# 4. SITE 527[1]

Shipboard Scientific Party[2]

## HOLE 527

**Date occupied:** 28 June 1980

**Date departed:** 4 July 1980

**Time on hole:** 5 days 14 hrs. 42 min.

**Position:** 28°02.49′S; 01°45.80′E

**Water depth (sea level; corrected m, echo-sounding):** 4428

**Water depth (rig floor; corrected m, echo-sounding):** 4438

**Bottom felt (m, drill pipe):** 4437

**Penetration (m):** 384.5

**Number of cores:** 44

**Total length of cored section (m):** 384.5

**Total core recovered (m):** 243.9

**Core recovery (%):** 63

**Oldest sediment cored:**
Depth sub-bottom (m): 360
Nature: Calcareous claystone
Age: Middle Maestrichtian
Measured velocity (km/s): 1.88

**Basement:**
Depth sub-bottom (m): 384.5, top of basement complex 341.5 m
Nature: Basalt with intercalated sediment
Velocity range (km/s): 3.94–4.71

**Principal results:**

1. A complete sedimentary section from seafloor to 341 m sub-bottom was cored in a single, rotary-drilled hole. An additional 43 m of a basaltic basement complex was cored. Sediments varied from clays to carbonate-rich oozes and chalks, with volcanogenic material common in the basal (Maestrichtian) sedimentary units.

2. There is a marked hiatus in the section that ranges from the middle Miocene to the lower Oligocene. The recovery of a very short and poorly fossiliferous upper Miocene and upper middle Miocene section separates this break in the record from the better-preserved lower Pliocene.

3. Accumulation rates are very low in the mid- to upper Eocene through the lower Oligocene and in the upper middle Miocene. These intervals are associated with low carbonate content, poor preservation of calcareous microfossils, and nearby breaks in the stratigraphic record. Accumulation rates in the remainder of the section are as high as, or higher than, those at the shallower Site 525. Variations in accumulation rates in the two sites tend to parallel one another in the Plio–Pleistocene and in the lower Paleogene–Upper Cretaceous.

4. Carbonate preservation in the remainder of the section is moderate except for the middle Eocene, where, as in many other South Atlantic sites, recrystallization mars the preservation of the calcareous assemblages. The overall lithology and biotic content of the section is strongly controlled by variation through time in carbonate dissolution. Even the abundance of the benthic fauna appears to be directly related to the degree of carbonate dissolution.

5. Sedimentation appears to be continuous across the Cretaceous/Tertiary boundary.

6. Incomplete paleomagnetic sequences were identified for the lowermost Oligocene and the mid- to lower Eocene. A nearly complete sequence was obtained for the Paleocene and the upper Maestrichtian.

7. The recovered basement complex of 43 m has an age of middle Maestrichtian (approximately 68 Ma), in agreement with seafloor magnetic anomalies and the preliminary interpretation of magnetic measurements made on the sediments.

8. As at Sites 525 and 528 on the Walvis Ridge, the basalts of the basement complex are intercalated with sediments. The sediments form about 10% of the recovered basement section. The basalts are divided into five separate units by these sediments. The units vary from phyric to aphyric, from fine to coarse grained, and are subophitic to intergranular in texture. At least three of the units have abundant plagioclase phenocrysts.

9. Sediments near basement contain benthic microfossils that indicate bathyal depths (≥2000 m); this agrees with paleodepth estimates based on the depth versus time backtracking technique.

## BACKGROUND AND OBJECTIVES

### Geologic and Oceanographic Setting

Site 527 (planned as SAII-5) is the deepest site in the transect of sites extending down the western slope of a NNW-SSE-trending block in the Walvis Ridge (Fig. 1). Reflection records of the *Vema* and *Thomas B. Davie* (Fig. 1) show the presence of 0.36 s of sediments (approximately 330 m) conformably overlying a relatively flat acoustic basement. Studies of the crustal magnetic anomalies indicate that the basement age should be slightly less than 70 m.y. old (about Anomaly 31—middle Maestrichtian—time). Results from nearby Sites 525 and 528 support the estimate of basement age and indicate that the acoustic basement is associated with a complex of basalt flows interbedded with sediments.

Acoustic reflectors within the sedimentary column cannot be directly traced between Sites 525 and 527; however, the results at Site 525, together with those of sites drilled in the Angola Basin during Legs 40 and 73, suggest that much of the middle Tertiary biogenic sedi-

---

[1] Moore, T. C., Jr., Rabinowitz, P. D., et al., *Init. Repts. DSDP*, 74: Washington (U.S. Govt. Printing Office).

[2] Theodore C. Moore, Jr. (Co-chief Scientist), Graduate School of Oceanography, University of Rhode Island, Kingston, Rhode Island (present address: Exxon Production Research Co., P.O. Box 2189, Houston TX 77001); Philip D. Rabinowitz (Co-chief Scientist), Lamont-Doherty Geological Observatory, Palisades, New York (present address: Department of Oceanography, Texas A&M University, College Station, TX 77843); Anne Boersma, Lamont-Doherty Geological Observatory, Palisades, New York (present address: P.O. Box 404, R.R. 1, Stony Point, NY 10980); Peter E. Borella, Deep Sea Drilling Project, Scripps Institution of Oceanography, La Jolla, California; Alan D. Chave, Geological Research Division, Scripps Institution of Oceanography, La Jolla, California (present address: Institute of Geophysics and Planetary Physics, University of California, San Diego, La Jolla, California); Gérard Duée, Laboratoire Géologie Stratigraphique, Université des Sciences et Techniques de Lille, Villeneuve d'Ascq, France; Dieter Fütterer, Geologisch-Paläontologisches Institut und Museum der Universität Kiel, Kiel, Federal Republic of Germany; Ming Jung Jiang, Department of Oceanography, Texas A&M University, College Station, Texas (present address: Robertson Research [U.S.] Inc., Houston, Tex.); Klaus Kleinert, Geologisches Institut der Universitat Tübingen, Tübingen, Federal Republic of Germany; Andrew Lever, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom (present address: Department of Mineral Resources Engineering, Imperial College of Sciences and Technology, London, U.K.); Hélène Manivit, Laboratoire de Palynologie, BRGM, Orléans, France; Suzanne O'Connell, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts (present address: Lamont-Doherty Geological Observatory, Palisades, NY 10964); Stephen H. Richardson, Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts; and Nicholas J. Shackleton, Godwin Laboratory, University of Cambridge, Cambridge, United Kingdom.

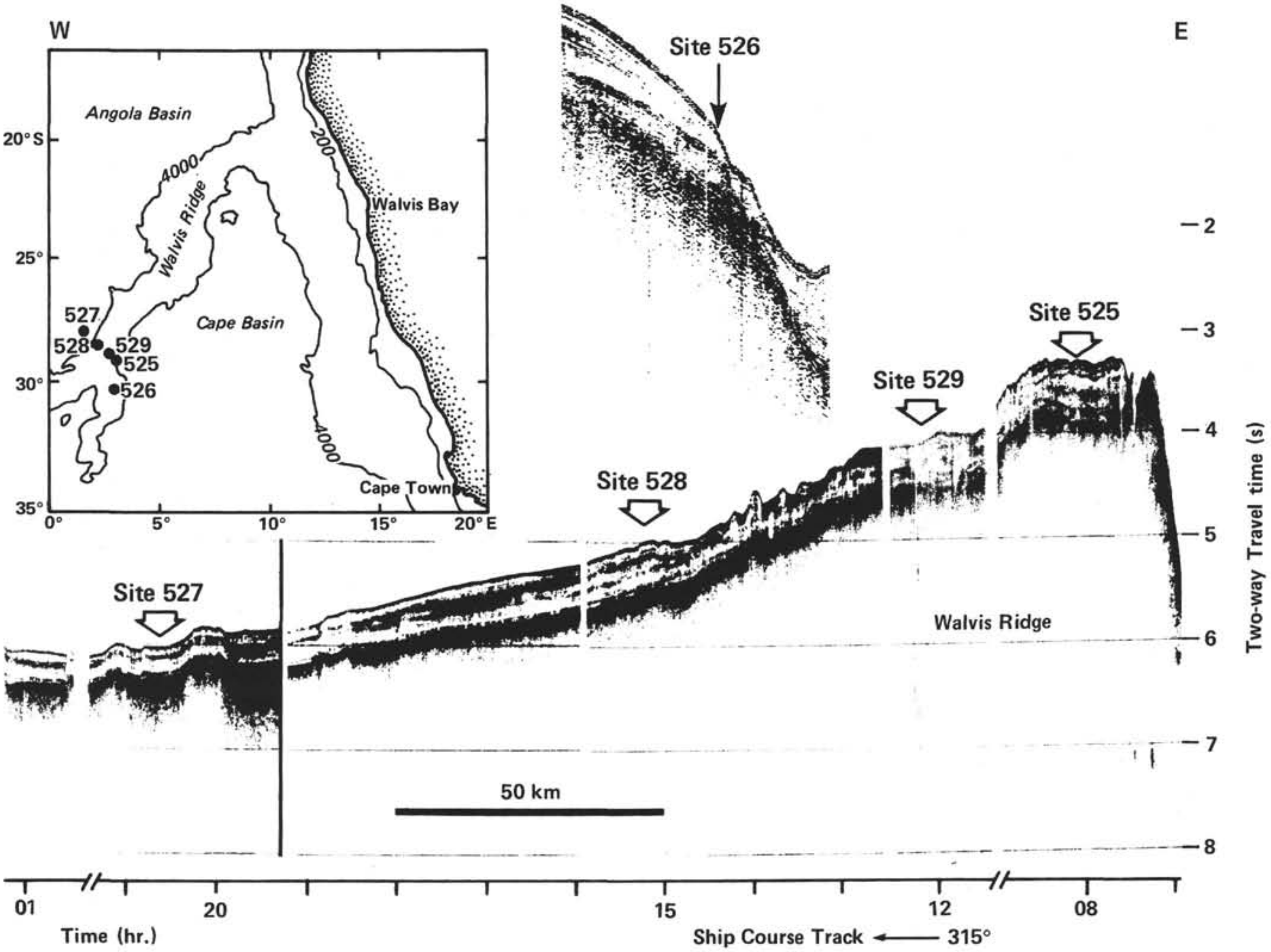


Figure 1. Index and location map for Site 527 and reflection profile record of *Vema* and *Thomas B. Davie*.

ments may be poorly preserved or missing. Results at Site 525 also suggest that the Walvis Ridge has followed a normal depth versus age cooling curve; therefore, the lower part of the section was probably deposited at intermediate depths (2000–3000 m) and thus are likely to contain well-preserved microfossils.

The oceanographic setting of this site is almost identical to that of Site 526, the most distant site, approximately 230 km to the south. It is assumed that the biogenic and detrital supply to the seafloor is approximately the same at all sites of the transect. The major oceanographic difference in the site locations is in their water depth. Site 527 is in 4428 m of water, approximately 3400 m deeper than Site 526. Site 527 presently lies within that interval of the seafloor bathed by North Atlantic Deep Water (NADW). This water mass dominates the Angola Basin in modern times, and the relatively lower dissolved $CO_2$ content (high alkalinity) of these waters is associated with excellent preservation of biogenic carbonates. Results of earlier drilling within the Angola Basin indicate, however, that calcite preservation was markedly reduced in the mid-Miocene and Eocene.

## Scientific Objectives

The scientific objectives at this site, which is part of the Walvis Ridge transect, focus on three main topics: (1) the history of bottom waters within the eastern South Atlantic, (2) the development of detailed biostratigraphies and paleomagnetic stratigraphies, and (3) the tectonic evolution of the Walvis Ridge.

Site 527 is the deepest site to be drilled on this leg and provides the bottom tie on our depth versus time transects. This transect is particularly important for the study of the early Tertiary and Late Cretaceous history of deep water masses, because few other sites in this basin span an appropriate range of depths over this time interval.

Although we anticipated rather poor calcite preservation in parts of the mid-Tertiary, we expected preservation in the upper and lower Tertiary to be quite good. Because of the reduced overburden, the lower Tertiary section is as well, or even better, preserved than at Site 525. Thus the lower part of the section is of particular value to paleomagnetic and biostratigraphic studies. The basement rocks recovered at this and other sites of the transect should provide information on the evolution of the Walvis Ridge.

Because of time constraints on the drilling program and the low probability of recovering a well-preserved Neogene section, it was decided to rotary drill and core the entire section rather than to use the hydraulic piston corer for the upper part.

## OPERATIONS

*Glomar Challenger* departed Walvis Bay on 22 June 1980 at 1424 hr. after disembarking an ill seaman. The ship's track en route to Site 526 (SAII-7) on the Walvis Ridge traversed the Mesozoic sequence of magnetic anomalies and the Cretaceous magnetic quiet zone in the Cape Basin. Continuous seismic profiles, magnetic anomalies, and bathymetry were collected. The track was planned so as not to duplicate other geophysical traverses in the region.

A geophysical site survey was conducted prior to Leg 74 by *Thomas B. Davie* of the University of Cape Town on all of the Walvis Ridge sites to be drilled on this leg (Rabinowitz and Simpson, 1979). Other geological/geophysical ships' tracks in the vicinity which were of importance in the site selection included those of *Vema* (L-DGO) and *Atlantis II* (WHOI). A predrilling survey by *Challenger* in the site area was not necessary.

*Glomar Challenger* reached Site 526 and dropped a beacon at 1149 hr. on 26 June 1980. We were beset by foul weather (a combination of wind, swell, and currents) that did not allow us both to position the ship over the beacon and to maintain the necessary safety requirements for drilling. We did not lower pipe at this site. At the request of the operations manager, we labeled this a site even though drilling never commenced. At 1948 hr. on 27 June, we got under way, streaming the profiling and magnetometer equipment, for Site 527 (SAII-5).

