3. SITE 520[1]

Shipboard Scientific Party[2]

HOLE 520

Date occupied: 0014, 28 April 1980

Date departed: 0955, 1 May 1980

Time on hole: 82 hr.

Position: 25°31.40′S; 11°11.14′W

Water depth (sea level; corrected m; echo-sounding): 4207.0

Water depth (rig floor; corrected m; echo-sounding): 4217.0

Bottom felt (m, drill pipe): 4217.0

Penetration (m): 458.5

Number of cores: 31

Total length of cored section (m): 246.5

Total core recovery (m): 69.4

Core recovery (%): 28.1

Oldest sediment cored:
Depth sub-bottom (m): 449
Nature: Nannofossil ooze
Age: middle Miocene (Langhian)
Measured velocity (km/s): 1.56

Basement:
Depth sub-bottom (m): 449
Nature: Basalt
Velocity range (km/s): 5.70–5.91 (one anisotropic sample)

Principal results: See discussion following Hole 520A data.

HOLE 520A

Date occupied: 0955, 1 May 1980

Date departed: 2054, 1 May 1980

Time on hole: 23 hr.

Position: 25°31.40′S; 11°11.14′W

Water depth (sea level; corrected m; echo-sounding): 4207.0

Water depth (rig floor; corrected m; echo-sounding): 4217.0

Bottom felt (m, drill pipe): 4217.0

Penetration (m): 18.5

Number of cores: 1

Total length of cored section (m): 2.4

Total core recovery (m): 2.4

Core recovery (%): 100

Oldest sediment cored:
Depth sub-bottom (m): 18.5
Nature: Nannofossil ooze
Age: Quaternary
Measured velocity (km/s): 1.56

Basement:
Depth sub-bottom (m): Not reached
Nature: Basalt
Velocity range (km/s): 5.70–5.91 (one anisotropic sample)

Principal results: Holes 520, 520A—

1. Confirmation of linear spreading rate during the middle Miocene in the South Atlantic.
2. Calibration of the age of Magnetic Anomaly 5B.
3. Reconnaissance exploration of the sedimentary and paleoceanography histories of a silled basin on the flank of the Mid-Atlantic Ridge.
4. Discovery of a thick upper Miocene diatomite sequence, with diatoms selectively preserved in a stagnant basin environment.
5. Use of diatom occurrences as a tracer for the flow path of the Benguela Current during the late Neogene.
6. Acquiring data for reconstructing the calcite dissolution history of the South Atlantic; confirmation of very high calcite compensation depth (CCD) (above 3600 m) during the middle Miocene (12 to 14 m.y.).
7. Establishment of a facies model for resedimentation by slumping: a slump block at the base is overlain (successively) by a partially dispersed slump block with intricate folds, mud-pebble ooze, and homogenized ooze, and in places it is topped by a graded bed of foraminifer sand or mud.

BACKGROUND AND OBJECTIVES

Site 520 was the second of three sites drilled to study the Miocene of the South Atlantic. The site is on the younger transition boundary of Magnetic Anomaly 5B. An estimated age of earliest Serravalian or 14.5 m.y. was assigned to the basement on the basis of the magnetic anomaly identification.

The objective of drilling the site was to recover as complete a section of the upper and middle Miocene sediments as possible in the central depression of a ridge-flank basin for biostratigraphical, paleoceanographical, and paleoclimatological analyses. The rather precise location of Site 520 with respect to magnetic anomalies would also permit an evaluation of magnetostratigraphic–biostratigraphic correlations.

The analysis of data from Site 519 suggested that a significant portion of the upper Miocene section was missing. Slumping and dissolution are two possible

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

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mechanisms that result in this type of unconformity. In order to eliminate a third, the depositional hiatus commonly present at the edge of a basin, we chose a location for Site 520 that was near the axis of a deep narrow basin that should have acted as a sediment trap since the basin's generation near the spreading axis. It was unavoidable that sedimentation in such a setting would include thick layers of slump and turbidite deposits, especially those of Quaternary and Pliocene age. The deposits would give confusing paleomagnetic and biostratigraphical signals, yield many samples unsuitable for paleoceanographical analysis, and result in poor core recovery. On the other hand, this would be the only site in a three-hole Miocene transect that would be drilled in a setting where we might sample a basinal facies of local depressions on the Mid-Atlantic Ridge at this latitude. We could also be certain that we could obtain a relatively complete stratigraphic section, including the older sediments. We particularly wanted to sample the Serravalian sediments at this particular location. The sediments would have been deposited in a basin on a newly created ridge, and they should have a paleodepth of about 2500 m; thus, they might have been laid down above the relatively high calcite compensation depth (CCD) that prevailed during the middle Miocene. If calcareous fossils in these sediments were preserved or partially preserved they could yield critical biostratigraphical, paleoecological, and paleontological information not obtainable from previously drilled DSDP sites. Further, the biostratigraphic analysis of dissolution, if interpreted within the framework of changing paleodepths, might yield information on rate of rise and fall of lysoclines.

A special objective was to investigate the paleoceanographic significance of the Pliocene diatom *Ethmodiscus rex*, layers of which were first discovered at Site 17 (Leg 3) again at Site 519. Sampling in this transect of holes might provide information on the gradients of surface currents and the possible geographical shift of the location of the South Atlantic gyres.

It was further recognized that the Leg 3 holes of the South Atlantic Mid-Atlantic Ridge transect were all drilled on topographic elevation or on edges of basins where sediment thickness is considerably less than maximal. Sampling of basinal sediments permits us to reconstruct the history of sedimentation here and deduct a model of sedimentary infill of elongate valleys in the rough basement province of a slowly spreading ridge.

Secondary objectives were to obtain Fe-Mn–rich sediment above basement, if present, and to obtain basalt samples to study the geographical variation of basalt geochemistry.

The primary goal of drilling here was thus to reach the older draped sediments. We did not plan to use the hydraulic piston corer (HPC) to drill the ponded facies of Quaternary and Pliocene age, which were obtained with the HPC at nearby Site 519, unless we should discover that those cores would be more valuable than those obtainable from other holes. The preliminary site surveys and the *Challenger* survey before final positioning revealed that the basement depth here might range from 300 to 400 m, but this interpretation was uncertain because of side echoes from basement highs buried nearby. Our tactic was to rotary core at 50-m intervals to a level above the Pliocene/Miocene boundary or to a level where sediment compaction was becoming too great for the HPC. We planned to core the underlying section continuously to the basement. After sampling the basement we would return to the mudline and use the HPC to drill missing sections, time permitting. We were warned that washing to the desired sequences with the bitless HPC assembly would be difficult if not impossible, but we planned nevertheless to try a conversion from rotary coring to HPC without tripping the drill string.

OPERATIONS

Site Approach

The *Glomar Challenger* approached Site 520 and started a predrilling survey on 27 April. The survey started at 2012Z, when speed was changed to 160/160 and heading to 30°. The course was corrected after 2104Z to 40°. At 2146Z the vessel passed over the site and the beacon was dropped. A short site survey was conducted (Fig. 1) before the vessel homed on beacon at 2253Z. It was decided that the site chosen was adequate. The course was changed to 270°, and at 2302Z the marine technicians started to pull in the gear. The gear was in at 2318Z, and the vessel was headed back to the beacon, arriving on site at 0014Z 28 April.

Hole 520 Coring Operations

The drilling crew started making up the bottom hole assembly (BHA) for rotary coring at 0035Z 28 April. Hole 520 was spudded in at 1045Z at a water depth of 4217 m. It was decided to take a mudline core. Core 1 was hauled up at 1147Z; it was empty except for a smear of pale brown ooze containing Quaternary nannofossils. The drill bit hit a hard layer at about 20 m sub-bottom; it took some 5 min. to penetrate this layer. Afterward the drill string was washed down easily, and Core 2 was cut at 56.5 m sub-bottom (Table 1). After the core was on deck, it proved to be impossible to pull the plastic liner out of the barrel without breaking it. The broken liner contained only traces of white ooze. Many hours later the rest of the broken liner of Core 2 was taken out of the barrel; it contained a small lump of the same Quaternary white ooze. Meanwhile, the drill string was washed farther down according to original plan. At 0035Z 29 April, Core 5, cut from 218.5 to 227.0 m sub-bottom depth, was brought on deck; it was found to contain ooze with early Pliocene (NN13) nannofossils. Lithologic correlation suggested that we might have drilled into a sediment correlative to Lithologic Unit 1 of Site 519. It was decided to start coring continuously. A small pebble was found at the bottom of Core 5. Subsequent events indicated that there must have been a cave-in, with gravels from the hard layer at about 15 to 20 m sub-bottom falling down to the bottom of the hole. The small pebble in Core 5 was one of those picked up, and one or two more were picked up later. This

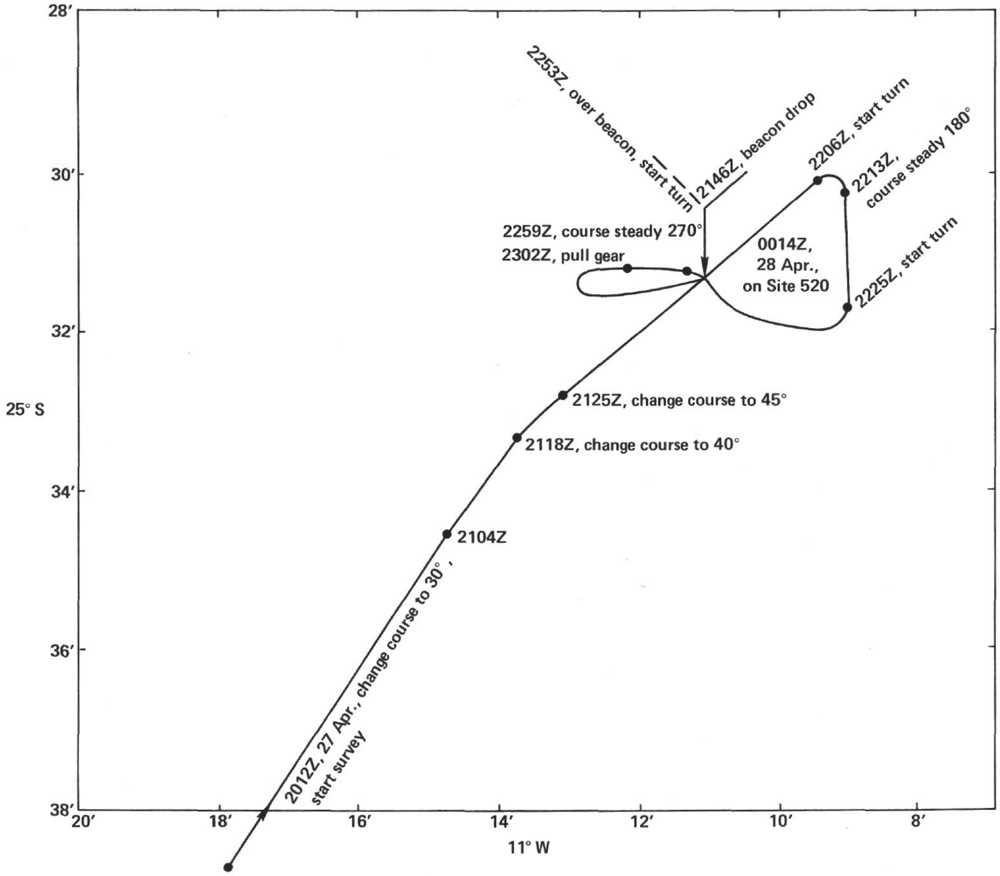

Figure 1. Site survey track line prior to drilling at Site 520.

event might be responsible for the fact that we obtained *no* recovery in our next two attempts! A large basalt cobble must have completely blocked the entry of the barrel for some time before it was ground down, and it was finally hauled up with Core 8.

Some 2.3 m of stiff nannofossil ooze were recovered from Core 8, but recovery remained poor to moderate throughout the hole. From 0630Z until the end of the day (29 April) continuous coring proceeded in a routine fashion. Cores were hauled up at 2-hr. intervals. Lower Pliocene and upper Miocene diatomaceous oozes and laminated diatomites were identified; the recovery percentage was poor.

It was decided at 0015Z 30 April, after Core 17 came up with only 22% recovery, to cut only half a barrel at a time. The percentage of recovery did improve, but the rate of penetration was cut in half. At 1005Z 30 April, when it was realized that we had drilled into a thick slump deposit, the normal coring routine (with the 9.5-m barrel) was resumed. Because of the very fast rate of sedimentation, a single nannofossil assemblage (Zone NN11) was identified from Cores 17 to 28 (275–427 m depth). Although rare intervals of pelagic diatomite were encountered (e.g., in Cores 16, 24, and 26), most of the penetrated section consisted of resedimented slump blocks and oozes. We decided to cut two joints (19.0 m) before making a wireline trip and to resume normal operation when we had drilled through the slump deposit. Penetration proved to be very slow in the resedimented deposits, so pump strokes were increased from 5 to 10. The resulting rate of cutting was reasonable, but core recovery was poor. At 2035Z Core 28 came up; recovery was poor, but we found no recognizable slump deposits. The co-chiefs decided then to resume normal continuous coring. Core 29 contained middle Miocene oozes, and Core 30 contained oozes and basalt basement. We then invested 4 hr. in cutting a basement core and obtained less than 2% recovery. It was decided that the drill bit had worn out. The coring operation at Hole 520 was terminated at 0540Z 1 May, and the drill string was raised to the mudline at 0720Z.

Hole 520A Coring Operations

The operation at Hole 520A was carried out to test the feasibility of dropping the rotary drill bit and washing into sediment with the HPC.

At 0955 1 May, Hole 520A was spudded in. The HPC washed easily in soft sediments. Core 1 was taken 16 m sub-bottom, near the level where a hard layer was encountered in Hole 520 (Table 1). At 1225Z, Core 1 was hauled up. The plastic liner was broken. The core was very disturbed, with nearly vertical contact between white and pale brown layers. The core barrel was pumped down for a second attempt, but no progress was made after some 20 min. of washing. It was decided that the drill string had encountered a hard layer (rock slide debris?) and could make no more progress. Consequently, Hole 520A was terminated. The drill string cleared the

Table 1. Coring summary, Holes 520 and 520A.

Core	Date (1980)	Time (hr.)	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Recovery (%)
Hole 520							
1	28 April	1147	4217.0–4223.0	0–6	6.0	0	0
2	28	1443	4273.5–4283.0	56.5–66.0	9.5	tr	0
3	28	1738	4330.5–4340.0	103.5–123.0	9.5	5.3	56
4	28	2118	4387.5–4397.0	170.5–180.0	9.5	4.4	46
5	29	0035	4435.0–4444.5	218.0–227.5	9.5	1.2	13
6	29	0234	4444.5–4454.0	227.5–237.0	9.5	tr	0
7	29	0423	4454.0–4463.5	237.0–246.5	9.5	0	0
8	29	0630	4463.5–4473.0	246.5–256.0	9.5	2.3	24
9	29	0845	4473.0–4482.5	256.0–265.5	9.5	7.6	80
10	29	1046	4482.5–4492.0	265.5–275.0	9.5	0.6	0.5
11	29	1247	4492.0–4501.5	275.0–284.5	9.5	5.4	57
12	29	1441	4501.5–4511.0	284.5–294.0	9.5	2.0	21
13	29	1624	4511.0–4516.0	294.0–299.0	5.0	0.2	1
14	29	1819	4516.0–4520.5	299.0–303.5	4.5	3.6	80
15	29	2009	4520.5–4530.0	303.5–313.0	9.5	2.6	27
16	29	2205	4530.0–4539.5	313.0–322.5	9.5	5.2	58
17	30	0015	4539.5–4549.0	322.5–332.0	9.5	2.2	22
18	30	0158	4549.0–4553.5	332.0–336.5	4.5	1.2	27
19	30	0405	4553.5–4558.5	336.5–341.5	5.0	1.6	32
20	30	0540	4558.5–4563.0	341.5–346.0	4.5	3.1	67
21	30	0710	4563.0–4568.0	346.0–351.0	5.0	2.6	52
22	30	0835	4568.0–4572.5	351.0–355.5	4.5	1.0	22
23	30	1005	4572.5–4577.5	355.5–360.5	5.0	2.7	54
24	30	1222	4577.5–4587.0	360.5–370.0	9.5	4.2	44
25	30	1430	4587.0–4596.5	370.0–379.5	9.5	2.8	29
			4696.5–4606.0	379.5–389.0	Drill with core barrel		
26	30	1635	4606.0–4615.5	389.0–398.5	9.5	2.8	29
27	30	1835	4615.5–4625.0	398.5–408.0	9.5	0.2	0.02
			2625.0–2634.5	408.0–417.5	Drill with core barrel		
28	30	2035	4634.5–4644.0	417.5–427.0	9.5	0.5	0.05
			4644.0–4653.5	427.0–436.5	Drill with core barrel		
29	30	2330	4653.5–4663.0	436.5–446.0	9.5	2.8	29
30	1 May	0135	4663.0–4667.5	446.0–450.5	4.5	1.05	23
31	1	0540	4667.5–4675.5	450.5–458.5	8.0	0.16	0.02
Total					246.5	69.3	28.1
Hole 520A							
1	1 May	1240	4233.1–4237.6	16.1–18.5	2.4	2.4	100

mudline at 1303Z, and we departed for Site 521 at 2054Z 1 May 1980.

LITHOLOGY

Sediments and Sedimentary Rocks

At Hole 520, a 450-m-thick sequence of interbedded pelagic sediments and slump deposits was cored by conventional rotary drilling. Three units were differentiated on the basis of color, carbonate content, and composition (Fig. 2).

Unit 1 (0–256.0 m, Cores 1–8, Hole 520; 16–18.5 m, Core 1, Hole 520A) consists of very pale brown, pale yellow, white, and light gray homogeneous nannofossil ooze. Bioturbation is variable throughout the unit. Calcium carbonate content varies between 75 and 80%; calcareous nannofossils are the main constituents of the sediments, with foraminifers comprising between 1 and 10%. In Core 4 there is a light gray layer of nannofossil-diatom ooze. A weathered basalt fragment was recovered from the base of Core 5.

The uppermost diatom ooze near the base of Core 8 marks the top of Unit 2 (256.0–398.5 m, Cores 9–26, Hole 520). This unit consists of gray, light olive to dark gray nannofossil diatom oozes and nannofossil diatomites which are commonly laminated. Burrowed intervals sometimes occur between laminated ones. In addition, some thin intervals (1–2 cm) appear to be graded. Carbonate content is low, between ~23 and 36%.

Very pale brown, yellow to brown nannofossil marl and dark brown nannofossil mudstone are intercalated with the diatomaceous sediments. The calcium carbonate content of the marl ranges between 60 and 90%; the mudstone contains less carbonate (30–50%). The transition from ooze to marl occurs at about 305 m in Core 15; both are generally homogeneous, with scattered burrows. A remarkable interval of evenly spaced, backfilled *Zoophycos* burrows was recovered in Section 1 of Core 24.

Unit 2 also includes at least four sequences of slump deposits within the pelagic diatomites and marls (Cores 16, 17, 20–23, and 24–25). Texturally, these deposits are mud-pebble conglomerates and mudstones. Some slump deposits are crudely graded, and syngenetic folds are common. Pebbles and clasts composed of marl and mudstone are embedded in a matrix of calcareous and nannofossil marl. Rare clasts of weathered basalt and volcanic glass fragments are present. The lowest diatomite occurrence marks the bottom of Unit 2.

Unit 3 (398.5–446.5 m; Cores 27–30, Hole 520) is pale yellow to light olive brown clayey nannofossil marl (Cores 27 and 28) and dark reddish brown bioturbated

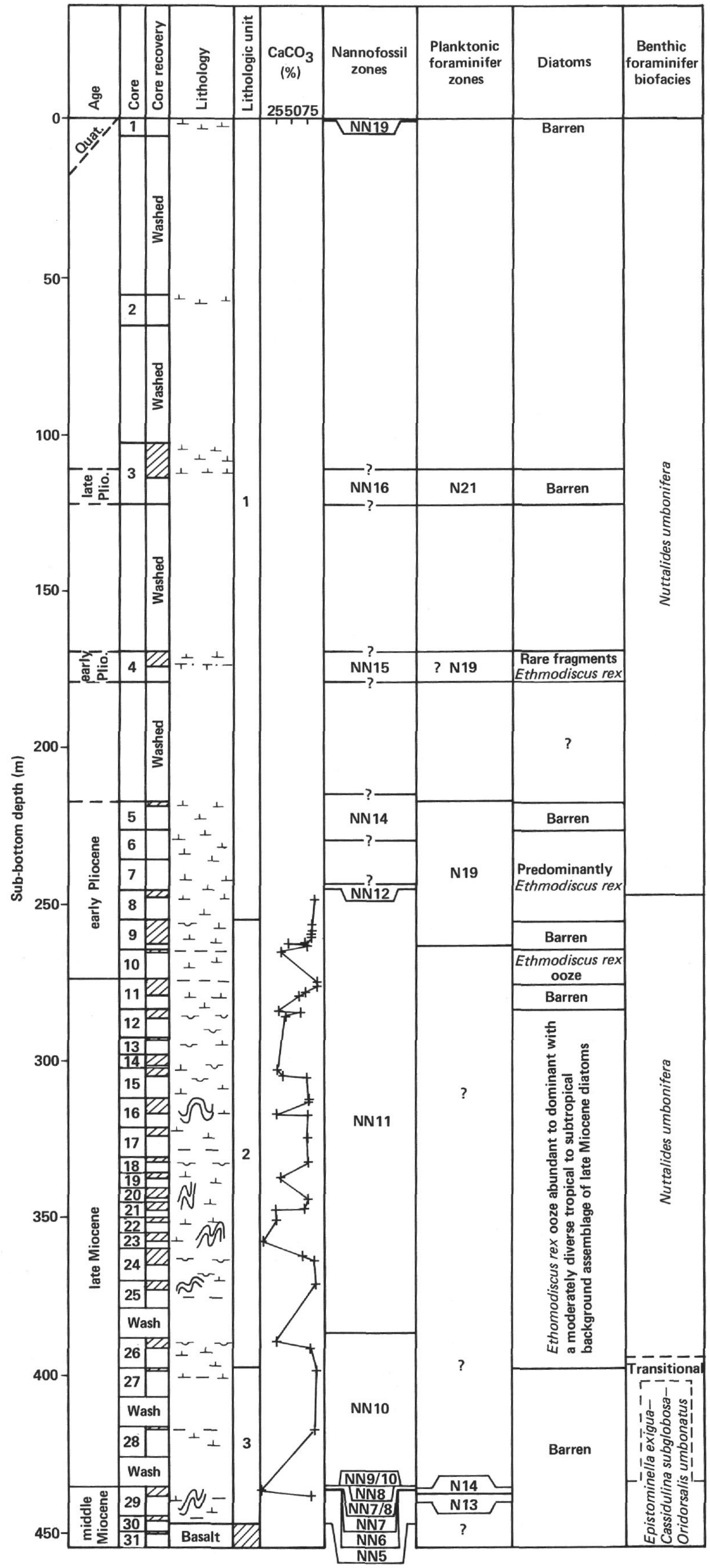

Figure 2. Stratigraphic summary of section at Hole 520. Lithology is defined in Hsü, LaBrecque, et al. (this vol.). Folds indicate slump deposits.

claystone (0.3% $CaCO_3$). Above the claystone a slump deposit of folded brownish yellow to dark yellowish brown nannofossil marl occurs in Core 29. Altered basaltic fragments were recovered at the base of the slump.

