# 9. SITE 631: EXUMA SOUND[1]

Shipboard Scientific Party[2]

## HOLE 631A

**Date occupied:** 23 February 1985, 1115 EST

**Date departed:** 24 February 1985, 2115 EST

**Time on hole:** 1 day, 10 hr

**Position:** 23°35.2′N, 75°44.56′W

**Water depth (sea level; corrected m, echo-sounding):** 1081

**Water depth (rig floor; corrected m, echo-sounding):** 1091

**Bottom felt (m, drill pipe):** 1102

**Total depth (m):** 1346.3

**Penetration (m):** 244.3

**Number of cores:** 25

**Total length of cored section (m):** 244.3

**Total core recovered (m):** 159

**Core recovery (%):** 65.1

**Oldest sediment cored:**
Depth sub-bottom (m): 244.3
Nature: chalk and ooze with bank-derived aragonite
Age: Oligocene–Miocene
Measured velocity (km/s): approximately 1.9 from physical-property measurements, 1.9 from nearby sonobuoy

**Principal results:** Site 631 in Exuma Sound was occupied on 23 and 24 February 1985. One hole was drilled at 23°35.20′N, 75°44.56′W, in a water depth of 1081 m. A total of 244 m of sediment was penetrated with hydraulic-piston-core/extended-core-barrel (HPC/XCB) techniques; recovery was 65%.

Site 631, representing the upper end of the slope transect in Exuma Sound, is located on a 1600-m-high, 10°–12° slope (as compared with a 900-m height and a 2°–3° declivity at Site 630). The following sequence was penetrated: (1) 0–24 m sub-bottom; periplatform carbonate ooze, alternations of greenish, organic-rich and white, lean intervals, strong odor of hydrogen sulfide, Quaternary; and (2) 24–244 m sub-bottom; chalk with some ooze, rich in bank-derived aragonite, pyrite, and odor of hydrogen sulfide, Oligocene–Miocene to early Pliocene.

Even though bypassing by sandy turbidity currents was almost complete and no turbidites were observed in the section, sedimentation rates were high (30–75 m/m.y.). Rapid burial of organic matter led to sulfate reduction in the subsurface and to abundant production of hydrogen sulfide throughout the sequence.

Diagenesis of periplatform ooze was very rapid. Four-million-year-old sediment having 100 m of overburden is nearly completely lithified to chalk, and some primary aragonite remains to drive the cementation process even further.

## BACKGROUND AND OBJECTIVES

### Background

#### *Shallow Stratigraphy: Development of a Bypass Carbonate Slope*

As described in detail in the Site 627 chapter, previously collected geological and geophysical data from carbonate slopes suggest that these slopes steepen with time, are characterized by facies belts that generally parallel bathymetric contours, and respond differently from their siliciclastic counterparts to relative changes in eustatic sea level (Mullins and Neumann, 1979; Schlager and Ginsburg, 1981; Van Buren and Mullins, 1983; Mullins et al., 1984; Droxler et al., 1984).

Sampling of the northern slope of Little Bahama Bank (Sites 627, 628, and 629/630) was designed to document the evolution of a gentle, rapidly prograding slope, generally characterized by a 2°–3° declivity and less than 800–900 m of height. In particular, this first slope transect of ODP Leg 101 compared the upper gullied slope (Site 630) with both the upper rise at toe-of-slope (Site 628) and the lower rise far from nonpelagic input except for scattered distal turbidites associated with periods of bank progradation (Fig. 2, Site 627 chapter).

The second Leg 101 slope transect in Exuma Sound was intended to contrast development of a carbonate slope characterized by a 10°–12° declivity and 1600 m of height where bypassing was expected to be far more advanced than at the northern slope of Little Bahama Bank. In addition, Exuma Sound drilling would allow a direct comparison of the effects of a protected vs. open-ocean (Little Bahama Bank) depositional setting on the response of these slopes to presumably synchronous sea-level events. Specifically, BAH-11-A (Site 631), like Site 630, was designed to sample the upper, gullied portion of the slope, where bypassing of bank material should be most complete.

[1] Austin, J. A., Jr., Schlager, W., Palmer, A. A., et al., 1986. *Proc., Init. Repts. (Pt. A), ODP*, 101.

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Previous submersible observations, along with piston coring and high-resolution seismic surveys, of a similar slope in the Tongue of the Ocean had indicated the presence of many small, erosional channels separated by irregular interfluves composed of periplatform ooze (Schlager et al., 1976; Mullins and Neumann, 1979), but the dynamics of downslope sediment transport were still poorly understood without three-dimensional facies control. Drilling would supply this information on the third dimension.

BAH-11-B (Site 633), in tandem with Site 628, would examine the toe-of-slope environment and sample the sediments that had bypassed the upper, steep slope in sediment gravity flows.

Finally, BAH-11-C (Site 632) would document the record of rapidly deposited ooze-turbidite sequences within an enclosed basin, in contrast to the open-ocean rise environment prevailing at Site 627. The ultimate goal of all three Exuma Sound sites was to define a sediment budget for a Bahamian deep embayment and to relate it to its various forcing functions through time: sea level, climatic fluctuations, carbonate-bank productivity, and regional tectonism.

### *Deep Stratigraphy: Platform Drowning and Regional Seismic Correlations*

The second major goal of drilling in Exuma Sound was to continue to calibrate local seismic stratigraphic frameworks developed for various parts of the Bahamas in order to develop viable regional correlations (Sheridan et al., 1981; Van Buren and Mullins, 1983; Schlager et al., 1984). Site 632 (BAH-11C) was selected for this purpose and was designed to provide an understanding of the evolution of the present bank-trough configuration of the carbonate platform in order to differentiate between "megaplatform" and "graben" hypotheses (see "Background and Objectives," Site 626 chapter). As was the case at Site 627, a velocity discontinuity (from 4.1 to 6.7 km/s) had been identified beneath parts of Exuma Sound. At BAH-11-C, this acoustic unconformity/velocity boundary occurred at a two-way traveltime of approximately 3.6 s, translating to a sub-bottom depth of about 1300 m (see "Seismic Stratigraphy" section, Site 632 chapter). Unfortunately, these deep objectives could not be addressed, as drilling had to be abandoned at 240 m for safety reasons.

In order both to characterize the thickness and structure of the Exuma Sound sedimentary section in greater detail and to supplement the available seismic data in the region for evaluations of drilling safety, UTIG conducted a 325-n. mi geophysical site survey of southeastern Exuma Sound in April 1984 (Fig. 1). Spacing of 24-trace, 12-fold water-gun seismic-reflection profiles averaged 2 n. mi on the slopes, and northeast-southwest-trending dip lines at similar spacing were collected from one side of the basin to the other. All sites in Exuma Sound (Fig. 1) were chosen on the basis of isopach and structure maps developed from these profiles (and sonobuoys).

## Objectives

In summary, the Exuma Sound transect was intended to address the following questions:

1. What are the variations in development of a steep bypass slope and adjacent basin fill, particularly with respect to relative input from pelagic vs. shallow-water, bank-derived sediment sources (i.e., gravity flows and turbidites)? What do the resultant facies patterns look like both horizontally and vertically? (For example, does the geologic record of such a gullied slope resemble a series of channel fills analogous to those left behind by accreting tidal flats, or is it simply a section of periplatform ooze?) Finally, how does the sediment record compare and contrast with Sites 627, 628, and 630 north of Little Bahama Bank?
2. How does Exuma Sound respond to paleoceanographic events? Does it react differently, either in timing or degree, from Little Bahama Bank by being effectively restricted from the open ocean?
3. How does shallow-burial diagenesis affect sediments on a bypass slope? Is periplatform ooze deposited on interfluves subjected to subsurface conditions very different from coarser grained off-bank detritus incorporated in rapidly deposited gravity flows and turbidites of the basin fill?
4. Does the velocity discontinuity associated with the downward transition from faulted, acoustically laminated sequences with velocities of 3.45–3.55 km/s to a hummocky facies with velocities over 6 km/s at about 1300 m sub-bottom mark the top of a drowned carbonate platform (see also "Seismic Stratigraphy" section, Site 632 chapter)? Why is this acoustic transition from presumed basin fill to platform facies so different beneath Exuma Sound and north of Little Bahama Bank, even though the magnitude of the velocity discontinuity in both cases is approximately the same?

# OPERATIONS SUMMARY

## Introduction

Site 631 (BAH-11-A) was the first of three Leg 101 sites designed to examine the evolution of Exuma Sound, a major deep embayment of the Bahama carbonate platform (see "Background and Objectives" section, this chapter). The primary goal of studies at Site 631 was to trace the stratigraphic development of the upper, gullied part of a bypass carbonate slope to compare and contrast it with Sites 629 and 630, the equivalent positions on the accretionary slope north of Little Bahama Bank.

## Transit: Sites 630 to 631

The *JOIDES Resolution* left the northern slope of Little Bahama Bank for Exuma Sound at 2300 hr, 21 February. For most of the approximately 30-hr transit, ship speed was maintained at approximately 10 kt. A single-channel analog/digital seismic profile was collected during this transit on the Atlantic side of the Bahama Platform. A single 80-in.$^3$ water gun was used as the sound source, and 12- and 3.5-kHz records were also collected (see "Underway Geophysics" chapter, this volume).

The ship rounded the southeastern end of Cat Island and entered Exuma Sound at approximately 0230 hr, 23 February. At that point, speed was reduced to 4 kt, and the 400-in.$^3$ water gun was deployed, enroute to BAH-11-A, to collect a deep-penetration, high-resolution single-channel profile, which would complement the regional geophysical profiles already available (Fig. 1). Following gun deployment, speed was gradually increased to 8 kt, and data collection began at 0300 hr. Unfortunately, the Norwegian float used for stabilizing the gun broke free at 0440 hr, necessitating a sound source change to two 80-in.$^3$ water guns. Both were in the water and firing by 0530 hr. No further equipment problems were encountered; an analog display of the line is shown (see "Underway Geophysics" chapter, this volume).

## Site 631

The designated BAH-11-A position at the intersection of site-survey profiles ES-07 and ES-13 (Fig. 1) was reached at 0741 hr, and the ship started a slow 90° turn to port to retrieve the seismic gear while running at 4 kt parallel to the shore of Great Exuma Island only 3.5 n. mi away (Fig. 1). All gear was secured on deck by 0810 hr, and the *JOIDES Resolution* turned back in the direction of BAH-11-A. After initial examination of 3.5-kHz profiles, which showed rough topography but 10–15 m of sub-bottom penetration, the taut wire and a 14.5-kHz beacon were lowered at 1000 hr. Subsequent radar bearings from the adjacent island and continuous monitoring of water depth suggested

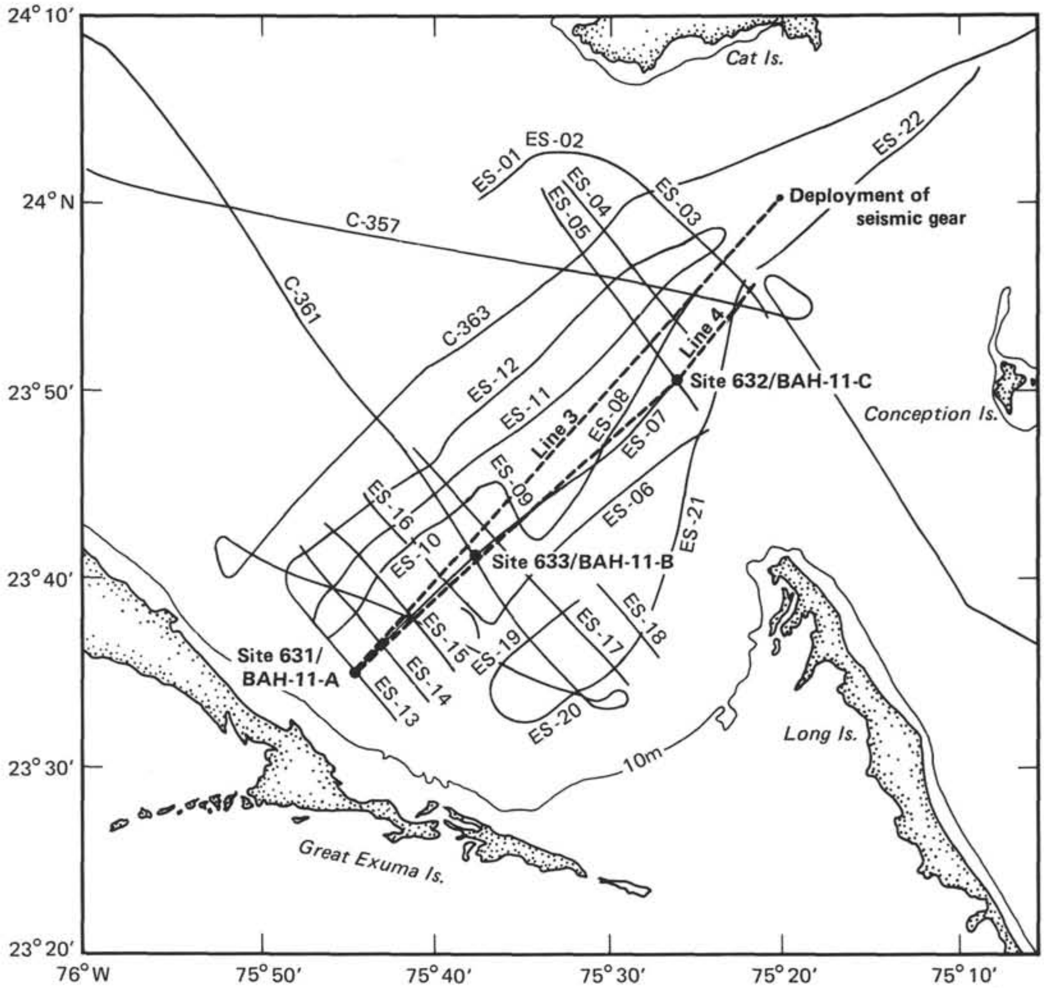


Figure 1. Geophysical data coverage in southeastern Exuma Sound. Lines marked *ES* are UTIG site-survey lines, whereas lines marked *C* are LDGO MCS profiles. Lines 3 and 4 were collected by *JOIDES Resolution.*

that the ship was too far downslope, and the taut wire was retrieved. Additional maneuvering approximately 0.25–0.5 n. mi to the southeast took about 40 min, and the taut wire and beacon were redeployed at 1115 hr. This final Site 631 position was 23°35.2′N, 75°44.56′W (average of good SATNAV fixes during the operations period at this location; LORAN C in Exuma Sound was not reliable). Water depth was 1071 m (uncorr.), and 1081 m (corr.), compared to an estimated 1050 m at the originally designated BAH-11-A position. Assuming an average 10°–12° slope observed on bathymetric maps of Exuma Sound, the differential in water depths suggests that Site 631 was approximately 150–175 m downslope of BAH-11-A.

During final siting, the drill pipe was run in the hole (RIH) to a depth below the rig floor of 1073 m. A successful mud-line hydraulic-piston core (HPC) was recovered at 1430 hr, 23 February, from a depth of 1102 m below the rig floor, suggesting a 10-m discrepancy between the corrected 12-kHz reading and the actual water depth, probably an error produced by the locally steep slope. Over the next 6 hr, 10 HPC cores were recovered to 96.6 m sub-bottom, recovery being 98.2%. A switch to the extended core barrel (XCB) was made for Core 631-13X, and over the next 21.5 hr, 15 XCB cores were collected to 244.3 m sub-bottom. Recovery with the XCB was 43.4%. The last core came on deck at 1800 hr, 24 February. All pipe was pulled out of the hole (POOH) at Hole 631A by 2115 hr, and a magnaflux inspection of the drill collars and subs lasted until approximately 0115 hr, 25 February. The taut wire and beacon were secured at 0210 hr, and by 0230 hr, the *JOIDES Resolution* was under way in dynamic-positioning mode with thrusters extended at 4 kt to Site 632 (BAH-11-C), approximately 23 n. mi away, 25 February.

The coring summary for Site 631 appears in Table 1.

## SEDIMENTOLOGY

### Introduction

A single hole was drilled at Site 631, penetrating to 244.3 m sub-bottom and recovering 159 m of core (65.1%). The sediments recovered at Site 631 consist primarily of chalks and oozes exhibiting varying levels of induration. Above 24.1 m sub-bottom (Core 631A-3H), nannofossils either are the most abundant component or are subequal with micrite, which includes bank-derived aragonite needles. Below this depth, micrite is dominant. Foraminifers are not abundant, never composing more than 20% of the sediment.

No prominent lithologic changes exist in the sediment recovered; therefore, the sediment is considered to belong to a single lithologic unit. This unit is divided into two subunits to accommodate slight variations in lithology.

Subunit IA consists of nannofossil-rich periplatform ooze with some chalk. Subunit IB contains couplets of periplatform ooze and chalk.

Table 1. Coring summary, Site 631.

| Core no. | Core type[a] | Date (Feb. 1985) | Time | Sub-bottom depths (m) | Length cored (m) | Length recovered (m) | Percentage recovered |
|---|---|---|---|---|---|---|---|
| Hole 631A | | | | | | | |
| 1 | H | 23 | 1430 | 0-9.7 | 9.7 | 9.71 | 100 |
| 2 | H | 23 | 1530 | 9.7-19.6 | 9.9 | 10.00 | 101 |
| 3 | H | 23 | 1600 | 19.6-29.5 | 9.9 | 9.59 | 96 |
| 4 | H | 23 | 1630 | 29.5-39.1 | 9.6 | 8.92 | 92 |
| 5 | H | 23 | 1700 | 39.1-48.7 | 9.6 | 9.56 | 99 |
| 6 | H | 23 | 1730 | 48.7-58.2 | 9.5 | 9.84 | 103 |
| 7 | H | 23 | 1800 | 58.2-68.0 | 9.8 | 9.60 | 99 |
| 8 | H | 23 | 1915 | 68.0-77.5 | 9.5 | 9.65 | 101 |
| 9 | H | 23 | 1945 | 77.5-87.2 | 9.7 | 9.92 | 103 |
| 10 | H | 23 | 2030 | 87.2-96.6 | 9.4 | 9.68 | 102 |
| 11 | X | 23 | 2200 | 96.6-109.7 | 13.1 | 8.95 | 68 |
| 12 | X | 23 | 2300 | 109.7-119.2 | 9.5 | 9.89 | 104 |
| 13 | X | 23 | 2356 | 119.2-128.8 | 9.6 | 9.28 | 96 |
| 14 | X | 24 | 0130 | 128.8-138.4 | 9.6 | 9.56 | 99 |
| 15 | X | 24 | 0250 | 138.4-147.9 | 9.5 | 3.59 | 37 |
| 16 | X | 24 | 0420 | 147.9-157.5 | 9.6 | 3.71 | 38 |
| 17 | X | 24 | 0525 | 157.5-167.2 | 9.7 | 3.80 | 39 |
| 18 | X | 24 | 0715 | 167.2-176.9 | 9.7 | 0.82 | 8 |
| 19 | X | 24 | 0845 | 176.9-186.5 | 9.6 | 9.82 | 102 |
| 20 | X | 24 | 1000 | 186.5-196.1 | 9.6 | 0.48 | 4 |
| 21 | X | 24 | 1212 | 196.1-205.6 | 9.5 | 0.21 | 2 |
| 22 | X | 24 | 1330 | 205.6-215.3 | 9.7 | 1.43 | 14 |
| 23 | X | 24 | 1510 | 215.3-224.9 | 9.6 | 0.17 | 1 |
| 24 | X | 24 | 1630 | 224.9-234.5 | 9.6 | 0.87 | 9 |
| 25 | X | 24 | 1800 | 234.5-244.3 | 9.8 | 1.50 | 15 |

[a] H = hydraulic piston; X = extended core barrel.

### Subunit IA (0-24.1 m sub-bottom; Core 631A-1H to base of Core 631A-3H-3)

Subunit IA consists of periplatform ooze of varying stiffness and some chalk. Nannofossils are the major contributor to the sediment (30%-60%); micrite is subordinate (Fig. 2). Bank-derived aragonite needles are included with micrite in the smear slide estimates. Aragonite needles are estimated to form between 5% and 20% of the total sediment, according to examination of smear slides. The ooze is predominantly white (10YR 8/1), and some is light gray (2.5Y 7/2). The interval 631A-1H-5, 0-150 cm, is light brownish gray (10YR 6/2). Color variations are prominent in Core 631A-1H and, to a lesser extent, in Cores 631A-2H and 631A-3H, which have dark burrow fills (2.5Y 4/4, olive brown, and 2.5Y 6/2, light brownish gray), pyrite streaks, and black and gray streaks and bands (7.5YR 7/0, light gray, and 10YR 6/1 and 10YR 6/2, light brownish gray). Horizontal bands are probably caused by organic material or clay. Figure 3 shows a pyrite halo around a burrow in Sample 631A-1H-3, 19 cm. A seed with a shoot (Fig. 4) was found at 2.6 m sub-bottom (Sample 631A-1H-2, 110 cm). Cores 631A-2H and 631A-3H each contain a single thin (less than 10-cm) layer of unlithified packstone, and Core 631A-2H contains a single 2-cm-thick layer of unlithified mudstone.

No well-preserved burrows are visible between 9.7 and 15.7 m sub-bottom (Core 631A-2H). Partial lithification of the sediment begins at 10.5 m sub-bottom (Sample 631A-2H-1, 80 cm), although unlithified sediment predominates to 19.6 m sub-bottom (Core 631A-3H). Below this depth, friable chalk forms the bulk of the sediment, and unlithified ooze is typically subordinate. A disturbed region between 11.3 and 11.5 m sub-bottom (Sample 631A-2H-2, 7-34 cm) may represent a slump or, alternatively, may be the result of drilling disturbance.

This subunit is dated as Pleistocene, and its base may correspond to a possible Pliocene/Pleistocene unconformity ("Biostratigraphy" section, this chapter).

### Subunit IB (24.1-244.3 m sub-bottom; base of Core 631A-3H to Core 631A-25X)

This subunit makes up the bulk of the recovered sediment. It consists predominantly of alternating couplets of periplatform ooze and chalk, usually on a scale from 5 to 10 cm. Chalk layers are fractured by drilling, the thinnest layers being most highly disrupted. Some thicker layers of chalk and ooze exist. The primary constituent of the sediment is micrite (25%-60%), again including aragonite needles, and subordinate amounts of nannofossils, clasts, and skeletal fragments (Fig. 2). Aragonite needles compose 5%-15% of the total sediment, according to smear slide analysis. The amount of aragonite does not appear to differ from that in Subunit IA. Planktonic foraminifers are a minor constituent. Color changes are subtle shades of white, predominantly 10YR 8/1, 2.5Y 8/1, and 2.5Y 8/2 above 149.5 m sub-bottom (Core 631-15X) and predominantly 2.5Y 8/2 below this depth. Light gray material (2.5Y 7/2) occurs in some intervals.

These sediments are exceptional in that a strong odor of hydrogen sulfide is associated with the sediment throughout the cored interval ("Organic Geochemistry" section, this chapter). Pyrite occurs as streaks, specks, and also as scattered laminations to 87.2 m sub-bottom (bottom of Core 631A-9H), below which it was not observed. Glauconite surrounds a lithified burrow at 43.5 m sub-bottom (Sample 631A-5H-3, 145-150 cm). Glauconite was also observed at 149.5 m sub-bottom (Section 631A-16X-2) as a burrow filling and was distributed in the sediment in Core 631A-17X.

Lithification increases with depth. At 96 m sub-bottom, lithification necessitated a change to XCB coring and at 138.4 m sub-bottom (Core 631A-15X) was sufficient to cause reduced recovery and to require a saw for splitting the cores. Visible burrows are generally rare, being most prominent where a smooth surface could be obtained in ooze-rich zones with thin chalk layers. Beginning with Core 631A-15X, at 138.4 m sub-bottom,

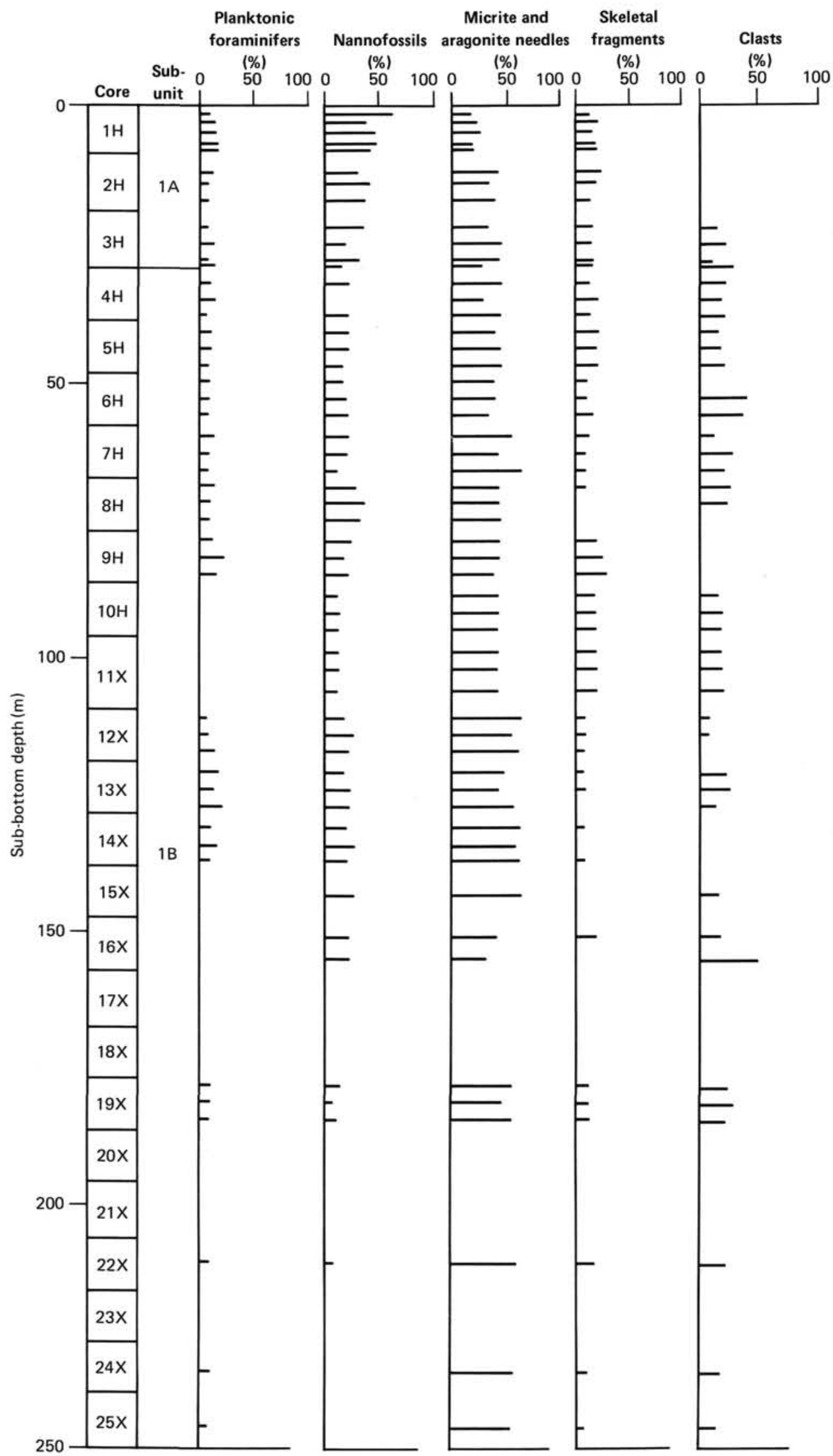


Figure 2. Proportions of major constituents of sediment at Site 631, based on smear slides.