*Glomar Challenger* approached Site 527 from the northwest on a course of 120° and a speed of 7 kt. The beacon was dropped at 1128 hr., 28 June 1980, based on a depth of 4437 m and a sediment thickness of 0.35 s (two-way reflection time) observed on seismic reflection profiles aboard *Challenger* and its correlation to the predrilling drilling site surveys. We continued on this course for 1.5 n.m. in order to obtain a *Challenger* seismic reflection profile across the site. At 1151 hr., we reversed course to approach site and commenced pulling the towed geophysical gear. Figure 2 shows the ship's track for the approach on site.

At Site 527 we planned to rotary core through the sediment section into basement and log the hole. We also planned making engineering tests relating to the

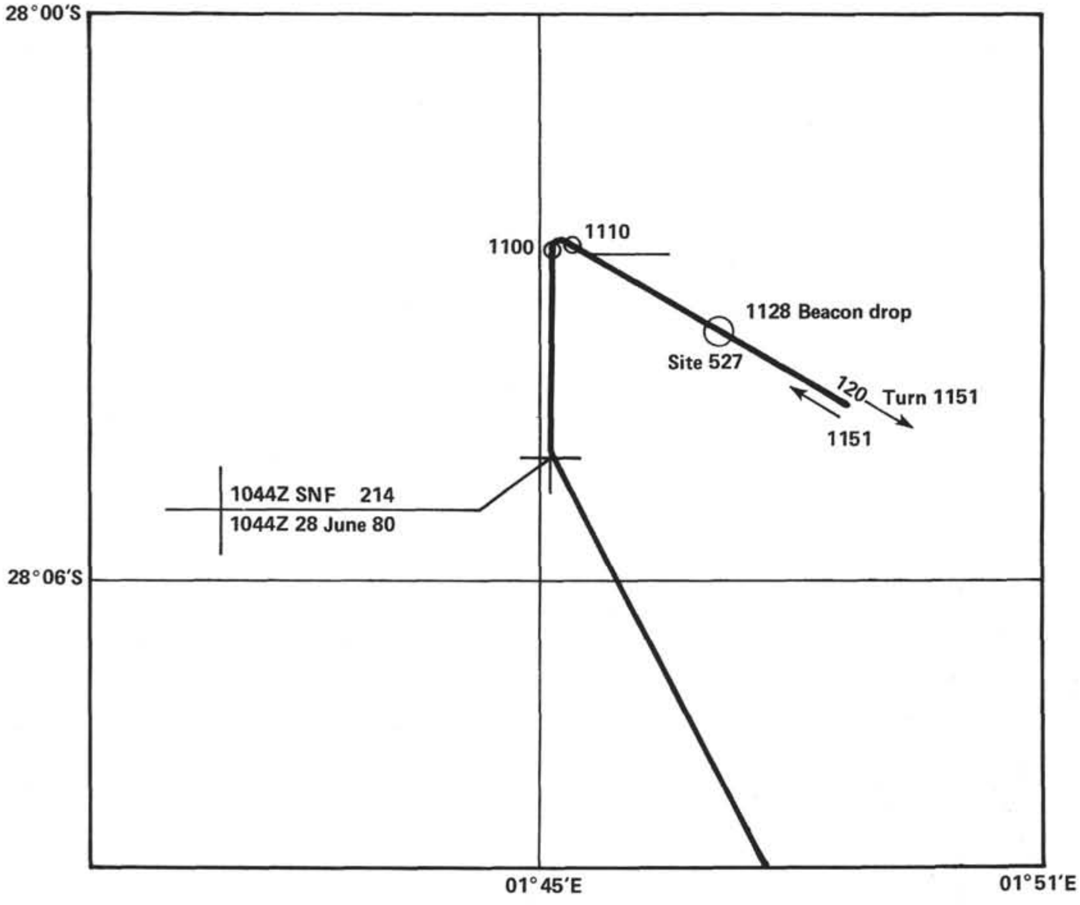


Figure 2. Ship's track for the approach to Site 527.

pressure core barrel (PCB) and drill bit motion indicator (DBMI). The engineering tests required a bit size smaller than the one normally used for rotary coring (similar to Site 525). The PCB tests were unsuccessful. Apparently one of the DBMI tests did work with limited success. The results of these tests should be noted in the operations manager's report. We should note here that use of a bit with a smaller core opening (necessary for the PCB tests) decreased the diameter of the core recovered. Since the core liner is designed for a standard bit, there is an open space between the recovered core and the core liner. This results in a slurry developing along the length of the core and may inhibit the preservation of sediment structures as well as degrade stratigraphic resolution.

Forty-four cores were obtained in Hole 527 with a total penetration of 384.5 m below the seafloor (see Table 1). A basement rock complex was first encountered in Core 38 at 341.0 m sub-bottom. We thus cored 341.0 m of sediment and 43.5 m of basement, with a combined recovery rate of 63%. The recovery rate of sediment was 62%; the recovery rate of the basement complex was 76%.

After completion of the rotary drilling, we logged the hole. We logged only density successfully before the hole caved in. We incurred lost time during the logging operation because of difficulties in releasing the drill bit, an inoperative Schlumberger winch, power supply problems in the logging cabin, and malfunction of the sonic tool.

Table 1. Coring summary, Hole 527.

| Core No. | Date (June 1980) | Time | Depth from Drill Floor (m) Top Bottom | Depth below Seafloor (m) Top Bottom | Length Cored (m) | Length Recovered (m) | Recovery (%) |
|---|---|---|---|---|---|---|---|
| 1 | 29 | 1032 | 4437.0-4446.0 | 0.0-9.0 | 9.0 | 9.0 | 100 |
| 2 | 29 | 1201 | 4446.0-4455.5 | 9.0-18.5 | 9.5 | 4.4 | 46 |
| 3 | 29 | 1335 | 4455.5-4465.0 | 18.5-28.0 | 9.5 | 6.3 | 66 |
| 4 | 29 | 1455 | 4465.0-4474.5 | 28.0-37.5 | 9.5 | 2.0 | 21 |
| 5 | 29 | 1625 | 4474.5-4484.0 | 37.5-47.0 | 9.5 | 3.6 | 38 |
| 6 | 29 | 1758 | 4484.0-4493.5 | 47.0-56.5 | 9.5 | 9.8 | 100 + |
| 7 | 29 | 1940 | 4493.5-4503.0 | 56.5-66.0 | 9.5 | 3.1 | 33 |
| 8 | 29 | 2106 | 4503.0-4512.5 | 66.0-75.5 | 9.5 | 7.7 | 81 |
| 9 | 29 | 2245 | 4512.5-4522.0 | 75.5-85.0 | 9.5 | 1.2 | 13 |
| 10 | 30 | 0130 | 4522.0-4526.5 | 85.0-89.5 | 4.5 | 0.0 | 0 |
| 11 | 30 | 0303 | 4526.5-4531.5 | 89.5-94.5 | 5.0 | 0.5 | 10 |
| 12 | 30 | 0443 | 4531.5-4541.0 | 94.5-104.0 | 9.5 | 7.0 | 74 |
| 13 | 30 | 0650 | 4541.0-4550.5 | 104.0-113.5 | 9.5 | 9.9 | 100 + |
| 14 | 30 | 0827 | 4550.5-4560.0 | 113.5-123.0 | 9.5 | 9.6 | 100 + |
| 15 | 30 | 0955 | 4560.0-4569.5 | 123.0-132.5 | 9.5 | 3.2 | 34 |
| 16 | 30 | 1138 | 4569.5-4579.0 | 132.5-142.0 | 9.5 | 7.2 | 76 |
| 17 | 30 | 1302 | 4579.0-4588.5 | 142.0-151.5 | 9.5 | 6.5 | 68 |
| 18 | 30 | 1419 | 4588.5-4598.0 | 151.5-161.0 | 9.5 | 4.5 | 47 |
| 19 | 30 | 1615 | 4598.0-4607.5 | 161.0-170.5 | 9.5 | 7.5 | 79 |
| 20 | 30 | 1745 | 4607.5-4617.0 | 170.5-180.0 | 9.5 | 5.1 | 54 |
| 21 | 30 | 1950 | 4617.0-4621.5 | 180.0-184.5 | 4.5 | 0.4 | 9 |
| 22 | 30 | 2137 | 4621.5-4626.5 | 184.5-189.5 | 5.0 | 2.3 | 46 |
| 23 | 30 | 2310 | 4626.5-4636.0 | 189.5-199.0 | 9.5 | 2.5 | 26 |
| 24 | 1 | 0050 | 4636.0-4645.5 | 199.0-208.5 | 9.5 | 5.6 | 59 |
| 25 | 1 | 0234 | 4645.5-4655.0 | 208.5-218.0 | 9.5 | 3.2 | 34 |
| 26 | 1 | 0407 | 4655.0-4664.5 | 218.0-227.5 | 9.5 | 3.6 | 38 |
| 27 | 1 | 0543 | 4664.5-4674.0 | 227.5-237.0 | 9.5 | 5.0 | 53 |
| 28 | 1 | 0723 | 4674.0-4683.5 | 237.0-246.5 | 9.5 | 8.7 | 92 |
| 29 | 1 | 0901 | 4683.5-4693.0 | 246.5-256.0 | 9.5 | 3.6 | 38 |
| 30 | 1 | 1032 | 4693.0-4702.5 | 256.0-265.5 | 9.5 | 5.4 | 57 |
| 31 | 1 | 1205 | 4702.5-4712.0 | 265.5-275.0 | 9.5 | 7.5 | 79 |
| 32 | 1 | 1333 | 4712.0-4721.5 | 275.0-284.5 | 9.5 | 9.2 | 97 |
| 33 | 1 | 1455 | 4721.5-4731.0 | 284.5-294.0 | 9.5 | 5.1 | 5 |
| 34 | 1 | 1620 | 4731.0-4740.5 | 294.0-303.5 | 9.5 | 9.6 | 100 + |
| 35 | 1 | 1754 | 4740.5-4750.0 | 303.5-313.0 | 9.5 | 7.1 | 75 |
| 36 | 1 | 1920 | 4750.0-4759.5 | 313.0-322.5 | 9.5 | 7.9 | 83 |
| 37 | 1 | 2055 | 4759.5-4769.0 | 322.5-332.0 | 9.5 | 9.4 | 99 |
| 38 | 1 | 2232 | 4769.0-4778.5 | 332.0-341.5 | 9.5 | 6.8 | 72 |
| 39 | 2 | 0239 | 4778.5-4783.5 | 341.5-346.5 | 5.0 | 4.8 | 96 |
| 40 | 2 | 0541 | 4783.5-4787.5 | 346.5-350.5 | 4.0 | 2.6 | 65 |
| 41 | 2 | 0955 | 4787.5-4796.5 | 350.5-359.5 | 9.0 | 6.6 | 73 |
| 42 | 2 | 1305 | 4796.5-4805.5 | 359.5-368.5 | 9.0 | 6.2 | 69 |
| 43 | 2 | 1624 | 4805.5-4814.5 | 368.5-377.5 | 9.0 | 6.0 | 67 |
| 44 | 2 | 2035 | 4814.5-4821.5 | 377.5-384.5 | 7.0 | 6.7 | 96 |
|  |  |  |  | Totals | 384.5 | 243.9 | 63 |

## SEDIMENT LITHOLOGY

One hole was rotary-drilled and continuously cored at Site 527. A sedimentary sequence 341.5 m thick, of Pleistocene to Maestrichtian age, was recovered. It is underlain by a basaltic sequence interlayered with late Maestrichtian sediments which was cored to a total depth of 384.5 m sub-bottom (Fig. 3)

The dominant lithologies are nannofossil ooze and chalk, clayey nannofossil ooze and chalk, nannofossil clay, and basalt. We divided the recovered section into five lithologic units on the basis of calcium carbonate content, composition (based mainly on smear slide analyses), and color. Color changes occur near, but are often not coincident with, changes in lithology. This is a result of the effect on color of small amounts of clay (< 10%) that are not included in the DSDP standard descriptive classification system. In these cases, unit boundaries are defined in accordance with the descriptive lithology classification system, not with color changes or minor changes in composition.

### Unit I

This unit extends from the mud line to 104.0 m sub-bottom (Cores 1-12). The sediments consist predominantly of white (N9) or pinkish gray (5YR8/1) to very pale orange (10YR8/2) homogeneous nannofossil ooze. Only the upper portion (Cores 1 and 2) consists of alternating yellowish brown (10YR4/2) to yellowish gray (5Y8/1) foraminifer-nannofossil ooze.

A distinct color change occurs at 94.5 m (top of Core 12) because of a slight increase of clay content. Calcium carbonate content in the biogenic ooze of Unit I averages over 90%, dropping to about 80% in Core 12 and causing the color change. Slight bioturbation activity by some *Planolites* and halo burrows is recognizable only in the upper part of this unit from 0-28 meters (Cores 1-3).

The alternating colors in Cores 1 and 2 may represent sedimentary cycles between 20-70 cm in thickness. Vague traces of the preserved cyclic sedimentation pattern are present in the underlying homogeneous nannofossil ooze as well.

### Unit II

Sediments extend from 104.0 to 142.0 m sub-bottom (Cores 13-16; 38 m thickness) and consist of pale yellowish brown (10YR6/2) to dark yellowish brown (10YR 4/2) marly nannofossil oozes and pale brown (10YR6/2) to dark brown (7.5YR4/4) pelagic nannofossil clays. These carbonate-poor lithologies include an interval (121.0-approx. 130 m) of very pale orange (10YR8/2) nannofossil ooze with interbedded chalk layers separating the unit into upper and lower subunits. The changes from marly nannofossil ooze to nannofossil clay to nannofossil ooze are well documented by corresponding decreases and increases of calcium carbonate content (Fig. 3) and fit well with distinct color changes in the unit.