The pelagic part (i.e., non-redeposited) of the sedimentary sequence at Site 520 provides a record of past oceanographic conditions. The Pliocene and Quaternary pelagic nannofossil ooze comprising the upper part of the section was deposited above the CCD but probably below the foraminifer lysocline.

The underlying upper Miocene sequence of alternating diatom ooze–diatomite, nannofossil ooze–marl, and thin calcareous mudstone records a complex environmental history. Two carbonate-poor facies exist: diatomites and thin, dark brown mudstones. Both facies were probably deposited near the CCD but reflect variations in bottom-water conditions. Laminated diatomites with rare burrowed intervals contain significant pyrite and probably indicate an oxygen-depleted, reducing environment in a partially restricted basin. The brown mudstones contain greater amounts of manganese–iron oxides and clay and have lower carbonate (nannofossil) and diatom contents than the associated diatomites. They represent deposition in an oxidizing environment. The carbonate-rich pelagic facies in this sequence was deposited above the CCD but below the foraminifer lysocline. Common burrows and rare laminations in this facies suggest deposition in an oxygenated environment.

Middle Miocene marl below the sequence of alternating diatomite, marl, and mudstone signals a depression of the CCD. Interbedded dark brown mudstone reflects a combination of a CCD rise and an iron-oxide and clay contribution from the underlying or nearby basalt.

The redeposited sediments at Site 520 are nannofossil marls and calcareous mudstones (pebbly marls) that were probably originally deposited as pelagic oozes on the basin flanks above the CCD. Diatomites within these slump deposits occur only as discrete rip-up clasts. The absence of slumped diatomites suggests that either they were not deposited on the basin flanks or that they were preferentially winnowed after being deposited. Diatoms deposited on the flanks may also have dissolved in the carbonate-rich sediment.

Igneous Rocks

The rocks in Hole 520 are the only ones from Leg 73 that show typical variolitic structure. This term is used for the occurrence of relatively coarse, strongly spreading sheaf-shaped and radial clusters of plagioclase fibers (Pl. 1, Fig. 1) intergrown with very fine augite dendrites (Pl. 1, Figs. 2 and 3).

Exotic Fragment

The interval from 106 to 109 cm in the sediments of Core 29, Section 1 is occupied by a 3-cm-long loose fragment of pale green plagioclase phyric basalt altered to a mineral assemblage very similar to that of low grade greenschist facies metamorphism. The rock has undergone no deformation, and fine quench textures are well preserved. (For definitions and discussion of quench texture see Dietrich et al., this vol. and site chapter for Hole 519A, Pl. 1–3.)

The original texture was coarsely porphyritic (0.25–4.0 mm), with plagioclase phenocrysts composing 20 to 25% of the rock. These appear to have been corroded or inclusion filled, but subsequent alteration obscures the details. The phenocrysts are set in a finely quenched and variolitic groundmass of skeletal plagioclase and pyroxene. All plagioclase seems to be altered to a sodic composition (albite or oligoclase), and it contains patches of epidote and chlorite. Chlorite also veins the rock, giving it a characteristic light gray green color. Large (up to 1 mm) equant opaque minerals comprise 3 to 5% of the rock, and all such grains appear to be altered to hematite.

Turbidites and slump structures are common in Hole 520, and contorted beds immediately overlie the stratum that contained the exotic fragment being described. Therefore it is presumed that the piece represents a sample from a slump, turbidity flow, or talus deposit intercalated with the oozes of the sedimentary material. However, the ultimate origin of the clast is not certain. The two most likely possibilities are (1) that the rock is from an altered sequence deep in the volcanic pile that has been exposed by faulting and (2) that the rock has been altered by long-continued rather high-temperature hydrothermal action at or near the surface of the volcanic pile. Such action might be related to the fracture zone a few kilometers north of Site 520.

Basement Basalt

Drilling was extended into basalt to be certain that basement had been reached. The total distance drilled below the sediments was 10.5 m (Cores 30 and 31), and recovery was 1.7 m (16%). The basalts consisted of seven rollers and three oriented rounds. Chemically the rocks fall well within the range of ocean-floor plagioclase tholeiites (Dietrich et al., this vol.), but they are more evolved in general than those in Holes 519A and 522B (see site chapters), with normative quartz, lower Mg numbers (0.54–0.56), higher TiO_2, Y, Zr, and lower Cr. However, Ba, Rb, Sr, and Ni do not show this relation for basalts from the other two holes.

Seven of the ten pieces appear identical and have fresh glassy rinds from 0.5 to 2 cm thick. All are very fine grained. Thin sections show them to be aphyric tholeiitic basalts with textures and structures ranging from glassy through spherulitic (Pl. 1, Fig. 4) to variolitic and coarse quench (Pl. 1, Figs. 5 and 6, Pl. 2, Figs. 1 and 2). Olivine comprises about 5% in each rock, and all rocks contain fresh or only partly altered grains. Olivine is least altered in rocks with glass or very fine quench textures, and in these rocks there is the suggestion of resorption by the magma such as bulbous reentrants (Pl. 2, Fig. 3). In coarser rocks it was difficult to detect such evidence, although more extensive alteration to smectite somewhat obscures relations. A reaction of olivine with the magma is certainly in keeping with the quartz normative nature of the rocks. Compositions of minerals appear to be normal (olivine Fo_{85}, plagioclase

An_{60-70}, normal augite, magnetite and ilmenite as opaques). All rocks appear to be fresher than in other holes of Leg 73.

Conclusions

The rocks of Cores 30 and 31 are essentially monolithologic, with a very narrow range of composition, texture, and degree of alteration. They could well have come from an area of bedrock less than a meter square. All represent the outermost few centimeters of chilled basalt, showing only quench textures.

These facts suggest that the drilling pierced a unit of pillowed basalt. The proportions of recovery and of rollers to oriented pieces are typical of many cores from pillowed basalts.

The possibility that the basalts were a transported rubble layer cannot be completely excluded. However, the variation in the exotic pieces in the overlying sediments would lead one to expect a transported rubble deposit to be polymictic in terms of composition, texture, and alteration. Therefore, the favored interpretation is that the basalts are *in situ* pillows, and it is concluded that the hole ended either in a pillowed flow unit or the pillowed top of a more massive flow unit.

BIOSTRATIGRAPHY

Summary

Foraminifers and calcareous nannofossils were encountered throughout most of the 450-m middle Miocene to Quaternary section recovered at Hole 520. Diatoms were recovered from the upper 400 m (Fig. 2). In general, the calcareous nannofossils and diatoms are well preserved. The planktonic foraminifers are less well preserved and show signs of moderate to strong dissolution in Cores 4 through 10 and in Core 29. Those specimens in Cores 11 through 17 are intensely dissolved.

Biostratigraphic occurrences and conclusions are shown in Figure 3 and discussed below. Because of discontinuous coring in the upper 220 m of this hole, biostratigraphic resolution is poor in this interval. The calcareous nannofossils indicate the Pliocene/Quaternary boundary to lie between Cores 2 and 3 and the Miocene/Pliocene boundary to lie in the upper part of Core 8. The presence of *Globorotalia crassaformis*, an early Pliocene planktonic foraminifer, in Sample 520-9,CC would suggest a lower position for the latter boundary; however, the higher position (in Core 8) is preferred because it is based on a within-core sample instead of a core-catcher sample.

The calcareous nannofossils indicate the middle Miocene/late Miocene boundary to be in a strongly condensed section in Core 29, Section 1. The planktonic foraminifers of this brown clay sequence in Core 29 also indicate a middle Miocene age, but precise correlation between nannofossil and foraminiferal zones is unclear and does not agree. The disagreement develops in Core 29, Section 2. The planktonic foraminifers from the top of this section down to 86 cm in the section yield an N13 assemblage (*Sphaeroidinellopsis subdehiscens*). According to the standard biostratigraphic correlation, the nannofossils should be no older than NN7. Nevertheless, the highest occurrence of *Discoaster deflandrei* (top of NN6) occurs at Core 29, Section 2, 0 cm, and the highest occurrence of *Sphenolithus heteromorphus* (top of NN5) lies at Core 29, Section 2, 61 cm. The reasons for the problem are not clear. The calcareous nannofossils may be reworked; there is evidence of significant slumping at this site in Cores 18 through 25. On the other hand, the correlation of middle Miocene nannofossil and foraminifer zonations is somewhat uncertain (see Hsü, Percival, et al., this vol.).

Calcareous Nannoplankton

We assign Core 1 in Hole 520 to Quaternary NN19 because of the presence of *Pseudoemiliania lacunosa* Gartner. We assign Core 3, Section 7 top to the late Pliocene NN16 because of the occurrence of *Discoaster surculus* Martini and Bramlette without *Reticulofenestra pseudoumbilica* Gartner. Core 4 is assigned to bottom NN15 (early Pliocene age) because of the presence of *R. pseudoumbilicia* Gartner. Samples 520-5-1, 32–33 cm and 520-5,CC contain *Amaurolithus tricorniculatus* (Gartner), a species that indicates NN14. Core 6 still contains *D. asymmetricus* Gartner, a species in NN14.

The presence of *A. amplificus* (Bukry and Percival) and the absence of *D. quinqueramus* Gartner place Sample 520-8-2, 10–11 cm in NN12 late Miocene. The interval from Sample 520-8-2, 62–63 cm to 520-26-2, 78–79 cm is believed to be late Miocene NN11 in age because of the presence of *D. quinqueramus* Gartner. The interval from the bottom of Core 26 to Sample 520-29-1, 10–11 cm is assigned to NN10 because of the absence of *D. quinqueramus* Gartner and *Catinaster calyculus* Martini and Bramlette. *Amaurolithus* spp. are absent below Sample 520-23,CC. Samples 520-29-1, 20–21 cm to 520-29-1, 70–71 cm contain frequent specimens of *C. calyculus* Martini and Bramlette (NN8/10 undifferentiated).

Middle Miocene species are present from Sample 520-29-1, 80–81 cm to 520-29,CC. The interval from Sample 520-29-1, 80–81 cm to 520-29-1, 110–111 cm is assigned to NN8 because of the absence of *D. pentaradiatus* Tan Sin Hok. Samples 520-29-1, 120–121 cm to 520-29-1, 138–139 cm are assigned to NN7/8 because of the absence of *C. coalitus* Martini and Bramlette and *D. kugleri* Martini and Bramlette. Samples 520-29-1, 140–141 cm to 520-29-1, 149–150 cm are assigned to NN7 because of the presence of *D. kugleri* Martini and Bramlette. The interval from Sample 520-29-2, 0 cm to 520-29-2, 49–50 cm is assigned to NN6 because of the occurrence of *D. deflandrei* Bramlette and Reidel and *Cyclicargolithus floridanus* (Hay and Roth). The remainder of the section to Sample 520-30-1, 50–51 cm is assigned to NN5 because of the presence of *Sphenolithus heteromorphus* Bramlette and Wilcoxon.

Planktonic Foraminifers

Planktonic foraminifers are poorly represented in the sediments recovered at Hole 520. Almost all samples examined show evidence of moderate to intense dissolution.

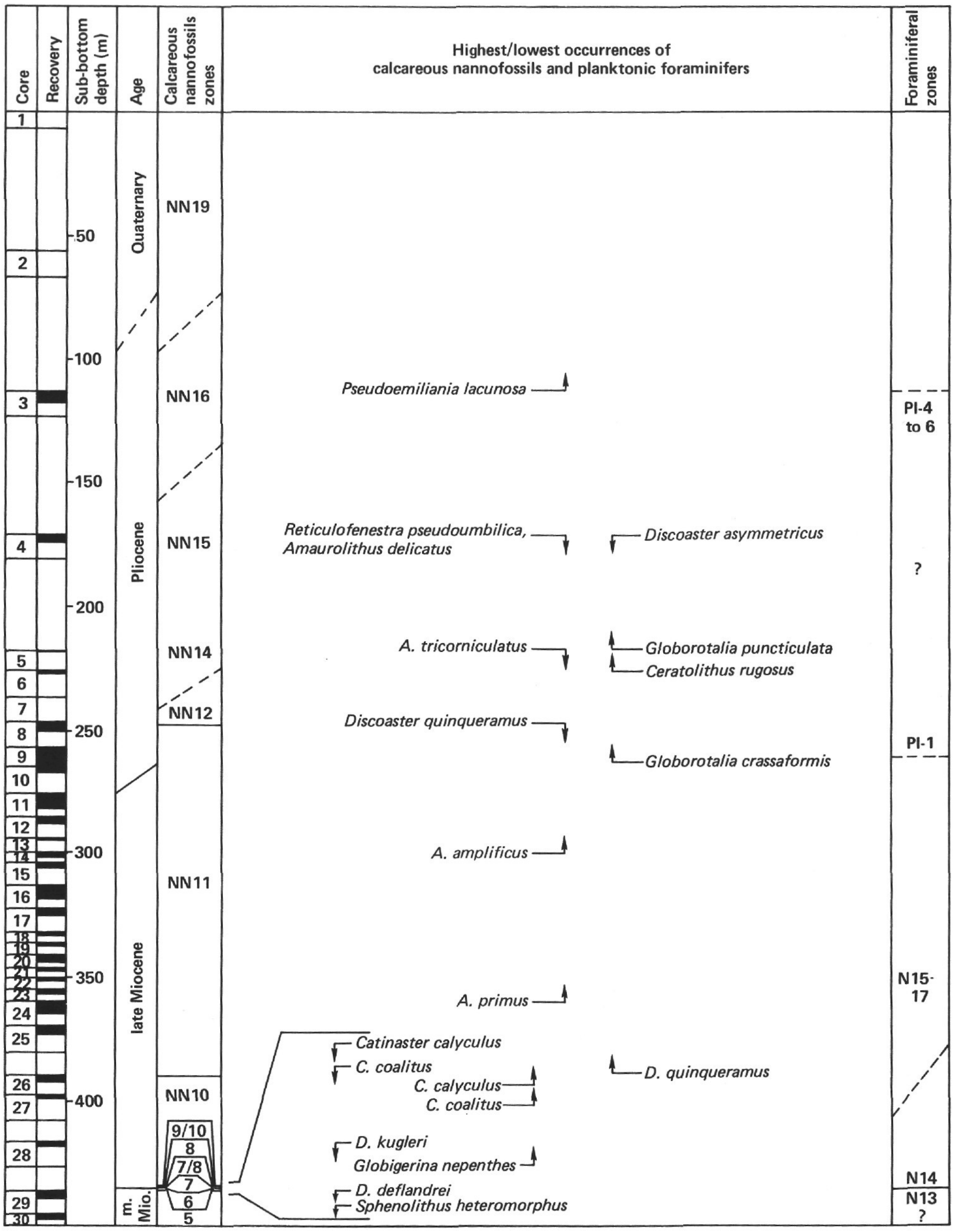

Figure 3. Biostratigraphic summary of significant calcareous and planktonic microfossils, Hole 520.

A trace of Quaternary sediment was recovered in Core 1 and a collapsed core liner caused problems with Core 2. Thus, these cores were not examined for foraminifers. A relatively well preserved late Pliocene foraminifer assemblage occurs in Sample 520-3-7, 5–7 cm. Taxa present include *Globigerinoides ruber, G. obliquus, G. extremus, G. conglobatus, Globorotalia crassaformis*, and *G. inflata*.

Cores 4 through 10 yield sparse, poorly preserved assemblages. The occurrence of *G. puncticulata* in Sample 520-5,CC supports the early Pliocene age for this interval that is indicated by the calcareous nannofossils. A few specimens of *G. crassaformis* in Sample 520-9,CC indicate a Pliocene age assignment; nannofossils in Sample 520-9,CC, however, suggest an upper Miocene age assignment.

Samples from Cores 11 through 17 contain extremely poor, dissolution assemblages or are barren of planktonic foraminifers. Planktonic foraminifers are more common and better preserved in Cores 18 through 25, but these cores are from an interval that consists mostly of a number of slump deposits that are interrupted with minor amounts of *in situ* sediments. Taxa that occur commonly throughout this interval include: *Sphaeroidinellopsis subdehiscens, S. seminulina, Globigerina nepenthes, Globoquadrina dehiscens, G. altispira*, and *Globorotalia conoidea* (s.l.). The slump deposits occur down into Core 29, but planktonic foraminifers are essentially absent from Cores 26 and 27. Sample 520-28,CC is contaminated with Quaternary through lower Pliocene species. The interval from Core 11 to Core 28 is assigned to the upper Miocene nannofossil zone NN11.

The last slump deposit in Section 1 of Core 29 is underlain by brown clays that yield highly dissolved middle Miocene assemblages. Sample 520-29-1, 143 cm contains *Sphaeroidinellopsis subdehiscens, Globigerina druryi*, and rare specimens of *G. nepenthes*. Samples from Section 2 of Core 29 contain *G. druryi, Globoquadrina dehiscens, Orbulina* spp., *S. seminulina*, and *S. subdehiscens* (down to Sample 520-29-2, 86 cm). Section 2 of Core 29 is assigned to Zone N13, and the lower part of Section 1 is assigned to Zone N14. Assemblages from samples in Cores 29 and 30 below Sample 520-29-2, 109 cm are too sparse to allow a zone assignment.

Note that the age assignment for the lower part of Core 29 by planktonic foraminifers is slightly younger than the age assignment suggested by the nannofossils. This problem could be caused by reworking of the robust nannofossil *Sphenolithus heteromorphus* or by the uncertainties concerning the age of the earliest occurrence of *Sphaeroidinellopsis subdehiscens.*

Diatoms

Diatoms occur sporadically in Hole 520 from Core 4 through 26. Cores 5, 9, 11, and 24 are barren of diatoms. The dominant constituent of the diatom assemblages in the other cores is *Ethmodiscus rex,* which occurs only as fragments. About 30 other diatom species were observed, in varying abundances, with *E. rex* in most cores (see Gombos, this vol., "Late Neogene Diatoms" for details of diatom distribution in Hole 520). Among the minor constituents of the diatom assemblage in the late Miocene of Hole 520 are *Actinocyclus ellipticus* and its varieties, *Asterolampra grevillei, A. marylandica, Asteromphalus arachne, Brunia mirabilis, Coscinodiscus curvatulus, C. lineatus, C. nodulifer, C. vetustissimus* v. *javanicus, Hemidiscus cuneiformis, Nitzschia marina*, and *Triceratium cinnamomeum*. These forms are indicative of subtropical and tropical water masses and are in agreement with the late Miocene to Pliocene age of Cores 4 through 26 as determined by calcareous microfossils.

Benthic Foraminifers

The pelagic sediments of the Pliocene to Quaternary sequence in Hole 520 contain a moderately diverse and well preserved benthic foraminiferal fauna. The fauna is dominated by *Nuttalides umbonifera*, with subordinate amounts of *Oridorsalis umbonatus, Globocassidulina subglobosa, Epistominella exigua, Planulina wuellerstorfi*, and *Pullenia* spp.

The late Miocene sequence is characterized by the erratic preservation of the benthic fauna and intervals of diatomaceous-rich sediments that are barren of benthic foraminifers. Anoxic conditions on the bottom may be the cause of these barren intervals. When present, the late Miocene fauna is the same as that of the overlying sequence. A major change in the fauna occurs between the bottom of Core 26 and Section 520-29-2 (398 to 438 m sub-bottom). Somewhere in this interval *N. umbonifera* ceases to be a dominant element in the fauna. Below this interval it is rare to absent in benthic assemblages. Because sample recovery and preservation in this interval is poor, the precise timing of this event is uncertain. An interpolation of the sedimentation rate curves (Fig. 4) indicates that this faunal transition may have occurred at any time between 8.1 and 13.9 m.y. ago. If the faunal transition occurred near the early (13.9 m.y.) end of the estimated range, the loss of *N. umbonifera* from the fauna may be explained by water depth. At this time the site lay at a water depth of 3400 m (Fig. 5), and it is below this depth that *N. umbonifera*-dominated faunas (Antarctic Bottom Water, AABW) thrive today.

SEDIMENTATION RATES

Sedimentation rates are difficult to calculate in Hole 520 because in the Pliocene to Quaternary sequence coring was discontinuous and in the middle to upper Miocene sequence core recovery was erratic. Futhermore, the preservation of calcareous microfossils was variable.

The extremely high sedimentation rate between 248 and 360 m sub-bottom (Fig. 4; Core 8 to Core 24) is a consequence of slumping from the flanks of the deep narrow basin in which Site 520 is located.

The extremely low sedimentation rates centered about 438 m sub-bottom (Cores 520–529 are due to high dissolution rates in the upper part of the middle Miocene sequence.

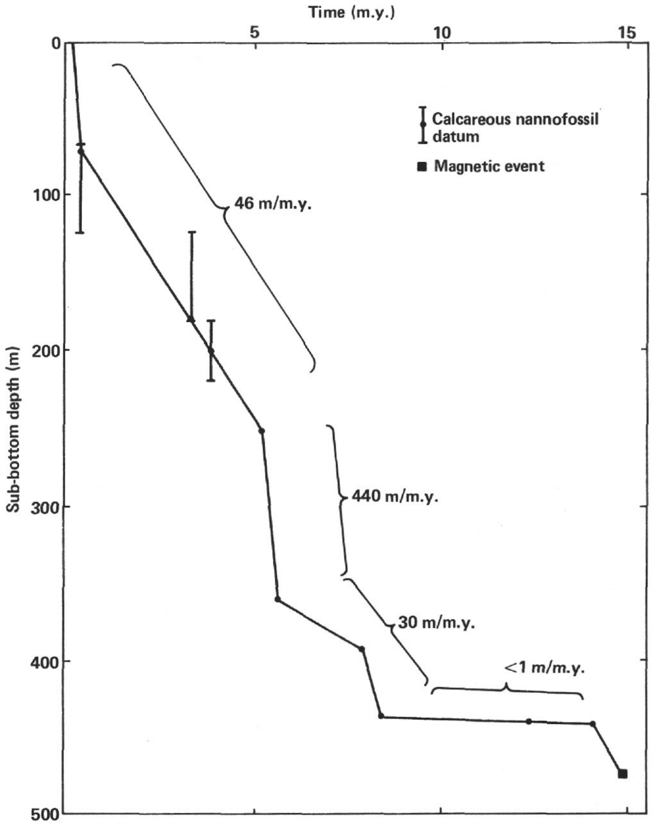

Figure 4. Sedimentation rates, Hole 520.