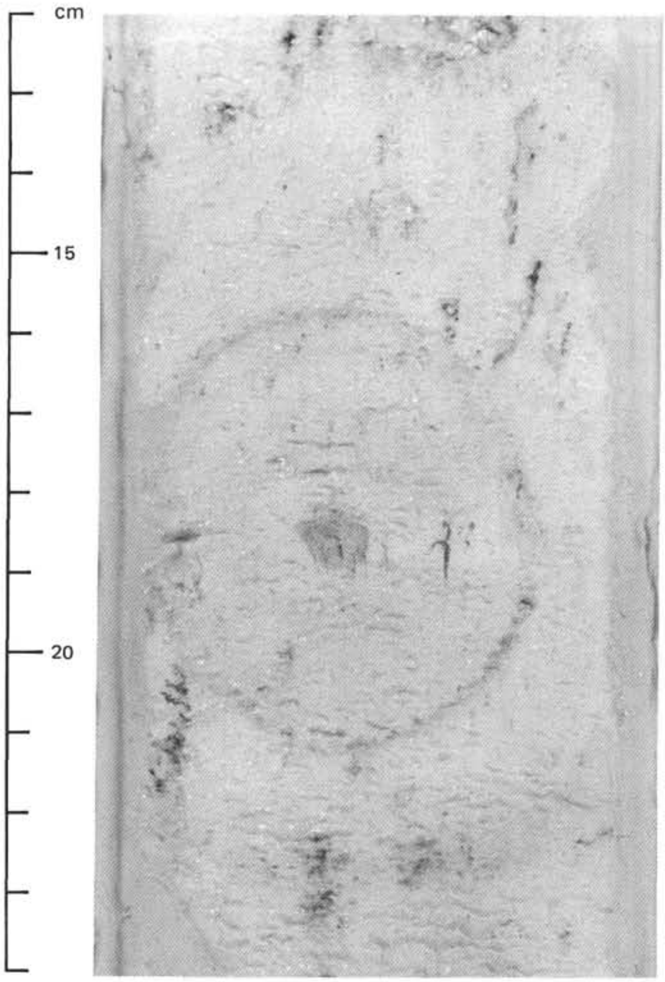


Figure 3. Pyrite halo surrounding burrow, Sample 631A-1H-3, 19 cm.

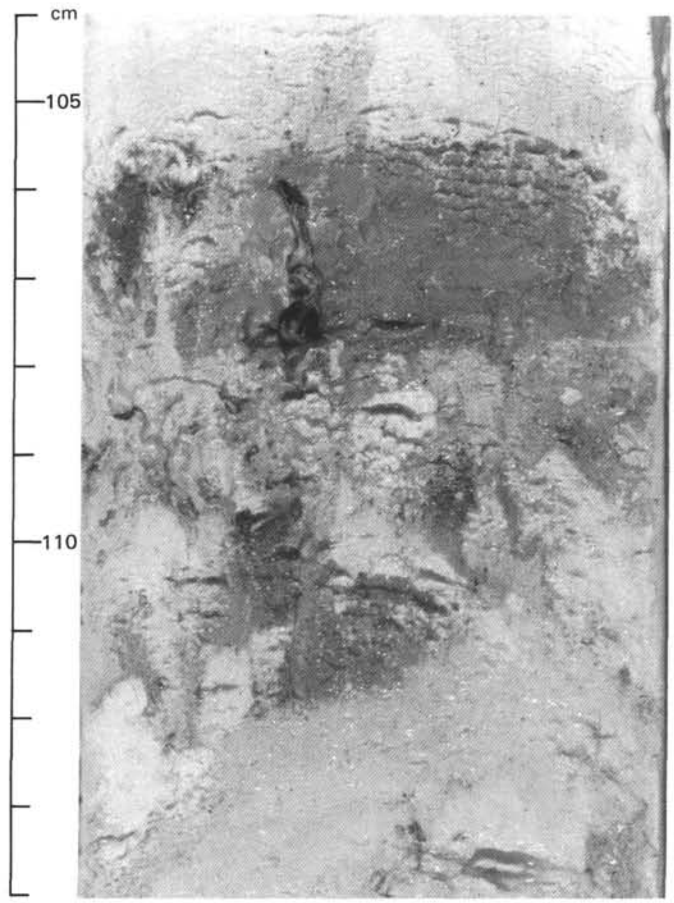


Figure 4. Seed with shoot in dark, possibly clay-rich, layer, Sample 631A-1H-2, 108 cm.

chalk pieces as long as 10 cm also clearly display burrows and some miliolid foraminifers on the smooth, cut surface. One chalk piece at 150.7 m sub-bottom (Sample 631A-16X-2, 129–138 cm) contains a scoured surface with a truncated burrow, which may represent a gully floor (Fig. 5).

The age of Subunit IB is late Miocene to early Pliocene ("Biostratigraphy" section, this chapter). Poor preservation of microfossils has hindered the determination of accurate ages aboard ship.

## Summary

The sediments recovered at Site 631 are considered to represent a single lithologic unit, which has been divided into two subunits:

Subunit IA (0–24.1 m sub-bottom; Core 631A-1H to the base of Core 631A-3H-3); periplatform ooze with some chalk, relatively rich in nannofossils.

Subunit IB (24.1–244.3 m sub-bottom; base of Core 631A-3H-3 to Core 631A-25X); periplatform ooze and chalk couplets.

## Discussion

The sediments recovered at Site 631 do not exhibit any major lithologic changes apart from increasing induration with depth. There is no evidence of gravity-flow deposits. However, the scoured surface at 150.7 m sub-bottom (Sample 631A-16X-2, 129–138 cm) may indicate erosion by turbidity currents. A questionable slump was observed at 11.3 m sub-bottom (Core 631A-

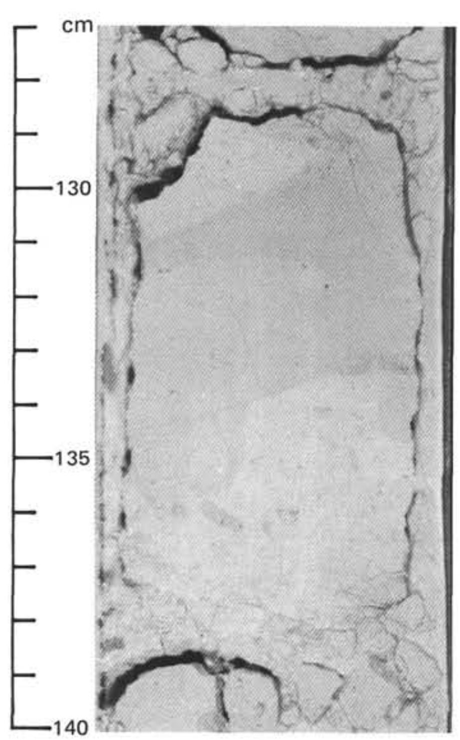


Figure 5. Scoured surface in chalk piece, showing truncated burrow in Sample 631A-16X-2, 134–136 cm.

2H). Coarse-grained channel lag deposits are absent, and micrite is the predominant constituent of the sediment. Visible aragonite needles form approximately 5%–20% of the total sediment and apparently do not decrease down the hole. This corresponds to x-ray-diffraction (XRD) results, which indicate that the sediments are 60%–70% aragonite throughout the cored interval between 90 and 190 m sub-bottom, and values (still ± 50%) fluctuate above this depth ("Inorganic Geochemistry" section, this chapter). Although deposition was probably of suspended material displaced by waves and transported by tides and currents or from the fringes of sediment gravity flows in nearby gullies on the slope, the sedimentation rate has been remarkably high (105 m/m.y.). This rate is higher than that during the bypass slope phase at Site 630 (Subunit IA, 25 m/m.y.). The scarcity of gully deposits at Site 631 indicates that lateral migration of gullies has been limited, at least since the late Miocene.

The sediment throughout the cored interval has undergone considerable diagenetic alteration, possibly related to a lowering of pH associated with the sulfate reduction that generated the hydrogen sulfide ("Inorganic Geochemistry" section, this chapter). This should enhance the dissolution of aragonite and magnesian calcite in the bank-derived sediment, allowing redeposition as overgrowths and cement. Preliminary XRD results, however, indicate that dolomite may be forming at the expense of calcite, with little or no reduction in the amount of aragonite ("Inorganic Geochemistry" section, this chapter).

All evidence suggests that the depositional environment has not changed significantly throughout the drilled interval. The setting has been that of a bypass slope adjacent to a shallow-water bank at least since the late Miocene.

An important question is whether the ooze–chalk couplets in Subunit IB are depositional features or artifacts of drilling. Below 138.4 m sub-bottom (Core 631A-15X), recovery was poor, but in the least disturbed sections, pieces of chalk as long as 10 cm were recovered, separated by small amounts of ooze and shorter, more fragmented chalk pieces. The ooze here may be a drilling paste, particularly because the XCB rotates while cutting a core. However, in the less well-indurated ooze–chalk sequence above 138.4 m sub-bottom, recovery was excellent. Probably only slight drilling disturbance occurred here, especially in the upper 96.6 m (Cores 631A-1H to 631A-10H) where the HPC was used; therefore, the ooze–chalk couplets in this region are most likely depositional and the result of diagenetic alteration. This may also be true below 138.4 m sub-bottom, because recovery of Core 631A-19X was complete, and couplets, similar to those at shallower levels, were recovered. However, no definitive answer concerning the origin of the couplets can yet be given.

## BIOSTRATIGRAPHY

### Introduction

Hole 631A was drilled at this site with the HPC to a depth of 96.6 m sub-bottom and with the XCB to 244.3 m sub-bottom (total depth). A thick section of Quaternary and Neogene periplatform oozes and chalks was recovered. In general, the planktonic microfossils are greatly diluted by micrite and other carbonate debris, presumably derived from the nearby platform. In addition, reworking of older planktonic microfossils (calcareous nannofossils) is evident in several samples. As a result, the planktonic biostratigraphy described as follows should be viewed as preliminary.

### Calcareous Nannofossils

Section 631A-1H-1 contains abundant *Emiliania huxleyi*, indicating an occurrence of the youngest part of Zone NN21, which correlates with the late Pleistocene to Holocene. This implies that the mud line was successfully recovered. Section 631A-1H, CC contains neither *E. huxleyi* nor *Pseudoemiliania lacunosa*, although the abundance of gephyrocapsids indicates that the assemblage is Pleistocene. The assemblage, therefore, is assigned to Zone NN20, which correlates with the middle Pleistocene. Core 631A-2H contains *P. lacunosa, Cyclococcolithina macintyrei*, and *Discoaster brouweri* without *Discoaster pentaradiatus*, indicating Zone NN18. This zone is correlated with the late Pliocene, although the planktonic foraminifers indicate a younger age, which suggests reworking of at least part of the nannofossil assemblage. In addition, the abundance of the predominantly Pleistocene species *Gephyrocapsa caribbeanica* suggests the reworking of Pliocene forms such as *Discoaster brouweri* and possibly some specimens of *C. macintyrei*. If this is true, then the assemblage should be placed in Zone NN19, which correlates with the latest Pliocene to middle Pleistocene.

In Cores 631A-3H and 631A-4H, the presence of *Discoaster brouweri, Discoaster pentaradiatus, Discoaster asymmetricus*, and *Discoaster surculus* indicates Zone NN16, which correlates with the late Pliocene.

In the interval from Cores 631A-5H through 631A-9H, *Reticulofenestra pseudoumbilica* and *D. asymmetricus* occur together, indicating nannofossil Zone NN14/15. A subdivision between these two zones is not currently possible, as the marker species for NN14 (*Amaurolithus tricorniculatus*) is generally rare and is not useful in this poorly preserved material. These two zones correlate with the late early Pliocene.

Core 631A-10H contains a few poorly preserved nannofossils, which include *Reticulofenestra pseudoumbilica* but not *D. asymmetricus*. This assemblage is tentatively assigned to NN12/13 (latest Miocene to earliest Pliocene) because of the absence of other marker taxa.

Much of the Neogene nannofossil biostratigraphy is based on the discoasters. In Core 631A-11X, these nannofossils are absent except for one indeterminate taxon; thus, a reliable zonal assignment is not possible at this time. In Cores 631A-12X and 631A-13X, overgrown discoasters, which are probably *Discoaster quinqueramus*, were encountered. These discoasters suggest that this poorly preserved assemblage could be placed in Zone NN11, which correlates with the late Miocene.

The interval from Cores 631A-14X through 631A-21X contains unusual nannofossil assemblages, which, in general, are moderately preserved and contain numerous nannofossils. In most intervals, however, the assemblages lack the taxa used for biostratigraphic zonation of the Neogene. Other assemblages appear to contain taxa that designate mutually exclusive zones, although the preservational state of these forms precludes exact taxonomic determination. Thus, the age of this sequence is indeterminate.

In Core 631A-22X, a few specimens of *Reticulofenestra bisecta* occur. This suggests an Oligocene to early Miocene age, although a zonal assignment cannot be made solely on the basis of the presence of this taxon. Evidence from Sites 632 and 633 (and from lower in the section at Site 631) indicates that reworking of Oligocene nannofossils is pervasive in the Neogene of the Exuma Sound transect. Section 631A-23X, CC is essentially barren of nannofossils.

Sections 631A-24X, CC and 631A-25X, CC contain rather well-preserved specimens of *R. bisecta, Cyclicargolithus floridanus*, and *Reticulofenestra umbilica*. This assemblage may be assigned to Zone NP22, which correlates with part of the early Oligocene. These two samples, however, also contain strongly overgrown Neogene nannofossils. In Sample 631A-25X, CC, a nannoflora has also been observed with *Discoaster aukalos, D. brouweri, D. pentaradiatus*, and *D. variabilis*. Such an obviously mixed assemblage can be assigned to NN9/11, which correlates with the late Miocene. The planktonic foraminifers from these samples are all of early Pliocene age, indicating a probable reworking.

### Planktonic Foraminifers

Poor preservation and atypical species composition characterize the planktonic-foraminiferal assemblages recovered from Hole 631A, particularly those of the Pliocene (uppermost Miocene?) section (Cores 631A-3H to 631A-25X). Calcite overgrowths hinder identifications throughout much of this sequence. Cores 631A-1H and 631A-2H (19.6 m sub-bottom) are Pleistocene in age (*Globorotalia truncatulinoides* Zone, N22/N23). A hiatus separating Pleistocene from Pliocene sediments may occur within Core 631A-3H.

A late early Pliocene to late Pliocene age is suggested for Cores 631A-3H, CC through 631A-14X (29.0–138.4 m sub-bottom), primarily by the co-occurrence of *Globorotalia crassaformis* and *Globigerinoides extremus*. *Globorotalia crassaformis* first occurs in the upper lower Pliocene and ranges to the Holocene, whereas *Globigerinoides extremus* last occurs near the Pliocene/Pleistocene boundary (Stainforth et al., 1975; Kennett and Srinivasan, 1983). Berggren et al. (1985) give a first-appearance datum (FAD) of 4.3 Ma for *G. crassaformis* s.l. and a last-appearance datum (LAD) of 1.8 Ma for *G. extremus*. The age is further constrained in Cores 631A-3H, 631A-4H, and 631A-5H by the occurrence of *Globorotalia miocenica*, which is restricted to the late Pliocene or perhaps to the earliest Pleistocene (Stainforth et al., 1975; Kennett and Srinivasan, 1983). According to Berggren et al. (1985), *G. miocenica* ranges from 3.4 to 2.2 Ma.

Cores 631A-6H through 631A-14X are probably late early Pliocene in age (*Globorotalia margaritae* Zone, N18/N19 part) because of the absence of *Globorotalia miocenica* and the persistent occurrence of *Globorotalia crassaformis*. This age assignment is corroborated by the presence of *Globorotalia margaritae* in Cores 631A-13X and 631A-14X. *Globorotalia crassaformis* may occur as low as Core 631A-18X. Other species in this interval include *Globigerinoides extremus, Globorotalia menardii, G. plesiotumida, G. scitula, Globigerina nepenthes, Globigerinella aequilateralis*, and *Neogloboquadrina acostaensis*.

Specimens assignable to *Globorotalia cibaoensis* (with close affinity to early Pliocene *G. margaritae*) occur in Cores 631A-17X through 631A-25X (157.5–244.3 m sub-bottom), suggesting an early Pliocene to late Miocene age for this interval. The occurrence of *Globorotalia margaritae* in Section 631A-25X, CC poses an interesting biostratigraphic problem and three possible explanations. The specimens of *G. margaritae* may be downhole contaminants, which would make the oldest possible age for Core 631A-25X, CC early late Miocene, according to the occurrence of *Globorotalia extremus*. This is unlikely owing to the paucity of *G. margaritae* in stratigraphically higher samples. Although unlikely, again, because of the paucity of *G. margaritae* in stratigraphically higher samples, some sections were perhaps repeated within the interval from Cores 631A-6H to 631A-25X, a possibility needing further study. A final possibility is that the entire section from Cores 631A-6H through 631A-25X is early Pliocene in age, assignable to the *G. margaritae* Zone. The loss of *G. crassaformis* (late early Pliocene to Holocene) with depth and the appearance of *G. cibaoensis* (late Miocene to earliest Pliocene) support the final interpretation.

### Larger Benthic Foraminifers

No larger benthic foraminifers were found at this upper-slope site.

## SEDIMENT-ACCUMULATION RATES

The uppermost Pliocene–Pleistocene sequence of periplatform ooze in Hole 631A accumulated at a rate of 13–25 m/m.y. (Fig. 6). A hiatus as great as 1–2 m.y. might have separated Pleistocene from lower Pliocene strata in Core 631A-3H. Alternatively, very low accumulation rates may have characterized late Pliocene time in Exuma Sound. Accumulation rates on the order of 105 m/m.y. characterize a monotonous section of uppermost Miocene(?)–lowermost Pliocene through mid-Pliocene periplatform ooze in Cores 631A-25X to 631A-3H. The rate in the lower unit is poorly constrained because of the paucity of short-range index fossils and the problems in identifying the Miocene/Pliocene boundary.

## INORGANIC GEOCHEMISTRY

### Interstitial Waters

Geochemical patterns in the interstitial waters squeezed from Site 631 deviated considerably from any of the sites previously investigated on Leg 101 (see Figs. 7 and 8 and Table 2). Of particular importance were the great increases in alkalinity (as much as 13 meq/kg) but little or no change in Ca or Mg. In fact, between 65.6 and 91.5 m sub-bottom, Ca levels fell below seawater concentrations, whereas Mg showed a small rise.

Throughout the hole, evidence of hydrogen sulfide ($H_2S$), generated by the utilization of sulfate by bacteria as an oxidant, was extensive. The presence of hydrogen sulfide was readily detectable by smell; however, the high interstitial sulfate concentration in the pore waters indicates that considerable amounts of reduction could still be taking place given sufficient organic material (Fig. 8). A further product of sulfate reduction is $CO_2$, which (1) increases the amount of total dissolved inorganic carbon, (2) lowers the pH, (3) changes the distribution of carbon-bearing species, and (4) raises the alkalinity. Overall, these changes do not seem to cause the dissolution of aragonite, although the absence of high-Mg calcite may be a result of dissolution rather than of a lack of primary input.

This change in $CO_2$ content is believed to control and reflect the precipitation of carbonate minerals, such as dolomite and low-Mg calcite, initiated by the great rise in alkalinity. This precipitation is evident in the presence of overgrowths on microfossils (see "Biostratigraphy" section, this chapter) and the generally cemented nature of the sediment. However, the precipitation of carbonate does not occur at the expense of aragonite dissolution (see the following discussion).

### X-Ray Diffraction

Site 631 is characterized by high amounts of aragonite extending from the Holocene boundary to as far as the Oligocene/Miocene boundary (see Fig. 9 and Table 3). High-Mg calcite (HMC) was present to a depth of at least 7.2 m sub-bottom. Showing a pronounced increase below 80 m, dolomite is ubiquitous throughout the hole. Quartz was not detected. Small amounts of clay minerals were detected in some of the samples (see Table 3).

The pattern of aragonite and calcite distribution in Hole 631A shows a reversal from what might be expected from a normal diagenetic sequence involving carbonates (Figs. 9 and 10). At a depth between 120 and 150 m sub-bottom, the amount of low-Mg calcite (LMC) actually decreases without a change in the amount of aragonite. This decrease in LMC occurs concomitant with an increase in dolomite (Table 3). Either these changes are primary or the pore waters are conducive to the dissolution of LMC but not to aragonite.

### Carbonate-Bomb Data

The percentage of carbonate generally was greater than 90%–93% throughout the hole (Fig. 11 and Table 4).

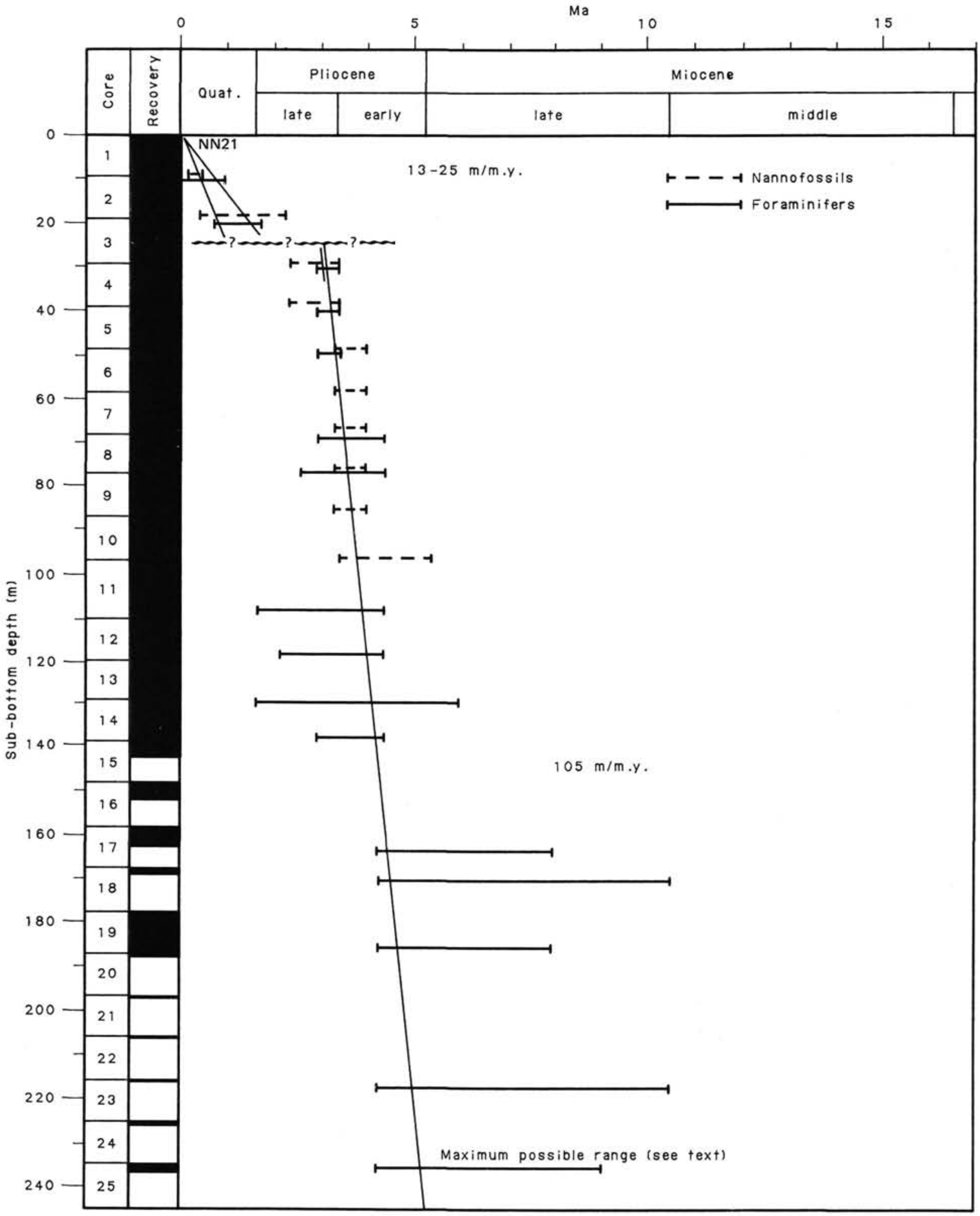


Figure 6. Sediment-accumulation rates, Site 631.

## ORGANIC GEOCHEMISTRY

Twenty-nine samples were taken from Hole 631A for analysis using the Rock-Eval (see Figs. 12–15). Some gas data were also obtained from unsplit cores.

The lithology at Site 631 consists of fairly uniform aragonite-rich periplatform ooze containing a little pyrite and, in one interval, glauconite. The organic matter consists of lipid-rich kerogen in the Pleistocene part of the section (top 10 m), probably corresponding to type II kerogen (planktonic; Fig. 12). A less lipid-rich component, probably approximating type III kerogen (terrestrial; Fig. 12) dominated the rest of the section (10–240 m). However, no total-organic-carbon (TOC) values were available for complete evaluation of kerogen type.

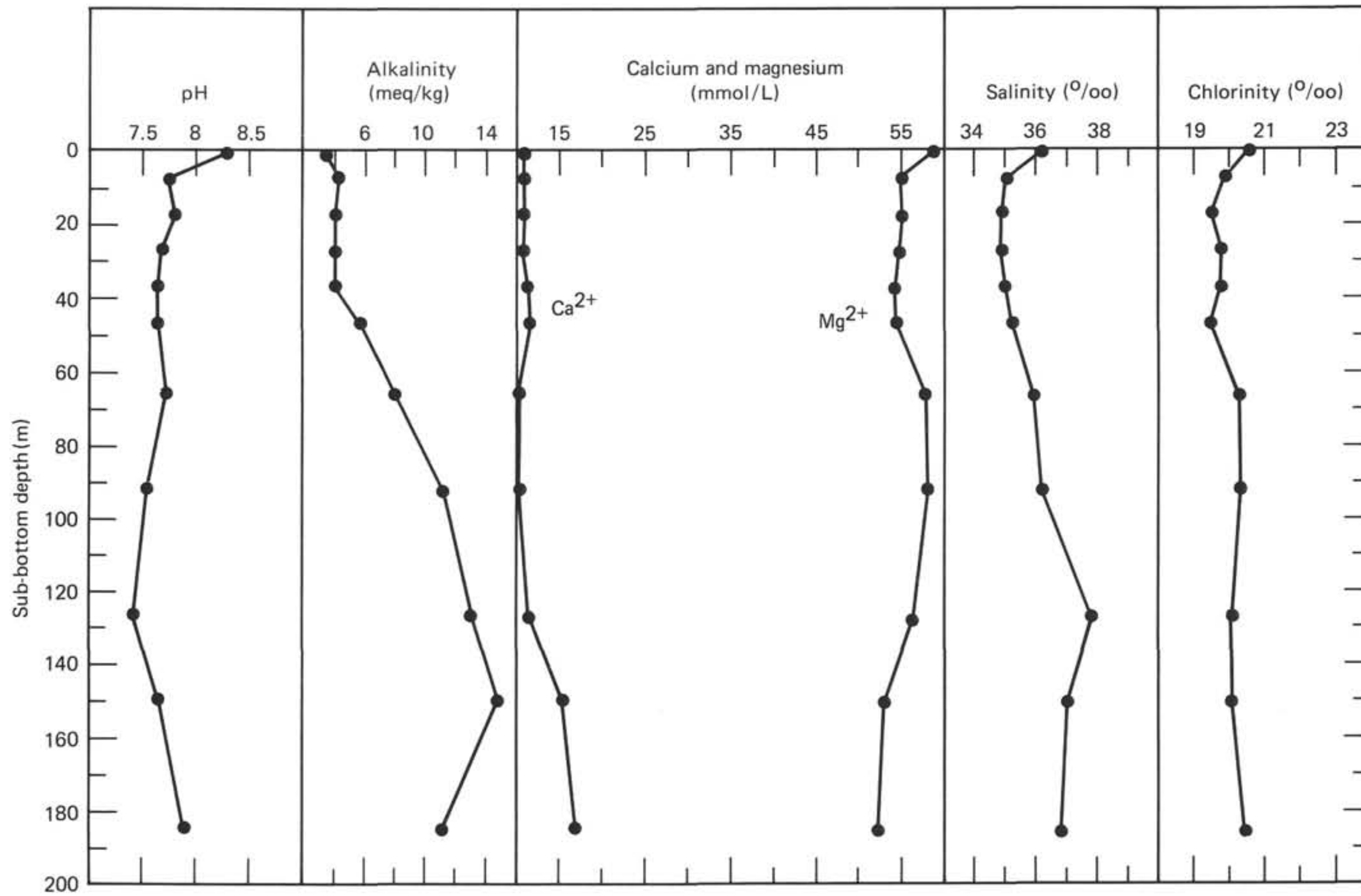


Figure 7. Summary of interstitial-water analyses, Site 631.

