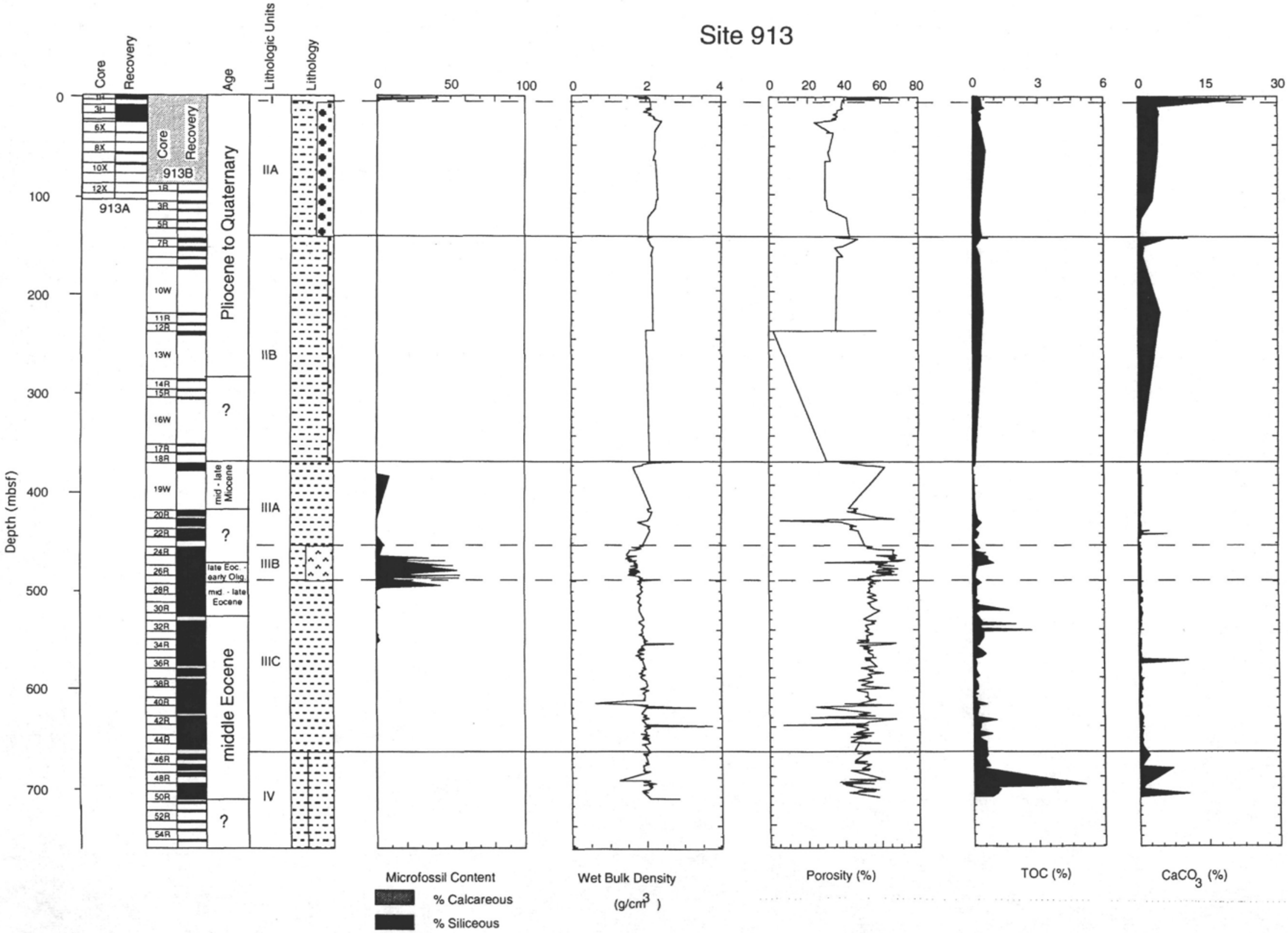


Figure 8. Summary of core recovery, age, lithologic units, sediment components, physical properties, and chemistry of Site 913.

OPERATIONS REPORT

The ODP Operations and Engineering personnel aboard *JOIDES Resolution* for Leg 151 were:

Operations Superintendent:	Gene Pollard
Schlumberger Engineer:	Steve Kittredge

ST. JOHN'S, NEWFOUNDLAND, PORT CALL

Leg 151 began officially with the first line ashore at Berth 17 in St. John's Harbor, Newfoundland, at 2015 hr (local), 24 July 1993. The crew change was completed on 25 July, and outgoing and incoming freight was handled. The pacing item at the Leg 151 port call was SEDCO's overhaul of the heave compensator and installation of a new electrical umbilical on the top drive. Lamont-Doherty Earth Observatory (LDEO) installed a new logging cable.

ST. JOHN'S TO SITE 907 (Proposed Site ICEP-1)

The last line was away at 1319 hr (local), 29 July 1993. The ship transited the entrance to St. John's Harbor, and the sea voyage to proposed site ICEP-1 (Site 907) began at 1400 hr, 29 July. The clock was advanced 0.5 hr on 30 July from 0000 to 0030 hr, 1.0 hr on 2 August from 0000 to 0100 hr, and 1 hr on 5 August from 0000 to 0100 hr to put the ship on Icelandic and UTC (GMT) time for the rest of the leg. The 1755-nmi transit required 159.7 hr for an average speed of 11.0 kt.

The seismic survey at Site 907 started at 0932 hr, 5 August, and covered 21.9 nmi in 3.6 hr at an average speed of 6.1 kt. The seismic gear was retrieved, and a Datasonics 354B beacon was dropped at 1051 hr, 5 August, at 69°14.944'N, 12°41.949'W. The survey was continued past the beacon drop for 6.1 nmi in 1.0 hr at 6.1 kt.

The ship was on location at 1248 hr. The Precision Depth Recorder (PDR) indicated a water depth of 1815.4 mbrf. The signal from the primary beacon was lost temporarily. The ship was stabilized in DP mode at 1315 hr, and a Datasonics 354B beacon was dropped for a backup beacon.

Hole 907A

An APC/XCB drill bit was run. The PDR indicated a water depth of 1815.4 mbrf, and Core 907A-1H was shot with the bit at 1809.4 m. The recovery was 7.27 m; therefore, the sediment surface depth was 1811.6 meters below rig floor (mbrf) and 1800.8 meters below sea level (mbsl). The location of Hole 907A is 69°14.989'N, 12°41.894'W. Cores 907A-1H to -23H were taken from 0.0-216.3 meters below seafloor (mbsf), with 216.3 m cored and 225.10 m recovered (104.1% recovery). Core 907A-23H bounced when it hit a hard object at the end of its stroke. Cores were not oriented because of the high latitude. The Adara temperature shoe was run on Cores 907A-3H, -6H, -9H, and -12H. Overpull on the APC increased from 10K lb at 35.8 mbsf up to 65K lb at 187.8 mbsf. The formation was silty clay with scattered ash layers, and some layers containing calcareous and siliceous microfossils with scattered basaltic pebbles. Negligible concentrations of biogenic methane (5 ppm) were encountered in headspace gas analyses.

Cores 907A-24X to -26X were taken from 216.3 to 224.1 mbsf, with 7.8 m cored and 4.88 m recovered (62.6% recovery). The formation was basalt. Coring with the XCB was terminated when two hard-formation TCI XCB shoes were destroyed.

The hole was prepared for logging by circulating the hole clean, making a conditioning trip to 63 mbsf, and going back to bottom. The bit was positioned at 82.77 mbsf for logging, with spacing to pick up to 63 mbsf to log the upper hole.

About 2.25 hr was lost when the first attempt to log was terminated because the old rope socket had two broken ground wires (it was rebuilt), and the second attempt to log was terminated when the head on the sonic tool failed a continuity test (it was replaced). The logs were run as follows:

Log no. 1: Dual Ind/Sonic. Log to 198.4 mbsf in 3.75 hr.
Log no. 2: Neutron/density. Log to 192.4 mbsf in 3.5 hr.
Log no. 3: FMS. Log to 192.4 mbsf in 3.0 hr.
Log no. 4: GST. Log to 189.3 mbsf in 2.75 hr.

The GST logging tool could not be pulled into the bit past the flapper valve, and attempts to clean out any obstructions by circulating and pumping 30 bbl high-viscosity mud pills were not successful. After 1.75 hr of work, the tool could not be pulled into the pipe enough to cause a pressure increase. The Kinley wireline crimping tool and cutter was dropped to cut the logging line in the bottom drill collar, and the line was retrieved. The drill string was retrieved without incident, and the bit and GST tool cleared the rotary table at 0400 hr, 8 August, ending Hole 907A. The GST tool (and americium radioactive source) was recovered without damage. No clay or torpedo damage was found to explain the flapper valve problem; therefore, the flapper was probably tripped by the square shoulder on the GST tool.

Emergency Medical Evacuation

On 7 August, a medical situation had developed that might require an emergency medical evacuation. After observing the patient for 24 hr, Dr. Hampton advised at 0600 hr, 8 August, that, although the patient's condition had stabilized for a few days, he felt the patient should be evacuated. The beacons were pulled immediately, and preparations made for the sea voyage. Iceland Coast Guard recommended that the best medical evacuation point was northwest Iceland. The U.S. Air Force base at Keflavik was contacted, and they sent two helicopters and a fixed-wing aircraft to the rendezvous point at 1448 hr, 8 August, with an ETA at the Reykjavik hospital of 1710 hr.

We decided to bypass Site 907 after the evacuation, proceed directly to the Fram Strait, and core in ice-free water at proposed site FRAM-2 until the ice-breaker *MSV Fennica* arrived, then go immediately to the Yermak Plateau sites.

TRANSIT TO SITE 908 (Proposed Site FRAM-2)

The 729-nmi transit required 84.5 hr for an average speed of 8.6 kt. The seismic survey at Site 908 started at 2115 hr, 11 August, and covered 28 nmi in 4.6 hr at an average speed of 6.1 kt. A Datasonics 354B beacon (S/N 763, 16.0 kHz, 208 dB) was dropped at 0058 hr, 12 August, the seismic gear was retrieved, and the ship returned to location.

The ship was on location in DP mode at 0221 hr; however, the signal from the primary beacon could not be acquired. A second (original backup) Datasonics 354B beacon (S/N 785, 15.0 kHz, 208 dB) was dropped at 0309 hr, 12 August. A third (backup) Datasonics 354B beacon (S/N 751, 14.5 kHz, 208 dB) was dropped at 0408 hr, 12 August.

Hole 908A

Hole 908A was started with an APC/XCB BHA. The PDR indicated a water depth of 1286.4 mbrf, and Core 908A-1H, with a recovery of 5.45 m, established the water depth of Hole 908A as 1273.5 mbsl (Latitude 78°23.112'N, Longitude 1°21.637'E). APC Cores 908A-1H to -10H were taken from 0.0 to 90.9 mbsf, with 90.9 m cored and 91.86 m recovered (101.1% recovery). APC coring was terminated after Core 908A-10H, because it was the third core with a partial stroke, and recovery was decreasing in the very stiff clays. Cores were not oriented because of the high latitude. The Adara temperature shoe was run on Cores 908A-4H, -7H, and -10H, and established a 55.64°C/km temperature gradient.

Cores 908A-11X to -37X were taken from 90.9 to 344.6 mbsf, with 253.7 m cored and 222.1 m recovered (87.5% recovery). XCB coring was terminated when the hard-formation XCB shoe packed off with clay, overheated by friction, and broke circumferentially in the threads. The cutting face was destroyed, and some metal was also lost in the hole.

The hole was prepared for logging by circulating the hole clean at 344.6 mbsf and making a conditioning trip to 83 mbsf. A bridge was tagged at 302.4 mbsf and reamed out, and the hole was cleaned out to total depth (TD). The bit was positioned at 79.33 mbsf for logging and was spaced out to pick up to 57 mbsf to log the upper hole.

The logs were run as follows:
Log no. 1: Induction/Di-Pole Sonic. Log to 287.5 mbsf in 4.0 hr.
Log no. 2: HLDT/Neutron/Density. Log to 237.5 mbsf in 3.25 hr.

The hole filled in 118.1 m in 11 hr; therefore, the pipe was run to clean out the hole again. A bridge was reamed out at 197 mbsf, and the hole was cleaned out to TD. The bit was repositioned at 1363.8 m again, and logging resumed.