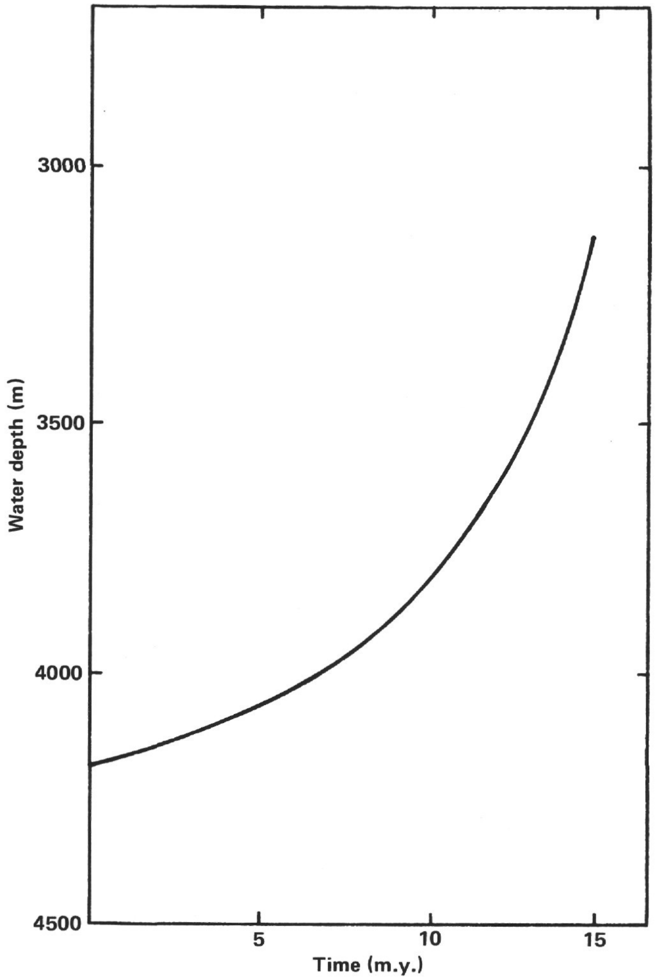

Figure 5. Bathymetry of Site 520. Based on subsidence curves corrected for sediment load (Berger and von Rad, 1972).

PALEOMAGNETISM

Sediments and Sedimentary Rocks

As a consequence of the low recovery rate and high incidence of slumping, only isolated fractions of the geomagnetic record were analyzed. The reliable data are listed in Table 2. We draw no conclusions about the geomagnetic time scale but note that Core 15 was normally magnetized, Core 24 was reversed, and Core 26 was of mixed polarity. The upper cores carried a large (normal) Brunhes overprint that was only removed (and the stable paleodirection isolated) after demagnetization in fields of order 200 to 300 Oe. In contrast, the laminated lower cores (24 and 26) were effectively magnetically cleaned in peak alternating fields as low as 50 Oe. This is best illustrated in a Zijderveld plot (Fig. 6). Here one horizontal component of magnetization (y) and the vertical component (z) are plotted as functions of their orthogonal component (x) for increments of demagnetizing field. A straight line converging on the origin upon demagnetization indicates the stable (presumably primary) magnetization direction. The soft normal overprint is indicated by the systematic downward shift in z (i.e., from negative toward positive) during the initial stages of demagnetization. The results in Figure 6, which are typical of the results for the lower and upper cores, imply a significant difference between the magnetic mineralogy of the older and younger sediments.

Table 2. Summary of reliable sediment paleomagnetic measurements, Hole 520.

Core-Section (level in cm)	Declination (°) NRM	Declination (°) AFD	Inclination (°) NRM	Inclination (°) AFD	Intensity ($\times 10^{-6}$ G) NRM	Intensity ($\times 10^{-6}$ G) AFD
15-1, 29	43.9	44.1	−46.9	−39.6	10.107	3.433
15-1, 45	199.7	210.5	−57.4	−45.6	10.510	4.915
15-1, 62	182.1	188.1	−16.7	−16.1	0.200	0.249
15-1, 120	353.4	358.1	−57.7	−61.5	10.690	3.930
15-2, 53	293.4	240.5	−31.7	−43.5	0.251	0.162
15-2, 82	31.0	277.0	−43.5	88.9	4.358	0.930
24-1, 51	49.7	31.5	−47.3	−52.4	8.831	1.905
24-1, 61	107.1	102.0	20.2	33.1	9.902	10.043
24-1, 77	251.3	253.6	5.3	9.1	5.792	4.594[a]
24-1, 111	58.1	59.2	2.7	17.7	0.319	0.338
24-1, 150	256.2	246.2	−11.8	11.5	0.424	0.198
26-1, 26	342.8	337.3	−40.7	−10.9	3.404	1.255
26-1, 52	—	126.6	—	22.5	—	0.192
26-1, 67	319.1	320.3	−9.8	−1.5	0.513	0.469
26-1, 105	240.3	133.7	−70.0	−10.9	0.130	0.131
26-1, 138	164.0	223.9	−66.6	25.5	1.412	1.535
26-2, 12	125.9	88.7	24.8	41.0	0.718	0.372
26-2, 29	264.1	249.2	13.0	8.8	0.341	0.532
26-2, 56	338.6	344.4	21.3	25.6	2.504	2.127
26-2, 94	206.2	141.1	−63.7	−74.6	4.167	0.276

Note: NRM = natural remanent magnetization, AFD = magnetization after alternating field demagnetization. AFD was at 200 Oe.
[a] Alternating field curve.

Igneous Rocks

Hole 520 was drilled on a negative anomaly on the younger side of Anomaly 5B. In total, 10.5 m of basalt were drilled, but only 1.21 m were recovered. Of the recovered material only two pieces were oriented. The results obtained from these samples are listed in Tables 3 and 4. The measured magnetization polarity of the two samples agrees with the sign of the overlying magnetic anomaly. The inclination values of the two oriented samples agree well with each other. It is therefore likely that the basalt basement has been penetrated.

Physical properties were measured on sections from Cores 8 through 30 by using the methods described for Hole 519. Cores 9 through 15 were sampled for water content and the density and porosity taken from the continous gamma-ray attenuation porosity evaluator (GRAPE) record of these cores. In Core 16 and below, the sediments were sufficiently indurated to allow the full set of gravimetric measurements to be performed on cubes cut from the sections. Compressional velocity and 2-min. GRAPE measurements were also made on these cubes, parallel and perpendicular to bedding. The results are summarized in Figure 7.

Nannofossil ooze was the main constituent of Cores 5 through 12, with some clay appearing in Core 10 and some diatom ooze in Cores 10 and 12. The first appearance of marl was noted in Core 13, with Cores 14 and 15 reverting to nannofossil and diatom oozes. This return to ooze is marked by lower compressional velocity and density. In Core 16 (~313 m sub-bottom) and below, pebbly marl slump deposits and interbedded diatomites become common, and this lithologic change is indicated

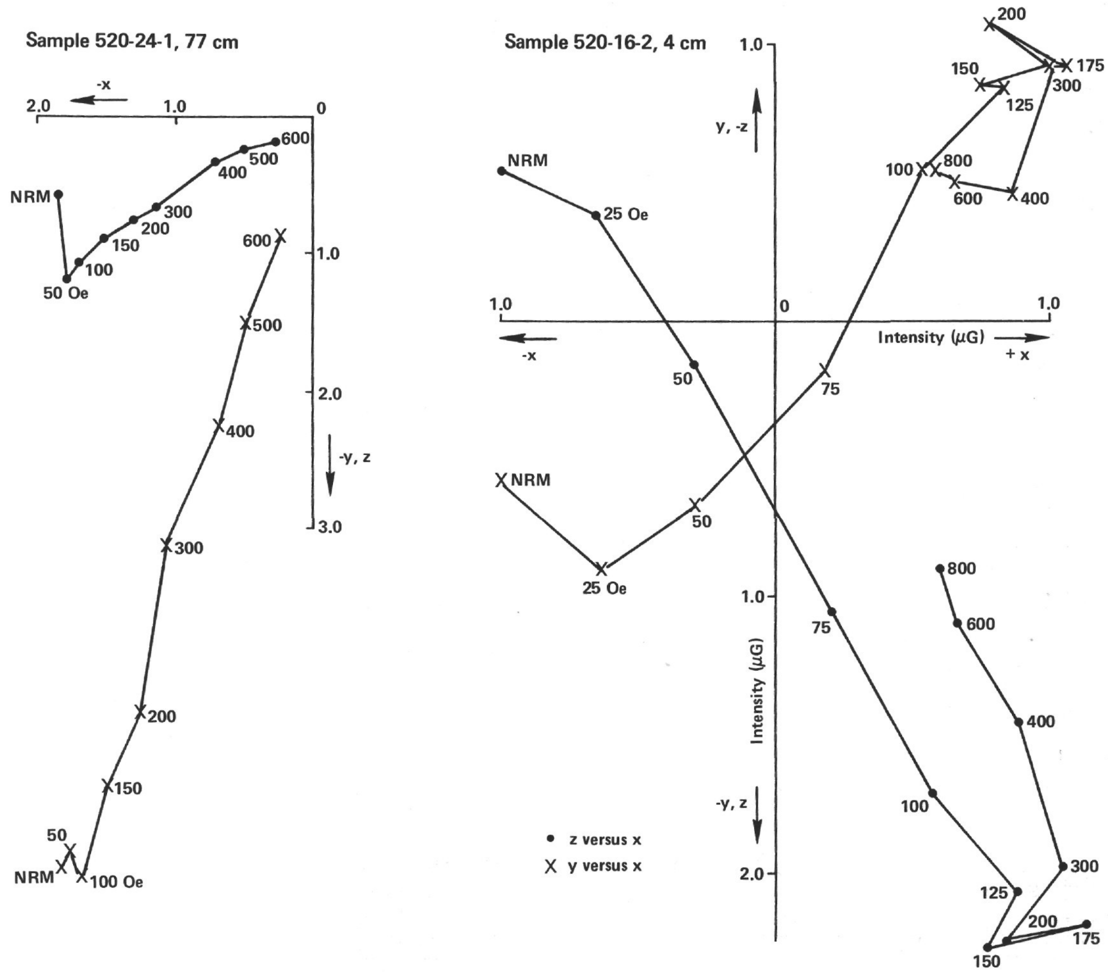

Figure 6. Zijderveld plots for sediment Samples 520-24-1, 77 cm and 520-16-2, 4 cm. See text for explanation.

Table 3. Paleomagnetism of basalts at Hole 520 with alternating field demagnetization.

Core-Section (interval in cm)	A.f. magnetic field (Oe)	Magnetization Intensity ($\times 10^{-4}$ G)	Inclination (°)	Declination (°)
30-1, 101-103	NRM	98.740	58.2	34.4
	200	94.490	60.7	28.5
	400	68.608	55.7	33.8
	600	44.686	59.1	37.9
31-1, 6-8	NRM	55.471	50.3	112.8
	100	54.439	50.7	112.1
	200	46.999	52.4	112.0
	400	31.039	53.6	112.1
	600	21.439	51.4	111.1
	800	26.094	8.6	116.7
	1000	42.680	−30.6	123.7
	1000 reversed	46.755	34.6	79.3

Table 4. Paleomagnetism of basalts at Hole 520.

Core-Section (level in cm)	NRM Intensity ($\times 10^{-4}$ G)	NRM Inclination[a] (°)	Stable inclination[a] (°)	MDF (Oe)	Susceptibility ($\times 10^{-4}$ G Oe^{-1})	Q-factor
30-1, 101-103	98.74	58.2	57.2	550	No data	No data
31-1, 6-8	55.47	50.3	53	460	42.2	49

Note: NRM = natural remanent magnetization, MDF = median destructive field.
[a] Positive inclination means reversed polarity on the Southern Hemisphere.

by an increase in sound velocity and a marked decrease in penetrometer readings. The density profile exhibits considerable scatter. Diatom and clay content increase with depth. The sample taken from Core 29 was from a claystone layer at the lower part of the core section.

Most of the basalt recovered in Cores 30 and 31 was altered. The piece selected for physical properties analysis (Sample 520-30-1, 103–106 cm; 447.0 m sub-bottom) was the least altered; a minicore was cut from its fresh center. The results for this piece are as follows. Horizontal velocity is 5.70 km/s, and vertical velocity is 5.91 km/s. Gravimetric data show density at 2.80 g/cc, water content at 1.78%, and porosity at 5.10%. The 2-min. GRAPE data show a density of 2.87 g/cc in the vertical axis and 2.48 g/cc in the horizontal axis; porosity is 1.87% in the vertical axis and 22.4% in the horizontal axis. Thermal conductivity, K, is 1.9 W/m°C.

INORGANIC GEOCHEMISTRY

Table 5 presents the results of analyses of interstitial water squeezed from sediments recovered at Site 520. Down to a depth of about 250 m sub-bottom, profiles differ little from the ideal diffusion gradients observed at many DSDP sites. Between 250 and 350 m, however, all trends reverse. This depth interval (Cores 16–21) corresponds to the shallowest occurrence of slump deposits recovered at this site. Below this, pyrite-rich diatoma-

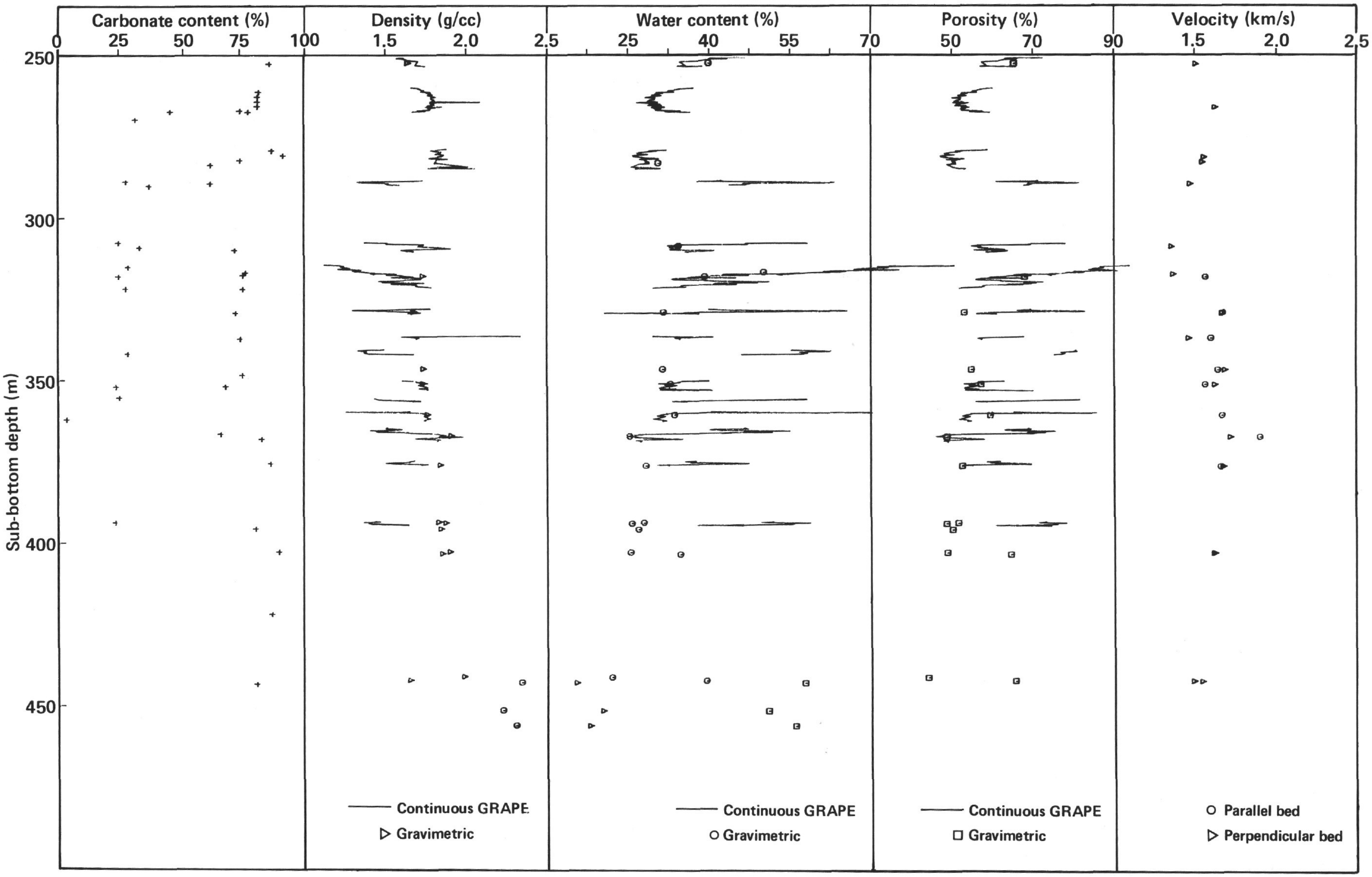

Figure 7. Summary of physical properties, Hole 520.

Table 5. Summary of shipboard geochemical data.

Core-Section (interval in cm)	Sub-bottom depth (m)	pH	Alkalinity (meq/l)	Salinity (‰)	Calcium (mmol/l)	Magnesium (mmol/m)	Chlorinity (‰)
3-6, 140–150	107.5–117.0	7.43	3.212	35.35	12.471	49.525	19.748
9-4, 140–150	256.0–265.5	7.607	5.289	35.2	14.184	45.18	19.172
12-1, 140–150	284.5–305.0	7.669	5.275	35.2	14.96	45.74	19.07
16-4, 140–150	313.0–322.5	7.699	5.376	35.2	14.87	46.18	19.41
21-2, 94–104	346.0–351.5	7.591	4.701	37.4	14.57	47.43	20.39

ceous sediments occur. Perhaps these reversals, particularly the slight alkalinity maximum, are related to the microbial production of bicarbonate during the oxidation of organic matter in these sediments.

CORRELATION OF SEISMIC RESULTS

The locations for Holes 520 and 520A were chosen on the basis of site survey data acquired by the University of Texas Marine Science Institute (UTMSI). Holes 520 and 520A are located within the short negative anomaly before Magnetic Anomaly 5B; the estimated basement age is 14.5 m.y. The sites are located within the axis of a small asymmetric, elongate basin (Fig. 8). Oceanic basement within a radius of 10 naut. mi. of the sites has a maximum relief of 1100 m.

Seismic reflection data over Site 520 reveal a change in acoustic sub-bottom reflection characteristics at approximately 0.2 s (two-way reflection time). The data above the 0.2 s boundary show parallel but diffuse reflectors; below 0.2 s the reflectors are denser and more coherent. The measured average sediment acoustic velocity is 1.5 km/s, so this change in reflection characteristics should occur at approximately 150 m sub-bottom.

No major changes were observed in lithology or the physical properties of the sediments within this 150-m interval, although the sequence above 218 m sub-bottom was only sparsely sampled. The first nannofossil diatom ooze was observed at 180 m sub-bottom (Core 4); thus, there may be a correlation between the lower reflector sequences and the occurrence of diatomite horizons. However, the major occurrences of diatomites do not occur until deeper within the sequences. These reflector horizons are more likely to be manifestations of the many slumps and turbidite flows encountered in this part of the section. The high deposition rate due to the redeposition of sediment has been suggested as a mechanism for diatom preservation. The velocity contrasts within slump horizons are probably accentuated by lithification down section.

No basement reflections were observed in either the UTMSI sparker or the *Challenger* seismic data. Downwarp in the basin sediments was greatest beneath Site 520, suggesting that this position marks the axis of the basin. The concave reflector lineations are probably due to a combination of sediment drape over basement and differential compaction due to varying sediment thickness, both probably further complicated by side echoes from the steep sides of a buried basement high.

SUMMARY AND CONCLUSIONS

This site was the middle of a three-site transect made to study the middle Miocene seafloor spreading rate and CCD crisis and was positioned near the axis of a local valley on Magnetic Anomaly 5B. We had only spot cores for the Pliocene–Quaternary ponded sediments, but the sediments below 218 m sub-bottom (except for three short intervals) were cored continuously until we reached basalt at 458 m sub-bottom. We have done no magnetostratigraphy in the spot-cored section, and little in the continuously cored lower sequence, because NRM signals are difficult to interpret. The difficulty of interpretation stems from incomplete recovery (28%), core disturbance, and resedimentation. Biostratigraphic methods provide the only means of determining the ages and rates of sedimentation at this site.

The site was over the central depression of a ridge-flank basin. This position was chosen (1) to ensure the recovery of oldest sediment to permit the seafloor anomaly to be dated and (2) to ensure the sampling of a complete Miocene section without erosional unconformities. We discovered that a basinal position is optimal for neither studies in precision stratigraphy nor the investigation of those aspects of paleoceanography that require the precise dating of events. The sedimentation rate is too fast to permit deep stratigraphic penetration by HPC. Nevertheless, it is of value to have explored the sedimentary and paleoceanographic history of at least one silled basin on the Mid-Atlantic Ridge: diatomites were discovered at the site, a surprise that we believe justifies the investment of ship time in the reconnaissance of the basinal environment.

Lithostratigraphy

Hole 520 was drilled into a ponded sequence. The seismic record indicated that the very thin sediments of the draped facies on the flanks of the basin extended basinward and should be encountered beneath the thick ponded facies. The drilling confirmed the prediction. The late Neogene sequence is largely resedimented down to about 440 m sub-bottom. Only a thin veneer of older middle Miocene ooze was draped over the basalt basement.

Lithologic Unit 1 (0–256.0 m) includes mainly Pliocene–Quaternary oozes and is represented by spot cores with very poor recovery. The nannofossil oozes are massive or layered and are commonly homogeneous in appearance. Some of the intervals are clearly bioturbated. A few layers of diatom (*Ethmodiscus rex*) ooze are intercalated in the Pliocene sequence.

The homogeneous nannofossil oozes are indistinguishable from pelagic sediments, nor do they differ from homogeneous oozes in slump deposits. The ponded nature of the sediments and the very high sedimentation rate of the unit suggest that much of the bulk must have been the product of resedimentation.