The $S_2/S_3$ index (see Fig. 13) always gave values less than 0.8, indicating that the kerogen was mainly gas-prone. However, as reported earlier, this ratio may not be reliable in aragonite-rich sediments. No significant trend was noted from these data.

The content of extractables ($S_1$, see Fig. 14) varied as did the $S_2$ content (Fig. 13). The top of the section showed a high content of extractables.

The most striking feature of the organic matter sampled at Site 631 was the consistency of the $T_{max}$ results, showing virtually no downhole gradient (see Fig. 15). The high observed $T_{max}$ values of 430°C are on the border of the oil-generation zone. The implication that erosion and redeposition of a single, nearly mature source of organic matter had taken place on this slope is difficult to accept. Reworked organic-matter contributions normally will give a considerable scatter of $T_{max}$ results, reflecting a wide range of provenances and maturities (see "Organic Geochemistry" sections, Sites 628 and 630 chapters, this volume).

Recent organic matter of the Bahamas was studied by one of us (A. Moore), who noted a high content of dead sea grass in certain Bahamian depositional environments, particularly in low-energy marine areas. This material was collected, dried, and analyzed by the Rock-Eval technique. Although completely "immature," sea grass (*Thalassia* sp.) apparently gives a high $T_{max}$ (>400°C) reading. Therefore, the high organic content ($S_2$) and stable $T_{max}$ of Site 631 could reasonably be explained by a constant influx of decayed sea grass. Changes in $S_2$ values of organic matter at the top of the section (Fig. 12) could reflect a higher marine-algae content.

Much gas evolution was observed within the cored section. Gas bubbles could be seen actively forming on the interior of the core liner. When cut, some of the core sections violently expelled unconsolidated sediment. This gas was nonflammable, being high in hydrogen sulfide but low in methane. Gas-chromatographic analysis indicated that carbon dioxide was 6 times more abundant than methane. Apparently, active sulfate reduction of the organic matter is occurring *in situ*. The products of this reaction, hydrogen sulfide and carbon dioxide, probably create steep diagenetic gradients. This may partly explain the observed calcite overgrowths on many of the foraminifers and nannofossils at this site (see "Inorganic Geochemistry" section, this chapter).

### Discussion

The unusually high sedimentation rates (up to 105 m/m.y.) at Site 631 may have led to enhanced preservation of organic detritus. Aerobic bacteria and benthic invertebrates would have had insufficient time to destroy all the organic matter.

High sedimentation rates, however, do not fully explain the particularly high $S_2$ values of the section top (Pleistocene), where sedimentation rates of 13–25 m/m.y. were observed. Perhaps the position of Site 631 near the mid-water oxygen minimum enhanced the preservation of organic matter. Further shore-based organic geochemical work will be required to confirm this speculation.

## PALEOMAGNETISM

### Natural Remanent Magnetization

Forty-one oriented 7-$cm^3$ paleomagnetic samples were obtained from Cores 631A-1H through 631A-3H and Cores 631A-

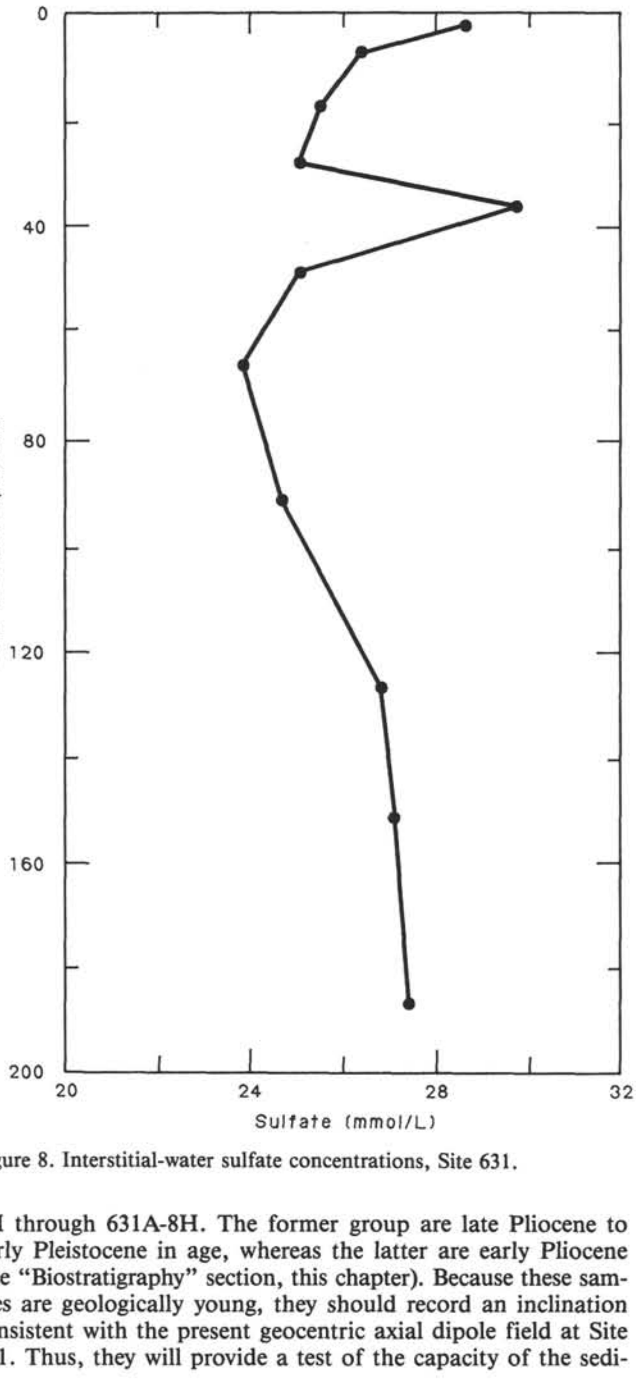


Figure 8. Interstitial-water sulfate concentrations, Site 631.

6H through 631A-8H. The former group are late Pliocene to early Pleistocene in age, whereas the latter are early Pliocene (see "Biostratigraphy" section, this chapter). Because these samples are geologically young, they should record an inclination consistent with the present geocentric axial dipole field at Site 631. Thus, they will provide a test of the capacity of the sediments from Hole 631A and, by inference, other similar sediments drilled on Leg 101 to record the geomagnetic field. All 41 samples from Hole 631A are too weakly magnetized to be accurately measured on the shipboard Molspin spinner magnetometer.

## Magnetic Susceptibility

The measuring scheme was modified to reduce the large number of datum points being handled. Whole-core susceptibility measurements were still made at 10-cm intervals, but as long as values corresponding to carbonate material lacking any magnetic minerals (i.e., approximately $-0.4 \times 10^{-6}$ G/Oe) were obtained with little variation, only even-numbered core sections were measured. All cores that gave susceptibilities consistently greater than 0.0 were measured in their entirety. By this procedure, many susceptibility spikes, attributed to metallic contamination at the top of each core in previous holes, were avoided. In all, 869 susceptibility measurements were made on sediments from Hole 631A.

Several susceptibility spikes still remained in the record. One was traced to a piece of steel flange from the drill string caught up in the sediments (Section 631A-2H-2). Several others occurred in Cores 631A-22X and 631A-25X. Both cores exhibited low recovery in hard sediments, so these spikes were interpreted as being metallic contamination caused by the abrasion of the XCB drill bit. The few remaining spikes occurring in the first section of several cores were also interpreted as having been caused by metallic contamination, as discussed in the site summary for Hole 627B.

By removing most of the susceptibility anomalies thought to have been caused by metallic contamination, the susceptibility vs. depth plot (Fig. 16) shows only a few departures from a base level of about $-0.4 \times 10^{-6}$ G/Oe, which corresponds to carbonate material. Two spikes at 206 and 235 m sub-bottom are measurements made from Cores 631A-22X and 631A-25X. Even with removal of the largest susceptibility readings from the top of each core, higher than average values still appear. Because the material recovered from these cores is essentially the same as that obtained higher in the hole (see "Sedimentology" section, this chapter), both cores are probably entirely contaminated with material from the drill.

At a sub-bottom depth of 68 m, susceptibility readings averaging about $2.5 \times 10^{-6}$ G/Oe were recorded in Core 631A-8H. Because these high values are restricted to Core 631A-8H, and because the liner for this core exhibited several breaks, it appears as if this feature of the susceptibility record is also an effect of metallic contamination. At about 10–20 m sub-bottom, another feature, which rises slowly from the base value to a maximum in Core 631A-2H-4, cannot easily be explained as contamination. Although this feature is small, having an amplitude of less than $1 \times 10^{-6}$ G/Oe, it appears to begin in the lower part of Core 631A-1H and to continue into the first sec-

**Table 2. Analyses of interstitial waters from Hole 631A.**

| Sub-bottom depth (m) | pH | Alkalinity (meq/kg) | Salinity (‰) | Chlorinity (‰) | Ca (mmol/L) | Mg (mmol/L) | $SO_4$ (mmol/L) |
|---|---|---|---|---|---|---|---|
| Surface seawater | 8.28 | 2.45 | 36.2 | 20.53 | 10.66 | 58.91 | 28.76 |
| 7.4 | 7.72 | 3.30 | 35.0 | 19.81 | 10.70 | 54.68 | 26.54 |
| 17.1 | 7.79 | 2.99 | 34.8 | 19.44 | 10.78 | 54.96 | 25.56 |
| 27.0 | 7.67 | 2.98 | 34.8 | 19.75 | 10.51 | 54.63 | 25.32 |
| 36.9 | 7.64 | 3.00 | 35.0 | 19.71 | 11.32 | 54.06 | 29.89 |
| 46.5 | 7.64 | 4.65 | 35.2 | 19.41 | 11.58 | 54.28 | 25.17 |
| 65.6 | 7.71 | 6.90 | 35.9 | 20.22 | 9.97 | 57.68 | 23.91 |
| 91.5 | 7.52 | 10.18 | 36.2 | 20.29 | 10.36 | 57.89 | 24.72 |
| 126.7 | 7.41 | 12.02 | 37.8 | 20.05 | 11.51 | 56.14 | 26.88 |
| 149.4 | 7.66 | 13.77 | 37.0 | 21.07 | 15.25 | 53.88 | 27.40 |
| 184.4 | 7.90 | 10.09 | 36.8 | 20.46 | 16.84 | 52.13 | 27.54 |

**Table 3. X-ray analyses of samples from Hole 631.**

| Sub-bottom depth (m) | Calcite (%) | Aragonite (%) | Dolomite (%) | Quartz (%) | Comments |
|---|---|---|---|---|---|
| 7.4 | 28 | 70 | 2 | 0 | Illite-montmorillonite present; low-Mg calcite, 53%; high-Mg calcite, 47% |
| 17.1 | 41 | 56 | 3 | 0 | Illite-montmorillonite present |
| 27.0 | 47 | 51 | 2 | 0 | |
| 36.8 | 28 | 69 | 3 | 0 | Illite-montmorillonite present |
| 47.5 | 39 | 61 | 0 | 0 | |
| 65.6 | 32 | 66 | 0 | 0 | Palygorskite(?) present |
| 70.2 | 39 | 56 | 4 | 0 | Palygorskite(?) present |
| 81.2 | 37 | 56 | 6 | 0 | Illite-montmorillonite present |
| 89.4 | 18 | 70 | 12 | 0 | |
| 94.6 | 25 | 68 | 7 | 0 | Illite-montmorillonite present |
| 124.4 | 14 | 71 | 15 | 0 | |
| 126.6 | 17 | 69 | 14 | 0 | Illite-montmorillonite present |
| 131.0 | 20 | 68 | 12 | 0 | Illite-montmorillonite present |
| 137.0 | 24 | 66 | 10 | 0 | Illite-montmorillonite present |
| 149.3 | 22 | 66 | 12 | 0 | |
| 159.6 | 32 | 60 | 8 | 0 | |
| 184.3 | 25 | 65 | 10 | 0 | |
| 206.2 | 51 | 42 | 6 | 0 | |
| 236.1 | 71 | 19 | 10 | 0 | |

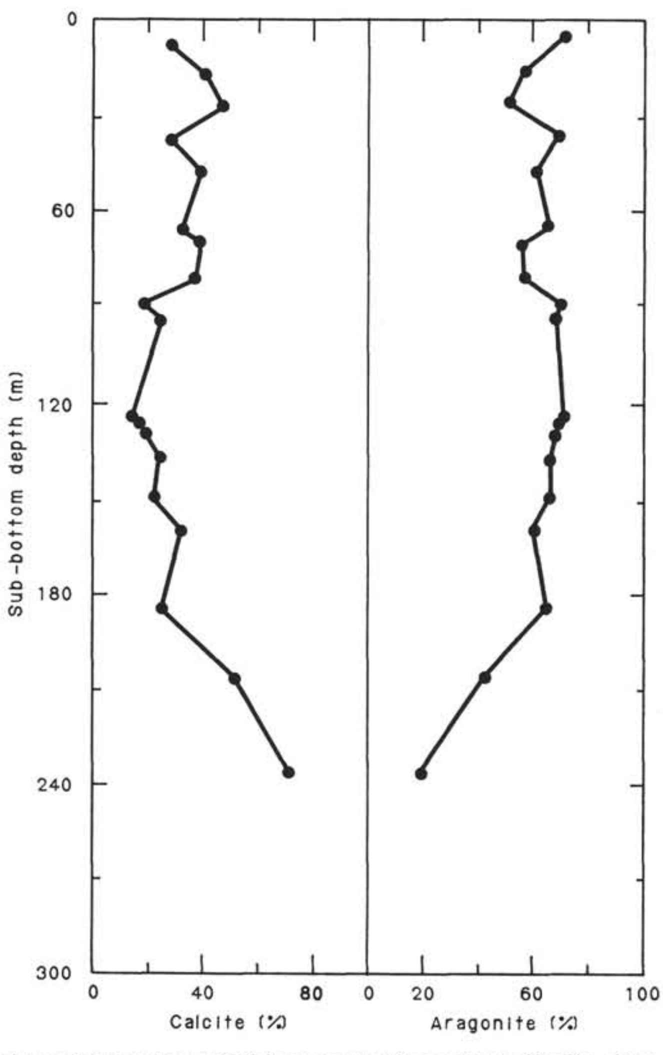


Figure 9. Percentages of calcite and aragonite content at Site 631, determined by x-ray diffraction.

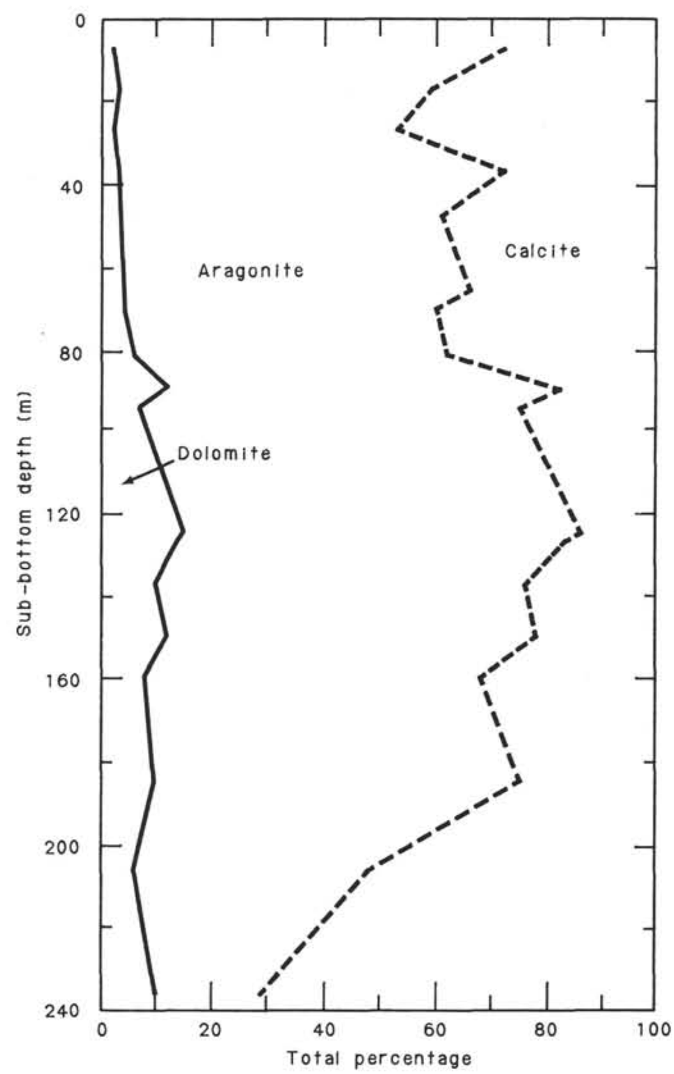


Figure 10. X-ray data, Site 631.

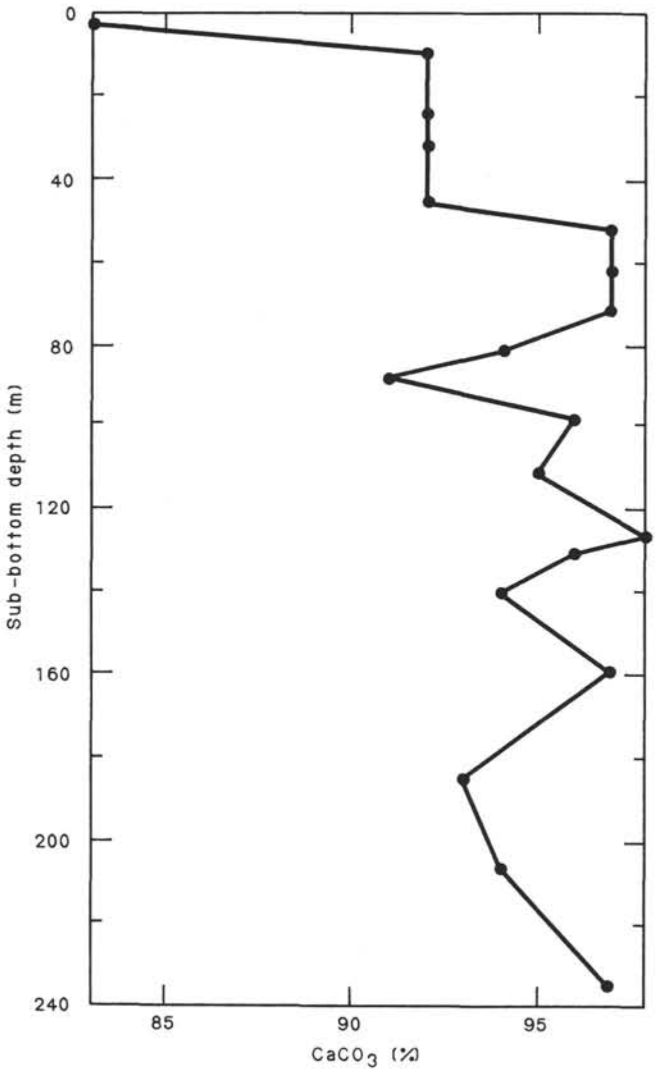


Figure 11. Carbonate-bomb data, Site 631.

**Table 4. Carbonate-bomb data, Site 631.**

| Sub-bottom depth (m) | $CaCO_3$ content (%) |
|---|---|
| 5.2 | 83 |
| 11.9 | 92 |
| 24.8 | 92 |
| 31.7 | 92 |
| 47.3 | 92 |
| 53.9 | 97 |
| 63.4 | 97 |
| 73.2 | 97 |
| 82.7 | 94 |
| 89.4 | 91 |
| 98.8 | 96 |
| 111.9 | 95 |
| 127.4 | 98 |
| 131.0 | 96 |
| 140.6 | 94 |
| 159.6 | 97 |
| 185.1 | 93 |
| 206.2 | 94 |
| 235.1 | 97 |

tion of Core 631A-3H. This anomaly may be a contamination effect, or it could originate from the notably higher than average susceptibility values recorded near the seafloor in the first and second cores of Holes 627B and 632A.

## PHYSICAL PROPERTIES

Physical-property measurements were made of sediments recovered from Site 631 as described in the "Introduction and Explanatory Notes" chapter of this volume. Continuous density determination by the Gamma Ray Attenuation Porosity Evaluator (GRAPE) could not be made because of a broken drive belt. Therefore, 2-min GRAPE counts were taken on the same discrete samples used for velocity and index-property measurements. Data are plentiful to 132.6 m sub-bottom. Poor recovery below that point is reflected in the few datum points plotted (Fig. 17).

In general, the physical-property parameters display depth gradients stronger than those of Site 630 (see Site 630 chapter, this volume).

### Compressional Wave Velocity

Compressional wave velocities were measured on sediments inside the core liner and of discrete samples removed from the liner. Both techniques yielded essentially the same results at this site (Table 5).

Sediment velocity increases linearly from 1600 m/s at 5 m sub-bottom to 1900 m/s at 243 m sub-bottom. When compared with the downhole distribution curve of Hole 630A, velocity values are about 100 m/s higher than those in Hole 630A at the same depth (Fig. 17A). This is a minimum value; velocity measurements made on discrete samples show a greater difference (Fig. 17B).

### Wet-Bulk Density, Water Content, and Porosity

Wet-bulk density increases linearly downhole from an average value of 1.72 ($g/cm^3$) in the first 9 m to 1.97 ($g/cm^3$) at 243.6 m sub-bottom. Compared with Hole 630A, density values are significantly higher throughout the entire hole (Fig. 18).

Dry water content and porosity values measured from Site 631 decrease downhole from high values of 63% (water content) and 61% (porosity) to low values of 30% (water content) and 45% (porosity) at 240 m sub-bottom. All three values show a change in slope between 95 m and 120 m sub-bottom. This zone of decreasing water content and porosity coincides with the depth (96.6 m sub-bottom) at which operations were switched from HPC to XCB drilling and at which an increase in chalk was recorded (see "Sedimentology" and "Summary and Conclusions" sections, this chapter).

### Thermal Conductivity

Thermal conductivity increases from an average value of 2.4 $\times 10^{-3}$ cal $\times$ °$C^{-1} \times cm^{-1} \times s^{-1}$ in the first 9 m sub-bottom to 2.9 $\times 10^{-3}$ cal $\times$ °$C^{-1} \times cm^{-1} \times s^{-1}$ at 214 m sub-bottom. The datum points plotted (Fig. 19) show considerable fluctuation around this general trend.

### Shear Strength

Shear strength ranges from 5 to 10 kPa within the first 40 m sub-bottom. It increases between 40 and 75 m sub-bottom and shows extreme values at 48 (16 kPa) and 70 m sub-bottom (34.2 kPa), although varying considerably. Below 80 m sub-bottom, shear strength is only slightly higher than in the top 40 m (Fig. 19).

### Discussion

Physical-property values measured at Site 631 are different from those measured at Site 630, although both sites were similar lithologically. The individual values start at both sites with

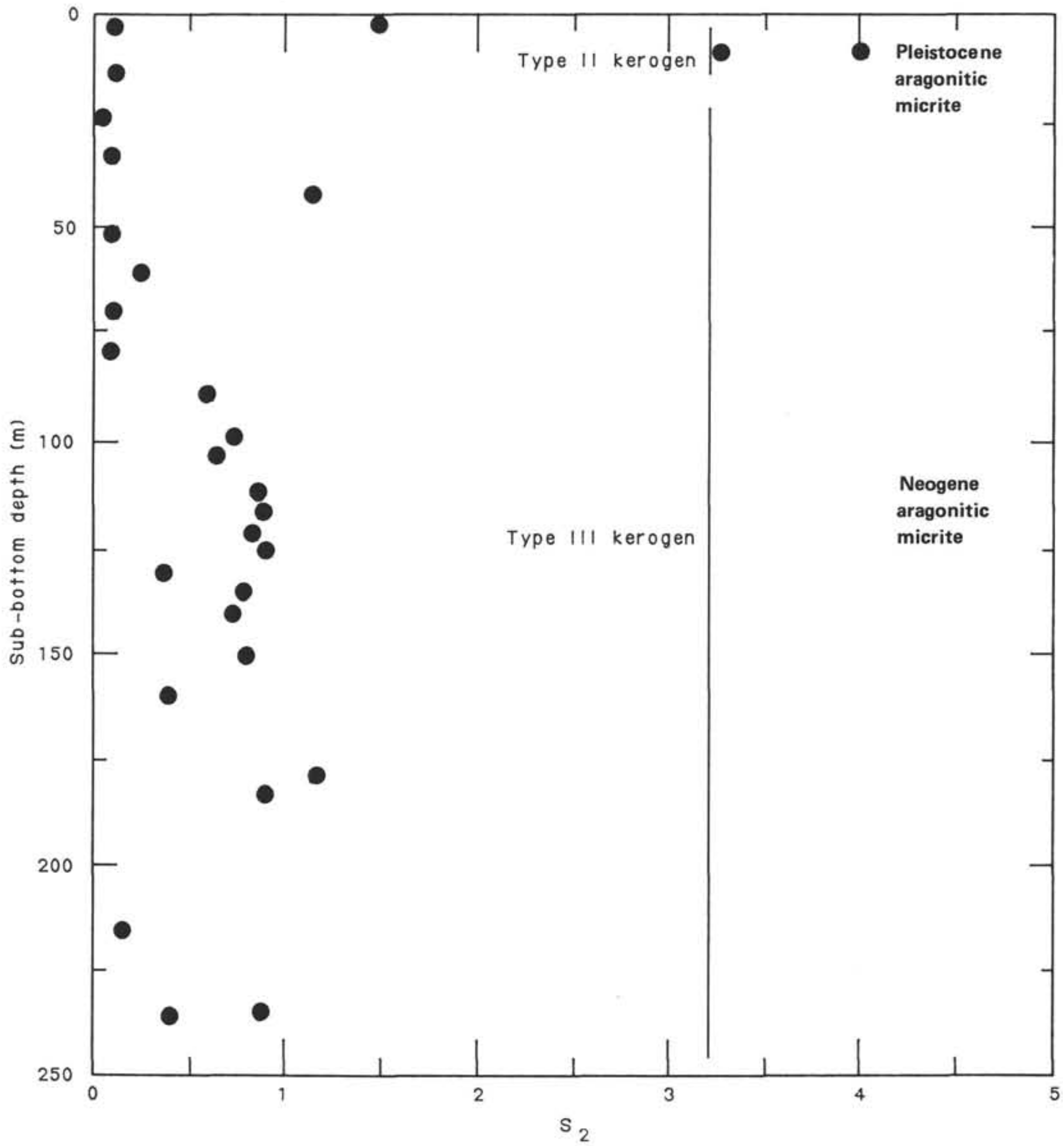


Figure 12. $S_2$ content of lithologies at Site 631, showing an upper interval (late Pleistocene) containing lipid-rich kerogen, and a lower interval (Miocene to Pleistocene) containing less lipid-rich kerogen. The whole section was higher in $S_2$ than previously drilled Neogene sections during Leg 101 (note difference in scale compared with previous drill sites).

similar values, but different gradients develop downhole. Compressional wave velocity and density values are consistently higher at Site 631 than at Site 630 at comparable depths (Figs. 17 and 18B). Similarly, water content and porosity show consistently lower values at Site 630 than those measured from Site 631 (Fig. 18). No shifts in the downhole distribution curves of Site 631 occur, which would indicate a separation into different units (like slumps) or the erosion of an additional overburden at any point in the recovered sedimentary column. Thus, the continuous curves suggest that sediments from Hole 631A are more diagenetically altered than are sediments from Hole 630A.