Log no. 3: FMS. Log to 187.5 mbsf in 2.75 hr.

The hole continued to fill in rapidly, so logging was terminated. The hole was filled with heavy mud, and the bit cleared the seafloor at 0341 hr, 15 August, ending Hole 908A.

Hole 908B

The ship was moved 20 m north, and Hole 908B was spudded at 0452 hr, 15 August, to provide high-resolution sampling. Core 908B-1H established a water depth of 1273.0 mbsl. Cores 908B-1H to -10H were taken from 0.0 to 83.4 mbsf, with 83.4 m cored and 78.01 m recovered (93.5%

recovery). APC coring was terminated after Core 908B-10H because it was the third core with a partial stroke. Cores were not oriented, and heat-flow measurements were not taken. The bit cleared the rotary table at 1300 hr, 15 August, ending Hole 908B. All three beacons were recovered; therefore, we assumed that the first beacon was turned off inadvertently by the PDR or other ship noise.

TRANSIT TO SITE 909 (Proposed Site FRAM-1A)

The icebreaker *MSV Fennica* advised that it would arrive on schedule at proposed site FRAM-1B at 0300 hr, 16 August; therefore, it was decided to initiate coring at proposed site FRAM-1A (Site 909) until the ice conditions could be determined in the Yermak Plateau area. The 18-nmi transit required 2.0 hr for an average speed of 9.0 kt. The seismic survey at Site 909 started at 1506 hr, 15 August, and covered 13 nmi in 2.5 hr at 5.2 kt. A Datasonics 354B beacon (S/N 785, 15.0 kHz, 208 dB) was dropped at 1625 hr, the seismic gear was retrieved, and the ship returned to location. A second (original backup) Datasonics 354B beacon (S/N 763, 16.0 kHz, 208 dB) was dropped at 1835 hr.

Hole 909A

An APC/XCB bit was run for the first and second holes. The PDR indicated a water depth of 2534.4 mbrf, and Hole 909A was spudded at 0021 hr, 16 August, at 78°35.065'N, 3°4.378'E. Core 909A-1H established the water depth as 2519.0 mbsl. Cores 909A-1H to -11H were taken from 0.0 to 92.5 mbsf, with 92.5 m cored and 94.78 m recovered (102.5% recovery). APC coring was terminated after Core 909A-11H because it was the fourth core with a partial stroke in very stiff clays. Cores were not oriented. Adara heat-flow measurements were taken on Cores 909A-4H, -7H, and -10H. The bit cleared the seafloor at 0934 hr, 16 August, ending Hole 909A.

Icebreaker *MSV Fennica* Arrives

The icebreaker *MSV Fennica* arrived at Site 909 at 0600 hr, 16 August. Two personnel were transferred to *MSV Fennica* to gauge the fuel tanks as per the contract. Two Scott Polar Research Institute ice scientists and three NDR German TV crew were transferred to *JOIDES Resolution* for initial introductions and planning meetings. Personnel were returned to their respective ships, and at

1110 hr, 16 August, *MSV Fennica* departed *JOIDES Resolution* and headed northwest to locate the pack ice nearest *JOIDES Resolution* and determine its condition.

MSV Fennica First Scouting Trip

MSV Fennica located the ice edge in dense fog at 79°24'N, 02°55'E, and found a tightly packed mix of slush up to rotten, first-year ice, 1 to 1.5 m thick and in 20 m x 20 m blocks. There was a 100-m-wide band of scattered 10-cm x 10-cm brash ice, but no loose ice anywhere. *MSV Fennica* proceeded up to proposed site YERM-4, arriving at 0500 hr, 17 August, and found the area ice free in a 34-nmi radius at 0900, 17 August. Plans were made to finish Hole 909B (then in progress) and go immediately to proposed site YERM-4. *MSV Fennica* returned to *JOIDES Resolution*, arriving at 1500 hr, 17 August. The two Scott Polar scientists and three NDR German TV crew were transferred to *JOIDES Resolution.* Video tapes, course plots, and ice maps were reviewed to better understand ice conditions.

Hole 909B

The ship was moved 20 m north, and Hole 909B was spudded at 1019 hr, 16 August, to provide high-resolution sampling. Core 909B-1H established the water depth as 2519.1 mbsl. Cores 909A-1H to -16H were taken from 0.0 to 135.1 mbsf, with 135.1 m cored and 139.57 m recovered (103.3% recovery). APC coring was terminated after Core 909B-16H. Cores were not oriented, and heat-flow measurements were not taken. The bit cleared the rotary table at 0213 hr, 17 August, ending Hole 909B. Both beacons were recovered.

MSV Fennica Second Scouting Trip

Proposed site YERM-4 was clear of any ice, so *MSV Fennica* was directed to proceed north to proposed site YERM-1 to determine ice conditions, and map the edge of the ice pack to the northeast of *JOIDES Resolution* and proposed site YERM-3 to determine if YERM-3 was ice free. *MSV Fennica* departed *JOIDES Resolution* at 1735 hr, 18 August.

TRANSIT TO SITE 910 (Proposed Site YERM-4)

The 113-nmi transit required 10.1 hr for an average speed of 11.2 kt. The seismic survey at Site 910 started at 1248 hr, 17 August, and covered 18 nmi in 2.7 hr at 6.4 kt. A Datasonics 354B beacon (S/N 779, 14.5 kHz, 205 dB) was dropped at 1446 hr, the seismic gear was retrieved, and the ship returned to location. A backup Datasonics 354B beacon (S/N 770, 16.0 khz, 205 dB) was dropped at 1620 hr.

Hole 910A

An APC/XCB BHA was run. The PDR indicated a water depth of 567.4 mbrf, and the first core recovered only 0.30 m, which was declared to be a "water core" and donated to the paleontologists. Core 910A-1H determined the water depth to be 556.4 mbsl, and the location as 80°15.882'N, 6°35.405'E. Cores 910A-1H to -4H were taken from 0.0 to 24.5 mbsf, with 24.5 m cored and 24.05 m recovered (98.2% recovery). APC coring was terminated after Core 910-4H because it was the third core with a partial stroke and blown liner in the extremely stiff clays. Cores were not oriented because of the high latitude. The Adara temperature shoe was run on Core 910A-4H. The formation was extremely stiff, compacted, gray silty clay with scattered ice-rafted debris (IRD) pebbles.

The XCB coring assembly was run, and Core 910A-5X was taken from 24.5 to 28.7 mbsf, with 4.2 m cored and 0.21 m recovered (5.0% recovery). The 4.2-m core required 47 min to cut, and the soft formation XCB shoe was jammed with baked clay.

Negligible concentrations of biogenic methane (5 ppm) were encountered in headspace gas analyses at this depth.

An erratic current was fluctuating east to west for short periods (20 min up to 2 hr) and increasing to 1.0 kt for short periods. Sudden rip-tide-type current shifts were noted at 12-hr intervals and caused some excursions to nearly 3% of water depth. These currents could be seen as a surface disturbance at times. The air was noticeably colder near the ice, and dense fog, drizzle, rain, and heavy overcast skies were persistent as low-pressure centers passed east to west over the area.

When a high-pressure cell predominated on 19 to 20 August, the wind dropped, and the sea surface was calm.

Hole 910B

The ship was moved 20 m south, and Hole 910B was spudded at 0003 hr, 18 August, to provide high-resolution sampling. Core 910B-1H determined the water depth to be 557.0 mbsl. Cores 910B-1H to -2H were taken from 0.0 to 15.4 mbsf, with 15.4 m cored and 15.37 m recovered (99.8% recovery). APC coring was terminated after Core 910B-2H was a partial stroke. Cores were not oriented, and heat-flow measurements were not taken. Coring parameters and formation remained the same as in Hole 910A. The bit cleared the rotary table at 0332 hr, 18 August, ending Hole 910B.

Hole 910C

The ship was moved 40 m north. An RCB BHA was run with a mechanical bit release. The water depth was 556.4 mbsl. Hole 910C was spudded at 0847 hr, 18 August. Cores 910C-1R to -53R were taken from 0.0 to 507.4 mbsf, with 507.4 m cored and 293.5 m recovered (57.8% recovery). Coring was terminated because we reached the approved depth for drilling at this site. A WSTP heat-flow measurement was taken after Cores 910C-7R and -10R. The air temperature grew noticeably colder, and it snowed on 19 August.

The coring results at this site are strikingly similar to results from Prydz Bay Sites 739 and 742 on Leg 119. The clays near the seafloor were so compacted they were similar to what is normal clay compaction at a depth of over 500 mbsf. One suggestion is that the clays were compacted by ice loading during glacial periods. No better explanation has come forward.

Capillary suction tests on clays at 122, 151, and 257 mbsf indicated that the clays were drastically affected by contact with freshwater but had no noticeable reaction to 50% fresh/50% seawater, 1 or 2% KCl. Therefore, chemical inhibition of the clays during logging did not appear to be feasible.

First Ice

At 0050 hr, 20 August, an ice pack was spotted moving toward the southwest and *JOIDES Resolution* at up to 0.7 kt. *MSV Fennica* was recalled from proposed site YERM-1, with an estimated transit time of 12 hr back to *JOIDES Resolution.* The ice advanced on a 120°-wide front and was up to 5 m thick. A free-fall funnel was prepared as a precaution. The ice had advanced to within 3.8 nmi by 0630 hr but appeared to stall in a dead-calm sea. The ship's X-band (3 cm) radar was able to detect thick bergie bits at 6-nmi range. *MSV Fennica* returned to *JOIDES Resolution* at 1200 hr and determined that the ice floe was a tongue of bergie bits (3-m-high old ice). The NDR

TV crew came aboard *JOIDES Resolution* to start filming, and *MSV Fennica* took up ice patrol around *JOIDES Resolution.*

TRANSIT TO SITE 911 (Proposed Site YERM-3)

The 18-nmi transit to Site 911 required 1.75 hr for an average speed of 10.6 kt. The seismic survey started at 0200 hr, 22 August, and covered 12 nmi in 2.25 hr at 5.3 kt. A Datasonics 354B beacon was dropped at 0520 hr, the seismic gear was retrieved, and the ship returned to location.

Hole 911A

An APC/XCB BHA was run. The PDR indicated a water depth of 918.4 mbrf. Core 911A-1H established the water depth as 901.6 mbsl. Cores 911A-1H to -15H were taken from 0.0 to 139.9 mbsf, with 139.9 m cored and 141.90 m recovered (101.4% recovery). APC coring was terminated after Core 911A-15H because it was the eleventh core with a partial stroke in very stiff clays. Cores were not oriented because of the high latitude. The Adara temperature shoe was run on Cores 911A-4H, -7H, and -10H. The formation was extremely stiff, compacted, gray silty clay with scattered ice-rafted-debris (IRD) pebbles.

Cores 911A-16X to -53X were taken with the XCB from 139.9 to 505.8 mbsf, with 365.9 m cored and 322.61 m recovered (88.2% recovery). Headspace gas increased to 600,000 ppm at 50 mbsf. C1/C2 ratios of about 2000 to 4000 indicate the gas was biogenic. Gas breakout in the core liners caused considerable core disturbance, and holes had to be drilled in the liners to relieve the gas. Some slight H_2S odor was detected at 400 mbsf.

The hole was prepared for logging by circulating the hole clean at TD and making a conditioning trip to 78.9 mbsf. A bridge was reamed out at 392 m, and 28 m of fill was cleaned out to 505.8 mbsf TD. The bit was positioned at 78.9 mbsf for logging. There was a strong desire to log down to the bottom of the hole; therefore, the side-entry sub (SES) was put in the string and required 2.5 hr to rig up.

The logs were run as follows:

Log no. 1: Induction/Sonic (DITE/HLDT/SDTC/NGTC). Log to 488.6 mbsf (28 m fill) in 5.5 hr.

Log no. 2: FMS/NGTC. Found bottom at 1255 m and log up. Run in with SES to 434.0 mbsf. The FMS would not clear the bit until it was circulated free. The FMS was run to 452.6 mbsf and logged up with the SES in 2.75 hr.

Log no. 3: Geochemical. Log to 455.6 mbsf without the SES in 5.75 hr.

Soft clays were apparently closing in the hole. The SES required 1.5 hr to rig down and was used to run the FMS log 110 m deeper. The hole was displaced with heavy mud, and the bit cleared the seafloor at 1234 hr, 26 August, ending Hole 911A.