Lithologic Unit 2 is Tortonian (NN11) in age and is characterized by the presence of diatomites. The siliceous oozes are interbedded with homogeneous nannofossil oozes down to 313 m sub-bottom (Core 15). Furthermore, the siliceous sediments are mainly very evenly laminated, greenish gray diatomite (see Pl. 3, Fig. 1). Benthic foraminifers are absent in the diatomites but are present in calcareous oozes. A dark brown marly ooze (Sample 520-26-2, 98 cm) contains a very diversified

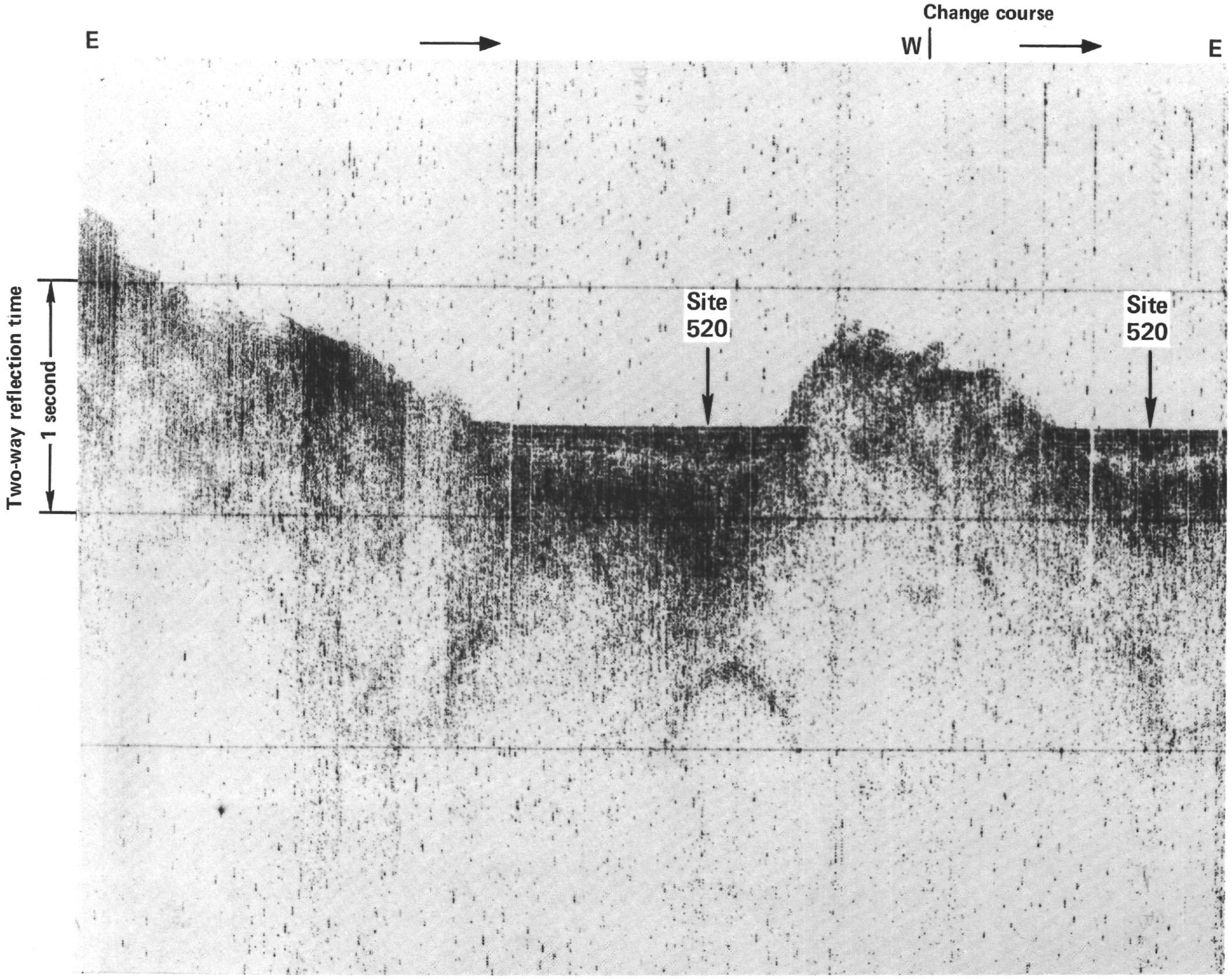

Figure 8. Seismic reflection profile over Site 520.

benthic microfauna. Burrowing structures of *Zoophycos*, chondrites, and so forth are common in marly oozes (Pl. 3, Figs. 2–4). Also present in the lower part of Unit 2 are at least four thick slump deposits (Cores 16, 17, 20–23, and 24 and 25).

Unit 3 (398.5–446.5 m) consists of marly oozes with a few intercalations of slumped deposits (e.g., Core 29, Section 1). The oozes are burrowed and have been subjected to a considerable degree of calcite dissolution.

Redeposited Sediments

Slumping was the main process of resedimentation in this basinal setting. Topping a slump deposit is commonly turbidite. A typical succession of the types of sediment in a slump deposit is illustrated by Figure 9. The divisions are (from the bottom upward): (a) slump block with slump folds and microfaults that have not yet disintegrated (Pl. 4, Fig. 1); (b) slump block that is partially disintegrated and embedded in mud-pebble ooze, or homogenized ooze (Pl. 4, Fig. 1); (c) mud-pebble ooze, with rounded flat pebbles of mud or oozes dispersed in a mud or ooze matrix and grading upward to a mud-chip ooze with salt and pepper texture (Pl. 4, Fig. 2); (d) homogenized ooze locally with traces of mud chips (Pl. 4, Fig. 3); (e) turbidite sand, with distinct graded bedding; and (f) normal anoxic basin pelagic diatomite. Diatom or foraminifer sands appear, on top of large slump blocks, and thin layers of these sands also appear singly, interlayered in laminated diatomites. They all show the graded bedding typical of sediments deposited by turbidity currents (Pl. 5). Those currents were probably generated by catastrophic slumping (Kelts and Hsü, 1980; Hsü et al., 1980).

As mentioned previously, a resedimented ooze is not always distinguishable from a pelagic ooze, but the presence of exotic pebbles (like those in, for example, Core 15, Section 2, Core 17, Section 2, and Core 29, Section 1) can betray their resedimented origin (Pl. 6). This kind of evidence indicates that the homogeneous nannofossil oozes between 310 and 380 m sub-bottom (Cores 16–25)

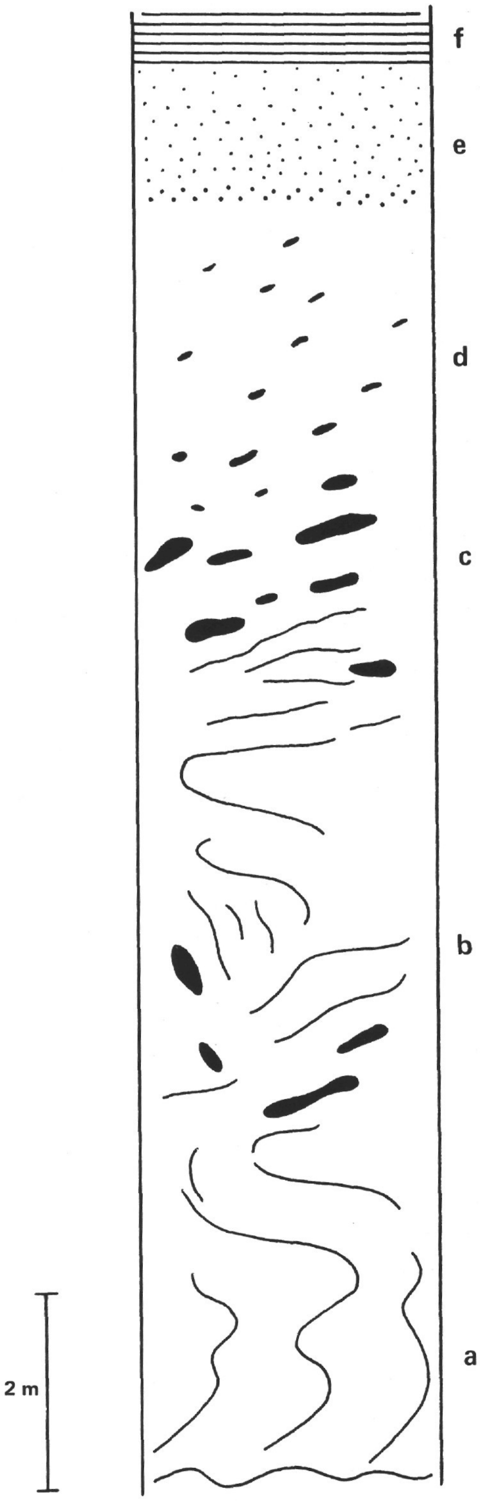

Figure 9. Schematic diagram showing five divisions of a catastrophic slump deposit. See text for explanation.

are mostly resedimented. Some of the homogeneous oozes in the overlying and underlying sediments were probably also a product of resedimentation.

Biostratigraphy and Sedimentation Rate

The biostratigraphic subdivision of the sequence has been based almost entirely on the highest and lowest occurrences (HOs and LOs) of certain nannofossil species. Despite the condensed middle Miocene section, practically all the nannofossil zones from NN5 to NN12 could be recognized (Percival, this vol.). However, the use of the HOs and LOs to estimate sedimentation rates has been rendered uncertain by several factors. In the upper 250 m of sediments, where the coring is very spotty and the recovery poor, the depth of the well dated datum levels can not be accurately determined. The HO of *Discoaster brouweri* was placed between 56 and 122 m sub-bottom because no samples of the intervening interval were available. The placement of this and other HOs is further complicated by the redeposition of sediment. For example, the sediment of Lithologic Unit 2, which is about 150 m thick, has all been assigned an age of NN11 on the basis of the presence of the nannofossil *D. quinqueramus*, an assignment that implies an enormous sedimentation rate. This species is not dissolution resistant and was found in only one sample at Site 519 because of the intense calcite dissolution during the late Miocene. Site 520 should have subsided deeper than Site 519 (4000 m vs. 3300 m), and the common occurrence of this nannofossil species here must be attributed to preservation in rapidly redeposited sediments. Thus, the HO of *D. quinqueramus* here most probably does not correspond to the last appearance datum (LAD) of the species.

The depth determinations of the various HOs and LOs are more accurate in the continuously cored lower half of the sequence, but several of the upper and middle Miocene datum levels have not yet been precisely calibrated. The lowest occurrence of *D. quinqueramus* at 391.29 m (Sample 520-26-2, 78–79 cm) probably corresponds to the first appearance datum (FAD) of the species, but we have no magnetostratigraphy to date the event. Nor could we cite the previous calibrations, such as the one adopted by Leg 40 scientists, because *D. quinqueramus* and several other late and middle Miocene species have their LOs in Hole 519 at magnetostratigraphically calibrated horizons systematically (1–3 m.y.) later than those assumed by Bolli, Ryan, et al. (1978, p. 14). The correlation of nannoplankton and foraminiferal zones is problematic in certain intervals, as discussed in the stratigraphic summary. Data from Site 521 indicate that the base of the zone N13 should be revised and placed at an older horizon. It does seem as though we can trust the HO of *Sphenolithus heteromorphus* as marking the top of NN5, however.

Resedimentation became a major factor above the datum level of the LO of *Catinaster calyculus* at 437.6 m sub-bottom. The tentative calibration at Site 519 indicates that the FAD of the species should be at 8 to 9 m.y., and a straight line can be drawn to represent the average sediment accumulation rate from the seafloor to this datum level (Fig. 10). This line passes through the ranges of all the other inaccurately estimated datum levels (Fig. 10). The resulting average sedimentation rate of the upper two lithologic units (which reach a depth of $\approx$400 m sub-bottom) is about 50 m/m.y. This rate is three or four times the more common sedimentation rates of the late Neogene nannofossil oozes in the South Atlantic.

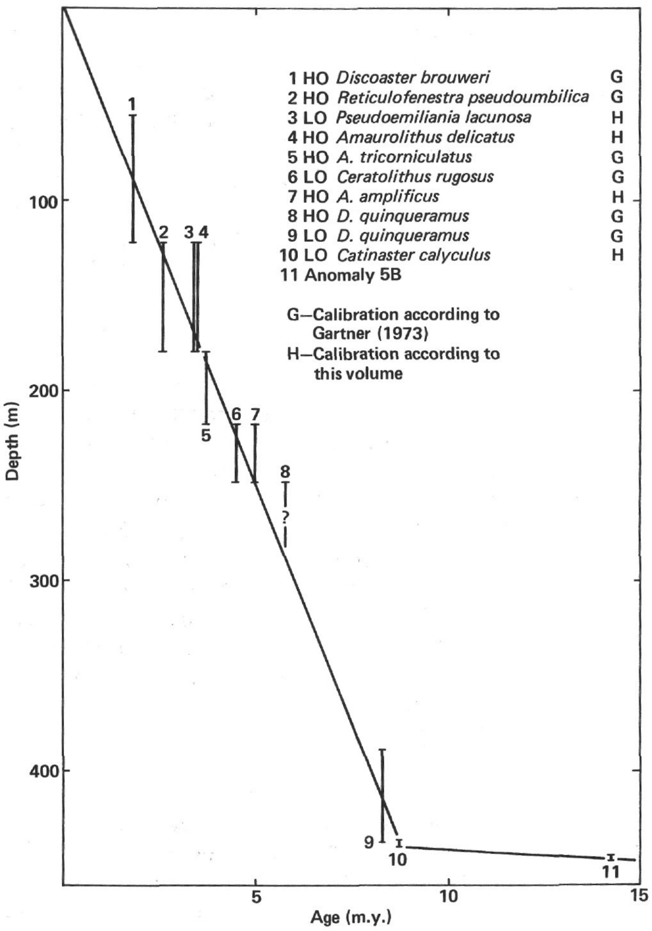

Figure 10. Summary of estimated sedimentation rates at Site 520. See text for explanation. LO = lowest occurrence, HO = highest occurrence.

The sediments below the LO of *C. calyculus* are mainly pelagic, and they were deposited at an average rate of 6.2 m/m.y. Departures from this average are suggested by the lithologic changes of the interbedded oozes, marls, and red clays.

Calcite Dissolution

The Pliocene–Quaternary oozes at this site show little effect of dissolution. The upper and middle Miocene pelagic sediments, however, are marly or diatomaceous. Random analyses of those samples indicate an insoluble-residue content that is variable and ranges commonly from 20 to 80%. The marly sediments are mainly resedimented nannofossil oozes that were deposited too rapidly to have undergone much dissolution. The diatomaceous sediments are either biogenic (diatom oozes, diatomites) or terrigenous (dark brown marls and red clays). Practically all of the samples examined contain identifiable nannofossils, although preservation is poor in sediments from the middle Miocene nannofossil zones. One sample in Core 29, which is late middle Miocene (12–14 m.y.) in age, is a hololytic red clay devoid of calcium carbonate, a composition that indicates that the CCD rose above the paleodepth of about 3600 m at the height of the dissolution crisis. Another red clay (2% $CaCO_3$; Core 23) is intercalated with diatomites of NN11, and its age should be somewhere between 8 and 6 m.y. The average rate of pelagic sedimentation during the middle Miocene at Site 520 (6.2 m/m.y.) falls within the range of late Miocene sedimentation rates at Site 519 (4.2–10.4 m/m.y.), a similarity that suggests that the degree of dissolution at these sites was about the same when the sites were at similar depths.

Paleoceanography

The discovery of diatomites in an open ocean environment distant from coastal, polar, and equatorial high-productivity belts was a surprise. A diatom flora is present in the Pliocene as well as the late Miocene sediments. The assemblage is composed predominantly of strongly silicified, solution-resistant species, *Ethmodiscus rex* being the most abundant diatom species. The diversity of the overall assemblage is not great; only about 30 species were observed. The most diverse flora is from the lower part of Lithologic Unit 2. The flora is comparable to the subtropical or tropical assemblage from the Walvis Ridge (Site 362) and is distinct from the Antarctic assemblage reported in the Argentine Basin (Sites 331 and 358; Gombos, this vol., "Late Neogene Diatoms").

The Pliocene *Ethmodiscus* oozes, like those found at Site 17, are intercalated in nannofossil oozes that are bioturbated and contain normal foraminiferal assemblages. The laminated diatomites in the lower half of this lithologic unit (Unit 1), which are greenish gray in color, show no evidence of bioturbation, however, nor do they contain a benthic microfauna. The faunal and sedimentological evidence indicate the absence of a benthic community in this basinal environment at the time when the diatomites were laid down.

The organic carbon content of the diatomites and associated sediments ranges from 0.14 to 0.36% (Herbin and Deroo, this vol.). This content is about an order of magnitude less than that in the sapropels of the South Atlantic. Much, if not all, of the organic material from siliceous or calcareous organisms seems to have oxidized before reaching the ocean bottom. However, the organic content is still an order of magnitude greater than that in most of the oceanic oozes sampled during the leg (it was 0.026–0.052% at Site 519, for example). The lack of bioturbation and of benthic fossils suggests an oxygen-poor, if not entirely anoxic, condition; thus, the organic matter that did settle on the basin floor was largely preserved. The hydrocarbon content per ton of rock (0.5 kg; Herbin and Deroo, this vol.) certainly would not make this sediment a good source of petroleum, but this content is still considerably greater than that of oozes deposited on well oxygenated ocean bottom.

Gombos (this vol., "Late Neogene Diatoms") believed that the occurrence of the diatomites was the result of favorable preservation in an unusual environment. Certainly the *Ethmodiscus* assemblage seems to be of the type that results from differential dissolution. Even the more diverse diatom assemblages in the diatomites consist mainly of solution-resistant species, and the assemblages are less diverse than those from the shallower Site 362 on the Walvis Ridge.

Differential preservation could also explain the absence of less resistant species; the valves of those taxa were easily dissolved as they sank downward through the deep water column. The more resistant skeletons, which managed to settle, landed on a basin floor where the CO_2-rich, stagnant bottom water mass was relatively low in pH and was thus favorable for the preservation of siliceous fossils. Preservation might be further enhanced because of rapid burial under thick layers of redeposited sediments. The same condition also may have preserved the organic matter that was deposited.

The position of the silica-corrosion zone in the uppermost kilometer of surface water places some constraints on the hypothesis of differential preservation in a basinal environment. Furthermore, such a hypothesis does not explain the rich Neogene diatom flora in the oozes deposited in the well oxygenated environments at Sites 17, 362, and 519.

Schrader (1978a) noted that nutrient-rich surface waters, which led directly to high diatom production at Site 362, first reached the Walvis Region some time during the late Miocene. The unusually high plankton fertility is also reflected by the very high sedimentation rate at this site during the time represented by the *Discoaster quinqueramus* zone (Bolli, Ryan, et al., 1978). Schrader (1978b) failed to find marine diatoms of late Miocene or Pliocene age at Sites 366 to 369 near the West African Coast. It seemed that the Pliocene–Miocene diatom blooms took place in the waters of the Benguela Current system, while the Canary Current did not yield sufficient nutrients for much diatom production.

The distribution of the Benguela Current is shown by Figure 11, which is based on a chart prepared by the U.S. Department of Navy. We note that not only Site 362 but also Sites 17, 519, and 520 lie under the Benguela Current. The sites on the west side of the ocean lie beneath the Brazil Current. The late Neogene sediments there have either no diatom floras (Sites 15, 16, 21, and 355–357) or they have allochthonous floras transported there by the AABW (Sites 331 and 358).

Small diatoms, such as the 70-μm *Coscinodiscus* spp., which have a settling velocity of about 15 m/day, could have been transported for a distance of about 3000 km if the Benguela Current had a depth of 500 m and a speed of 1 m/s. On the other hand, *E. rex* has a settling velocity of about 500 m/day (Berger, 1976), and the transport distance of millimeter-sized diatoms like it could not be more than 100 km even if we assume that the Pliocene–Miocene Benguela Current was very strong. Since *E. rex* is either abundant or the dominant species in all the flora samples, these diatoms must have been indigenous to surface waters not very distant from Site 520. The only other possibility is that the diatoms bloomed in upwelling coastal waters and subsequently lived and floated in the current for several weeks before they died and started their downward journey; however, this possibility is considered highly unlikely.

The calcite dissolution history has not been systematically investigated at this site. The *Nuttalides umbonifera* fauna first became dominant during the time represented by the interval from 438 to 398 m sub-bottom (Core 29, Section 2 to Core 26), or between 8 and 14 m.y. ago. The first appearance was earlier than that at Site 519, probably because this site, with its older crust, subsided to a water depth of 3400 m at a much earlier time (13.5 m.y. vs. 6 m.y.). It is below this depth today that the AABW fauna thrives. Intense calcite dissolution may have preceded the arrival of the fauna, because the nannofossils are poorly preserved even in the oldest sediment at this site. The high fertility during the late Miocene and Pliocene, as indicated by the diatom blooms, did not seem to have led to the excessive production of calcareous planktons in the South Atlantic. The preservation of the calcareous sediments of NN11 age at this site is related to their fast burial, while the regional CCD remained high, as indicated by studies of dissolution at other South Atlantic sites.

Seafloor Spreading and Basement Age

Site 520 was positioned over a negative anomaly just west of Anomaly 5B and should be about 14.3 m.y. old. The nannofossils in the oldest sediment belong to the zone NN5, which has been given an age of 14.7 to 16.2 m.y. (Bolli, Ryan, et al., 1978, p. 14). However, a calibration with reference to magnetostratigraphy at Site 521 indicates that the top of NN5 is appreciably younger than 14.7 m.y., or the age of the top of Chron C-5B. The middle portion of the NN5 sediments is correlated to Chron C-5B at both sites. The 14.3 m.y. age for the basement is thus in agreement with our new calibration. The basalt at the sediment/basement contact is reversely magnetized, as predicted.

Inasmuch as the age of Anomaly 5B is that predicted on the basis of a linear rate of seafloor spreading, our results negate the hypothesis that seafloor spreading slowed or ceased during the middle Miocene in the South Atlantic, a hypothesis advanced by several previous investigators (e.g., Hsü and Andrews, in Maxwell et al., 1970).

The basement is covered by a thin layer of transported basalt rubble. The top is a pillow basalt unit, which has a very narrow range of composition, texture, and degree of alteration. The chemistry of the basalt is typical of mid-ocean-ridge basalts (Dietrich et al., this vol.).

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Date of Initial Receipt: August 12, 1982

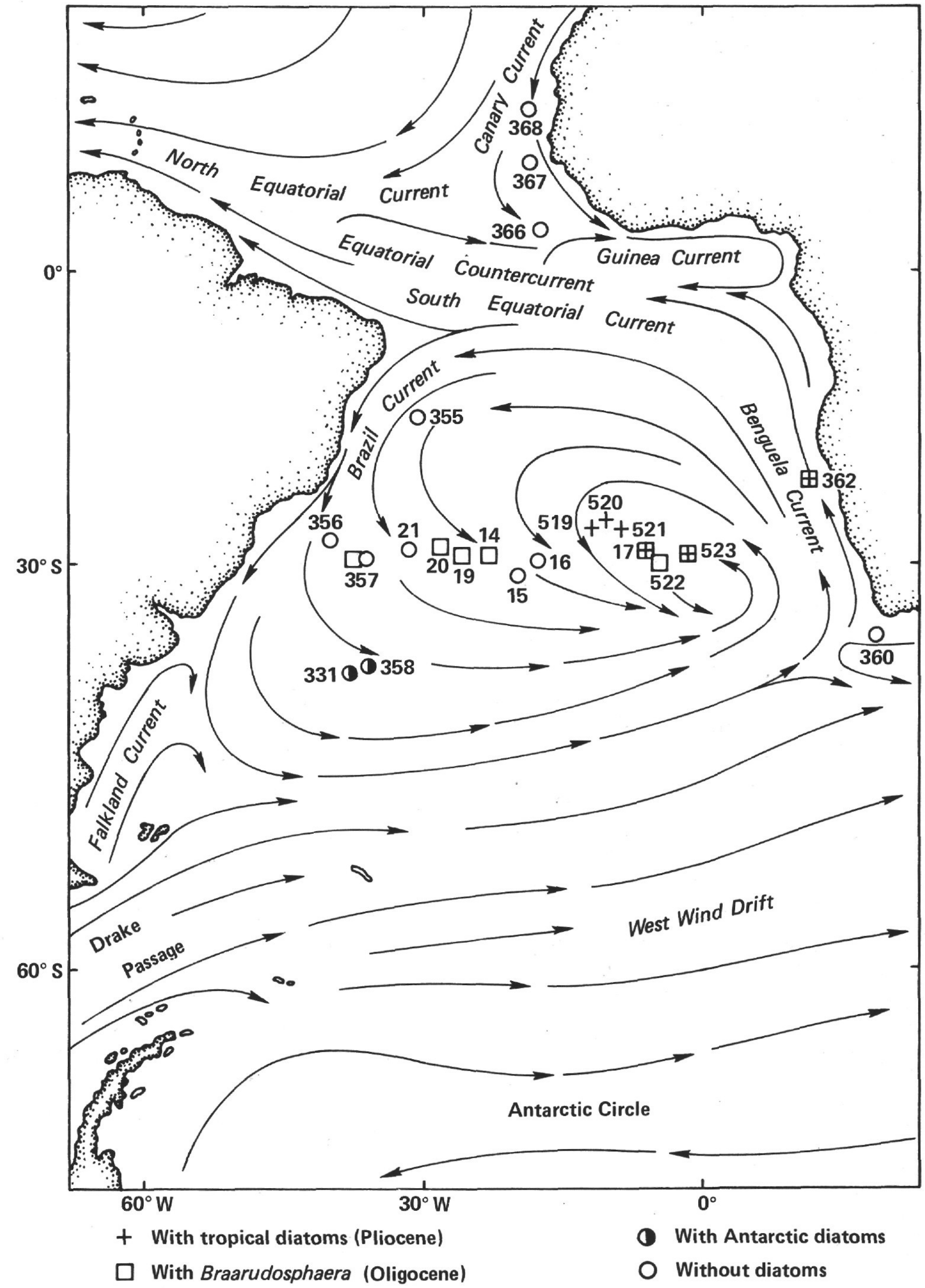


Figure 11. Distribution of the Pliocene diatoms and the Oligocene *Braarudosphaera* chalk in the South Atlantic and their relation to the present day Benguela Current system.