## SEISMIC STRATIGRAPHY

### Introduction

Site 631 (BAH-11-A) lies at the shallow end of the Exuma Sound slope transect. This site was located at the intersection of site survey lines ES-07 and ES-13 (see "Background and Objectives" and "Operations Summary" sections, this chapter; Figs. 20 and 21). The primary objective was to define the perennial depositional signal on a bypass carbonate slope, which would then be compared with the "bypass" record to be sampled at the toe-of-slope (BAH-11-B) and out on the basin floor (BAH-11-C).

### Acoustic Correlations: Site 631

Because of the steepness of the slope (10°–12°) and the rough bottom topography at Site 631, interval velocities derived from semblance analyses of the site-survey profiles in this area are scattered. However, Hamilton Frame velocities measured on Site 631 samples aboard the *JOIDES Resolution* show a consistent increase from 1.6 km/s at the surface to 2.0 km/s at approximately 220 m sub-bottom ("Physical Properties" section, this chapter). Inspection of these results suggests that a value of 1.8 km/s can be used as a representative average interval velocity for the section sampled at Site 631. Using this velocity for

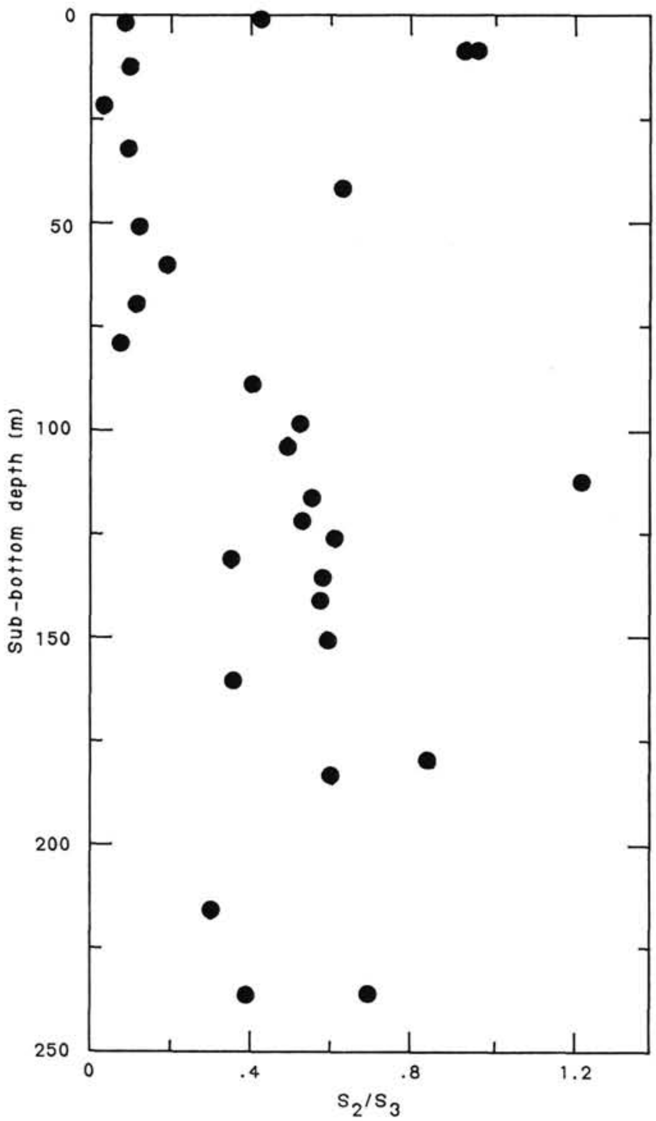


Figure 13. $S_2/S_3$ ratios, indicating gas potential for Site 631. The $S_3$ content measured on the Rock-Eval instrument is misleading because it may contain a contribution from carbonate pyrolysis rather than from kerogen pyrolysis.

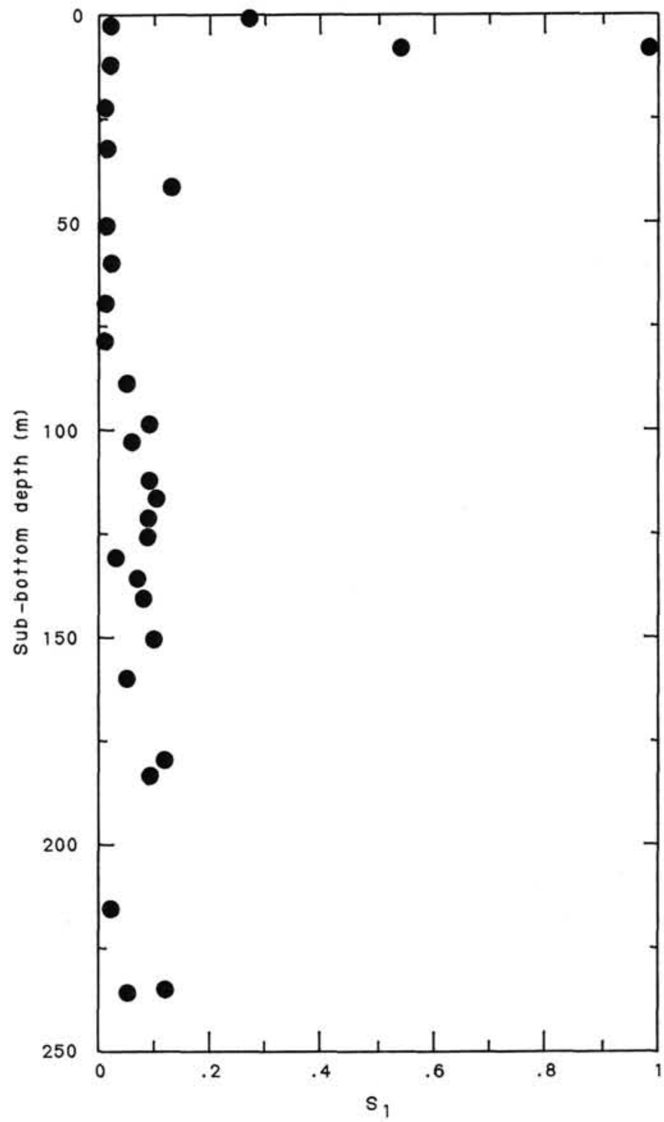


Figure 14. $S_1$ content of lithologies at Site 631, showing high bitumen content in the lower Pleistocene interval. $S_1$ values between 0.5 and 1 are characteristic of rocks with fair oil source potential.

depth-to-traveltime conversion, Hole 631A penetrated 0.27 s of section on lines ES-07 and ES-13 (Figs. 20 and 21).

Both the lithostratigraphic and biostratigraphic results from Hole 631A indicate rapid, continuous deposition. Examination of both seismic lines ES-07 and ES-13 suggests the following:

1. Hole 631A apparently sampled an interfluve-levee system (hummocky clinoforms) developed on the northwestern flank of a channel characterized by higher amplitude parallel reflections. The interfluve on the other side of this channel is also discernible approximately 0.75 n. mi to the southeast (Fig. 20). Drilling into such an interfluve sequence would explain both the prevalence of bioturbated chalk-ooze and the evident lack of turbidite material in Hole 631A, whereas the intrachannel reflections presumably are either coarser grained off-bank material deposited as turbidites or a series of hardgrounds.
2. The predominant seismic facies patterns at Site 631 are shingling and hummocky clinoforms, both indicative of progradation (Mitchum et al., 1977). Traveltime thicknesses of the intervals between discernible reflections within the shingling pattern are 0.015–0.1 s, or 13.5–90 m, at the 1.8 km/s velocity estimated for this section (Fig. 21). The high accumulation rates at this site (up to 90 m/m.y.; see "Sediment-Accumulation Rates," this chapter), along with the apparent lack of repeated sections (see "Biostratigraphy," this chapter), suggest gradual upbuilding of interfluves on bypass slopes by stacking of thin sedimentary slices. This could occur as a result of either continuous downslope creep or tranquil slumping, as opposed to the more episodic nature of turbidite deposition within the channels. The shingled facies also appears to prograde basinward with time, although not very far (less than 1.0 n. mi; Fig. 21). This evidence also supports gradual gravitational mass-wasting as the primary mechanism for growth on this bypass slope.

## SUMMARY AND CONCLUSIONS

One hole was drilled at Site 631 at the upslope end of the Exuma Sound slope transect. A total of 244 m of sediment was penetrated with the HPC/XCB system. The sequence is rather monotonous and is considered one lithologic unit with subdivisions (see "Sedimentology" and "Biostratigraphy" sections, this

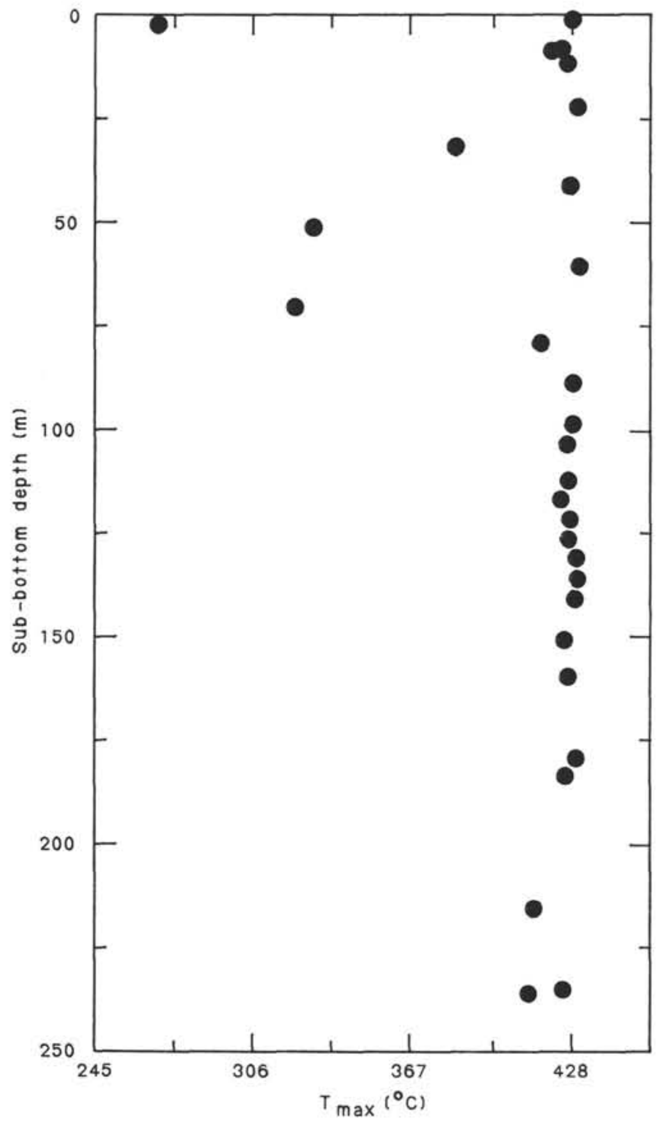


Figure 15. $T_{max}$ at Site 631, showing consistent, unusually high, values for the organic component. Identical maturity (and presumably provenance) is interpreted here as *Thalassia* sp. input (see text).

chapter and Fig. 22): (1) Subunit IA, periplatform ooze with some chalk, cyclic alternations of organic-rich and lean intervals, late Pliocene–Pleistocene, 24 m; and (2) Subunit IB, periplatform ooze and chalk, rich in pyrite, some glauconite, significant downward increase in hardness at 100 m sub-bottom, late Miocene(?)–late Pliocene, 220 m.

Abundant aragonite needles and admixtures of neritic benthos identify the sediment as periplatform ooze. The conspicuous absence of graded sand layers suggests efficient bypassing of the site by turbidity currents. This inference is supported by the presence of gullies, interpreted as the erosional pathways of turbidity currents (Hooke and Schlager, 1980).

Biostratigraphy at this site suffers from strong overgrowth on fossils and from reworking. What little time control is available indicates sedimentation rates as high as 90 m/m.y., exceeding the maximum rates observed at Site 630 in a similar setting (62 m/m.y.). Both Sites 630 and 631 have a positive sediment budget and are accreting, despite much of the sediment load being carried by turbidity currents and bypassing the slopes. At Site 630, accretion clearly results from rapid deposition of periplatform ooze in a stratigraphically undisturbed succession. The

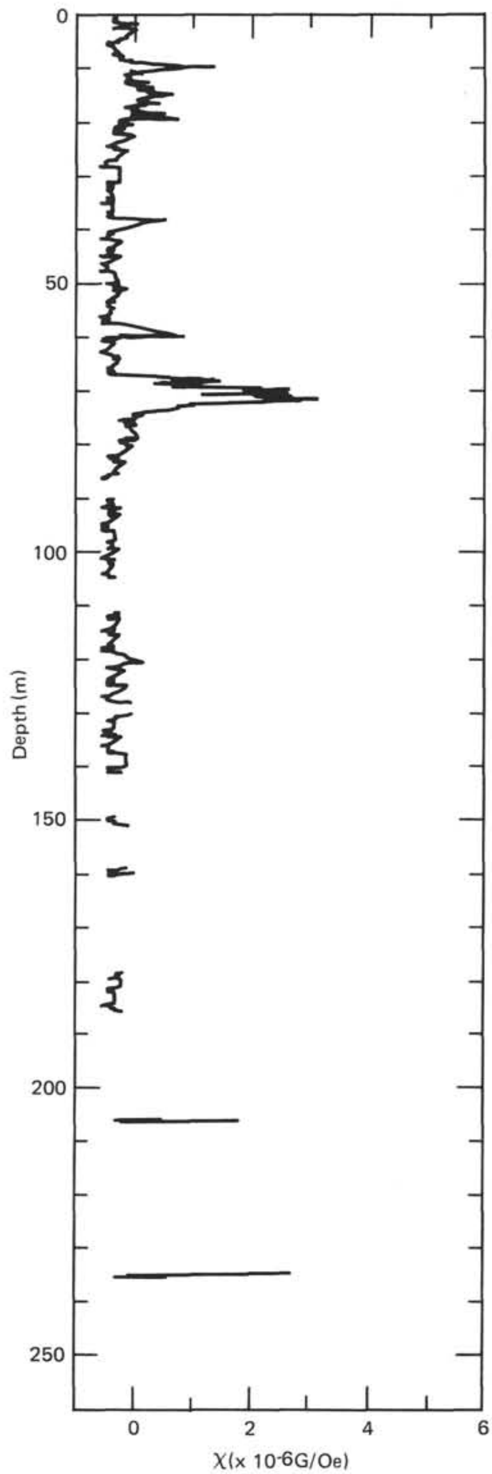


Figure 16. Magnetic susceptibility ($\times 10^{-6}$ G/Oe) plotted vs. sub-bottom depth. Probable metallic-contamination effects have been suppressed by excluding the first section of each core from measurement and by excising large-amplitude, short-wavelength spikes.

cause of sedimentation at Site 631 is more ambiguous owing to insufficient biostratigraphic control. For example, the section below 24 m in the hole could consist of one or several large slumps. This interpretation is compatible with the seismic records ("Seismic Stratigraphy" section, this chapter) but derives little support from direct observations of the cores.

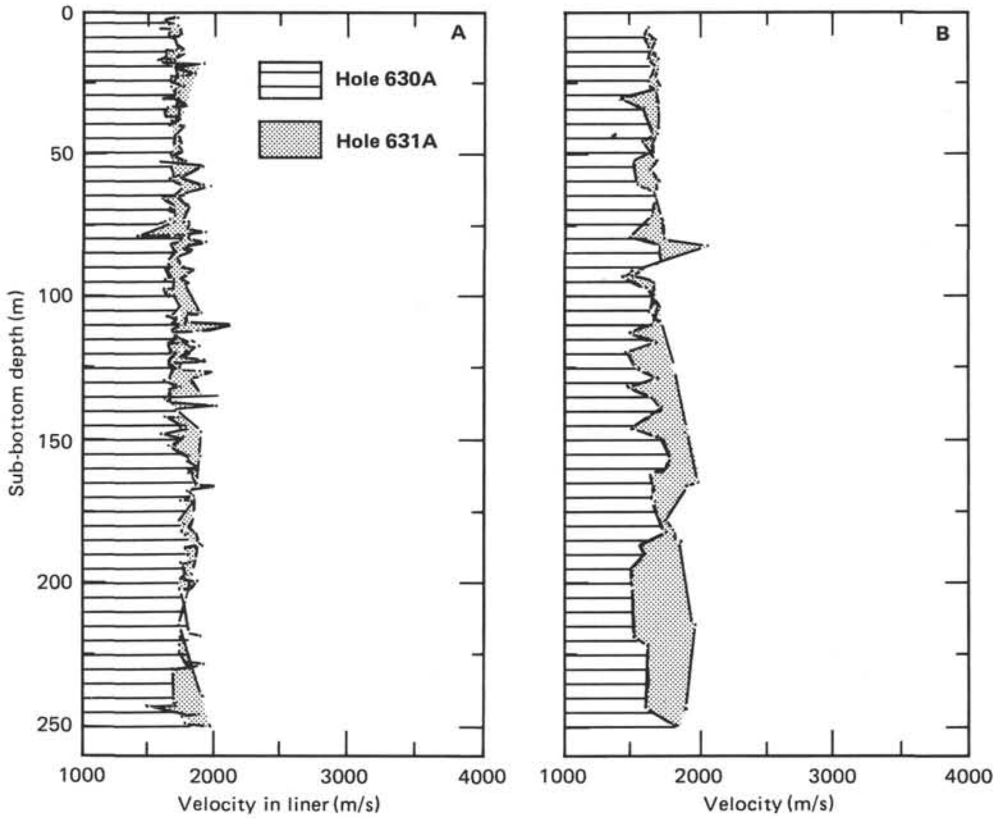


Figure 17. Comparison of the velocity distribution curves of Holes 630A and 631A. A. Velocity measured in the core liner. B. Velocity measured on discrete samples removed from the core liner.

The content of organic matter in Hole 631A is higher than at any preceding site ("Organic Geochemistry" section, this chapter). Nearly constant (apparent) $T_{max}$ of about 400° throughout the hole suggests a source other than marine algae or protists, probably sea grass, from the platform tops.

Diagenesis of the periplatform ooze in Hole 631A has progressed more rapidly downhole than in the preceding holes ("Sedimentology" and "Inorganic Geochemistry" sections, this chapter). At 100 m below seafloor and at an age of 5 Ma, the sediment is largely cemented. Throughout the hole, aragonite remains abundant, and dolomite appears as a diagenetic mineral. Interstitial waters show a pronounced increase in alkalinity driven by decomposition of organic matter. This increase governs the dissolution of magnesian calcite and aragonite and the precipitation of dolomite.

Steeper diagenetic gradients compared with the other sites are also indicated by more rapid decrease in water content and porosity and concomitant increases in density and sonic velocity ("Physical Properties" section, this chapter). The gradients are steady and without significant steps, consistent with the notion of continuous, rapid, and monotonous sedimentation.

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**Table 5. Physical properties of sediments, Site 631.**

| Sample (level in cm) | Sub-bottom depth (m) | Velocity (m/s) | Velocity in liner (m/s) | Wet-bulk density ($g/cm^3$) | Dry water content (%) | Porosity (%) | Thermal conductivity ($10^{-3} \times cal \times °C^{-1} \times cm^{-1} \times s^{-1}$) | Shear strength (kPa) |
|---|---|---|---|---|---|---|---|---|
| 1-2, 20 | | | 1422 | | | | | |
| 1-2, 70 | 2.2 | | 1436 | 1.8 | 42.53 | 53.65 | 2.697 | 5.78 |
| 1-2, 100 | | | 14.38 | | | | | |
| 1-3, 75 | 3.7 | | | | | | 2.595 | |
| 1-4, 20 | | | 1607 | | | | | |
| 1-4, 70 | 5.2 | 1642 | 1598 | 1.67 | 62.96 | 64.65 | 2.075 | 6.03 |
| 1-4, 100 | | | 1650 | | | | | |
| 1-5, 75 | 6.7 | | | | | | 2.177 | |
| 1-6, 20 | | | 1647 | | | | | |
| 1-6, 70 | 8.2 | 1619 | 1647 | 1.70 | 60.89 | 64.47 | 2.253 | 5.90 |
| 1-6, 100 | | | 1685 | | | | | |
| 2-2, 35 | 11.5 | | 1706 | | | | | |
| 2-2, 70 | 11.9 | 1642 | 1730 | 1.79 | 46.69 | 56.78 | 2.569 | 2.26 |
| 2-2, 100 | | | 1763 | | | | | |
| 2-3, 75 | 13.4 | | | | | | 2.889 | |
| 2-4, 20 | | | 1665 | | | | | |
| 2-4, 70 | 14.9 | 1708 | 1517 | 1.79 | 48.45 | 58.25 | 2.838 | 5.02 |
| 2-5, 75 | 16.4 | | | | | | 2.885 | |
| 2-6, 20 | | | 1907 | | | | | |
| 2-6, 70 | 17.9 | 1628 | 1651 | 1.78 | 48.85 | 58.47 | 2.457 | 3.77 |
| 3-2, 20 | | | 1843 | | | | | |
| 3-2, 70 | 21.8 | | 1635 | 1.73 | 54.81 | 61.15 | 2.713 | 10.04 |
| 3-2, 110 | | | 1737 | | | | | |
| 3-3, 75 | 23.3 | | | | | | 2.712 | |
| 3-4, 20 | | | 1647 | | | | | |
| 3-4, 70 | 24.8 | 1646 | 1745 | 1.77 | 51.31 | 59.97 | 2.463 | 6.53 |
| 3-5, 75 | | | | | | | 2.736 | |
| 3-6, 30 | | | 1665 | | | | | |
| 3-6, 70 | 27.8 | 1701 | 1721 | 1.90 | 40.55 | 54.55 | 2.902 | 9.29 |
| 3-6, 100 | | | 1704 | | | | | |
| 4-2, 20 | | | 1784 | | | | | |
| 4-2, 70 | 31.7 | 1697 | 1725 | 1.79 | 48.49 | 58.25 | 2.833 | 8.04 |
| 4-3, 75 | 33.2 | | | | | | 2.436 | |
| 4-4, 75 | 34.7 | | | | | | 2.727 | |
| 4-5, 70 | 36.2 | | | | | | 2.455 | |
| 4-6, 20 | | | 1724 | | | | | |
| 4-6, 75 | 37.7 | | 1714 | 1.83 | 46.17 | 57.73 | 2.494 | 5.52 |
| 4-6, 140 | | | 1745 | | | | | |
| 5-2, 20 | 40.8 | | 1692 | | | | | |
| 5-2, 70 | 41.3 | 1705 | 1713 | 1.89 | 41.04 | 54.82 | 2.546 | 4.02 |
| 5-2, 100 | 41.6 | | 1701 | | | | | |
| 5-3, 75 | 42.8 | | | | | | 2.489 | |
| 5-4, 20 | 43.8 | | 1729 | | | | | |
| 5-4, 70 | 44.3 | 1676 | 1708 | 1.79 | 49.44 | 59.27 | 2.593 | 6.53 |
| 5-4, 100 | 44.6 | | 1727 | | | | | |
| 5-5, 75 | 45.8 | | | | | | 2.817 | |
| 5-6, 20 | | | 1740 | | | | | |
| 5-6, 70 | 47.3 | 1668 | 1726 | 1.82 | 49.92 | 60.73 | 2.496 | 16.07 |
| 5-6, 100 | | | 1628 | | | | | |
| 6-2, 75 | 50.9 | | | 1.88 | 37.72 | 51.29 | 2.648 | |
| 6-3, 20 | | | 1758 | | | | | |
| 6-3, 70 | 52.4 | 1528 | 1553 | | | | 2.692 | 8.29 |
| 6-3, 100 | | | 1854 | | | | | |
| 6-4, 20 | | | 1903 | | | | | |
| 6-4, 70 | 53.9 | 1477 | 1844 | 1.83 | 44.52 | 56.34 | 2.842 | 7.03 |
| 6-4, 100 | | | 1875 | | | | | |
| 6-5, 75 | 55.4 | | | | | | 2.850 | |
| 6-6, 20 | | | 1490 | | | | | |
| 6-6, 70 | 56.9 | 1491 | 1713 | 1.87 | 41.26 | 54.37 | 2.925 | 7.28 |
| 6-6, 100 | | | 1752 | | | | | |
| 7-2, 20 | | | 1902 | | | | | |
| 7-2, 70 | 60.4 | 1555 | 1963 | 1.89 | 38.42 | 52.27 | 2.897 | 12.56 |
| 7-2, 100 | | | 1974 | | | | | |
| 7-3, 75 | 61.9 | | | | | | 2.569 | |
| 7-4, 20 | | | 1762 | | | | | |
| 7-4, 70 | 63.4 | 1685 | 1746 | 1.83 | 43.17 | 55.02 | 2.857 | 7.53 |
| 7-4, 100 | | | 1707 | | | | | |
| 7-5 | 64.9 | | | | | | 2.845 | |
| 7-6, 20 | | | 1803 | | | | | |
| 7-6, 70 | 66.4 | | 1766 | 1.89 | 38.65 | 52.52 | | 22.10 |
| 7-6, 100 | | | 1752 | | | | | |
| 8-2, 20 | | | 1757 | | | | | |
| 8-2, 70 | 70.0 | | 1816 | 1.89 | 35.88 | 49.61 | 2.885 | 34.15 |
| 8-2, 100 | | | 1853 | | | | | |
| 8-3, 75 | 71.5 | | | | | | 2.791 | |
| 8-4, 20 | | | 1797 | | | | | |
| 8-4, 70 | 73.0 | 1507 | 1732 | 1.90 | 38.26 | 52.34 | 2.847 | 11.30 |
| 8-4, 100 | | | 1760 | | | | | |
| 8-5, 75 | 74.5 | | | | | | 2.801 | |
| 8-6, 20 | | | 1847 | | | | | |
| 8-6, 70 | 76.0 | | 1912 | 1.93 | 37.88 | 52.83 | 2.789 | 11.55 |
| 8-6, 100 | | | 1776 | | | | | |

