4. SITE 521[1]

Shipboard Scientific Party[2]

HOLE 521

Date occupied: 0740, 2 May 1980

Date departed: 0108, 4 May 1980

Time on hole: 43 hr.

Position: 26°4.43′S; 10°15.87′W

Water depth (sea level; corrected m; echo-sounding): 4125

Water depth (rig floor; corrected m; echo-sounding): 4135

Bottom felt (m, drill pipe): 4141

Penetration (m): 84.0

Number of cores: 21

Total length of cored section (m): 84.0

Total core recovery (m): 75.4

Core recovery (%): 90

Oldest sediment cored:
Depth sub-bottom (m): 84.0
Nature: Nannofossil ooze
Age: middle Miocene
Measured velocity (km/s): 1.54

Basement sub-bottom depth (m): 84.0

Principal results: See discussion following Hole 521A data.

HOLE 521A

Date occupied: 0108, 4 May 1980

Date departed: 0604, 5 May 1980

Time on hole: 29 hr.

Position: 26°4.54′S; 10°15.59′W

Water depth (sea level; corrected m; echo-sounding): 4130

Water depth (rig floor; corrected m; echo-sounding): 4140

Bottom felt (m, drill pipe): 4140.6

Penetration (m): 71.1

Number of cores: 17

Total length of cored section (m): 71.1

Total core recovery (m): 64.3

Core recovery (%): 90

Oldest sediment cored:
Depth sub-bottom (m): 71.1
Nature: Nannofossil ooze
Age: middle Miocene
Measured velocity (km/s): 1.54

Basement sub-bottom depth (m): 71.1

Principal results: Holes 521, 521A—

1. Establishment of partial correlation of biostratigraphy, magnetostratigraphy, and seafloor lineation down to early Miocene (Nannofossil Zone NN4, Foraminifer Zone N8, Magnetostratigraphic Chron C-16-N, seafloor Anomaly 5C).
2. Confirmation by biostratigraphic data of a basement age of NN4 deduced from the assumption of a linear seafloor spreading rate.
3. Magnetostratigraphic calibrations of the following datum levels: lowest occurrence (LO) of *Discoaster brouweri*, 14.9 m.y.; LO of *D. exilis*, 15.8 m.y.; highest occurrence (HO) of *Helicosphaera euphratis*, 16.1 m.y.
4. Confirmation of previously calibrated datum levels of some key Neogene nannofossil and foraminifer species, notably the *Orbulina* datum at 15.1 m.y.
5. Reinforcement of conclusions derived from other Leg 73 sites, where our new magnetostratigraphic calibrations contradict the presently established datum levels, notably the LOs for foraminifers *Globigerina nepenthes, G. druryi, Sphaeroidinellopsis subdehiscens* (all of which were too low here) and nannofossils *Catinaster coalitus, C. calyculus*, and *D. quinqueramus* (all of which were too high here).
6. Recognition of an oxygen-isotope shift (in the benthic foraminifers) of more than 1‰ during a 1-m.y. interval starting about 14 Ma, synchronous in timing with a worldwide cooling event.
7. Recognition of two dissolution events during the Serravalian and early Tortonian (13 to 9 or 8 Ma) and during the Messinian and early Pliocene (6.5 to 4 Ma).
8. Recording of a bulk sedimentation rate of about 2 m/m.y. for highly dissolved sediments and of 6 to 11 m/m.y. for less dissolved sediments. Insoluble-residue accumulation rates of 1.0 to 1.4 m/m.y. were recorded for all sediments.

BACKGROUND AND OBJECTIVES

Site 521 is the easternmost of the three-site Miocene transect drilled during Leg 73. The original objectives of the leg, as defined by the Ocean Paleoenvironment Panel, were (1) to obtain calcareous middle Miocene samples for paleoceanographic analysis, (2) to analyze and correlate the biostratigraphic and magnetostratigraphic time scales, (3) to ascertain whether the South Atlantic seafloor spreading rate has been linear since the beginning of the middle Miocene or whether the spreading slowed or halted during the middle Miocene, and (4) to compare the results of drilling on the eastern and western flanks of the Mid-Atlantic Ridge. The site was to be

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[1] Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office).

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positioned on or near Anomaly 5C above a Langhian crust about 17 m.y. old, some 2 m.y. older than the crust at Site 520. The site was selected on the basis of geophysical data provided by a cruise of the R/V *Conrad*. A detailed seismic survey carried out by the University of Texas Marine Science Institute (UTMSI) at Galveston in 1979 indicated the presence of small local basins in this region. Two alternative sites, designated SA IV-3A and SA IV-3B, were originally chosen on the slope and in the center of a basin, because it was not possible to determine during the panel discussions whether a slope or a valley site would be preferable for paleoceanographic sampling. The shipboard co-chiefs were to decide the drill site after drilling at Sites SA IV-1 (Site 519) and SA IV-2 (Site 520).

The experience of drilling the first two sites proved that it is important to study the sediments in both types of locations. The common preference for submarine highs for drilling may have biased the sampling of ocean sediments. During Leg 3, for example, almost all the drilling was done on hill-slope sites, and sedimentary sequences with depositional unconformities were encountered. The drilling at Site 520, which was in a small valley of nearly maximum accumulation, resulted in the surprising discovery that basinal sediments may belong to facies quite distinct from slope sediments. Yet the experience we acquired also taught us that sample materials from ponded facies, which include biogenic debris of unknown origin, are of very little use for the detailed analysis of paleoceanographic events. The pelagic sediments on a slope, despite the unavoidable unconformities due to erosion or dissolution, can at least provide useful samples from time intervals of moderate or fast sediment deposition (10 m/m.y. or greater). Furthermore, rotary coring is necessary in very deep sediments; rotary drill cores are usually disturbed, and recovery is often poor (e.g., 28% at Site 520). These cores are practically useless for the paleomagnetic studies needed for precision stratigraphy. Therefore, to complement the basin flank and center sites already drilled (Sites 519 and 520), we located Site 521 on a hilltop in a pelagic sequence where both slumping and the trapping of redeposited sediments by basement relief would be unlikely. We further hoped that the effects of dissolution, which had greatly condensed some of the upper and middle Miocene sediments at the two previous sites, would be minimized by the higher elevation of the site.

The final location selection was based on a sparker profile by UTMSI, which showed sediment deposits of nearly uniform thickness draping an undulating hill slightly west of the two originally suggested drill sites.

We were able to find the site, but the shipboard air gun profiling was inadequate. It was not clear whether the dark reflectors beneath the transparent part of the section were lithified sediments or basement. The lower reflector showed strong lineations suggestive of the lower reflector sequence at Site 520. Therefore, basement depth was estimated to range from 100 to 250 m. We believed it would be possible, in either case, to penetrate the entire section with the hydraulic piston corer (HPC). Consequently we decided to use the HPC, as the panel had recommended. If the drilling was successful, the cores might provide detailed biostratigraphic and magnetostratigraphic results from undisturbed sediments as old as late early Miocene. Our specific objectives at this site were (1) to analyze the calcite compensation depth (CCD) changes in the late Miocene and early Pliocene (which were first discovered at Site 519), such analysis to include the duration and magnitude of the changes; (2) to determine whether the late Miocene and early Pliocene diatomaceous sediments that were preserved as laminated diatomites at the basinal Site 520 were present as oozes at this site; (3) to investigate the details of the magnetostratigraphy in a section not severely affected by dissolution and to date more precisely the biostratigraphic datums; and (4) to correlate the magnetostratigraphy with magnetic seafloor anomalies and thus to further calibrate the rate of seafloor spreading.

Inasmuch as the site had originally been chosen for hydraulic piston coring, there was no plan to sample the basement if the oldest sediment age agreed with that predicted. However, it was suggested that the pelagic sections be drilled twice to acquire duplicate hydraulic piston cores.

OPERATIONS

Site Approach and Departure

Previous experience at Sites 519 and 520 led us to place Site 521 over a pelagic drape sequence. The new site was selected from UTMSI Line 11, which indicated a regional high (water depth: 4000 m) with 100 to 200 m of pelagic drape sediments. The site was west of proposed Sites IV-3A and IV-3B. In order to complement UTMSI Line 11, the *Glomar Challenger* track was planned to intersect the UTMSI Line 11 in the region of interest. At approximately 0340Z on 2 May 1980, course was set at 80° with a speed of approximately 6 knots, and a reconnaissance of the region was conducted. At 0444Z, a beacon was dropped over an apparently undisturbed region of pelagic drape. The *Challenger* continued past the beacon to execute a short survey that ended with a pass over the deployed beacon. Upon departure from Site 521, the ship executed a second pass over the beacon to supplement the existing geophysical data about the relocated site. Figures 1 and 2 display the ship's track during the approach to and departure from Site 521.

Coring Operations

At 0740Z on 2 May, the vessel was in auto on site. The crew started running pipe down at 0800Z. The schedule called for continuous coring by HPC. The hole was spudded in at 1644Z, 4141 m water depth, and the first core was hauled up at 1847Z (Table 1). Coring continued smoothly all night long. Eleven cores came up at 1.5-hr. intervals, with almost total recovery until 0720Z on 3 May. Cores 11 and 12 recovered red brown marl oozes. The next two cores contained more calcareous nannofossil oozes. At 1235Z, Core 15 came up and was empty except for a lump of brown nannofossil clay adhering to the core catcher. (The sample was sent for

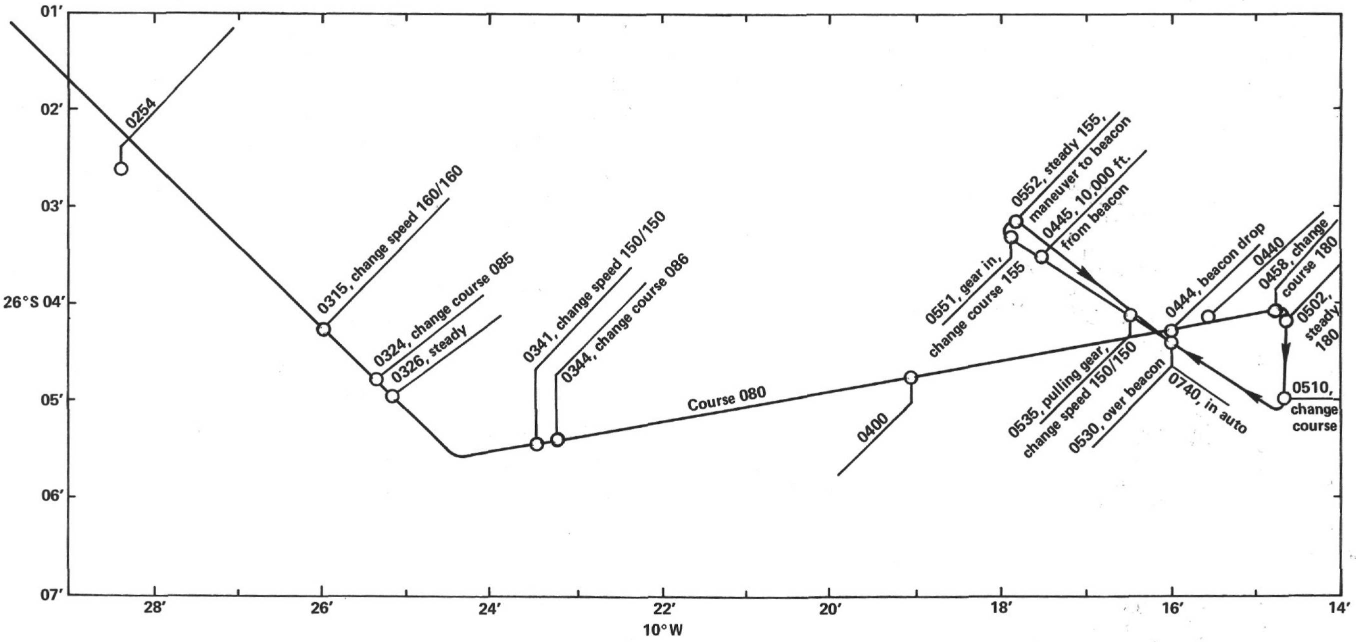

Figure 1. *Glomar Challenger* approach track to Site 521.

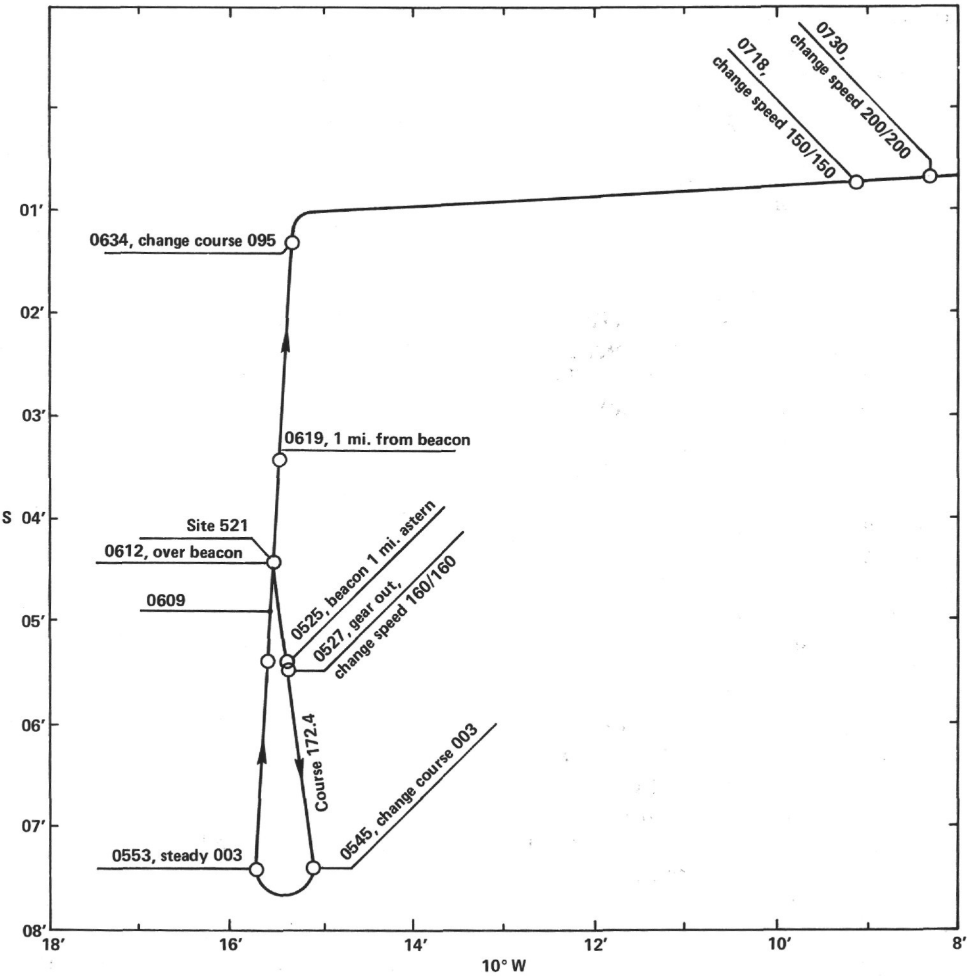

Figure 2. *Glomar Challenger* departure track from Site 521.

Table. 1. Coring summary, Hole 521.

Core	Date (May 1980)	Time (hr.)	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Recovery (%)
Hole 521							
1	2	1842	4141–4144	0–3.0	3.0	3.0	100
2	2	1955	4144–4148.5	3.0–7.5	4.5	4.5	100
3	2	2115	4148.5–4153.0	7.5–12.0	4.5	4.4	98
4	2	2222	4153.0–4157.5	12.0–16.5	4.5	4.1	91
5	2	2340	4157.5–4162.0	16.5–21.0	4.5	4.1	91
6	3	0048	4162.0–4166.5	21.0–25.5	4.5	4.4	98
7	3	0210	4166.5–4171.0	25.5–30.0	4.5	4.4	98
8	3	0335	4171.0–4175.5	30.0–34.5	4.5	4.3	96
9	3	0445	4175.5–4180.0	34.5–39.0	4.5	3.8	86
10	3	0600	4180.0–4184.5	39.0–43.5	4.5	4.4	98
11	3	0720	4184.5–4187.5	43.5–46.5	4.5	2.9	100
12	3	0838	4187.5–4192.0	46.5–51.0	4.5	3.3	73
13	3	0950	4192.0–4196.5	51.0–55.5	4.5	4.5	100
14	3	1120	4196.5–4199.5	55.5–58.5	3.0	3.0	100
15	3	1235	4199.5–4202.5	58.5–61.5	3.0	tr	0
16	3	1405	4202.5–4207.0	61.5–66.0	4.5	2.8	62
17	3	1510	4107.0–4211.5	66.0–70.5	4.5	4.3	96
18	3	1615	4211.5–4215.9	70.5–74.9	4.4	4.3	96
19	3	1730	4215.9–4220.3	74.9–79.3	4.4	4.2	93
20	3	1845	4220.3–4224.7	79.3–83.7	4.4	4.3	96
21	3	2007	4224.7–4225.0	83.7–84.0	0.3	0.25	100
Total					84.0	75.35	90
Hole 521A							
1	4	0132	4140.6–4143.5	0–2.8	2.8	2.8	100
2	4	0247	4143.5–4147.8	2.8–7.2	4.4	3.9	88
3	4	0500	4147.8–4152.2	7.2–11.6	4.4	4.2	95
4	4	0615	4152.2–4156.6	11.6–16.0	4.4	4.3	97
5	4	0736	4156.6–4161.0	16.0–20.4	4.4	3.9	88
6	4	0845	4161.0–4165.4	20.4–24.8	4.4	4.4	100
7	4	0950	4165.4–4169.8	24.8–29.2	4.4	4.4	100
8	4	1110	4169.8–4174.2	29.2–33.6	4.4	4.4	100
9	4	1215	4174.2–4178.6	33.6–38.0	4.4	4.3	97
10	4	1325	4178.6–4183.0	38.0–42.4	4.4	3.1	70
11	4	1425	4183.0–4187.5	42.4–46.8	4.4	1.0	22
12	4	1535	4187.5–4190.9	46.8–50.3	3.5	3.5	100
13	4	1658	4190.9–4195.3	50.3–54.7	4.4	4.3	97
14	4	1820	4195.3–4199.7	54.7–59.1	4.4	3.7	84
15	4	1920	4199.7–4204.1	59.1–63.5	4.4	4.5	102
16	4	2027	4204.1–4208.5	63.5–67.9	4.4	4.4	100
17	4	2144	4208.5–4211.7	67.9–71.1	3.2	3.2	100
Total					71.1	64.3	90

Note: Basement was reached as the last core in Hole 521 was drilled, and the end of the core catcher was denoted.

$CaCO_3$ determination after a smear slide examination by a nannofossil specialist). The barrel might have been empty because the flapper valve of the core catcher failed to close; the great resistance of the red nannofossil clay makes such a failure more likely. Since it was not certain whether the HPC had achieved a full stroke, the next interval was washed 3 m down only. When the next core was split it was found to have been badly sheared on the margin. Some badly disturbed materials at the top of Core 16 might represent sediment that fell from the core barrel when Core 15 (with its flapper valve open) was hauled up. The recovery of Core 17 oozes was again normal. After that we again used the normal 4.4-m interval of washing down before using the HPC. At 2007Z Core 21 was brought up after the HPC hit a hard object (presumably basement). The core catcher was damaged, and an HPC shaft was bent. Basal sediment 0.95 m thick was recovered, but no basalt detritus was obtained. The drill bit was lowered and turned to test the durability of the resistant layer. It was the opinion of the tool pusher that basement had been reached.

After a conference, the scientific staff decided that a second continuous coring by HPC at this site would be desirable to fill in the missing intervals and to provide more material for scientific investigation. The investment of time would be 24 to 30 hr.

After the drill string was raised above the mudline, the ship was offset 800 feet to the south and 1250 feet to the east. Hole 521A was spudded in at 0108Z on 4 May. Coring proceeded smoothly until 1425Z, when Core 11 was on deck. Core 11 consisted of the same red marl and clay as encountered in Core 15 in Hole 521. Although the flapper valve of the core catcher was closed when it was examined on deck, it may have snapped shut while the barrel was on its way up. In any case, only 1.0 m of sediment was obtained from Core 11. The intervals cored below Core 11 consisted mainly of nannofossil oozes, and coring continued with almost 100% recovery until the HPC apparently hit basement. The last core was up at 2144Z on 4 May, so the duplicate coring operation was completed in only 24 hr.

Recovery was excellent in both Holes 521 and 521A (average: 90%). Any missing intervals should have been largely compensated for by the duplication of the continuous coring.

At 0445Z the drill bit was on deck. After beacons were soaked for the next sites, the vessel departed (at 0512 on 5 May) for a short postdrilling site survey before proceeding, at 0604 on 5 May, to Site 522.

LITHOLOGY

The two holes drilled at Site 521, which were about 300 m apart, penetrated similar sedimentary sequences. At Hole 521 we cored 84 m of foraminifer–nannofossil ooze, marly nannofossil ooze, and nannofossil clay. The adjacent section of Hole 521A was similar but only 71.1 m thick. We distinguished two lithologic units at this site on the basis of color, microfossil content, and carbonate content (Fig. 3). We further subdivided the lower unit on the same basis.

Unit 1 (0–44 m sub-bottom, Core 1 to Core 11, Section 1, Hole 521; 0–39.4 m sub-bottom, Core 1 to Core 10, Section 1, Hole 521A) consists of homogeneous very pale brown, pale brown to light yellowish brown foraminifer–nannofossil ooze. In Hole 521, carbonate content ranges between 82 and 95% in Cores 1 to 9 (not shown in Fig. 3); values drop slightly to 52 to 80% in Core 10. Burrows are common and especially prominent where subtle color changes occur. Patches of white nannofossil ooze are scattered throughout this unit. A particularly distinct zone of white ooze and very pale brown ooze mixed by burrowing in Core 10, Hole 521, resembles a similar zone in Core 9, Hole 521A.

The first occurrence of dark brown and dark reddish brown nannofossil clay marks the top of Unit 2 (44.2–84.0 m sub-bottom, Core 11, Section 1 to Core 21, Hole 521; 39.4–71.1 m sub-bottom, Core 10, Section 1 to Core 17, Hole 521A). This unit consists of alternating nannofossil clay and marly nannofossil ooze overlying foraminifer–nannofossil ooze. Carbonate content is variable and has been used to further subdivide this unit.

Subunit 2a consists of alternating brown, dark brown to dark reddish brown nannofossil clay and yellowish

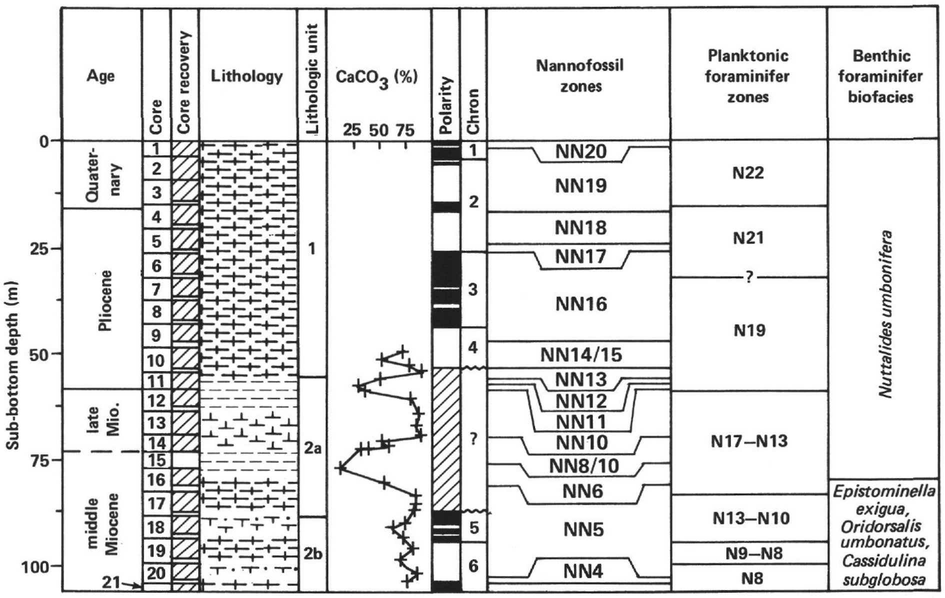

Figure 3. Stratigraphic summary, Hole 521. Lithology is defined in Hsü, LaBrecque, et al. (this vol.). Solid blocks denote intervals of normal polarity, cross-hatched blocks intervals of unknown polarity.

brown and dark yellowish brown marly nannofossil ooze. The carbonate content of the nannofossil clay ranges from 15 to 55% and that of the ooze from 80 to 90%. The distinctly clay-rich intervals are defined by the carbonate profile for Hole 521 (Fig. 3). Both light and dark lithologies are burrowed. Color changes are gradational and mixed by burrowing.

We place the upper boundary of Subunit 2b where foraminifers are common in the sediment and where carbonate content is constant at about 80%. Exact boundaries are difficult to specify because changes in both foraminifer and carbonate content are gradational (Fig. 3). This subunit consists of yellowish brown foraminifer-nannofossil ooze and dark yellowish brown marly foraminifer-nannofossil ooze. The carbonate content ranges from 63 to 85%. In Hole 521 four thin (1-9 cm) layers of nannofossil-foraminifer ooze occur; all four layers have sharp basal contacts and gradational, burrowed tops. At least one layer is graded. No similar layers were recovered in Hole 521A.

The pelagic carbonate sequences at Site 521 record temporal fluctuations in the dissolution of calcium carbonate. The foraminifer-nannofossil ooze that makes up Lithologic Unit 1 was deposited above the CCD and the foraminifer lysocline. The underlying sedimentary sequence of Subunit 2a records two major dissolution cycles that are related to oscillations of the CCD. The marly foraminifer-nannofossil ooze of Subunit 2b indicates a depression of the foraminifer lysocline and CCD.

Our correlation between Holes 521 and 521A suggests that sedimentation rates may have been slightly higher at Hole 521. The difference in thickness between the two holes may be due to redeposition at Hole 521, because burrowed lenses of white nannofossil ooze, which were less common in Hole 521A, appear in the lower part of Unit 1, and foraminifer turbidites appear in Subunit 2b.

BIOSTRATIGRAPHY

Summary

Continuous coring at Hole 521 through 84 m of sediment yielded 21 hydraulic piston cores that ranged in age from middle Miocene to Quaternary. A biostratigraphic summary is given in Figures 3 and 4. Foraminifers and calcareous nannofossils are present throughout the hole, although the planktonic foraminifer assemblages of Cores 11 to 16 exhibit low species diversity and are intensely fragmented, probably as a result of carbonate dissolution.

In general, the epoch and age boundaries of the planktonic foraminifer and calcareous nannoplankton zonations are comparable. The Pleistocene/Pliocene boundary occurs within Core 4. The topmost sediments of that core are Pleistocene by virtue of the presence of *Pseudoemiliania lacunosa, Gephyrocapsa* spp., and the lowest occurrence of *Globorotalia truncatulinoides.* The middle part of the core contains abundant *Discoaster brouweri* and is therefore Pliocene. The upper/lower Pliocene boundary occurs somewhere between Samples 521-8,CC and 521-9,CC.