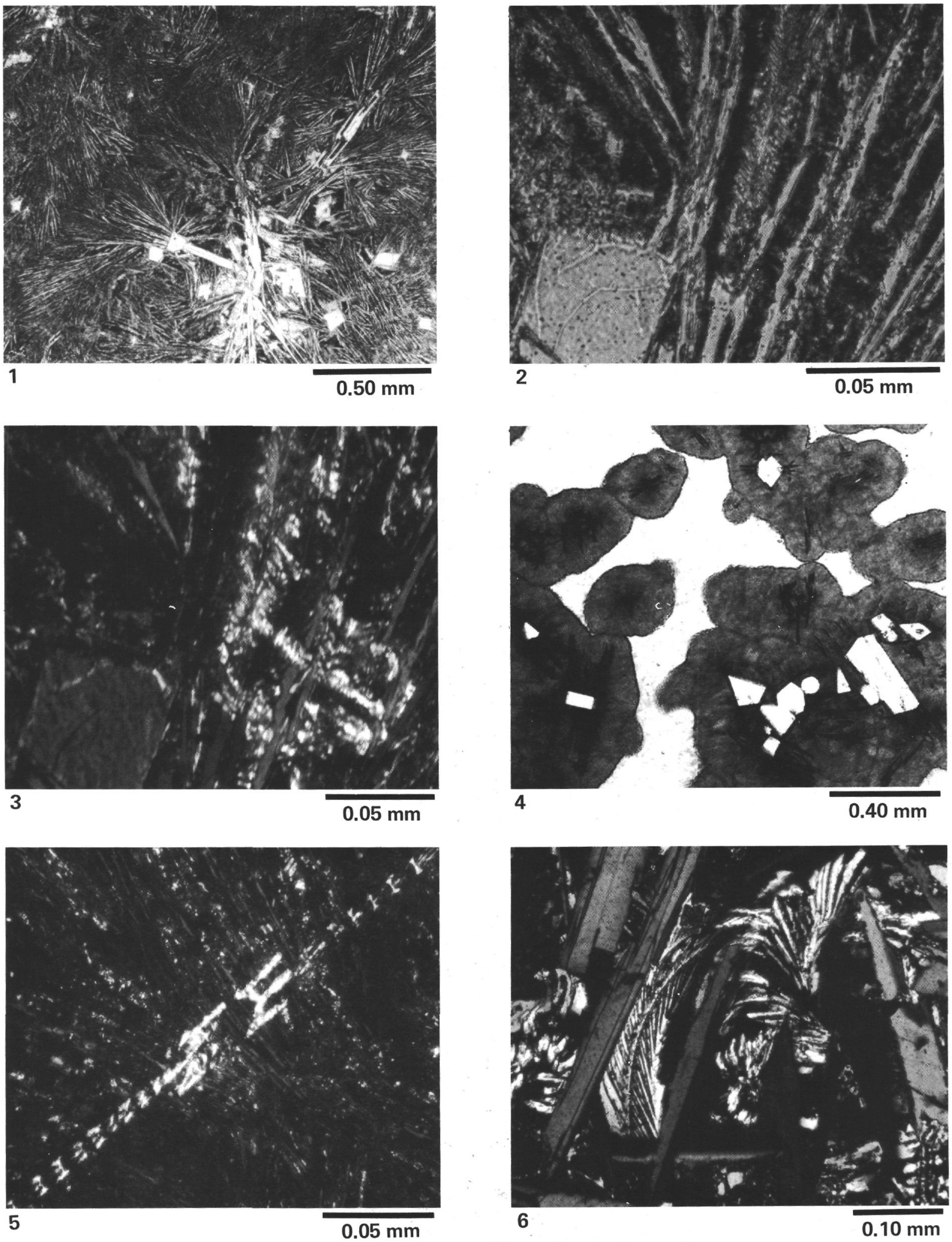


Plate 1. Photomicrographs of basalts, Site 520. **1.** Fine quench texture with variolitic structure consisting of radiating plagioclase fibers, many centered on an equant euhedrual olivine microphenocryst. Sparse elongated dark areas are spherules composed chiefly of augite dendrites. Sample 520-30-1, 89–95 cm (Piece 5), 2 cm from glassy zone. Plane light. **2.** Detail of variole, showing equant olivine core, plagioclase fibers, and very finely dendritic augite. Same sample as Fig. 1. Plane light. **3.** Same as Fig. 2 under crossed polarizers to accentuate augite dendrites (white). **4.** Spherulitic structure in glassy zone, with subequant euhedral olivine microphenocrysts. Same sample as Fig. 1. Plane light. **5.** Chain link olivine in mesostasis of plagioclase fibers and augite dendrites in variolitic zone. Same as Fig. 4. Crossed nichols. **6.** Curved coarse augite dendrites in coarse quench texture. Sample 520-31-1, 6–8 cm (Piece 1a). Crossed nichols.

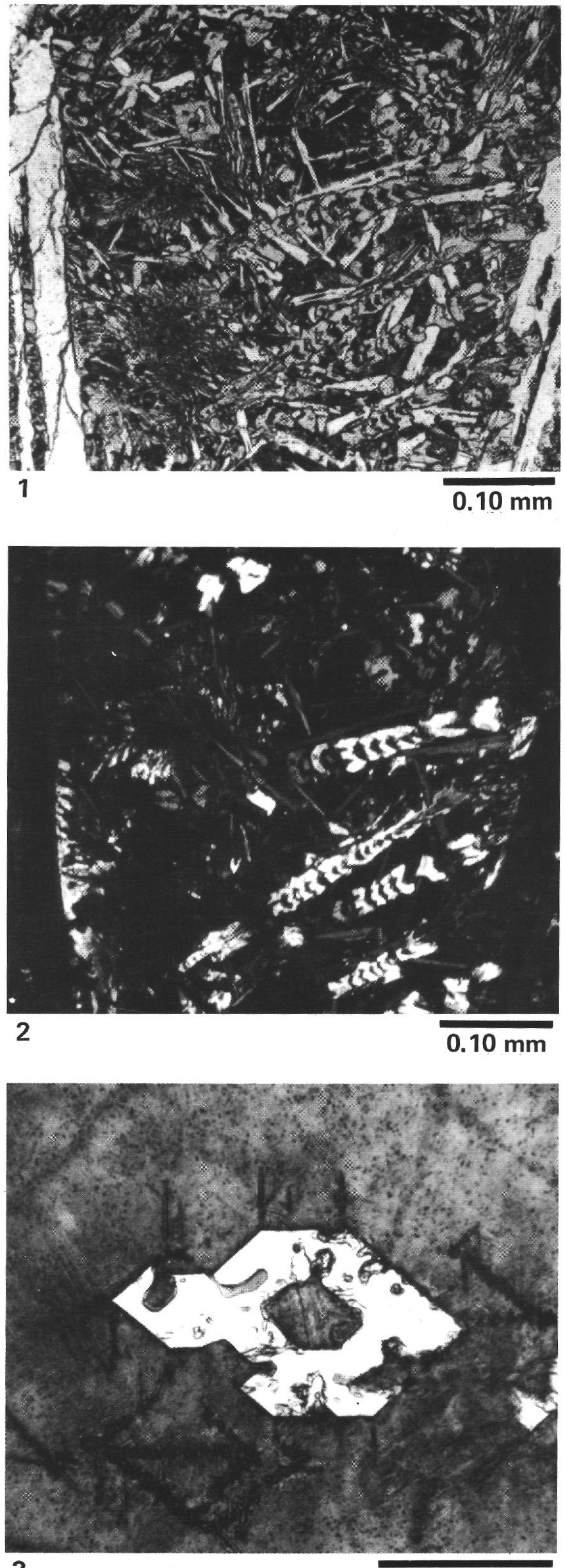


Plate 2. Photomicrographs of basalts, Site 520. **1.** Chain link augite in coarse quench texture. Same sample as Pl. 1, Fig. 6. Plane light. **2.** Same as Fig. 1. Crossed nichols. **3.** Resorbed(?) olivine microphenocryst. Same sample as Pl. 1, Fig. 1. Plane light.

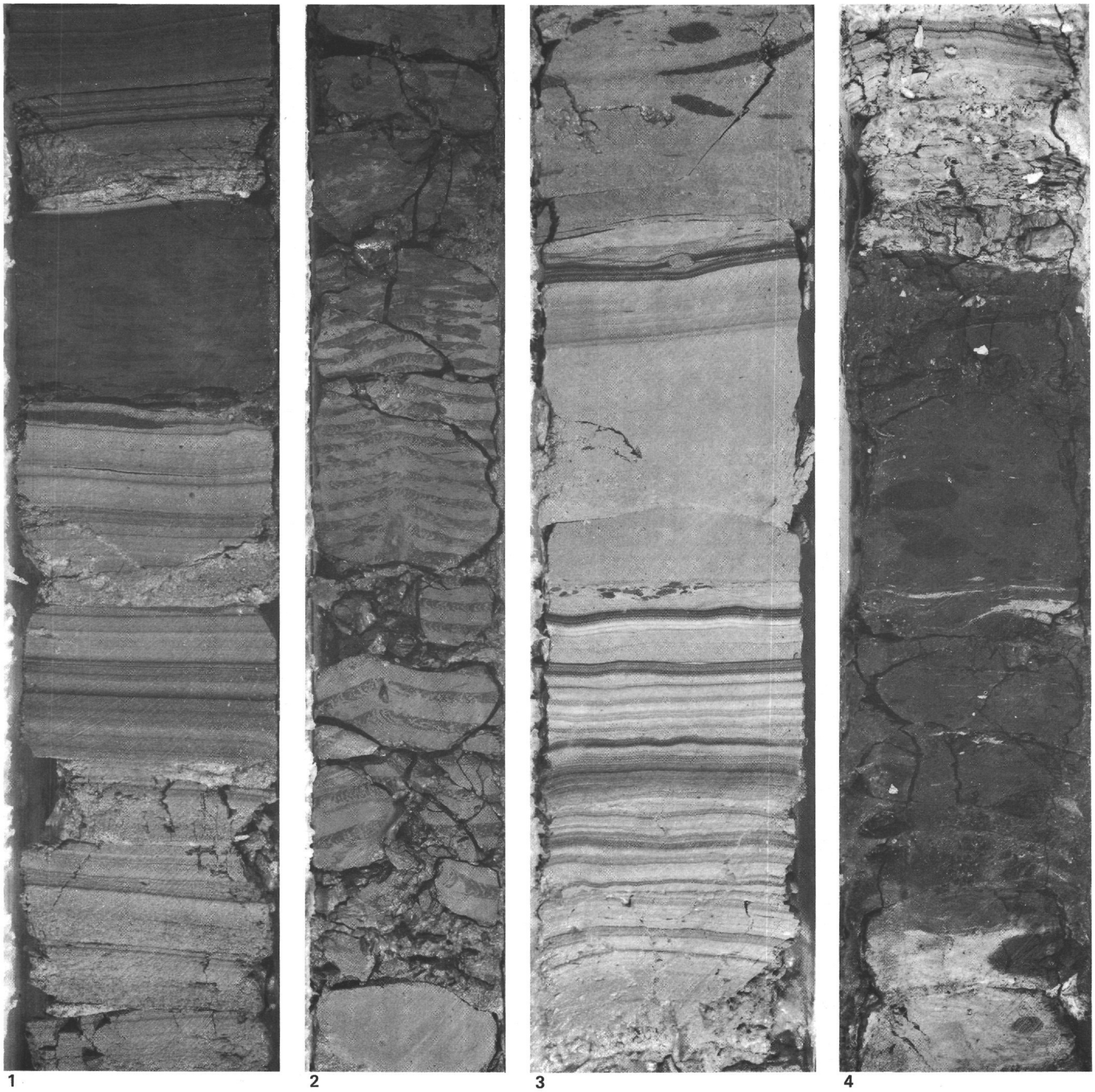


Plate 3. Sedimentary structures in sediments of Lithologic Unit 2, Site 520. **1.** Laminated diatomite. **2.** Bioturbated ooze. **3.** Laminated diatomite, overlain by bioturbated ooze. **4.** Bioturbated ooze.

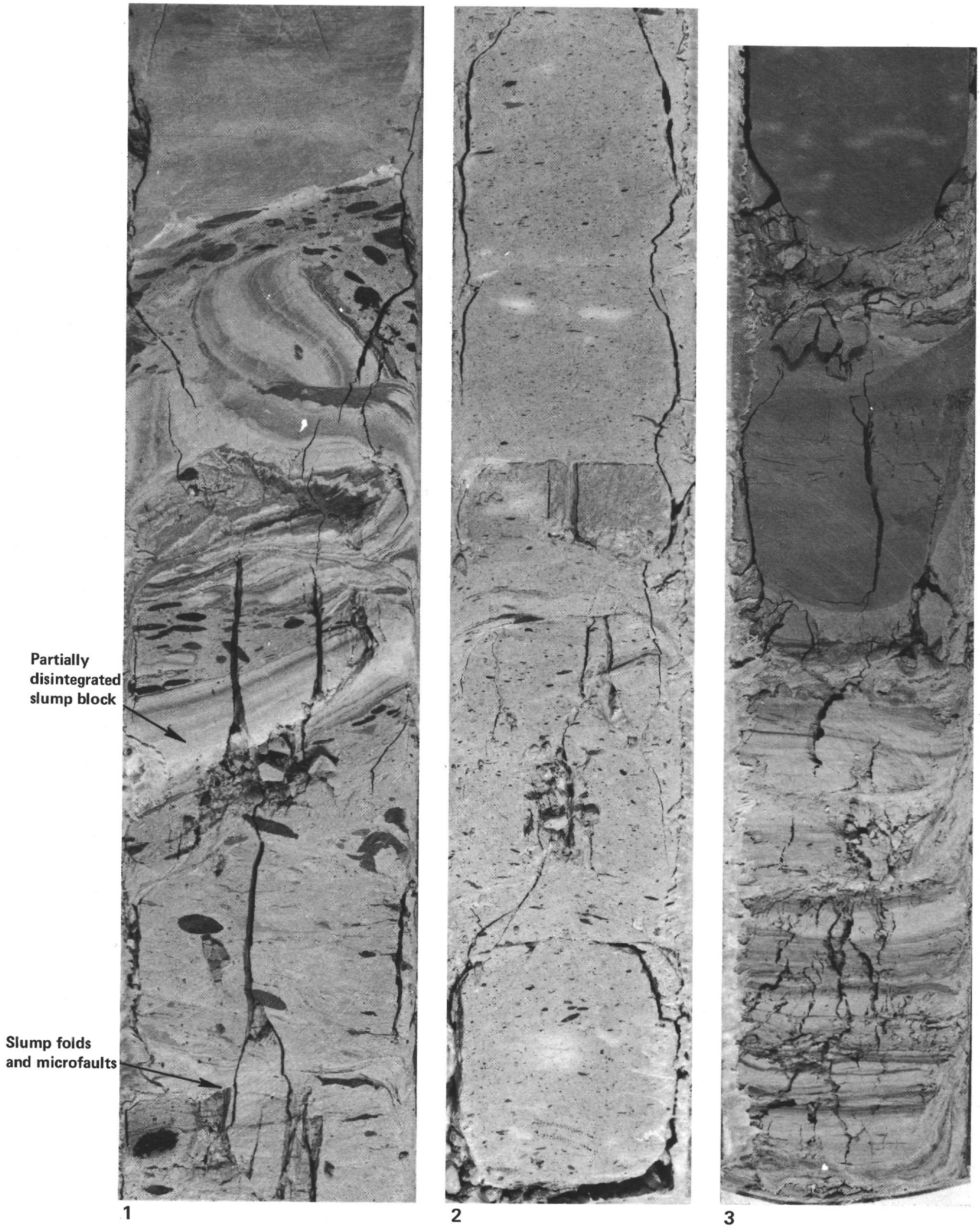
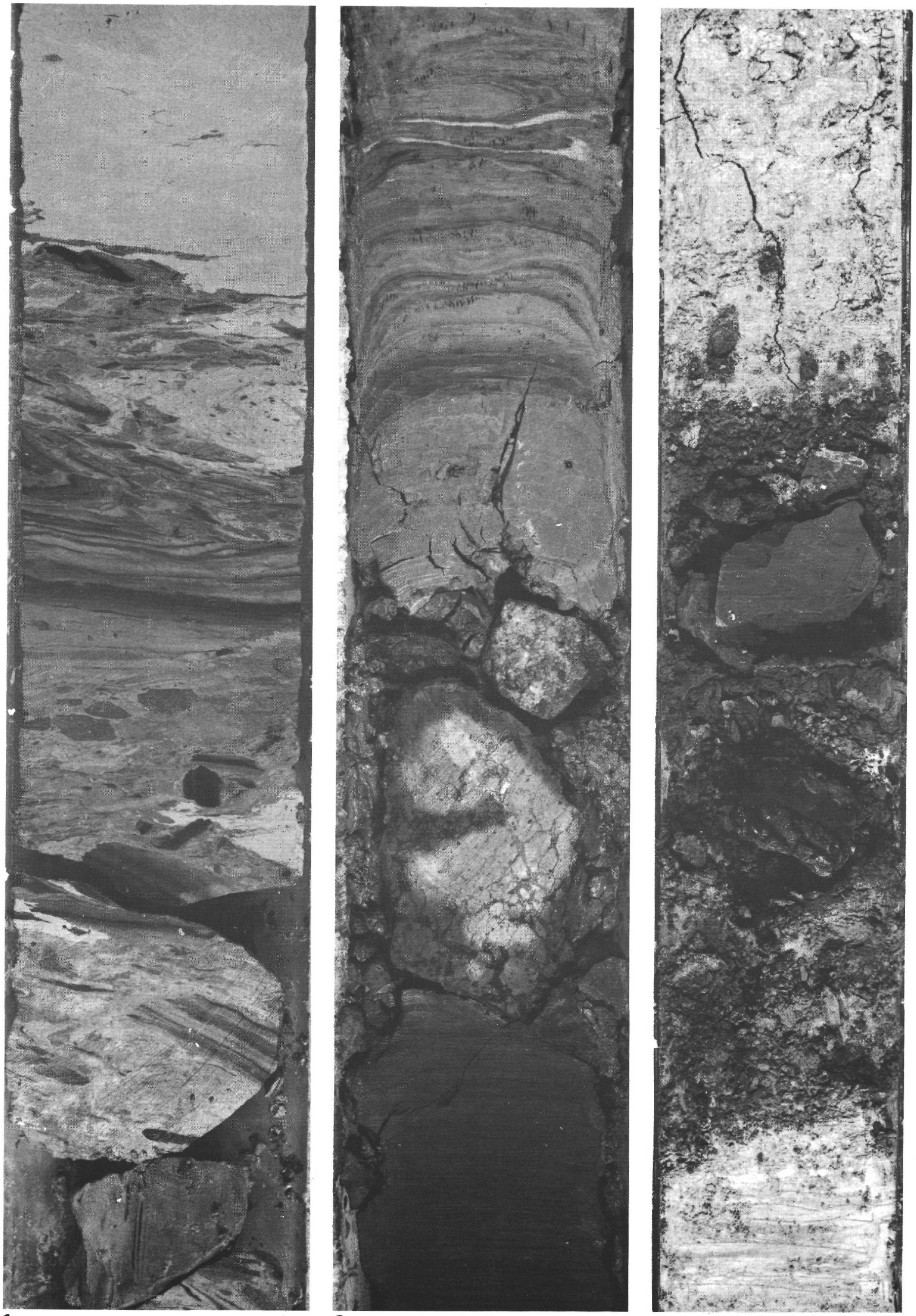


Plate 4. Typical succession of sediment types and structures in slump deposits at Site 520. See text and Fig. 9 for further explanation. **1.** Division a, slump deposit with slump folds and microfault. Division b, slump deposit with partially disintegrated block embedded in mud-pebble ooze. **2.** Division c, slump deposit, mud-pebble ooze. **3.** Division d, slump deposit, homogenized ooze.

Plate 5. Turbidite beds between laminated diatomite layers.



1 2 3

Plate 6. Exotic pebbles in resedimented ooze, Hole 520. **1.** Section 17-2, 25–51 cm. **2.** Section 29-1, 90–120 cm. **3.** Section 15-2, 9–46 cm.