Hole 911B

The ship was moved 20 m north, and Hole 911B was spudded at 1320 hr, 26 August, to provide high-resolution sampling. Core 911B-1H established the water depth as 901.0 mbsl. Cores 911B-1H to -15H were taken from 0.0 to 112.1 mbsf, with 112.1 m cored and 112.89 m recovered (100.7% recovery). APC coring was terminated after Cores 911B-7H to -15H were partial strokes with the advance by recovery method used. Cores were not oriented, and heat-flow measurements were not taken. Coring parameters and formation remained the same as in Hole 911A. The bit cleared the seafloor at 1930 hr, 26 August, ending Hole 911B.

Hole 911C

The ship was moved 20 m north, and Hole 911C was spudded at 2000 hr, 26 August, to provide high-resolution sampling. Core 911C-1H established the water depth as 902.0 mbsl. Cores 911C-1H to -15H were taken from 0.0 to 127.9 mbsf, with 127.9 m cored and 126.07 m recovered (98.6% recovery). APC coring was terminated after Cores 911C-8H to -15H were partial strokes with the advance by recovery method used. Cores were not oriented, and heat-flow measurements were not taken. Coring parameters and formation remained the same as in Hole 911A. The bit cleared the rotary table at 0747 hr, 27 August, ending Hole 911C.

Ice Observations

MSV Fennica was sent to proposed site YERM-1 to report on the ice condition. The ice was 3-4 m thick in 20 m x 20 m blocks about 2 nmi from the location; however, the ice moved within 0.6 nmi when the current shifted to the north. The location was in a bay in the ice, and the conclusion was that *MSV Fennica* could not protect the location; therefore, a decision was made to go to proposed site YERM-2A for about 5 days to allow the ice at proposed site YERM-1 to clear more.

TRANSIT TO SITE 912 (Proposed Site YERM-2A)

The 35-nmi transit to proposed site YERM-2A required 3.6 hr for an average speed of 9.7 kt. The seismic survey at proposed site YERM-2A started at 1136 hr, 27 August, and covered 13 nmi in 2.3 hr at 5.6 kt. A Datasonics 354B beacon was dropped at 1256 hr, the seismic gear was retrieved, and the ship returned to location.

Hole 912A

MSV Fennica found some scattered ice on location and pushed it away before *JOIDES Resolution* arrived. The closest ice to the location was a 15-nmi-long by 0.1-nmi-wide ice tongue about 5.2 nmi from the location at heading 335°.

An APC/XCB BHA was run. The PDR indicated a water depth of 1048.4 mbrf. Core 912A-1H established the water depth as 1047.9 mbrf. Cores 912A-1H to -8H were taken from 0.0 to 70.5 mbsf, with 70.5 m cored and 74.80 m recovered (106.1% recovery). APC coring was terminated after Core 912A-8H because it was a very hard claystone. Cores were not oriented because of the high latitude. The Adara temperature shoe was run on Cores 912A-4H and -7H. The formation was extremely stiff, compacted, gray silty clay with scattered ice-rafted-debris (IRD) pebbles and a hard claystone on bottom.

The XCB coring assembly was run, and Cores 912A-9X to -16X were taken from 70.5 to 145.4 mbsf, with 74.9 m cored and 43.59 m recovered (58.2% recovery). The shoe of Core 912A-16X contained about 0.3 m of diorite (probably a large ice-rafted dropstone).

The ice tongue had been moving SSW at about 0.5 kt, with the current from the north and wind from the east. *MSV Fennica* attempted to push and wash the ice away from *JOIDES Resolution* with some success, but the ice tongue was too large and closing back together. *MSV Fennica* reported it could not move one ice block 20 m x 30 m x 15 m. It appeared the ice would pass along a line 0.5 nmi SSW of the ship, and at 0515, 28 August, the ice tongue approached within 1.5 nmi of the ship, moving at 0.3 kt. The bit was pulled to within one stand of the seafloor as a precaution. The ice moved SSE of the ship, stopped, reversed course again, and seemed to stall about 1 nmi north of the ship.

<u>Hole 912B</u>

Hole 912B was spudded in the interim after 1 hr of observing the ice. The ice seemed to be slowing down to 0.2 kt, which would allow enough time to core a second shallow APC hole for high-resolution studies. Core 912B-1H established the water depth as 1048.6 mbrf. Cores 912B-1H to -5H were taken from 0.0 to 40.5 mbsf, with 40.5 m cored and 41.77 m recovered (103.1% recovery). No cores were oriented because of the high latitude, and no temperatures were taken. The formation was extremely stiff, compacted, gray silty clay with scattered ice-rafted-debris (IRD) pebbles.

The ice had continued to move toward the ship at 0.2 kt despite attempts by *MSV Fennica* to push and wash it back. APC coring was terminated after Core 912B-5H because the ice moved to within

0.3 nmi of *JOIDES Resolution*, and *MSV Fennica* was unable to open a path for the ship or control the many 6 m x 2 m x 2 m blocks advancing on a 3-nmi front. One block of ice 20 m x 30 m x 15 m could not be controlled at all. Additional ice floes were seen on radar in the area.

The pipe was pulled above the seafloor at 1350 hr. *JOIDES Resolution* moved one nmi away in DP mode to monitor the ice, which stayed on the location until 1800 hr, when a decision was made to return to Site 910. The bit was pulled through the rotary table at 2017 hr, 28 August, ending Hole 912B. Two beacons were left on location because they were covered by the ice floe.

RETURN TO SITE 910

Drilling operations were halted at Site 912 because of ice floes that came over the site. Therefore, we decided to return to Site 910 to drill a special hole dedicated to geotechnical studies of the overconsolidated sequence that was discovered in Holes 910A, B, and C. The 23-nmi transit from Site 912 to Site 910 required 1.9 hr for an average speed of 12.1 kt. No seismic survey was conducted. A Datasonics 354B beacon was dropped at 2310 hr, 28 August, on the original Site 910 GPS position. Two ice floes were 3.65 nmi northwest and 4 nmi north of the location, moving northwest at 0.2 kt. Visibility was less than 1/2 nmi.

Hole 910D

An APC/XCB BHA was run. Core 910D-1H established the water depth as 556.5 mbsl. Cores 910D-1H to -3H were taken from 0.0 to 18.6 mbsf, with 18.6 m cored and 18.55 m recovered (99.7% recovery). No cores were oriented because of the high latitude, and a good temperature gradient was obtained in the A and B holes. The formation was extremely stiff, compacted, gray silty clay with scattered ice-rafted-debris (IRD) pebbles. The last two APC cores were partial strokes with advance by recovery; therefore, the XCB system was used next.

The XCB coring assembly was run, and Cores 910D-4X to -18X were taken from 18.6 to 160.6 mbsf, with 142.0 m cored and 84.91 m recovered (59.8% recovery).

TRANSIT TO PROPOSED SITE YERM-1D

At 1730 hr, 29 August, *MSV Fennica* was sent to proposed site YERM-1 to survey the ice edge and reported that proposed sites YERM-1 and -1C were in the hard pack ice again, but that new proposed location YERM-1D (10 nmi south of YERM-1) was in open water. The ODP safety panel had approved YERM-1D, but the Norwegian Petroleum Directorate (NPD) advised they would telex their decision to ODP on 30 August. Since proposed site YERM-2A was also covered by ice tongues (which were not discernible even on the SAR images), a decision was made to time the departure for proposed site YERM-1D so that we could start coring as soon as NPD approval was received.

The 34-nmi transit to proposed site YERM-4 required 3.3 hr, for an average speed of 10.3 kt. *JOIDES Resolution* passed through several ice tongues on the way and saw four seals. A 21-nmi seismic survey was conducted in 3.3 hr at 6.4 kt. A Benthos 210 beacon was dropped at 0935 hr, 30 August, on the GPS position; proposed site YERM-1D was 6-7 nmi from the ice edge, with small, brash ice rafts in the area.

PROPOSED SITE YERM-1D

An RCB BHA was run to 880 mbrf, and we waited on approval for 2 hr. We were advised at 1530 hr, 30 August, that the NPD had refused permission to core at new proposed site YERM-1D because "it lies within an area of possible closure within the sedimentary sequence, where the seismic events also exhibit a distinct brightening." The drill string was pulled, and preparations were made to go back to Site 912 (or Site 909 as an alternate).

TRANSIT TO SITE 912

The 61-nmi transit to Site 912 required 5.9 hr, for an average speed of 10.3 kt. Two ice tongues were crossed on the way. *MSV Fennica* crossed through the ice tongues 15 nmi ahead of *JOIDES Resolution*, but the ice closed in before *JOIDES Resolution* arrived, forcing it to find a lead in the ice. *MSV Fennica* reported that Site 912 was completely covered by heavy pack ice; therefore, a decision was made to go to Site 909 to core the deep RCB hole and allow the ice pack to reassemble.

RETURN TO SITE 909

The 105-nmi transit to Site 909 required 11.0 hr, for an average speed of 9.5 kt. No seismic survey was conducted. A single Datasonics 354B beacon was dropped at 1201 hr, 31 August, on the GPS position 78°35.093'N, 03°04.283'E (south and west of the original two holes).

Hole 909C

An RCB BHA was run. The water depth was 2529.0 mbrf. Hole 909C was spudded at 1638 hr, 31 August, and the hole was drilled from 0 to 85.0 mbsf. Cores 909C-1R to -103R were taken from 85.0 to 1061.8 mbsf, with 976.8 m cored and 605.4 m recovered (62.0% recovery). Heat-flow measurements taken in Hole 909A indicated a temperature gradient of 88°C. A deviation survey at 500 mbsf indicated a 10° angle, and over 17° at 800 mbsf. Logs indicated that below 600 mbsf, the hole had an almost straight azimuth of 45° (i.e., NE), at an angle that increased steadily from 14° at 600 mbsf to 25.5° at 1060 mbsf.

Headspace and vacutainer gas concentrations were measured, and the Natural Gas Analyzer (NGA) gas chromatograph was also used, owing to the occurrence of significant amounts of higher molecular weight gases. Coring was terminated following PPSP guidelines when anomalous increases in heavy hydrocarbons were detected.

Hole 909C was terminated at 1061.8 mbsf because of the following reasons:

1) Heavier hydrocarbons started to appear, with normal hexane (C6) in Core 909C-101R (1051 mbsf), and heptane (C7) in Core 909C-93R (973 mbsf).
2) Abrupt, strong increases occurred in heavy hydrocarbons (C3 to C7) in Cores 909C-97R (1019 mbsf) and -101R (1051 mbsf).
3) After treating core samples with 1,1,1-Tri-chloroethane, Core 909C-67R (730.4 mbsf) exhibited yellow fluorescence under ultraviolet light on some sample particles 20 min after being soaked. By Core 909C-101R (1052.7 mbsf), a strong light yellow "cut" fluorescence occurred, sample particles fluoresced yellow all over, and a yellow fluorescent ring was left on the sample dish. A white bluish fluorescence occurred in Cores 909C-102R and -103R.

4) A seismic reflector (thought to be acoustic basement) at 1.23 s TWT bsf was estimated to occur between 1050 and 1200 mbsf. In the cores, siltstones with increasing coarseness to 10% sand were observed interbedded with silty clay/mud and sandy silt. After Core 909C-94R (990.7 mbsf), the ROP increased from 8.5 to 6.5 min/m. At Core 909C-102R, the ROP decreased again from 7.3 to 22.0 to 33.4 min/m, and the siltstone cores became distinctly harder. The combination of events suggested a potential for penetration of successive slightly pressured permeable zones under cap-rock seals.
5) Gas was observed bleeding from pores in Core 909C-101R, and the core had a much stronger petroleum odor.
6) Kerogen slides indicated a large amount of thermally mature kerogen, and total organic carbon increased from 1.0% to 2.6%.

Resistivity logs indicated that a 7 m thick sandy unit at 931 mbsf has a 1-m, slightly permeable zone, but unprocessed resistivities never exceeded 1.5 ohm/m; therefore, liquid hydrocarbons were not evident in the hole, based on logs.

The hole had been filling rapidly. The open drill string was run to 491 mbsf, where a 150-sack (41-m-thick) plug of cement was set from 491 to 440 mbsf. The hole was also loaded with heavy mud. The BHA cleared the rotary table at 1630 hr, 11 September, ending Hole 909C.