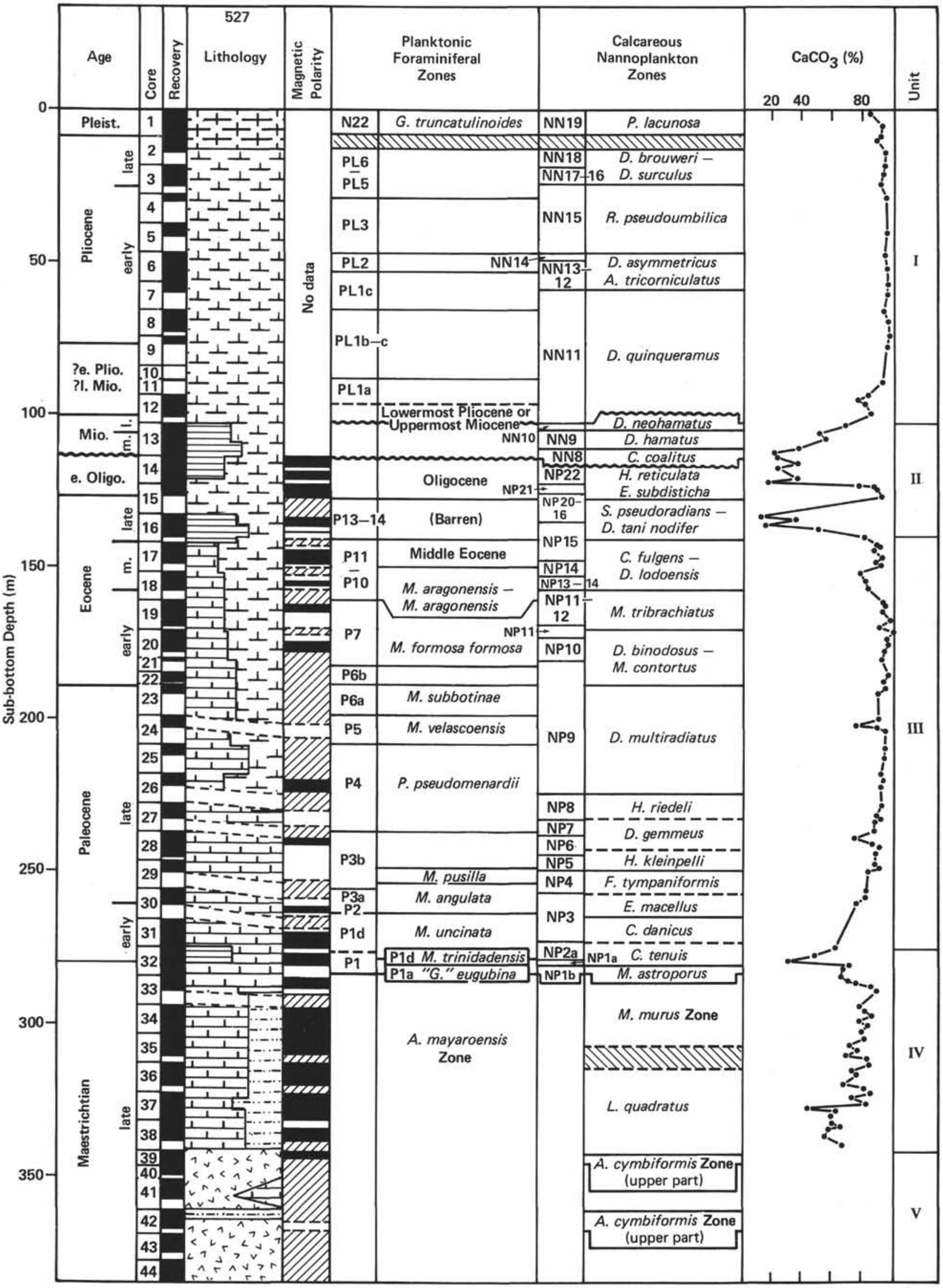


Figure 3. Lithostratigraphic and biostratigraphic summary for Site 527.

A cyclic sedimentation pattern indicated by changes in color and clay content is present in the carbonate-poor subunits. Each cycle ranges from 15 to 240 cm in length.

Bioturbation is strong throughout this unit. *Planolites* are predominant, but halo burrows, *Chondrites*, and *Zoophycos* are present as well.

From 104.20 to 112.0 m (Core 13), the dark yellowish brown (10YR4/2) marly nannofossil ooze-nannofossil clay contains very pale orange (10YR6/2) blobs of nannofossil ooze. The outlines of the blobs are irregular and blurred. Though drilling disturbance is strong, the blobs are not an effect of drilling, as evidenced by a *Zoophycos* burrow crosscutting in a straight line both the blobs as well as the surrounding sediment (Fig. 4).

Sediments of Unit II represent an extensive dissolution facies. Fluctuations in calcium carbonate content indicate major dissolution events which are probably additionally modified by smaller cycles recognized from changes in color and clay content.

### Unit III

This unit extends from 142.0 to 275.0 m sub-bottom (Cores 17-31; 133 m thickness) and consists of alternating layers of very pale orange (10YR8/2), yellowish gray (5YR8/1), and light gray (10YR8/7) nannofossil ooze and nannofossil chalk. There is a distinct color change at 256 m (Core 30) to very pale brown (10YR7/3), which is caused by an increasing clay content (cf. Unit I).

At the top of Unit III, the ooze-chalk sequence shows cycles which repeat about every 50 cm with a predominance of ooze. Farther down, the frequency of the cycles as well as the thickness of the chalk layers increases, leading to an almost continuous chalk sequence at a depth of about 235 m (Core 27). This represents the normal diagenetic path from ooze to chalk with increasing depth.

Calcium carbonate content fluctuates around 90% throughout this unit, dropping to about 80% at the color change below 256 m (Cores 30-31; cf. Unit I).

Bioturbation is slight in the upper part of Unit III but increases gradually downward, showing a pronounced increase in sediment beneath the color change at 256 m (Cores 30, 31). *Planolites* is the most abundant ichnofossil, halo burrows, *Chondrites*, composite burrows, *Zoophycos*, and *Teichichnus* also present, as well as long, vertical burrows (Fig. 5).

The interval from 218.0 to 237.0 m (Cores 26, 27) contains small (1 mm-1 cm) black concretions which may be Mn micronodules. Shipboard XRD analyses did not result in identifiable peaks owing to the probable presence of X-ray amorphous Mn oxides (see XRD Analysis, this chapter).

### Unit IV

Unit IV extends from 275.0 to 341.5 m sub-bottom (Cores 32-38; 66.5 m thickness). It consists of light brown (5YR6/4) to very pale brown (10YR7/4) marly nannofossil chalk at the top from 275.0 to 280.5 m (Core 32) and of a multicolored predominantly reddish yellow (5YR6/6) to pink (5YR7/4) muddy nannofossil chalk beneath, separated by an interval of pink (5YR8/4) to very pale brown (10YR7/4) nannofossil chalk (Fig. 3).

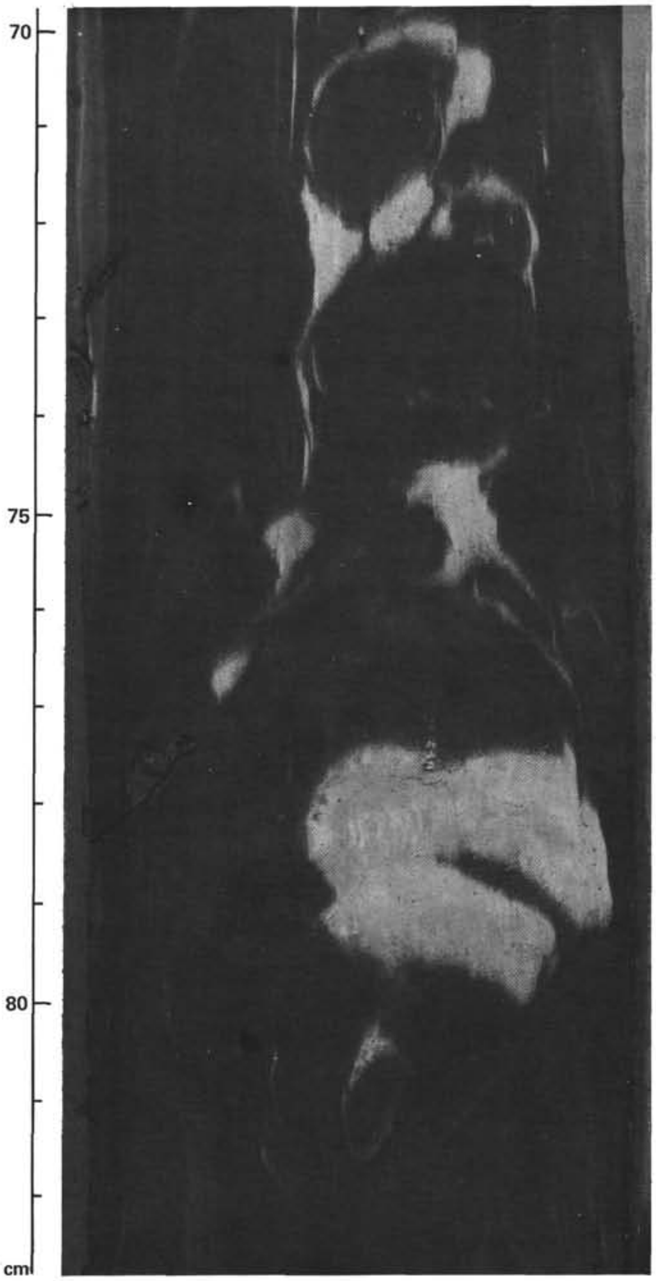


Figure 4. Sample 527-13-2, 70-80 cm. Blobs of nannofossil ooze included in marly nannofossil ooze and clay. Note *Zoophycos* burrow which cross-cuts both the blob and the surrounding sediment.

The marly nannofossil chalk contains a considerable amount of pelagic clay. The smear slide findings fit well with the relatively low calcium carbonate contents of 30-60% from the carbonate bomb. At the bottom of this unit, the Cretaceous/Tertiary boundary (see Biostratigraphic Summary, this chapter) is marked by a sharp color change (Fig. 6).

The muddy nannofossil chalk of Unit IV is characterized by volcanic glass and palagonite that increases with depth. The smear slide results agree well with the cal-

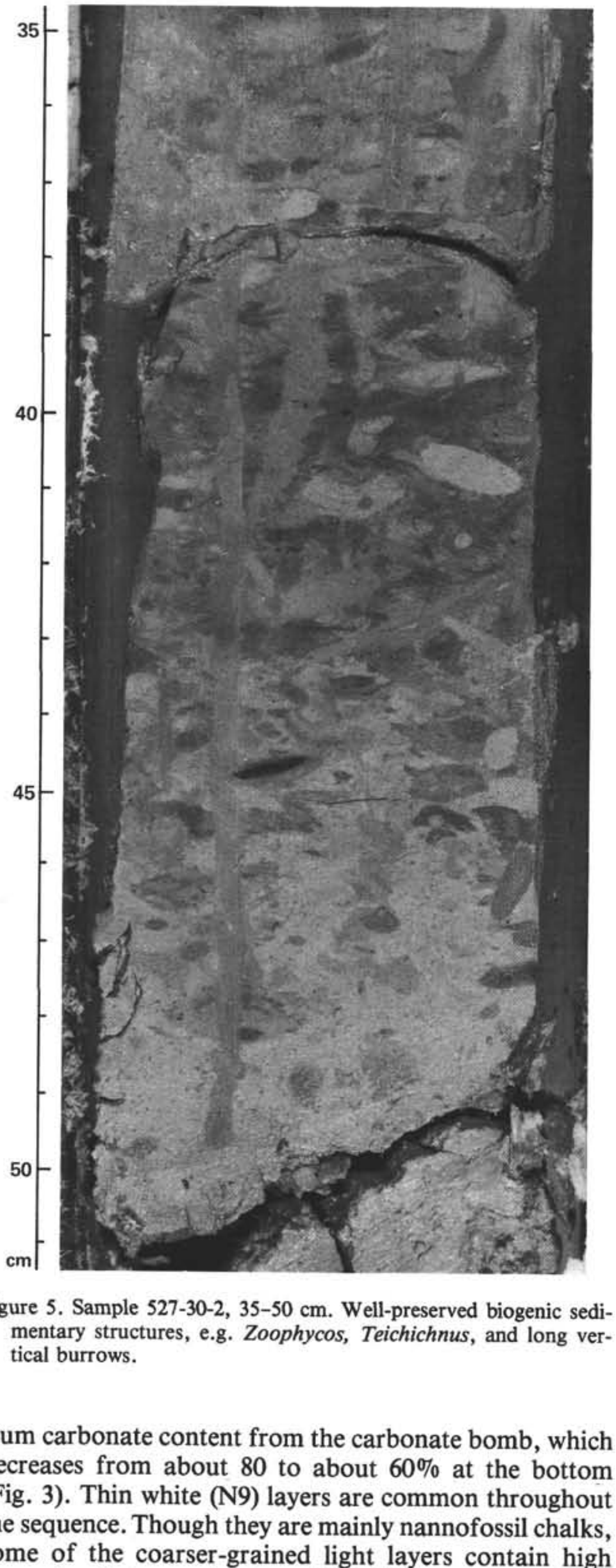


Figure 5. Sample 527-30-2, 35–50 cm. Well-preserved biogenic sedimentary structures, e.g. *Zoophycos, Teichichnus*, and long vertical burrows.

cium carbonate content from the carbonate bomb, which decreases from about 80 to about 60% at the bottom (Fig. 3). Thin white (N9) layers are common throughout the sequence. Though they are mainly nannofossil chalks, some of the coarser-grained light layers contain high amounts of glass and palagonite, which point to volcanic origin. Color changes are abundant, suggesting changing environmental conditions.

Sedimentary structures are very common in this unit. Horizontal and inclined laminations, convolute bedding, and cross-laminations indicate either small current activity (contour currents?) and/or deformation due to loading (Figs. 7 and 8). Though sediment structures are well preserved in some parts, bioturbation is moderate to strong. In general, the same ichnofossil association is found as in Unit III: predominantly *Planolites*, with halo burrows, *Chondrites*, and *Zoophycos*.

### Unit V

This unit comprises the interbedded sedimentary rocks of the basaltic basement complex, extending from 341.5 to 384.5 m sub-bottom (Cores 39–44; 43 m thickness).