The Pliocene/Miocene boundary appears to be associated with the facies boundary in Core 11, in which foraminifer-nannofossil ooze is underlain by red brown nannofossil clay. The highest Miocene nannofossil assemblage occurs in Sample 521-11,CC. However, the absence of *Ceratolithus* spp. below Core 11, Section 1, 90 cm leaves open the possibility that the boundary is as high as that point. The lowest Pliocene foraminifer assemblage occurs in Sample 521-11,CC. (Unfortunately, this assemblage, like all those in this core below Section

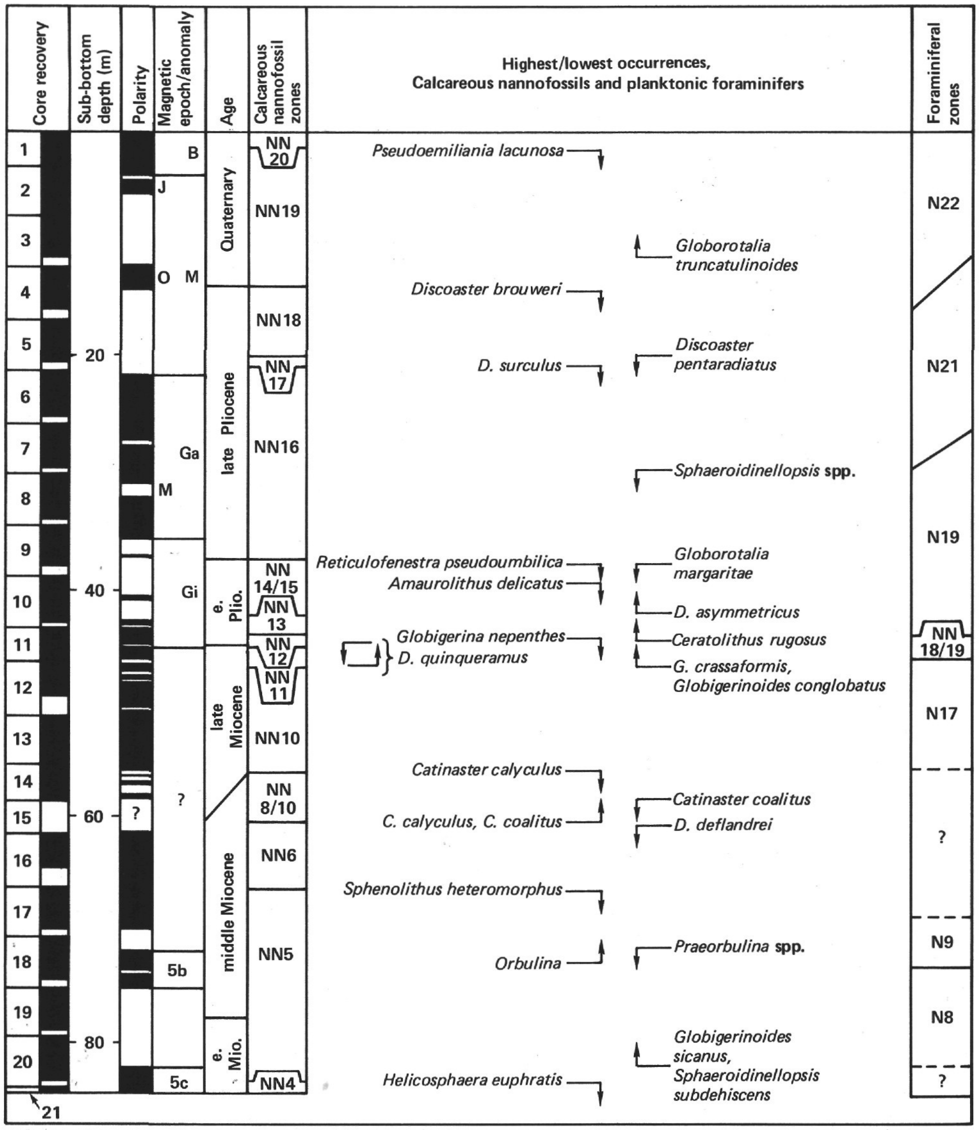

Figure 4. Biostratigraphic summary of significant calcareous planktonic microfossils, Hole 521. Solid blocks denote intervals of normal polarity. Magnetic epochs are Brunhes (B); Matuyama (M); Jaramillo (J); Olduvai (O); Gauss (Ga); Mammoth (M); and Gilbert (Gi).

1, 60 cm, is strongly dissolved and consequently somewhat suspect.) The highest definite Miocene foraminifer assemblage occurrence is in Sample 521-13,CC, where the first downhole occurrence of *G. dehiscens* is noted.

Because of uncertainty in the nannoplankton zonation and dissolution in the planktonic foraminifers, the middle/upper Miocene boundary may lie as low as Sample 521-14,CC (or Sample 521-15,CC, where the core liner was empty), that is, at the base of NN8–10 (undifferentiated), or as high as Sample 521-13,CC, where the nannofossil assemblage is NN10 (middle Miocene).

In Cores 17 to 20 the nannofossil zone NN5 is identified on the basis of *Sphenolithus heteromorphus*. Foraminiferal assemblages from the same samples yield conflicting evidence for zonal assignments. The preferred interpretation is that *Sphaeroidinellopsis subdehiscens* has a lower stratigraphic first occurrence than Zone N13, as commonly assumed.

Calcareous Nannoplanktons

Hole 521

Sample 521-1-1, 68–69 cm is assigned to NN20 (Quaternary) because of the presence of *Gephyrocapsa oceanica* (Kamptner) and the absence of *Pseudoemiliania lacunosa* Gartner. The interval from Sample 521-1-2, 68–69 cm to 521-4-1, 65 cm is Quaternary NN19 in age because of the presence of *P. lacunosa* Gartner.

The interval from Sample 521-4-2, 65–66 cm to 521-5-2, 86–87 cm is late Pliocene NN18, as indicated by an abundance of *Discoaster brouweri* Tan Sin Hok. Sample 521-5-3, 86–87 cm is assigned to late Pliocene NN17 because of the occurrence of *D. pentaradiatus* Tan Sin Hok. Samples 521-5,CC through 521-9-2, 103–104 cm contain *D. surculus* Martini and Bramlette without *Reticulofenestra pseudoumbilica* Gartner and are assigned to NN16 (late Pliocene). *R. pseudoumbilica*

Gartner is found in Samples 521-9-2, 103–104 cm to 521-10-2, 100–101 cm, which indicates NN14/15. The interval from Sample 521-10-3, 100–101 cm to Sample 521-11-1, 62–63 cm is NN13 because of the absence of *D. asymmetricus* Gartner and the presence of *Ceratolithus rugosus* Bramlette and Bukry.

Nannofossil Zone NN12 is found in Sample 521-11-1, 90–91 cm because of the absence of *Ceratolithus* spp. The last downhole occurrence of *Amaurolithus* spp. is in Sample 521-11,CC which is assigned to NN11 on the basis of the presence of *D. quinqueramus* Gartner. A late Miocene NN10 age is suggested for Cores 12 and 13 because of the absence of *D. quinqueramus* Gartner and *Catinaster calyculus* Martini and Bramlette. Samples 521-14-1, 115–116 cm to 521-14-2, 73–74 cm are late Miocene NN8/10 because of the occurrence of *C. calyculus* Martini and Bramlette. A middle to late Miocene age, NN8/10 is indicated for Sample 521-14,CC, which contains *C. calyculus* Martini and Bramlette and *C. coalitus* Martini and Bramlette. Samples 521-16-1, 84–85 cm to 521-16,CC are middle Miocene NN6 because of the occurrence of *Cyclicargolithus floridanus* (Hay and Roth). Samples 521-17-1, 74–75 cm through 521-20-3, 65–66 cm contain *Sphenolithus heteromorphus* Bramlette and Wilcoxon, which indicates NN5 middle Miocene. Cores 521-20,CC and 521-21,CC contain *Helicosphaera euphratis* Haq, which indicates NN4.

Hole 521A

Samples 521A-1,CC through 521A-3,CC represent Quaternary NN19, according to the occurrence of *Pseudoemiliania lacunosa* Gartner.

Late Pliocene NN17 sediment was found in the core catcher for Core 5, as indicated by *Discoaster pentaradiatus* Tan Sin Hok. The core catchers of Cores 6 to 7 belong to late Pliocene NN16, because of the occurrence of *D. surculus* Martini and Bramlette without *Reticulofenestra pseudoumbilica* Gartner. An early Pliocene NN14/15 age is assigned to core-catcher sediments for Core 8 because of the presence of *Reticulofenestra pseudoumbilica* Gartner. The core catcher for Core 9 is NN13 because of *Ceratolithus rugosus* Bramlette and Bukry.

A late Miocene NN12 age is assigned to core-catcher sediment for Core 10 because of the presence of *Amaurolithus amplificus* (Bukry and Percival). Core 11 is assigned to NN10 because of the absence of *D. quinqueramus* Gartner and *Catinaster calyculus* Martini and Bramlette. Core 12 is NN9/10 because of the occurrence of *D. prepentaradiatus* Bukry and Percival.

The core-catcher sediments in Cores 13 through 16 are NN5 or middle Miocene in age, as indicated by the presence of *Sphenolithus heteromorphus* Bramlette and Wilcoxon. The core-catcher sediment for Core 17 is NN4 because of the presence of *Helicosphaera euphratis* Haq. A more thorough investigation of the nannofossil stratigraphy of Hole 521A was carried out by von Salis (this vol.).

Planktonic Foraminifers

Samples from Hole 521A were not examined for planktonic foraminifers; thus, the entire discussion below pertains to Hole 521. Planktonic foraminifers are abundant and well preserved in Cores 1 through 10. Within Section 1 of Core 11, the preservation and abundance of planktonic foraminifers declines markedly because of increased dissolution. Dissolved assemblages consisting of resistant taxa, such as *Globoquadrina dehiscens, Globigerina nepenthes*, and *Globorotalia conoidea*, along with abundant fragments, are present from the bottom of Core 11 through Core 16. The preservation of planktonic foraminifers begins to improve in Core 13 and continues to improve downsection to the sediment/basalt contact in Core 21.

The Pliocene/Pleistocene boundary is placed between Sample 521-3,CC and 521-4,CC because of the first (lowest) occurrence of *G. truncatulinoides* in Sample 521-3,CC. Samples 521-4,CC through 521-10,CC contain relatively diverse Pliocene assemblages. Cores 4 through 6 are post-*Sphaeroidinellopsis* extinction, whereas Cores 7 through 10 are pre-*Sphaeroidinellopsis* extinction. Sample 521-11,CC yields a highly dissolved assemblage with primitive forms of *G. crassaformis* and rare *Globigerinoides conglobatus*. Sample 521-11,CC is tentatively assigned to Zone PL1 (N18 or lower N19).

A meager assemblage from Sample 521-12,CC is not age diagnostic, but the occurrence of *Globoquadrina dehiscens* in Sample 521-13,CC indicates a late Miocene (N17) or older age assignment. The planktonic foraminifer assemblages from Cores 14 through 16 are only diagnostic of middle to late Miocene.

Forms referred to *Sphaeroidinellopsis subdehiscens* occur down through Core 21, which suggests a Zone N12 or younger assignment. The age assignment suggested by *S. subdehiscens* is contradicted, however, by the occurrences of *Globigerinoides sicanus* and *Praeorbulina* spp. in Cores 19 through 21 and the presence of the nannofossil *Sphenolithus heteromorphus* in Cores 17 through 21. It seems likely that Cores 17 through 21 are referable to Zones N9 and N8 and that *Sphaeroidinellopsis subdehiscens* as identified in Hole 521 extends down into the lower Miocene. The age discrepancy between foraminifers and nannofossils in Hole 520 is also due to the lower stratigraphic limit of *S. subdehiscens*.

Diatoms

All core samples examined from Hole 521 are barren of diatoms. Samples from Hole 521A were not examined for diatoms.

Benthic Foraminifers

The benthic foraminifer fauna in Hole 521 is common and moderately well preserved. The late Miocene to Quaternary assemblages (those above Core 16) are dominated by *Nuttalides umbonifera*, with subordinate numbers of *Oridorsalis umbonatus, Globocassidulina subglobosa, Epistominella exigua, Planulina wuellerstorfi*, and *Pullenia* spp. (*P. osloensis, P. bulloides*, and *P. subcarinata*). Below Core 16 the contribution of *N. umbonifera* and *Planulina wuellerstorfi* declines significantly, whereas there are increased numbers of *Cibicidoides kullenbergi* and *Eponides* spp.

The transition between the *N. umbonifera*-dominated fauna and the *N. umbonifera*-poor fauna occurs between 63 and 66 m sub-bottom. Sediments at this depth have an interpolated age of 13.6 to 14.1 m.y., according to the sedimentation rate curves for Hole 521. A backtrack subsidence curve constructed for Site 521 shows that water depths during this interval were approximately 3200 to 3300 m (Fig. 5). A site at this depth can reasonably be interpreted as being in transition between the deeper Antarctic Bottom Water dominated by *N. umbonifera* (Lohmann, 1978) and a shallower, warmer, more saline, oxygen-rich water mass (here tentatively labeled as Miocene South Atlantic Deep Water).

Dissolution

Figure 6 shows the downcore distribution of two measures of dissolution, the ratio of benthic to planktonic foraminifers and the degree of fragmentation among planktonic foraminifer tests. The curves behave sympathetically, with the percentage of fragments being a more sensitive measure of dissolution during episodes of low to moderate dissolution and the percentage of benthic foraminifers being more sensitive during episodes of moderate to intense dissolution.

Dissolution studies indicate that Site 521 lay at or below the CCD during the deposition of the sediments that now lie between 57 and 66 m sub-bottom. The lack of paleomagnetic data from this interval, coupled with poor biostratigraphic zonation, precludes precise dating of this episode of dissolution. The best estimate would place it between 9 and 14 m.y. ago, in the middle Miocene or early late Miocene. Site 521 also lay near, but above, the CCD during the deposition of sediments that now lie in the interval between 44 and 48 m sub-bottom. These sediments were deposited between 4.4 and 5.8 Ma, in the late Miocene to early Pliocene.

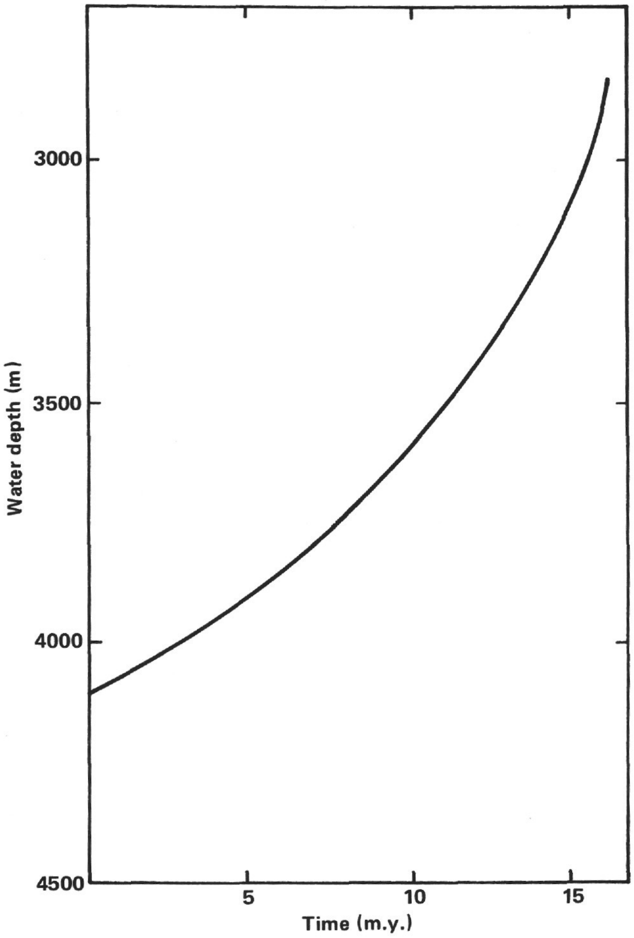

Figure 5. Bathymetry of Site 521 based on subsidence curves corrected for sediment load (Berger and von Rad, 1972).

Sedimentation Rates

The good magnetic data recovered from the upper (0–46 m sub-bottom) and lower (73–84 m sub-bottom) sequences of Hole 521 permitted the identification of numerous events that could be used in the calculation of sedimentation rates (Fig. 7). The chronology of the paleomagnetic datums is essentially that of LaBrecque et al. (1977) as modified by Mankinen and Dalrymple (1979) using the new decay and abundance constants recommended by the International Union of Geological Sciences Subcommission on Geochronology. The upper Miocene intervals were represented by dissolution facies and yielded poor magnetic resolution. Although biostratigraphic resolution also deteriorates in intervals of dissolution, one event, the LAD of *Catinaster calyculus*, could be recognized and was used to supplement the magnetic data.

PALEOMAGNETISM

At first, the Hole 521 cores were analyzed by using the long core spinner magnetometer on unsplit cores in conjunction with the analysis of discrete samples that were taken every 20 cm. The long core spinner procedure was discontinued after the seventh core (middle Gauss) owing to the ambiguity of results. The poor quality of the long core spinner data is due to three potentially solvable problems, the most debilitating of which is rust contamination. The drill pipe had been rattled in port and used for two previous holes, but significant amounts of rust were still present in the cores. The inability to remove the pervasive normal (Bruhnes) overprint from whole cores (present in sediments as young as upper Matuyama) made the interpretation of the polarity of even the rust-free sediments difficult. A third problem was the poor core-to-core orientation. This problem necessitated discrete sampling in order to resolve inclinations (and hence polarity) in each core.

A summary of the magnetic polarity stratigraphy at Hole 521 is presented in Figure 8. Detailed alternating field (a.f.) demagnetization curves obtained on samples distributed throughout the entire section indicated the presence of a soft normal overprint that was removed by peak alternating fields of 100 to 200 Oe. All specimens were therefore demagnetized. Cores 11 to 17 retained a large normal overprint that was stable with respect to a.f. demagnetization. It was suspected that this overprint was carried principally by goethite (which was seen in thin section). Thermal demagnetization at 200°C of samples from this interval resulted in some magnetic reversals but did not completely remove the suspected overprint (Fig. 8).

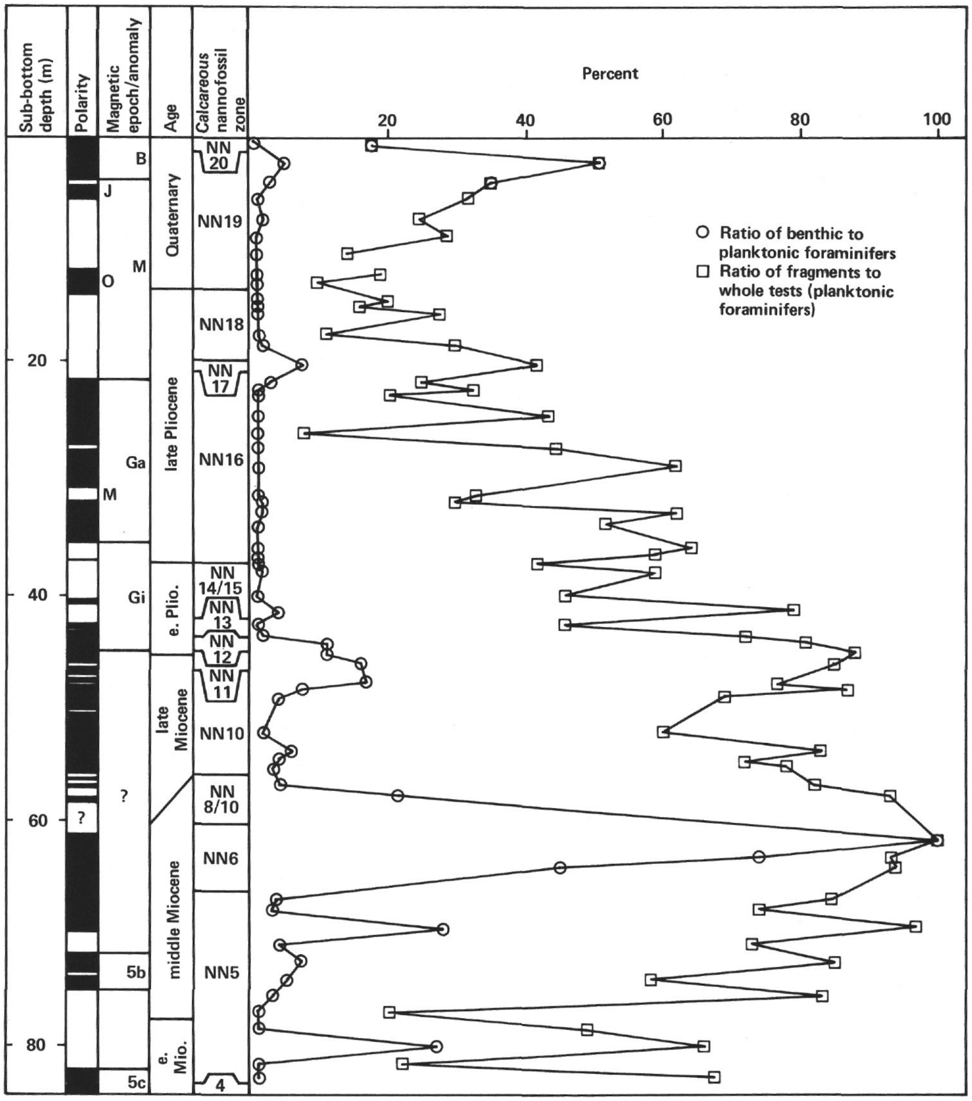

Figure 6. Dissolution indices, Hole 521. See text for discussion. Magnetic polarity and epochs as in Fig. 4.

A detailed investigation of the magnetostratigraphy of Hole 521A was carried out on shore by Heller et al. (this vol.).

PHYSICAL PROPERTIES

Velocity, density, water content, and porosity were measured on every other section in the cores recovered at this site. Thermal conductivity was measured on eight of the cores. The clay-rich sections were not sampled for gravimetric measurements in order to avoid depleting core intervals that would needed for paleomagnetic and paleontological studies. The physical properties of the sediments are summarized in Figure 9. Velocity, gravimetrically determined and continuous GRAPE density, water content, and porosity are plotted as a function of depth together with the results of the carbonate analyses.

Velocity exhibits a shallow minimum in the upper 20 m of the core and slowly increases linearly with depth. No significant discontinuities mark the presence of the clay layers. The gravimetrically determined density and water content show consistent trends except in the interval from 25 to 35 m, where there is a decrease in density with no corresponding variation in water content. In the gravimetric sampling technique, some air is trapped in the sample, and this tends to result in lower values of density. In this instance it is clear that we are seeing an artifact of the technique rather than a real change in the density of the sediment. The continuous GRAPE density data show greater variability than the gravimetric data, and in spite of the scatter, the trace does appear to mark the presence of the two clayey intervals, which are clearly indicated in the carbonate data.

Thermal conductivity ranged between 1.77 and 1.21 W/m °C, with a mean value equal to 1.53 and a standard deviation of 0.18 W/m °C. The low value of 1.21 correlates with the presence of the clay layer at 56 to 66 m, but the second low value of 1.30 does not correlate with the presence of a clay layer; therefore, no firm conclusion can be drawn about the relationship between thermal conductivity and changes in the core.

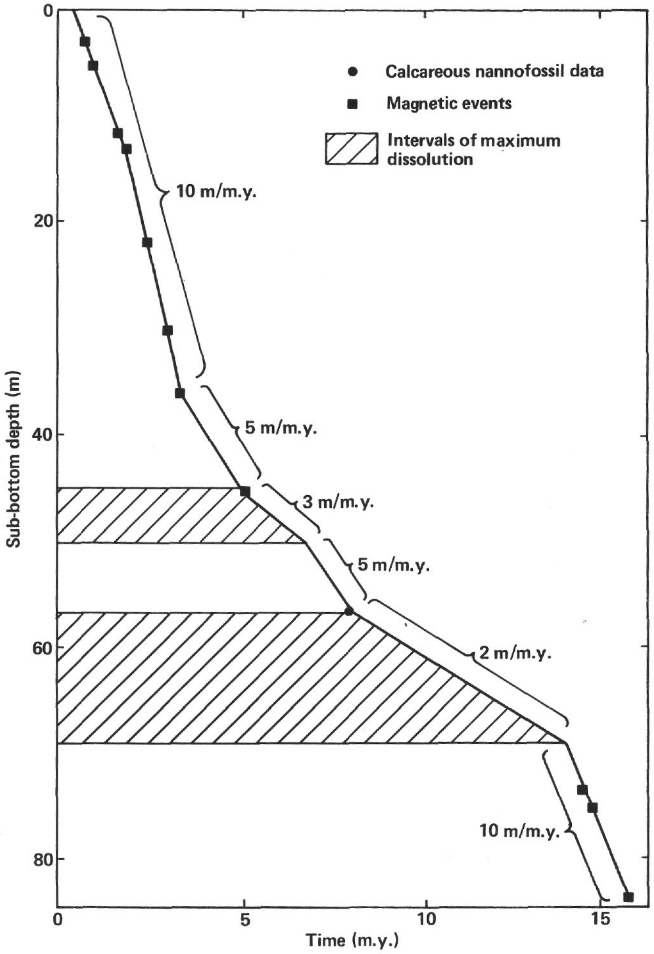

Figure 7. Sedimentation rates, Hole 521.

INORGANIC GEOCHEMISTRY

Table 2 summarizes the chemical data for the interstitial waters squeezed from sediments at Site 521. Two samples come from Hole 521, a third from Hole 521A. Although hardly representative, the results indicate no significant trends in chemical constituents with depth. The single sample from Hole 521A was taken just above presumed basaltic basement. The lack of chemical variation indicates that neither basalt alteration nor sediment diagenesis affects the interstitial water chemistry in these shallow holes.

CORRELATION BETWEEN DRILLING RESULTS AND GEOPHYSICAL DATA

Site 521 is located on the western margin of a small basin 10 to 15 km south of a fracture zone with 18 km left lateral offset (the Moore Fracture Zone). The local relief is 600 m (Fig. 10).

The magnetic lineation pattern is displayed in Figure 10. Site 521 is located over Magnetic Anomaly 5C, suggesting a basement age of 16 m.y. or late Burdigalian (early–middle Miocene). Recovered basal sediments of Nannofossil Zone NN4 support this prediction of basement age. The magnetostratigraphic data from the basal sediments show a strong correlation with the magnetic anomaly pattern.

Seismic data over the site (Figs. 11 and 12) indicate a transparent pelagic sequence underlain by a zone of strong coherent multiple reflectors at 1 s sub-bottom. It was uncertain whether this sequence of strong reflectors represented basement or a zone of sediments and intercalated basalts.

SUMMARY AND CONCLUSIONS

The hilltop position of the site turned out to be ideal for ocean paleoenvironmental studies, and we therefore obtained a duplicate set of hydraulic piston cores. In both sets of cores we encountered a condensed Miocene section and acquired evidence that indicates a linear rate of seafloor spreading. However, work will have to be done at other sites to acquire a magnetostratigraphy adequate to calibrate the chronology of middle Miocene datum levels.

Lithostratigraphy

The lithologic sequence with this relatively flat topography consists mainly of draped pelagic sediments, although thin layers of deposited sediments were found in the middle Miocene and Pliocene sediments of Hole 521. The lithologic units were distinguished by characteristics that resulted from different degrees of dissolution. The Pliocene–Quaternary sediments are eolytic or oligolytic nannofossil oozes. The older sections include mesolytic and pleistolytic sediments.

Biostratigraphy and Magnetostratigraphy

Hole 521

Our stratigraphic interpretation of Hole 521 (original) is shown in Figure 13. Percival was able to zone the whole sequence by nannofossils, although the highest and lowest occurrences (HOs and LOs) of some key species that define zonal boundaries may not have been their true first and last appearance datums (FADs and LADs) because of calcite dissolution. The planktonic foraminifers in the core-catcher samples were studied on board ship, and the ages thus determined agreed on the whole with the conclusions derived from the nannofossil studies. The data from the preliminary core-catcher studies are included in the biostratigraphic summary but are not shown here. Poore did carry out shore-based work to define the *Orbulina* datum more accurately.