**Table 5 (continued).**

| Sample (level in cm) | Sub-bottom depth (m) | Velocity (m/s) | Velocity in liner (m/s) | Wet-bulk density (g/cm$^3$) | Dry water content (%) | Porosity (%) | Thermal conductivity ($10^{-3}$ × cal × °C$^{-1}$ × cm$^{-1}$ × s$^{-1}$) | Shear strength (kPa) |
|---|---|---|---|---|---|---|---|---|
| 9-2, 20 | | | 1800 | | | | | |
| 9-2, 70 | 79.3 | 1756 | 1803 | 1.79 | 41.58 | 52.52 | 2.732 | 9.04 |
| 9-2, 100 | | | 1932 | | | | | |
| 9-3, 75 | 80.8 | | | | | | 2.767 | |
| 9-4, 40 | | | 1850 | | | | | |
| 9-4, 70 | 82.3 | 2067 | 1761 | 1.99 | 35.61 | 51.93 | 2.977 | 9.29 |
| 9-4, 100 | | | 1698 | | | | | |
| 9-5, 75 | 83.8 | | | | | | 2.504 | |
| 9-6, 20 | | | 1726 | | | | | |
| 9-6, 70 | 85.3 | | 1724 | 1.87 | 41.05 | 54.17 | 2.61 | 6.28 |
| 9-6, 100 | | | 1707 | | | | | |
| 10-2, 20 | | | 1761 | | | | | |
| 10-2, 70 | 89.2 | 1651 | 1729 | 1.86 | 43.00 | 55.70 | 2.675 | 6.53 |
| 10-2, 100 | | | 1841 | | | | | |
| 10-3, 75 | 90.7 | | | | | | 2.959 | |
| 10-4, 20 | | | 1777 | | | | | |
| 10-4, 70 | 92.2 | 1521 | | 1.97 | 34.25 | 50.04 | 3.010 | 9.04 |
| 10-4, 100 | | | 1724 | | | | | |
| 10-5, 75 | 93.7 | | | | | | 2.991 | |
| 10-6, 20 | | | 1829 | | | | | |
| 10-6, 70 | 95.2 | 1666 | 1699 | 1.82 | 46.17 | 57.50 | 2.725 | 7.53 |
| 10-6, 100 | | | 1779 | | | | | |
| 11-2, 20 | | | 1908 | | | | | |
| 11-2, 70 | 98.8 | 1637 | 1803 | 1.87 | 39.81 | 53.04 | 2.627 | 8.79 |
| 11-2, 100 | | | 1787 | | | | | |
| 11-3, 75 | 100.3 | | | | | | 2.785 | |
| 11-4, 20 | | 1780 | | | | | | |
| 11-4, 70 | 101.8 | 1719 | 2115 | 1.94 | 37.72 | 52.82 | 3.017 | 4.27 |
| 11-5, 75 | 103.3 | | | | | | 2.871 | |
| 11-6, 20 | | | 1883 | | | | | |
| 11-6, 70 | 104.8 | | 1844 | 1.93 | 34.68 | 49.40 | 2.635 | 9.29 |
| 11-6, 100 | | | 1690 | | | | | |
| 12-2, 30 | | | 1660 | | | | | |
| 12-2, 70 | 111.9 | | 1735 | 1.96 | 32.20 | 47.45 | 2.951 | 17.58 |
| 12-2, 100 | | | 1723 | | | | | |
| 12-3, 75 | 113.4 | | | | | | 2.640 | |
| 12-4, 30 | | | 1741 | | | | | |
| 12-4, 70 | 114.9 | | 1725 | 1.96 | 33.54 | 48.93 | 2.729 | 7.53 |
| 12-4, 100 | | | 1882 | | | | | |
| 12-5, 75 | 116.4 | | | | | | 2.949 | |
| 12-6, 30 | | | 1738 | | | | | |
| 12-6, 70 | 117.9 | | 1842 | 2.02 | 29.76 | 45.93 | 3.037 | 10.80 |
| 12-6, 100 | | | 1713 | | | | | |
| 13-2, 20 | | | 1926 | | | | | |
| 13-2, 70 | 121.4 | 1452 | 1897 | 2.01 | 30.61 | 46.69 | 2.901 | 8.75 |
| 13-2, 100 | | | 1714 | | | | | |
| 13-3, 75 | 122.9 | | | | | | 2.595 | |
| 13-4, 20 | | | 1739 | | | | | |
| 13-4, 70 | 124.4 | 1825 | 1981 | 1.99 | 32.69 | 48.76 | 2.824 | 3.01 |
| 13-4, 100 | | | 1884 | | | | | |
| 13-5, 75 | 125.9 | | | | | | 2.760 | |
| 13-6, 20 | | | 1856 | | | | | |
| 13-6, 70 | 127.4 | | 1817 | 1.96 | 34.95 | 50.56 | 3.204 | 6.53 |
| 14-2, 30 | | | 1502 | | | | | |
| 14-2, 70 | 131.0 | | 1605 | 1.96 | 32.76 | 48.03 | 2.842 | 4.77 |
| 14-2, 105 | | | 1453 | | | | | |
| 14-3, 75 | 132.5 | | | | | | 2.754 | |
| 14-4, 30 | | | 1907 | | | | | |
| 14-4, 70 | 134.0 | | 2034 | 1.99 | 34.01 | 50.08 | 2.731 | 12.85 |
| 14-4, 100 | | | 1612 | | | | | |
| 14-5, 75 | 135.5 | | | | | | 2.95 | |
| 14-6, 30 | 137.0 | | 1631 | | | | | |
| 14-6, 70 | | | 2009 | 1.98 | 32.67 | 48.53 | 2.901 | 8.04 |
| 14-6, 100 | | | 1691 | | | | | |
| 15-1, 75 | 139.1 | | | | | | 2.975 | |
| 15-2, 70 | 140.6 | 1899 | | 1.94 | 35.01 | 50.01 | | |
| 16-1, 75 | 148.6 | | | | | | 2.949 | |
| 16-2, 75 | 150.1 | | | | | | 2.869 | |
| 16-3, 15 | 151.6 | | | | | | 3.177 | |
| 17-1, 75 | 158.2 | 1995 | | | | | 2.403 | |
| 17-2, 85 | 159.7 | 1911 | | 1.86 | 41.35 | 54.13 | | |
| 17-3, 30 | 161.2 | | | | | | 3.072 | |
| 19-2, 70 | 179.1 | 1745 | 1842 | 1.88 | 39.18 | 52.69 | 2.825 | |
| 19-3, 75 | 180.6 | | | | | | 3.231 | |
| 19-4, 25 | | | 1810 | | | | | |
| 19-4, 75 | 182.1 | 1816 | | | | | 2.704 | |
| 19-4, 100 | | | 1860 | 1.88 | 40.67 | 54.19 | | |
| 19-5, 75 | 183.6 | | | | | | 2.814 | |
| 19-6, 40 | 185.1 | 1883 | | | | | | |
| 19-6, 75 | | | | 1.94 | 35.57 | 50.68 | 2.795 | |
| 22-1, 15 | 205.8 | 1815 | | | | | 3.237 | |
| 22-1, 75 | 206.4 | 1909 | | 1.95 | 33.77 | 48.93 | 2.572 | |
| 25-1, 60 | 235.1 | 1904 | | 1.97 | 29.79 | 44.92 | | |

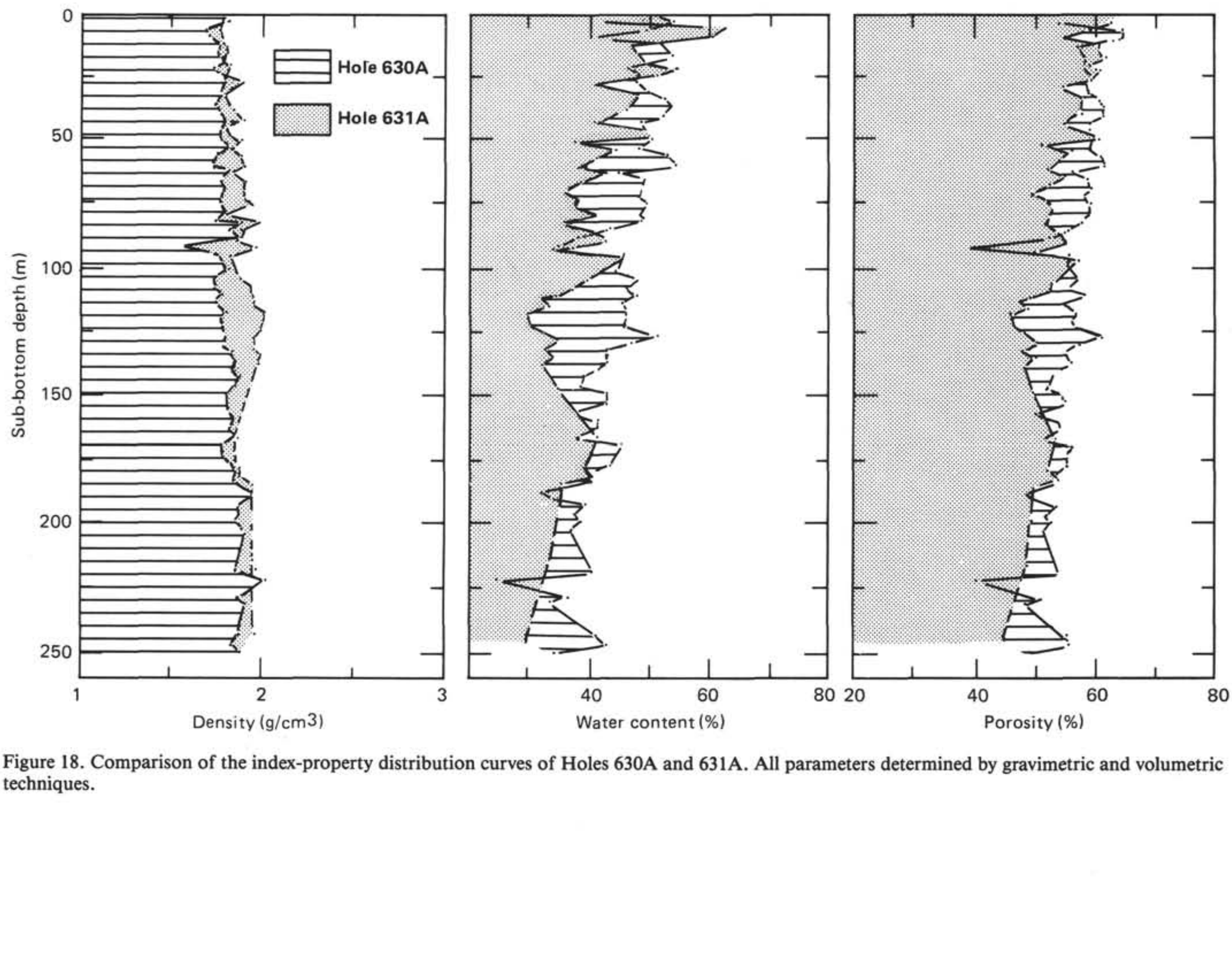



Figure 18. Comparison of the index-property distribution curves of Holes 630A and 631A. All parameters determined by gravimetric and volumetric techniques.

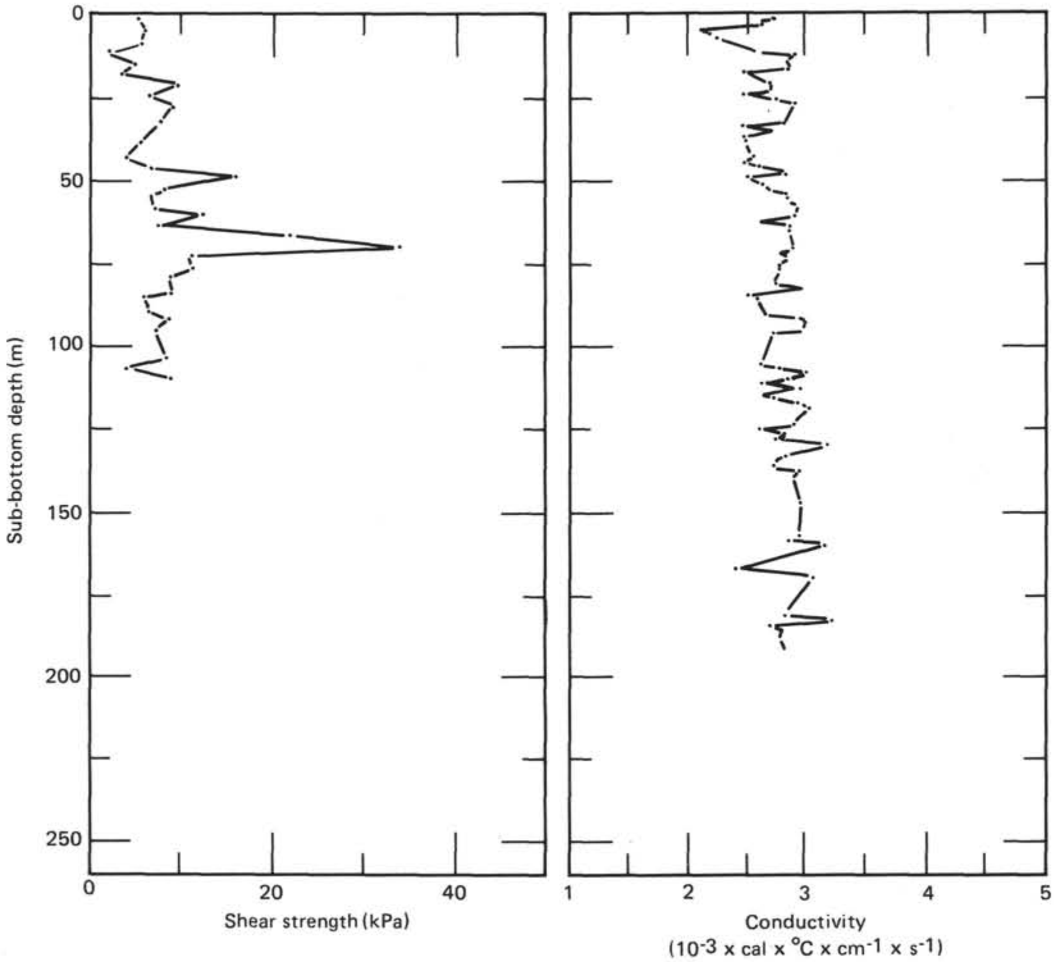



Figure 19. Thermal-conductivity and shear-strength downhole distribution curves at Site 631.

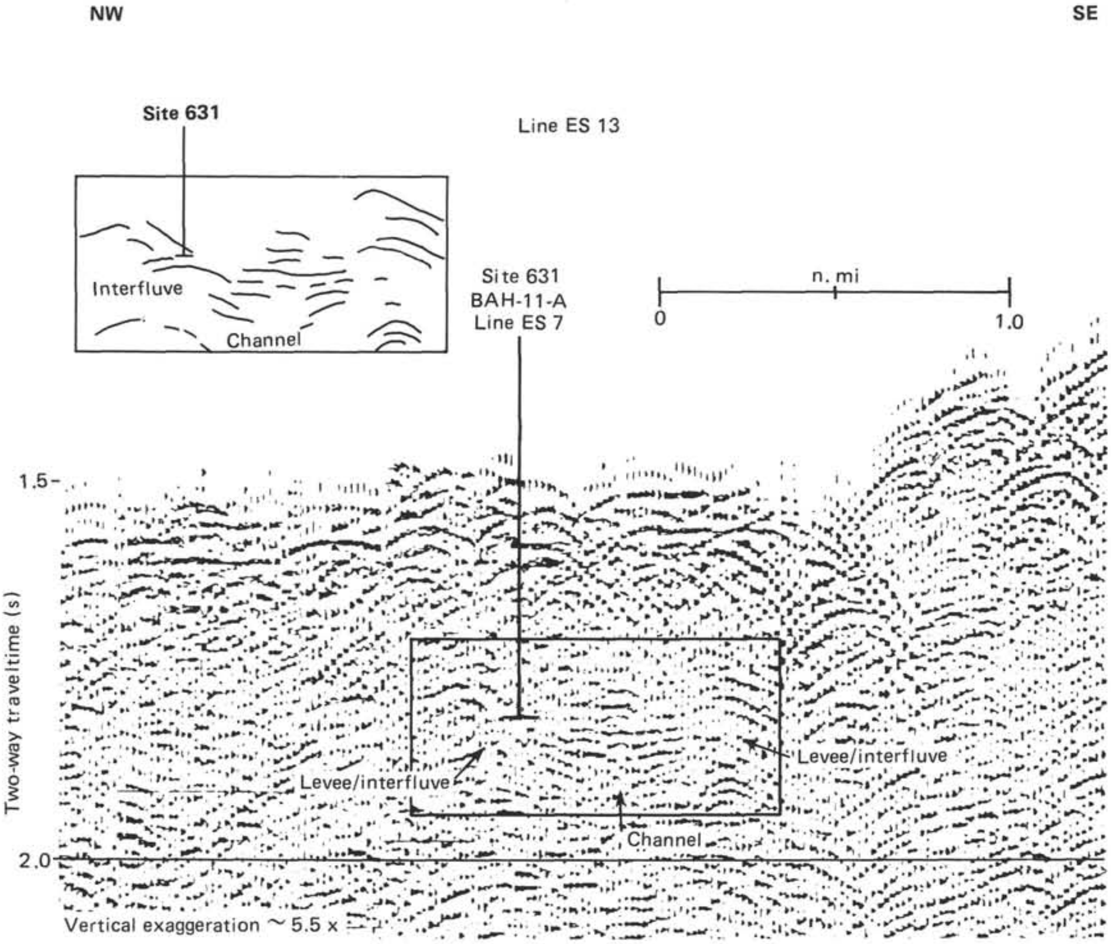



Figure 20. Part of strike (slope parallel) site-survey line ES-13, showing subsurface configuration of channel–interfluve system in the vicinity of Hole 631A (see inset). Vertical line shows the depth of penetration into the interfluve sequence. For location of profile, see Figure 1.

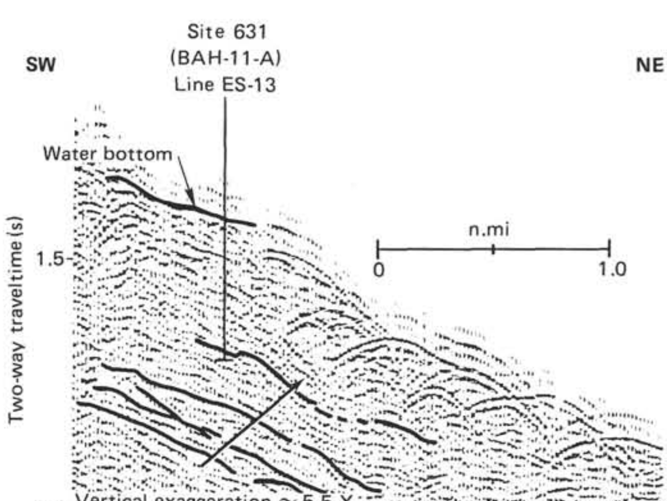



Figure 21. Part of dip line ES-07, illustrating the "shingled" seismic pattern interpreted here as the upbuilding and progradation of the interfluve sampled at Site 631. Arrow indicates progradation through time. For location of profile, see Figure 1. Vertical line is depth of penetration at Site 631.

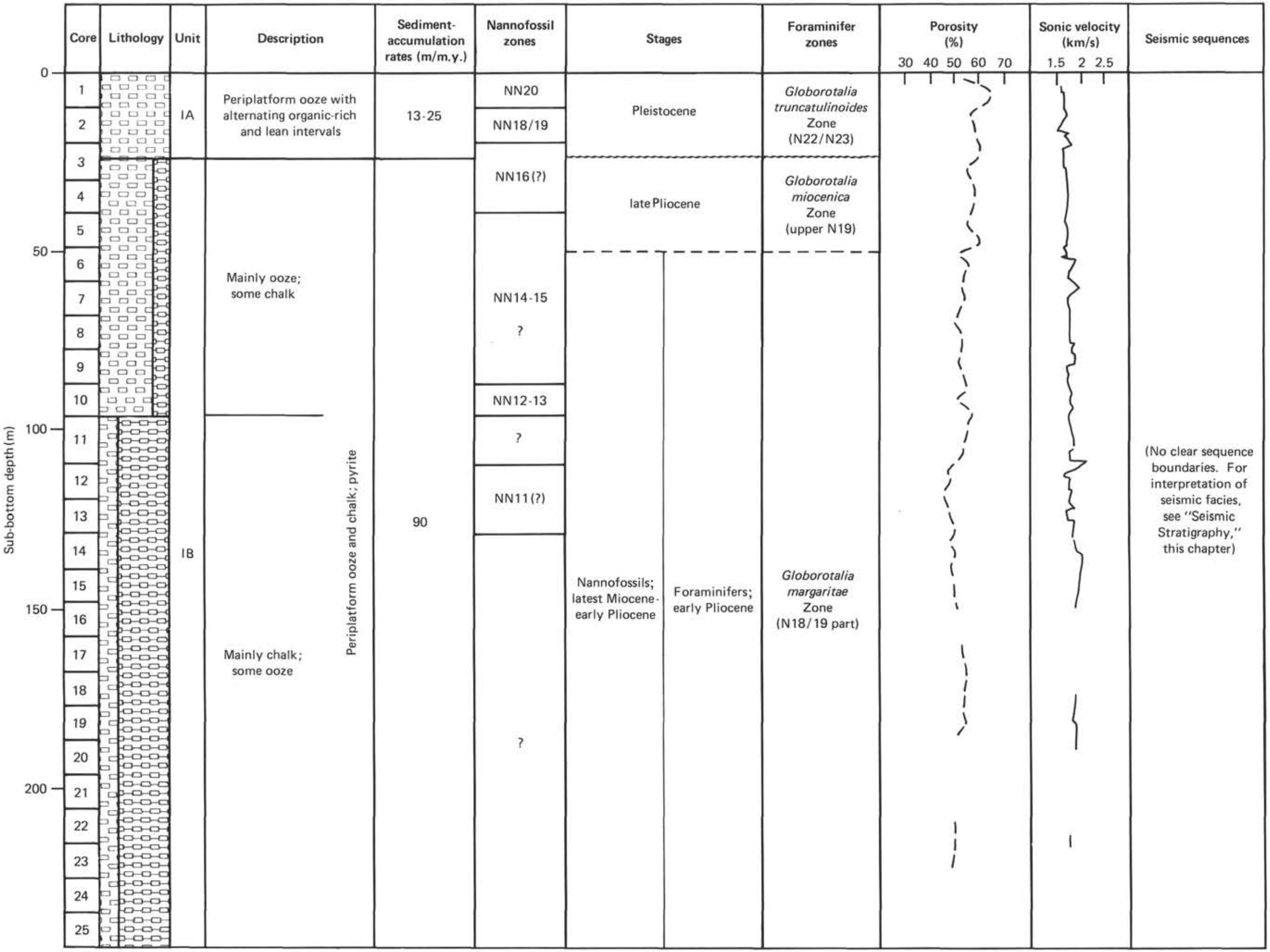
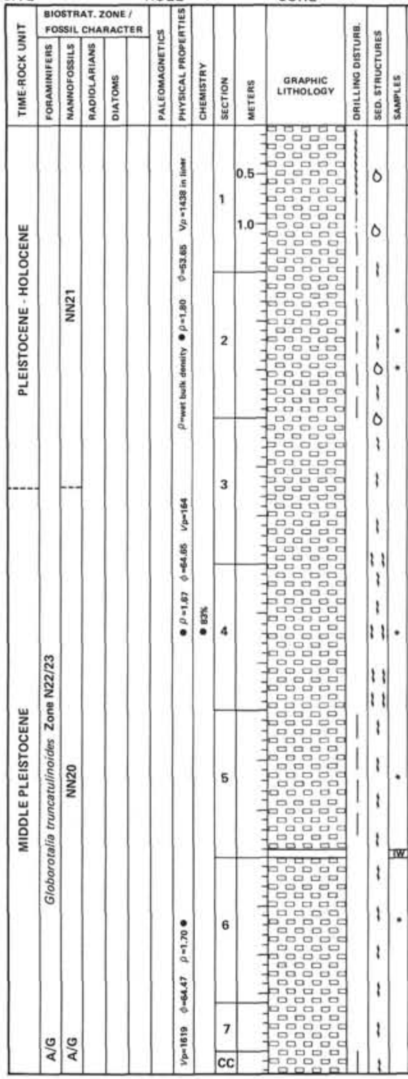



Figure 22. Summary of data for Site 631.

SITE 631 HOLE A CORE 1H CORED INTERVAL 1091.5-1101.2 mbsl; 0.0-9.7 mbsf




LITHOLOGIC DESCRIPTION

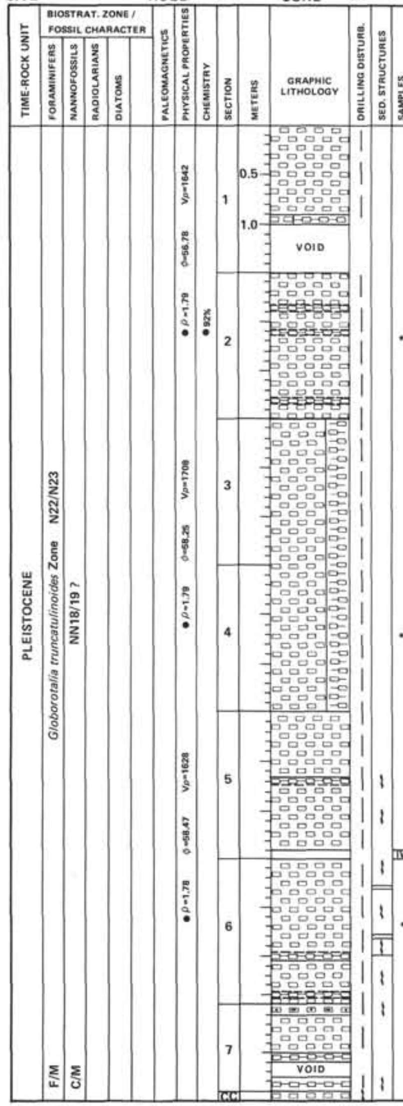
CALCAREOUS OOZE

CALCAREOUS OOZE, white (10YR 8/1, 5Y 8/2) to light gray (2.5Y 7/2), throughout core. Whole coiled pteropods and intact bivalves in Section 1, 38-146 cm. Some gray (10YR 6/1) streaks present. Burrows with dark brown (2.5Y 4/4) to light brownish gray (2.5Y 6/2) fill present in Sections 2 and 3. A plant seed was found in Section 2, 110 cm. A gradational color change from white to gray takes place in Section 4.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 5,75 | 6,75 | 2,96 |
|---|---|---|---|---|---|
| | D | D | D | D | M |
| COMPOSITION: | | | | | |
| Volcanic Glass | – | – | – | – | 5 |
| Foraminifers | 5 | 10 | 15 | 15 | 10 |
| Nannofossils | 60 | 45 | 45 | 40 | 35 |
| Pellets | 10 | 10 | 5 | 10 | 10 |
| Pteropods | Tr | 5 | 2 | 2 | 5 |
| Ostracods | – | – | – | Tr | – |
| Skeletal Fragments | 10 | 10 | 15 | 15 | 15 |
| Micrite | 15 | 20 | 18 | 18 | 20 |

SITE 631 HOLE A CORE 2H CORED INTERVAL 1101.2-1111.1 mbsl; 9.7-19.6 mbsf




LITHOLOGIC DESCRIPTION

CALCAREOUS OOZE with minor CHALK and UNLITHIFIED PACKSTONE

CALCAREOUS OOZE, white (10YR 8/1, 5Y 8/17.5YR 8/0) to light gray (2.5Y 7/0), throughout core with other lithologies interbedded. OOZE contains burrows and gray to black streaks.

CALCAREOUS OOZE and CHALK intercalated, white (10YR 8/1, 5Y 8/1), occurs in Section 1, 84-94 cm, and from Section 3, 0 cm, through Section 4, 150 cm. Contains some grain aggregates, but no obvious burrows.

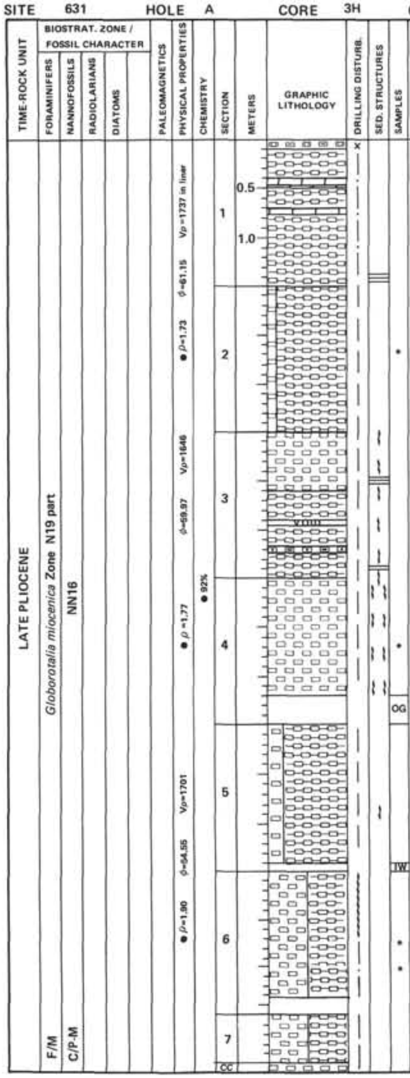
CHALK, white (10YR 8/1), occurs as thin beds in Section 2, 34-39 cm, 57-63 cm and 129-137 cm, in Section 5, 66-72 cm, in Section 6, 95-105 cm and 136-141 cm, and in Section 7, 51-62 cm and 75-90 cm.