Core 41 contains a 50-cm sequence of reddish brown (5YR4/4), partly recrystallized nannofossil chalk and pinkish gray (10YR6/2) marly nannofossil chalk with high amounts of volcanogenic material.

Core 42 contains a pinkish gray (5YR6/2) to reddish brown (5YR5/4) carbonate mudstone with high amounts of volcanogenic material. Bioturbation is strong in places, showing large vertical and horizontal burrows (probably *Planolites*).

These interlayered sediments appear highly altered and baked, owing possibly to heat from the basalt (for details see interstitial water studies in the next section).

### Remarks

The sedimentary sequence recovered at Site 527 provides some clues to the evolution of the Walvis Ridge and the oceanographic variations in the southwestern Angola Basin.

The Maestrichtian sequence of interbedded basalts and sediments (Unit V) was followed by a subsequent decrease in volcanic activity in surrounding areas—probably in the Walvis Ridge area—that produced a mixed sequence with decreasing fine-grained volcaniclastic (ash) material and increasing biogenic pelagic material (Unit IV) up to the Cretaceous/Tertiary boundary. Sediment structures suggest some current activity, probably of contour current type. The marly nannofossil chalk of the early Paleocene (still Unit IV) may reflect a temporary rise of the CCD. The subsequent sequence of nannofossil chalk and ooze (Unit III) characterizes a long period of pelagic conditions well above the CCD. The late Eocene to late Miocene history with its marly nannofossil oozes and nannofossil clays (Unit II) represents a time of fluctuating CCD. At least two main dissolution events are observed which probably are modified by superimposed additional smaller cycles. The overlying carbonate-rich sediments (Unit I) record a distinct lowering of the CCD at about latest Miocene times, with pure pelagic carbonate deposition extending to the present time.

## INORGANIC GEOCHEMISTRY—INTERSTITIAL WATER STUDIES

The results of the interstitial water studies for Hole 527 are shown in Figure 9 and tabulated in Table 2. pH, salinity, alkalinity, and chlorinity trends with depth are very similar to those obtained at Site 525. There is one anomalous salinity value at approximately 320 m sub-

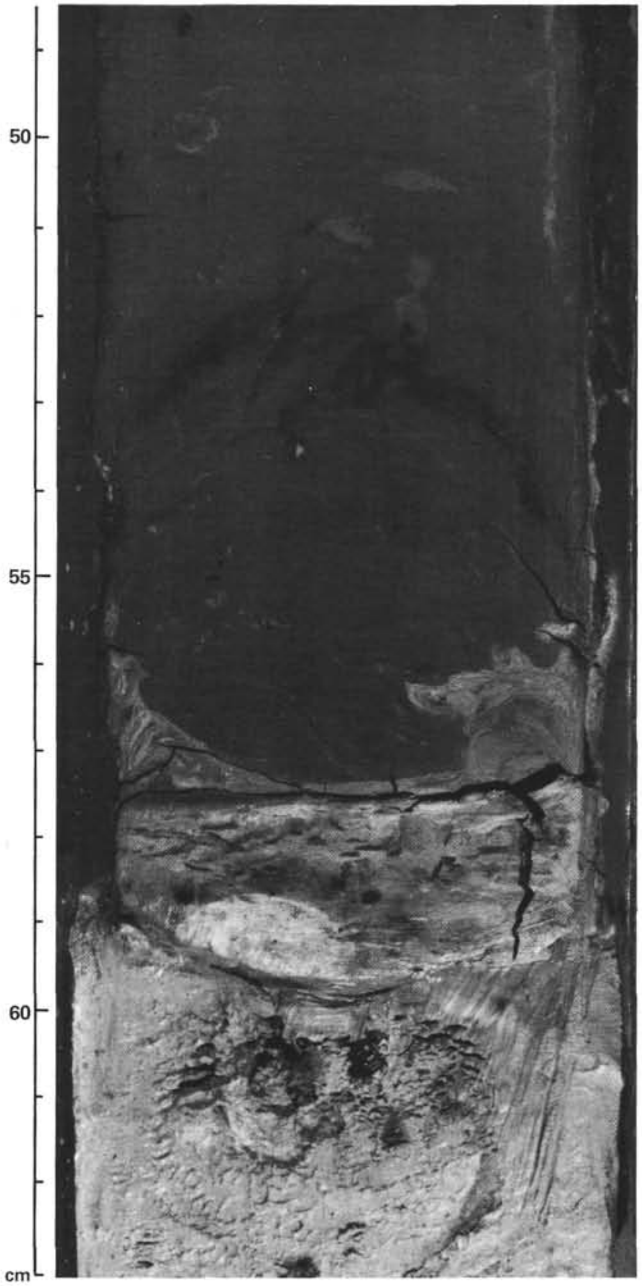


Figure 6. Sample 527-24-2, 40-65 cm. Core photograph of the Cretaceous/Tertiary boundary, marked by a sharp color change.

Table 2. Summary of shipboard pore water study, Hole 527.

| Sample No. | DSDP Sample (interval in cm) | Sub-bottom Depth (m) | pH | Alkalinity (meq/l) | Salinity (‰) | Calcium (mmoles/l) | Magnesium (mmoles/l) | Chlorinity (‰) |
|---|---|---|---|---|---|---|---|---|
| | IAPSO | | 7.844 | 2.361 | 35.2 | — | — | — |
| | SSW | | 8.012 | 2.186 | 35.8 | 10.71 | 54.77 | 19.80 |
| 42 | 1-4, 144-150 | 5.94-6.00 | 7.266 | 2.396 | 35.2 | 10.62 | 52.57 | 19.44 |
| 43 | 3-2, 140-150 | 21.46-21.50 | 7.255 | 2.439 | 35.2 | 11.43 | 52.11 | 19.60 |
| 44 | 5-2, 140-150 | 40.40-40.50 | 7.246 | 2.393 | 35.2 | 12.56 | 51.11 | 19.53 |
| 45 | 12-4, 144-150 | 100.40-100.50 | 7.296 | 1.816 | 35.2 | 15.14 | 47.31 | 19.60 |
| 46 | 13-4, 140-150 | 110.40-110.50 | 7.276 | 1.862 | 35.2 | 15.62 | 46.44 | 19.53 |
| 47 | 16-3, 140-150 | 136.90-137.00 | 7.257 | 1.549 | 35.2 | 17.60 | 45.95 | 19.55 |
| 48 | 20-2, 140-150 | 173.40-173.50 | 7.181 | 1.507 | 35.2 | 18.77 | 45.34 | 19.56 |
| 49 | 23-1, 140-150 | 190.90-191.00 | 7.196 | 1.572 | 35.2 | 19.76 | 44.47 | 19.73 |
| 50 | 27-3, 140-150 | 231.90-232.00 | 7.227 | 1.476 | 35.2 | 21.78 | 42.45 | 19.72 |
| 51 | 32-4, 140-150 | 280.90-281.00 | 7.214 | 1.237 | 35.2 | 24.44 | 40.97 | 19.73 |
| 52 | 35-4, 140-150 | 309.40-309.50 | 7.184 | 1.168 | 36.3 | 25.44 | 40.27 | 19.73 |
| 53 | 38-4, 140-150 | 337.90-338.00 | 7.214 | 0.674 | 35.5 | 26.46 | 39.34 | 19.72 |
| 54 | 42-2, 135-140 | 362.35-362.50 | 7.160 | 0.196 | 35.2 | 54.44 | 15.04 | 19.73 |

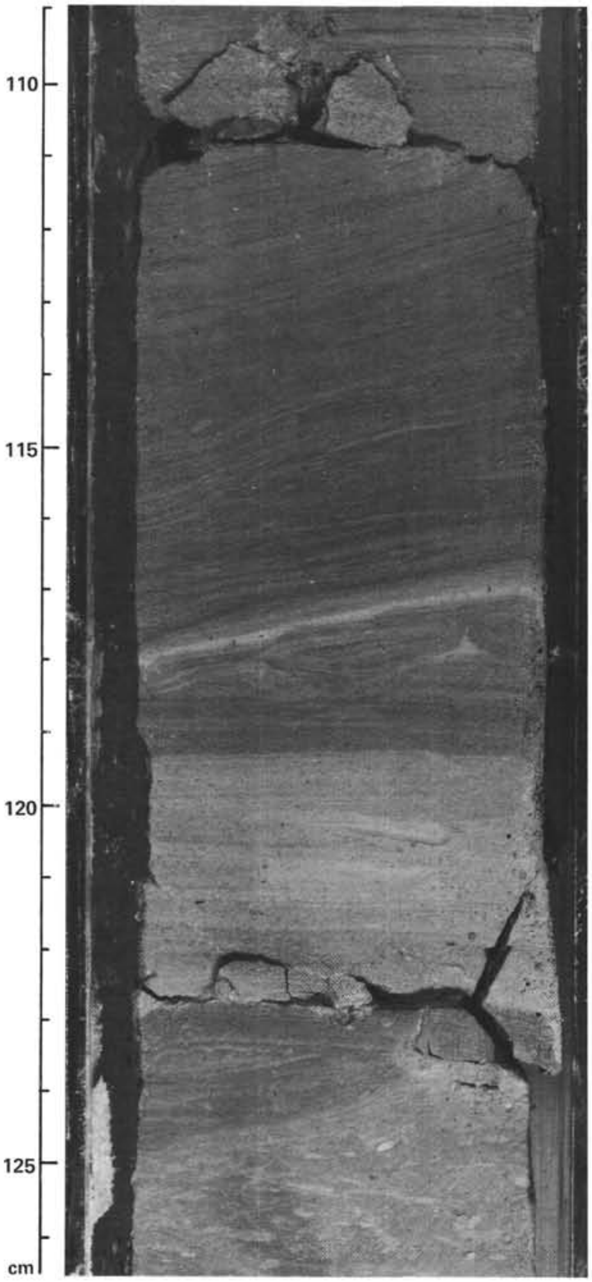


Figure 7. Sample 527-36-4, 110–125 cm. A well-preserved example of parallel and cross laminations indicating current activity during this time interval at Site 527.

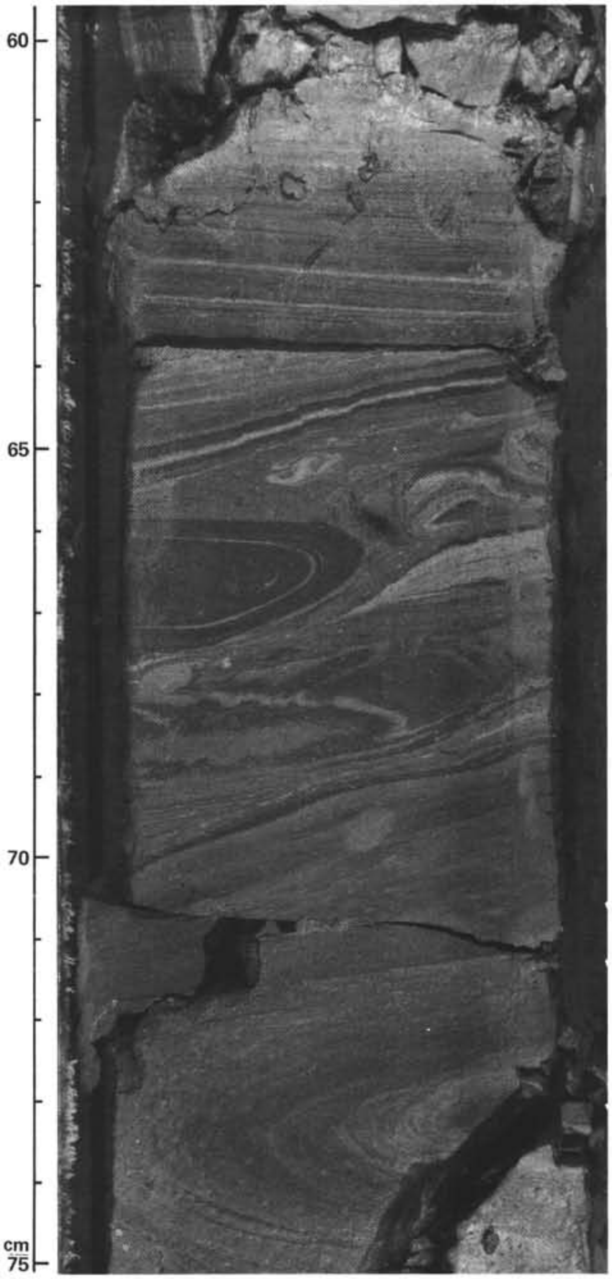


Figure 8. Sample 527-37-5, 60–75 cm. An example of convolute bedding overlain by parallel laminations. This may indicate slump and current activity or deformation due to loading.

bottom that is probably due to the analytical technique involved. Chlorinity at this depth is constant, as is alkalinity.