The correlation of the magnetostratigraphy with seafloor lineation is clear for the upper 40 m down to upper Gilbert (≈ Anomaly 2A), and it is clear again for Chrons 15 and 16 (Anomalies 5B and 5C or Chrons C-5B and C-5C; see Fig. 2 in Hsü, LaBrecque, et al., this vol.). The *Orbulina* datum lies at the Chron 15/16 boundary (15.1 m.y.), exactly as Opdyke et al. (1974) found in their studies of Pacific piston cores. The basalt basement on Anomaly 5C is correlated to Chron 16 (or Chron C-5C-N). A shore-based magnetostratigraphic study of Hole 521A samples by Heller et al. (this vol.) confirmed, on the whole, the conclusions of the investigations of Hole 521 (original) by the shipboard staff.

The following nannofossil datum levels have been calibrated for the first time with reference to a relatively clear magnetostratigraphy: LO *Discoaster brouweri*,

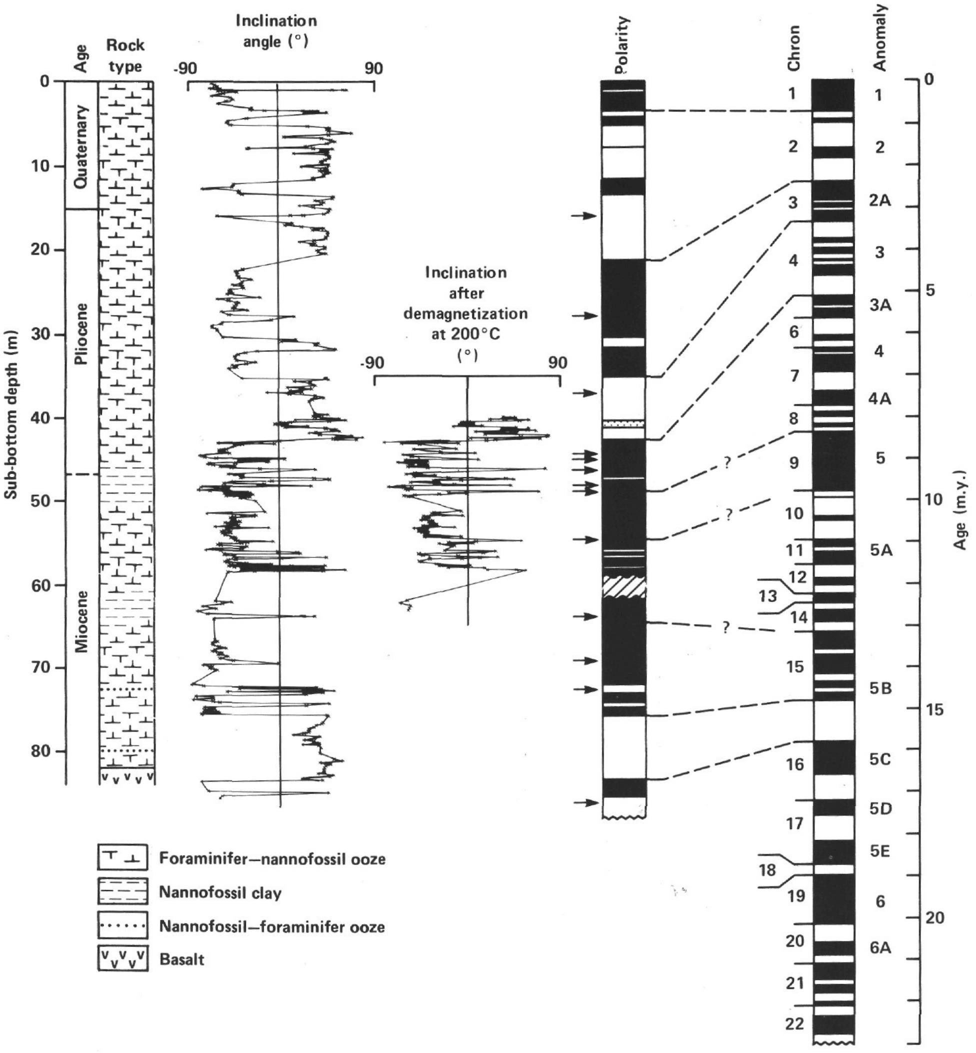

Figure 8. Summary of paleomagnetic results at Site 521. Solid blocks denote intervals of normal polarity, cross-hatched blocks intervals of unknown polarity. Arrows identify the positions of polarity units that are defined by single samples and are therefore tentative (see Tauxe et al., this vol.).

Table 2. Interstitial water chemistry, Site 521.

Sample (interval in cm)	Sub-bottom depth (m)	pH	Alkalinity (meq/l)	Salinity (‰)	Calcium (mmol/l)	Magnesium (mmol/l)	Chlorinity (‰)
521-7-2, 140–150	25.5–30.0	7.28	2.735	36.0	10.75	52.89	19.80
521-17-2, 140–150	66.0–71.5	7.307	2.728	35.5	10.40	51.40	19.77
521A-17-3, 0–9	67.9–71.1	7.29	2.577	35.5	10.191	51.306	19.511

14.9 m.y.; LO *D. exilis*, 15.8 m.y.; and HO *Helicosphaera euphratis*, 16.1 m.y.

The HO of *Sphenolithus heteromorphus* coincides approximately with the top of Chron 15, indicating an apparent last appearance of about 13 m.y., considerably younger than that postulated previously (cf. Bolli, Ryan, et al., 1978, p. 14). The HO of *Cyclicargolithus floridanus* at a horizon with an age of slightly less than 13 m.y. confirms the previous calibrations of the probable last appearance of this species.

The HOs and LOs of other Pliocene–Miocene species on the magnetostratigraphic time scale at this site agree on the whole with those at Site 519, and some disagree with previous calibrations. The relatively low LO of *Reticulofenestra pseudoumbilica* in the uppermost Gilbert sediments confirms our observation at Site 519 and emphasizes the need for further magnetostratigraphic calibration of the NN15/16 zonal boundary. The LO of *Pseudoemiliania lacunosa* is slightly below the Gilbert/Gauss epoch boundary at both Sites 519 and 521; this datum may be a better zonal marker, because the LO here is in good agreement with the reported FAD from other Atlantic and the Pacific coring sites. Other Pliocene–Quaternary datum levels at this site have ages that are about the same as those calibrated previously, as shown in the Site 519 chapter.

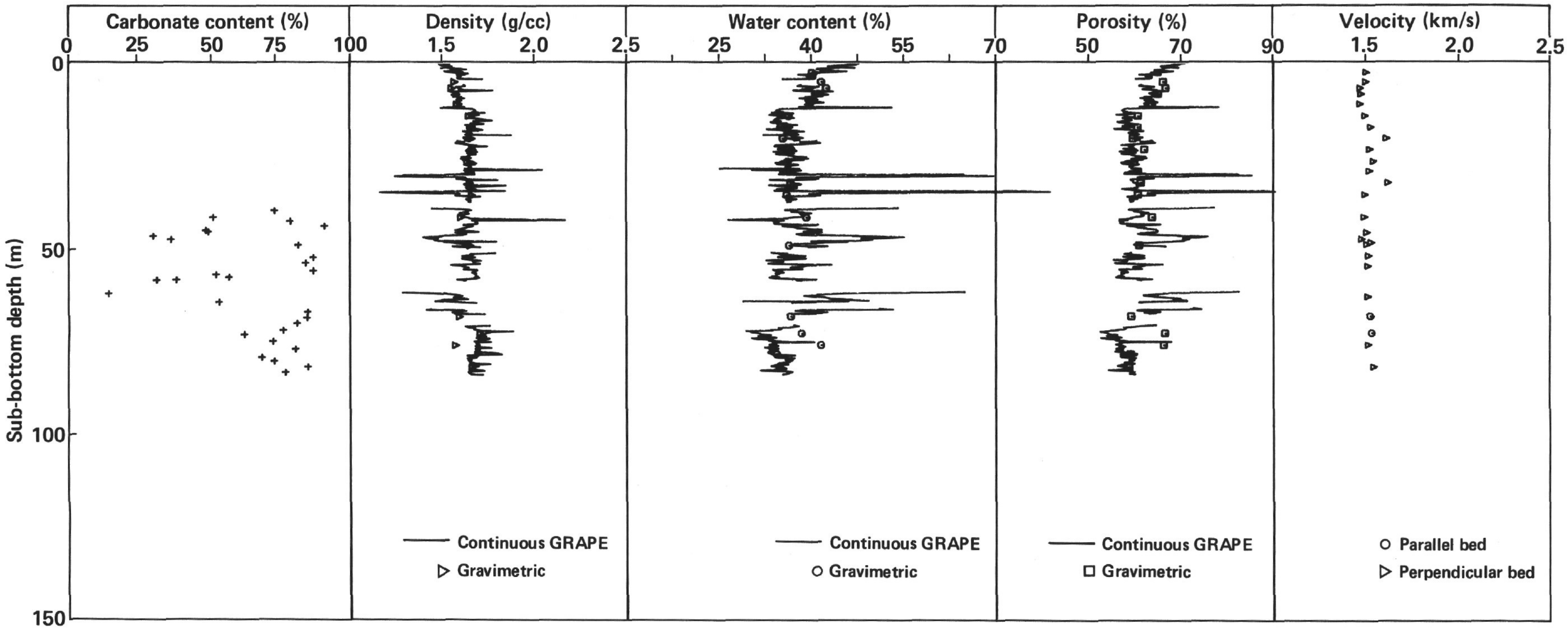

Figure 9. Summary of physical properties at Site 521.

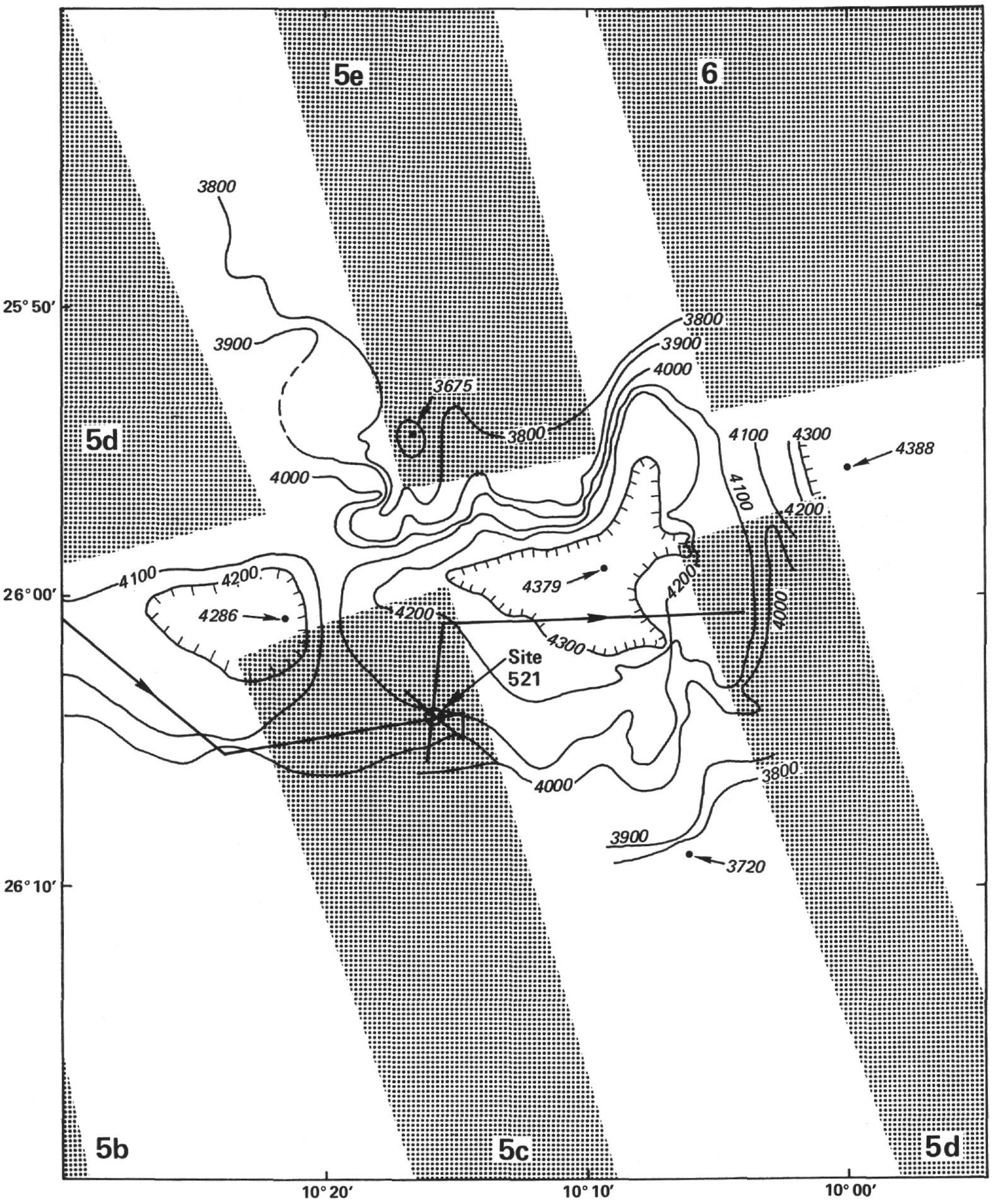

Figure 10. Bathymetric map of the area around Site 521. Bathymetry, in corrected meters; contour interval is 100 m. Magnetic anomalies are stippled and labeled (5b, 5c, etc.).

Late Miocene datum levels are poorly defined because of dissolution. The occurrences of *Amaurolithus primus, A. amplificus, A. delicatus*, and *D. quinqueramus* in highly dissolved sediments have been noted. The nannofossil stratigraphy indicates that the calcite dissolution must have peaked at this site during Chrons 5 and 6; the NN12 and NN11 sediments are only about 2 m thick. *D. quinqueramus* was found in only one sample at Site 519 and at this site, in contrast to the remarkably thick NN11 sequence at Site 520. On the other hand, NN10 sediments are thick at the two pelagic sedimentation sites (519 and 521) but very thin at the basinal site (520). Ryan et al. (1974) suggested a 9.5-m.y., middle-Chron 9 (Anomaly 5N or Chron C-5-N) age for the FAD of *D. quinqueramus*. The LO of this species at either Site 519 or 521 cannot be much older than 6.6 m.y. old (top of Chron 7). The LO at those sites probably resulted from truncation by dissolution.

Dissolution has also complicated the problem of interpreting the magnetostratigraphy. The interval between the LO of *D. quinqueramus* and the HO of *Catinaster calyculus* has been interpreted by Percival as NN11/10 at Site 519 and as NN10 at Site 521. The placement of the NN11/10 boundary has been made uncertain by the extensive dissolution of *D. quinqueramus*. For the sake of convenience, we shall refer to this interval as "NN10 at Sites 519 and/or 521," or in short "NN10." At Site 519, where the magnetostratigraphic signature is clearer, the "NN10" sediments are correlated with Chron 7 (Anomaly 4 or Chron C-4) and late Chron 8 (Anomaly 4′ or Chron C-4A). The "NN10" sediments at Site 521 are mainly positively magnetized

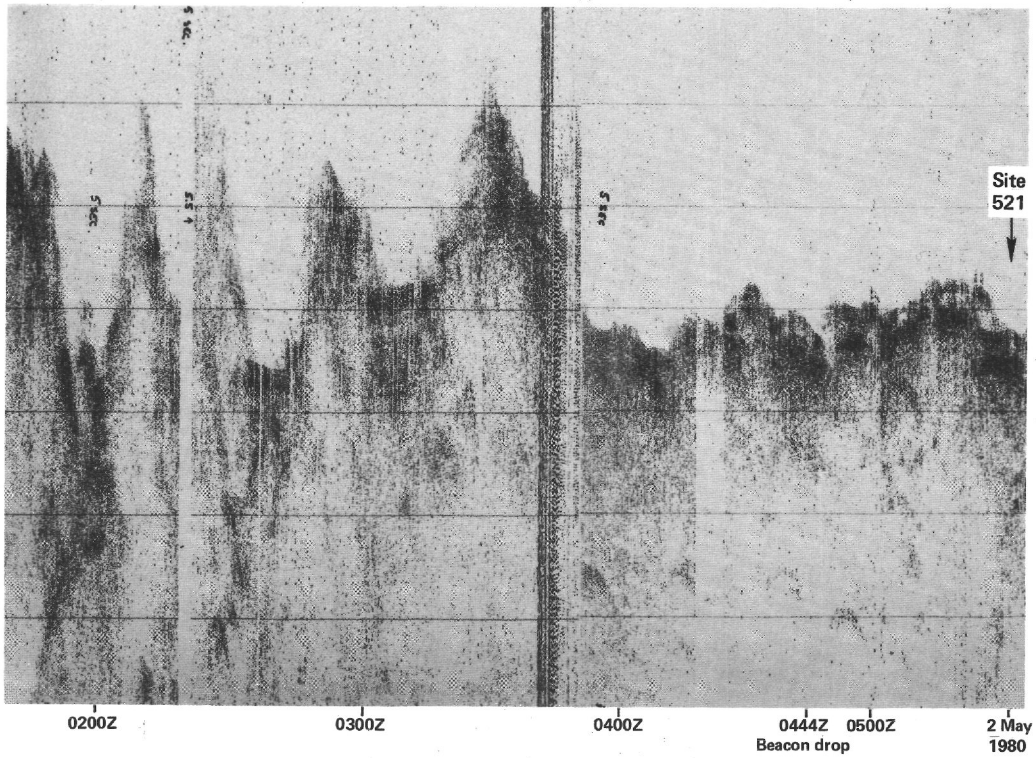

Figure 11. *Challenger* single-channel reflection profile approaching Site 521.

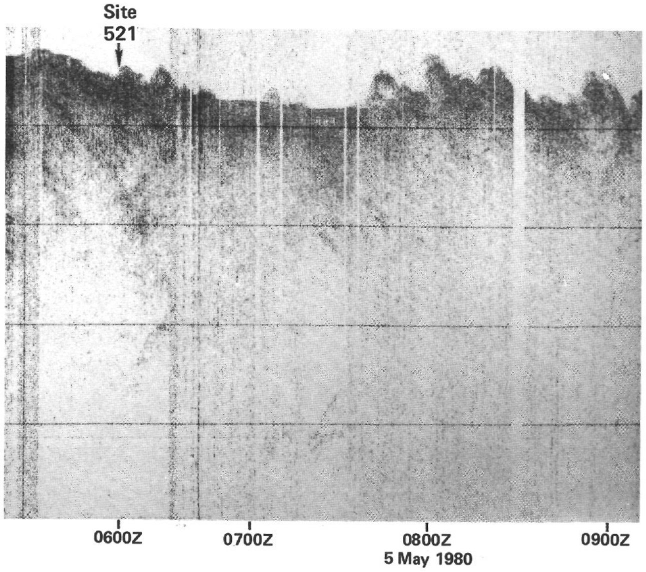

Figure 12. *Challenger* single-channel reflection profile departing from Site 521.

except for a thin interval in the middle and some intervals at the top and the bottom of the sequence. On board ship we tentatively correlated the lower longer interval of the positive magnetization with Chron 9 ("long normal" epoch). However, the apparently long epoch of normal magnetization may have been an artifact of rapid sedimentation rate during a period of reduced dissolution; we note that the "NN10" sediments are oligolytic and have little insoluble-residue content (<20%). A comparison of the natural remanent magnetization (NRM) and nannofossil records for Sites 519 and 521 seems to indicate that "NN10" at the latter site could also be correlated with Chron 7 (Anomalies 4 and 4′ or Chrons C-4 and C-4A). The two different interpretations are shown in Figure 13.

The LOs and HOs of *C. calyculus* and *C. coalitus* at Site 521 presented us with the same problem as the data from Site 519. The sediments that contain these nannofossils are much thinner at Site 521 than at Site 519, and we cannot obtain a clear magnetostratigraphy of the condensed sequence.

The occurrence of *Globigerina druryi, G. nepenthes*, and *Sphaeroidinellopsis subdehiscens* in sediments dated as belonging to the nannofossil zone NN5 confirm the observation first made at Site 520 that Blow's (1969) zonation needs revision. In his zonation, the FAD of *G. nepenthes* defines the base of N14, the FAD of *S. subdehiscens* defines the base of N13, and the FAD of *G. druryi* is considered to be near the top of N11. At Site 521 the LO of all those species is in a sediment belonging to the nannofossil zone NN5 and the foraminifer zone N8, much lower than Blow indicated.

Hole 521A

The results from the magnetostratigraphy and nannofossil stratigraphy of Hole 521A (see Heller et al., this vol.; and von Salis, this vol.) are shown next to the Hole 521 results in Figure 13. The sequence in Hole 521A is more condensed than in Hole 521, and the basement is reached in Hole 521A at 71.1 instead of 84.0 m sub-bottom. The condensation seems to result from a fur-

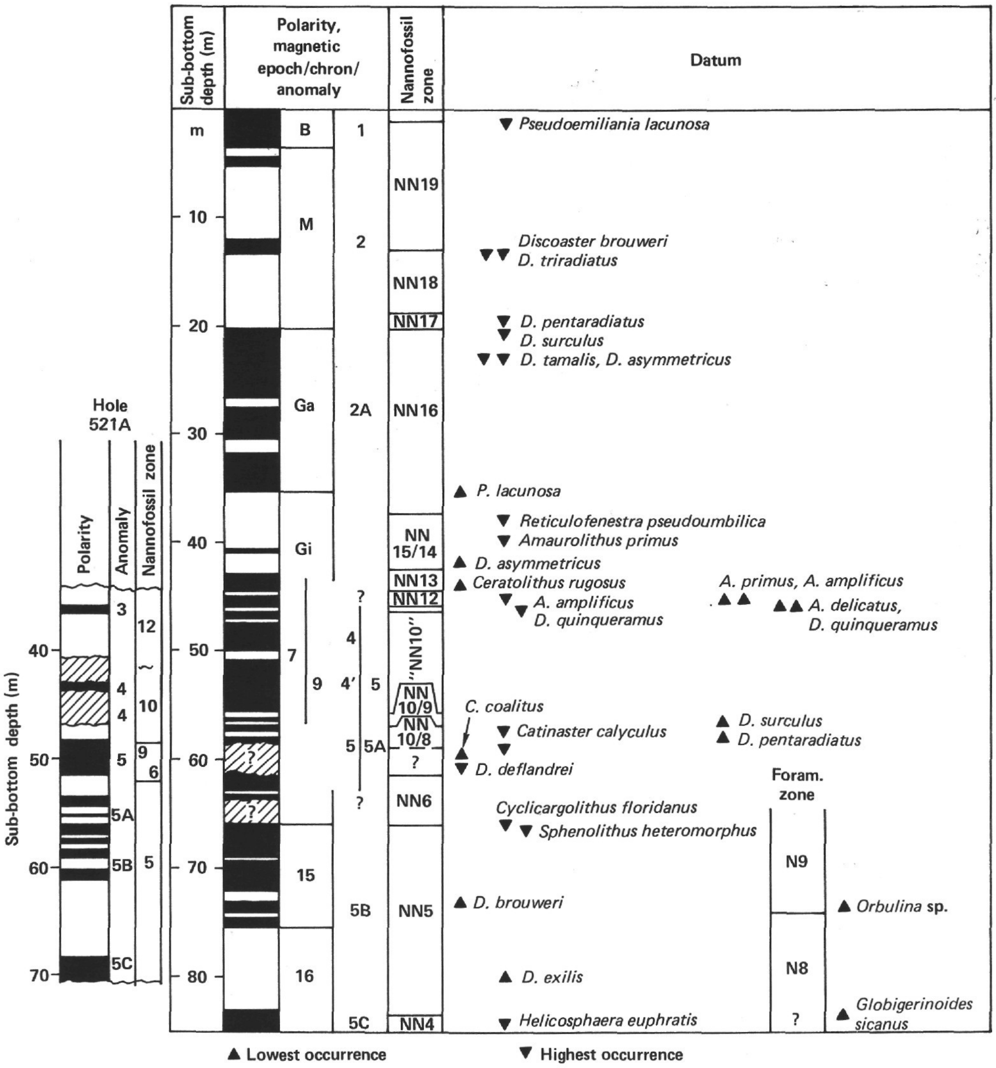

Figure 13. Magnetostratigraphy and biostratigraphy, Site 521 (see text for explanation of alternative correlations). Magnetic epochs as in Fig. 4.

ther condensation of the nannofossil zones NN6 to 10, especially NN7 to 9, which are present in red clays about 2 m thick. The results from Hole 521A strengthen the interpretation preferred by us that the nannofossil zones NN7 to 9 are correlative to Anomaly 5 (Chron C-5) and that "NN10" is roughly correlative to Anomalies 4 and 4′ (Chrons C-4 and C-4A)—an interpretation based primarily on the relatively clear signals from Chron C-5 at Site 519. If this interpretation is correct, the LOs of *Catinaster coalitus* and *C. calyculus* in the South Atlantic are definitely younger than the previously recorded FADs from the Pacific, and the discrepancies can hardly be attributed to the truncation of the lowest ranges by dissolution.

Calcite Dissolution

The degree of dissolution is manifested in the sediments in the insoluble-residue content (IR), the abundance of benthic foraminifers, and the fragmentation of planktonic foraminiferal tests. The three sets of criteria yield, on the whole, concordant data. Two major dissolution events have been recognized (Fig. 14).

The lowest sediments at this site, which were deposited at paleodepths of 2600 to 3400 m, are mainly oligolytic; most have an insoluble residue content of 15 to 30%. Two of the peaks in benthic foraminifer content (those up to 30%) may represent brief drifts of CCD. The average middle Miocene sedimentation rate is about 7 m/m.y., comparable to the late Miocene rates (7.0–10.4 m/m.y.) for comparable paleodepths at Site 519. The rate of the middle Miocene insoluble-residue accumulation, at 1.4 m/m.y. is, however, appreciably greater (vs. 0.7–1.0%). Whether the discrepancy is real or a consequence of inaccurate chronology cannot be ascertained.