Ice Observations

After permission to drill proposed site YERM-1D was rejected, alternate sites were proposed south of that point along Line UB 2-79. The NPD approved site YERM-1E at SP 1590 on 1 September; therefore, *MSV Fennica* was directed to proceed immediately to check out the ice conditions there. AT 1900 hr, 1 September, *MSV Fennica* reported that proposed site YERM-1 was 3 nmi inside heavy pack ice, and proposed site YERM-1C was covered by an ice tongue. Proposed site YERM-1D was clear and 6 nmi from the ice edge. The edge of the ice was 1 nmi south of proposed site YERM-1E and moving south at an average speed of 0.4 kt, with north-northwest winds. The leading edge was 0.1 nmi wide, consisting of a 30% cover of brash ice with 4-m-thick pack ice behind it. The average edge of the pack ice was 80°53'N between 6° and 8°E.

JOIDES Resolution was at Hole 909C, so *MSV Fennica* was recalled to deliver the NDR German TV crew for pickup by helicopter on 5 September. *MSV Fennica* reported an ice floe 50 nmi north-northwest of Site 909, moving southeast at 1.0 kt under a force-8 gale. The gale had northwest winds to 41 kt with a strong 1.0-kt northeast current, and the 8-nmi x 2-nmi ice floe passed 17 nmi west of Site 909 on 4 September, moving southwest at 1.0-1.4 kt.The ice floe began to disperse under the heavy winds. *MSV Fennica* was recalled to *JOIDES Resolution* to provide a pickup boat in case of an emergency with the helicopter.

Helicopter Rendezvous

The Bell 406 helicopter from Longyearbyen, Svalbard, arrived at 1118 hr, 5 September, carrying Dr. Philip Rabinowitz and John Beck from ODP, and a dynamic-positioning instructor and computer technician for *MSV Fennica*. The TV crew took videos of *JOIDES Resolution* and *MSV Fennica* from the air, and the helicopter was refueled. The helicopter departed for Longyearbyen at 1326 hr with the three TV crewmen. The four incoming personnel were transferred to *MSV Fennica*.

Ice Observations

MSV Fennica returned to ice patrol, and on 6 September reported the edge of the ice pack was 27 nmi northwest of Site 909. Site 912 was ice free, but proposed site YERM-1E was 31 nmi inside the ice edge. At 80°27'N, 7°37'E, *MSV Fennica* reported 20-m x 10-m x 6-m-thick blocks of ice, so the Scott Polar Research Institute scientists were permitted to work on the ice. *MSV Fennica* proceeded west into the ice to 80°38'N, 8°34'E, on 7 September, where it reported 50-m x 20-m x 6-m blocks of ice; therefore, the scientists were again allowed to work on the ice.

The weather started to moderate, and Hole 909C was nearing total depth; therefore, *MSV Fennica* was sent to Site 912 to report on the ice. On 8 September, at 1630 hr, *MSV Fennica* reported that Site 912 had scattered small ice on location but that it was accessible. Heavy ice with 80% cover was 9 nmi northwest, and blue ice with 10%-20% cover was 10 nmi northeast. *MSV Fennica* was sent to check proposed site YERM-5 and gather ice sediment samples. On 9 September, *MSV*

Fennica was at 79°58'N, 1°59'E, and the ice scientists were permitted to work on a 0.5-nmi x 1-nmi ice floe.

Coring operations were terminated at Site 909 on 9 September; therefore, *MSV Fennica* was sent to Site 912 and proposed site YERM-1E to check on ice conditions. At 1700 hr, *MSV Fennica* reported heavy ice 10 nmi northwest of Site 912 and small floes 9 nmi northeast of it. At 0800 hr, 10 September, *MSV Fennica* reported at 80°N, 6°37'E that proposed site YERM-1E was in heavy ice. The ice edge was at 80°50'N, 7°13'E, with a big ice tongue leading southwest. Proposed site EGM-2 was being considered for the next site because of the ice situation, but approval was granted by ODP to keep *MSV Fennica* an additional 3 days if necessary. We decided to risk a return to the ice-infested waters at Site 912 with the intention of RCB coring a deep hole. Approval had been granted to core to 1050 m at Site 912.

RETURN TO SITE 912

The 87-nmi transit from Site 909 to Site 912 required 7.75 hr, for an average speed of 11.2 kt. The site had been surveyed previously, so no seismic survey was conducted. The original Datasonics beacons were still operating, but a single Benthos 210 beacon was dropped (in case the ice returned and forced the ship off location again) at the original GPS position (south and east of Holes 912A and 912B). The two Datasonic beacons that were originally left on site were recalled and recovered. *MSV Fennica* reported that the edge of the pack ice was to the northwest, 4.9 nmi away and moving southeast at 0.3 kt. The ice consisted of heavy ice up to 4 m thick, with 100% cover and ridges 2 m high.

Hole 912C

An RCB BHA was run. The water depth was 1048.0 mbrf, and Hole 912C was spudded at 0700 hr, 12 September. The hole was drilled from 0.0 to 93.5 mbsf. Cores 912C-1R to -12R were taken from 93.5 to 209.1 mbsf, with 115.6 m cored and 5.91 m recovered (5.1% recovery). Heat-flow measurements taken in Hole 912A indicated a temperature gradient of 65.0°C.

The ice edge continued to advance to the east-southeast and at 2115 hr forced us to pull up to 60 mbsf with the ice only 1.69 nmi away, moving toward us at 0.6 kt. At 2215 hr, the ice edge had advanced to within 1.25 nmi, and the bit was pulled above the seafloor. The ice edge continued to advance, and it was obvious that the location could not be drilled; therefore the bit was pulled up to the ship, clearing the rotary table at 0120 hr, 13 September.

MSV Fennica Leaves

An ice breaker probably was not required at the next site (proposed site EGM-2), so *MSV Fennica* was called back to *JOIDES Resolution* for a final fuel-gauge check and released at 0140 hr, 13 September.

TRANSIT TO SITE 913 (Proposed Site EGM-2)

The 338-nmi transit to Site 913 required 30.6 hr, for an average speed of 11.0 kt. Five course changes were required to avoid the edge of the pack ice. Ice floes were noted near the location, and the survey course had to be altered twice to avoid ice. A 12-nmi seismic survey was conducted over the site in 1.75 hr at 6.8 kt. A Benthos 210 beacon was dropped at 1012 hr, 14 September. The survey continued for 15 nmi in 2.25 hr at 6.8 kt. The Benthos beacon had a weak signal; therefore, a Datasonics beacon was dropped at 1318 hr.

Hole 913A

An APC/XCB BHA was run. The PDR indicated a water depth of 3337.4 mbrf. Core 913A-1H established the water depth as 3330.0 mbrf. Core 913A-1H was taken from 0.0 to 4.4 mbsf, with advance by recovery. No cores were oriented because of the high latitude. The formation was unconsolidated silt with abundant large (up to 8 cm) dropstones. The APC core was a partial stroke that was stopped by the dropstones; therefore the XCB system was used to penetrate further. Core 913A-2X (4.4-9.3 mbsf) penetrated the upper layer of gravel, so the APC system was again used on Core 913A-3H. Cores 913A-3H to -5H (9.3-26.4 mbsf) recovered 17.18 m (100% recovery), but all were partial strokes. The XCB was then run for the remainder of the hole. Cores 913A-6X to -13X (26.4-103.6 mbsf) recovered 4.45 m (<5% recovery). The hole was terminated because of the slow penetration rate of the XCB system.

Hole 913B

An RCB BHA was run for Hole 913B. The water depth is 3330.0 mbsf. Hole 913B was spudded at 0828 hr, 16 September, and was washed down to 86.0 mbsf before coring began. Cores 913B-1R to -19R were taken from 86.0 to 172.7 mbsf and recovered 4.37 m (5.0% recovery). Heat-flow measurements were not taken in Hole 913A, but previous work in the area indicated a temperature gradient of about 55°C. Hydrocarbon gas was less than 10 ppm C1. Recovery was very poor again in the unconsolidated silt, and many dropstones jammed the core catcher and rotated under the bit, wiping out the fragile core pedestals before they could be caught. Permission was granted by ODP to spot core to 410 mbsf by alternately taking 2 cores and washing 5 cores. Approval was also given to core to 850 m TD and to eliminate logging in an effort to reach basement.

Spot coring was done from wash Core 913B-10W (172.7-204.0 mbsf). The pipe was stuck at 201.0 mbsf when a boulder apparently fell into the hole. The pipe was worked free without drag; therefore, washing resumed to 204.0 mbsf, where the rotary stalled at 800 amps and pump pressure increased from 200 to 2300 psi at 350 gpm (indicating that the hole had caved in). The pipe was pulled up 3 m, where normal pressure and torque were resumed. Washing operations continued from 204.0 to 220.8 mbsf. Core 913B-10W recovered 1.16 m of core.

Cores 913B-11R to -12R (220.8-240.0 mbsf) recovered 0.20 m. Wash Core 913B-13W was taken from 240.0 to 288.4 mbsf and recovered 1.38 m. Cores 913B-14R and -15R were taken from 288.4 to 307.7 mbsf and recovered 0.23 m. Wash Core 913B-16W (307.7-355.9 mbsf) and Cores 913B-17R and -18R (355.9-375.2 mbsf) did not recover any core. The silty formation was not entering the core barrel; however, a deplugger was dropped as a precaution. Wash Core 913B-19W was taken from 375.2 to 423.5 mbsf and recovered 7.16 m of core. Gas was negligible, with 20 ppm of C1 and no C2.

ODP gave approval to spot core to 490 mbsf; however, the formation changed from silty mud with dropstones to firm diatom-bearing silty claystone, and from Quaternary to middle Miocene in age. The drilling time and recovery rate both improved. Continuous RCB Cores 913B-20R to -55R were taken from 423.5 to 770.7 mbsf and recovered 205.46 m (59.2% recovery). Recovery was poor below 721.9 mbsf in unconsolidated silt interbedded with some hard carbonate-rich sandstone. Coring was terminated when time ran out. The bit cleared the rotary table at 2030 hr, 20 September, ending Hole 913B.

Daily position reports were sent via radio telex to the Forsvars Ministeriet in Greenland.

TRANSIT TO REYKJAVIK

The 871-nmi transit to Reykjavik, Iceland, required 80.5 hr for an average speed of 10.8 kts in good weather with a following current. The first line ashore at Sundahofn Pier 411 was at 0700 hr, 24 September 1993, ending Leg 151.

OPERATIONS SUMMARY
LEG 151

	Days
Total Days (24 July 1993 to 24 September 1993)	61.0
Total Days in Port	4.7
Total Days Underway	18.0
Total Days on Site	38.4

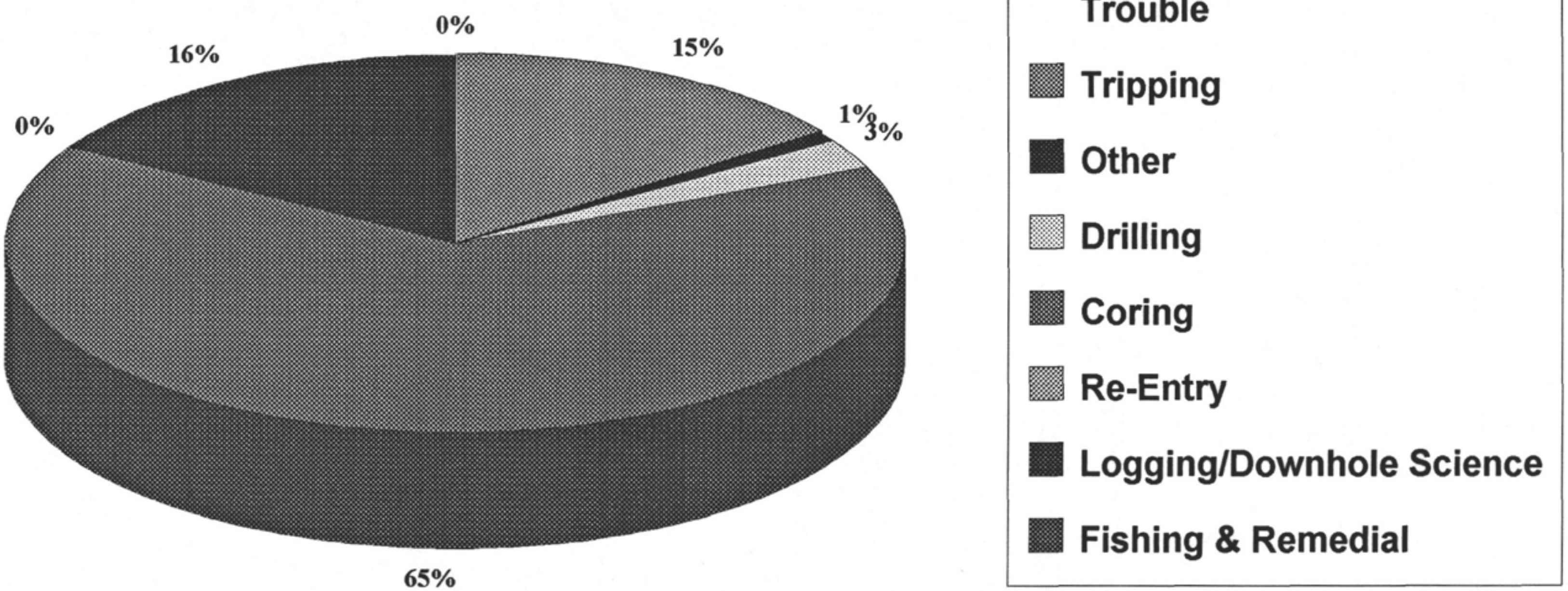
	Days
Stuck Pipe/Downhole Trouble	0.1
Tripping	5.7
Other	0.3
Drilling	1.0
Coring	24.9
Re-Entry	0.0
Logging/Downhole Science	6.2
Fishing and Remedial	0.0
Repair Time (ODP)	0.0
Development Engineering	0.0
Repair Time (Contractor)	0.0
W.O.W.	0.3
Casing and Cementing	0.0