SITE 520 HOLE CORE 1 CORED INTERVAL 0.0–6.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	MAGNETIC POLARITY	LITHOLOGIC DESCRIPTION
Quaternary	NN19 (N)						CC							Trace of very pale brown (10YR 8/3) NANNOFOSSIL OOZE in Core-Catcher. **NOTE: Core 2, 56.5–66.0 m: No core recovered. Core lodged in collapsed liner in core barrel.**

SITE 520 HOLE CORE 3 CORED INTERVAL 113.5–123.0 m

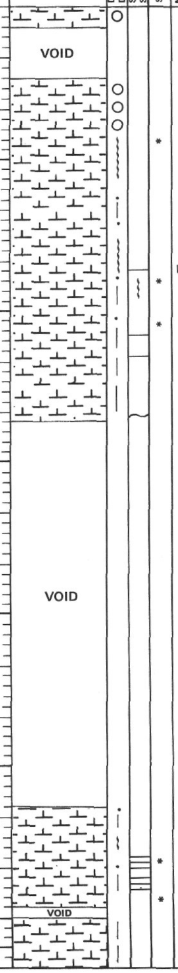
TIME – ROCK UNIT: upper Pliocene

BIOSTRATIGRAPHIC ZONE: N21 (F), NN16 (N)

FOSSIL CHARACTER: FORAMINIFERS CG; BENTHIC FORAMINIFERS CG

SECTION: 1, 2, 3, 4, 5, 6, 7, CC

METERS: 0.5, 1.0



very pale brown

white layer

very pale brown

white layer

grades to white

alternating brown and white

very pale brown

dark brown wavy layer

very pale brown

gray-white cycles

mottled light gray and white

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very pale brown (10YR 7/3–8/3) and white (5YR 8/1) to light gray (5YR 7/1). *Colors vary as shown. Sharp color changes* in Sections 2, 3, and 6. Section 6 contains approximately 5 cycles of white grading to light gray (top) sequence; contacts are sharp and centers of intervals appear burrowed. Foraminifers average approximately 1–2% in ooze. Section 1 disturbed by drilling.

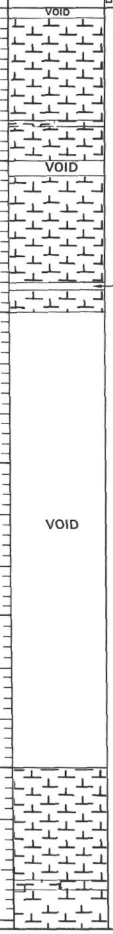
SMEAR SLIDE SUMMARY

	1-130 D	2-128 D	3-20 D	6-98 D	6-130 D
TEXTURE:					
Sand	5	10	4	5	5
Silt	93	90	96	95	92
Clay	2	–	–	–	3
COMPOSITION:					
Carbonate unspec.	1	–	–	–	1
Foraminifers	5	8	4	5	6
Calc. nannofossils	93	90	96	95	91
Diatoms	1	2	TR	TR	2
Iron-oxides	–	TR	–	–	–

SITE 520 HOLE CORE 4 CORED INTERVAL 170.5–180.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
lower Pliocene	NN15 (N)			RP	AP		1	0.5, 1.0
				RP	AP			
							2	
							3	
							4	
							5	
		FM				FM	6	
				RP	AP		CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY

LITHOLOGIC DESCRIPTION

mainly alternating white and very pale brown

diatom layer

white ooze

very pale brown

light gray

VOID

very pale brown

white

NANNOFOSSIL OOZE, variable colors – pale yellow (5Y 8/4), white (10YR 8/1), light gray (2.5Y 7/2), very pale brown (10YR 7/3) as shown. Sharp color changes and alternations common in Sections 1 and 2. Light gray diatom-rich layer occurs in Section 1. Similar colored interval in Section 2 (approximately 70–90 cm) contains only few diatoms. Section 6 is mainly very pale brown nannofossil ooze terminated at about 110 cm by a graded nannofossil foraminifer ooze. Subjacent nannofossil ooze is white.

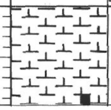
SMEAR SLIDE SUMMARY

	1-114	1-123	2-78	2-83	6-115
	M	M	D	M	M
TEXTURE:					
Sand	–	–	1	2	30
Silt	100	100	95	100	70
Clay	–	–	4	–	–
COMPOSITION:					
Carbonate unspec.	1	5	2	1	–
Foraminifers	–	TR	TR	–	30
Calc. nannofossils	40	95	96	99	70
Diatoms	60	–	2	TR	–
Radiolarians	–	–	TR	–	–

SITE 520 HOLE CORE 5 CORED INTERVAL 218.0–227.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
lower Pliocene	N19 (F) NN14 (N)	RM				B	1	0.5
					RP	FP		

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY

LITHOLOGIC DESCRIPTION

very pale brown

white

basalt pebble

NANNOFOSSIL OOZE, very pale brown (10YR 7/3) changing abruptly to white (10YR 8/2) at 74 cm. Distinct color variations in white interval between 74–84 cm (10YR 8/2–8/1); sharp contacts between these shades of white. Slightly weathered, vesicular basalt pebble at base of section.

SMEAR SLIDE SUMMARY

	1-70	1-76	1-95
	D	D	D
TEXTURE:			
Sand	–	–	–
Silt	95	95	90
Clay	5	5	10
COMPOSITION:			
Quartz	TR	TR	TR
Clay	TR	TR	5
Carbonate unspec.	–	5	5
Foraminifers	5	5	10
Calc. nannofossils	95	90	80
Diatoms	TR	–	TR

SITE 520 HOLE CORE 6 CORED INTERVAL 227.5–237.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
lower Pliocene	NN14 (N)	FP		CP	AP	B	CC	

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY

LITHOLOGIC DESCRIPTION

Trace of white to light gray NANNOFOSSIL OOZE in Core-Catcher.

NOTE: Core 7, 237.0–246.5 m: No recovery.

SITE 520 HOLE CORE 8 CORED INTERVAL 246.5–256.0 m

TIME – ROCK UNIT: Miocene

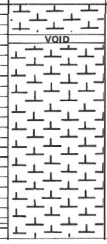
BIOSTRATIGRAPHIC ZONE: NN12 (N); NN11 (N)

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS; RADIOLARIANS: RP; DIATOMS: AP; BENTHIC FORAMINIFERS

SECTION: 1, 2, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY

white

sharp color changes

light gray

white

sharp color changes

light gray

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (5Y 8/1–8/2) to light gray (5Y 7/2), homogeneous except for sharp color changes at 108–120 cm, Section 1 and 40–57 cm, Section 2 as shown. Core becoming stiff and hard below 100 cm, Section 1. Single burrow noted between 40–55 cm, Section 2. Diatoms become more abundant near base of core and in Core-Catcher; light gray color sometimes is an indication.

SMEAR SLIDE SUMMARY

	1-90	1-145	2-46	2-59	CC, 10
	D	D	D	D	M
TEXTURE:					
Sand	–	–	–	–	–
Silt	80	90	80	80	80
Clay	20	10	20	20	20
COMPOSITION:					
Quartz	TR	TR	TR	TR	TR
Clay	5	TR	5	5	TR
Volcanic glass	–	–	–	TR	–
Pyrite	–	TR	TR	–	–
Carbonate unspec.	5	10	5	10	5
Calc. nannofossils	80	85	80	70	75
Diatoms	10	5	10	10	20
Sponge spicules	–	TR	TR	5	TR

ORGANIC CARBON AND CARBONATE

	CC
Organic carbon	–
Carbonate	85

SITE 520 HOLE CORE 9 CORED INTERVAL 256.0–265.5 m

TIME – ROCK UNIT: Miocene

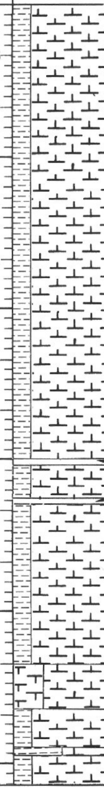
BIOSTRATIGRAPHIC ZONE: NN19 (F); NN11 (N)

FOSSIL CHARACTER: FORAMINIFERS: FM; NANNOFOSSILS; RADIOLARIANS: RP; DIATOMS: AP; BENTHIC FORAMINIFERS: FM

SECTION: 1, 2, 3, 4, 5, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY

IW

pale yellow

very pale brown

pale brown

VOID

brown and yellow

dark brown

alternating yellow, brown, dark brown and very pale brown

LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL OOZE, pale yellow (5Y 7/3) and very pale brown (10YR 7/3) changing down core to pale brown (10YR 6/3). Color changes again in Section 5 to alternating shades of yellow (10YR 7/6), brown (10YR 5/3) and dark brown (iron-oxides?) (10YR 3/3). Deformed (drilling) graded foraminifer-nannofossil ooze occurs in Section 5, approximately 65–95 cm; brown and yellow ooze below is burrowed. Core may be burrowed throughout but drilling disturbance obscures. Core-Catcher contains layers of white and gray (5Y 6/1) nannofossil ooze with scattered, dark iron-rich particles.

SMEAR SLIDE SUMMARY

	1-5	1-37	1-145	2-139	5-140
	D	D	D	D	M
TEXTURE:					
Sand	–	–	–	–	–
Silt	80	80	80	80	70
Clay	20	20	20	20	30
COMPOSITION:					
Quartz	TR	TR	TR	5	TR
Clay	TR	–	TR	TR	10
Volcanic glass	TR	TR	–	2	5?
Palagonite	–	.5?	10?	3	5?
Micronodules	–	–	5	5	5
Carbonate unspec.	10	10	10	10	5
Foraminifers	–	5	–	5	TR
Calc. nannofossils	85	80	75	70	50
Diatoms	5	–	–	–	TR
Sponge spicules	–	TR	TR	TR	–
Iron-oxides	–	–	TR	TR	10

ORGANIC CARBON AND CARBONATE

	1-138	2-138	3-138	4-130
Organic carbon	–	–	–	–
Carbonate	81	81	81	81

	5-120	5-140	5-146
Organic carbon	–	–	–
Carbonate	73	45	77

SITE 520 HOLE CORE 10 CORED INTERVAL 265.5–275.0 m

TIME – ROCK UNIT: Miocene
BIOSTRATIGRAPHIC ZONE: NN11 (N)
FOSSIL CHARACTER: Radiolarians RP; Diatoms AP, AP
SECTION: 1, CC
GRAPHIC LITHOLOGY: VOID

Colors: very pale brown; light gray

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very pale brown (10YR 8/3) changing to light gray NANNOFOSSIL DIATOM OOZE at 35 cm. No sedimentary structures noted.

SMEAR SLIDE SUMMARY

	1-35
	D
TEXTURE:	
Sand	–
Silt	100
Clay	–
COMPOSITION:	
Carbonate unspec.	3
Foraminifers	90
Diatoms	7

ORGANIC CARBON AND CARBONATE

	1-36
Organic carbon	–
Carbonate	31

SITE 520 HOLE CORE 11 CORED INTERVAL 275.0–284.5 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: N15–17 (F), NN11 (N)
FOSSIL CHARACTER: Foraminifers FM; Diatoms AP; Benthic foraminifers CM
SECTION: 1, 2, 3, 4, CC
METERS: 0.5, 1.0

Colors: brown; VOID; light yellowish brown and brown; dark yellowish brown

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, brown (7.5YR 5/4) and light yellowish brown (10YR 6/4) changing down core to yellowish brown (10YR 5/4) and dark yellowish brown MARLY NANNOFOSSIL OOZE. Ooze is mostly homogeneous with some burrowed zones. Ooze is becoming stiff. Structures obliterated by core splitting process. Dark brown patches scattered throughout appear to be more intensely burrowed.

SMEAR SLIDE SUMMARY

	2-145
	D
TEXTURE:	
Sand	TR
Silt	70
Clay	30
COMPOSITION:	
Clay	20
Micronodules	1
Carbonate unspec.	TR
Foraminifers	TR
Calc. nannofossils	88

ORGANIC CARBON AND CARBONATE

	1-35	2-35	3-35	4-35
Organic carbon	–	–	–	–
Carbonate	86	91	73	61

SITE 520 HOLE CORE 12 CORED INTERVAL 284.5–294.0 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: NN11 (N)
FOSSIL CHARACTER: Foraminifers RM; Radiolarians CP, CP; Diatoms AP, AP, AP; Benthic foraminifers B
SECTION: 1, 2, CC
METERS: 0.5, 1.0
SAMPLES: IW

Colors: light yellow brown; white; very pale brown; white; light gray; very pale brown; brownish yellow; light gray

LITHOLOGIC DESCRIPTION

DIATOM NANNOFOSSIL OOZE, light yellowish brown (10YR 6/4) and very pale brown (10YR 7/4) alternating with white (10YR 8/1) and light gray (10YR 7/1) NANNOFOSSIL DIATOM OOZE. Color changes between white or light gray and brown are generally sharp. No burrows noted. Core becoming stiff.

SMEAR SLIDE SUMMARY

	1-44	1-120	2-29
	D	D	D
TEXTURE:			
Sand	TR	1	1
Silt	100	89	92
Clay	–	10	7
COMPOSITION:			
Clay	TR	–	3
Volcanic glass	–	TR	TR
Palagonite	–	TR	–
Micronodules	–	TR	–
Carbonate unspec.	–	–	2
Foraminifers	–	TR	TR
Calc. nannofossils	70	96	60
Diatoms	30	3	30
Radiolarians	–	–	TR
Sponge spicules	–	–	TR

ORGANIC CARBON AND CARBONATE

	1-45	1-106	2-30
Organic carbon	–	–	–
Carbonate	27	61	36

SITE 520 HOLE CORE 13 CORED INTERVAL 294.0–299.0 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: NN11 (N)
FOSSIL CHARACTER: Radiolarians CP; Diatoms AP; Benthic foraminifers B
SECTION: 1, CC

LITHOLOGIC DESCRIPTION

Drilling breccia of pale yellow (5Y 7/3) and light gray (10YR 7/1) NANNOFOSSIL MARL.

SMEAR SLIDE SUMMARY

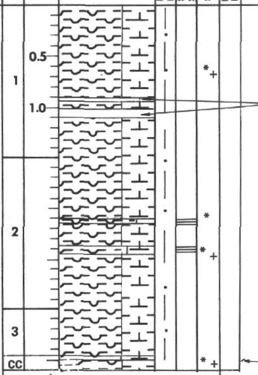
	1-2
	D
TEXTURE:	
Sand	–
Silt	90
Clay	10
COMPOSITION:	
Clay	10
Calc. nannofossils	90
Diatoms	TR
Iron-oxides	TR

SITE 520 HOLE CORE 14 CORED INTERVAL 299.0–303.5 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: NN11 (N)

FOSSIL CHARACTER: Section 1: Radiolarians R, Diatoms AP; Section 2: Radiolarians R, Diatoms AP; Section 3: Diatoms AP



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-DIATOM OOZE, gray (5Y 6/1–5/1) alternating with very dark gray (5Y 3/1) and black (5Y 2/1) (pyrite-rich). Splitting of stiff core obscures many structures, but color variations and diatom-rich intervals suggest laminations throughout. Core-Catcher contains dark olive gray (5Y 3/2) DIATOM NANNOFOSSIL CLAY at its base; color contrast with overlying ooze is sharp.

SMEAR SLIDE SUMMARY

	1-63 D	2-60 M	2-95 D	CC, 10 M
TEXTURE:				
Sand	TR	TR	–	3
Silt	95	90	90	37
Clay	5	10	10	60
COMPOSITION:				
Clay	5	2	10	60
Volcanic glass	TR	–	TR	2
Pyrite	–	5	2	TR
Micronodules	TR	–	–	TR
Foraminifers	1	–	–	–
Calc. nannofossils	50	13	75	33
Diatoms	45	80	15	5
Radiolarians	–	TR	TR	–
Sponge spicules	TR	TR	TR	TR

ORGANIC CARBON AND CARBONATE

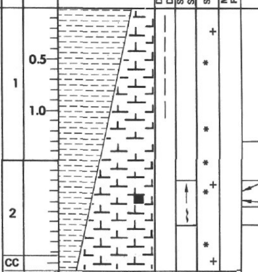
	1-67	2-91	CC, 13
Organic carbon	–	–	–
Carbonate	28	76	24

SITE 520 HOLE CORE 15 CORED INTERVAL 303.5–313.0 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: N15–17 (F) NN11 (N)

FOSSIL CHARACTER: Section 1: Radiolarians R, Diatoms AP; Section 2: Radiolarians R, Diatoms AP; CC: Foraminifers RM, Radiolarians RP, Diatoms AP, Benthic foraminifers RM



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAY, dark gray (5Y 4/1) and very dark gray (5Y 3/1) grading down core to gray (5Y 6/1). Then finally pale olive NANNOFOSSIL OOZE/MARL at base Section 1, top Section 2. Section 2, 20–40 cm, is olive (5Y 4/4) NANNOFOSSIL OOZE and contains an altered (palagonite?) fragment of basaltic glass. A gray MARLY NANNOFOSSIL OOZE follows grading to yellow. Burrows common in Section 2, 20–40 cm. Core partially lithified; notable carbonate recrystalization in lithified zones (e.g. discoaster overgrowths, etc.).

SMEAR SLIDE SUMMARY

	1-50 D	1-120 D	2-5 D	2-36 D	2-87 D
TEXTURE:					
Sand	–	–	5	–	–
Silt	40	80	60	40	70
Clay	60	20	35	60	30
COMPOSITION:					
Clay	60	20	35	60	30
Volcanic glass	–	TR	1	–	TR
Carbonate unspec.	TR	20	25	15	30
Foraminifers	TR	–	5	TR	–
Calc. nannofossils	25	40	30	25	35
Diatoms	25	20	5	–	5
Sponge spicules	TR	–	–	–	–
Iron-oxides	–	–	–	TR	–

ORGANIC CARBON AND CARBONATE

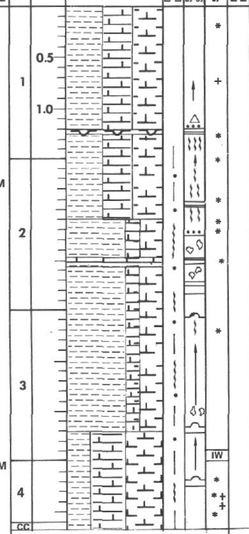
	1-20	2-22	CC
Organic carbon	–	–	–
Carbonate	24	32	71

SITE 520 HOLE CORE 16 CORED INTERVAL 313.0–322.5 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: N15–17 (F) NN11 (N)

FOSSIL CHARACTER: Section 1–2: Diatoms RP, Benthic foraminifers RM; Section 2: Diatoms RP; Section 3: Diatoms AP; Section 4: Foraminifers CM, Diatoms B, Benthic foraminifers CM; Diatoms AP



LITHOLOGIC DESCRIPTION

Interbedded CALCAREOUS (NANNOFOSSIL) MARL and *CALCAREOUS (NANNOFOSSIL)* CLAYSTONE. MARL is light gray (2.5Y 7/2), pale yellow (5Y 7/4) and yellowish brown (10YR 5/4) and burrowed in parts. Upper 120 cm of marl in Section 1 appears graded; it overlies pyrite-rich diatom layer. Subjacent marl is pale yellow and burrowed. From approximately 72 cm, Section 2 to approximately 30 cm, Section 4 is a sequence of mixed yellow brown and dark brown CALCAREOUS CLAYSTONE with abundant slump folds and occasional laminated chalk intercalations. Sediment changes to homogeneous MARL in Section 4; coccoliths show effects of dissolution and secondary overgrowths.

SMEAR SLIDE SUMMARY

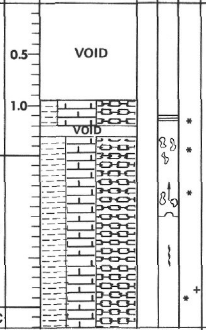
	1-20 D	2-65 D	2-73 D	3-28 M	4-32 D
TEXTURE:					
Sand	–	–	–	–	–
Silt	20	60	50	50	65
Clay	80	40	50	50	35
COMPOSITION:					
Quartz	TR	5	5	–	5
Clay	10	20	20	15	40
Volcanic glass	–	10	10	5	10
Palagonite	–	5	–	–	5
Micronodules	–	5	10	20	[illegible]
Carbonate unspec.	70	20	10	20	25
Calc. nannofossils	20	25	20	15	–
Diatoms	–	–	TR	25	–
Sponge spicules	–	–	–	TR	–
Iron-oxides	–	10	25	–	10

ORGANIC CARBON AND CARBONATE

	1-74	4-31	4-41
Organic carbon	–	–	–
Carbonate	75	27	75

SITE 520 HOLE CORE 17 CORED INTERVAL 322.5–332.0 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: N15–17 (F) NN11 (N)
FOSSIL CHARACTER: FORAMINIFERS RM; RADIOLARIANS R; DIATOMS AP; BENTHIC FORAMINIFERS B
SECTION: 1, 2, CC



LITHOLOGIC DESCRIPTION

CLAYEY CALCAREOUS (NANNOFOSSIL) MARL, very pale brown (10YR 7/4) to pale yellow (5Y 7/3) in Section 1. Base Section 1 to top 50 cm, Section 2 is slumped MARL with dark muddy clasts set in light olive gray (5Y 6/3) MARL; long axes of clasts parallel to bedding. Several dark gray diatom layers noted in slumped intervals. Several dark clasts in slump are laminated.

SMEAR SLIDE SUMMARY

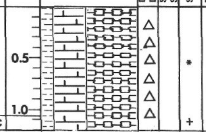
	1-120 M	1-149 M	2-36 D	2-140 D
TEXTURE:				
Sand	–	–	–	–
Silt	60	40	70	50
Clay	40	60	30	50
COMPOSITION:				
Quartz	TR	5	5	TR
Clay	10	10	30	25
Volcanic glass	TR	10	15	5
Micronodules	5	10	5	5
Carbonate unspec.	40	15	10	30
Calc. nannofossils	35	10	20	35
Diatoms	10	40	20	TR
Sponge spicules	TR	TR	TR	TR
Fish remains	–	–	5	TR

ORGANIC CARBON AND CARBONATE

	2-130
Organic carbon	–
Carbonate	72

SITE 520 HOLE CORE 18 CORED INTERVAL 332.0–336.5 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: N15–17 (F) NN11 (N)
FOSSIL CHARACTER: FORAMINIFERS CM; RADIOLARIANS R; DIATOMS AP; BENTHIC FORAMINIFERS FM
SECTION: 1, CC



LITHOLOGIC DESCRIPTION

Drilling breccia of light gray (5Y 7/2) MARL. Several fragments are laminated; others are a darker, olive color.

SMEAR SLIDE SUMMARY

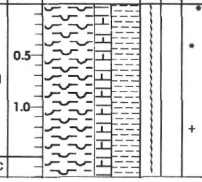
	1-56 D
TEXTURE:	
Sand	–
Silt	70
Clay	20
COMPOSITION:	
Clay	5
Micronodules	TR .
Carbonate unspec.	60
Calc. nannofossils	25
Fish remains	TR

ORGANIC CARBON AND CARBONATE

	CC
Organic carbon	–
Carbonate	74

SITE 520 HOLE CORE 19 CORED INTERVAL 336.5–341.5 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: NN11 (N)
FOSSIL CHARACTER: FORAMINIFERS FP; RADIOLARIANS R; DIATOMS AP; BENTHIC FORAMINIFERS B
SECTION: 1, CC



LITHOLOGIC DESCRIPTION

NANNOFOSSIL DIATOMITE, light gray (5Y 7/1) and white interlaminations. Core consists of "drilling biscuits" of laminated diatomite disposed in herring-bone pattern by drilling. Darker laminations are pyrite- and diatom-rich.