Figure 14 shows a systematic decrease of insoluble-residue content (36–11%) that begins at about the same time as the positive oxygen shift (+1.7 to +2.7‰) and shortly after the *Orbulina* datum. This interval of a dissolution minimum lasted less than 1 m.y. The major dis-

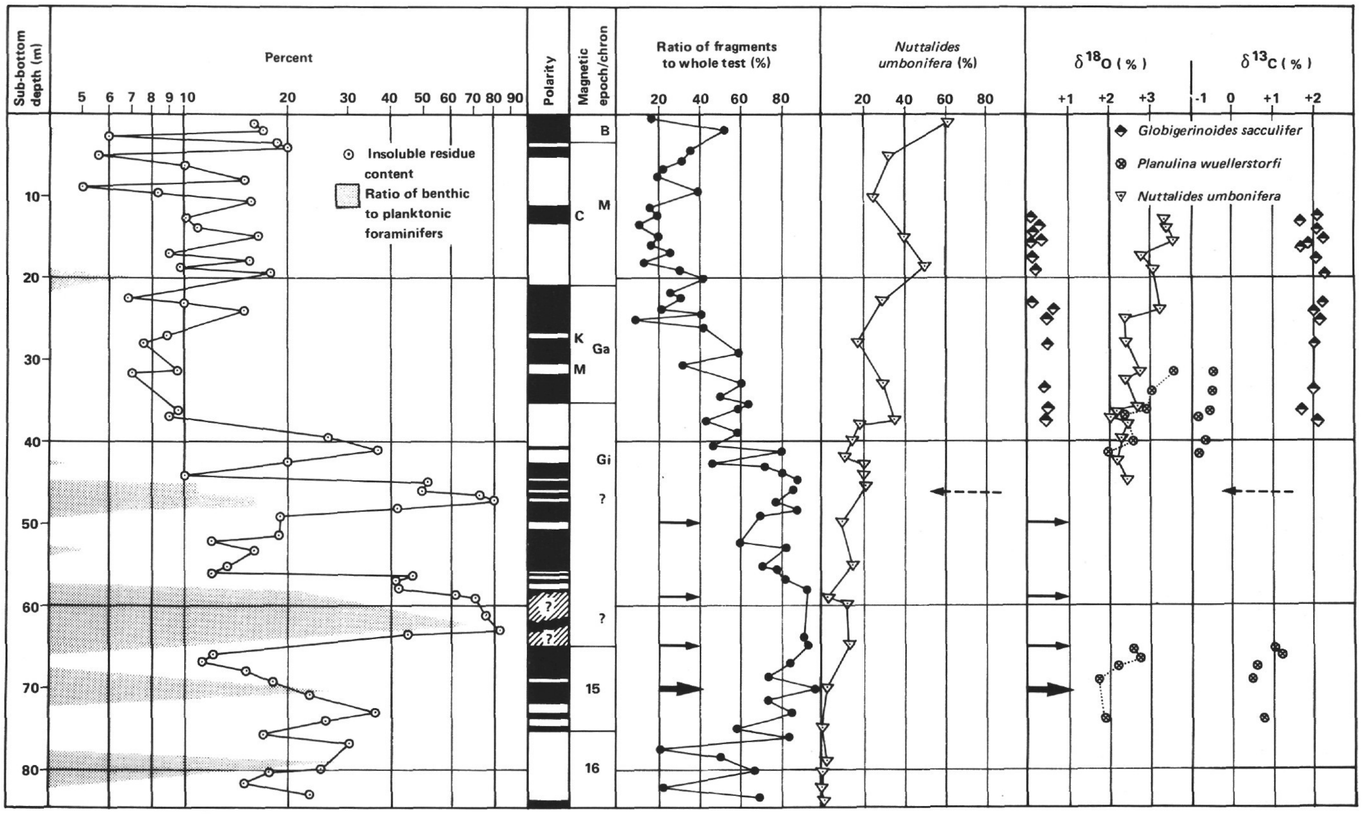

Figure 14. Paleoceanographic data, Site 521. Polarity and magnetic epochs as in Fig. 4. Dashed, solid, and heavy arrows denote, respectively, the second significant increase of *N. umbonifera*, times of major shift in CCD, and the beginning of the middle Miocene oxygen shift.

solution event started immediately after this brief pause at the beginning of NN6, or Chron 14, some 13 Ma. The marl oozes and red clays deposited during the dissolution maximum contain up to 84% insoluble residue and 70% benthic foraminifers. One thin layer of carbonate-free sediment in NN6/7 was identified during the detailed studies of Hole 521A samples for nannofossil stratigraphy (von Salis, this vol.), indicating that the CCD rose above the paleodepth of 3500 m some time between 12 and 10 Ma. Another period of reduced dissolution began when "NN10" sediments were about to be deposited. If those sediments are assumed to correlate with Chron 7 (Anomalies 4 and 4′ or Chrons C-4 and C-4A), the average sedimentation rate of the mesolytic and pleistolytic Miocene sediments should be 1.8 m/m.y. Such a correlation would also yield an accumulation rate of 6.2 m/m.y. for that part of the "NN10" sediments of supposedly Chron 7 age.

The second dissolution event, which occurred during the latest Miocene and early Pliocene, produced sediments that contain almost as much insoluble residue (up to 80%) but much less benthic foraminifer content (17% or less) than the event in the middle Miocene, even though the site had subsided considerably more since that time; the paleodepth at the end of the Miocene here should have been almost 4000 m. The mesolytic and pleistolytic sediments were deposited at an average rate of about 2.3 m/m.y.

The proposed correlations give insoluble-residue accumulation rates of 1.1, 1.1, and 1.0 m/m.y. for the two Miocene and Pliocene intervals, comparable to the rates at Site 519 (~1 m/m.y.) (see Table 3).

The sedimentation rate since the middle Pliocene at this site is 10.6 m/m.y. for the bulk and 1.3 m/m.y. for insoluble residue; both rates are somewhat less than the equivalent rates at Site 519. Light eolytic oozes and darker oligolytic marly oozes were deposited during interglacial and glacial epochs of the Pliocene–Quaternary (Weissert et al., this vol.).

The crust at Site 15, which was on the western flank of the Mid-Atlantic Ridge, was slightly older, yet the sediments of the equivalent facies there contain on the whole less insoluble residue and were deposited at slightly higher rates (Maxwell et al., 1970, pp. 445–453). The

Table 3. Sedimentation rates at Site 521.

Datum or interval	Depth (m)	Age (m.y.)	Sedimentation rate (m/m.y.) Interval	Insoluble residue
Seafloor	0	0		
Pliocene–Quaternary			10.6	1.3
Cochiti, top	40.25	3.86		
Miocene–Pliocene			7.3	1.0
Chron C-7, top	47.5	6.54		
"NN10"			6.2	1.1
Chron C-7, bottom	55.8	7.88		
Middle to late Miocene			1.8	1.1
Chron C-15, top	—	13.2		
NN5			7.0	1.4
Chron C-5C-N, top	84.2	15.8		

first occurrence of a mesolytic marl at Site 15, which signifies a rapid increase of dissolution, occurs at just about the *Orbulina* datum, so the dissolution event seems to have occurred slightly earlier there than that at Site 521. This is to be expected, however, in view of the older age of the crust there; Site 15 should have subsided below the lysocline at a slightly earlier time.

Paleoceanography

The timing of the dissolution events does not correlate simply to changes in ocean environments. The significant increase of *Nuttalides umbonifera* (up to 12%) (Fig. 14) seems to correlate with an oxygen shift and roughly to the beginning of the dissolution event. The oxygen shift and the increase of *N. umbonifera* were probably brought about when the site sank below 3400 m paleodepth into the zone of the Antarctic Bottom Water, and the timing did coincide more or less with a worldwide temperature drop that started 14 m.y. ago (Douglas and Savin, 1975). Yet a closer look at the record shows a correlation of decreasing insoluble-residue content with the positive oxygen shift in the interval from 70 to 66.5 m sub-bottom (Fig. 14). Thus, it seems difficult to draw a simple conclusion on the relation between the middle Miocene dissolution and Antarctic Bottom Water activities.

A second significant increase of *N. umbonifera* during the latest Miocene did coincide more or less in timing with the second dissolution event, yet the last increase, with a coincident oxygen shift, took place during the late Pliocene (Gauss/Matuyama boundary) when the CCD remained depressed. The data from Site 521 thus seem to reinforce our conclusion after drilling at Site 519; namely, the corrosive waters of the Antarctic Bottom Water may have led to locally increased dissolution of the second order, but the overall CCD of the world's oceans was controlled by other first-order factors, such as oceanic fertility.

The carbon-isotope values of the middle Miocene are considerably more positive than in the Pliocene, but the timing of the worldwide carbon shift cannot be accurately determined at this site because of the dissolution of the microfauna in the upper Miocene sediments.

Basement Age

Basement was not penetrated at this site, but it must be present at 84 m sub-bottom in Hole 521 (original), where the HPC hit an object so hard that it damaged the core catcher. The basement should have an age of 16.2 m.y. if it is correct to assume a linear seafloor spreading rate, and this age is almost exactly the age predicted for the youngest (NN4) sediments overlying the basement at this site (see Ryan et al., 1978, p. 14).

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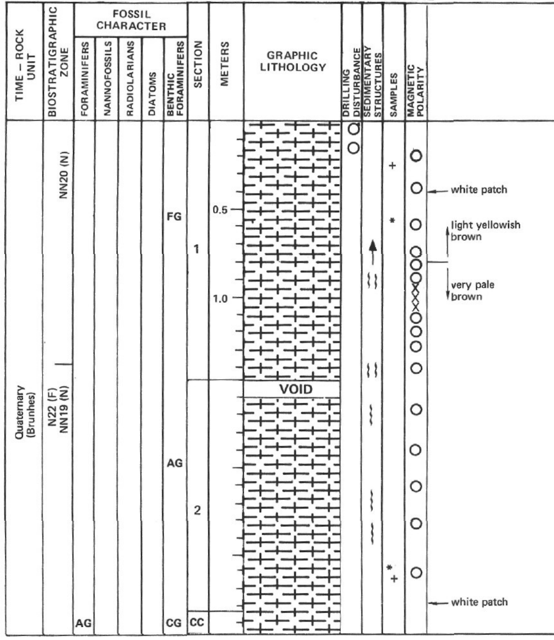
Date of Initial Receipt: August 12, 1982

SITE 521 HOLE CORE (HPC) 1 CORED INTERVAL 0.0–3.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, light yellowish brown (10YR 6/4) grading to very pale brown (10YR 8/3) across the burrowed interval at approximately 80 cm in Section 1. Bioturbation features most recognizable where color changes occur. Core generally homogeneous. Foraminifers average approximately 2–3%; volcanic glass fragments in lighter (very pale brown) ooze.

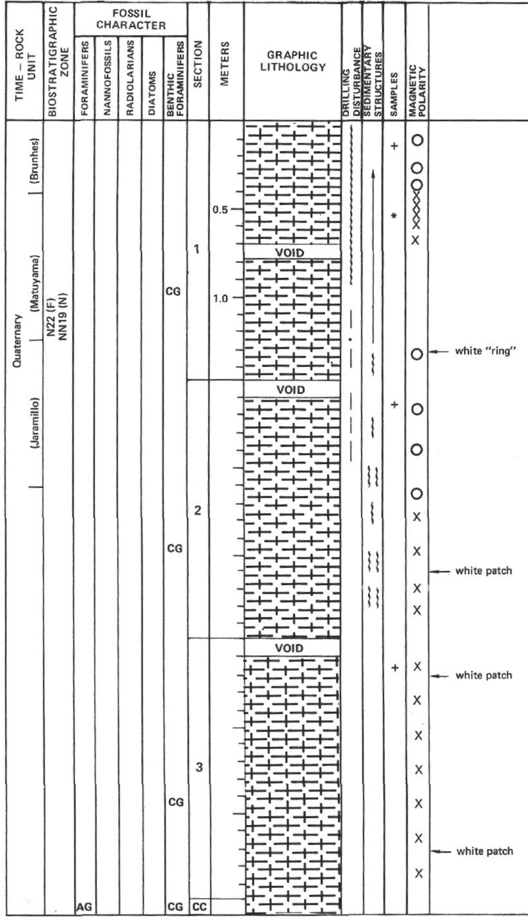
SMEAR SLIDE SUMMARY

	1-60 D	2-110 D
TEXTURE:		
Sand	5	5
Silt	90	95
Clay	5	–
COMPOSITION:		
Clay	59	–
Volcanic glass	–	2
Palagonite	2	1
Foraminifers	5	3
Calc. nannofossils	88	94

ORGANIC CARBON AND CARBONATE

	1-27	2-117
Organic carbon	–	–
Carbonate	86	94

SITE 521 HOLE CORE (HPC) 2 CORED INTERVAL 3.0–7.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, light yellowish brown (10YR 6/4) grading to very pale brown (10YR 7/4) in Section 1. Burrowed in Sections 1 and 2. Foraminifers approximately 2–5%. Scattered white patches.

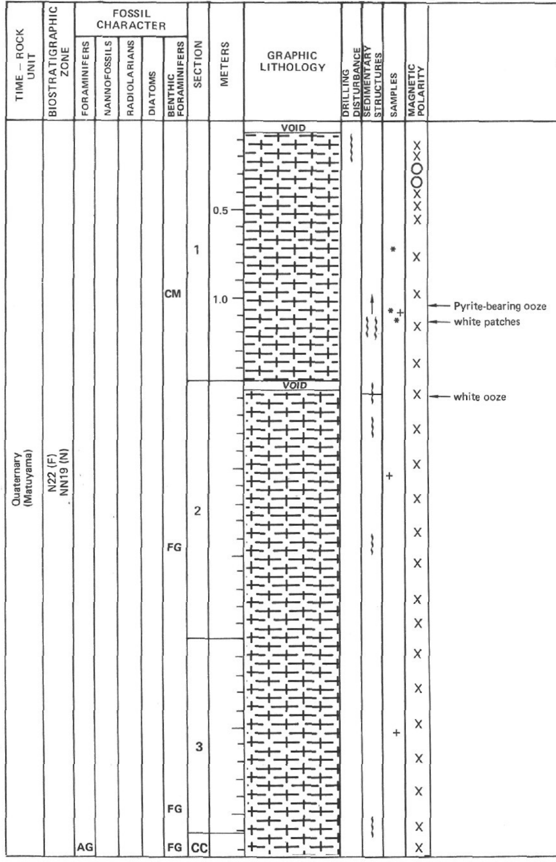
SMEAR SLIDE SUMMARY

	1-60 D
TEXTURE:	
Sand	5
Silt	95
Clay	–
COMPOSITION:	
Clay	TR
Palagonite(?)	5
Foraminifers	5
Calc. nannofossils	95

ORGANIC CARBON AND CARBONATE

	1-12	2-17	3-16
Organic carbon	–	–	–
Carbonate	82	94	94

SITE 521 HOLE CORE (HPC) 3 CORED INTERVAL 7.5–12.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale *brown (10YR 7/3) with patches of white (10YR 8/1)* ooze partly homogenized by burrowing. Light gray patches at approximately 110 cm, Section 1 contain pyrite. Presence of brownish palagonitic(?) silt-size particles in brown ooze is only difference from white ooze. No significant drilling disturbance.

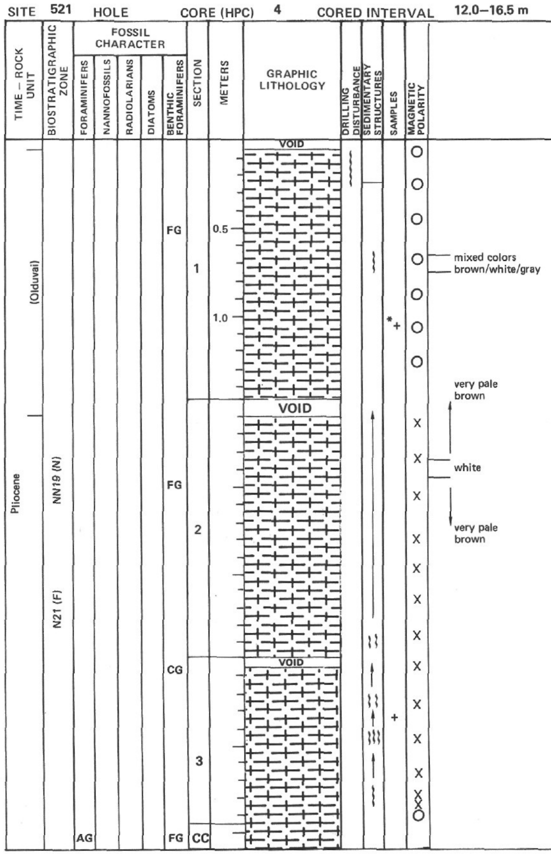
SMEAR SLIDE SUMMARY

	1-75 D	1-110 M	1-117 M
TEXTURE:			
Sand	3	3	3
Silt	97	97	97
Clay	–	–	TR
COMPOSITION:			
Clay	TR	TR	TR
Volcanic glass	1	TR	1
Palagonite	2	TR	1
Pyrite	–	2	–
Foraminifers	3	3	3
Calc. nannofossils	94	95	95

ORGANIC CARBON AND CARBONATE

	1-110	2-53	3-53
Organic carbon	–	–	–
Carbonate	89	94	88

SITE 521 HOLE CORE (HPC) 4 CORED INTERVAL 12.0–16.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, pale brown (10YR 6/3) to very pale brown (10YR 7/3) with several white (10YR 8/2) patches and intervals. Burrowing common in Sections 2 and 3. Minor drilling disturbance.

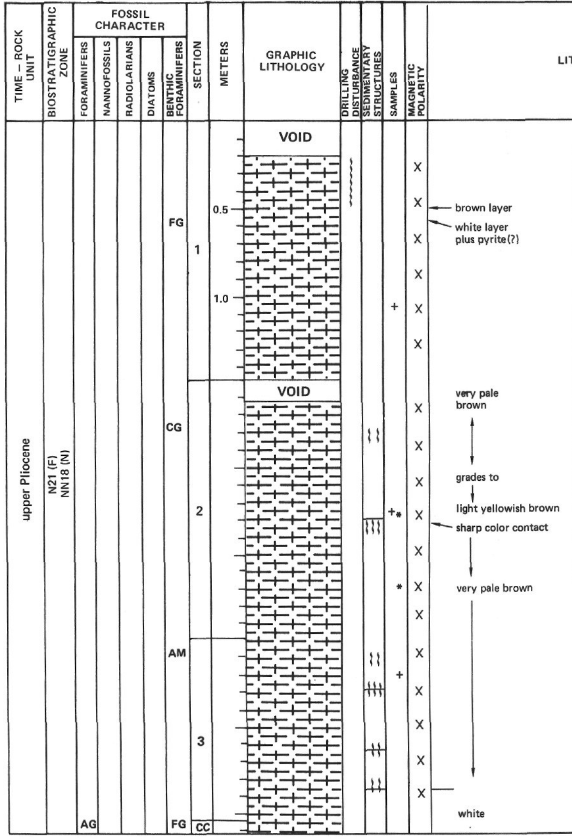
SMEAR SLIDE SUMMARY

	1-100 D
TEXTURE:	
Sand	–
Silt	90
Clay	10
COMPOSITION:	
Quartz	TR
Volcanic glass	TR
Palagonite	5
Micronodules	TR
Carbonate unspec.	10
Foraminifers	25
Calc. nannofossils	60
Fish remains	TR

ORGANIC CARBON AND CARBONATE

	1-100	*3-36*
Organic carbon	–	–
Carbonate	90	85

SITE 521 HOLE CORE (HPC) 5 CORED INTERVAL 16.5–21.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3), light yellowish brown (10YR 6/4) to white (10YR 8/2), homogeneous except for burrowed intervals in Sections 2 and 3. Color change boundaries show burrowing best. Minimal core disturbance.

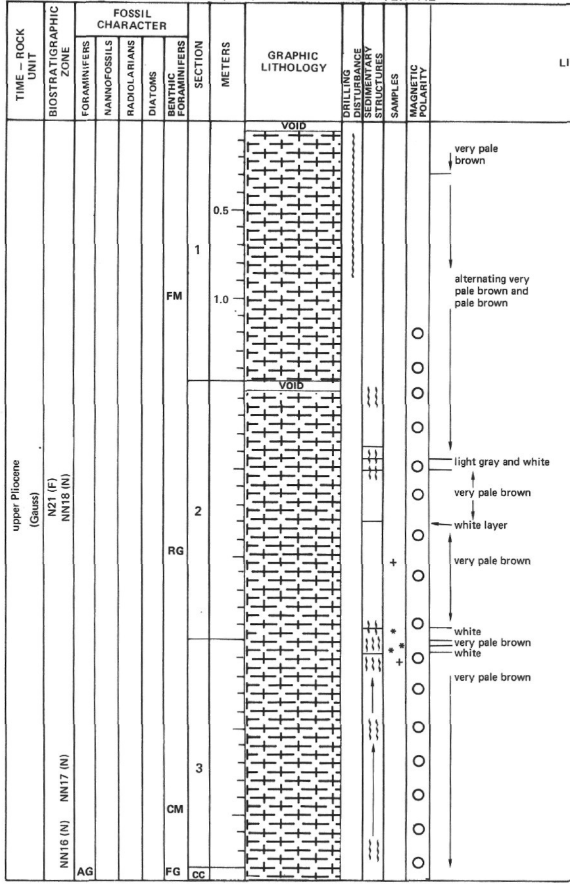
SMEAR SLIDE SUMMARY

	2-80 D	2-120 D
TEXTURE:		
Sand	–	–
Silt	90	95
Clay	10	5
COMPOSITION:		
Quartz	TR	TR
Clay	5	3
Volcanic glass	TR	TR
Palagonite	5	5
Micronodules	TR	–
Carbonate unspec.	10	15
Foraminifers	25	5
Calc. nannofossils	45	70
Sponge spicules	–	TR
Fish remains	–	TR
Iron-oxides	10	2

ORGANIC CARBON AND CARBONATE

	1-104	2-76	3-20
Organic carbon	–	–	–
Carbonate	94	85	84

SITE 521 HOLE CORE (HPC) 6 CORED INTERVAL 21.0–26.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, colors alternate on 1–100 cm scale between very pale brown (10YR 7/3), pale brown (10YR 6/3), white (5YR 8/1), and light gray (10YR 7/2). Darker colored sediment contains more silt-size iron-oxide and palagonite fragments than light sediments. Section 1 disturbed by drilling.

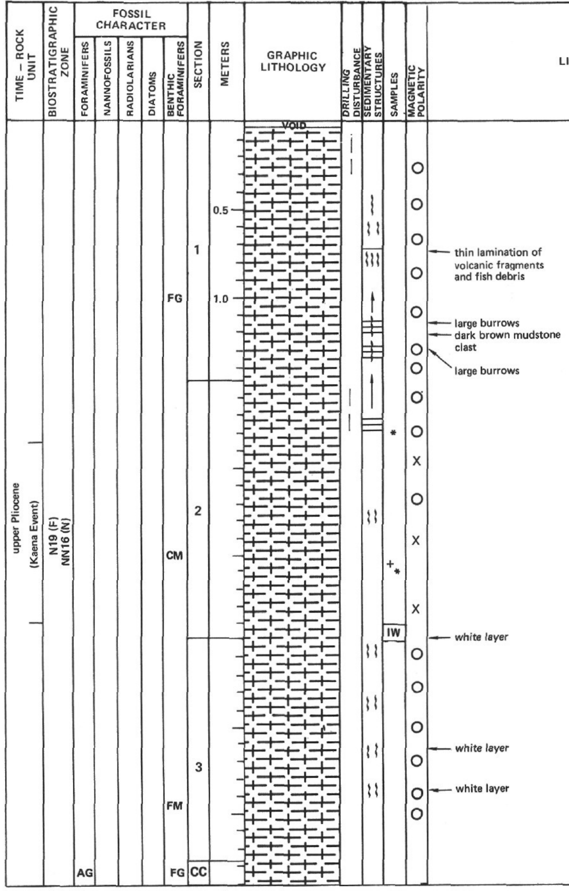
SMEAR SLIDE SUMMARY

	2-148 M	3-6 M	3-7 M
TEXTURE:			
Sand	10	TR	5
Silt	85	80	75
Clay	5	20	20
COMPOSITION:			
Quartz	TR	TR	–
Clay	5	TR	5
Volcanic glass	–	–	TR
Palagonite	TR	TR	5
Micronodules	5	5	10
Carbonate unspec.	15	15	10
Foraminifers	20	10	10
Calc. nannofossils	50	70	50
Fish remains	–	TR	–
Iron-oxides	5	–	10

ORGANIC CARBON AND CARBONATE

	2-108	3-12
Organic carbon	–	–
Carbonate	90	86

SITE 521 HOLE CORE (HPC) 7 CORED INTERVAL 25.5–30.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3) and homogeneous with burrowed intervals mixing white (5YR 8/1) ooze. Laminated white (light gray) and brown ooze base Section 1 contains large burrows; laminated ooze top Section 2 not burrowed. Dark brown (7.5YR 4/4) nannofossil mudstone clast approximately 2 cm across occurs at 119 cm, Section 1. Thin (0.5 cm thick) layer of basalt fragments, volcaniclastic particles, and zeolites and flish debris occurs at 74 cm, Section 1. Section 3 is burrowed.

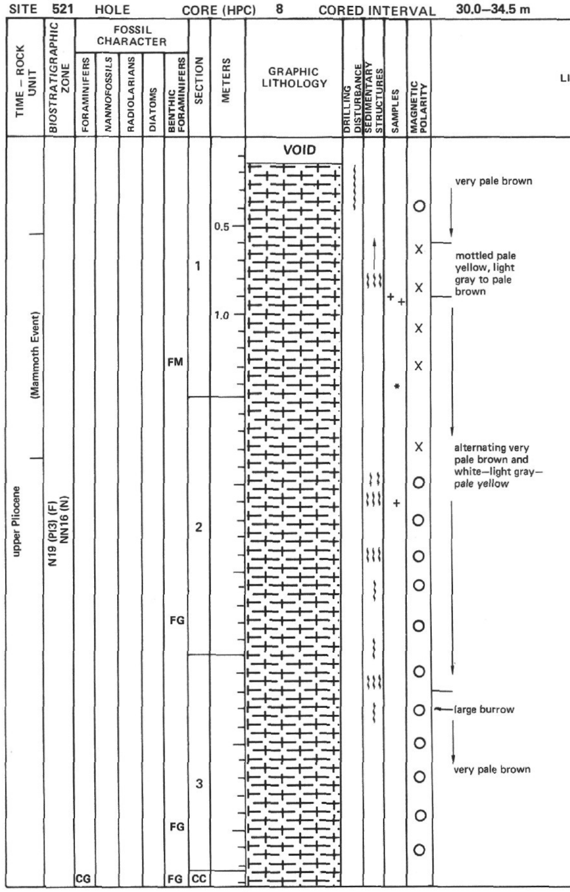
SMEAR SLIDE SUMMARY

	2-31	2-119
	D	M
TEXTURE:		
Sand	5	15
Silt	75	50
Clay	20	35
COMPOSITION:		
Clay	5	15
Volcanic glass	TR	–
Palagonite	–	5
Micronodules	5	10
Carbonate unspec.	25	15
Foraminifers	15	5
Calc. nannofossils	45	30
Iron-oxides	5	20

ORGANIC CARBON AND CARBONATE

	2-102
Organic carbon	–
Carbonate	95

SITE 521 HOLE CORE (HPC) 8 CORED INTERVAL 30.0–34.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3) alternating with lighter zones (white, [5YR 8/1], pale yellow and light gray). Burrowing common; enhanced by color changes. Large burrow 25–30 cm, Section 3. Minimal core disturbance.