Total Distance Traveled (nmi)	4307.0
Total Miles Transited	4187.0
Average Speed Transit (kts)	10.4
Total Miles Surveyed	120.0
Average Speed Survey (kts)	6.5
Number of Sites	7.0
Number of Holes	18.0
Total Interval Cored (m)	4210.8
Total Core Recovery (m)	3004.6
% Core Recovery	71.4
Total Interval Drilled (m)	457.5
Total Penetration	4668.3
Maximum Penetration (m)	1061.8
Maximum Water Depth (m from drilling datum)	3330.0
Minimum Water Depth (m from drilling datum)	567.4

SITE SUMMARY - LEG 151

Hole	Latitude	Longitude	Water Depth (mbsl)	Number Of Cores	Interval Cored (m)	Core Recovered (m)	Percent Recovered (%)	Drilled (meters)	Total Penetration (m)	Time On Hole (hr)	Time On Site (days)
907A	69°14.989'N	12°41.894'W	1800.83	26	224.1	229.98	102.6	0.0	224.1	65.25	2.72
		Site 907 Total		26	224.1	229.98	102.6	0.0	224.1	65.25	2.72
908A	78°23.112'N	01°21.637'E	1273.52	47	344.6	313.96	91.1	0.0	344.6	74.75	3.11
908B	78°23.125'N	01°21.644'E	1273.02	10	83.4	78.01	93.5	0.0	83.4	9.25	0.39
		Site 908 Total		57	428.0	391.97	91.6	0.0	428.0	84.00	3.50
909A	78°35.065'N	03°04.378'E	2519.04	11	92.5	94.78	102.5	0.0	92.5	17.00	0.71
909B	78°35.074'N	03°04.380'E	2519.12	16	135.1	139.57	103.3	0.0	135.1	16.75	0.70
909C	78°35.096'N	03°04.222'E	2517.71	103	976.8	605.40	62.0	85.0	1061.8	268.50	11.19
		Site 909 Total		130	1204.4	839.75	69.7	85.0	1289.4	302.25	12.59
910A	80°15.882'N	06°35.405'E	556.38	5	28.7	24.26	84.5	0.0	28.7	8.98	0.37
910B	80°15.876'N	06°35.451'E	556.98	2	15.4	15.37	99.8	0.0	15.4	3.75	0.16
910C	80°15.896'N	06°35.430'E	556.38	53	507.4	293.49	57.8	0.0	507.4	93.50	3.90
910D	80°15.881'N	06°35.424'E	556.54	18	160.6	103.46	64.4	0.0	160.6	28.25	1.18
		Site 910 Total		78	712.1	436.58	61.3	0.0	712.1	134.48	5.60
911A	80°28.466'N	08°13.640'E	901.58	53	505.8	464.51	91.8	0.0	505.8	98.00	4.08
911B	80°28.476'N	08°13.636'E	900.98	15	112.1	112.89	100.7	0.0	112.1	7.00	0.29
911C	80°28.485'N	08°13.637'E	902.01	15	127.9	126.07	98.6	0.0	127.9	12.25	0.51
		Site 911 Total		83	745.8	703.47	94.3	0.0	745.8	117.25	4.89
912A	79°57.557'N	05°27.360'E	1036.76	16	145.4	118.39	81.4	0.0	145.4	20.75	0.86
912B	79°57.533'N	05°27.397'E	1037.45	5	40.5	41.77	103.1	0.0	40.5	10.75	0.45
912C	79°57.523'N	05°27.363'E	1036.62	12	115.6	5.91	5.1	93.5	209.1	24.50	1.02
		Site 912 Total		33	301.5	166.07	55.1	93.5	395.0	56.00	2.33
913A	75°29.344'N	06°56.830'W	3318.62	13	103.6	26.44	25.5	0.0	103.6	24.50	1.02
913B	75°29.356'N	06°56.810'W	3318.43	55	491.3	210.29	42.8	279.0	770.3	187.25	7.80
		Site 913 Total		68	594.9	236.73	39.8	279.0	873.9	211.75	8.82
		LEG 151 TOTAL		**475**	**4210.8**	**3004.55**	**71.4**	**457.5**	**4668.3**	**970.98**	**40.46**

LEG 151
ON-SITE TIME DISTRIBUTION



ALL OTHER CATEGORIES < 1 DAY

TECHNICAL REPORT

The following ODP Technical and Logistics personnel were aboard *JOIDES Resolution* for Leg 151 of the Ocean Drilling Program:

Laboratory Officer:	Bill Mills
Assistant Laboratory Officer, X-Ray, Underway:	"Kuro" Kuroki
Marine Laboratory Specialist/Curatorial Representative:	Erinn McCarty
Marine Computer Specialist/System Manager:	Matt Mefferd
Marine Computer Specialist/System Manager:	Cesar Flores
Marine Computer Specialist /Yeoperson:	Jo Claesgens
Marine Laboratory Specialist/Chemistry:	Dennis Graham
Marine Laboratory Specialist/Chemistry:	Anne Pimmel
Marine Laboratory Specialist/Photography:	Brad Cook
Marine Laboratory Specialist/Physical Properties:	Jon Lloyd
Marine Laboratory Specialist/Storekeeper, Thin Sections:	Tim Bronk
Marine Laboratory Specialist/Magnetics:	Margaret Hastedt
Marine Laboratory Specialist/Underway, Fantail:	Dwight Mossman
Marine Laboratory Specialist/Downhole Measurements:	Jaque Ledbetter
Marine Laboratory Specialist/X-Ray Laboratory, Paleontology:	Wendy Autio
Marine Electronics Specialist:	Mark Watson
Marine Electronics Specialist:	Bill Stevens

INTRODUCTION

The objective of Leg 151 was to understand the paleoceanography of the Arctic Gateways area and its influence upon global climate and oceanic systems. Leg 151 cored 7 sites (18 holes) in 4 remote geographic regions above the Arctic Circle (Yermak Plateau, Fram Strait, East Greenland Margin, and Iceland Plateau). At 80.28°N, Site 911 became the highest latitude site cored by either DSDP or ODP.

JOIDES Resolution departed St. John's, Newfoundland, on 29 July 1993 with a crew of 110 (48 scientists and staff). Leg 151 ended in Reykjavik, Iceland, on 24 September after 57 days at sea. Because we would be operating in a remote region along the edge of the Arctic Ice Cap, The Ocean Drilling Program contracted with the Norwegian company Ugland Offshore to provide an ice escort vessel. On 16 August we rendezvoused with the Finnish icebreaker *MSV Fennica. MSV Fennica* mostly monitored ice conditions and movement. In addition to her ice escort duties, *MSV Fennica* supported two ice researchers from the Scott Polar Institute. The objective of their research was to correlate satellite telemetry with ice conditions at the surface.

PORT CALL, ST. JOHN'S

On 24 July 1993, *JOIDES Resolution* docked in St. John's, ending Leg 150. The following morning, the Leg 151 crew arrived and commenced with laboratory crossovers. During the remainder of the 6-day port call, Leg 150 freight was discharged and Leg 151 supplies were loaded. Stevedores handled all of the freight, which slowed down normal operations. All shipping activities were completed before departure. Other port-call activities included the re-upholstering of half the science lounge furniture and service calls from three vendors: Zeiss (general microscopes maintenance), 2G (cryogenic magnetometer helium refill and installation of the un-nested demagnetization coils), and Fisons (XRF repair).

SUMMARY OF UNDERWAY OPERATIONS

Technicians routinely collected bathymetric and magnetic data on all transits and site surveys. For site surveys, either the 80-in.^{3} or 200-in.^{3} water guns were used, depending on sediment thickness and water depth. Navigational data were acquired via GPS and plotted using either "pscoast" or "gmttrack" software on the SUN Sparc workstation.

Underway Geophysical Data: (all values are approximate and reported in nmi)

Total Transit:	4316
Bathymetry:	3600
Magnetics:	3500
Seismics:	50

SUMMARY OF ON-SITE OPERATIONS

Laboratory activities were typical for a high-resolution, paleoenvironmental leg. The pace of core processing was highly variable and depended not only on water depth but on the ability to recover glacio-marine sediments with dropstones. Shallow-water APC coring on the Yermak Plateau nearly swamped the core laboratory. In contrast, the abundance of dropstones and deep water at Iceland Plateau and Greenland Margin sites made for low recovery and a slower pace.

SPECIFIC LABORATORY OPERATIONS

Core Laboratory

Temperatures generally remained above freezing throughout most of August and into the first week of September, and the tarps stayed off. When temperatures started to remain below freezing, the wall tarps were replaced. The wash-down hoses occasionally froze but were thawed by allowing them to slowly drip. The catwalk was liberally dosed with salt to prevent icing.

While installing open grating over the catwalk drain, we discovered that some of the bolts had rusted completely away. Further inspection of the rest of the catwalk showed that this was true for all but a few bolts. The Captain instructed his crew to replace these bolts and remove 9 years' worth of paint accumulation on the catwalk. The superstructure under the catwalk deck still needed attention.

Inside the core laboratory, the rack extension was set up to handle the high-recovery sites. Also, a floor heater was placed under the core rack to assist the cores in warming up to room temperature.

Physical Properties Laboratory

A number of changes were made to the MST track at the beginning of Leg 151. Since the installation of the Natural Gamma System, and the subsequent extension of the track and chain, there have been many track problems. To resolve these problems, the track was shortened by 28 in., and the stepping motor was moved to the opposite end. This shortened the length of chain that was under tension by at least 20 ft. This one modification, along with fine-tuning the optical encoder's power supply, nearly fixed all track problems. Occasionally, problems occurred with slippage between the drive shaft and drive sprocket. In addition to these modifications, a new C-137 source and shielding for the GRAPE was installed. The old source was returned to TAMU for disposal.

The ODP shear vane was finally computerized and tested on the last site of this leg. A LabVIEW program was used to acquire data from the two optical encoders. Data were stored as a text file, but a 4th Dimension database is planned.

Magnetics Laboratory

Overall, the cryogenic magnetometer performed well, gathering data on approximately 300 cores and 75 discrete samples for a grand total of over 2100 runs. The new un-nested demagnetization coil installation proved successful and provided excellent pass-through data at double the previous demagnetization levels. Software revisions were made to add utility and convenience to present programs. Because of the reasonably high recovery, the other equipment in the laboratory saw little use.

Curation

This leg was typical for high-resolution paleoenvironment legs, having more requests for samples than could be taken. Many of the sample requests were either deferred to shore or reduced to pilot studies. Nevertheless, over 30,000 samples were taken.

A dedicated hole of whole-round cores was drilled to study the effects of ice loading. These cores will be processed at LDEO by Dr. Frank Rack.