In the sediments above basement, calcium and magnesium show the same trends (1:1 Ca increase with Mg decrease) that were reported at Site 525. This inverse relationship in the trends of Mg and Ca are discussed in the Site 525 chapter. In the sediments that are interbedded between basalt units, calcium increases and magnesium decreases dramatically. Alkalinity also shows a decrease. It appears that this rapid change is due to seawater-basement interaction, possibly at elevated temperatures. Magnesium is released during submarine weathering. It combines with $CO_3^=$ and forms a precipitate aiding in the cementation process. This also explains the decrease in alkalinity. Calcium increases in pore waters because of dissolution. Basalt weathering also adds calcium to seawater. Thus within the sediment pore waters, Mg is preferentially removed and Ca is enriched. Bischoff and Dickson (1975) showed that seawater reacting with basalt at 200°C and 500 bars for 198 days changed from a slightly basic to slightly acid solution. Mg and $SO_4^=$ decreased to near-detection limits and calcium increased to twice its initial value. Perhaps elevated temperatures are or were responsible for liberating calcium from the basalt into the pore waters. This, superim-

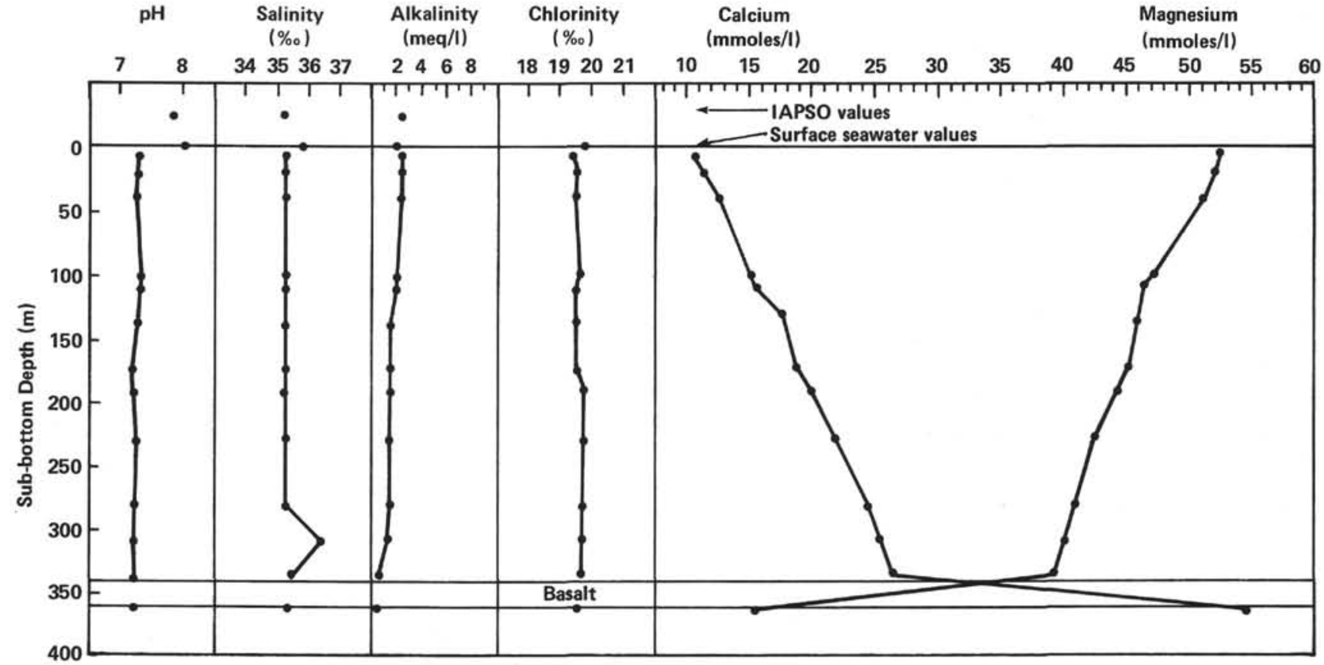


Figure 9. The results of the pore water chemistry plotted against depth at Site 527.

posed on the calcium put into solution by dissolution of calcite, may be responsible for the extremely high Ca$^{++}$ concentration in the sediment layers between basalt.

## X-RAY DIFFRACTION ANALYSIS

Twenty-one samples from Site 527 were analyzed by X-ray diffraction (XRD) by the same procedure as at Site 525.

The results are shown in Table 3. Not surprisingly, calcite is present in virtually all the samples in varying amounts, and the presence of detrital minerals confirms and supplements the information from the smear slides. The detrital minerals generally comprise illite and/or quartz, with various feldspars. Quartz was identified by its 100 peak at 20.8°$2\theta$ (4.26 Å) and illite by its 001 peak at 8.8°$2\theta$ (10 Å) and sometimes by its 002 at 17.8°$2\theta$ (5 Å). In many cases, however, these peaks were missing and only a 26.7°$2\theta$ (3.34 Å) peak was observed; this was interpreted as either the illite 003 or the quartz 101 or both. (Since the 101 is the dominant quartz peak and the illite 001 and 003 generally have roughly equal intensities, this probably indicates the presence of quartz.) In some cases, identification of feldspars was easy (e.g., anorthoclase in Cores 16, 24, and 34 and sanidine in Core 36), though in Cores 32 and 42 a broad band of diffuse reflections were observed between 27°$2\theta$ and 28.5°$2\theta$ (3.30–3.14 Å). These were probably due to the presence of many different feldspars, and no attempt was made to distinguish individual minerals. Kaolinite/chlorite was identified by a small peak at 12.4°$2\theta$ (7.14 Å) in Core 16 and by its peaks at 12.4°$2\theta$ and 24.9°$2\theta$ (3.58 Å) in the sample from Core 24.

Table 3. X-ray diffraction analysis, Site 527.

| Core–Section (level, interval in cm) | Dominant/Minor Lithology | Minerals Identified |
|---|---|---|
| 13,CC | Acid-insoluble | Quartz, plagioclase, illite |
| 15-2, 50 | D | Calcite |
| 16-1, 50 | D | Calcite, illite/quartz |
| 16-2, 50 | D | Calcite, illite/quartz, K-feldspar |
| 16-3, 50 | D | Calcite, illite, quartz, anorthoclase |
| 16-4, 50 | D | Calcite, halite, illite/quartz, kaolinite/chlorite |
| 16-5, 50 | D | Calcite |
| 24-1, 13–15 | Acid-insoluble | Quartz, illite, calcite, anorthoclase, kaolinite/chlorite |
| 24,CC | D | Calcite |
| 26-2, 42 | M (black concretion) | Calcite |
| 26-2, 42 | Acid-insoluble | Amorphous black material, Mn oxide(?), psilomelane(?) |
| 27-3, 110 | D | Calcite, illite |
| 31-1, 30 | M | Calcite |
| 32-1, 75 | D | Calcite, quartz, various feldspars |
| 34-6, 40 | D | Calcite, illite, quartz, anorthoclase |
| 36-3, 33 | M (white layer) | Calcite, illite/quartz, sanidine |
| 36-5, 52 | M (white layer) | Calcite, illite/quartz |
| 40-1, 64 | M (vein in basalt) | Quartz, smectite, diopside/augite |
| 40-2, 25 | M (vein in basalt) | Smectite |
| 40-2, 127 | M (phenocryst) | Plagioclase |
| 42-2, 75 | D | Calcite, illite, feldspars (various) |

Interspersed throughout the cores were many black nodular or concretionary grains, which we suspected to be a Mn oxide of some sort. Several of the larger nodules were sampled and analyzed on the XRD unit (e.g., Sample 527-26-2, 42 cm). Calcite was the only well-crystallized mineral present. The sample was then acidified and the residue X-rayed. The insoluble residue diffractogram was very poor, with only very small questionable peaks being recognized. This is not uncommon, since noncrystalline or X-ray amorphous oxides are abundant in nodules and, in fact, often predominate (Glasby, 1977, p. 54). Interestingly enough, the small peaks coincide with the X-ray diffraction pattern of the mineral psilomelane $[(Ba, K, Mn, CO)_2 Mn_5 O_{10} \cdot H_2O]$, an hydrated manganese oxide that has been reported in marine manganese nodules.

Two samples were taken from mineralized veins in the basalt of Core 40. These showed the presence of smectite as an alteration product and quartz in one of the veins. In one sample (Core 40, Section 1, at 64 cm), a prominent peak at 29.9°2$\theta$ was observed. This is probably a pyroxene peak, though the distinction between augite and diopside was not made because of the absence of any of the minor peaks. Finally, one sample was taken from one of the phenocrysts in the basalt, and the XRD trace showed only plagioclase peaks.

## BIOSTRATIGRAPHIC SUMMARY

Site 527 was drilled at a depth of 4437 m and is located at 28°02′S latitude and 01°45′E longitude, on the western section of the Walvis Ridge, in the path of the southern Atlantic subtropical gyre. One hole was continuously rotary-cored from the Pleistocene into the Maestrichtian, where basement was reached.

Nannofossils and planktonic and benthic foraminifers were studied throughout the section, although Miocene and upper Eocene sediments were barren of foraminifers. Biostratigraphic zonation of the section is based on the time scales described in the summary for Site 525. Results of study of all core catcher samples are shown in the biostratigraphic summary diagram (Fig. 3) and tabulated in the Hole Summary sheets.

### Calcareous Nannoplankton

At Site 527 calcareous nannoplankton were identified in all core catcher samples. Nevertheless, over some short intervals where nannofossil assemblages change very fast, closely spaced samples were investigated in order to extract maximum information from the slowly deposited sediments. A depositional hiatus was encountered between Cores 13 and 14, where the sediments are dominated by clay. The lower part of the middle Miocene through the upper Oligocene is missing. The Cretaceous/Tertiary boundary, on the other hand, was recovered in Core 32. Though there is a minor lithological change at this contact, paleontologically this sequence is continuous; a total thickness of about 2.5 m of the basal Tertiary NP1 Zone overlies the *Micula murus* Zone of the uppermost Cretaceous.

Basalt was encountered at the base of Core 38. The oldest sediments above the basalt in Core 38 and sandwiched within the basalt in Cores 41 and 42 belong to the upper part of the lower Maestrichtian, the upper part of the *Arkhangelskiella cymbiformis* Zone.

#### *Pleistocene (0–9.0 m)*

Quaternary sediments were recognized only in Core 1. The core catcher sample contains abundant *Emiliania ovata* and common *Pseudoemiliania lacunosa* and *Cyclococcolithus macintyrei*. This assemblage indicates the basal part of Zone NN19. Very rare discoasters were found in this sample. Tentatively, they are interpreted as reworked forms. Three other samples from the upper part of Core 1 (1-1, 29–30 cm, 1-2, 29–30 cm, and 1-3, 29–30 cm) were also investigated. These three samples all contain *C. macintyrei* and belong to the lower part of Zone NN19. Either no sediments younger than 1.51 m.y. old accumulated on the top of this site, or younger sediments were missed in the coring process.

#### *Pliocene (9.0–95[?] m)*

Sample 527-2,CC contains *Discoaster pentaradiatus* and belongs to Zone NN17 of the upper Pliocene. Abundant *Reticulofenestra pseudoumbilica* with no *Amaurolithus* species in Samples 527-3,CC to 527-5,CC indicate Zone NN15 of lower Pliocene. Sample 527-6, CC is assigned to NN13 or NN12 because it contains common *Amaurolithus* species with rare, questionable *Ceratolithus* sp. but without *D. asymmetricus*.

#### *Miocene (95[?]–112.79 m)*

Samples 527-7,CC through 527-12,CC contain transitional assemblages of the lower Pliocene and upper Miocene. *Discoaster quinqueramus*, the index fossil of Zone NN11, was not found at this site. The age assignment of these cores to Zone NN11 is based mainly on the presence of *Amaurolithus amplificus*, whose last occurrence could be within the upper part of Zone NN11. Because few to common *Amaurolithus* species were still found in these cores, the age of these cores is no older than the upper part of Zone NN11.

The sediment in Core 13 contains mainly barren clay. By selective sampling of light-colored calcareous mottles occurring in otherwise barren matrices, some nannofossils were found. All these mottles, of questionable origin, yielded adequate common to abundant nannofossil assemblages. The results of nannofossil investigation of these closely spaced samples is given in Figure 3. The top of Core 13 belongs to Zone NN10 or, at least, no higher than the lower part of Zone NN11.

*Discoaster hamatus* was consistently found from Sample 527-13-1, 63 cm down to 527-13-5, 44 cm, which limits this interval to Zone NN9 of the middle Miocene. Sample 527-13-5, 66 cm to 527-13-6, 129 cm, on the other hand, contains *Catinaster coalitus* and *C. calyculus*, without *D. hamatus*, and is attributed to Zone NN8 of the middle Miocene.

Obviously, dissolution has been important in Core 13. Nannofossil assemblages from this interval have been strongly and selectively altered, so that most placoliths and other coccoliths have been dissolved. A few specimens of *Reticulofenestra* sp., *Cyclococcolithus leptoporus*, and *Coccolithus pelagicus* are very poorly preserved. Discoasters, on the contrary, are enriched in the assemblages because of their resistance to dissolution. Their preservation remains good.

#### *Oligocene (113.84–123.0 m)*

The sediments in Core 14 are essentially the same as those in Core 13. Sample 527-14,CC contains an abundant yet poorly preserved nannofossil assemblage. The common occurrence of *Dictyococcites bisectus*, *Cyclicargolithus floridanus*, and *Sphenolithus predistentus*, together with *Helicosphaera compacta* and *Reticulofenestra umbilica*, without *Discoaster barbadiensis* or *D. saipanensis*, indicates Zone NP22 (NP21?) of the lower Oligocene. Two white calcareous mottles in Samples 527-14-1, 34 cm and 527-14-2, 118 cm contain less abundant nannofossil assemblages, probably of the same age as Sample 527-14,CC. The rare occurrence of *D. barbadiensis* and *D. saipanensis* in 527-14-1, 34 cm is tentatively interpreted as due to reworking.

### *Eocene (132.5–184.5 m)*

Upper Eocene sediment was encountered only in Sample 527-15,CC, which contains common *Dictyococcites bisectus* and some *Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis*, and *Helicosphaera compacta*. This assemblage represents the zonal interval from Zones NP16 to NP20. Detailed zonal assignment is impossible because of the absence of upper Eocene index fossils. In Sample 527,16,CC, *R. umbilica* is absent; the presence of *Chiphragmalithus fulgens* and *Chiasmolithus gigas* limits the core catcher sample to Zone NP15 of the middle Eocene. Sample 527-17,CC contains *Discoaster lodoensis, D. sublodoensis, Triquetrorhabdulus inversus*, and *Cyclococcolithus gammation*, which indicate Zone NP14 or the lower part of Zone NP15.

The presence of *Marthasterites tribrachiatus*, first encountered in Sample 527-18,CC, indicates Zone NP12 of the lower Eocene. Sample 527-18,CC, however, still contains rare *D. sublodoensis*, whose first occurrence defines the base of Zone NP13. Tentatively, this sample is attributed to Zone NP12.

In Samples 527-19,CC and 527-21,CC, *D. lodoensis* is absent. The assemblage is dominated by *Toweius* spp., *D. diastypus, D. salisburgensis*, and other lower Eocene species. Both cores are assigned to Zones NP11 to NP10 of the lower Eocene. Sample 527-20,CC contains *D. lodoensis* and is probably a mixed sample.