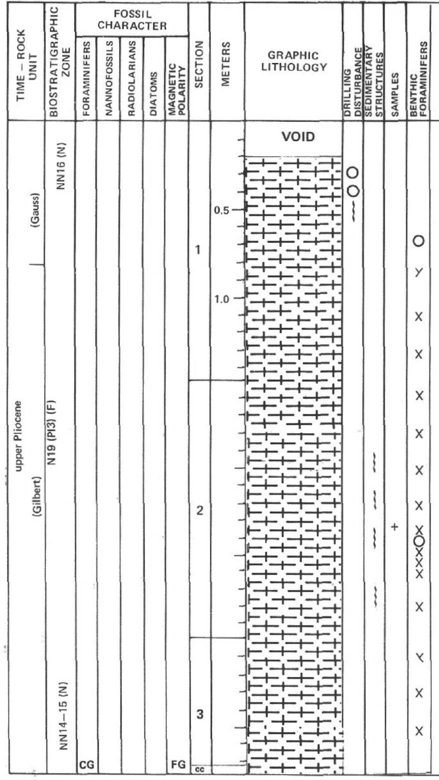
SMEAR SLIDE SUMMARY

	1-145
	D
TEXTURE:	
Sand	5
Silt	90
Clay	5
COMPOSITION:	
Clay	5
Volcanic glass	TR
Palagonite	5
Micronodules	5
Carbonate unspec.	15
Foraminifers	10
Calc. nannofossils	65
Iron-oxides	5

ORGANIC CARBON AND CARBONATE

	1-90	1-94	2-65
Organic carbon	—	—	—
Carbonate	93	93	91

SITE 521 HOLE CORE (HPC) 9 CORED INTERVAL 34.5–39.0 m



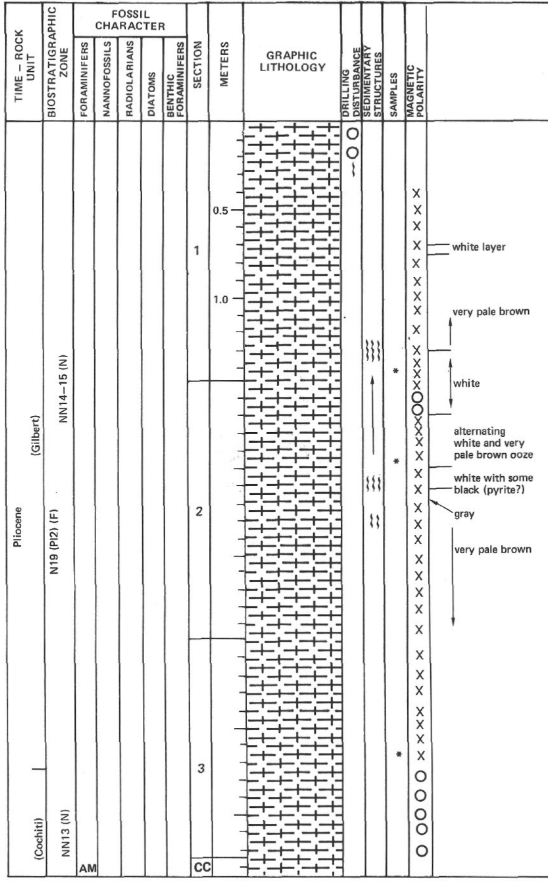
LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3), homogeneous except for several large burrows filled with white ooze in Section 2. Minimal core disturbance.

ORGANIC CARBON AND CARBONATE

	2-85
Organic carbon	–
Carbonate	91

SITE 521 HOLE CORE (HPC) 10 CORED INTERVAL 39.0–43.5 m



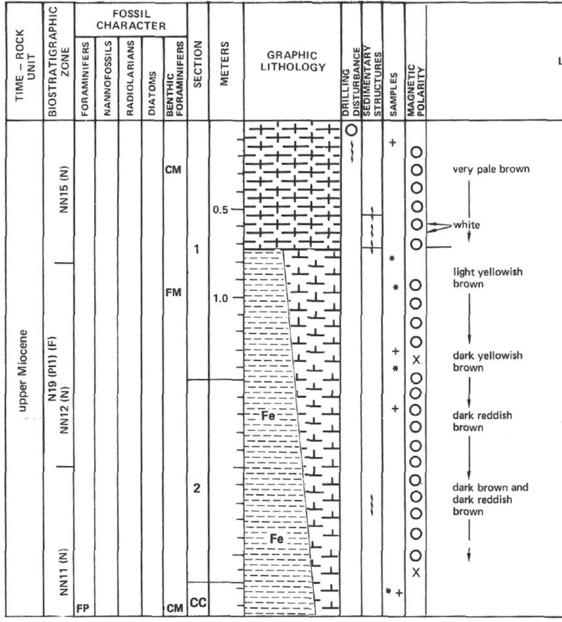
LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3) in Section 3 and most of Section 1. Base Section 1 and top Section 2 contain burrowed intervals where brown, white, and light gray ooze are mixed. Black streaks at approximately 48–54 cm, Section 2 are pyrite-bearing(?).

SMEAR SLIDE SUMMARY

	1-149 M	2-54 M	3-67 D
TEXTURE:			
Sand	5	10	TR
Silt	85	90	95
Clay	10	–	5
COMPOSITION:			
Quartz	TR	–	–
Clay	5	TR	TR
Volcanic glass	TR	TR	TR
Palagonite	5	–	–
Micronodules	5	10	–
Carbonate unspec.	20	15	15
Foraminifers	10	5	5
Calc. nannofossils	45	70	70
Iron-oxides	10	–	10

SITE 521 HOLE CORE (HPC) 11 CORED INTERVAL 43.5–46.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3), homogeneous with burrowed base at 80 cm, Section 1. Sharp contact in Section 1 at 80 cm; below this ooze changes to NANNOFOSSIL CLAY that becomes darker (light yellowish brown [10YR 6/4] to dark brown [7.5YR 4/4] *and dark reddish brown* [5YR 3/3]), contains less carbonate and more iron-oxides down core. Clay contains faint burrows.

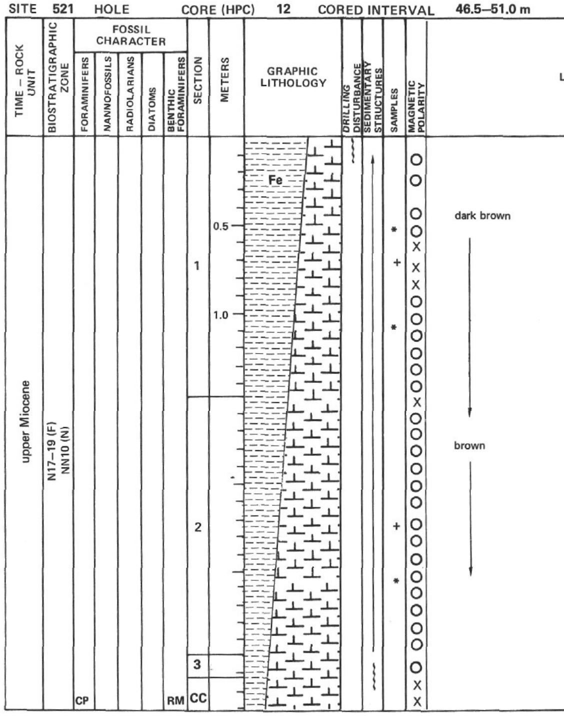
SMEAR SLIDE SUMMARY

	1-77 D	1-91 D	1-148 D	CC, 10 D
TEXTURE:				
Sand	–	5	10	10
Silt	85	60	50	50
Clay	15	85	40	40
COMPOSITION:				
Quartz	TR	TR	TR	TR
Clay	TR	15	15	15
Volcanic glass	TR	10	5	TR
Palagonite	–	TR	–	TR
Micronodules	–	5	10	10
Carbonate unspec.	10	10	10	15
Foraminifers	5	5	5	–
Calc. nannofossils	75	35	35	35
Iron-oxides	10	20	20	25

ORGANIC CARBON AND CARBONATE

	1-15	1-130	2-20	CC, 10
Organic carbon	–	–	–	–
Carbonate	92	49	50	31

SITE 521 HOLE CORE (HPC) 12 CORED INTERVAL 46.5–51.0 m



LITHOLOGIC DESCRIPTION

IRON-RICH NANNOFOSSIL CLAY grading down core to MARLY NANNOFOSSIL OOZE. Clay is dark brown (7.5YR 3/2); grades to brown (7.5YR 5/4) ooze. Core is burrowed throughout.

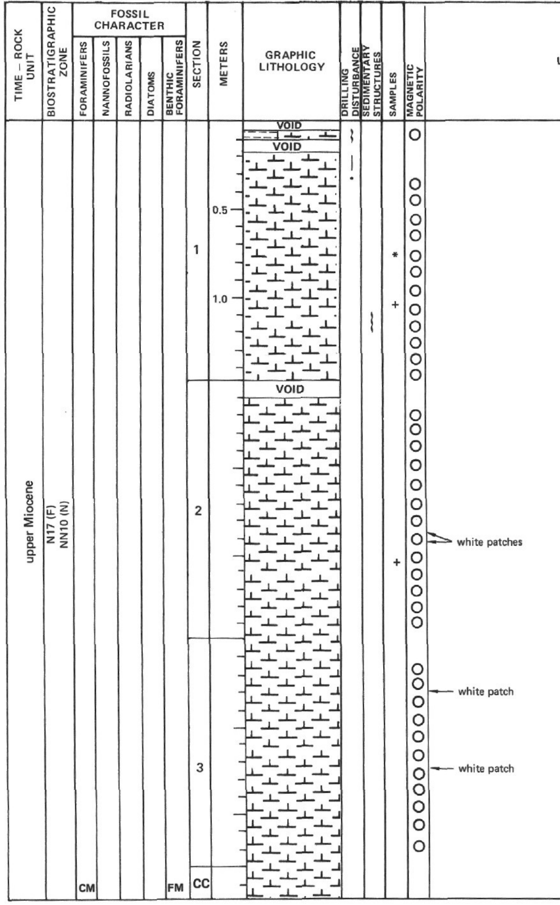
SMEAR SLIDE SUMMARY

	1-52 D	1-110 D	2-110 D
TEXTURE:			
Sand	3	3	1
Silt	40	40	95
Clay	57	57	4
COMPOSITION:			
Clay	50	50	4
Volcanic glass	1	1	TR
Palagonite	–	TR	–
Micronodules	1	1	1
Carbonate unspec.	5	3	5
Foraminifers	3	2	2
Calc. nannofossils	20	27	65
Iron-oxides	20	20	13

ORGANIC CARBON AND CARBONATE

	1-76	2-76
Organic carbon	–	–
Carbonate	37	83

SITE 521 HOLE CORE (HPC) 13 CORED INTERVAL 51.0–55.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light yellowish brown (10YR 6/4), homogeneous throughout except for rare burrows and white patches. Top 25 cm of Section 9 contains drilling mixture of brown MARLY OOZE.

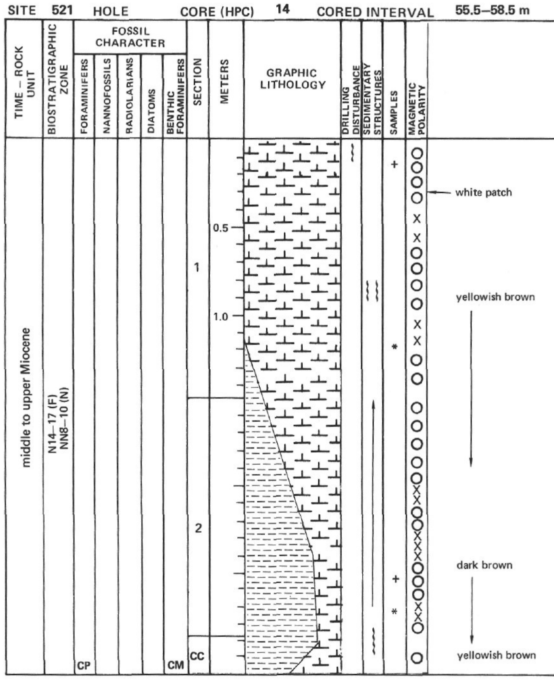
SMEAR SLIDE SUMMARY

	1-77
	D
TEXTURE:	
Sand	TR
Silt	95
Clay	5
COMPOSITION:	
Clay	5
Carbonate unspec.	30
Foraminifers	TR
Calc. nannofossils	65
Iron-oxides	5

ORGANIC CARBON AND CARBONATE

	1-105	2-103
Organic carbon	–	–
Carbonate	88	85

SITE 521 HOLE CORE (HPC) 14 CORED INTERVAL 55.5–58.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE grading down core to IRON-RICH NANNOFOSSIL CLAY at approximately 90 cm, Section 2. Ooze is yellowish brown (10YR 5/4) with scattered burrows; clay is dark brown (10YR 3/3) with common burrows throughout. Core-Catcher shows reversal from dark clay back to yellowish ooze. Top 5 cm, Section 1 contains drilling breccia of dark brown mudstone.

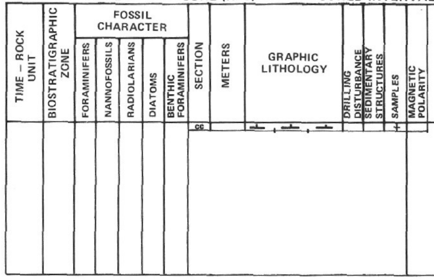
SMEAR SLIDE SUMMARY

	1-120
	D
TEXTURE:	
Sand	1
Silt	95
Clay	5
COMPOSITION:	
Clay	5
Palagonite	TR
Pyrite	TR
Micronodules	TR
Carbonate unspec.	20
Foraminifers	1
Calc. nannofossils	70
Iron-oxides	4

ORGANIC CARBON AND CARBONATE

	1-12	2-105
Organic carbon	–	–
Carbonate	88	32

SITE 521 HOLE CORE (HPC) 15 CORED INTERVAL 58.5–61.5 m



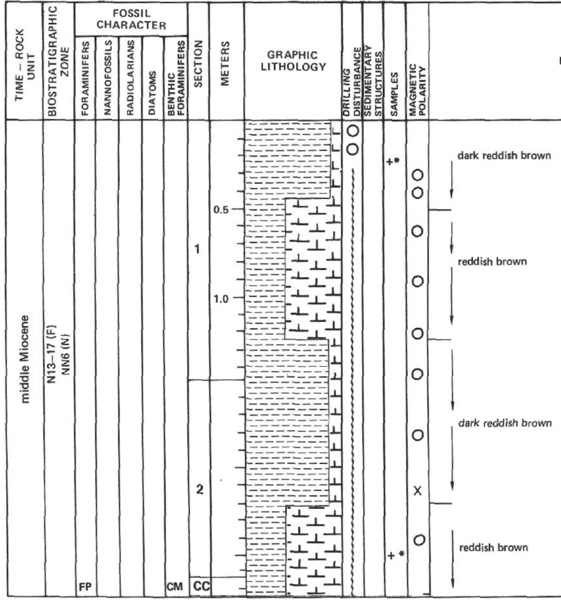
LITHOLOGIC DESCRIPTION

Trace of MARLY NANNOFOSSIL OOZE in Core-Catcher. Core was dropped – possible reason for core disturbance in Core 16.

ORGANIC CARBON AND CARBONATE

	CC
Organic carbon	–
Carbonate	26

SITE 521 HOLE CORE (HPC) 16 CORED INTERVAL 61.5–66.0 m



LITHOLOGIC DESCRIPTION

IRON-RICH NANNOFOSSIL CLAY alternating with MARLY NANNOFOSSIL OOZE. Clay is dark reddish brown (2.5Y 3/2) with few burrows; ooze is reddish brown (5YR 4/4), also slightly burrowed. Core is disturbed by drilling (probably resulted from dropping of Core 15); outer edges of Section *1 and part of Section 2 show vertical flow lines.*

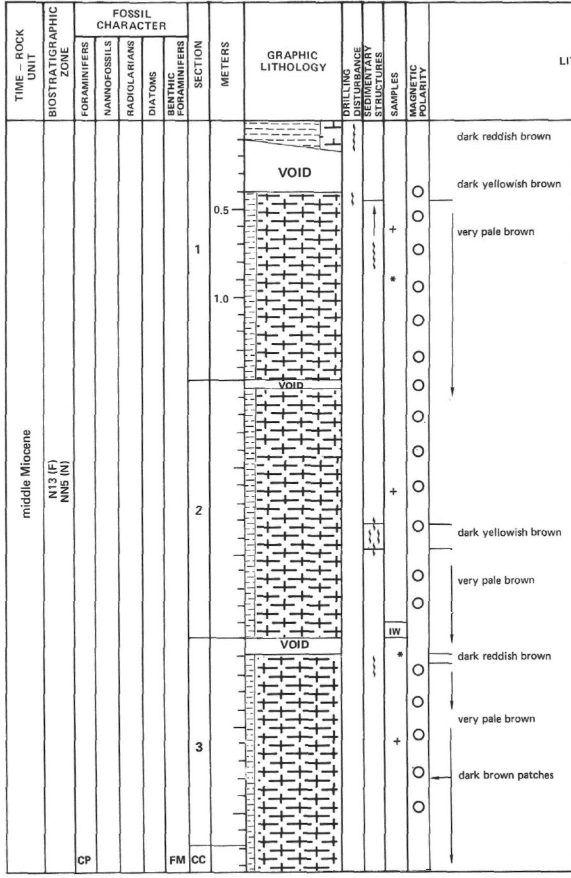
SMEAR SLIDE SUMMARY

	1-126	2-100
	D	D
TEXTURE:		
Sand	3	3
Silt	67	82
Clay	30	15
COMPOSITION:		
Quartz	TR	–
Clay	30	15
Volcanic glass	2	TR
Palagonite	TR	TR
Micronodules	1	2
Carbonate unspec.	10	5
Foraminifers	TR	TR
Calc. nannofossils	47	70
Iron-oxides	10	8

ORGANIC CARBON AND CARBONATE

	1-26	2-100
Organic carbon	–	–
Carbonate	15	54

SITE 521 HOLE CORE (HPC) 17 CORED INTERVAL 66.0–70.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 7/4) with mottled and burrowed intervals of dark yellowish brown (10YR 4/4). Dark reddish brown (5YR 3/4) NANNOFOSSIL CLAY occurs at top of Core (contamination?) and at top of Section 3. Pale brown and yellowish brown contacts show burrows best. Top of core only is disturbed.

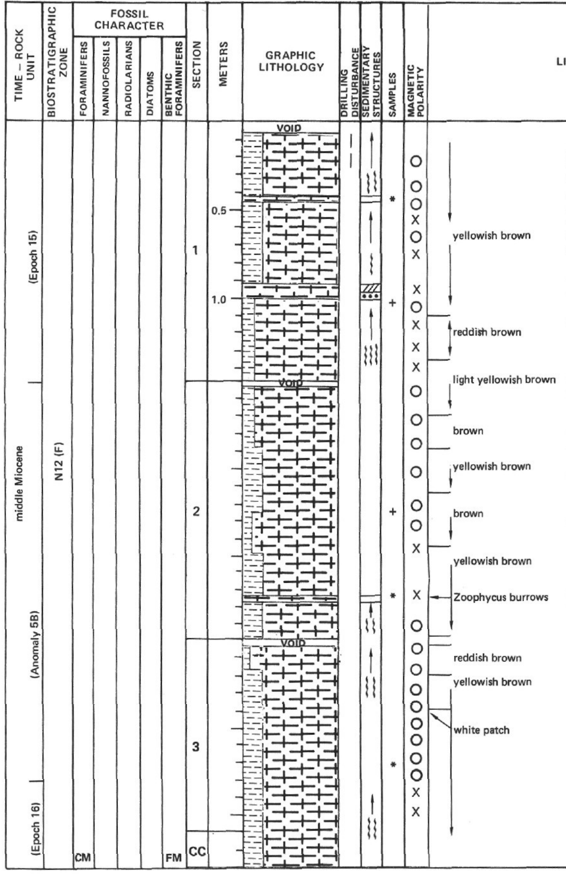
SMEAR SLIDE SUMMARY

	1-90	3-9
	D	M
TEXTURE:		
Sand	5	3
Silt	90	70
Clay	5	27
COMPOSITION:		
Clay	5	27
Volcanic glass	TR	–
Palagonite	–	TR
Micronodules	TR	–
Carbonate unspec.	–	10
Foraminifers	5	TR
Calc. nannofossils	85	58
Iron-oxides	5	5

ORGANIC CARBON AND CARBONATE

	1-64	2-65	3-65
Organic carbon	–	–	–
Carbonate	86	86	82

SITE 521 HOLE CORE (HPC) 18 CORED INTERVAL 70.5–74.9 m



LITHOLOGIC DESCRIPTION

MARLY FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/4) and light yellowish brown (10YR 6/4) to reddish brown (5YR 4/4) and brown (7.5YR 4/4). Three foraminifer layers noted (Sections 1 and 2). All have sharp basal contacts; only one is graded with possible cross laminations. Burrowed intervals are common. Horizontal, evenly spaced Zoophycus burrows occur between 130–145 cm in Section 4. White concentric patch occurs at 38 cm in Section 3; possible reduction ring due to burrowing.

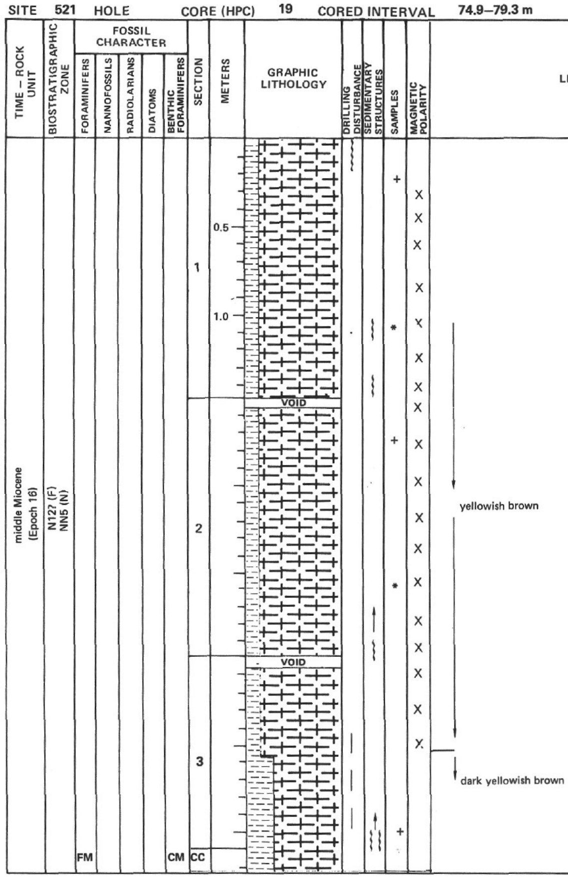
SMEAR SLIDE SUMMARY

	1-46	2-126	3-70
	M	M	D
TEXTURE:			
Sand	45	35	10
Silt	50	60	85
Clay	5	5	5
COMPOSITION:			
Clay	5	5	5
Volcanic glass	–	TR	–
Palagonite	–	–	TR
Micronodules	TR	TR	–
Carbonate unspec.	10	5	5
Foraminifers	40	30	10
Calc. nannofossils	34	60	80
Iron-oxides	1	1	1

ORGANIC CARBON AND CARBONATE

	1-107	2-71
Organic carbon	–	–
Carbonate	77	63

SITE 521 HOLE CORE (HPC) 19 CORED INTERVAL 74.9–79.3 m



LITHOLOGIC DESCRIPTION

MARLY FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/6) changing to dark yellowish brown (10YR 4/4) in Section 3. Burrowed zones enhanced by mix of yellowish brown ooze with minor grayish white ooze. Top 20 cm of core contains dark clay from downhole contamination.

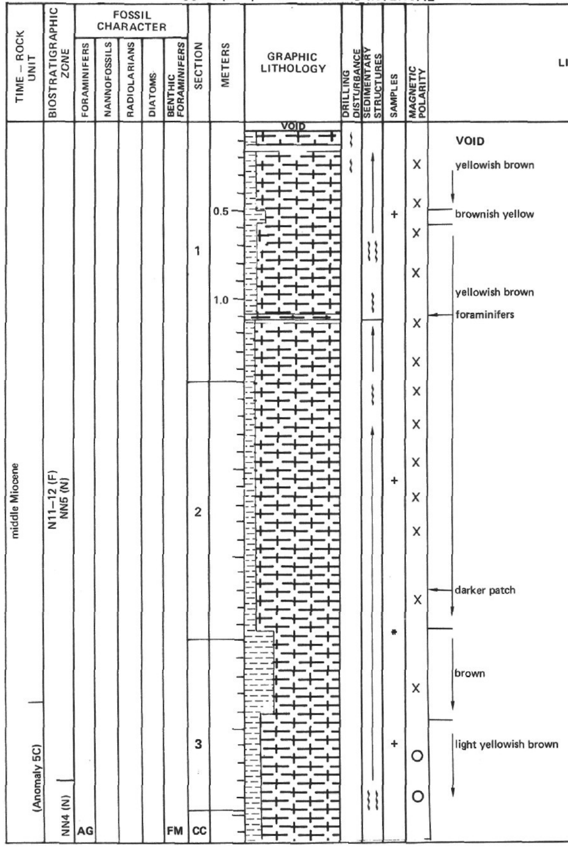
SMEAR SLIDE SUMMARY

	1-110	2-110
	D	D
TEXTURE:		
Sand	10	.5
Silt	85	90
Clay	5	5
COMPOSITION:		
Clay	5	5
Volcanic glass	TR	–
Carbonate unspec.	10	–
Foraminifers	10	5
Calc. nannofossils	70	85
Iron-oxides	5	5

ORGANIC CARBON AND CARBONATE

	2-23	3-100
Organic carbon	–	–
Carbonate	82	70

SITE 521 HOLE CORE (HPC) 20 CORED INTERVAL 79.3–83.7 m



LITHOLOGIC DESCRIPTION

MARLY FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/6) and brownish yellow (10YR 6/8) to light yellowish brown (10YR 6/4), and brown (7.5YR 5/2). Thin foraminifer sand with sharp basal contact and burrowed top occurs in Section 1. Burrows common throughout.

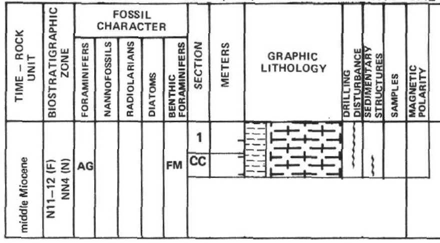
SMEAR SLIDE SUMMARY

	2-148 D
TEXTURE:	
Sand	5
Silt	85
Clay	10
COMPOSITION:	
Quartz	TR
Clay	5
Volcanic glass	5
Micronodules	TR
Carbonate unspec.	15
Foraminifers	15
Calc. nannofossils	50
Fish remains	5
Iron-oxides	5

ORGANIC CARBON AND CARBONATE

	1-58	2-58	3-58
Organic carbon	–	–	–
Carbonate	74	86	78

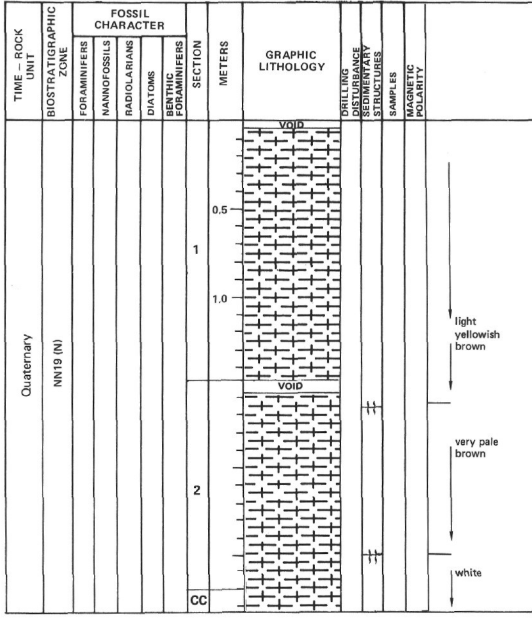
SITE 521 HOLE CORE (HPC) 21 CORED INTERVAL 83.7–84.0 m



LITHOLOGIC DESCRIPTION

MARLY FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/6), disturbed by drilling. Top 11 cm of core contain slurry of ooze and rust.