The usual problems occurred with gassy cores. Drilling numerous holes in the liner and allowing the cores to degas on the catwalk before cutting them into sections minimized most of the problems. On extremely cold days, hacksaws were used to cut the core into sections; otherwise, using the core cutters would cause the liners to shatter.

X-Ray Laboratory

The XRF was used extensively during this leg. After the service call in St. John's, goniometer 2 was calibrated for major elements on fused beads, and major elements on pressed pellets. It was not calibrated for trace-element analysis because the Leg 151 shipboard scientists did not require these data. Eight major-element samples were analyzed on fused beads for basement rocks, and 350 major-element analyses were performed on pressed-pellet sediment samples taken with a sampling frequency of 1 sample per core. Using the new XRF software, minimal matrix corrections (usually two per element) on these pressed pellets were very good and very repeatable.

Problems with goniometer 2 still existed and a service call was scheduled for Reykjavik. In spite of this one problem, the results of the hardware and software upgrades were encouraging.

Approximately 100 samples were run on the XRD. The XRD was used primarily by the organic geochemist on some of the carbonate samples and occasionally by other members of the scientific party to aid in mineral identification.

Chemistry Laboratory

In addition to the routine interstitial water analyses (90+ analyzed), an extensive inorganic and organic carbon study was conducted using the CNS (1000+), Coulometer (1000+), Rock-Eval (111+), and GHM (40+).

The Carle and NGA were used during this leg to provide real-time safety monitoring of the volatile hydrocarbons. Measurements were recorded on the routine "Opsgas" templates and a new template (designed by Dr. Stein) that provides analyses of C1/C2 vs. temperature.

Although, the Rock-Eval produced excellent S1 and S2 values, the S3 peak was lost early in the leg because of a faulty valve actuator. Dr. Stein prepared a short report comparing the results and use of the Rock-Eval and the GHM, and will prepare a more extensive report in the near future.

After departure from St. John's, an acceptable level of water quality (below 15 MOhms) could not be achieved, despite replacing the membrane and the three Nanopure cartridges. A strong chlorine smell was coming from both the reject water and the water in the ROpure tank. The high chlorine content in the feed water was probably responsible for the poor water quality. The Chief Engineer reported that the St. John's water had been given an extra heavy dose of chlorine. Water quality slowly improved on its own accord after the switch from St John's water to ship's water.

Paleontology Laboratory

The paleontology laboratory and microscope laboratory saw heavy use this cruise with seven paleontologists. For the most part, the laboratory functioned smoothly, with most of the supplies having been used by the paleontologists in adequate numbers, except for Norland Optical Adhesive, which was resupplied during the helicopter rendezvous. The IEC centrifuge was repaired with new brushes but failed to produce more than 2500 rpm. A new Marathon 6 centrifuge was ordered as a replacement.

Thin-Section Laboratory

A total of 37 thin sections were made, consisting of a variety of dropstones ranging from basalts to sandstones, coral, and laminated sediments (that required the impregnation). All the equipment worked well.

Microscopes

The microscopes performed well with the usual minor difficulties. During the St. John's port call, all microscopes received a thorough cleaning from the Zeiss service representative. The ocular head from one of the photomicroscopes was in need of repair and was hand carried back for repairs. It was to have been returned for Leg 152.

Shipboard Computer System

The shipboard computer system, as a whole, performed satisfactorily throughout the leg with the notable exception of ship-to-shore communications. The high latitudes of our sites placed us outside the normal Marisat range. About twice a day, for about 30 min, the satellite signal was strong enough for us to connect to the shore-based computer and transfer files, provided the seas were calm.

The partial loss of the Marisat system would not have been a major problem, because radio telex was still available for general text messages. Unfortunately, only the Marisat system could transfer large satellite images and their interpretation files. These files were needed to evaluate the surrounding ice conditions for planning drilling operations. A considerable amount of effort on the part of ship and shore personnel was needed to keep the ship supplied with this crucial information.

Shipboard Library

Some paleontological reprints are missing or not available. Many paleontology textbooks that are not used for regular taxonomic identification and biostratigraphy were moved to the library and were replaced with ODP *Scientific Results* volumes. Also, the old DSDP bound reprint collection in the library was sorted. About half of these volumes were packed for shipment to shore, as they are no longer useful on board. The other half, which contain many paleontological reprints for most fossil groups, were moved to the paleontology laboratory, where they are more accessible and visible to the scientists. During Leg 153, unbound reprints in the library will be shipped back to ODP to be bound in volumes and also placed in the paleontology laboratory.

Downhole Measurements Laboratory

Except for two sites, there was little scientific interest in heat-flow measurements. At least three temperature points at each site were routinely taken to establish the local thermal gradient. This information was used by the Operations Superintendent to monitor hydrocarbon safety. No in-situ water samples were taken.

Underway Geophysics Laboratory and Fantail

Eight short site surveys were made this leg with no major equipment failures due to the Arctic cold. We were prepared to set up the fantail for towing gear in ice-covered water, but this situation never occurred. The Captain kept the ship clear of the ice.

The starboard seismic and the port level winds initially jammed when they overran the end-of-run sensors. This was fixed by slowing down the maximum slew speed.

The AGCNav (real-time navigation software) was successful. The visual feedback of the ship's position is a great aid in providing accurate site surveys. At the last site, one of the Masscomps failed. Spare parts were to be hand-carried to the ship.

Photo Laboratory

Operations were routine except for the photographer's short excursion to the *MSV Fennica* to assist John Beck with public relations shots. The Kreonite processor was partially overhauled, and other minor maintenance projects were completed.

MISCELLANEOUS

The auxiliary A/C had to be switched off because it was sucking in cold air. This reduced the lab stack air pressure, and cold air was drawn through all the doors instead. Upon closer inspection of the auxiliary A/C, we discovered that the unit had an electric heater, which had never been wired up. The ship's electricians wired the unit to power and turned it on.

The plywood floor in the hold loft (the Bat Cave) was replaced with open Fibergrate decking.

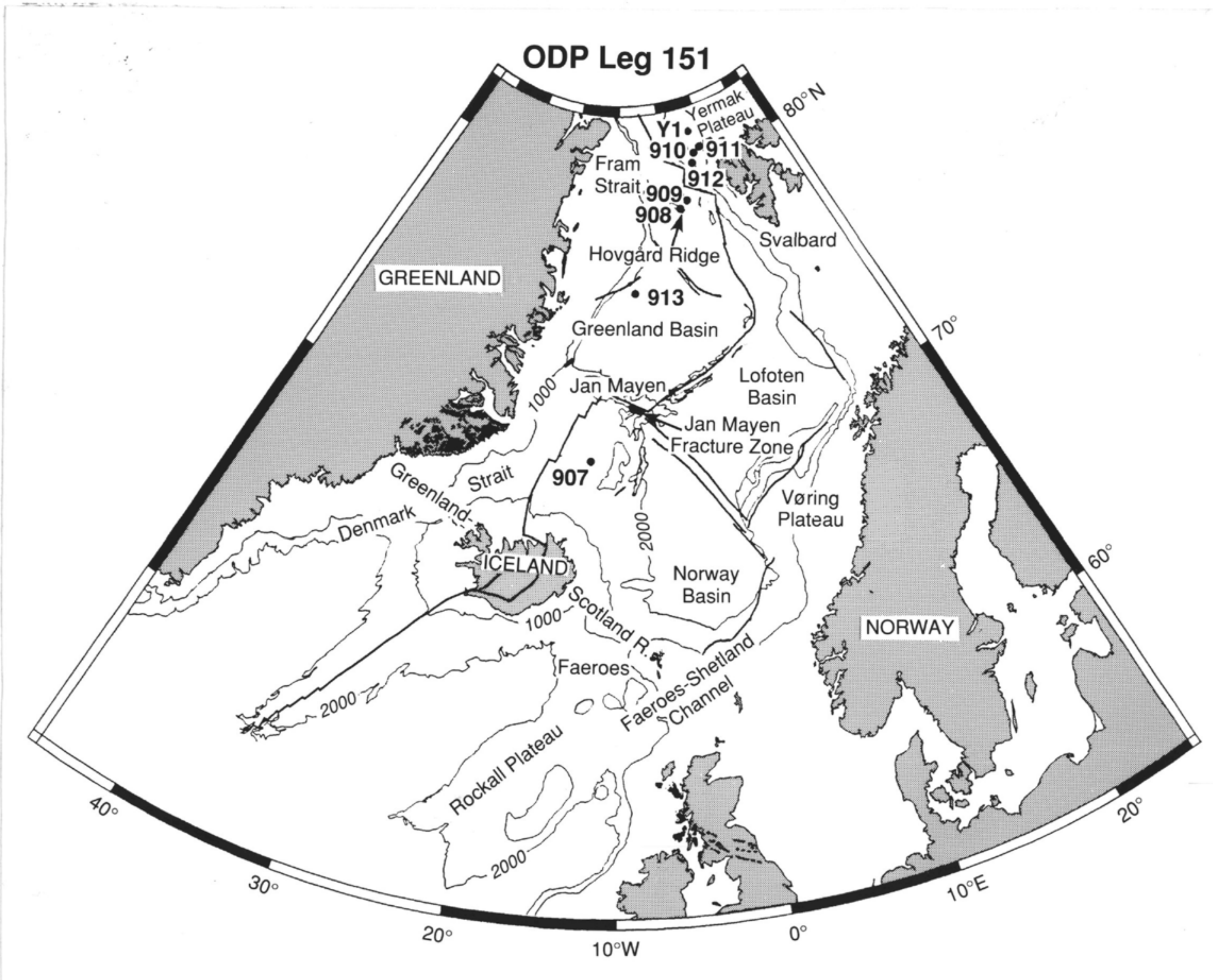


Figure 1. Location of Leg 151 drill sites. Y1 = proposed site YERM-1.

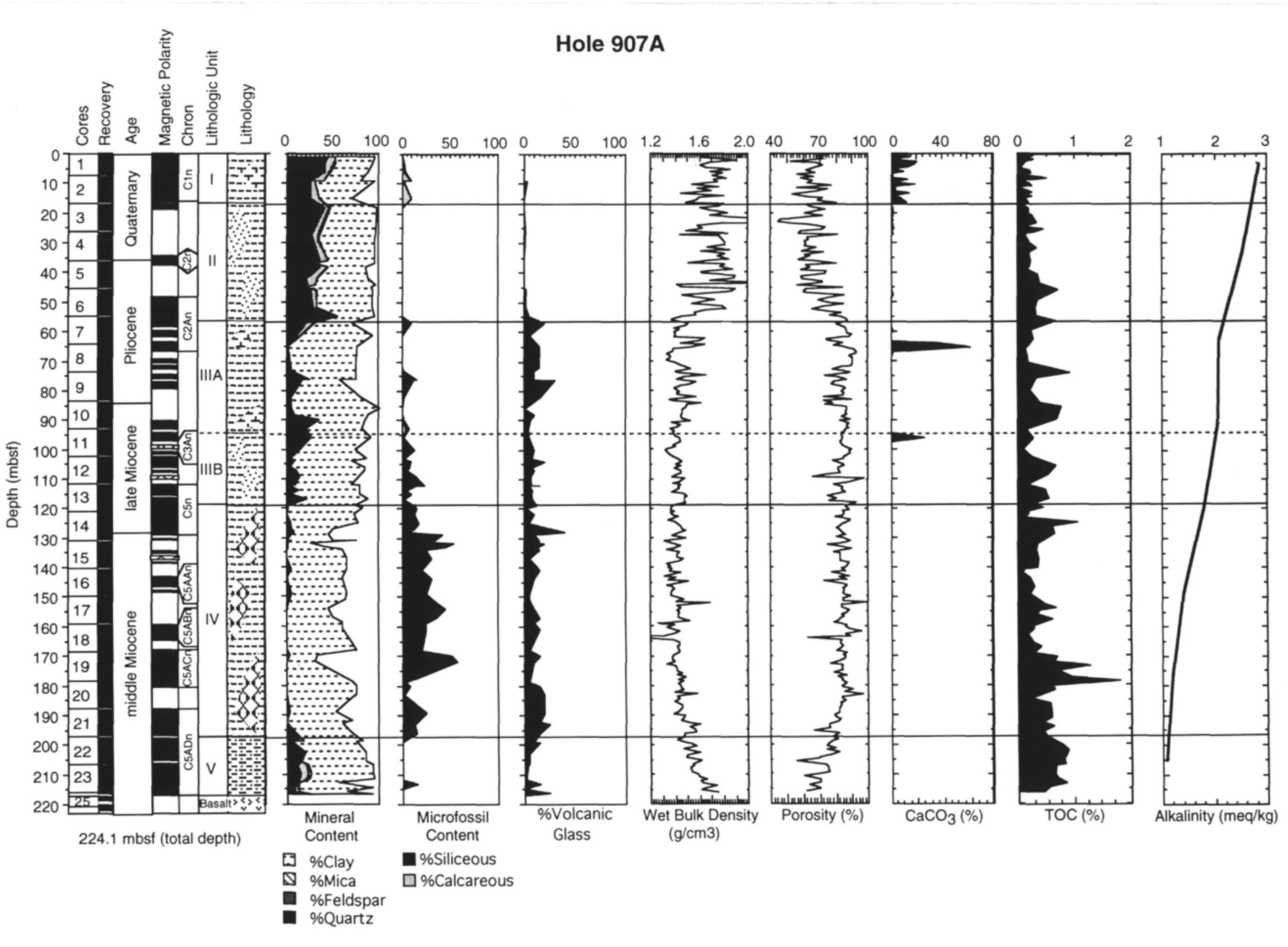


Figure 2. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 907.