### *Paleocene (189.5–280.0 m)*

Samples 527-22,CC through 527-25,CC contain common *Discoaster multiradiatus* together with abundant *Coccolithus pelagicus* and *Toweius* spp. and are typical of Zone NP9 of the upper Paleocene. The absence of *D. multiradiatus* and the presence of *Heliolithus* cf. *riedeli* in Sample 527-26,CC indicate that this sample belongs to Zone NP7 or NP8. The co-occurrence of *D. gemmeus* and *Heliolithus kleinpelli*, on the other hand, places Sample 527-27,CC in Zone NP7. In Sample 527-28,CC, both *D. gemmeus* and *H. kleinpelli* are absent. The assemblage is dominated by *Toweius* spp., *C. pelagicus*, and *Fasciculithus tympaniformis*, which suggest Zone NP5 of the upper Paleocene. Sample 527-29,CC, which contains rare *Ellipsolithus macellus*, without *F.* sp., is assigned to Zone NP4. In Sample 527-30,CC, the assemblage is dominated by *C. pelagicus* (= *C. cava*), *Zygodiscus sigmoides, Biscutum* cf. *dimorphosum, Cyclococcolithus robustus, Cruciplacolithus tenuis*, and *Chiasmolithus* sp. The *Chiasmolithus* species found in this core has a very small central opening and very tiny crossbars, which is not typical of *C. danicus*. Tentatively, this core is placed in Zone NP3 of the lower Paleocene. Sample 527-31,CC contains common *C. tenuis* and *Thoracosphaera* spp., without *Chiasmolithus* species, and is typical of Zone NP2 of the lower Paleocene (the Danian).

A continuous Cretaceous–Tertiary succession was encountered in Section 4 of Core 32 (280.0 m in depth). Closely spaced samples were taken immediately above and below the contact. Their nannofossil assemblages are as follows:

| Core/Section (interval, level in cm) | Age/Zone | *Braarudosphaera bigelowi* | *Thoracosphaera* | Cretaceous Forms |
|---|---|---|---|---|
| 32-1, top | NP2 | | F–C | |
| 32-2, top | NP2 | | F–C | |
| 32-2, 64–65 | NP2 | C | C | R |
| 32-2, 150 | NP1 | F | A | R |
| 32-4, 30 | NP1 | A | A | R |
| 32-4, 40 | NP1 | A | C | F |
| 32-4, 50 | NP1 | F | C | C |
| 32-4, 52 | Cretaceous | | C | Flooding |
| 32-4, 60 | Cretaceous | | | Flooding |
| 32-4, 150 | Cretaceous | | | Flooding |
| 32-5, 90 | Cretaceous | | | Flooding |

### *Maestrichtian (280.0–basement)*

Sample 527-32,CC contains an assemblage characteristic of Zone NP2. Obviously, it is a mixed sample. Sample 527-33,CC contains abundant Cretaceous species including *Micula murus, Lithraphidites quadratus, Ceratolithoides kamptneri*, and *Markalius astroporus*. It represents the uppermost Cretaceous *Micula murus* Zone. Sample 527-34,CC faunas contain rare *Nephrolithus frequens* without *M. murus*. It probably belongs to the *M. murus–Lithraphidites quadratus* zonal interval or to Perch-Nielsen's (1977) *Nephrolithus frequens* Zone. Samples 527-35,CC through 527-37,CC contain *L. quadratus*, without *N. frequens*, and are assigned to the *L. quadratus* Zone.

Basalt was encountered at the very base of Core 38. The oldest sediments above the basalt recovered in Core 38 and sandwiched within the basalt in Cores 41 and 42 are within the upper part of the *Arkhangelskiella cymbiformis* Zone. This conclusion is based on the absence of *L. quadratus, Broinsonia parca, Reinhardtites levis*, and *Tetralithus trifidus* in the assemblages. According to paleomagnetic data recovered at this site, the oldest sediments are within the lower part of Anomaly 31.

#### **Preservation**

Except for the pure red clay intervals, coccoliths and discoasters at Site 527 are generally abundant but moderately to poorly preserved. In the interval above the upper Miocene (above Sample 527-12,CC), nannofossils are slightly corroded or show slight overgrowth. Their state of preservation is moderate. In Core 13, dissolution was so extensive that most of the coccolith species were dissolved. Discoasters, on the contrary, are enriched and are well preserved because of their strong resistance to dissolution.

Below the Miocene hiatus, lower Oligocene through upper Paleocene nannofossils show strong overgrowth. Small species are not found and were probably dissolved.

Except for the very base of the Tertiary, nannofossils recovered for the lower Paleocene and Upper Cretaceous at this site show a moderate, sometimes moderate to good, state of preservation. This phenomenon corresponds to the higher sedimentation rate during that time at this site.

**Foraminifers**

We studied planktonic and benthic foraminifers from sediments of Pliocene-Pleistocene, Oligocene, middle to early Eocene, Paleocene, and Maestrichtian age. Miocene sediments are barren of foraminifers. Planktonic foraminifers are moderately to poorly preserved throughout much of the section; dissolution is intense in the Pliocene and Oligocene sediments, and middle Eocene faunas are badly dissolved and recrystallized. Paleocene sediments are moderately well preserved, as are the Maestrichtian levels down to the basalt. Foraminifers retrieved from sediments intercalated in basalt are generally poorly preserved.

A summary of the biostratigraphic zonation of the site according to planktonic foraminifers is shown in Figure 3.

### Neogene

#### *Pleistocene–Pliocene*

Samples in Core 1 contain Pleistocene faunas, including common *Globorotalia truncatulinoides*. The Pliocene/Pleistocene boundary is probably within the interval covered by Core 2, but the core is too disturbed to warrant detailed sampling.

Zones Pl5 and Pl6 cannot be separated at this site because of the absence of *G. miocenica*. Zones Pl4, Pl3, Pl2, and Pl1 were recognized. Dissolution increased dramatically within Core 12, so very few diagnostic specimens are present. *Globorotalia conomiozea* occurs, and rare *G. cibaoensis* are found in Core 12. Both these species first appeared within Magnetic Epoch 6 (about 6.5 Ma), so that this core is no older than upper Zone N17.

Core 13 is barren of foraminifers. The paradigm that more aggressive bottom waters (as indicated by the increased abundance of the Antarctic Bottom Water (AABW) index species *Nuttalides umbonifera*) correlate with increased carbonate dissolution (as indicated by the fragmentation of planktonic foraminifers) was examined but without corroboration at Site 527. Dissolution is strongest in the lowest part of the Pliocene; though many benthic foraminifers are dissolved, abundances of *N. umbonifera* are not accordingly higher. Preservation improves markedly up the section, but *N. umbonifera* does not decrease accordingly. Instead it has an abundance peak in Cores 3 and 4, where preservation is relatively good.

Generally, benthic foraminifers are much less abundant and more dissolved at Site 527 than at the shallower Site 525. Benthic invertebrates are considerably more abundant at Site 525, and diversity of both ostracodes and benthic foraminifers is greater than at Site 527. The rectilinear:rotalid ratio would suffice to demonstrate the vast differences between the faunas at the two sites. Interestingly, the first and only time when benthic invertebrates become abundant is in the most dissolved core (12). The amount of clay also increases in these sediments, as do the number of worm tubes preserved in the coarse fraction, which suggests that increased clay content also represents an increase in the amount of organic material available to support both the worm and other fossil invertebrate populations.

### Paleogene

The Paleogene section at this site contains one core (14) of very poorly preserved Oligocene faunas, one core (16) of very dissolved and recrystallized middle Eocene sediments, and a moderately well preserved continuous section from the lower Eocene through the Paleocene. The basal Tertiary "*Globigerina*" *eugubina* Zone is about 25 cm long (Samples 527-32-4, 25 cm to 527-32-4, 50 cm).

#### *Oligocene (Sample 527-14,CC)*

The Oligocene fauna is almost totally dissolved; the remaining species all belong to the genus *Catapsydrax*.

#### *Middle Eocene (Sample 527-16,CC)*

A very dissolved planktonic foraminiferal fauna, resembling those of middle Eocene age from Site 525 and several other South Atlantic DSDP sites, was found at this site. The presence of the middle Eocene acarininids and *Globigerina senni* and lack of *Morozovella aragonensis* are the only criteria for age designation.

A large amount of phosphatic debris, fish teeth, and clay accompany the largely calcareous benthic fauna, which is dominated by *Anomalina* cf. *spissiformis, Nuttalides truempyi, Anomalinoides aragonensis, Bulimina semicostata, Siphonodosaria modesta* and *Oridorsalis umbonifera*.

#### *Middle to Lower Eocene Transition*

Cores 17 and 18 consist almost entirely of fragments of foraminifers accompanied by phosphatic debris. The presence of rare specimens of *Morozovella aragonensis* places these cores in the range from lower to middle Eocene.

#### *Lower Eocene to Upper Paleocene Transition (Core 19–Sample 522-23,CC)*

Zone P7, absent or far too dissolved for recognition in Hole 525A, is well represented here. Forms trending to *Morozovella aragonensis* are present, accompanied by diverse morozovellids. The Paleocene/Eocene boundary was recognized on the basis of the appearance of the benthic *Gavelinella beccariiformis*.

#### *Upper Paleocene (Sections 527-24-2–527-30-3)*

Faunas from Zones P5, P4, and P3 show "chalky" preservation; acarininids and globigerinids dominate the faunas but are enriched in Core 26. Benthic foraminifers are not common in this, the most dissolved, sample. Fish teeth accompany *Gavelinella beccariiformis, Aragonia ouezzaensis,* pleurostomellids, *Nuttalides truempyi* and *Stilostomella abyssorum*.

### *Lower Paleocene (Sections 527-30-4–527-32-4)*

Zone P2 (Sections 527-30-4–527-30,CC), absent at Site 525, was identified here. The fossils are uniformly small and relatively well preserved. Although fragmented, the foraminifers contain less clay and are less "chalky" than those of younger age. Large specimens of *Alabamina dissonata* are accompanied by *Bolivinopsis* sp., *Anomalinoides* cf. *spissiformis, Nuttalides truempyi, Gavelinella beccariiformis*, and *Globocassidulina subglobosa*. Ostracodes occur occasionally.

The subzones of Zone P1 (Core 527-31–Section 527-32-4) are all present at this site, including the "*Globigerina*" *eugubina* Zone (now Pla) from Sample 527-32-4, 25 cm to 527-32-4, 50 cm.

Preservation throughout this interval is moderate; planktonic forms are dissolved but not strongly recrystallized. No recrystallization is observed in the "*G.*" *eugubina* Zone.

The amount of clay, its color, and the amount of dissolution all suggest deposition close to a paleo-CCD at the Cretaceous/Tertiary boundary.

### *Cretaceous*

Maestrichtian planktonic foraminifers belonging to the *Abathomphalus mayaroensis* Zone occur in all cores from 32 to 38 where basalt was reached and in Core 42 in sediment intercalated in basalt. Foraminifers are dissolved by, filled with, or dyed by reddish clay. Glass fragments occur commonly; ostracodes, mollusk fragments, and echinoids are occasionally present.

Planktonic foraminiferal faunas, markedly more diverse than their equivalents at Site 525, contain common *A. mayaroensis, Globotruncana contusa, Racemiguembelina fructicosa, G. stuarti, G. stuartiformis, Rugoglobigerina rotundata*, and *Gublerina. Globotruncana conica* becomes frequent in Core 38. Benthic faunas above basalt are small and include *Gavelinella beccariiformis*, nodosarids, *Gyroidina* spp., several pleurostomellids, and lenticulinids; all are indicative of bathyal depths.

Foraminifers from the multicolored clay-rich sediments intercalated in basalt (Sample 527-42-1, 62 cm) resemble those in overlying cores. Benthic faunas, however, differ: echinoid remains and ostracodes are common and large in size. Benthic foraminifers are much larger in size and contain some different species, including a large bolivinid also associated with basalt at Site 525.

## Summary

Examination of core catcher samples, supplemented by close sampling in the Miocene for nannofossils and across the Cretaceous/Tertiary boundary for both nannofossils and foraminifers, produced the following results:

1) The section at Site 527 consists of calcareous Pleistocene through Pliocene oozes, grading into ooze–clay sediments at the base of the Pliocene, then predominantly red clays of Miocene through Oligocene age containing some calcareous mottles which allow age designation. Oligocene and upper Eocene clay-rich sediments with little carbonate overlie a calcareous sequence of middle Eocene through Paleocene age. Maestrichtian-age calcareous sediments occur to the bottom where basalt was reached and at several levels intercalated within the basalt.

2) Hiatuses in carbonate sedimentation were identified primarily using nannofossils from the upper middle Miocene through the lower Oligocene, from the lower Oligocene into the upper Eocene, and from the upper Eocene to the middle Eocene. Sedimentation below this is considered continuous, even across the Cretaceous/Tertiary boundary.

3) Preservation through the sequence varied from moderate to very poor; in the Pliocene, foraminifers and nannofossils are moderately preserved, with several levels of more intense dissolution occurring in the Pliocene through upper Miocene. Dissolution has removed almost all of the calcareous fossils through the Miocene; those remaining in the middle Miocene are thought to have been preserved in worm burrows. Preservation is very poor in the Oligocene, where almost the entire foraminiferal fauna is missing, leaving only fragments. The upper Eocene is barren of foraminifers but contains poorly preserved nannofossils. The middle Eocene is poorly preserved, owing to recrystallization rather than to simple dissolution. Nannofossils are overgrown, and foraminifers are recrystallized and recemented. In the lower Eocene, foraminifer preservation improves, but that of nannofossils does not. Through the Paleocene, preservation is moderate. Presumably through this level, the ooze–chalk transition is reached and fossils reflect that degree of diagenesis; foraminifers appear "chalky" below the upper Paleocene. Preservation in the basal Tertiary is better than at the shallower Site 525; some small coccoliths were found, and most foraminifers are whole. The red to brown coloration and clay content of basal Tertiary sediments suggest deposition well into the range of the paleolysocline. Preservation through the Maestrichtian is moderate but significantly better than at Site 525, where most of the foraminifers were dissolved.