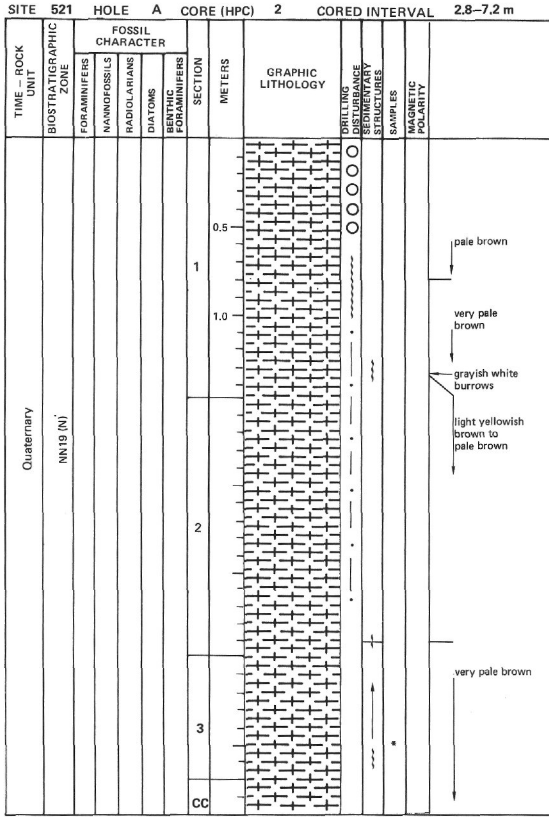
SITE 521 HOLE A CORE (HPC) 1 CORED INTERVAL 0.0–2.8 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, light yellowish brown (10YR 6/4) changing down core to very pale brown (10YR 7/3) then white (10YR 8/2). Color changes are distinct and mixed by burrowing.

SITE 521 HOLE A CORE (HPC) 2 CORED INTERVAL 2.8–7.2 m



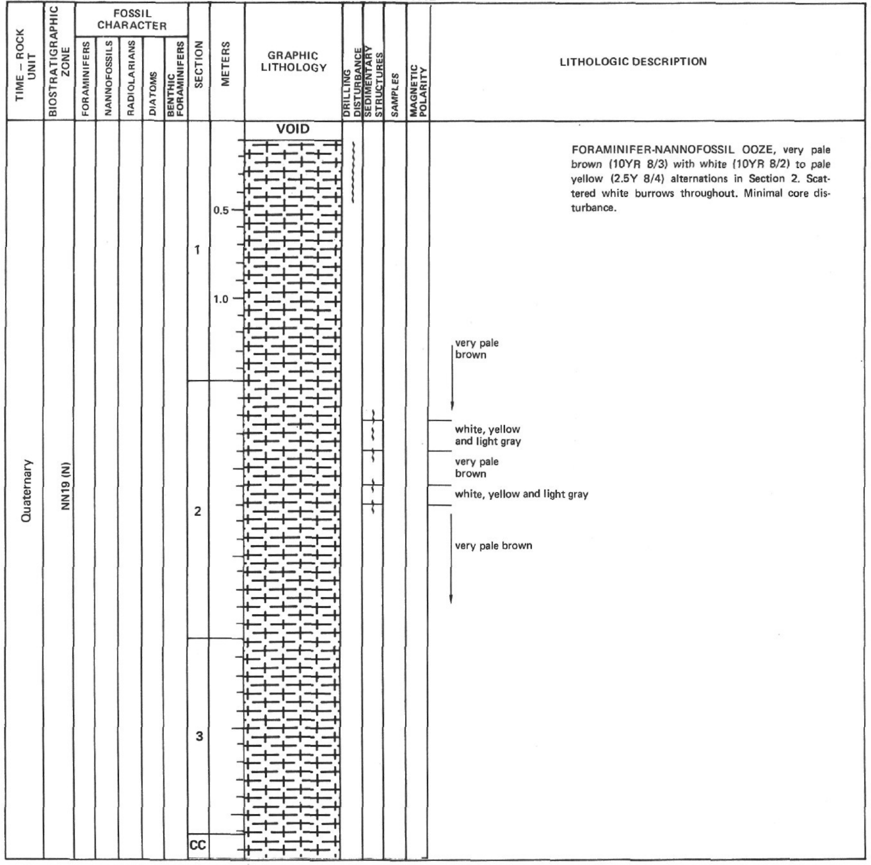
LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, pale brown (10YR 6/3). very pale brown (10YR 8/3) to light yellowish brown (10YR 6/4) as shown; homogeneous except for several burrowed intervals. Core-Catcher contains ooze of several shades of brown.

SMEAR SLIDE SUMMARY

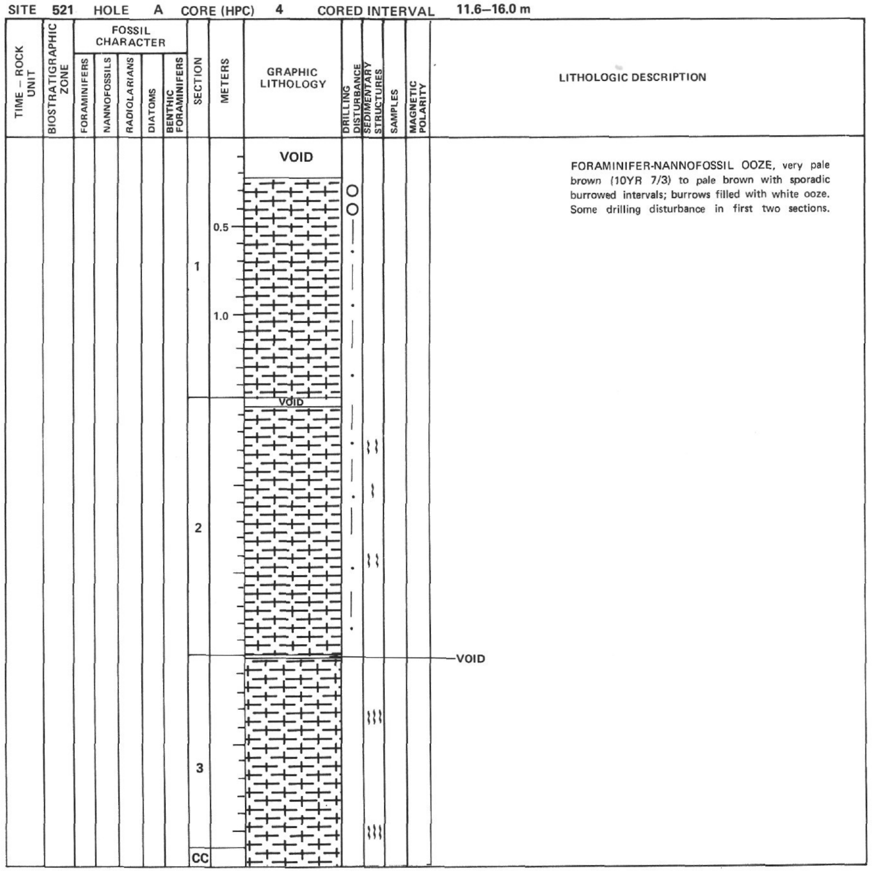
	3-50 **D**
TEXTURE:	
Sand	5
Silt	90
Clay	5
COMPOSITION:	
Quartz	TR
Clay	5
Volcanic glass	TR
Palagonite	TR
Micronodules	TR
Carbonate unspec.	10
Foraminifers	10
Calc. nannofossils	70
Fish remains	TR
Iron-oxides	5

SITE 521 HOLE A CORE (HPC) 3 CORED INTERVAL 7.2–11.6 m



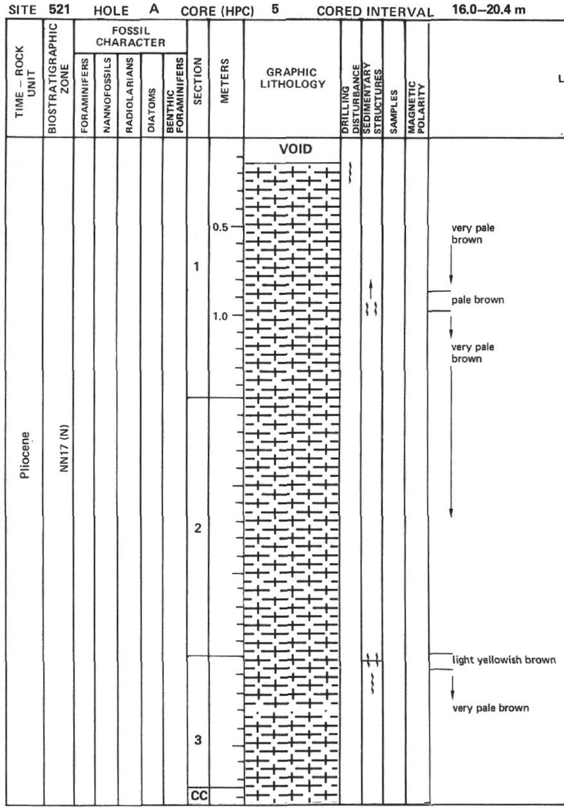
FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3) with white (10YR 8/2) to pale yellow (2.5Y 8/4) alternations in Section 2. Scattered white burrows throughout. Minimal core disturbance.

SITE 521 HOLE A CORE (HPC) 4 CORED INTERVAL 11.6–16.0 m



FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 7/3) to pale brown with sporadic burrowed intervals; burrows filled with white ooze. Some drilling disturbance in first two sections.

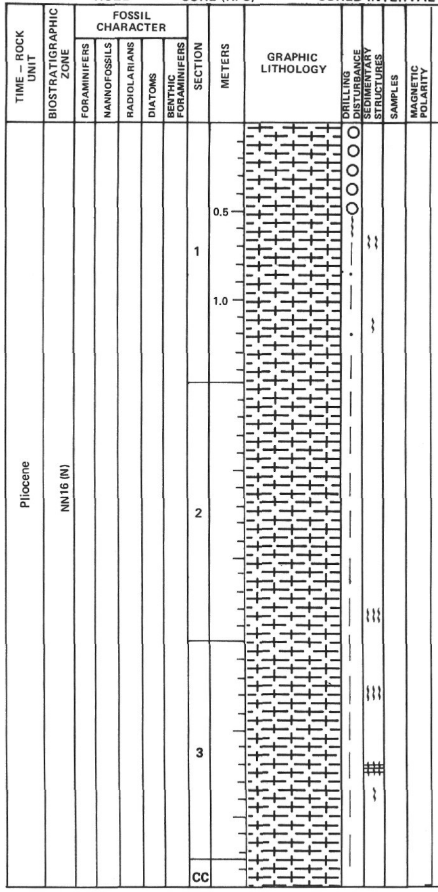
SITE 521 HOLE A CORE (HPC) 5 CORED INTERVAL 16.0–20.4 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, pale brown (10YR 6/3) and very pale brown (10YR 8/3) to light yellowish brown (10YR 6/4), homogeneous except for burrowed intervals in Sections 1 and 3 as shown. Minimal core disturbance.

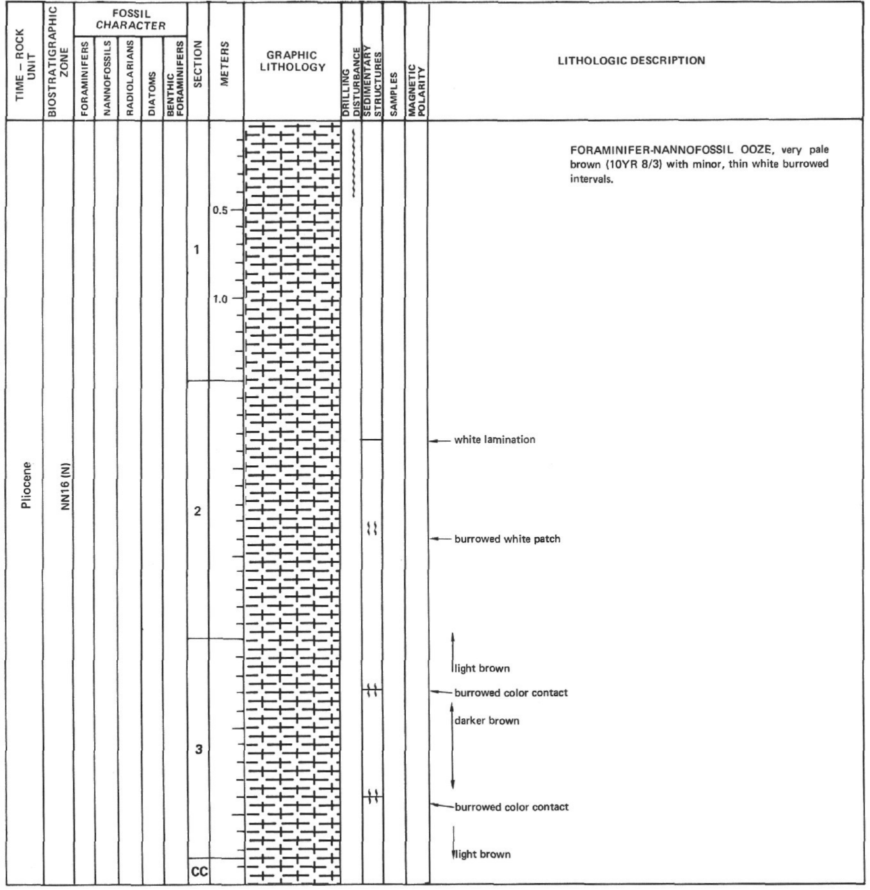
SITE 521 HOLE A CORE (HPC) 6 CORED INTERVAL 20.4–24.8 m



LITHOLOGIC DESCRIPTION

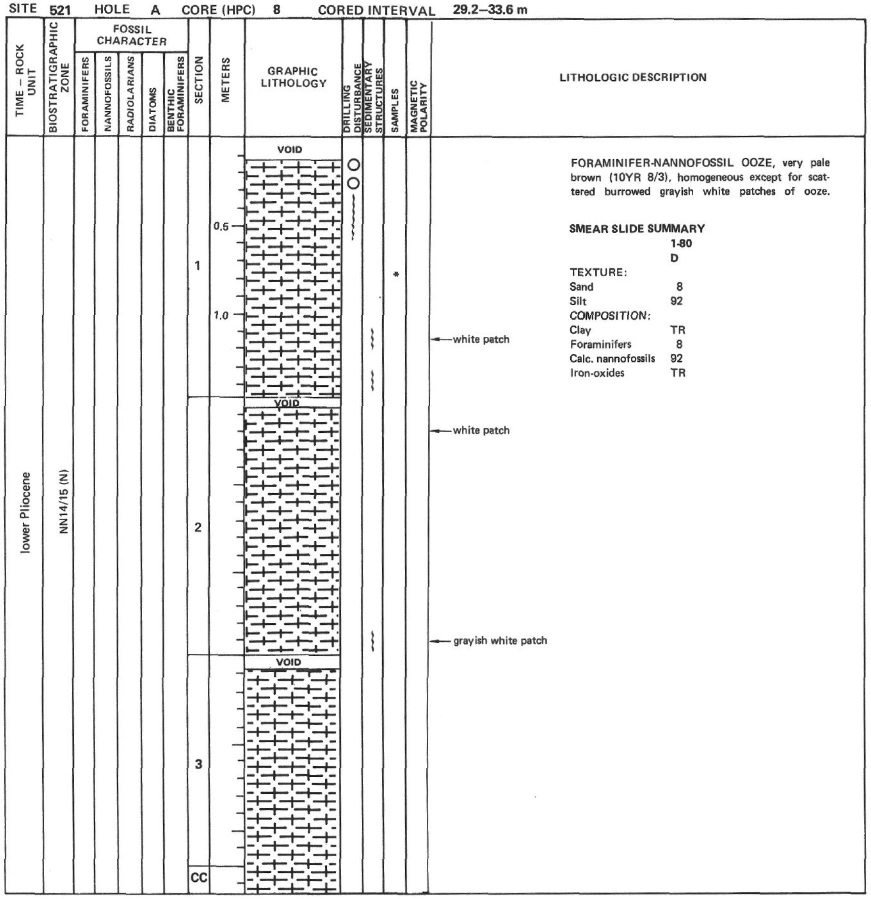
FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 7/3), with burrow mottled thin intervals of white and light gray ooze; these may have been laminated white and gray ooze disrupted by burrowing. Minimal core disturbance except upper 60 cm in Section 1.

SITE 521 HOLE A CORE (HPC) 7 CORED INTERVAL 24.8–29.2 m



FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3) with minor, thin white burrowed intervals.

SITE 521 HOLE A CORE (HPC) 8 CORED INTERVAL 29.2–33.6 m

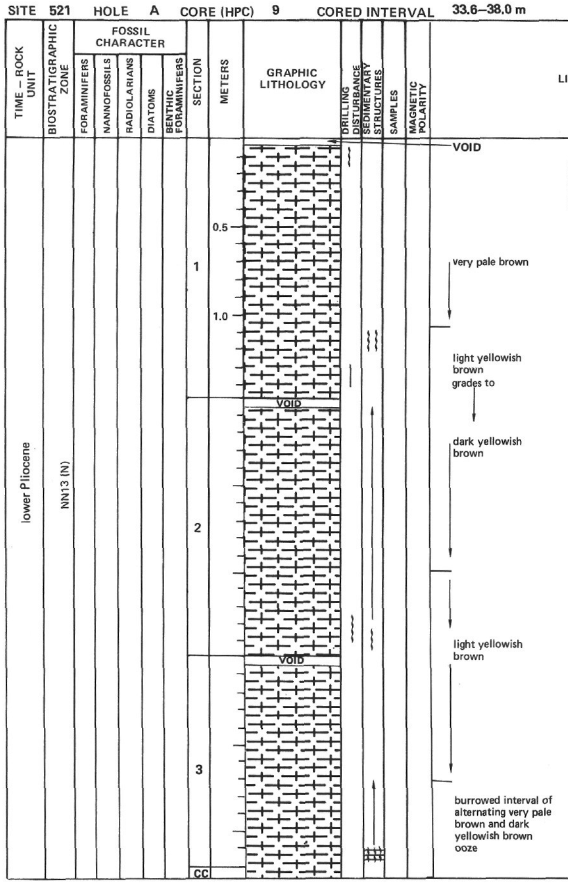


FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 8/3), homogeneous except for scattered burrowed grayish white patches of ooze.

SMEAR SLIDE SUMMARY

	1-80
	D
TEXTURE:	
Sand	8
Silt	92
COMPOSITION:	
Clay	TR
Foraminifers	8
Calc. nannofossils	92
Iron-oxides	TR

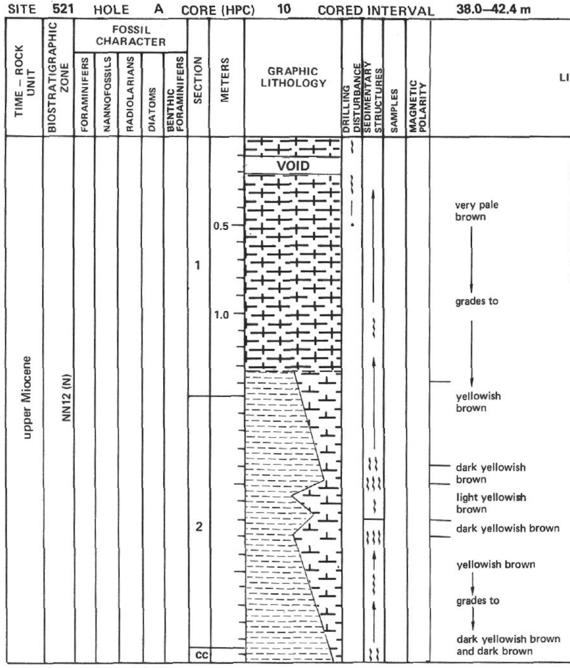
SITE 521 HOLE A CORE (HPC) 9 CORED INTERVAL 33.6–38.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, very pale brown (10YR 7/4) to light yellowish brown (10YR 6/4) and dark yellowish brown. Burrowed throughout with intensely burrowed zone at base Section 3.

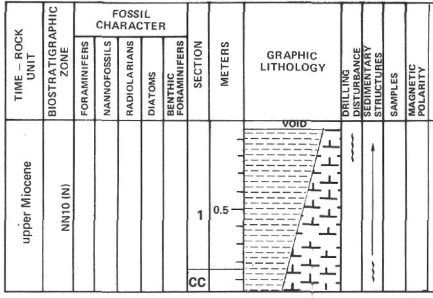
SITE 521 HOLE A CORE (HPC) 10 CORED INTERVAL 38.0–42.4 m



LITHOLOGIC DESCRIPTION

Alternating FORAMINIFER-NANNOFOSSIL OOZE, MARLY NANNOFOSSIL OOZE and NANNOFOSSIL CLAY form sequences of very pale brown (10YR 8/3) ooze grading to yellowish brown (10YR 5/4) dark yellowish brown (10YR 4/4) marly ooze; last sequence grades to dark brown (10YR 3/3) nannofossil clay. Burrows common throughout; most common near upper contact of light ooze with darker marly ooze. Minimal drilling disturbance.

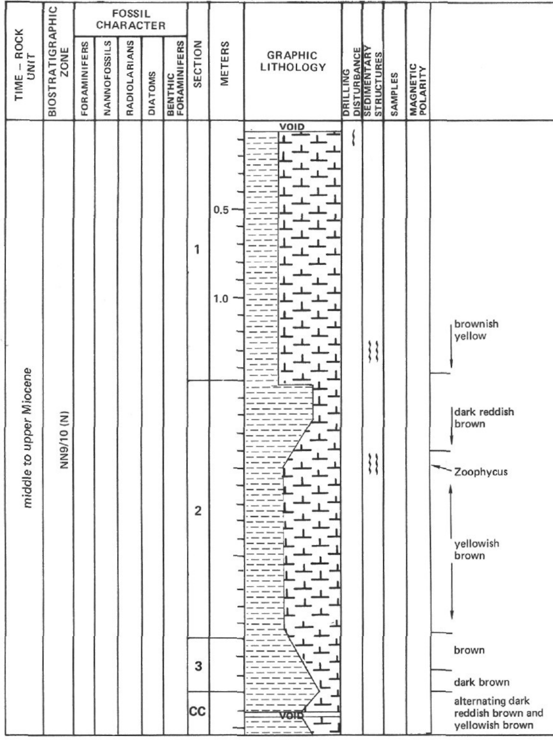
SITE 521 HOLE A CORE (HPC) 11 CORED INTERVAL 42.4–46.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAY, dark reddish brown (10YR 3/3) grading down core to dark yellowish brown MARLY NANNOFOSSIL OOZE. Burrowed throughout with one large vertical Zoophycus burrow at 64 cm. Top 23 cm of core contain drilling debris.

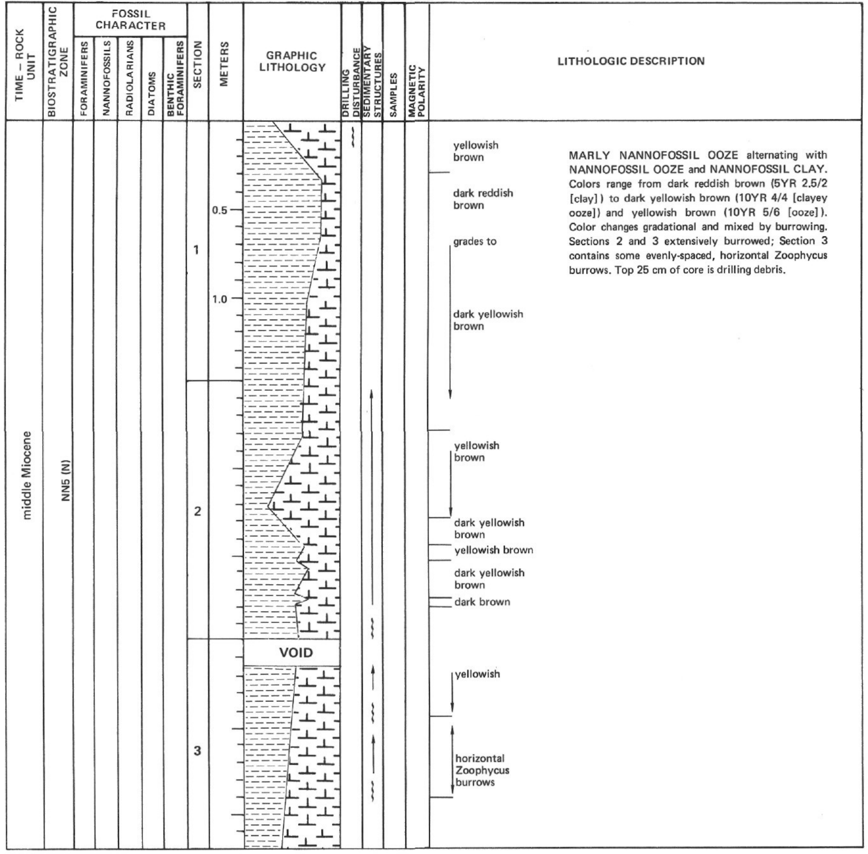
SITE 521 HOLE A CORE (HPC) 12 CORED INTERVAL 46.8–50.3 m



LITHOLOGIC DESCRIPTION

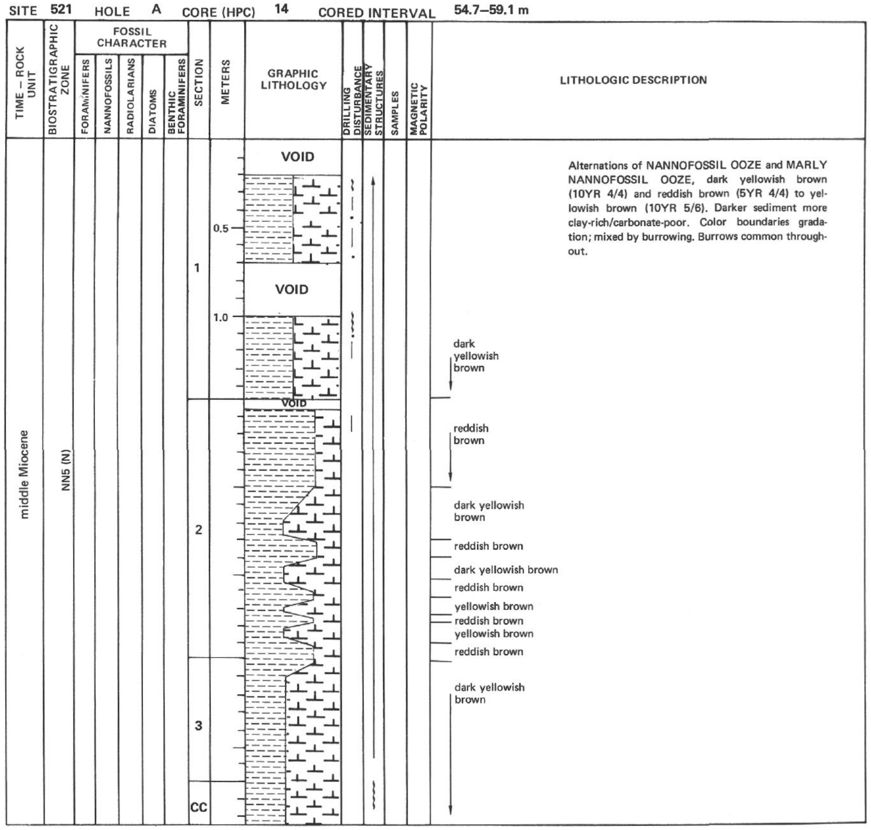
Alternating brownish yellow (10YR 6/6) and yellowish brown (10YR 5/6) MARLY NANNOFOSSIL OOZE and brown (7.5YR 4/4) to dark reddish brown (5YR 3/3) NANNOFOSSIL CLAY. Contacts between two lithologies are gradational over several cm to tens of cm. Burrows common and best seen in color transitions (light to dark). Several large horizontal Zoophycus burrows in Section 2. Mimimal core disturbance.