SMEAR SLIDE SUMMARY

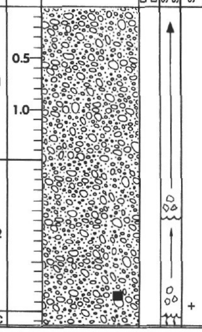
	1-5 D	1-94 M
TEXTURE:		
Sand	–	–
Silt	40	40
Clay	60	60
COMPOSITION:		
Quartz	5	TR
Clay	30	20
Volcanic glass	TR	5
Pyrite	–	20
Carbonate unspec.	10	20
Calc. nannofossils	20	10
Diatoms	25	20
Sponge spicules	5	5
Fish remains	5	–

ORGANIC CARBON AND CARBONATE

	1-129
Organic carbon	–
Carbonate	28

SITE 520 HOLE CORE 20 CORED INTERVAL 341.5–346.0 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: N15–17 (F) NN11 (N)
FOSSIL CHARACTER: FORAMINIFERS CM; RADIOLARIANS R, RP; DIATOMS AP; BENTHIC FORAMINIFERS FM
SECTION: 1, 2, CC



LITHOLOGIC DESCRIPTION

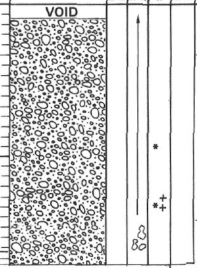
PEBBLY MARL, light olive gray (5Y 6/2) grading to pale yellow (5Y 7/3). Abundant dark mud clasts lay with long axes parallel to bedding. Matrix is marl. Sharp erosional(?) contacts in Core 2 and Core-Catcher as shown. A fragment of altered volcanic glass occurs near base Section 2. Burrowed interval in Core-Catcher. Several thin gray layers in Sections 1 and 2 may be diatom-rich. Carbonate mostly altered/recrystallized nannofossils.

ORGANIC CARBON AND CARBONATE

	2-140
Organic carbon	–
Carbonate	75

SITE 520 HOLE CORE 21 CORED INTERVAL 346.0–351.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
upper Miocene	N15–17 (F) NN11 (N)	CM			CP	FM	1, 2, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

PEBBLY MARL, pale yellow (2.5Y 7/3) clay-calcareous (altered nannofossils) matrix with dark brown, dark gray, and white mudstone clasts and scattered volcanic fragments throughout. Mudstone clasts up to 5 cm in length.

SMEAR SLIDE SUMMARY

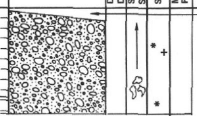
	1-140 D	2-50 M
TEXTURE:		
Sand	–	–
Silt	30	40
Clay	70	60
COMPOSITION:		
Quartz	5	5
Clay	10	35
Volcanic glass	5	5
Palagonite	5	5
Zeolite	–	10
Carbonate unspec.	35	15
Calc. nannofossils	40	20
Diatoms	TR	–
Radiolarians	TR	–
Sponge spicules	TR	5
Fish remains	TR	–
Iron-oxides	–	TR

ORGANIC CARBON AND CARBONATE

	2-43	2-49
Organic carbon	–	–
Carbonate	68	23

SITE 520 HOLE CORE 22 CORED INTERVAL 351.0–355.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
upper Miocene	N15–17 (F) NN11 (N)	AM		FM	CM	FM	1, CC	0.5



LITHOLOGIC DESCRIPTION

PEBBLY MARL, pale yellow (2.5Y 7/3), calcareous matrix with several large olive gray clasts of similar but more clay-rich composition.

SMEAR SLIDE SUMMARY

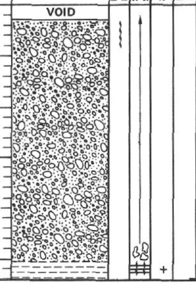
	1-34 M	CC D
TEXTURE:		
Sand	–	–
Silt	40	40
Clay	60	60
COMPOSITION:		
Quartz	5	5
Clay	20	15
Volcanic glass	5	5
Palagonite	–	5
Micronodules	TR	–
Carbonate unspec.	25	30
Foraminifers	–	TR
Calc. nannofossils	30	30
Diatoms	TR	5
Radiolarians	TR	–
Sponge spicules	5	5
Fish remains	TR	TR

ORGANIC CARBON AND CARBONATE

	1-34
Organic carbon	–
Carbonate	24

SITE 520 HOLE CORE 23 CORED INTERVAL 355.5–360.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
upper Miocene	N15–17 (F) NN11 (N)	CM		FP	AP	FM	1, 2, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

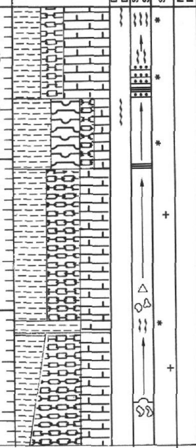
PEBBLY MARL, pale yellow (2.5Y 7/4) calcareous matrix with dark grayish brown and olive gray claystone and volcanic clasts; Abundant clasts near base Section 2 suggests grading. Core-Catcher is laminated and burrowed, pale olive CLAYSTONE, in place or possible a large clast in overlying marl.

ORGANIC CARBON AND CARBONATE

	CC, 13
Organic carbon	–
Carbonate	3

SITE 520 HOLE CORE 24 CORED INTERVAL 360.5–370.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
upper Miocene	N15–17 (F) NN11 (N)	CG		B, R, R, B	B, AP, AP	FM	1, 2, 3, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

Interbedded light olive (5Y 6/2) CLAYEY NANNOFOSSIL MARL, laminated gray-green CLAYEY NANNOFOSSIL *DIATOMITE*, and pale yellow (2.5Y 7/4) PEBBLY MARL. MARL in upper 50 cm, Section 1 is burrowed; between 35–55 cm are series of horizontal back-filled burrows evenly spaced approximately 0.5 cm apart. Graded thin foraminifer layers occur between 65–85 cm, Section 1. Gray-green diatomite between 100 cm, Section 1 and 10 cm, Section 2 is laminated on mm-scale; dark gray to black laminations are pyrite-rich. Section 2 is a graded PEBBLY MARL that may extend to base Section 3; large included claystone fragment near top Section 3. Folds common between 20–100 cm. Section 3, base of core is homogeneous, pale yellow, NANNOFOSSIL CHALK.

SMEAR SLIDE SUMMARY

	1-15 D	1-75 M	1-136 D	3-18 M
TEXTURE:				
Sand	5	25	4	2
Silt	70	65	35	38
Clay	25	10	60	60
COMPOSITION:				
Quartz	–	TR	–	4
Clay	25	8	40	60
Volcanic glass	TR	–	–	TR
Palagonite	–	–	–	2
Carbonate unspec.	10	5	18	–
Foraminifers	2	20	TR	–
Calc. nannofossils	60	66	20	30
Diatoms	2	1	22	TR
Sponge spicules	–	TR	TR	–

ORGANIC CARBON AND CARBONATE

	2-57	3-57
Organic carbon	–	–
Carbonate	66	83

SITE 520 HOLE CORE 25 CORED INTERVAL 370.0–379.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	MAGNETIC POLARITY
upper Miocene	N15–17 (F) NN11 (N)	AM			B	FM	1, 2, CC	0.5, 1.0				* +	

LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL CHALK, light yellowish brown (2.5Y 6/4) with abundant slump folds throughout.

SMEAR SLIDE SUMMAR

	1-107 D
TEXTURE:	
Sand	3
Silt	72
Clay	25
COMPOSITION:	
Clay	25
Palagonite	TR
Carbonate unspec.	12
Foraminifers	2
Calc. nannofossils	60
Diatoms	TR
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE

	1-107
Organic carbon	–
Carbonate	87

SITE 520 HOLE CORE 26 CORED INTERVAL 389.0–398.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	MAGNETIC POLARITY
upper Miocene	NN11 (N)			CP	CR		1	0.5, 1.0				* +	
				AP		B							
	NN10–11 (N)	FP		AP	AP	CM	2, CC					* * +	

basalt clast

sharp "drilling"(?) contact

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAYEY DIATOMITE and NANNOFOSSIL MARL. Diatomite is light olive (5Y 6/2) and alternately burrowed and laminated; dark laminations are pyrite-rich. Some 2–3 cm-rich intervals in Section 1 appear to be graded. Marl occurs below diatomite in Section 2 at 60 cm; sharp contact appears artificial (drilling artifact). Chalk is homogeneous, perhaps burrowed throughout. Aphanitic basalt fragment at top of core.

SMEAR SLIDE SUMMARY

	1-40 D	2-30 D	2-95 D
TEXTURE:			
Sand	5	20	3
Silt	30	70	82
Clay	65	10	15
COMPOSITION:			
Clay	65	10	15
Volcanic glass	2	–	–
Palagonite	1	TR	TR
Pyrite	–	10	–
Carbonate unspec.	2	–	10
Calc. nannofossils	15	20	65
Diatoms	15	60	10
Radiolarians	TR	TR	–
Fish remains	TR	–	–

ORGANIC CARBON AND CARBONATE

	1-60	2-100
Organic carbon	–	–
Carbonate	23	80

SITE 520 HOLE CORE 27 CORED INTERVAL 398.5–408.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	MAGNETIC POLARITY
upper Miocene	NN10 (N)	FM		B	B	FG	1			△ △		+ *	

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL, pale yellow (2.5Y 7/4), homogeneous; broken by drilling.

SMEAR SLIDE SUMMARY

	1-28 D
TEXTURE:	
Sand	–
Silt	85
Clay	15
COMPOSITION:	
Clay	15
Palagonite	2
Carbonate unspec.	40
Foraminifers	1
Calc. nannofossils	40
Diatoms	TR

ORGANIC CARBON AND CARBONATE

	1-12
Organic carbon	–
Carbonate	90

SITE 520 HOLE CORE 28 CORED INTERVAL 417.5–427.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	MAGNETIC POLARITY
upper Miocene	NN11 (N)	FP		B	B	AG	1, CC					+	

LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL, pale yellow (2.5Y 6/6) and light olive brown (2.5Y 5/4), homogeneous except for basal burrowed interval.

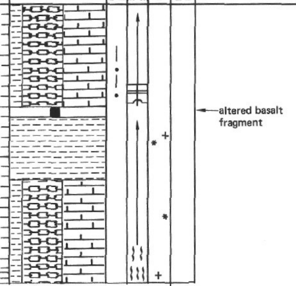
ORGANIC CARBON AND CARBONATE

	1-16
Organic carbon	–
Carbonate	87

SITE 520 **HOLE** **CORE** 29 **CORED INTERVAL** 436.5–446.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
middle Miocene	N14 (F) / NN7–10 (N); N13 (F) / NN6 (N) ?; NN5 (N)			B	B	AM	1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MARL and CLAYSTONE. Marl is brownish yellow (10YR 6/8) to dark yellowish brown (10YR 4/4) laminated and intensely folded. Marl is separated from underlying claystone by an altered basalt fragment. Claystone is dark reddish brown (5YR 2/2) and moderately burrowed throughout. Faint laminations disrupted by burrows also occur sporadically.

SMEAR SLIDE SUMMARY

	1-138	2-66
	D	D
TEXTURE:		
Sand	–	–
Silt	20	40
Clay	80	60
COMPOSITION:		
Quartz	5	5
Clay	30	15
Volcanic glass	5	5
Palagonite	10	5
Micronodules	10	5
Carbonate unspec.	5	25
Calc. nannofossils	15	30
Sponge spicules	TR	TR
Fish remains	TR	TR
Iron-oxides	20	10

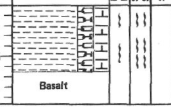
ORGANIC CARBON AND CARBONATE

	1-133	CC, 17
Organic carbon	–	–
Carbonate	0.3	81

SITE 520 **HOLE** **CORE** 30 **CORED INTERVAL** 446.0–450.5 m

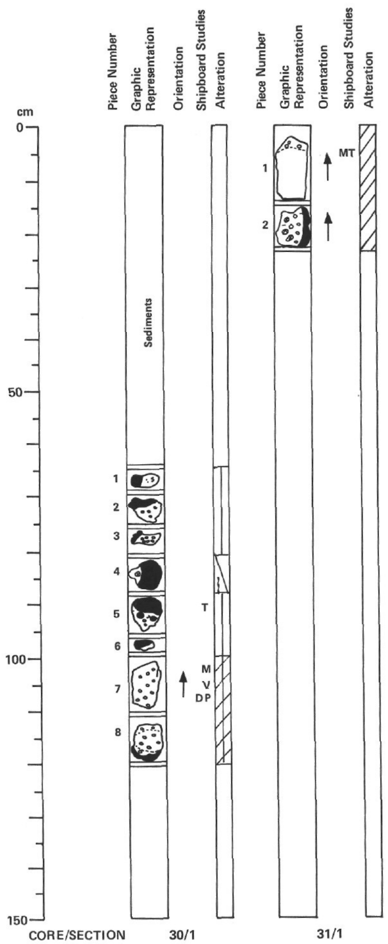
TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	BENTHIC FORAMINIFERS	SECTION	METERS
middle Miocene	NN5 (N)	FP				CM	1	0.5

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES / MAGNETIC POLARITY



LITHOLOGIC DESCRIPTION

CALCAREOUS CLAYSTONE, dark brown (7.5YR 4/4), burrowed. Basalt begins at 64 cm.



HOLE 520, CORE 30, SECTION 1, 446.0–447.2 m

MAJOR ROCK TYPES – BASALT

Macroscopic Description

Basalt – Aphyric to sparsely microporphyritic. Pieces 1–3 have black glassy margins that grade into sparsely vesicular, very fine- to fine-grained altered basalt. Two cm glassy rind on Piece 5 bordered by 2 mm thick vesicular zone of brown devitrified glass which grades to very fine-grained basalt. Piece 6 is mostly glass with a wide spherulitic and variolitic zone grading into basalt completely altered to pale green smectite. Pieces 7–8 are very fine- to fine-grained, finely vesicular aphyric basalt. Abundance of glass and poor recovery suggests pillows.

Nannofossil Clay – See sediment description form.

Thin Section Summary

Sparsely microporphyritic with small (0.05–0.3 mm) microphenocrysts of olivine (Fo80–85) and larger (0.25–0.6 mm) plagioclase. Olivine is euhedral and skeletal with central inclusions and plagioclase is glomerocrystic; both form centers of radial clusters of variolitic quench texture formed by exceedingly elongate plagioclase intergrown with augite. Microphenocryst ratio olivine/plagioclase ~4/1. Small (0.01–0.05 mm), rounded, sparse vesicles filled with yellow smectite. Olivine slightly rimmed with yellow smectite. Approximate mode: plagioclase 40, clinopyroxene 40, opaques 15, olivine 5.

Shipboard Studies

Sample	D	P	V⊥	V∥	NRM1	NRM2	S. I.
Sec. 1, Piece 7	2.86	5.1	5.91	5.70	9.874	58.2	57.5

HOLE 520, CORE 31, SECTION 1, 450.5–450.7 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – Piece 1 is very fine-grained and phyric, finely vesicular on one side; slightly to moderately altered. Piece 2 has 1.5 cm thick glassy rind on very fine-grained variolitic aphyric basalt. Variolitic rock is black to greenish gray; large (1–1.5 mm) varioles in gray part.

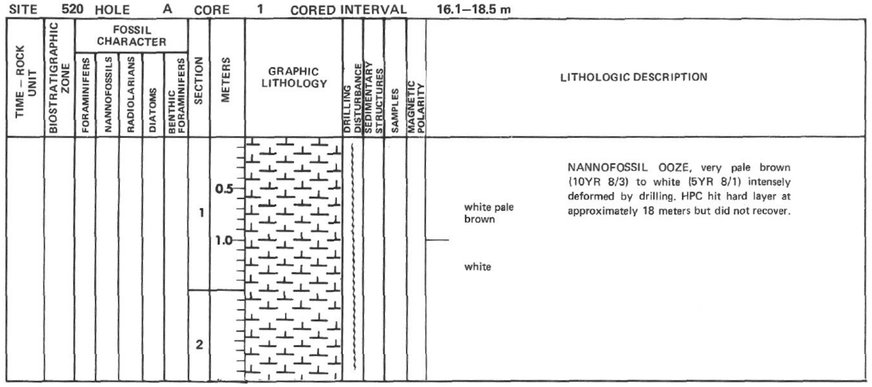
Thin Section Summary

Very sparsely (< 1%) microporphyritic with anhedral (corroded?) plagioclase phenocrysts (1–2 mm). Coarse quench texture. Plagioclase has two generations: 1) skeletal crystals, both swallowtail and hollow box about 0.2–1.0 mm long with; 2) interstitial twinned microlites (~ 0.03–0.05 mm). Clinopyroxene (normal augite), 0.1–0.4 mm units, shows spectacular plumose and chain link textures. Olivine (Fo80–85) as fresh, 0.04–0.25 mm, euhedral equant grains and as elongated cores in spherules and varioles. Opaques (0.002–0.04 mm) as cubes, plates and serrated skeletal grains in very finely crystalline interstices between larger generations of plagioclase. Approximate mode: olivine 10–15, plagioclase 35–40, clinopyroxene 35–40, opaques 5–10.

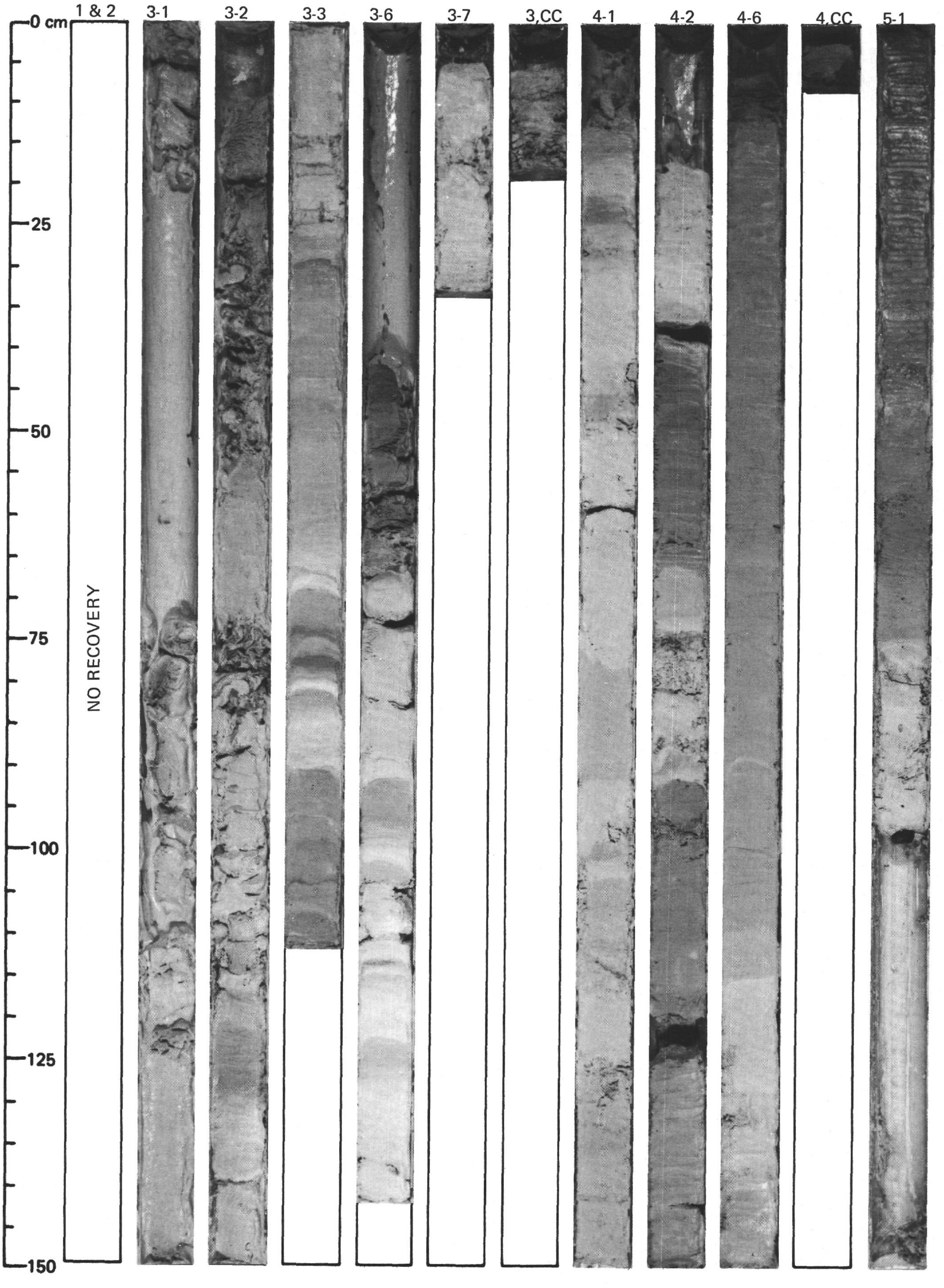
Shipboard Studies

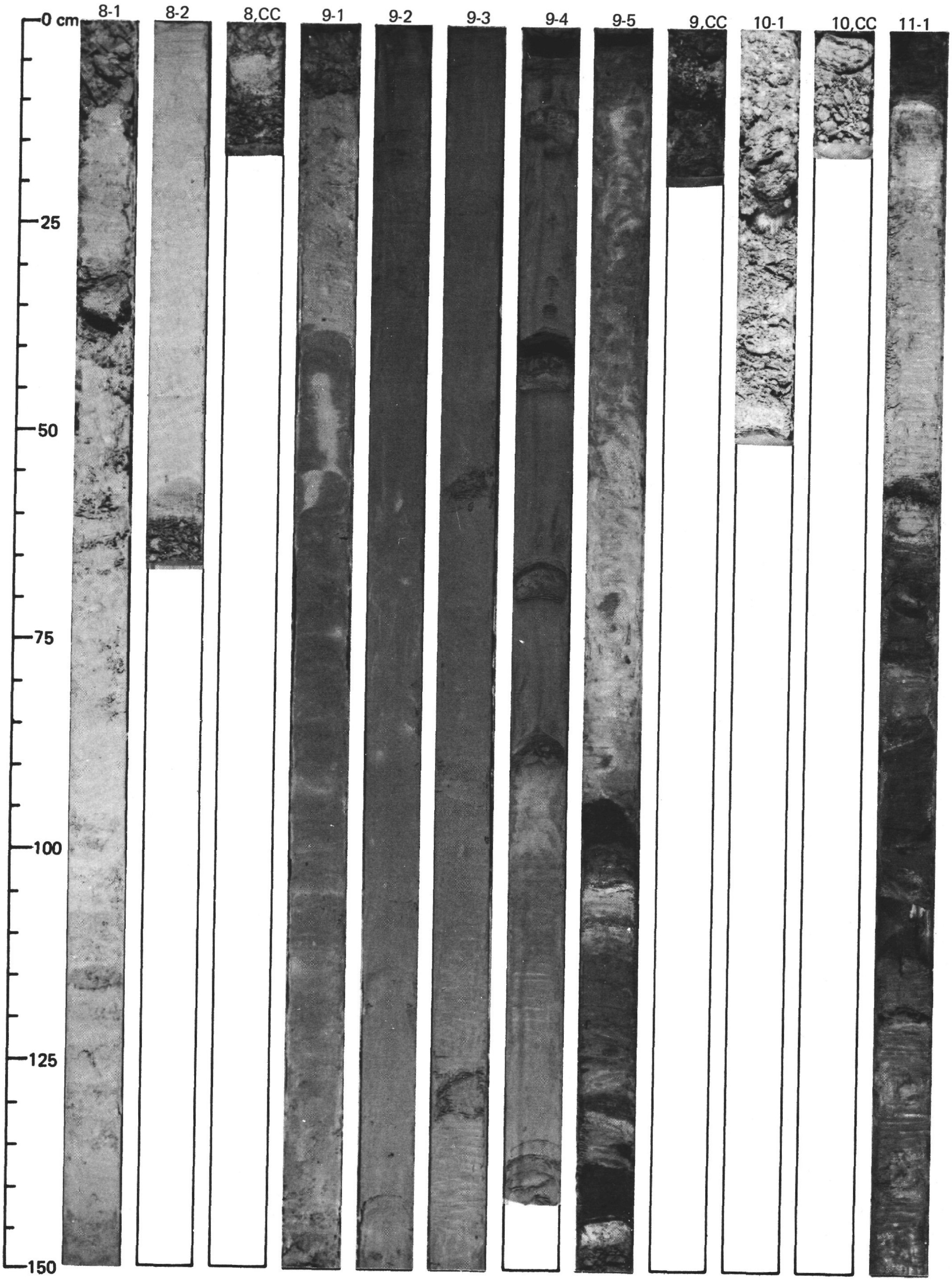
Sample	D	P	V⊥	V∥	NRM1	NRM2	S. I.
Sec. 1, Piece 1	–	–	–	–	55.471	50.3	53