UNLITHIFIED PACKSTONE, white (10YR 8/1), occurs in Section 7, 0-10 cm.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| | D | D | D |
| COMPOSITION: | | | |
| Foraminifers | 10 | 5 | 5 |
| Nannofossils | 30 | 40 | 35 |
| Pellets | 5 | 10 | 15 |
| Pteropods | Tr | – | – |
| Skeletal Fragments | 15 | 15 | 10 |
| Micrite (arag. needles) | 40 | 30 | 30 |

SITE 631 HOLE A CORE 3H CORED INTERVAL 1111.1-1121.0 mbsl; 19.6-29.5 mbsf




## LITHOLOGIC DESCRIPTION

CHALK, CALCAREOUS OOZE, with minor UNLITHIFIED PACKSTONE, LIMESTONE (LITHIFIED OOZE) and UNLITHIFIED FLOATSTONE (probably drilling breccia)

CHALK and CALCAREOUS OOZE intercalated, various shades of white (2.5Y 8/0, 2.5Y 8/2, 7.5YR 8/0, 10YR 8/1), occurs in Section 2, 0-150 cm, and from Section 5, 0 cm, through Section 7, 50 cm. Possibly bioturbated, but burrows are not distinct. Contains grain aggregates up to 0.3 cm diameter. Relative proportions of OOZE and CHALK vary.

CHALK, various shades of white (2.5Y 8/0, 2.5Y 8/2, 7.5YR 8/0), in Section 1, 10-150 cm, and in Section 3, 60-150 cm, with minor lithologies interbedded.

CALCAREOUS OOZE, white (2.5Y 8/0, 10YR 8/1), occurs in Section 3, 0-60 cm, Section 4, 0-120 cm, and in the CC, 0-10 cm.

UNLITHIFIED PACKSTONE, white (2.5Y 8/0), occurs as a single thin bed in Section 3, 118-120 cm.

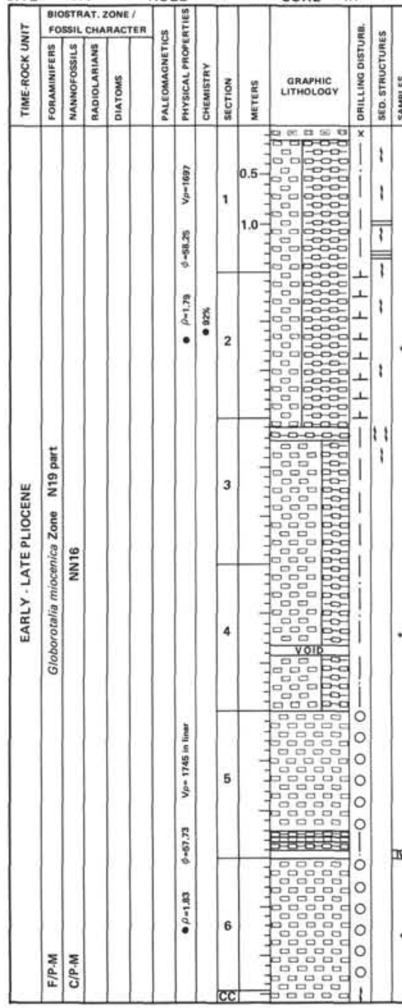
LIMESTONE (LITHIFIED OOZE), white (2.5Y 8/0), occurs in Section 1, 46-50 cm and 65-70 cm.

UNLITHIFIED FLOATSTONE, white (2.5Y 8/0), occurs in Section 1; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D | 6,106 D |
|---|---|---|---|---|
| COMPOSITION: | | | | |
| Foraminifers | 5 | 10 | 5 | 10 |
| Nannofossils | 35 | 15 | 30 | 15 |
| Pellets | 5 | 5 | 5 | 10 |
| Skeletal Fragments | 10 | 10 | 10 | 10 |
| Clasts | 15 | 20 | 10 | 30 |
| Micrite | 30 | 40 | 40 | 25 |

SITE 631 HOLE A CORE 4H CORED INTERVAL 1121.0-1130.6 mbsl; 29.5-39.1 mbsf




## LITHOLOGIC DESCRIPTION

CHALK and CALCAREOUS OOZE, with minor UNLITHIFIED FLOATSTONE *(probably drilling breccia)*

CHALK and CALCAREOUS OOZE intercalated, white (10YR 8/1, 2.5Y 8/2), occurs from Section 1, 15 cm, through Section 4, 82 cm. *Contains light gray (10YR 7/2) burrow fills. Relative proportions* of OOZE and CHALK vary.

CALCAREOUS OOZE, light gray (2.5Y 7/2), from Section 5, 0 cm, through the base of the core, with two thin interbeds of CHALK. OOZE is soupy, contains medium to coarse sized grain aggregates.

UNLITHIFIED FLOATSTONE, white (10YR 8/1), occurs in Section 1, 0-154 cm; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D |
|---|---|---|---|
| COMPOSITION: | | | |
| Foraminifers | 5 | 10 | 5 |
| Nannofossils | 20 | 25 | 20 |
| Pellets | 5 | 5 | 5 |
| Pteropods | – | Tr | – |
| Skeletal Fragments | 10 | 15 | 10 |
| Clasts | 20 | 20 | 20 |
| Micrite | 40 | 25 | 40 |

SITE 631 HOLE A CORE 5H CORED INTERVAL 1130.6-1140.2 mbsl; 39.1-48.7 mbsf

| TIME-ROCK UNIT | FORAMINIFERS | NANNOFOSSILS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION |
|---|---|---|---|---|---|
| LATE PLIOCENE | *Globorotalia miocenica* Zone N19 part; R/P | NN15/14; C/P-M | Vp=1705, φ=54.82, ● ρ=1.89, Vp=1676, φ=59.27, ● ρ=1.79, Vp=1658, φ=60.73, ● ρ=1.82 | ● 97% | 1–7, CC |

LITHOLOGIC DESCRIPTION

CALCAREOUS OOZE and CHALK with minor UNLITHIFIED FLOATSTONE (probably drilling breccia). Strong odor of hydrogen sulfide.

CALCAREOUS OOZE and CHALK intercalated, white (10YR 8/1, 2.5Y 8/2) to light gray (2.5Y 7/2), occurs from Section 1, 12 cm, through Section 6, 150 cm. Core material varies in degree of lithification, alternating from OOZE to CHALK. Bioturbation throughout. Relative proportions of OOZE and CHALK vary.

CHALK, white (10YR 8/1), from Section 7, 0 cm, through base of core.

UNLITHIFIED FLOATSTONE, white (10YR 8/1), in Section 1, 0-12 cm; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| COMPOSITION: | | | |
| Foraminifers | 10 | 10 | 5 |
| Nannofossils | 20 | 20 | 15 |
| Pellets | 3 | – | 5 |
| Pteropods | 2 | Tr | Tr |
| Skeletal Fragments | 15 | 15 | 15 |
| Clasts | 15 | 15 | 20 |
| Micrite | 35 | 40 | 40 |

SITE 631 HOLE A CORE 6H CORED INTERVAL 1140.2-1149.7 mbsl; 48.7-58.2 mbsf

| TIME-ROCK UNIT | FORAMINIFERS | NANNOFOSSILS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION |
|---|---|---|---|---|---|
| EARLY PLIOCENE | *Globorotalia margaritae* Zone (N18/N19 part); B | NN14/15; R/P | φ=61.29, ● ρ=1.88, Vp=1844 in liner, φ=56.34, ● ρ=1.83, Vp=1721 in liner, φ=54.37, ● ρ=1.87 | ● 97% | 1–7, CC |

LITHOLOGIC DESCRIPTION

CALCAREOUS OOZE, CHALK, and UNLITHIFIED RUDSTONE (probably drilling breccia). Strong odor of hydrogen sulfide.

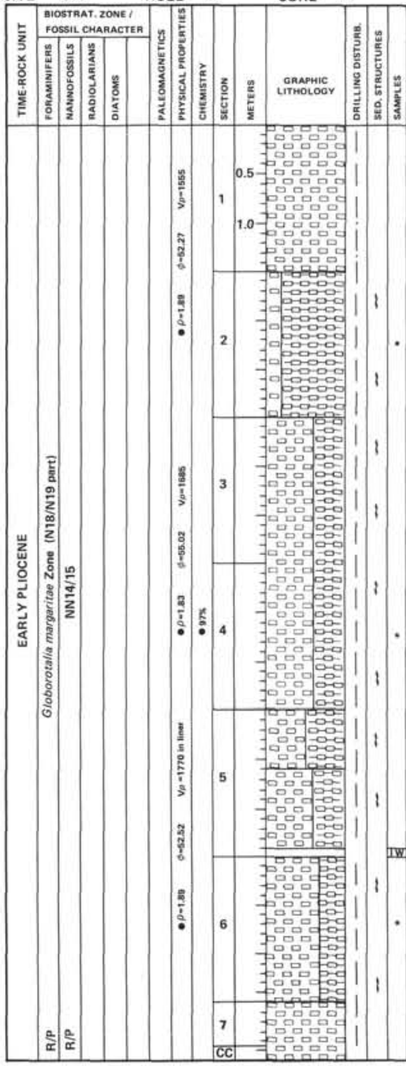
CALCAREOUS OOZE and CHALK intercalated, white (10YR 8/1, 2.5Y 8/2), occur throughout core with minor lithologies interbedded. Relative proportions of OOZE and CHALK vary.

UNLITHIFIED RUDSTONE, white (10YR 8/1), occurs in Section 1, 0-5 cm; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| | D | D | D |
| COMPOSITION: | | | |
| Foraminifers | 5 | 5 | 5 |
| Nannofossils | 15 | 15 | 20 |
| Skeletal Fragments | 5 | 5 | 10 |
| Clasts | 40 | 40 | 35 |
| Micrite | 35 | 35 | 30 |

SITE 631 HOLE A CORE 7H CORED INTERVAL 1149.7-1159.5 mbsl; 58.2-68.0 mbsf




LITHOLOGIC DESCRIPTION

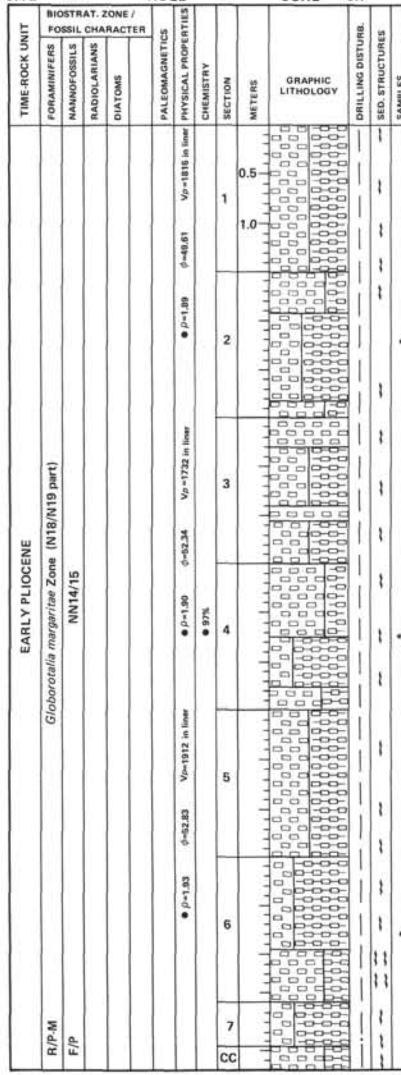
CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, various shades of white (10YR 8/1, 5Y 8/1, 2.5Y 8/2) to light gray (10YR 7/1), throughout core; bioturbated. Relative proportions of OOZE and CHALK vary. A few indurated burrows (1.5 cm diameter) are present.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| COMPOSITION: | | | |
| Foraminifers | 10 | 5 | 5 |
| Nannofossils | 20 | 20 | 10 |
| Skeletal Fragments | 10 | 5 | 5 |
| Clasts | 10 | 30 | 20 |
| Micrite | 50 | 40 | 60 |

SITE 631 HOLE A CORE 8H CORED INTERVAL 1159.5-1169.0 mbsl; 68.0-77.5 mbsf




LITHOLOGIC DESCRIPTION

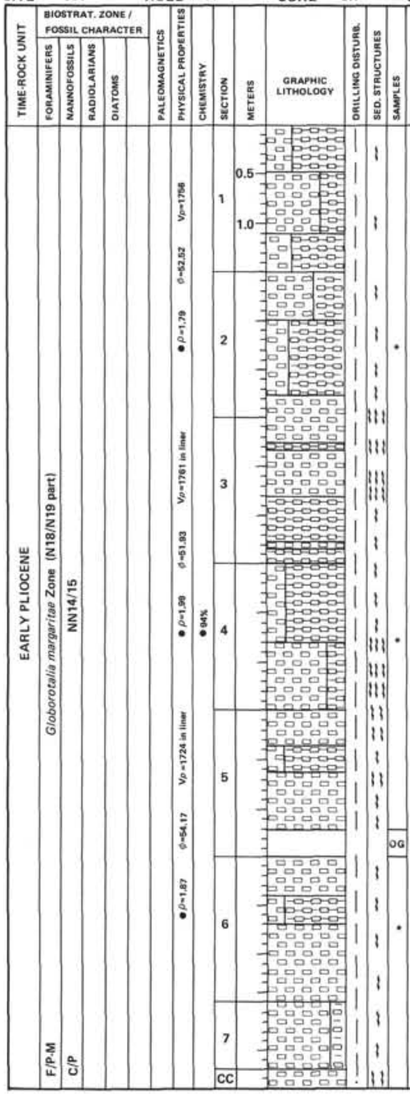
CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, various shades of white (5Y 8/1, 2.5Y 8/1, 10YR 8/1), occurs throughout core. Slightly bioturbated, pyrite is both disseminated throughout and concentrated in blebs. Relative proportions of OOZE and CHALK vary.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| | D | D | D |
| COMPOSITION: | | | |
| Accessory Minerals: | | | |
| Palagonite ? | – | Tr | Tr |
| Foraminifers | 10 | 5 | 5 |
| Nannofossils | 25 | 35 | 30 |
| Skeletal Fragments | 5 | – | – |
| Clasts | 20 | 20 | 25 |
| Micrite | 40 | 40 | 40 |

SITE 631 HOLE A CORE 9H CORED INTERVAL 1169.0-1178.7 mbsl; 77.5-87.2 mbsf




LITHOLOGIC DESCRIPTION

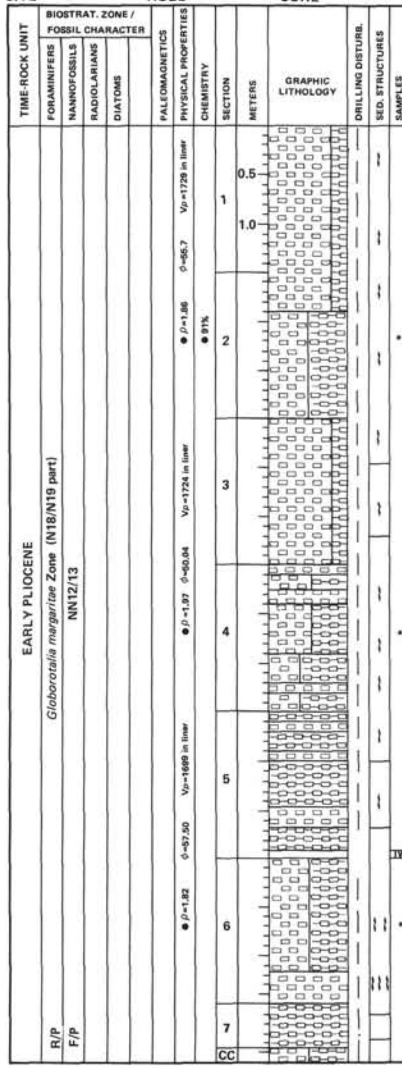
CALCAREOUS OOZE and CHALK. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, white (2.5Y 8/1, 10YR 8/1), occurs throughout core with minor lithologies interbedded. Slightly bioturbated; pyrite disseminated throughout and concentrated in blebs. Relative proportions of OOZE and CHALK vary.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D |
|---|---|---|---|
| COMPOSITION: | | | |
| Quartz | – | – | Tr |
| Calcite/Dolomite | – | – | 5 |
| Foraminifers | 10 | 20 | 10 |
| Nannofossils | 20 | 15 | 20 |
| Sponge Spicules | Tr | Tr | – |
| Skeletal Fragments | 15 | 20 | 25 |
| Pellets | 15 | 5 | 5 |
| Micrite | 40 | 40 | 35 |

SITE 631 HOLE A CORE 10H CORED INTERVAL 1178.7-1188.1 mbsl; 87.2-96.6 mbsf




LITHOLOGIC DESCRIPTION

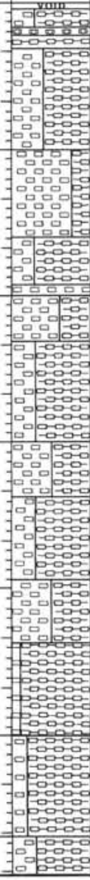
CALCAREOUS OOZE and CHALK. Strong odor of hydrogen sulfide.

CALCAREOUS OOZE and CHALK intercalated, various shades of white (10YR 8/1, 10YR 8/2, 5Y 8/1), occurs throughout core with minor lithologies interbedded. Slight bioturbation; no pyrite observed. Relative proportions of OOZE and CHALK vary.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D |
|---|---|---|---|
| COMPOSITION: | | | |
| Calcite | 20 | 20 | 20 |
| Nannofossils | 10 | 10 | 10 |
| Skeletal Fragments/Clasts | 30 | 30 | 30 |
| Micrite | 40 | 40 | 40 |

SITE 631 HOLE A CORE 11X CORED INTERVAL 1188.1-1201.2 mbsl; 96.6-109.7 mbsf

| TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EARLY PLIOCENE | *Globorotalia margaritae* Zone (N18/N19 part); F/M | Indeterminate; F/P | | | | Vp =1803 in liner; φ=53.04; ● ρ=1.87; Vp=1719; φ=52.82; ● ρ=1.94; Vp =1844 in liner; φ=49.40; ● ρ=1.93 | ● 96% | 1, 2, 3, 4, 5, 6, CC | 0.5, 1.0 |  | | | * * * |

CHALK and CALCAREOUS OOZE and MINOR UNLITHIFIED RUDSTONE (probably drilling breccia). Strong odor of hydrogen sulfide.

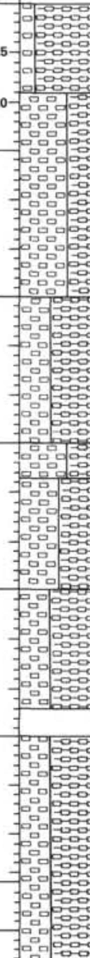
CHALK and CALCAREOUS OOZE intercalated, white (10YR 8/1), occurs throughout core with minor lithologies interbedded. Slight bioturbation, more visible in OOZE intervals. No pyrite observed. CHALK is fractured (probably by drilling). Some OOZE/CHALK couplets are present. Relative proportions of OOZE and CHALK vary.

UNLITHIFIED RUDSTONE, white (10YR 8/1), occurs in Section 1, 23-33 cm. Contains chalky clasts up to 2 cm diameter; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 2,25 | 4,75 | 6,75 |
|---|---|---|---|
| | D | D | D |
| COMPOSITION: | | | |
| Calcite | 20 | 20 | 20 |
| Foraminifers | Tr | Tr | – |
| Nannofossils | 10 | 10 | 10 |
| Skeletal Fragments/Clasts | 30 | 30 | 30 |
| Micrite | 40 | 40 | 40 |

SITE 631 HOLE A CORE 12X CORED INTERVAL 1201.2-1210.7 mbsl; 109.7-119.2 mbsf

| TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EARLY PLIOCENE | *Globorotalia margaritae* Zone (N18/N19 part); R/P | Indeterminate; F/P | | | | Vp=1735 in liner; φ=47.45; ● ρ=1.96; Vp =1725 in liner; φ=48.93; ● ρ=1.96; Vp =1842 in liner; φ=45.93; ● ρ=2.02 | ● 95% | 1, 2, 3, 4, 5, 6, 7, CC | 0.5, 1.0 |  | | | * * OG * |

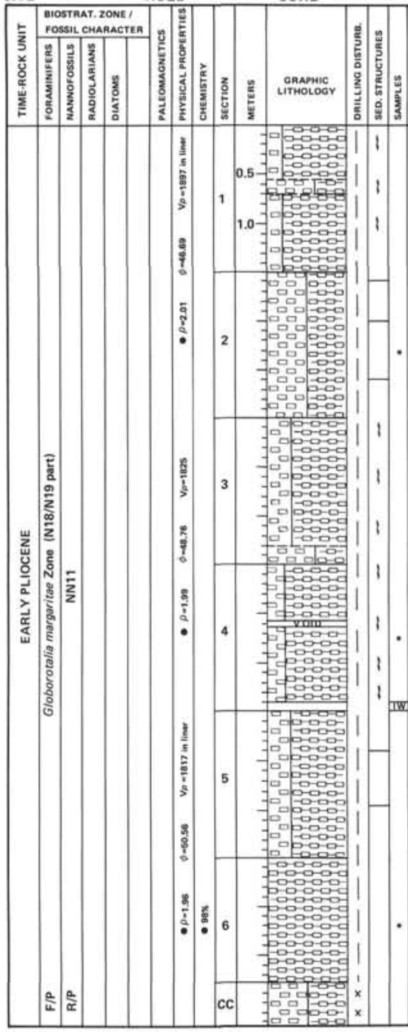
CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, white (10YR 8/1), occurs throughout core. Slight bioturbation, more visible in OOZE intervals. Some OOZE/CHALK couplets are present. Some CHALK is fractured (probably by drilling). Relative proportions of OOZE and CHALK vary.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| COMPOSITION: | | | |
| Calcite | 10 | 5 | 5 |
| Foraminifers | 5 | 5 | 10 |
| Nannofossils | 15 | 25 | 20 |
| Tunicate Spicules | Tr | Tr | Tr |
| Skeletal Fragments | 5 | 5 | 5 |
| Clasts | 5 | 5 | – |
| Micrite | 60 | 55 | 60 |

SITE 631 HOLE A CORE 13X CORED INTERVAL 1210.7-1220.3 mbsl; 119.2-128.8 mbsf




LITHOLOGIC DESCRIPTION

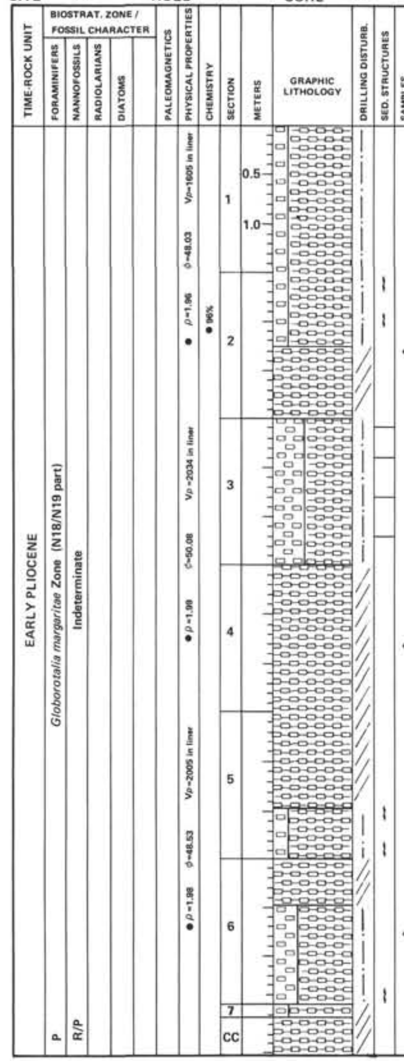
CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, white (10YR 8/1), throughout core. Bioturbation is most prominent in OOZE-rich layers. Some OOZE/CHALK couplets are present. Relative proportions of OOZE and CHALK vary. CHALK, white (10YR 8/1), in Section 6 as a thick bed.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D |
|---|---|---|---|
| COMPOSITION: | | | |
| Accessory Minerals | Tr | Tr | – |
| Foraminifers | 15 | 10 | 15 |
| Nannofossils | 15 | 20 | 20 |
| Skeletal Fragments | 5 | 5 | – |
| Clasts | 20 | 25 | 10 |
| Micrite | 45 | 40 | 55 |

SITE 631 HOLE A CORE 14X CORED INTERVAL 1220.3-1229.9 mbsl; 128.8-138.4 mbsf




LITHOLOGIC DESCRIPTION

CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE intercalated, white (10YR 8/1), occurs throughout core. No obvious bioturbation; no pyrite. Some OOZE/CHALK couplets are present. CHALK is fractured, possibly a result of drilling. Relative proportions of OOZE and CHALK vary, but CHALK predominates.

SMEAR SLIDE SUMMARY (%):

| | 2,75 D | 4,75 D | 6,75 D |
|---|---|---|---|
| COMPOSITION: | | | |
| Calcite/Dolomite | 10 | 5 | 5 |
| Foraminifers | 5 | 10 | 5 |
| Nannofossils | 20 | 25 | 20 |
| Tunicate Spicules | – | Tr | Tr |
| Skeletal Fragments | 5 | – | 5 |
| Micrite | 60 | 55 | 60 |
| Pellets | – | 5 | 5 |

SITE 631 HOLE A CORE 15X CORED INTERVAL 1229.9-1239.4 mbsl; 138.4-147.9 mbsf

TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Foraminifers: Indeterminate. Nannofossils: Indeterminate, R/P. Physical properties: ● ρ=1.94 φ=50.01 Vp=1899. Chemistry: ● 94%. Sections: 1, 2, 3, CC. Meters: 0.5, 1.0. Graphic lithology: VOID; VOID. Samples: OG; *

CHALK and CALCAREOUS OOZE (may be drilling paste), with minor UNLITHIFIED RUDSTONE (probably drilling breccia); core material is all highly fragmented. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE (may be drilling paste), white (2.5Y 8/2), throughout core (except for drilling breccia in Section 1). OOZE may really be a "drilling paste" formed between "biscuits" of CHALK. Well preserved miliolid foraminifers observed at several levels in Section 1; a large benthic foraminifer occurs in Section 2. CHALK is bioturbated, and fractured by drilling.

UNLITHIFIED RUDSTONE, white (2.5Y 8/2), occurs in Section 1, 0-30 cm; is probably drilling breccia.

*SMEAR SLIDE SUMMARY (%):*

| | 2,75 |
|---|---|
| | D |
| COMPOSITION: | |
| Foraminifers | Tr |
| Nannofossils | 25 |
| Tunicate Spicules | Tr |
| Clasts | 15 |
| *Micrite* | 60 |

SITE 631 HOLE A CORE 16X CORED INTERVAL 1239.4-1249.0 mbsl; 147.9-157.5 mbsf

TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Foraminifers: Indeterminate. Nannofossils: Indeterminate, R/P. Sections: 1, 2, 3, CC. Meters: 0.5, 1.0. Samples: *; IW; *

CHALK and CALCAREOUS OOZE (may be drilling paste), with minor UNLITHIFIED RUDSTONE (probably drilling breccia). Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (2.5Y 8/2), occurs throughout core (except for drilling breccia in Section 1). OOZE may really be a "drilling paste" formed between "biscuits" of CHALK. CHALK is well-indurated and bioturbated. An erosional surface is present in Section 2, 129-138 cm. Glauconite present in some burrows; miliolid foraminifers and skeletal molds (pteropods, molluscs) also present.

UNLITHIFIED RUDSTONE, white (2.5Y 8/2), in Section 1, 0-36 cm; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 1,41 | 2,75 |
|---|---|---|
| | D | D |
| COMPOSITION: | | |
| Calcite | 10 | – |
| Nannofossils | 20 | 20 |
| Micrite | 40 | 30 |
| Clasts & Skeletal Fragments | 30 | 50 |

SITE 631 HOLE A CORE 17X CORED INTERVAL 1249.0-1258.7 mbsl; 157.5-167.2 mbsf

TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Time-rock unit: EARLY PLIOCENE. Foraminifers: *Globorotalia margaritae* Zone (N18/N19 part), F/P. Nannofossils: Indeterminate, R/P. Physical properties: ● ρ=1.86 φ=54.13 Vp=1911. Chemistry: ● 97%. Sections: 1, 2, 3, CC. Meters: 0.5, 1.0.