SITE 521 HOLE A CORE (HPC) 13 CORED INTERVAL 50.3–54.7 m



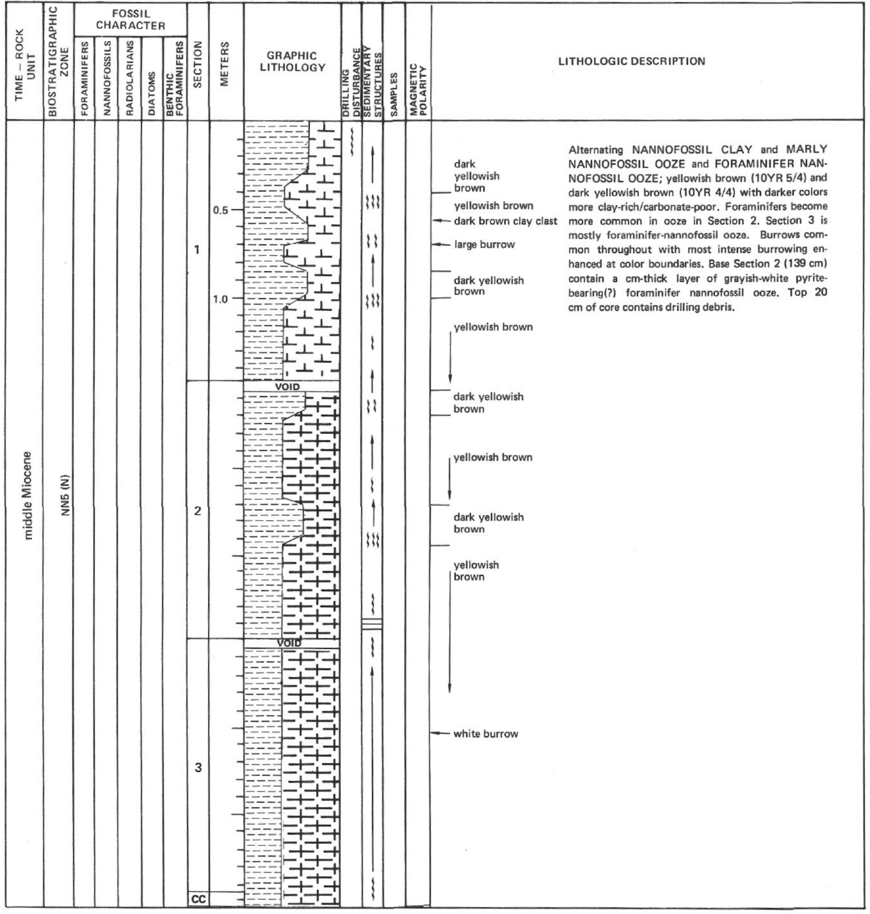
MARLY NANNOFOSSIL OOZE alternating with NANNOFOSSIL OOZE and NANNOFOSSIL CLAY. Colors range from dark reddish brown (5YR 2.5/2 [clay]) to dark yellowish brown (10YR 4/4 [clayey ooze]) and yellowish brown (10YR 5/6 [ooze]). Color changes gradational and mixed by burrowing. Sections 2 and 3 extensively burrowed; Section 3 contains some evenly-spaced, horizontal Zoophycus burrows. Top 25 cm of core is drilling debris.

SITE 521 HOLE A CORE (HPC) 14 CORED INTERVAL 54.7–59.1 m



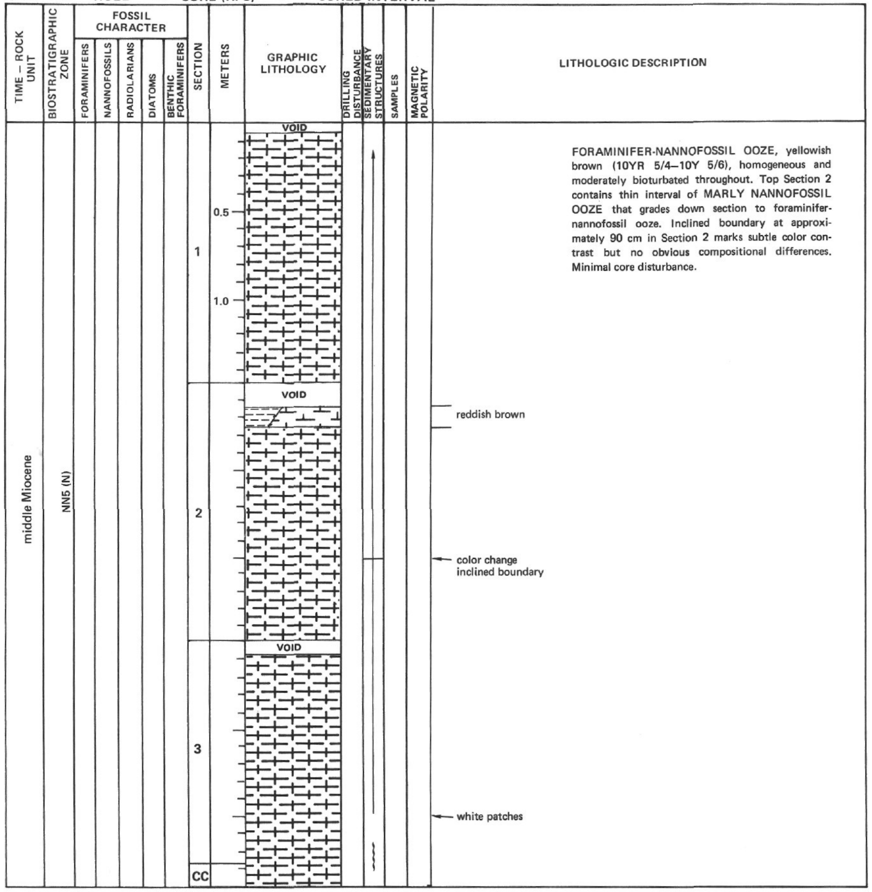
Alternations of NANNOFOSSIL OOZE and MARLY NANNOFOSSIL OOZE, dark yellowish brown (10YR 4/4) and reddish brown (5YR 4/4) to yellowish brown (10YR 5/6). Darker sediment more clay-rich/carbonate-poor. Color boundaries gradation; mixed by burrowing. Burrows common throughout.

SITE 521 HOLE A CORE (HPC) 15 CORED INTERVAL 59.1–63.5 m



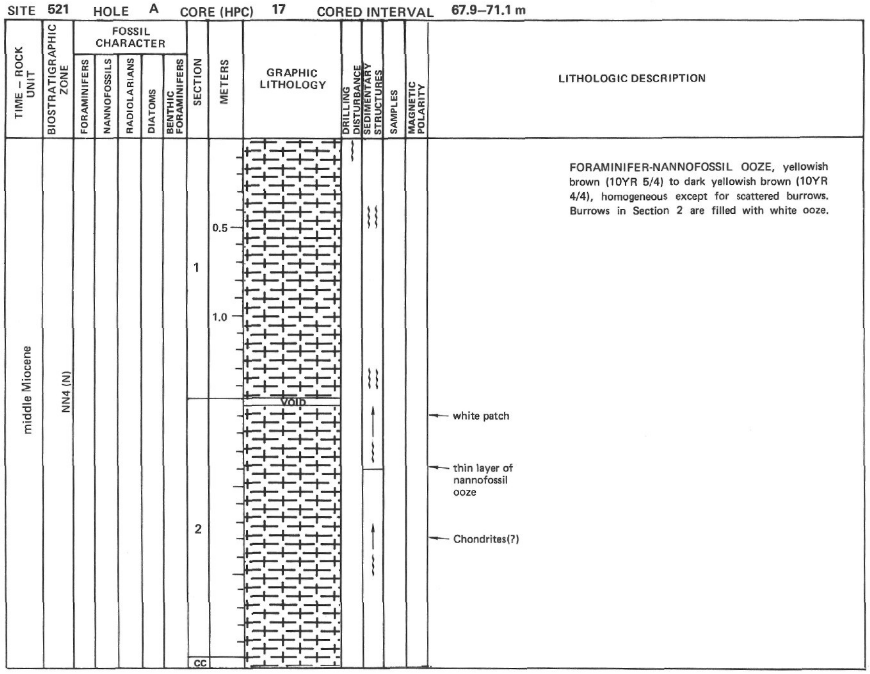
Alternating NANNOFOSSIL CLAY and MARLY NANNOFOSSIL OOZE and FORAMINIFER NANNOFOSSIL OOZE; yellowish brown (10YR 5/4) and dark yellowish brown (10YR 4/4) with darker colors more clay-rich/carbonate-poor. Foraminifers become more common in ooze in Section 2. Section 3 is mostly foraminifer-nannofossil ooze. Burrows common throughout with most intense burrowing enhanced at color boundaries. Base Section 2 (139 cm) contain a cm-thick layer of grayish-white pyrite-bearing(?) foraminifer nannofossil ooze. Top 20 cm of core contains drilling debris.

SITE 521 HOLE A CORE (HPC) 16 CORED INTERVAL 63.5–67.9 m

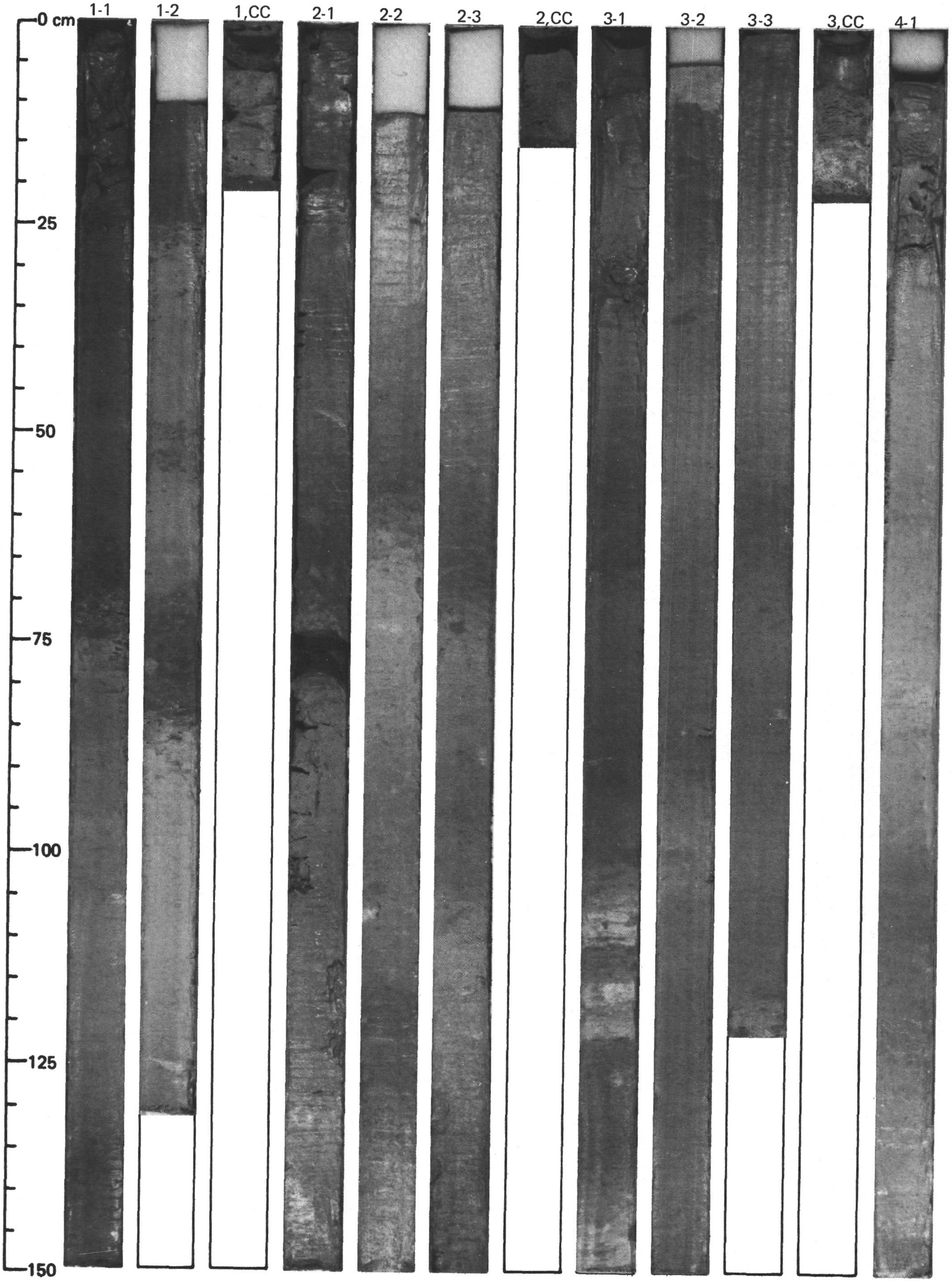


FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/4–10Y 5/6), homogeneous and moderately bioturbated throughout. Top Section 2 contains thin interval of MARLY NANNOFOSSIL OOZE that grades down section to foraminifer-nannofossil ooze. Inclined boundary at approximately 90 cm in Section 2 marks subtle color contrast but no obvious compositional differences. Minimal core disturbance.

SITE 521 HOLE A CORE (HPC) 17 CORED INTERVAL 67.9–71.1 m



FORAMINIFER-NANNOFOSSIL OOZE, yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/4), homogeneous except for scattered burrows. Burrows in Section 2 are filled with white ooze.


0 cm
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125
150
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1-2
1,CC
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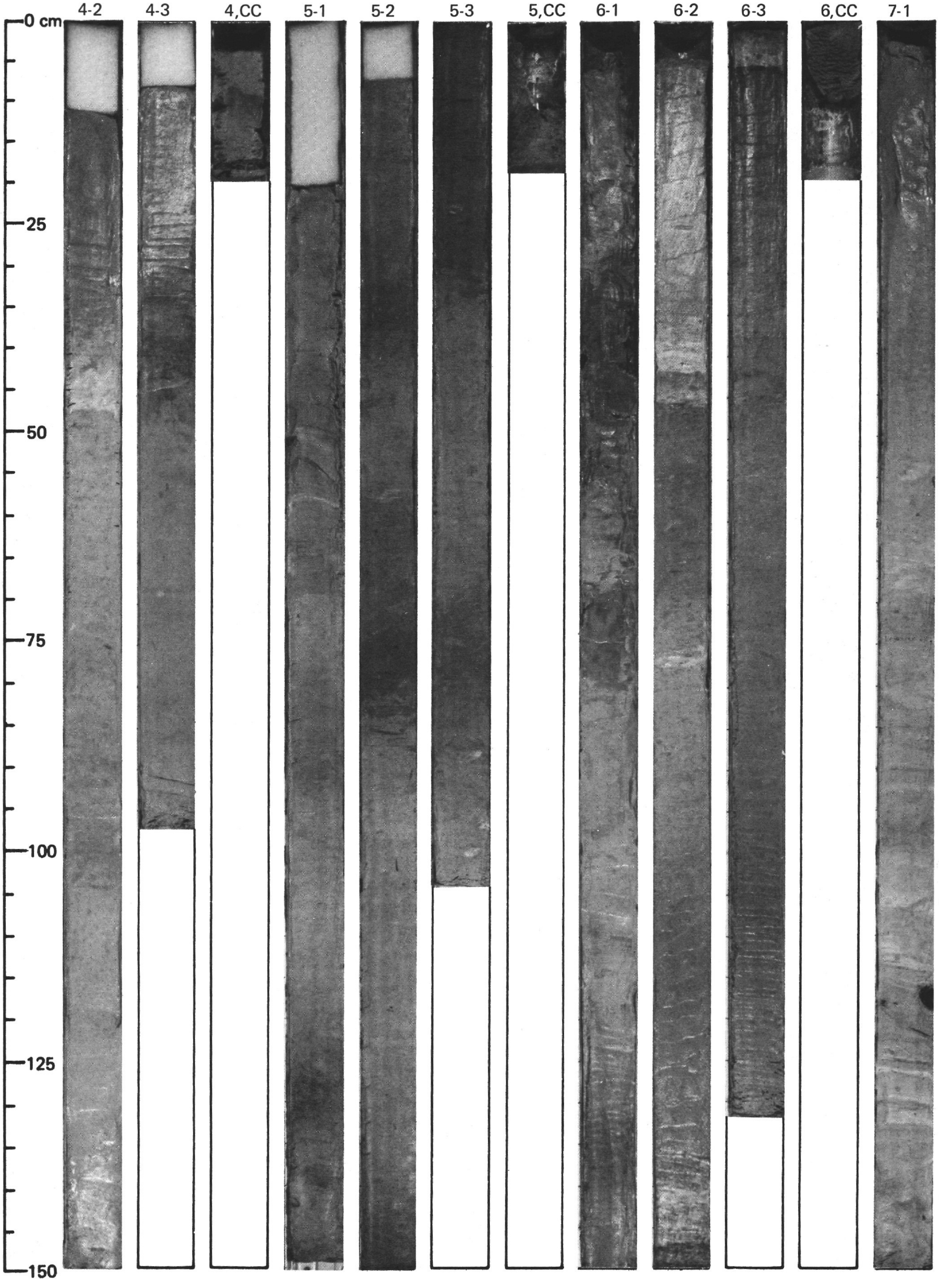
2-2
2-3
2,CC
3-1
3-2
3-3
3,CC
4-1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4-3
4,CC
5-1
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5-3
5,CC
6-1
6-2
6-3
6,CC
7-1
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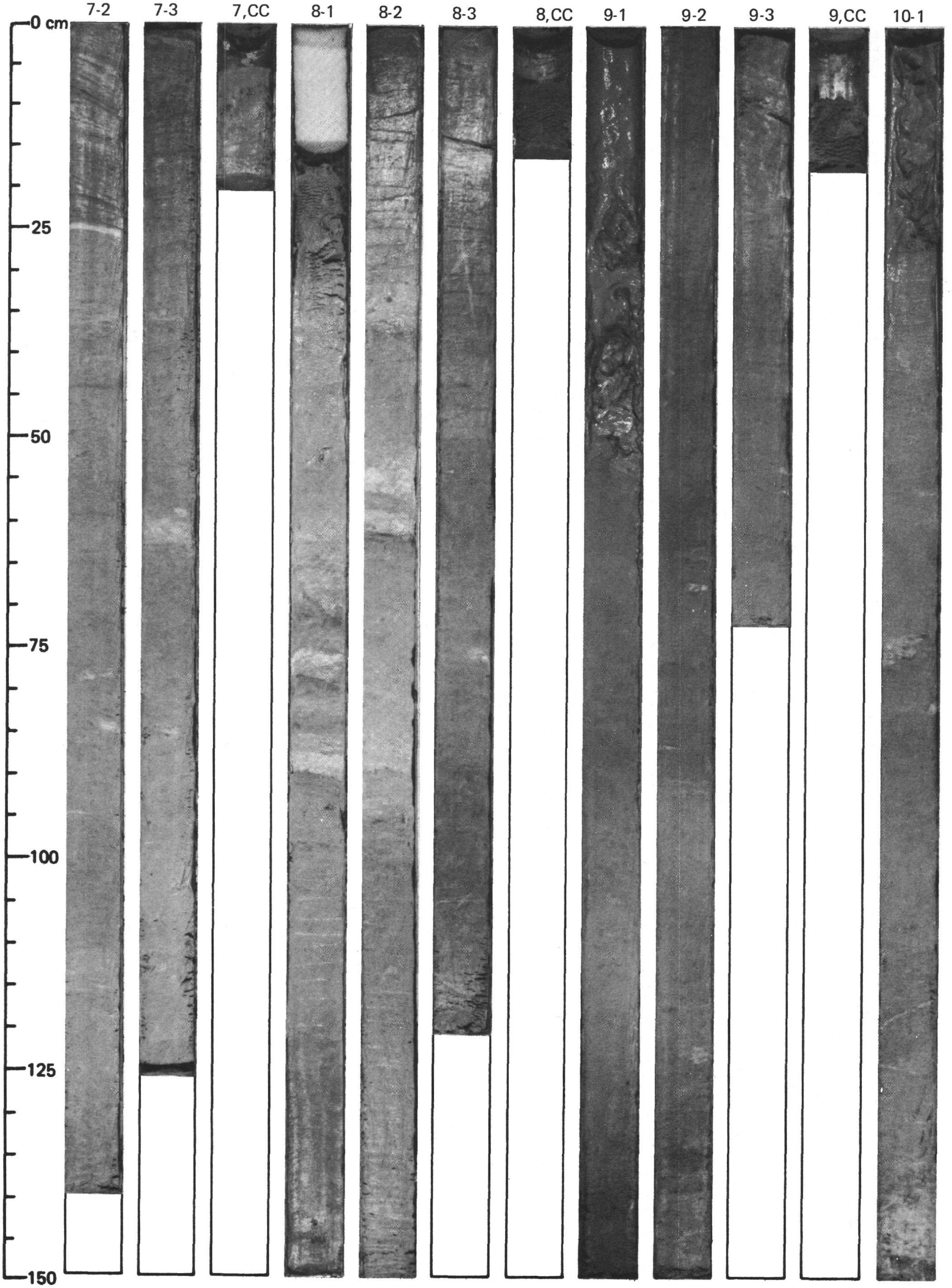
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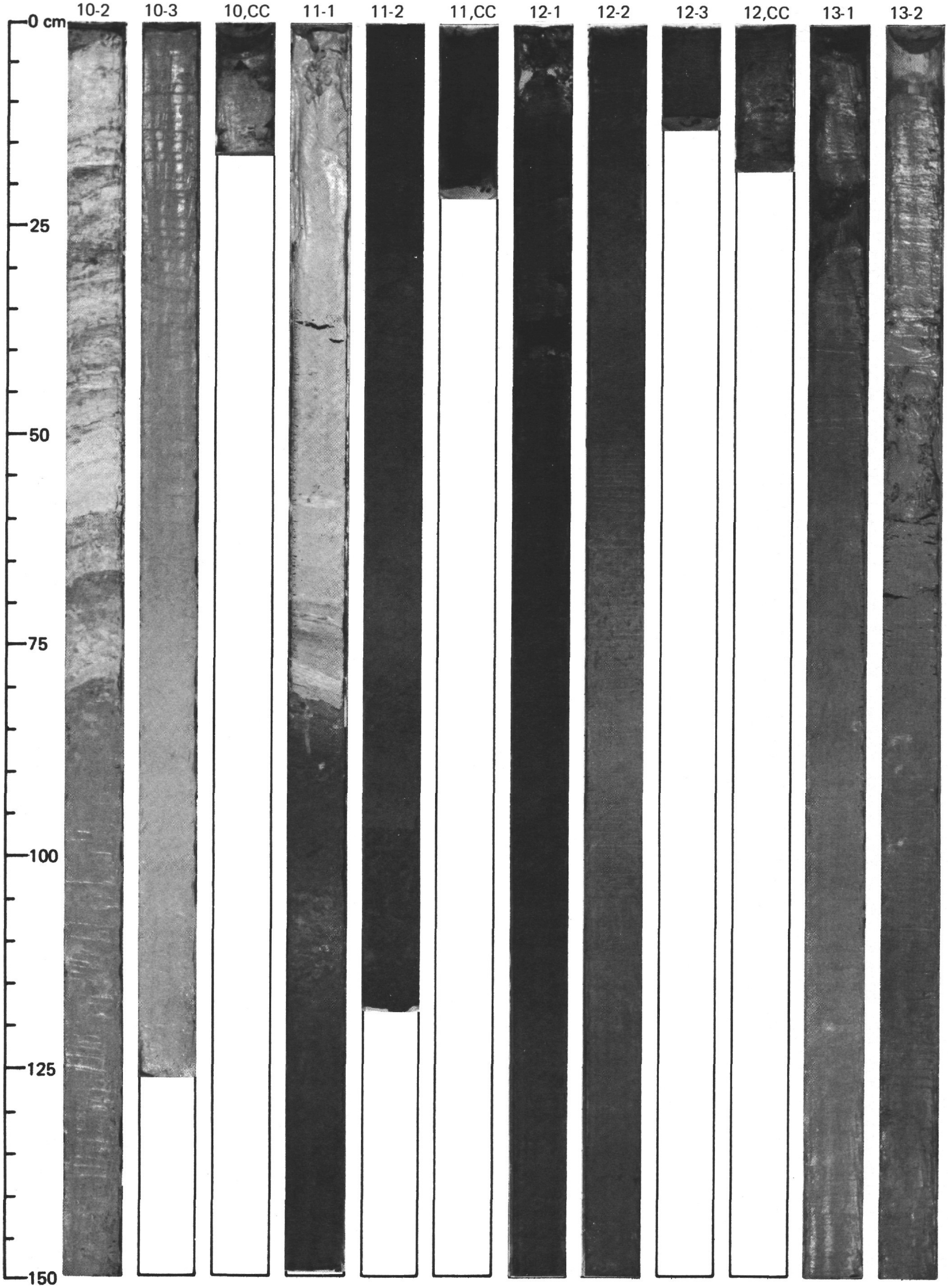
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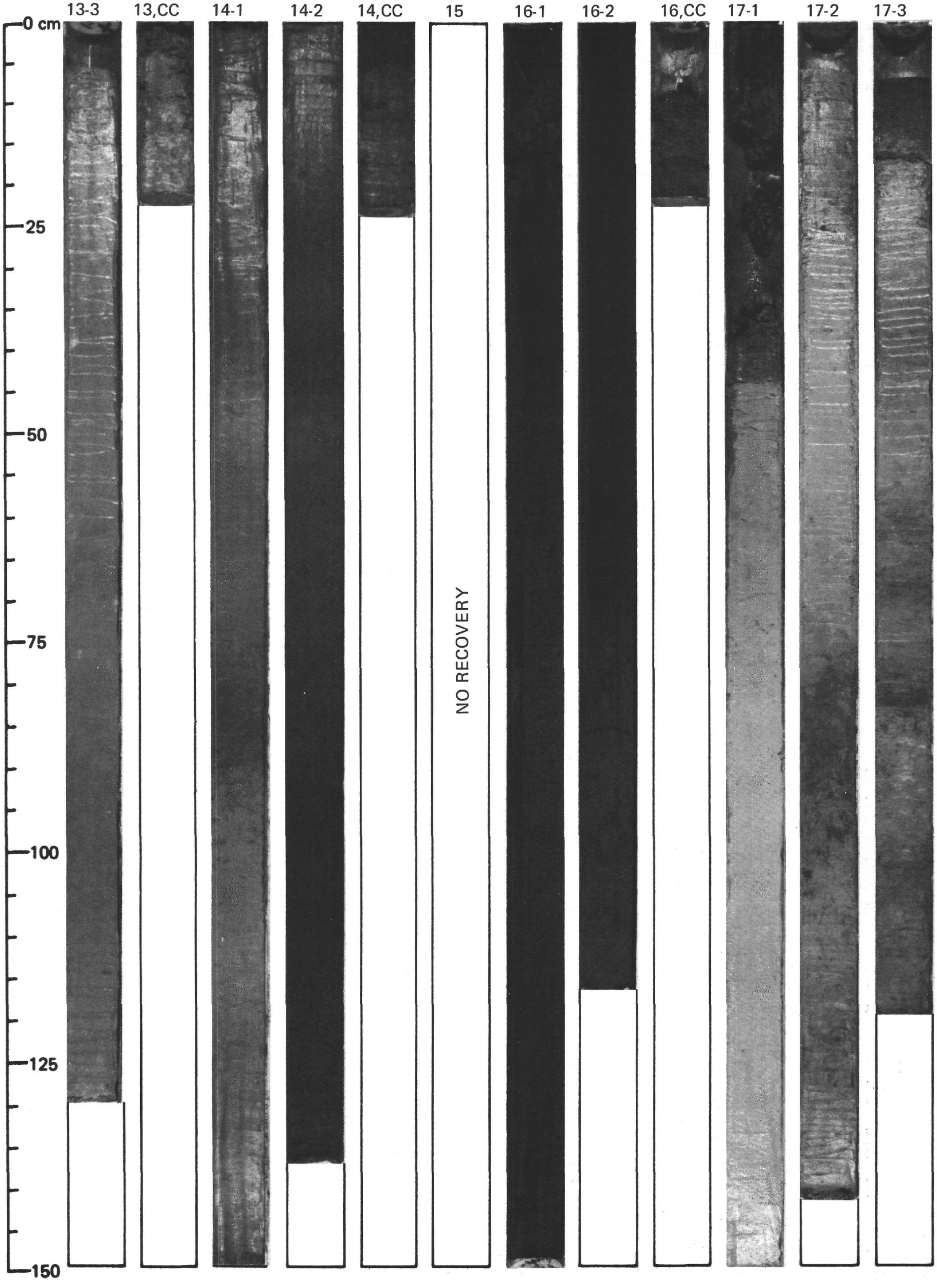
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17-1
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17-3
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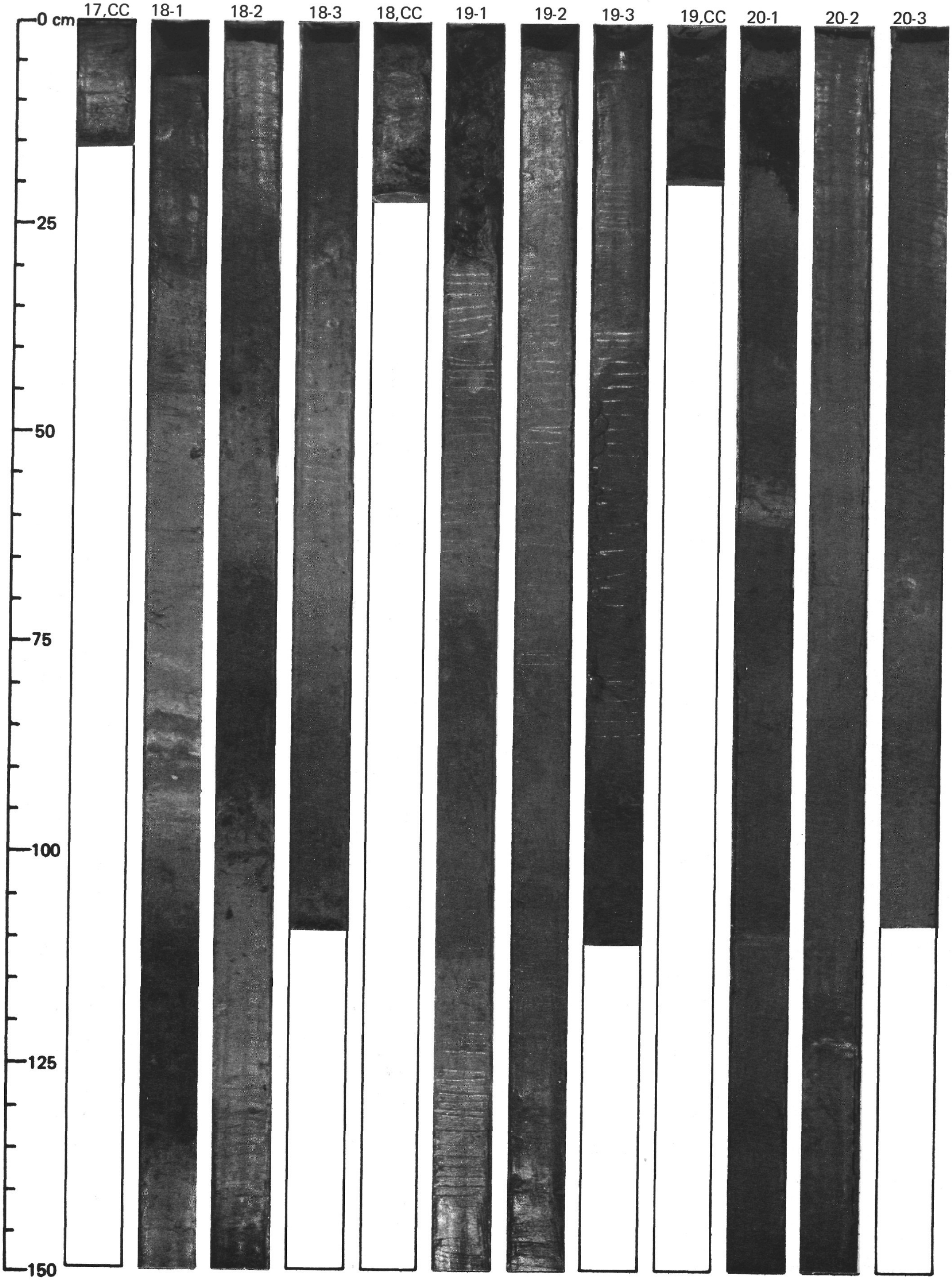
NO RECOVERY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19-3
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20-1
20-2
20-3
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125
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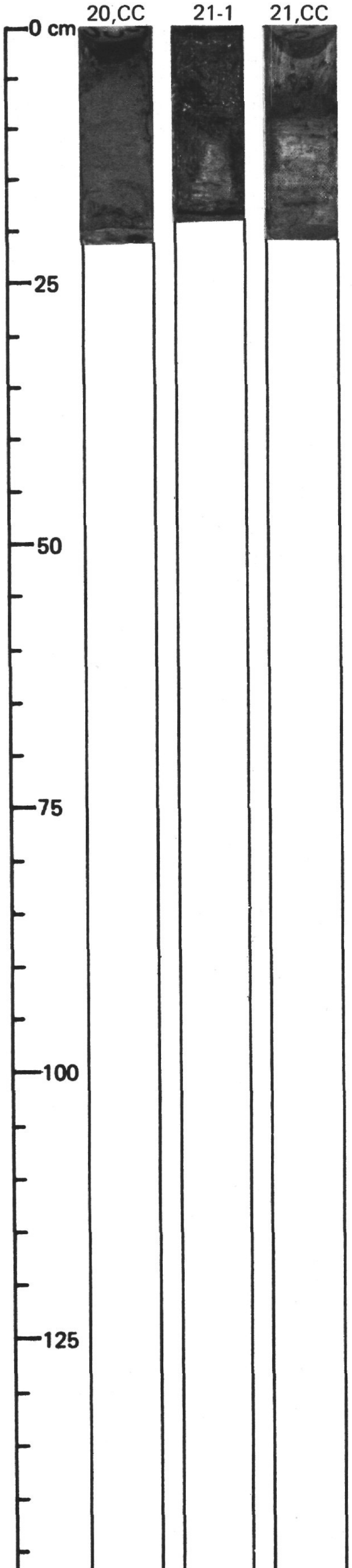