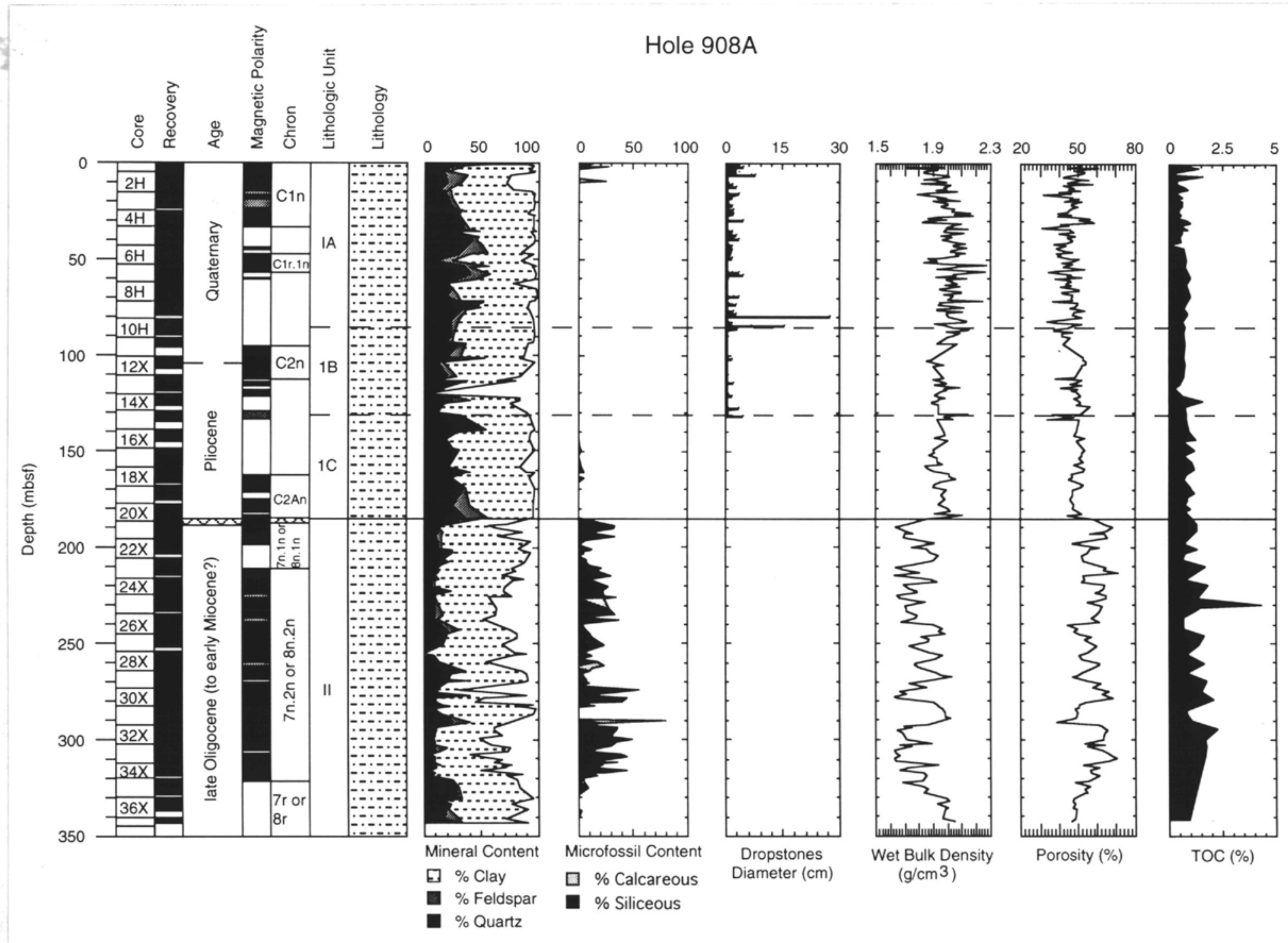


Figure 3. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 908.

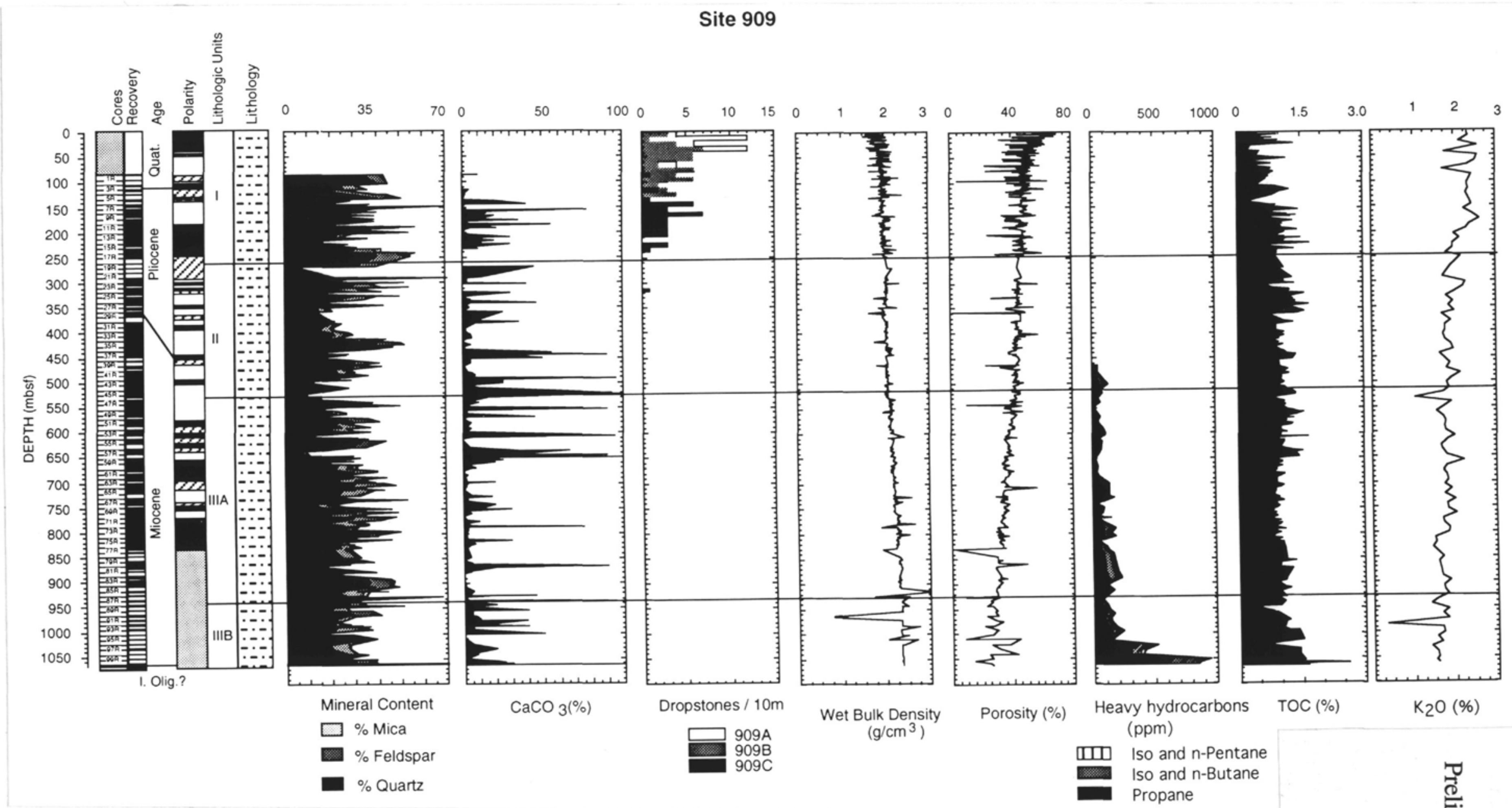


Figure 4. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 909.

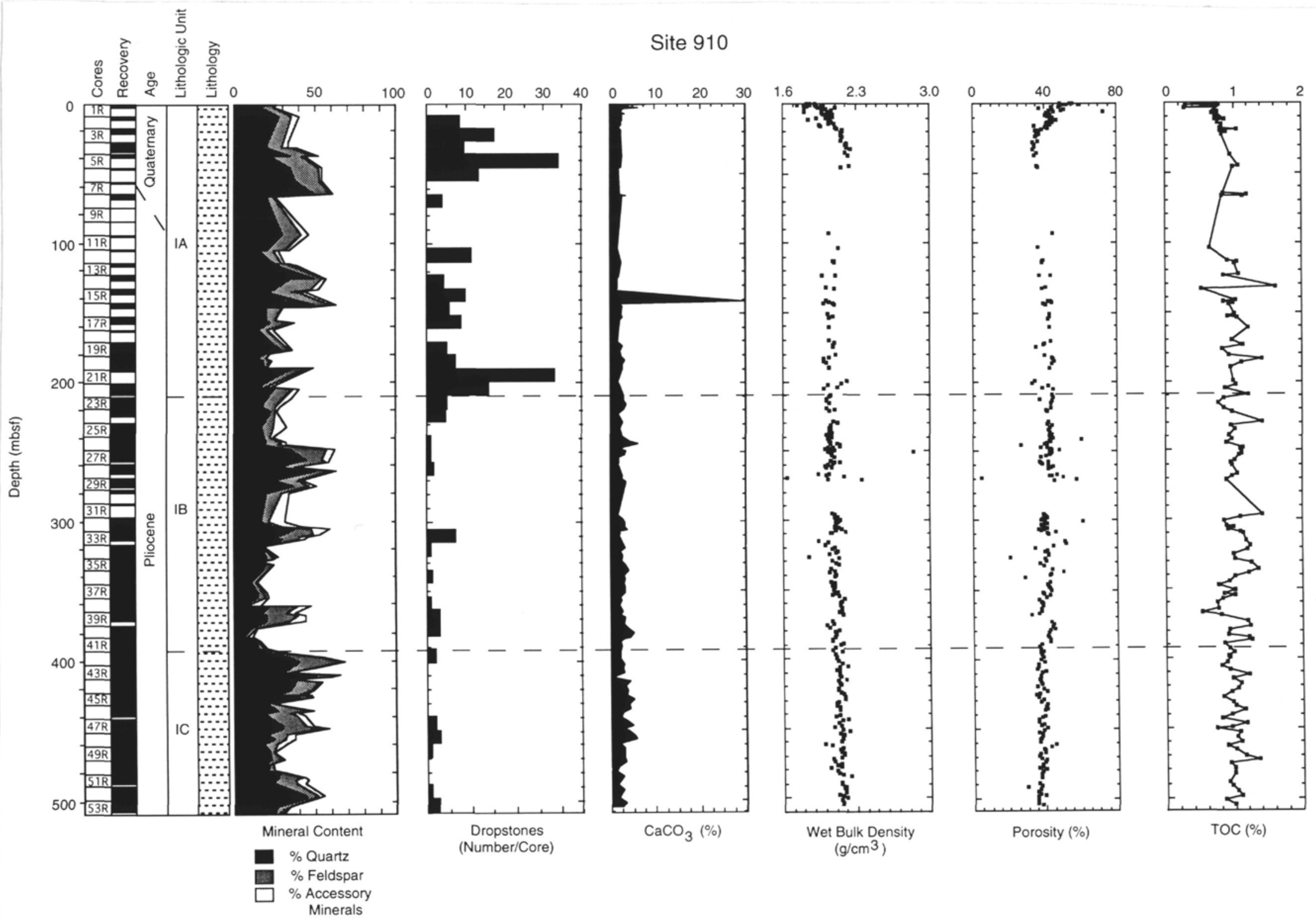


Figure 5. Summary of core recovery, age, lithologic units, sediment components, physical properties, and chemistry of Site 910.