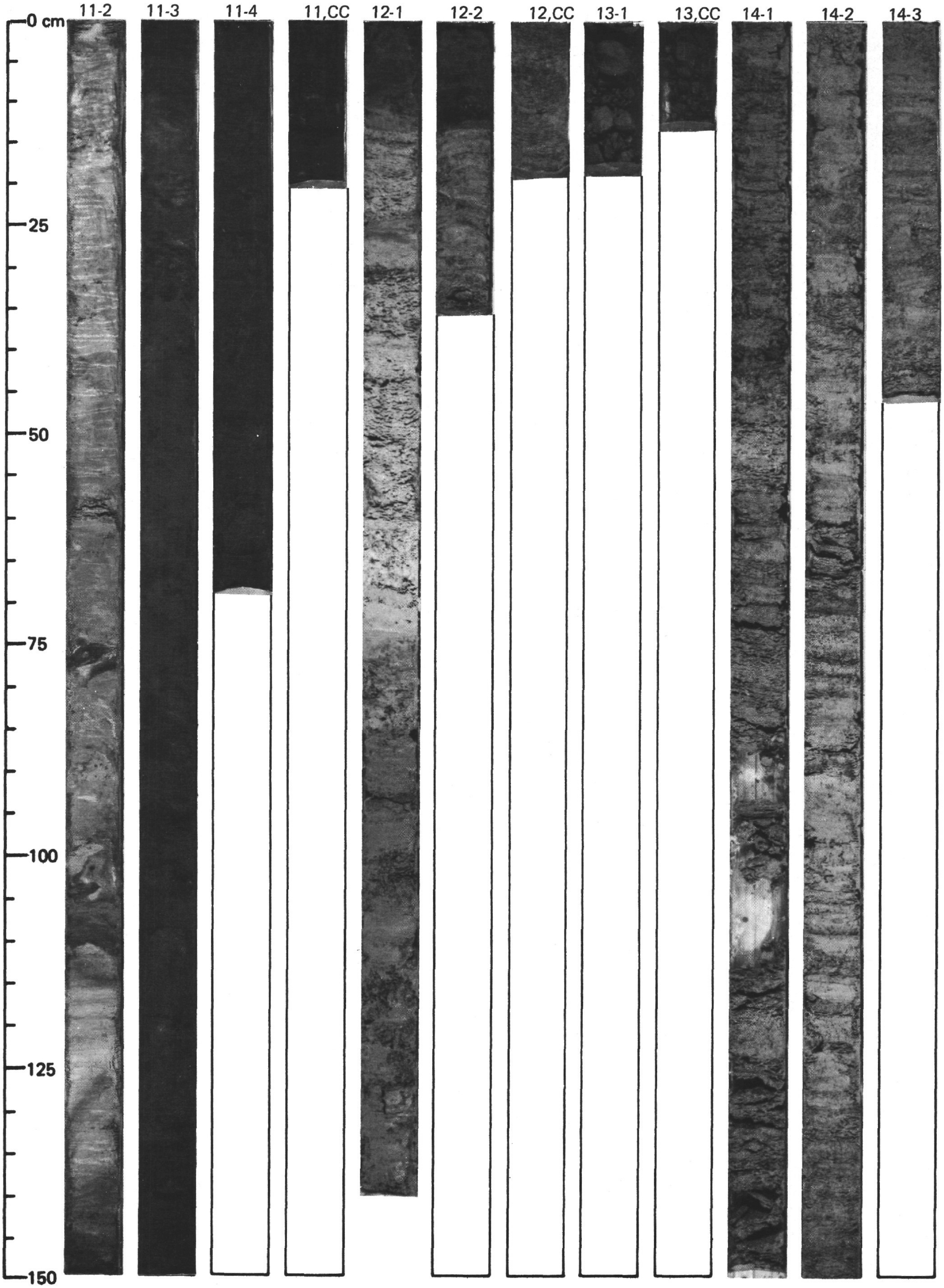
SITE 520 HOLE A CORE 1 CORED INTERVAL 16.1–18.5 m

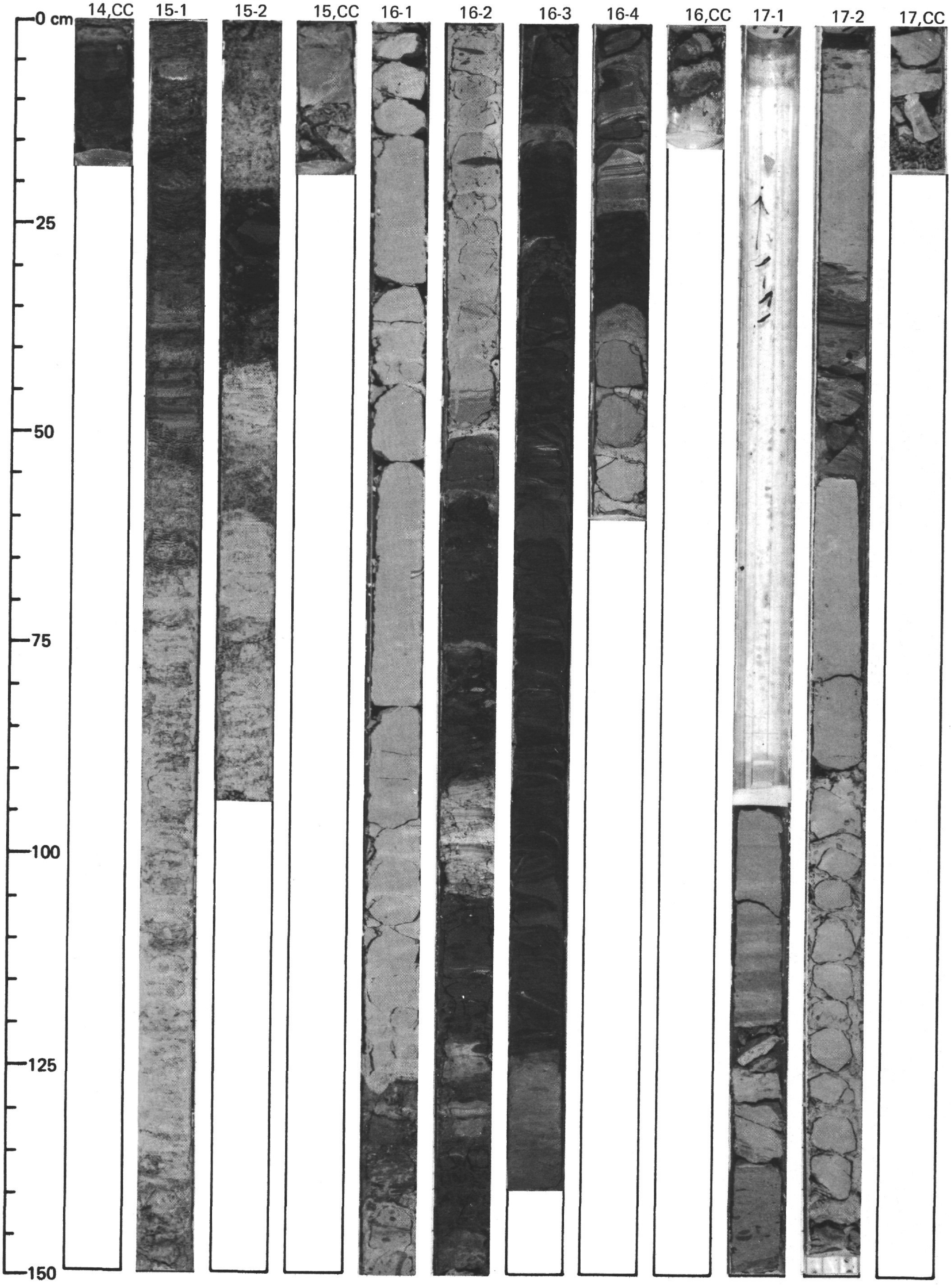


NANNOFOSSIL OOZE, very pale brown (10YR 8/3) to white (5YR 8/1) intensely deformed by drilling. HPC hit hard layer at approximately 18 meters but did not recover.

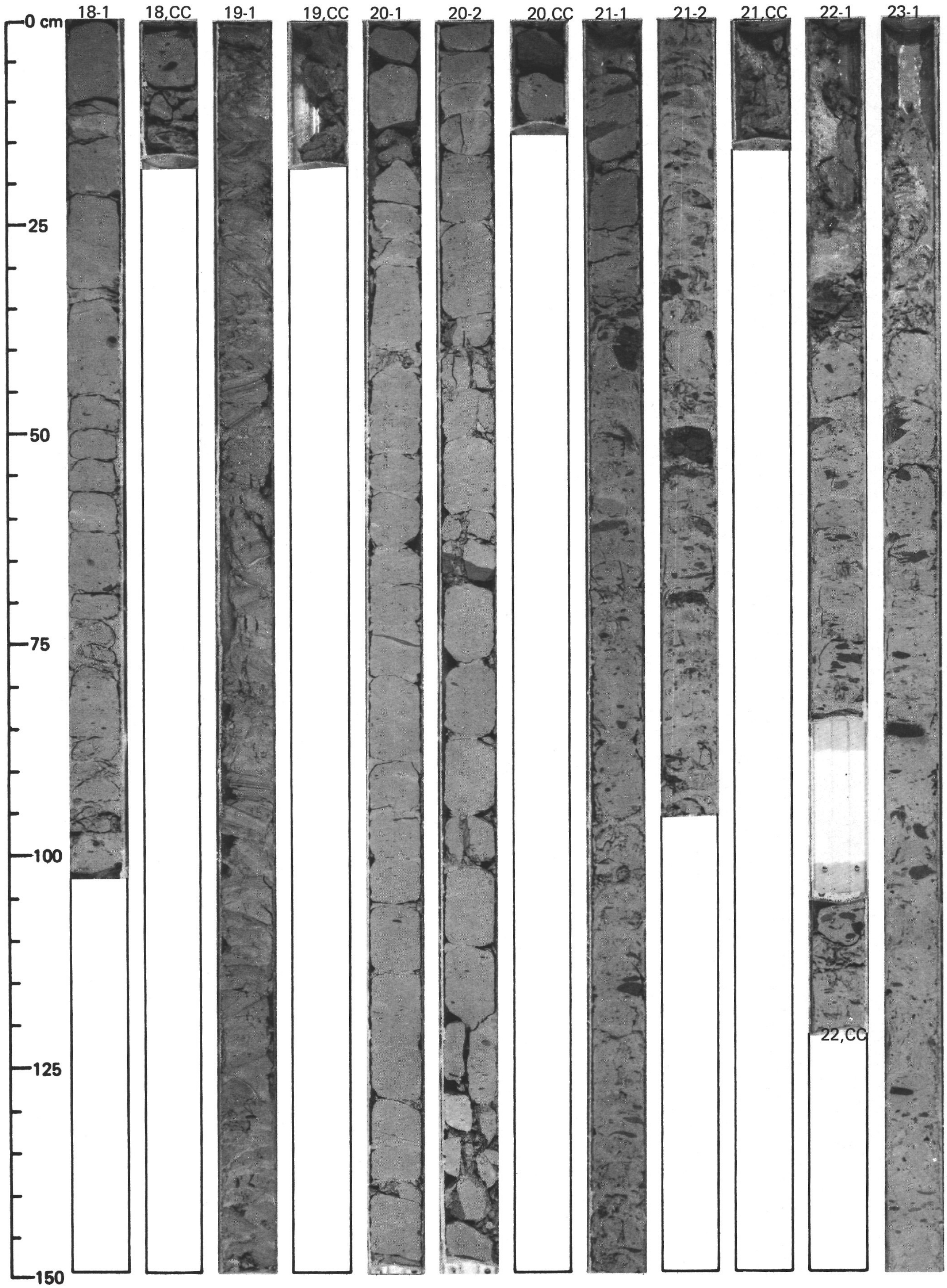

0 cm
25
50
75
100
125
150
1 & 2
NO RECOVERY
3-1
3-2
3-3
3-6
3-7
3,CC
4-1
4-2
4-6
4,CC
5-1

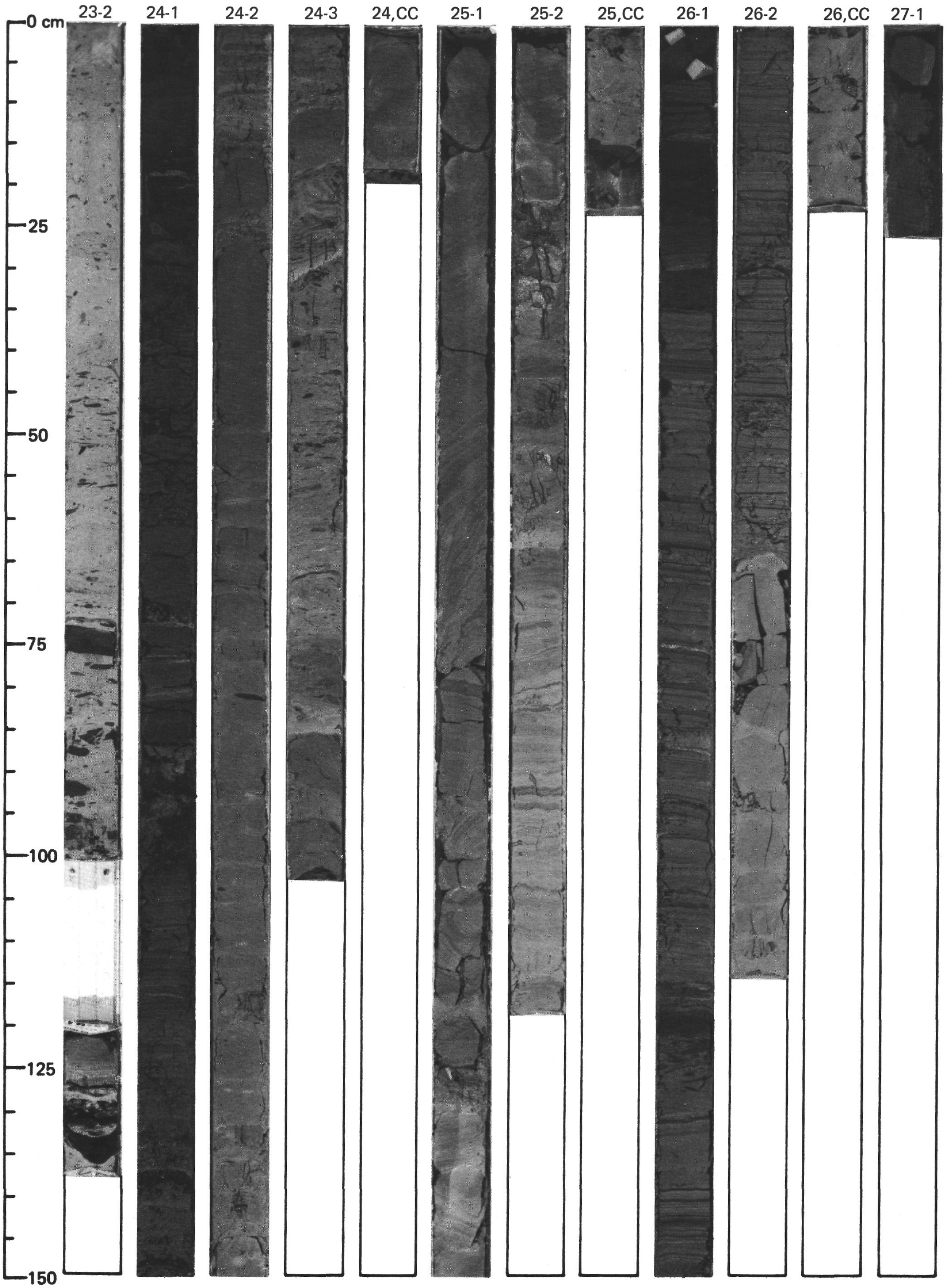

0 cm
25
50
75
100
125
150
8-1
8-2
8,CC
9-1
9-2
9-3
9-4
9-5
9,CC
10-1
10,CC
11-1

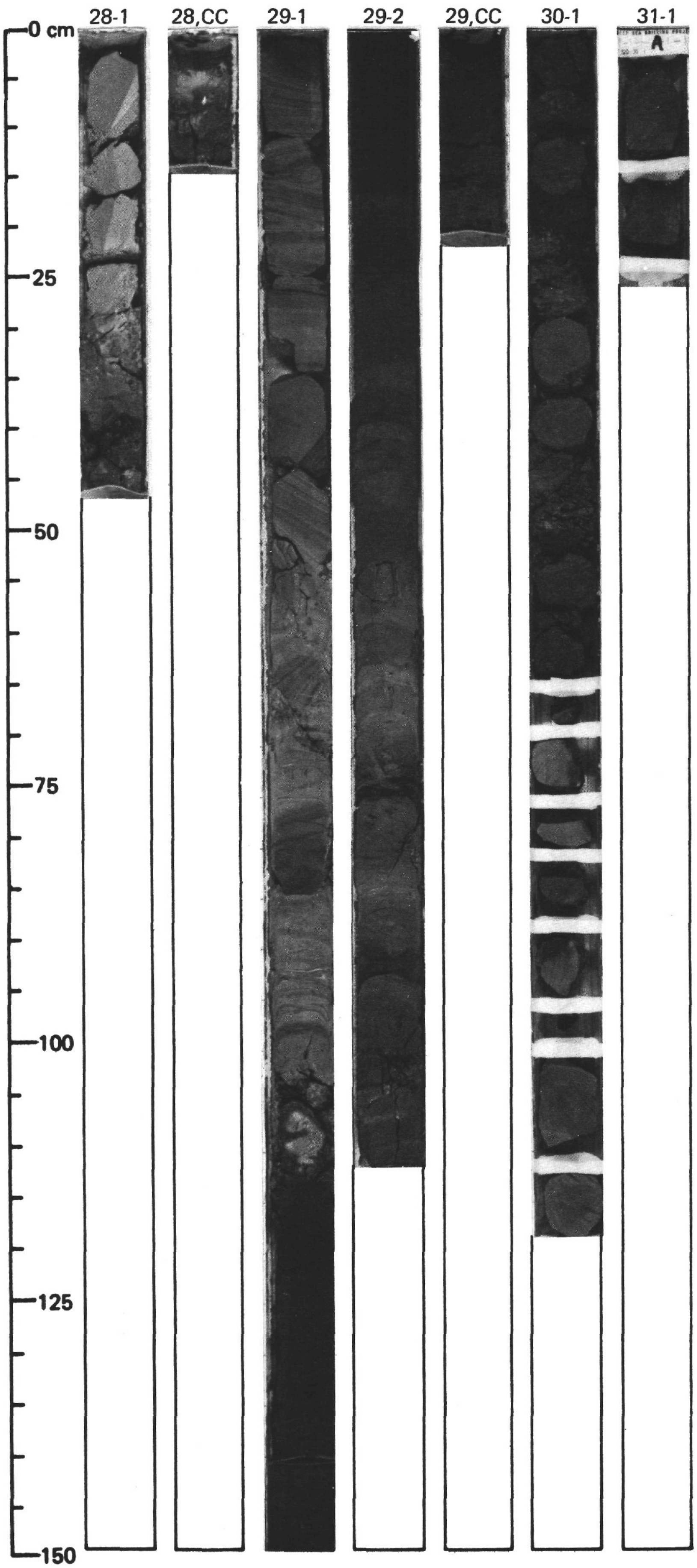

11-2
11-3
11-4
11,CC
12-1
12-2
12,CC
13-1
13,CC
14-1
14-2
14-3
0 cm
25
50
75
100
125
150

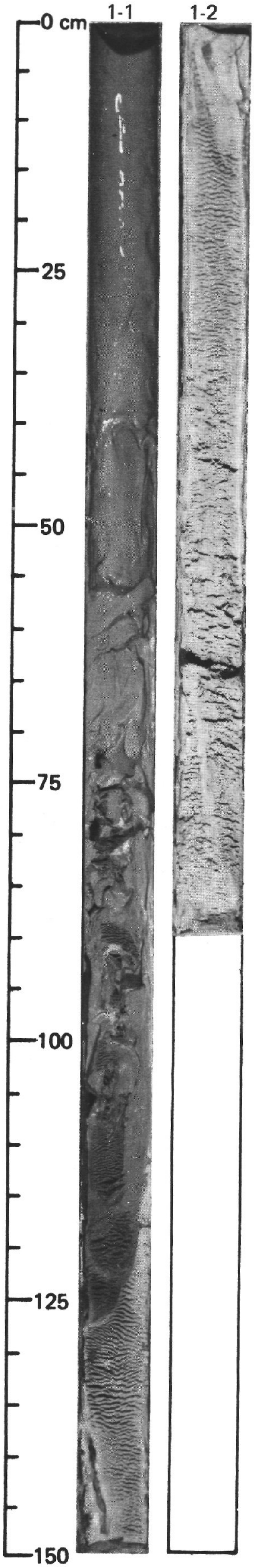


0 cm
25
50
75
100
125
150
14,CC
15-1
15-2
15,CC
16-1
16-2
16-3
16-4
16,CC
17-1
17-2
17,CC


18-1
18,CC
19-1
19,CC
20-1
20-2
20,CC
21-1
21-2
21,CC
22-1
23-1
22,CC
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
23-2
24-1
24-2
24-3
24,CC
25-1
25-2
25,CC
26-1
26-2
26,CC
27-1


28-1
28,CC
29-1
29-2
29,CC
30-1
31-1
0 cm
25
50
75
100
125
150


0 cm
1-1
1-2
25
50
75
100
125
150