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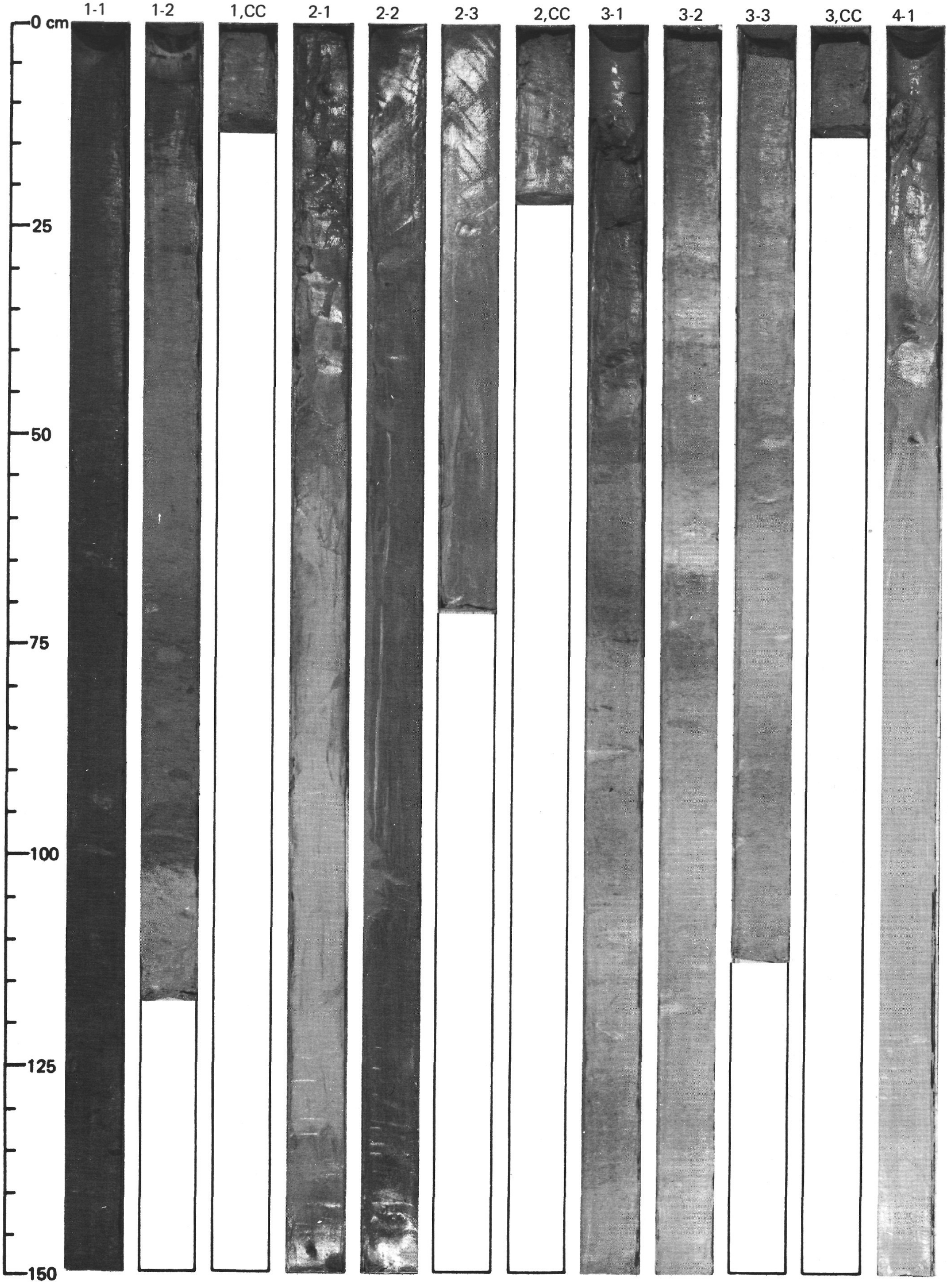
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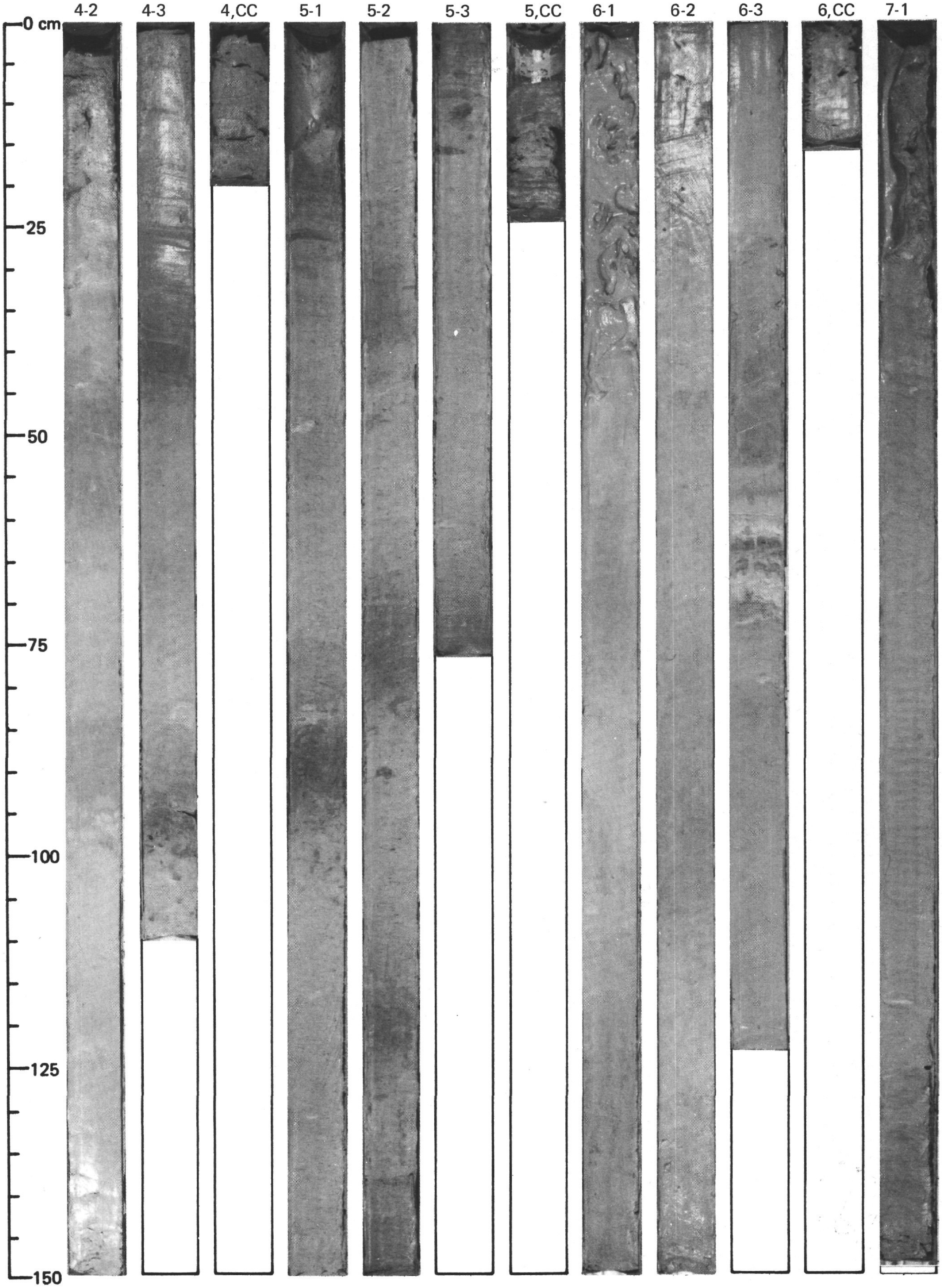
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7-1
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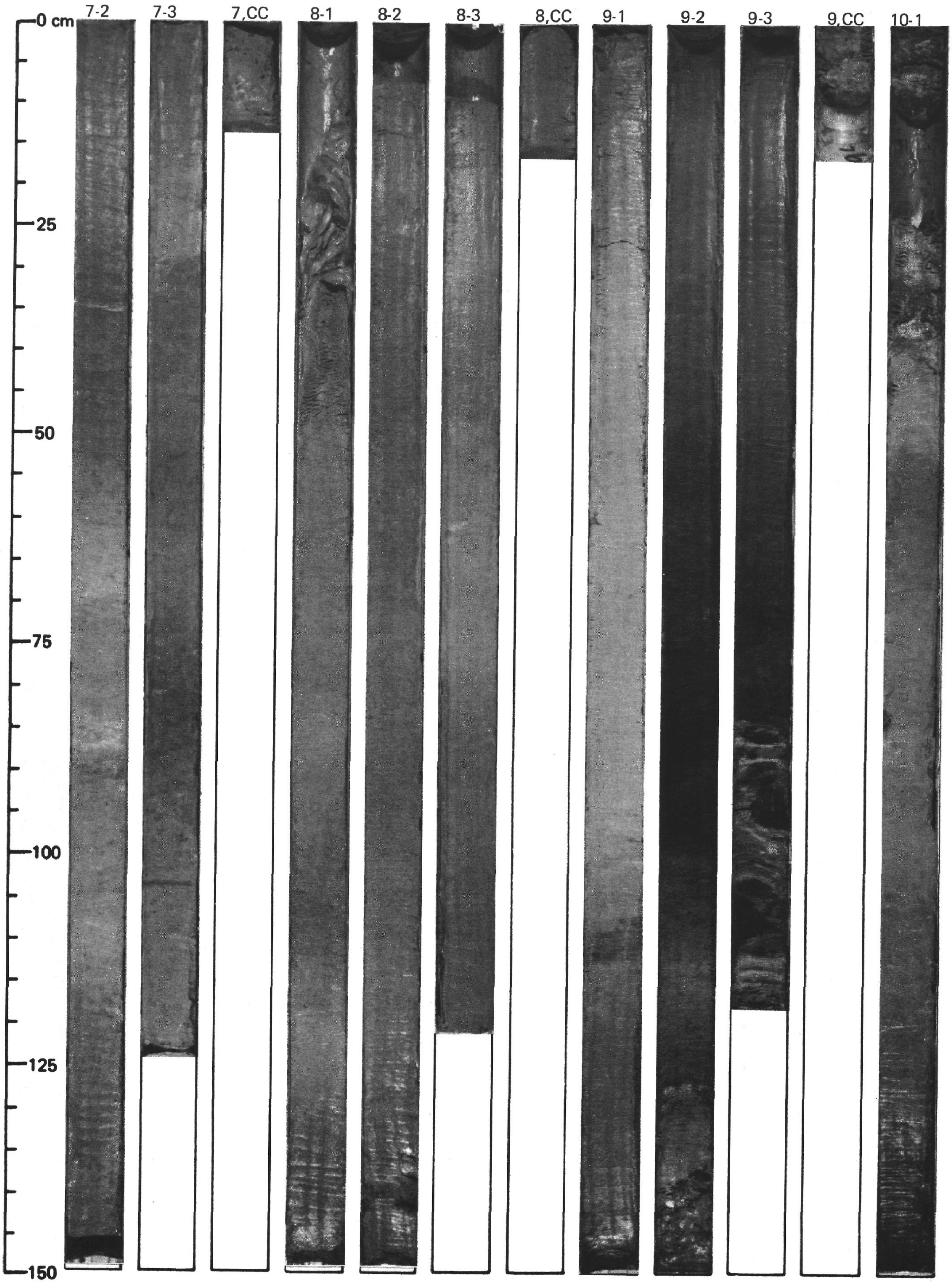
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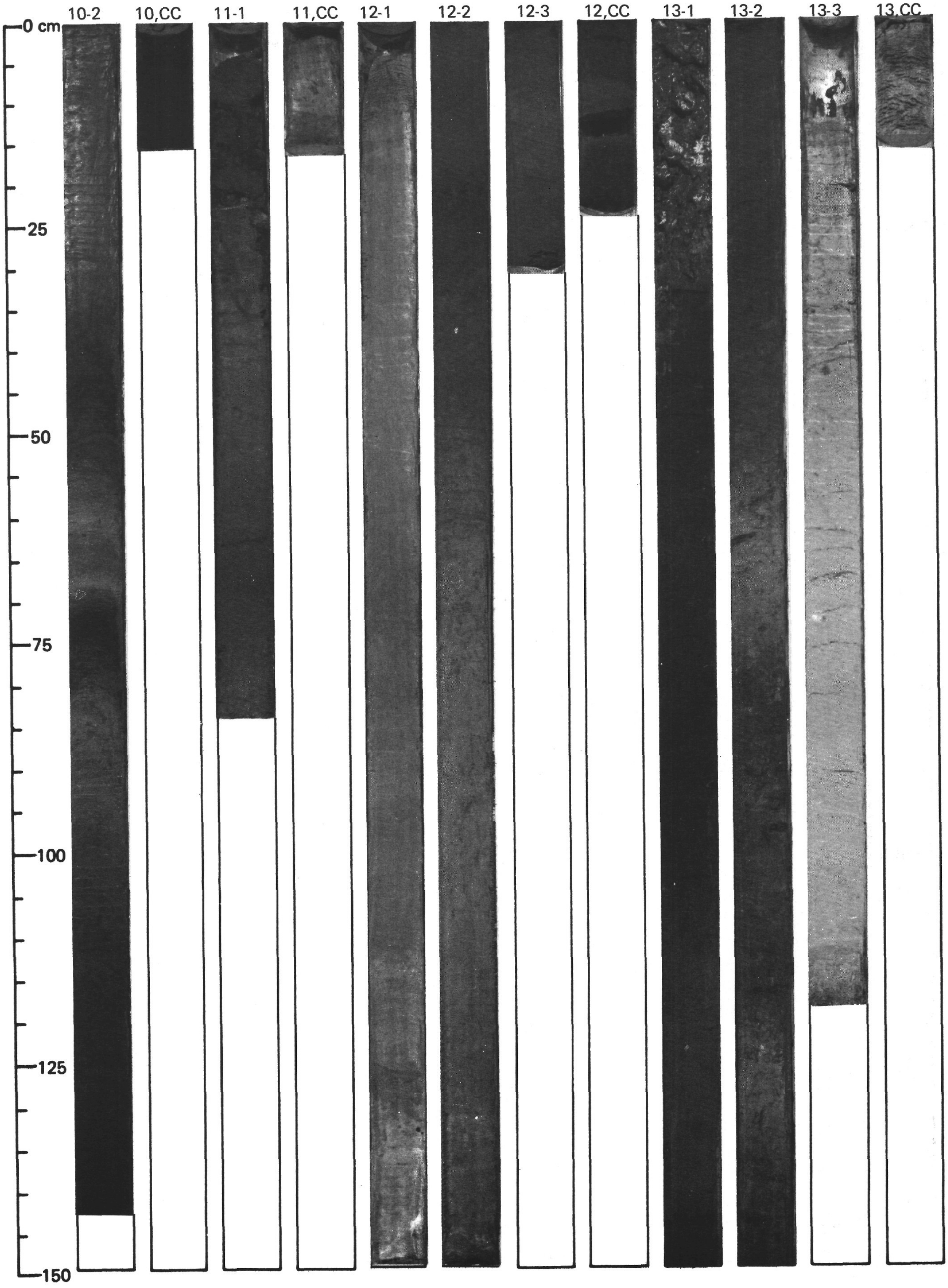
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11,CC
12-1
12-2
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13-2
13-3
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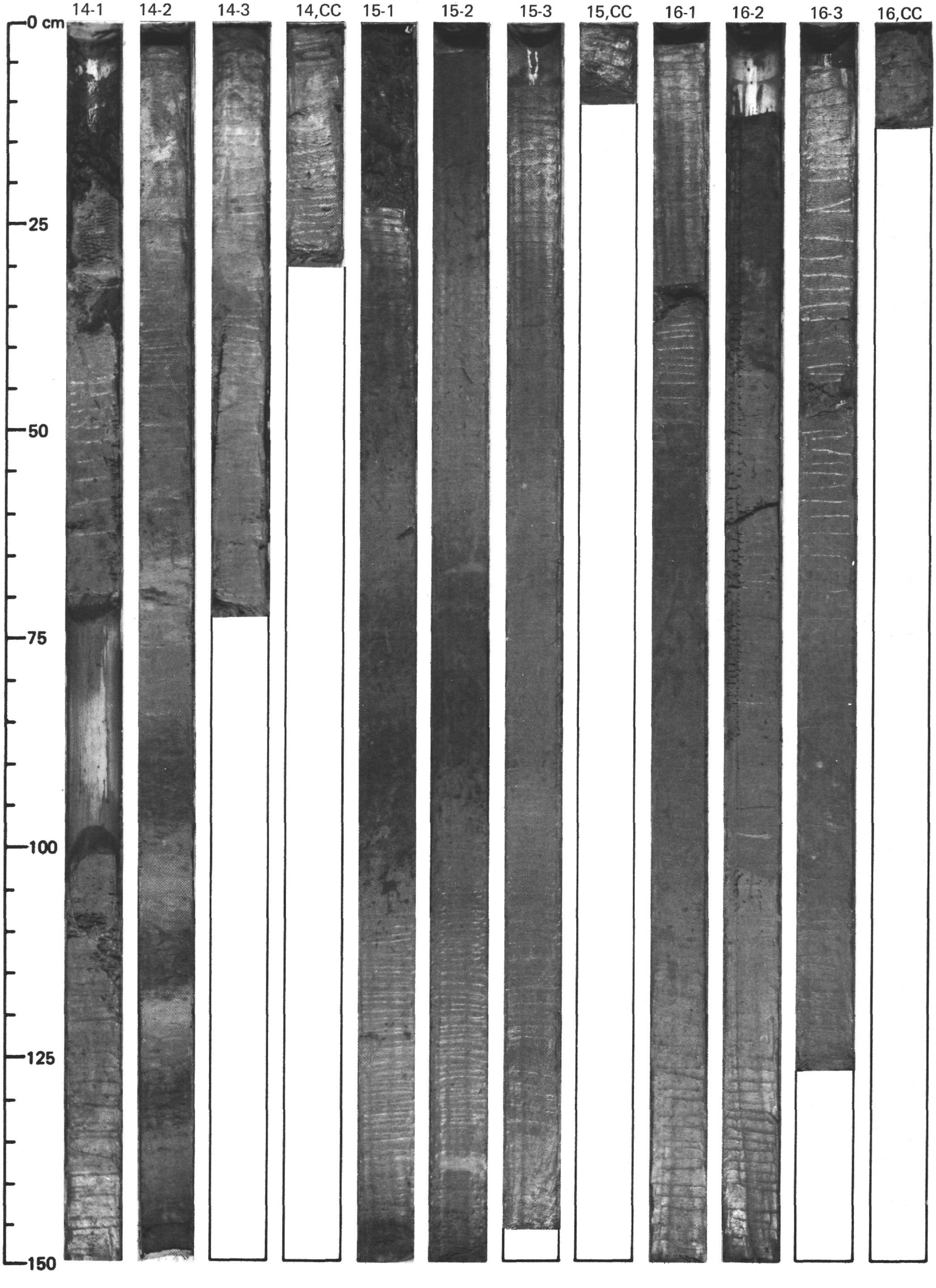
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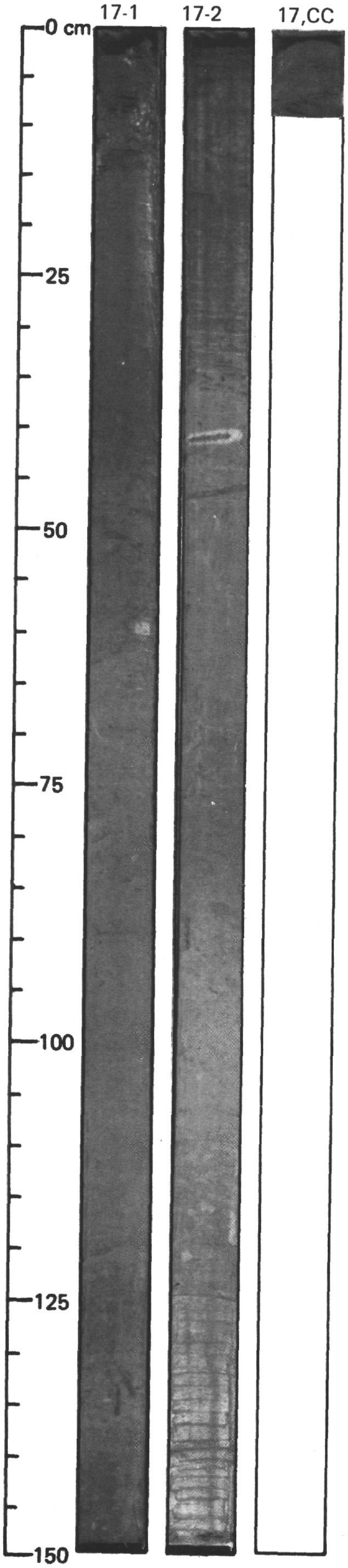
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150
17-1
17-2
17,CC