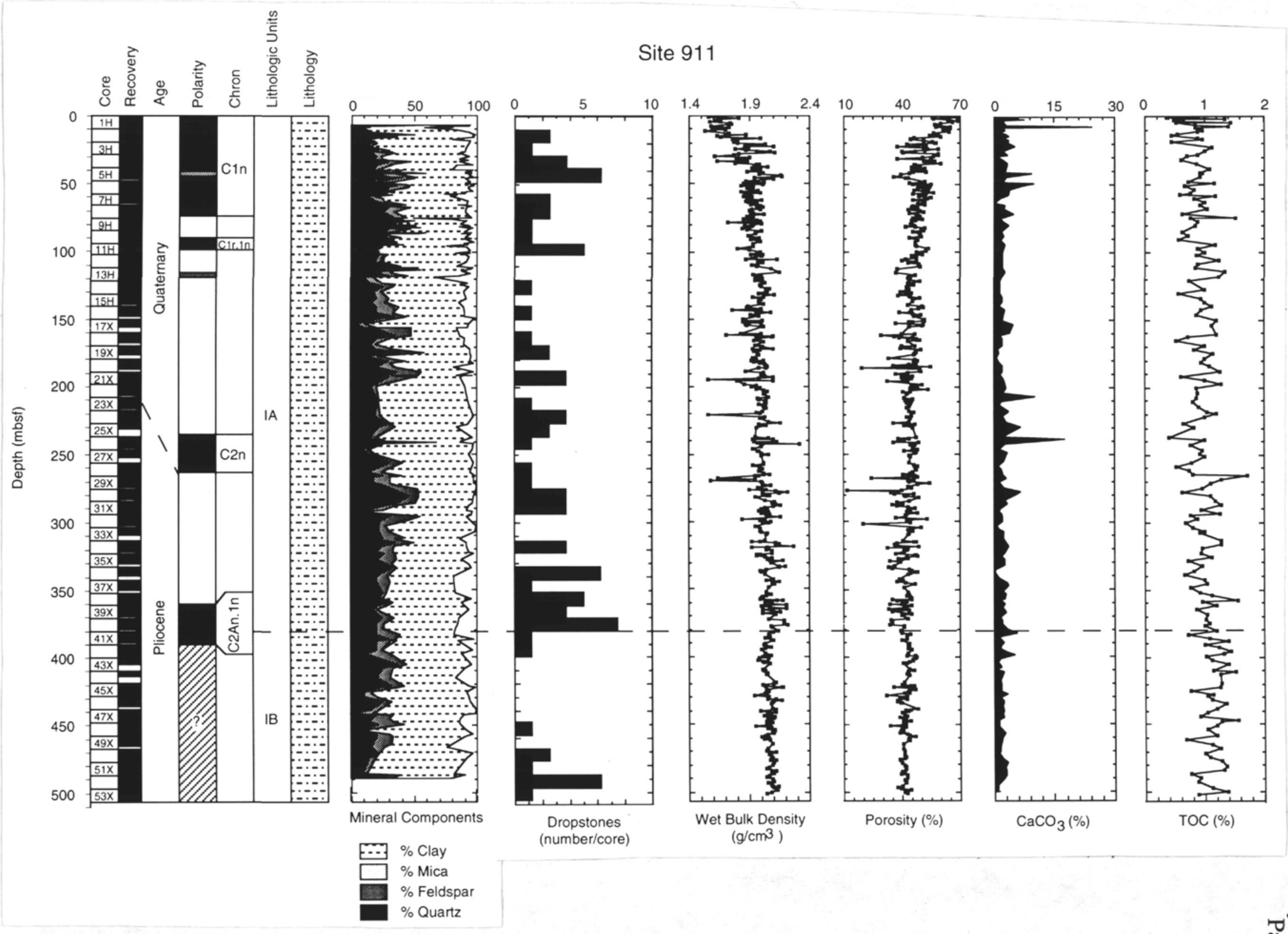


Figure 6. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 911.

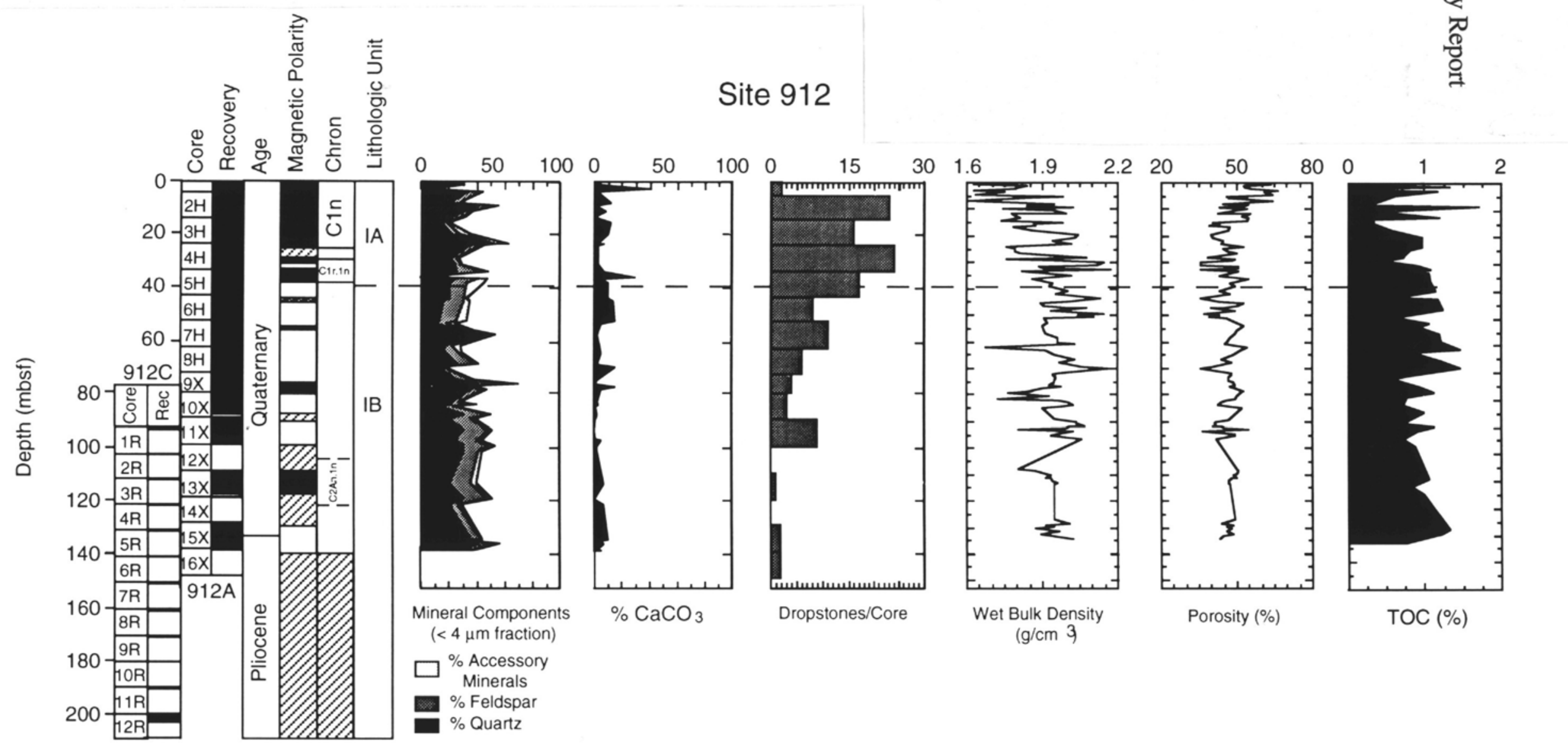


Figure 7. Summary of core recovery, age, polarity reversal stratigraphy, lithologic units, sediment components, physical properties, and chemistry of Site 912.

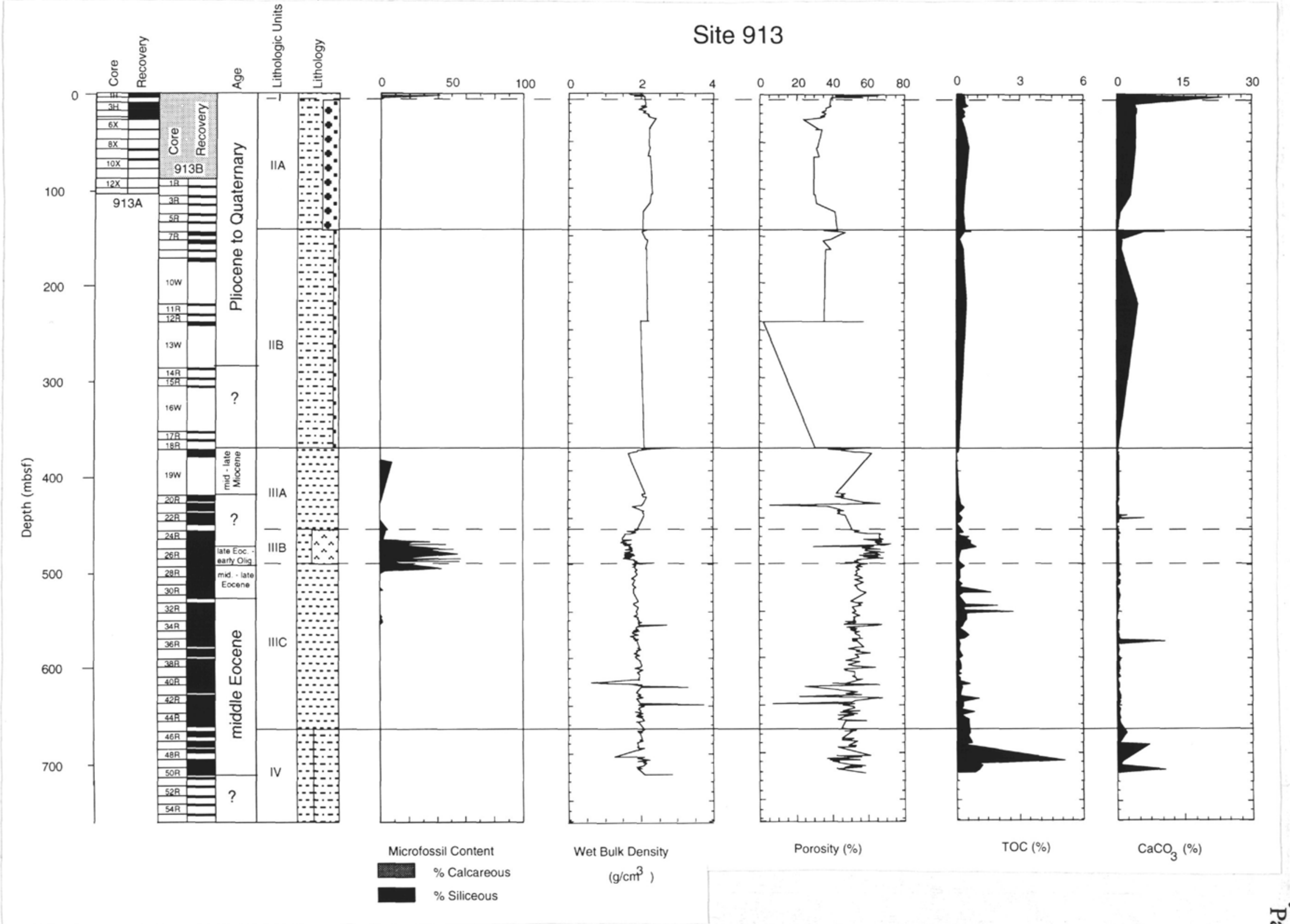


Figure 8. Summary of core recovery, age, lithologic units, sediment components, physical properties, and chemistry of Site 913.