CHALK and CALCAREOUS OOZE (may be drilling paste). Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (2.5Y 8/2, 10YR 8/1), occurs throughout core. OOZE may really be a "drilling paste" formed between "biscuits" of CHALK. CHALK is bioturbated; also highly fractured.

SITE 631 HOLE A CORE 18X CORED INTERVAL 1258.7-1268.4 mbsl; 167.2-176.9 mbsf

TIME-ROCK UNIT | BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Foraminifers: Indeterminate. Nannofossils: Indeterminate, R/P. Sections: 1, CC. Meters: 0.5.

CHALK with minor UNLITHIFIED FLOATSTONE (probably drilling breccia); *core material is highly brecciated. Strong odor of hydrogen* sulfide.

CHALK, white (2.5Y 8/2), occurs in Section 1. CHALK is bioturbated, contains miliolids and shallow-water skeletal debris.

UNLITHIFIED FLOATSTONE, white (2.5Y 8/1), in the CC. Contains CHALK clasts in an OOZE matrix (probably drilling breccia.

SITE 631 HOLE A CORE 19X CORED INTERVAL 1268.4-1278.0 mbsl; 176.9-186.5 mbsf

TIME-ROCK UNIT: EARLY PLIOCENE

BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS: *Globorotalia margaritae* Zone (N18/N19 part), R/P; NANNOFOSSILS: Indeterminate, R/P

PHYSICAL PROPERTIES: V=1842 in liner; φ=52.65; ρ=1.88; V=1816; φ=54.19; ρ=1.88; V=1883; φ=50.88; ρ=1.94

CHEMISTRY: 93%

SECTIONS: 1, 2, 3, 4, 5, 6, 7, CC; METERS: 0.5, 1.0

SAMPLES: IW

LITHOLOGIC DESCRIPTION

CHALK and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (10YR 8/1, 2.5Y 8/2), alternating throughout core; CHALK may be "drilling biscuits," OOZE may be "drilling paste." CHALK is bioturbated, with burrows of small (0.3 cm diameter) and large (1 cm diameter) size. CHALK is highly fractured.

SMEAR SLIDE SUMMARY (%):

| | 2,75 | 4,75 | 6,75 |
|---|---|---|---|
| | D | D | D |
| COMPOSITION: | | | |
| Foraminifers | 5 | 5 | 5 |
| Nannofossils | 10 | 5 | 10 |
| Skeletal Fragments | 10 | 10 | 10 |
| Clasts | 20 | 30 | 20 |
| Micrite | 55 | 45 | 55 |
| Pellets | – | 5 | – |

SITE 631 HOLE A CORE 20X CORED INTERVAL 1278.0-1287.6 mbsl; 186.5-196.1 mbsf

BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS: Indeterminate; NANNOFOSSILS: Indeterminate, R/P

SECTION: CC

LITHOLOGIC DESCRIPTION

Empty core liner. CC contains CHALK fragments with minor CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (2.5Y 8/2), in CC; highly fragmented. Bioturbated, contains some miliolid foraminifers. OOZE may be "drilling paste."

SITE 631 HOLE A CORE 21X CORED INTERVAL 1287.6-1297.1 mbsl; 196.1-205.6 mbsf

BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS: Indeterminate; NANNOFOSSILS: R/P

SECTION: CC

LITHOLOGIC DESCRIPTION

Empty core liner. CC contains CHALK fragments and CALCAREOUS OOZE. Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (2.5Y 8/2), in CC; highly fragmented. Slightly bioturbated, a few miliolid foraminifers present. OOZE may be "drilling paste."

SITE 631 HOLE A CORE 22X CORED INTERVAL 1297.1-1306.8 mbsl; 205.6-215.3 mbsf

BIOSTRAT. ZONE / FOSSIL CHARACTER: FORAMINIFERS: Indeterminate, R-F/P; NANNOFOSSILS: Indeterminate, R/P

PHYSICAL PROPERTIES: Vp=1809; φ=48.93; ρ=1.95

CHEMISTRY: 94%

SECTIONS: 1, CC; METERS: 0.5

LITHOLOGIC DESCRIPTION

CHALK and CALCAREOUS OOZE, with minor UNLITHIFIED FLOATSTONE (probably drilling breccia). Strong odor of hydrogen sulfide.

CHALK and CALCAREOUS OOZE, white (2.5Y 8/2), throughout core (apart from drilling breccia in Section 1). CHALK is bioturbated and fragmented. OOZE may be "drilling paste."

UNLITHIFIED FLOATSTONE, white (2.5Y 8/2), in Section 1, 0-26 cm; is probably drilling breccia.

SMEAR SLIDE SUMMARY (%):

| | 1,75 |
|---|---|
| | D |
| COMPOSITION: | |
| Foraminifers | 5 |
| Nannofossils | 5 |
| Sponge Spicules | Tr |
| Skeletal Fragments | 15 |
| Clasts | 25 |
| Micrite | 50 |

SITE 631 HOLE A CORE 23X CORED INTERVAL 1306.8-1316.4 mbsl; 215.3-224.9 mbsf

| TIME-ROCK UNIT | FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age Indeter. | R/P | | | | | | CC | | | | | | Empty core liner. CHALK fragments in CC. CHALK, white (2.5Y 8/2), in CC; highly fragmented. |

Empty core liner. CHALK fragments in CC.

CHALK, white (2.5Y 8/2), in CC; highly fragmented.

SITE 631 HOLE A CORE 24X CORED INTERVAL 1316.4-1326.0 mbsl; 224.0-234.5 mbsf

| TIME-ROCK UNIT | FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EARLY PLIOCENE | R/P *Globorotalia margaritae* Zone (N18/N19 part) | C/P-M | | | | | | 1 | | | / × × | | * | |
| | | | | | | | | CC | | | × × | | | |

CHALK and CALCAREOUS OOZE, highly brecciated (may be drilling breccia)

CHALK and CALCAREOUS OOZE, light gray (2.5Y 7/2) and white (2.5Y 7/2), highly fragmented, occurs throughout core. Material from Section 1, 15 cm, through the base of the core, may be drilling breccia.

SITE 631 HOLE A CORE 25X CORED INTERVAL 1326.0-1335.8 mbsl; 234.5-244.3 mbsf

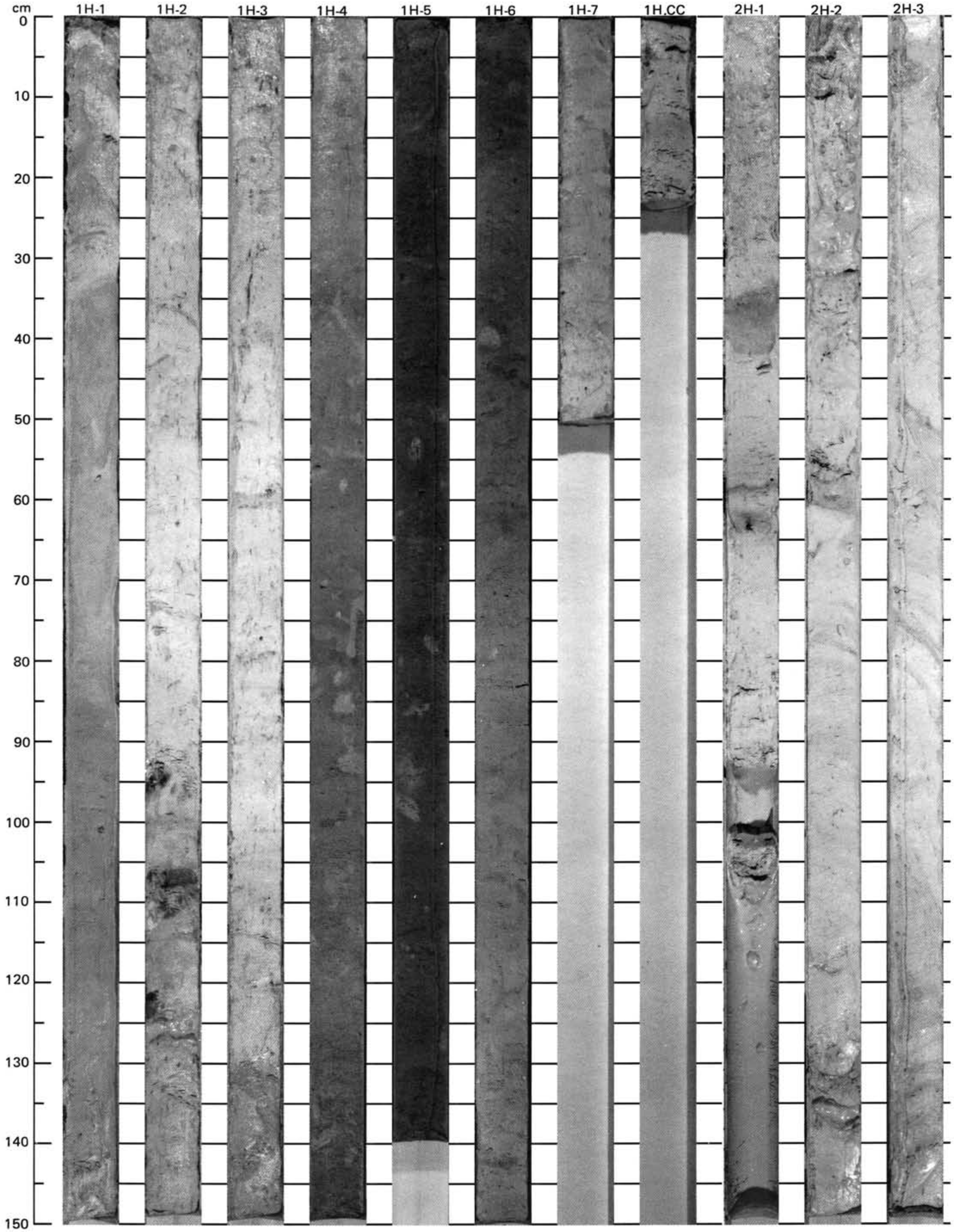
| TIME-ROCK UNIT | FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS | PALEOMAGNETICS | PHYSICAL PROPERTIES | CHEMISTRY | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURB. | SED. STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EARLY PLIOCENE | F/P-M *Globorotalia margaritae* Zone (N18/N19 part) | C-P NN9/11 ? | | | | Vp=1904 φ =44.92 ρ =1.97 ● | 97% ● | 1 | 0.5, 1.0 | | × / / / / / / × | | • | |
| | | | | | | | | CC | | | × × | | | |

CHALK and CALCAREOUS OOZE

CHALK and CALCAREOUS OOZE, white (5Y 8/1, 2.5Y 8/0, 5Y 8/2), throughout core, although material in Section 1, 0-25 cm, and in the CC may be drilling breccia. OOZE/CHALK couplets present in Section 1, 25-115 cm, probably drilling biscuits. CHALK is bioturbated and fractured.

SMEAR SLIDE SUMMARY (%):