4) The "*Globigerina*" *eugubina* Zone of the basal Tertiary is well represented at this site (25 cm in length). Faunas are well preserved, probably more so than at any level above or below.

5) Maestrichtian planktonic foraminifers are moderately well preserved; *Abathomphalus mayaroensis* is surprisingly common in these faunas and has a range coincident with those of *Globotruncana contusa* and *Racemiguembelina fructicosa. A. mayaroensis* is found at least 1 m.y. earlier than generally accepted, in the upper part of the *A. cymbiformis* nannofossil zone, at approximately 68 Ma (equivalent to the lower part of Magnetic Anomaly 31).

6) Planktonic foraminifers throughout the Neogene section are typical of temperate water masses; however, the removal of species by dissolution is intense at many levels. Faunas distorted by dissolution appear to be cooler than they actually were. Nevertheless, several faunal events, including small floods of *Globorotalia margaritae* and *Sphaeroidinellopsis seminulina*, and the

switch in abundance from *G. puncticulata* to *G. crassa* at the base of the Gauss can be correlated between Sites 525 and 527.

7) Benthic foraminifers are generally rare at this site except in the one Pleistocene sample examined. Their abundance did not correlate strictly with dissolution; that is, they were not enriched in more dissolved samples. Rather the opposite: they were less frequent in the most dissolved samples, demonstrating that they too had undergone intense dissolution. No correlation could be demonstrated between the abundance of *Nuttalides umbonifera*, supposedly associated with bottom waters that are more corrosive with respect to calcite, and the degree of carbonate dissolution at this site. Fluctuations in the abundance of other benthic foraminifers—for example, *Uvigerina hispida*—can be shown to be diachronous with similar events at the shallower Site 525. Abundance of benthic invertebrates is lower than at Site 525, except at the very base of the Pliocene, where increased clay contents and worm burrows suggest a higher supply of organic carbon available to support an increased biomass of invertebrates.

8) Paleogene and Maestrichtian benthic foraminiferal faunas were similar, small, and indicative of bathyal depths. In the most dissolved sample, of Oligocene age, a predominantly agglutinated fauna was found, attesting to the position of the sample close to the paleo-CCD. Maestrichtian benthic forms above basalt are typical of bathyal depths and demonstrate that basalt at this site was emplaced at greater depths than that at nearby Site 525. Benthic foraminifers and invertebrates from the sediments intercalated within the basalt are larger in size, more abundant, and include several species that have thus far been found only in conjunction with basalts (both at this site and at Site 525). We can assume that this site was slightly shallower at the time of deposition of the interlayered sediments, that warmer water masses entered the area, or that these faunas are accommodating to special conditions related to the presence of the basalt.

## SEDIMENT ACCUMULATION RATES

The age-depth plot for Site 527 (Fig. 10) was constructed using the time scales discussed in the Explanatory Notes (introductory chapter, this volume). Table 4 gives the samples in which the upper and lower part of each zone were observed, and the ages used.

To facilitate comparison with Site 525, accumulation rates of sedimentary components have been estimated, assuming, where the data permit, that changes in accumulation rate occurred simultaneously at the two sites. For example, the data for Site 527 are consistent with a change in accumulation rate at 3 Ma. Assuming zero age at the seafloor, the average over the past 3 m.y. is 1.0 cm/$10^3$ y. and over the 3 to 4.7 m.y. interval, 2.4 cm/$10^3$ y.

In Cores 8 to 11, there is an apparent inconsistency between nannofossil and foraminiferal age assignments. Since the former group relies on negative evidence at this point (absence of *Ceratolithus acutus*) whereas the foraminiferal evidence is positive (presence of *Globorotalia puncticulata*), we have followed the latter group, which requires a higher accumulation—about 4 cm/$10^3$ y.—in the earliest Pliocene. Extrapolating this rate into the intensely dissolved Core 12 implies that this core was deposited within the last 0.2 m.y., at most, of the Miocene. This is consistent with Diester-Haas's observations (1978) at Sites 366 and 397 in the North Atlantic, which showed intense dissolution within the Messinian interval, terminating just prior to the Miocene/Pliocene boundary. A hiatus spanning about 5 m.y. separates the base of Core 12 from the top of Core 13, and a second hiatus, spanning about 22 m.y., separates Core 13 from Core 14. It is possible that accumulation was continuous at about 0.16 cm/$10^3$ y. throughout the middle and upper Eocene, although fossil preservation is so poor that not even more detailed sampling would permit possible hiatuses to be identified. Between about 61 and 51 Ma the upper Paleocene and lower Eocene sediments accumulated at about 1.1 cm/$10^3$ y. The somewhat lower accumulation rate in the lower Paleocene and the higher rate in the Maestrichtian are poorly constrained at present.

Accumulation rate in g/cm$^2$/$10^3$ y. of total sediment and of the various sedimentary components is shown in Figure 11. This is obtained according to the procedures outlined for Site 525. The values used to plot Figure 11 are given in Table 5. Note that the apparent spike in the earliest Pliocene may be an artifact of uncertainty in the age assumed for the sediments, as discussed in the foregoing.

## IGNEOUS PETROLOGY

### Summary

Hole 527 was drilled approximately 160 km down the northwest flank of the Walvis Ridge and encountered basaltic basement at a sub-bottom depth of 341 m. Drilling in basalt was terminated at 384 m sub-bottom, corresponding to a thickness of 43 m. The sampled portion of the basement complex consists of massive basalt flows with minor intercalated sediments at depths of 349, 358, and 360 m. Of 33 m of material recovered (average recovery rate of 77%), 29 m were basalt. The intercalated sediments and two recovered upper glassy chilled margins form the basis for subdivision of the basalt pile into five units. A stratigraphic column indicating this subdivision, together with lithology and details of recovery, is presented in Figure 12.

Unit 1 is 5 m thick and underlies a marly nannofossil chalk of middle Maestrichtian age at the base of the sediment pile. It consists of a fine- to medium-grained, sparsely to moderately plagioclase, olivine, clinopyroxene (in order of decreasing abundance) phyric basalt with intergranular texture. It is medium gray in color and slightly altered. The uppermost recovered basaltic fragment (Sample 527-38,CC) has an aphanitic margin suggestive of an original glassy flow top. Unit 1 is immediately underlain by Unit 2, which comprises an approximately 2 m thick fine-grained basalt flow with a chilled upper margin complete with glass rind. This basalt is essentially identical to that comprising Unit 1. Unit 2 also has a very fine grained chilled lower margin and is sepa-

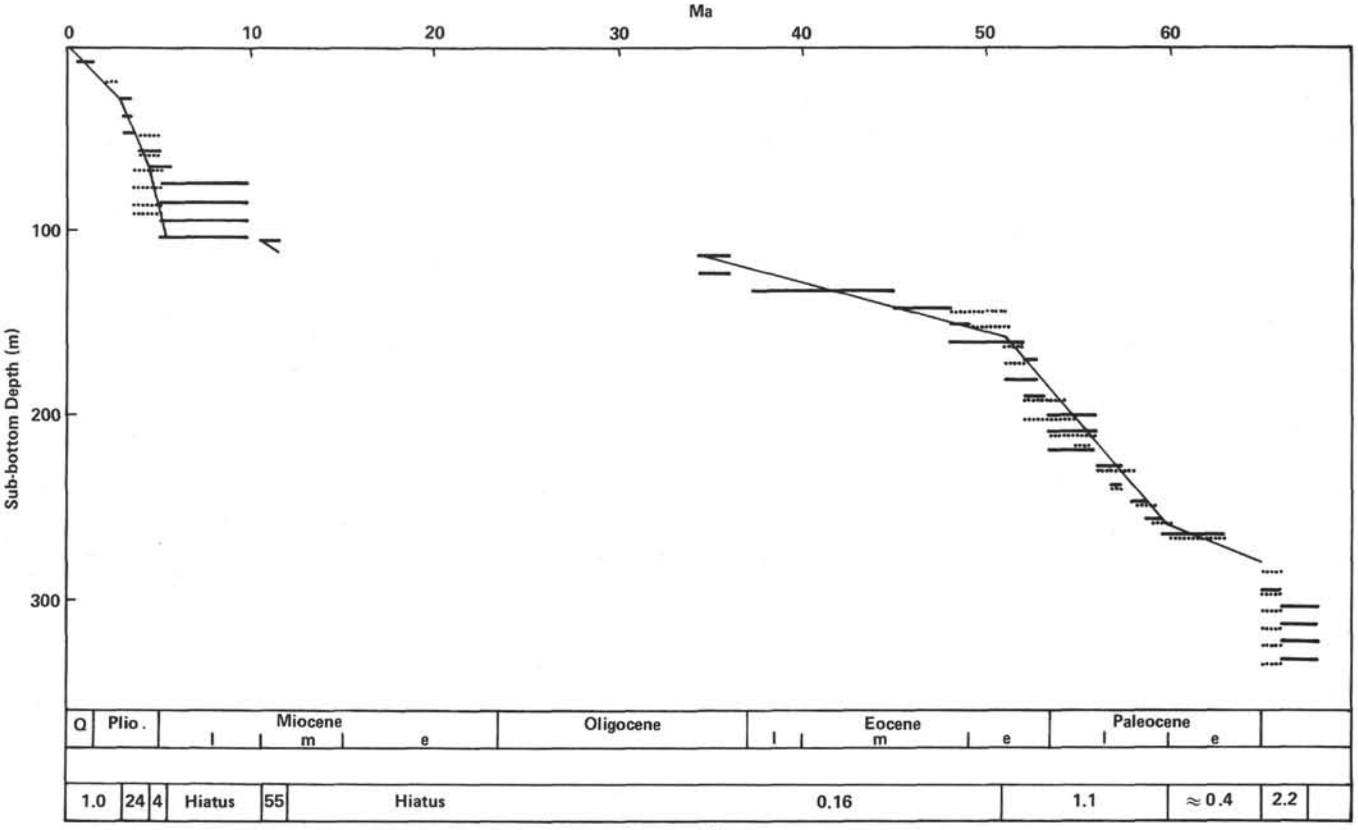


Figure 10. Age–depth plot for Site 527. Horizontal lines represent ranges in ages determined by nannofossils (solid line) and foraminifers (dashed line).

rated in the recovery from underlying Unit 3 by a single limestone fragment, 2 cm in diameter.

Unit 3 is approximately 9 m thick and consists of a highly plagioclase phyric basalt. The plagioclase phenocrysts are up to 2 cm in diameter and comprise 20 to 30% of the rock. Very sparse clinopyroxene and olivine phenocrysts are also present. The basalt is medium gray, has a medium-grained subophitic groundmass, and shows only slight alteration to green clay. No chilled margins were recovered. Unit 3 is underlain by a 60+ -cm-thick layered chalk.

Unit 4 is 40+ cm thick and comprises a single thin flow with a chilled upper margin with altered glass rind in contact with overlying nannofossil chalk. It consists of a medium gray, fine-grained, sparsely plagioclase phyric basalt with subophitic texture. This unit rests on a 3.5-m-thick bioturbated claystone.

Hole 527 was terminated 21 m into Unit 5, which consists of a massive fine- to coarse-grained aphyric basalt. The texture is subophitic to intergranular and the microscopic degree of alteration moderate, in spite of the macroscopically fresh appearance. Patchy development of very coarse grained "pegmatitic" zones is evident. Scattered dark green smectite veins lined with pyrite and pyrite emplaced in the basalt matrix are observed.

This basalt sequence is interpreted as the upper portion of oceanic basement at Site 527, located at the Angola ocean basin end of the Walvis Ridge transect. The biostratigraphic age of the oldest chalk overlying the basalt pile (see Biostratigraphic Summary, this chapter), as well as the intercalated chalks, is middle Maestrichtian (approximately 68 Ma). This is in excellent agreement with the age of Magnetic Anomaly 31, which is close to Site 527 (see Background and Objectives, this chapter). The two glassy basalt chilled margins recovered confirm the subaqueous environment of basalt extrusion indicated by the bathyal benthic foraminiferal fauna in the oldest overlying sediment.

As at Site 525 (Walvis Ridge crest), basalts display none of the few mineralogical characteristics indicative of an alkaline affinity. A tholeiitic compositional character is therefore assumed, pending shore-based geochemical studies.

## Petrography

Three petrographically distinct varieties of basalt are present in the succession drilled at Site 527. Units 1, 2, and 4 are composed of fine- to medium-grained sparsely phyric basalt. The second variety, comprising Unit 3, is a medium-grained, highly plagioclase phyric basalt. The third is a medium- to coarse-grained aphyric basalt comprising Unit 5, within which Hole 527 was terminated.