| | 1,84 |
|---|---|
| | D |
| COMPOSITION: | |
| Foraminifers | 5 |
| Nannofossils | 15 |
| Sponge Spicules | 2 |
| Skeletal Fragments | 8 |
| Clasts | 15 |
| Micrite | 55 |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1H-4
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1H-6
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1H,CC
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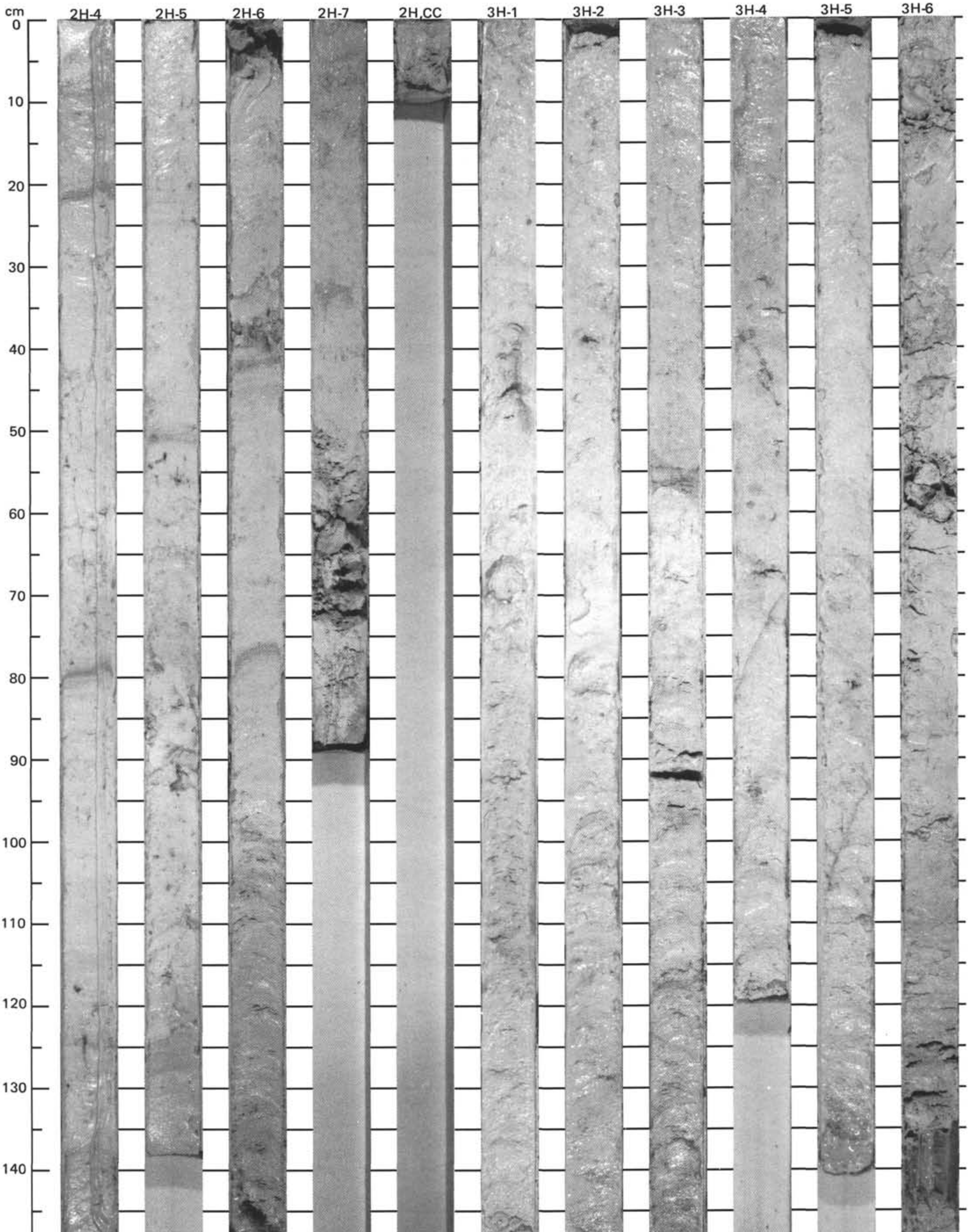
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2H,CC
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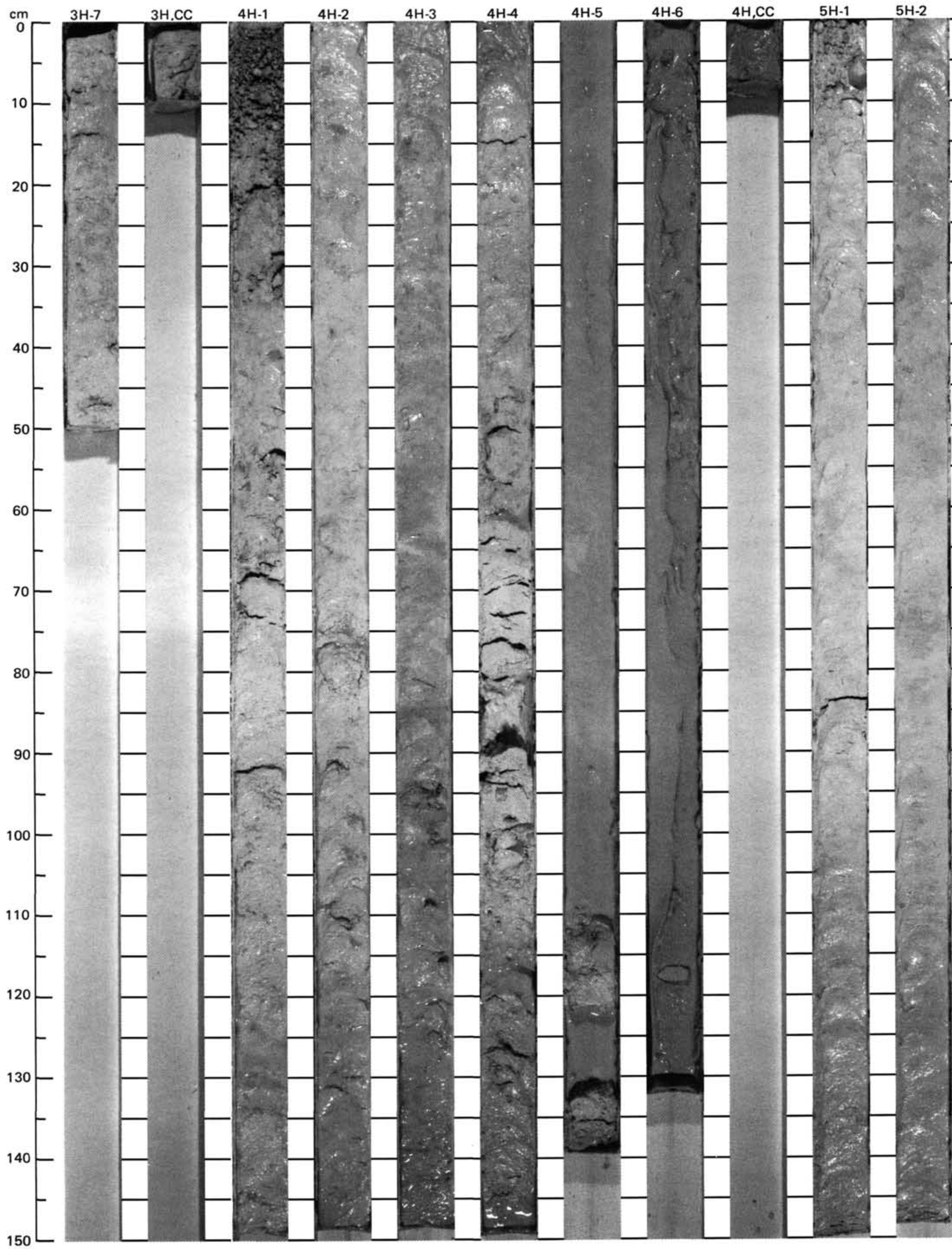
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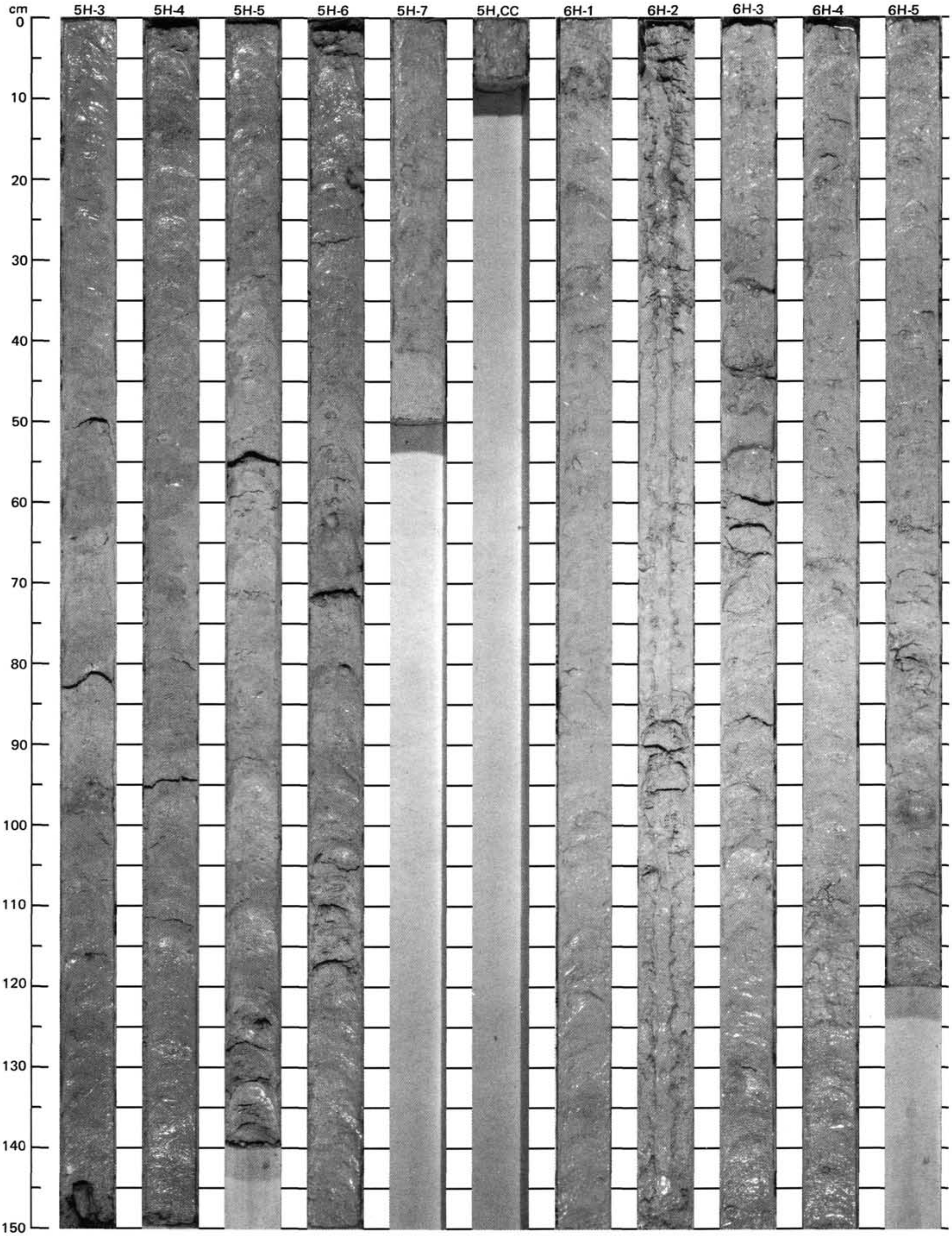
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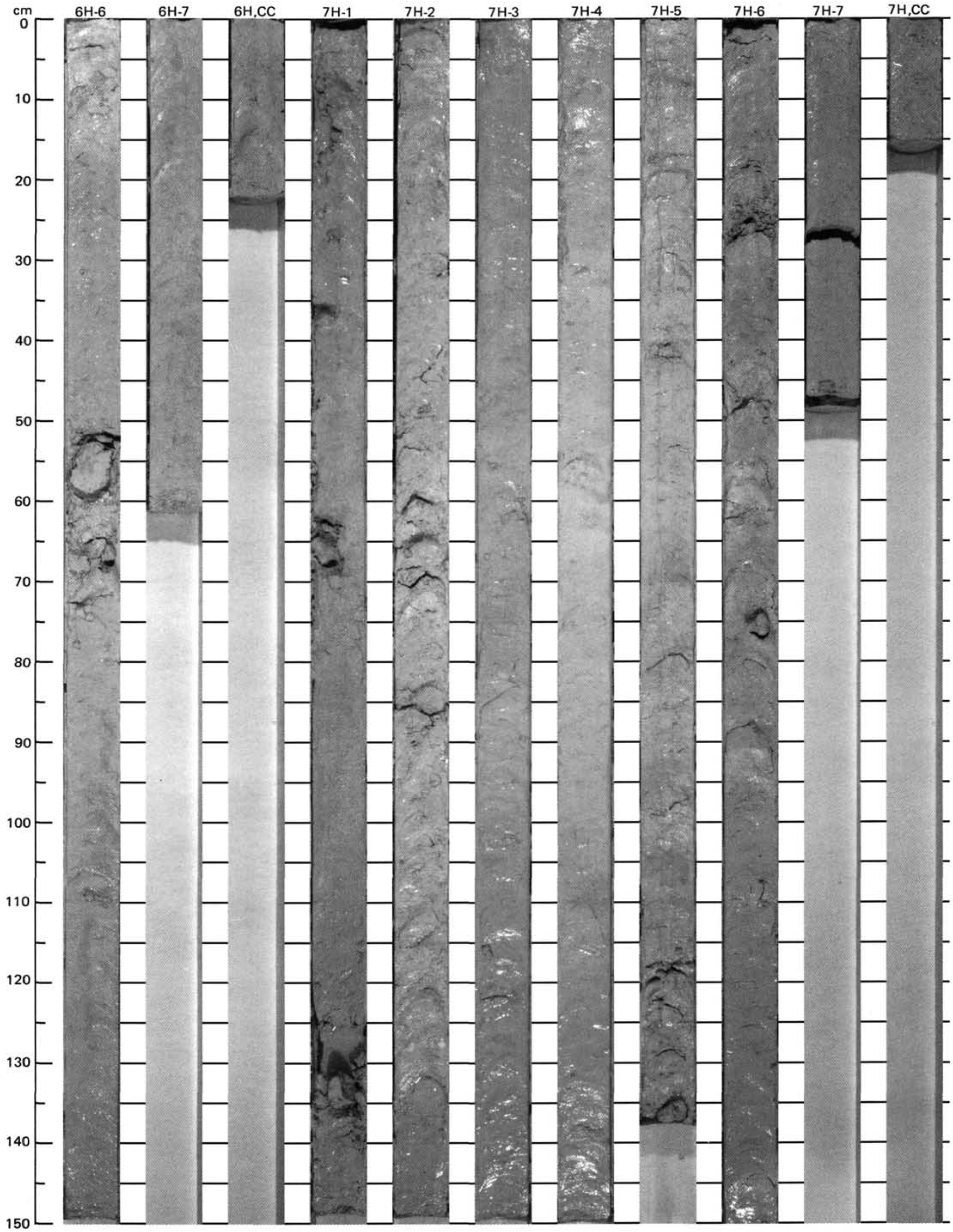
6H-5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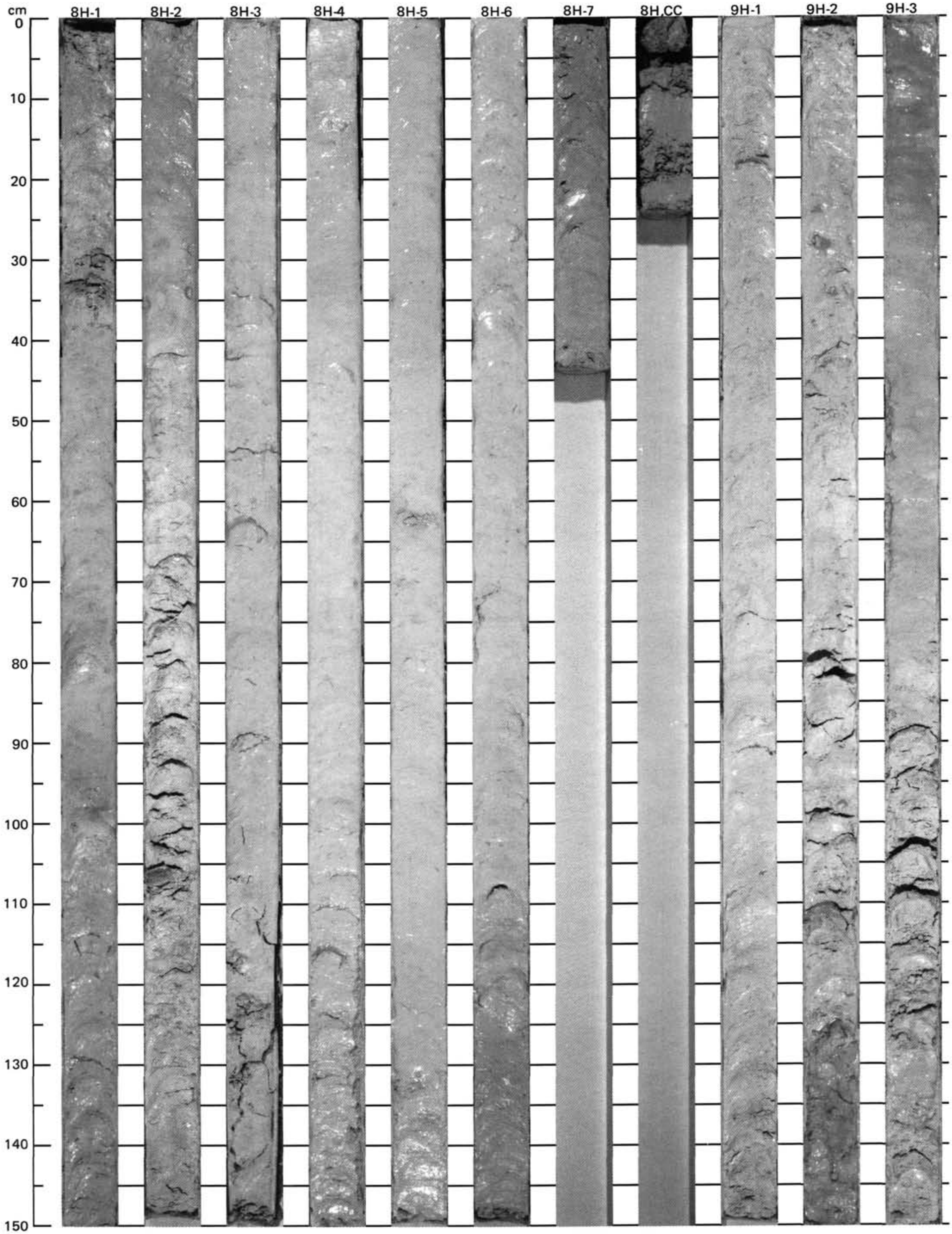
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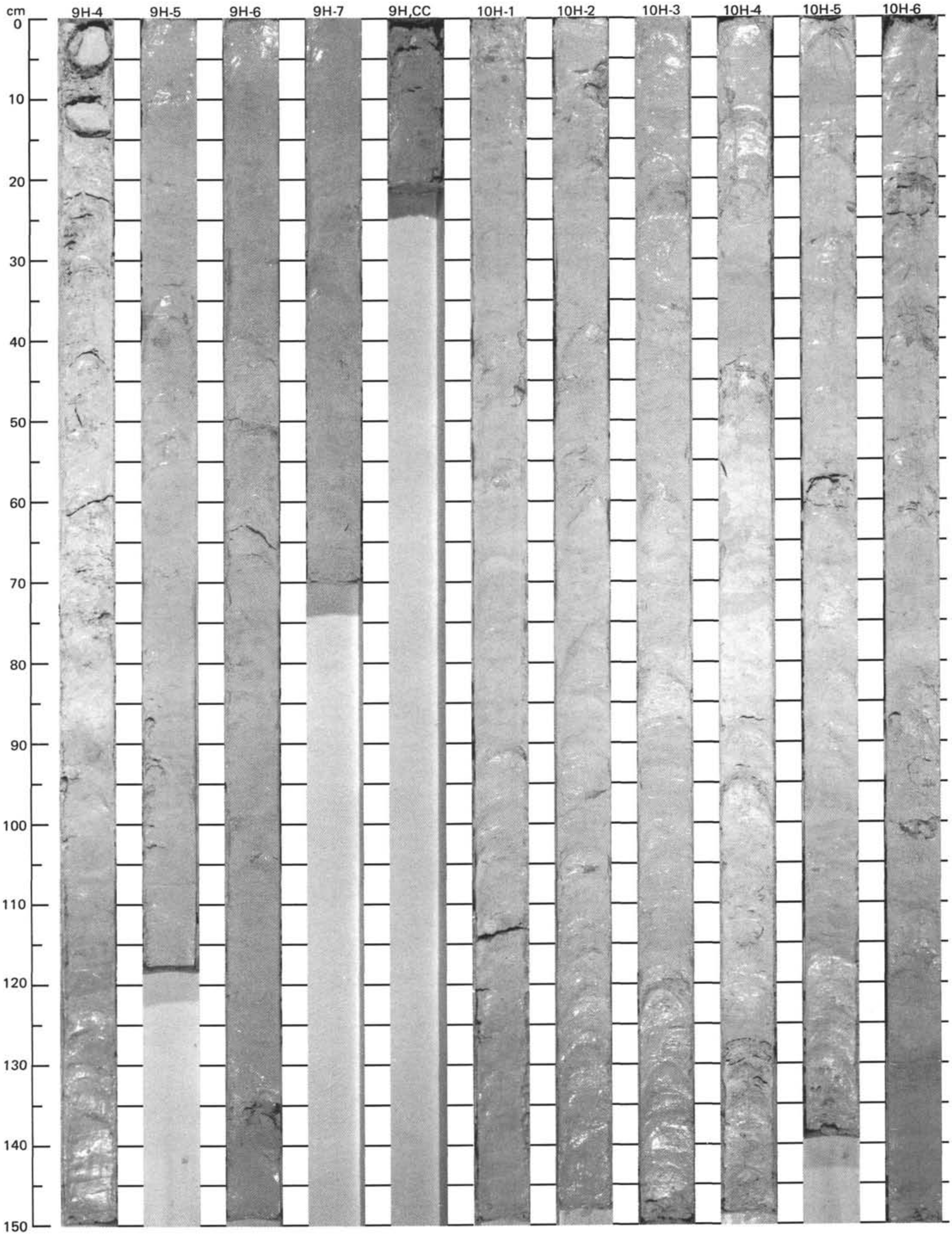
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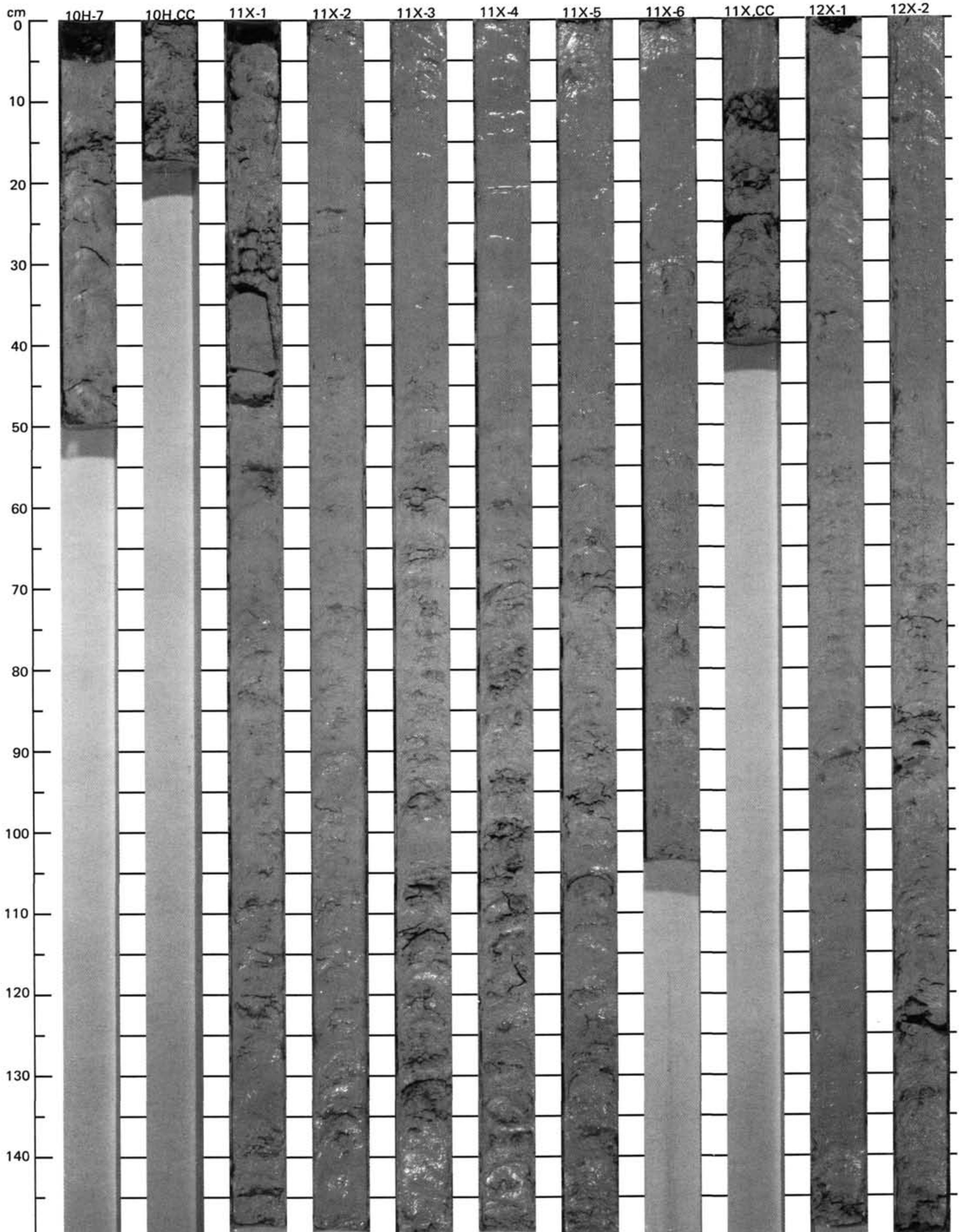
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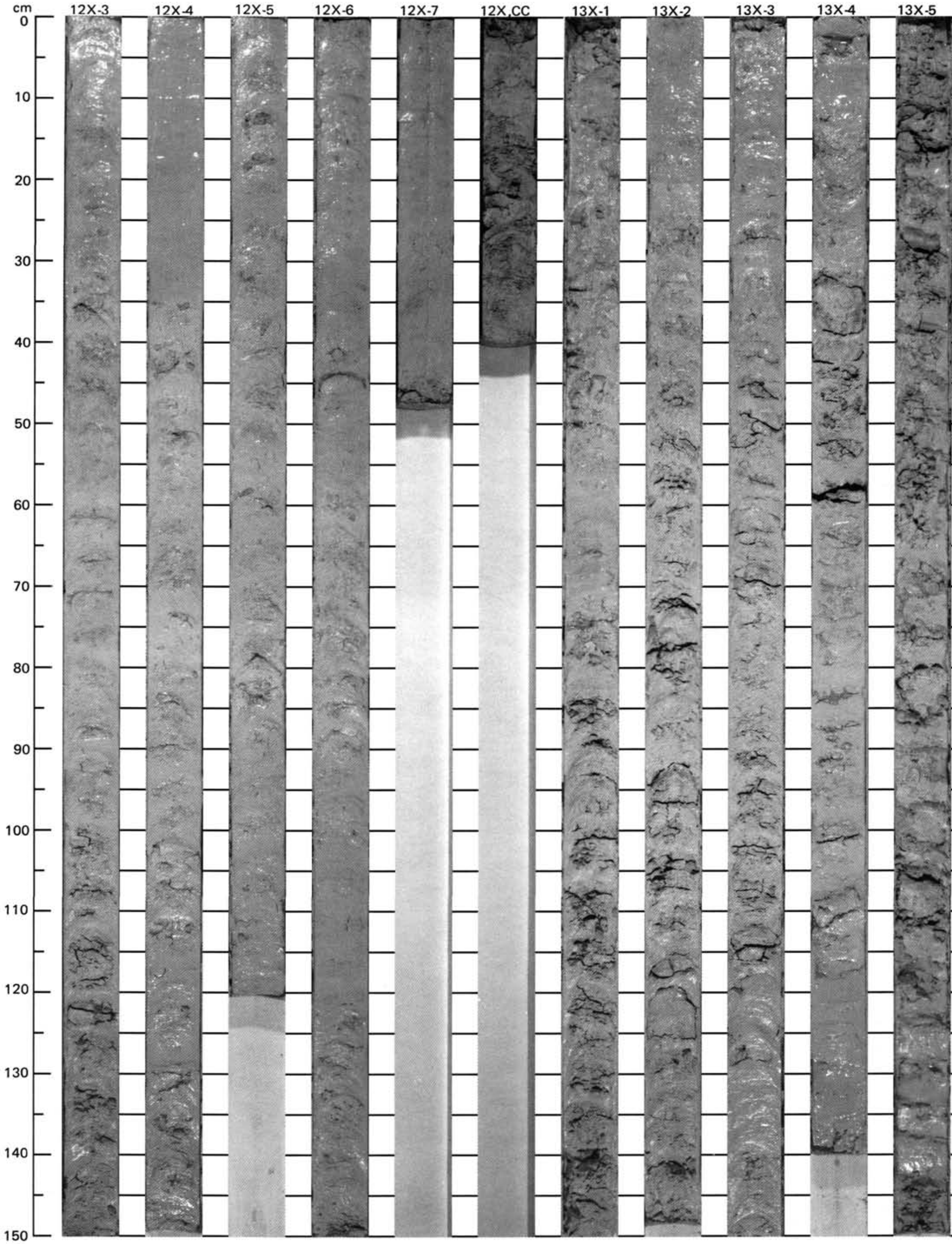
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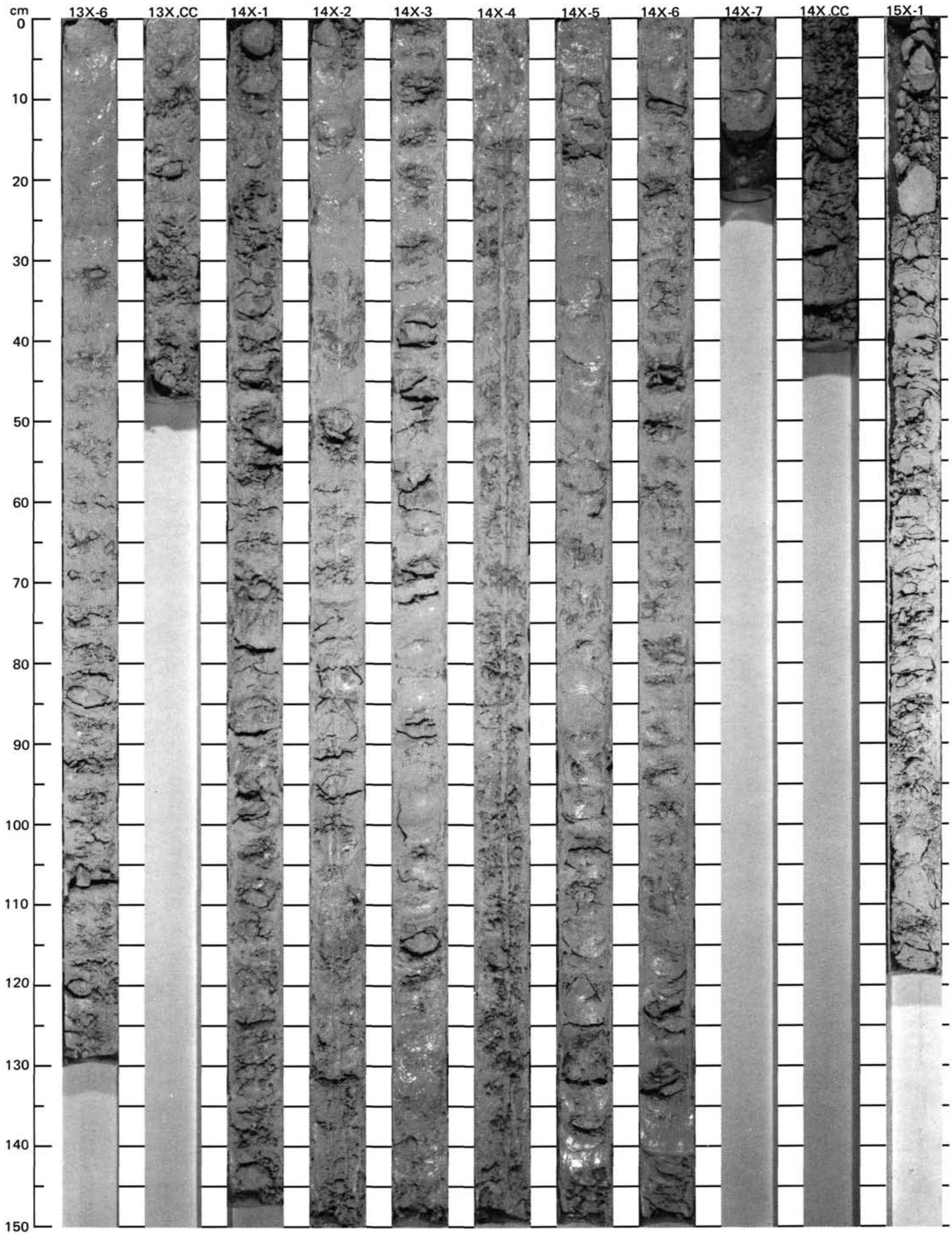
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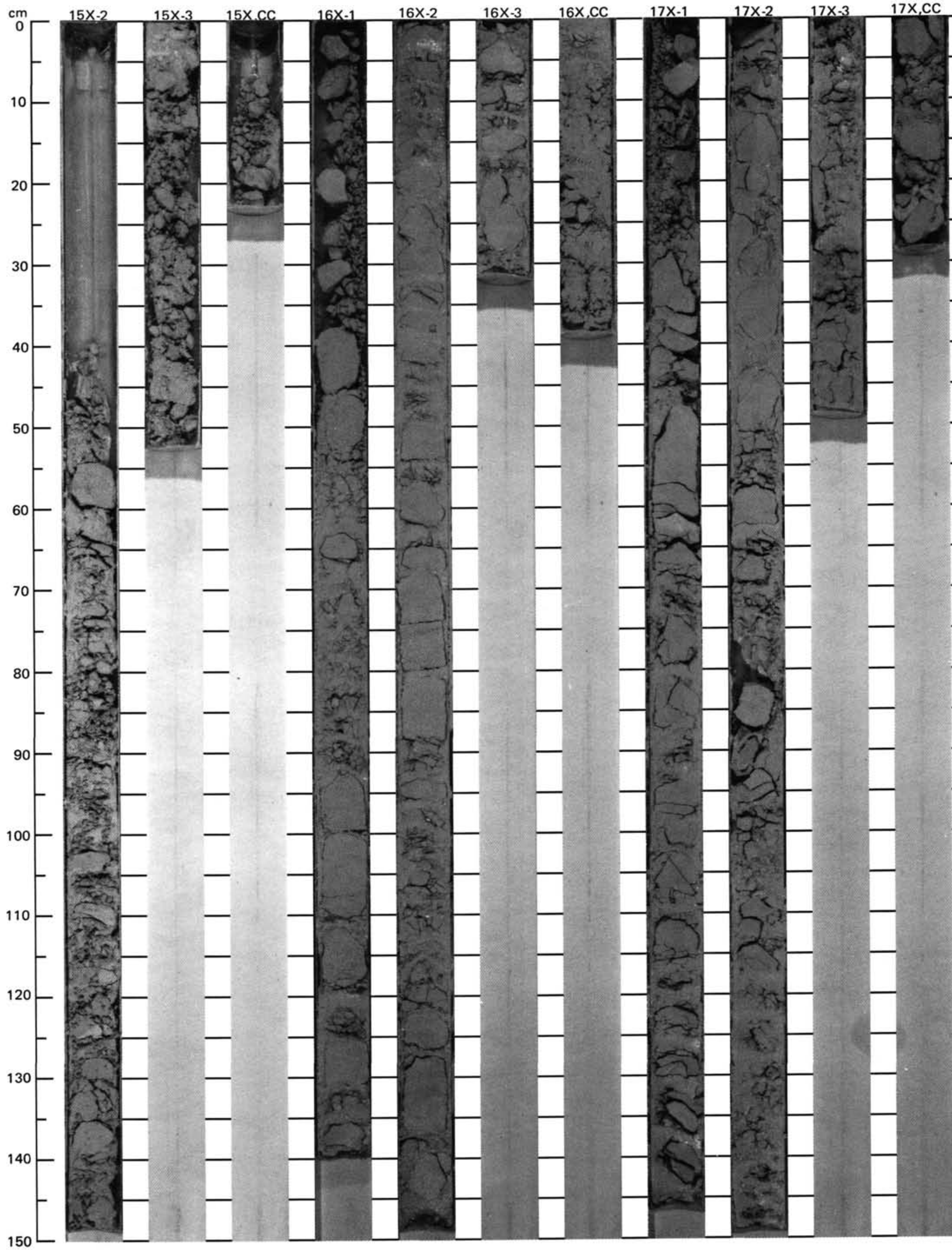
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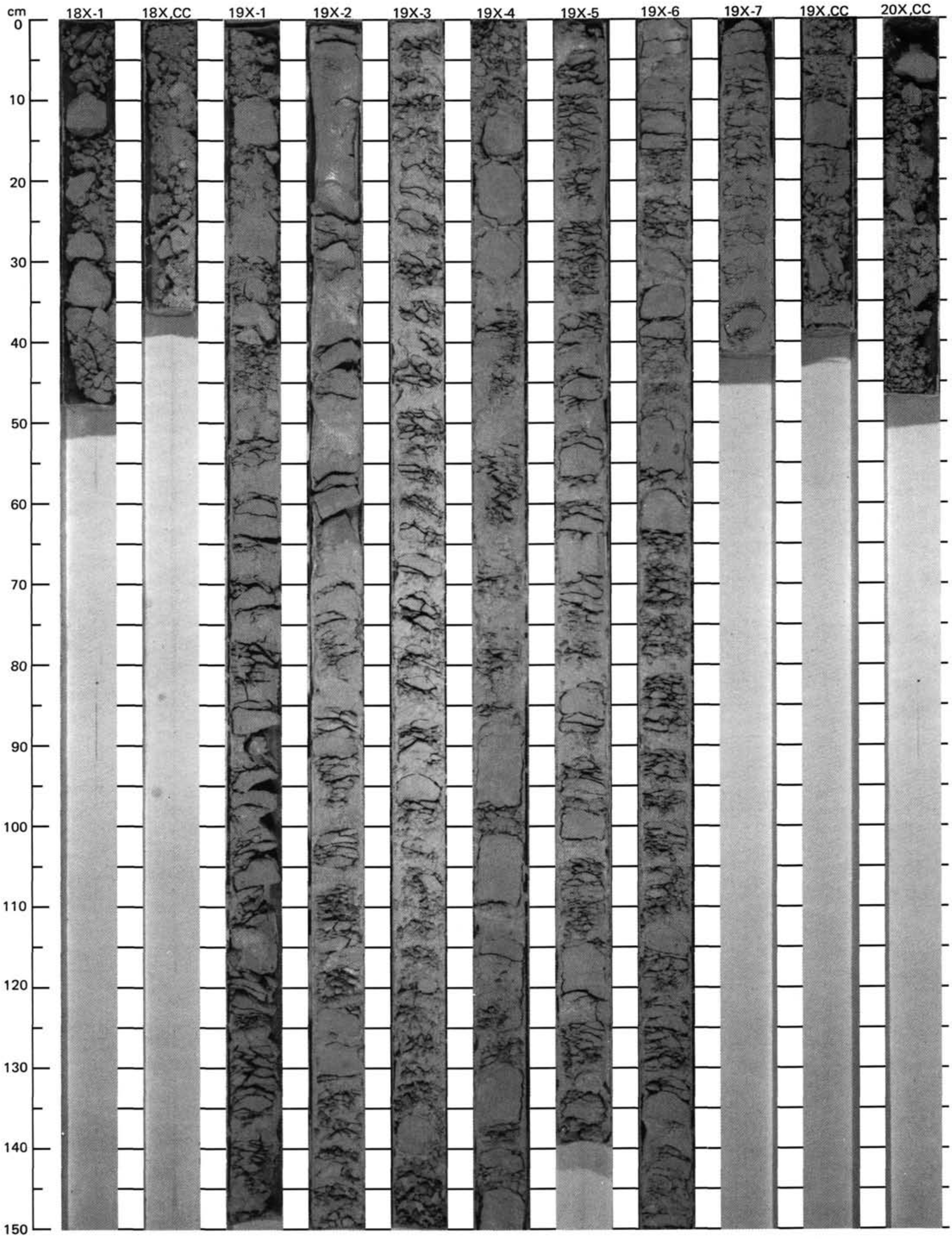
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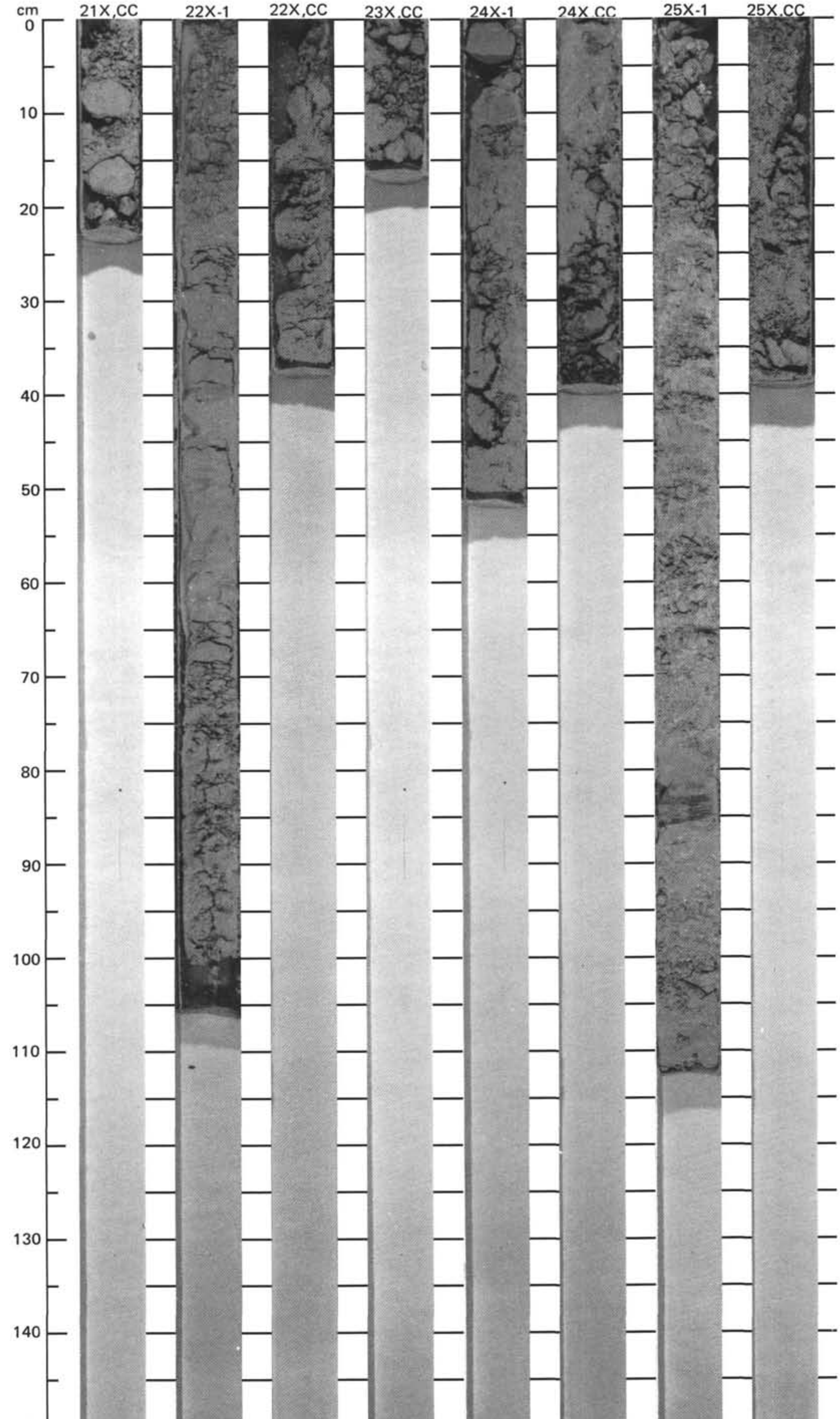
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