The phenocryst assemblages in the phyric basalts are dominated by plagioclase (80–100%) with subordinate olivine (0–15%) and minor clinopyroxene (0–5%). The

Table 4. Foraminifer and nannofossil data used to construct age–depth curve (Fig. 10), Hole 527.

| Core/Section (level, interval in cm) | Depth below Seafloor (m) | Nannofossil Zone | Foraminifer Zone | Nannofossil Age (m.y.) | Foraminifer Age (m.y.) |
|---|---|---|---|---|---|
| 1,CC | 9.0 | NN19 | N22 | 1.5–1.6 | 0–1.8 |
| 2,CC | 18.5 | NN17 | PL5/6 | 2.0–2.3 | 1.8–2.8 |
| 3,CC | 28.0 | NN15 | PL4 | 3.0–3.5 | 2.8–3.0 |
| 4,CC | 37.5 | NN15 | PL3 | 3.0–3.5 | 3.0–3.3 |
| 5,CC | 47.0 | NN15 | PL3 | 3.0–3.5 | 3.0–3.3 |
| 6,CC | 56.5 | NN13 | PL1 | 4.0–4.5 | 3.7–5.0 |
| 7,CC | 66.0 | NN12 | PL1 | 4.4–5.0 | 3.7–5.0 |
| 8,CC | 75.5 | NN12 | PL1 | 4.4–5.0 | 3.7–5.0 |
| 9,CC | 85 | NN11 | PL1 | 5.0–9.9 | 3.7–5.0 |
| 10,CC | 89.5 | | | | |
| 11,CC | 94.5 | NN11 | L. Mio–Plio. | 5.0–9.9 | |
| 12,CC | 104 | NN11 | L. Mio–Plio. | 5.0–9.9 | |
| 13,CC | 113.5 | | | | |
| 14,CC | 123.0 | NP22 | Olig.–Mio. | 34.3–36.0 | 15.5–22.5 |
| 15,CC | 132.5 | NP16–20 | | 37.2–45.0 | |
| 16,CC | 142 | NP15 | mid-Eocene | 45.0–48.0 | |
| 17,CC | 151.5 | NP14 | P8–10 | 48.0–49.0 | 47.3–51.0 |
| 18,CC | 161 | NP12–14 | P8–10 | 48.0–52.0 | 49.0–51.0 |
| 19,CC | 170.5 | NP11 | P7 | 52.0–52.6 | 51.0–52.0 |
| 20,CC | 180 | (NP12) | P7 | | 51.0–52.0 |
| 21-1, 45 | 180.5 | NP10/11 | P6 | 52.0–53.3 | 52.0–54.5 |
| 22,CC | 189.5 | NP9 | P6 | 53.3–56.0 | 52.0–54.5 |
| 23,CC | 199.0 | NP9 | P6 | 53.3–56.0 | 52.0–54.5 |
| 24-2, 61 | 201.1 | | P5 | | 54.5–56.0 |
| 24,CC | 208.5 | NP9 | | 53.3–56.0 | |
| 25,CC | 218 | NP9 | P5 | 53.3–56.0 | 54.5–56.0 |
| 26,CC | 227.5 | NP7/8 | P4 | 56.0–57.4 | 56.0–58.0 |
| 27,CC | 237.0 | NP7 | P4 | 56.7–57.4 | 56.0–58.0 |
| 28,CC | 246.5 | NP5 | P3G | 57.8–58.6 | 58.0–59.0 |
| 29,CC | 256.0 | NP4 | P3a | 58.6–59.5 | 59.0–60.0 |
| 30,CC | 265.5 | NP3 | P2/P1d | 59.5–63.0 | 60.0–63.0 |
| 31,CC | 275.0 | NP2 | P1d | 63.0–64.5 | 62.0–63.0 |
| 32,CC | 284.5 | NP2 | | | 65.0–66.0 |
| 33,CC | 294.0 | | | 65.0–66.0 | |
| 34,CC | 303.5 | | | 66.0–68.0 | |
| 35,CC | 313.0 | | | 66.0–68.0 | |
| 36,CC | 322.5 | | | 66.0–68.0 | |
| 37,CC | 332.0 | | | 66.0–68.0 | 65.0–66.0 |
| 38,CC | 341.5 | | | | |
| 32-4, 50 | 280.0 | | | | |
| 13-2, 88 | 106.38 | NN9 | | 10.5–11.6 | |
| 13-3, 83 | 107.83 | NN8/9 | | 10.5–11.9 | |
| 13-6, 129 | 112.79 | NN8 | | 11.6–11.9 | |
| 14-1, 34 | 113.84 | NP22 | | 34.3–36.0 | |
| 14-2, 118 | 116.18 | NP22/23 | | 29.0–36.0 | |
| 4-1, 20–22 | 28.20 | | PL4 | | 2.8–3.0 |
| 4-2, 20–22 | 29.70 | | PL3 | | 3.0–3.3 |
| 6-1, 40–42 | 47.40 | | PL2 | | 3.3–3.7 |
| 6-2, 40–42 | 48.90 | | PL2 | | 3.3–3.7 |
| 6-5, 40–42 | 53.40 | | PL1 | | 3.7–5.0 |
| 7-1, 110–112 | 57.60 | | PL1 | | 3.7–5.0 |
| 9-1, 20–22 | 75.70 | NP12 | PC1 | | 3.7–5.0 |
| 30-3, 41 | 259.41 | | P3a | | 59.0–60.0 |
| 30-4, 41 | 260.91 | | P2 | | 60.0–62.0 |
| 32-4, 25 | | | P1a | | 63.8–65.0 |
| 32-4, 50 | | | P1a | | 63.8–65.0 |
| 38,CC | | | | 68.0–69.0 | 65.0–69.0 |
| 11-1, 37–39 | 89.87 | | PL1G | | 3.7–5.0 |

size of plagioclase phenocrysts ranges from up to 5 × 3 mm in the sparsely phyric basalts to up to 25 × 10 mm in the highly phyric basalts. Plagioclase phenocrysts occur as stubby laths and glomerocrysts that are complexly twinned and zoned. The compositional range (Michel-Levy method) spans that of labradorite. The sizes of euhedral olivine phenocrysts range from 0.6 × 0.3 mm to 2 × 1 mm. They are, however, recognizable only on the basis of their morphology, as they have been completely altered to green and brown clays. Subhedral clinopyroxene phenocrysts range in size from 0.5 × 0.3 to 1.5 × 1 mm and partially enclose smaller plagioclase laths. Their compositions are augitic and they are generally unaltered.

The basalt groundmasses consist of an intergranular network of plagioclase laths enclosing clinopyroxene and magnetite in Units 1 and 2 and a subophitic intergrowth of plagioclase and clinopyroxene in Units 3 and 4. In Unit 5, groundmass texture varies from subophitic to intergranular to "pegmatitic," indicative of local internal differentiation. Plagioclase forms 55 to 60% of the groundmass, except in the case of the highly plagioclase phyric basalt, where it is roughly equivalent in abundance to pyroxene (48% of groundmass). It forms euhedral laths ranging on the average from 0.5 × 0.1 mm to 0.7 × 0.2 mm. It is essentially unaltered, except in Unit 5, where some laths show partial conversion to saussurite.

Anhedral and subhedral clinopyroxene forms 38 to 48% of the groundmass, is colorless, and lacks pleochroism. Clinopyroxene twinning and zoning are observable in the coarse-grained groundmass of Unit 5 aphyric basalt. A few of the zoned augite grains show distinct mantles, which may consist of pigeonite, by analogy with similar textures in diabases. The degree of alteration of clinopyroxene varies from minimal to almost complete conversion to brown clay in parts of Unit 5. In the latter condition, altered pyroxene is distinguishable from associated altered interstitial mesostasis only by the presence of accessory apatite needles.

Opaques comprise the remaining 2 to 5% of groundmass material. They occur in subhedral, anhedral interstitial, and skeletal forms. No attempt has been made to distinguish between magnetite, which probably predominates, and other opaque minerals. Secondary pyrite probably contributes to proportions of opaques, especially in Unit 5, where its presence in veins and groundmass is macroscopically observable.

Vesicles are absent throughout the basalt succession. In Unit 5, scattered voids (up to 1 cm in diameter) are filled with blue green clay. Thin smectite-filled and often pyrite-lined veins occur at 20 to 50 cm intervals through most of the units. Veins filled with secondary carbonate are rare.

### Conclusions

In Hole 527, down the northwest flank of the Walvis Ridge, a 43-m sequence of basalts comprising phyric and aphyric flows, with minor intercalated pelagic and volcaniclastic sediments, was recovered from oceanic basement. Their age is identical to that expected from magnetic anomaly correlation and their morphology and petrography consistent with formation at a mid-ocean ridge.

## MAGNETICS

Paleomagnetic samples were obtained in the undisturbed sections of Cores 14–38. Owing to poor recovery, the record is incomplete below the Cretaceous/Tertiary boundary. Alternating field demagnetization was used to remove a strong viscous overprint. The polarity interpretation appears in Figure 3. Additional information on the early Paleocene–Cretaceous section is contained in the sedimentary paleomagnetism section (Chave, this volume). The polarity information is consistent with the Ness et al. (1980) time scale and suggests a basement age of Anomaly 31 time (~68–70 Ma).

## PHYSICAL PROPERTIES

Lithologic Unit I, which is composed of carbonate ooze, showed the most obvious changes in the upper 30 to 50 m. (The physical properties of the samples taken at Site 527 are listed in Table 6 and shown as diagrams ver-

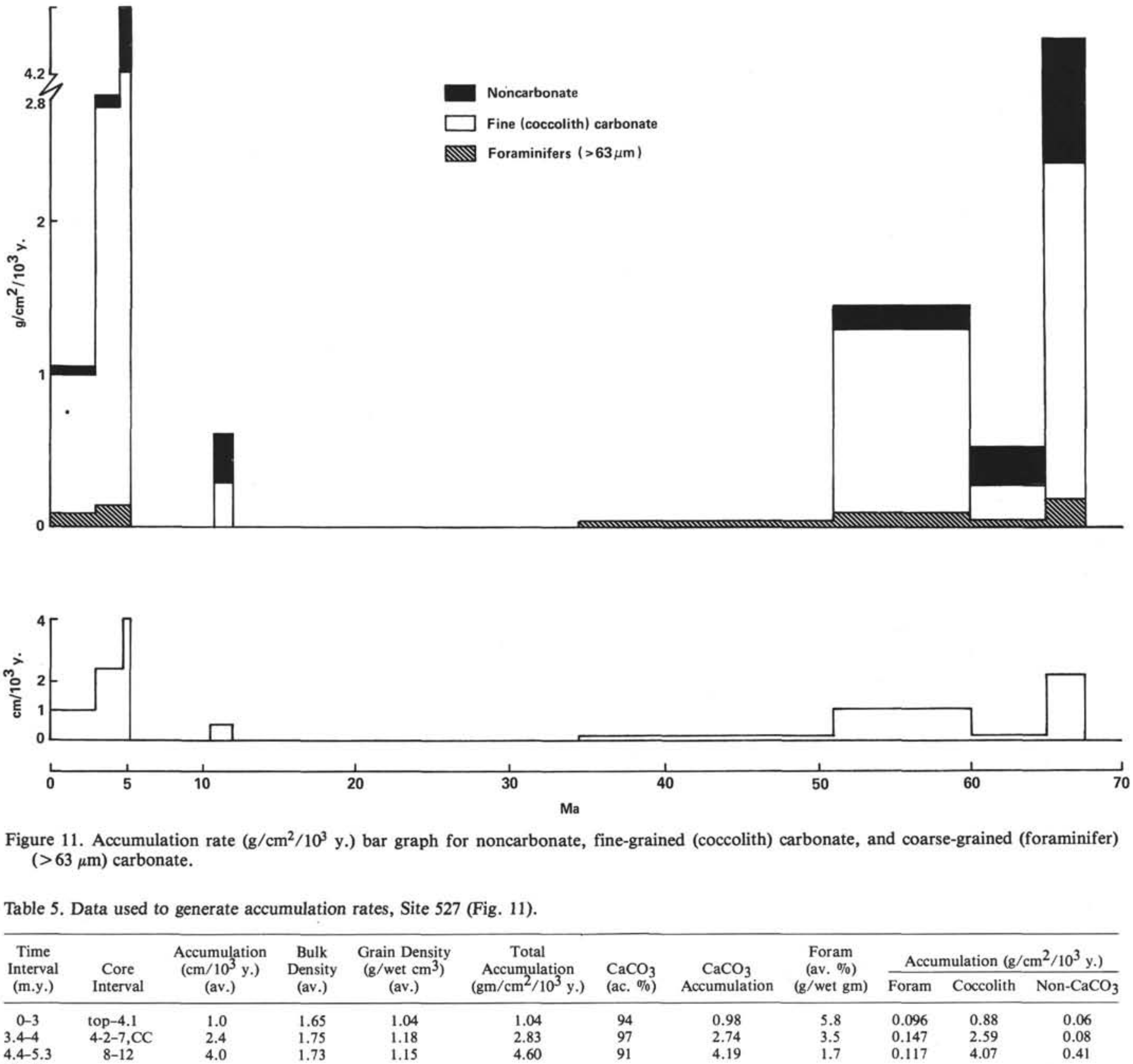


Figure 11. Accumulation rate (g/cm²/10³ y.) bar graph for noncarbonate, fine-grained (coccolith) carbonate, and coarse-grained (foraminifer) (>63 µm) carbonate.

Table 5. Data used to generate accumulation rates, Site 527 (Fig. 11).

| Time Interval (m.y.) | Core Interval | Accumulation (cm/10³ y.) (av.) | Bulk Density (av.) | Grain Density (g/wet cm³) (av.) | Total Accumulation (gm/cm²/10³ y.) | $CaCO_3$ (ac. %) | $CaCO_3$ Accumulation | Foram (av. %) (g/wet gm) | Accumulation (g/cm²/10³ y.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Foram | Coccolith | Non-$CaCO_3$ |
| 0–3 | top–4.1 | 1.0 | 1.65 | 1.04 | 1.04 | 94 | 0.98 | 5.8 | 0.096 | 0.88 | 0.06 |
| 3.4–4 | 4-2-7,CC | 2.4 | 1.75 | 1.18 | 2.83 | 97 | 2.74 | 3.5 | 0.147 | 2.59 | 0.08 |
| 4.4–5.3 | 8–12 | 4.0 | 1.73 | 1.15 | 4.60 | 91 | 4.19 | 1.7 | 0.117 | 4.07 | 0.41 |
| hiatus | | | | | | | | | | | |
| | 13 | 0.55 | 1.76 | 1.13 | 0.61 | 47 | 0.29 | 0 | 0 | 0.29 | 0.32 |
| hiatus | | | | | | | | | | | |
| 34–51 | 14–18 | 0.16 | 1.75 | 1.16 | 0.19 | 6.5 | 0.12 | 0.3 | 0.008 | 0.11 | 0.07 |
| 51–60 | 19–30 | 1.1 | 1.88 | 1.32 | 1.45 | 90 | 1.31 | 4.5 | 0.093 | 1.21 | 0.14 |
| 60–65 | 31–32.4 | 0.4 | 1.84 | 1.30 | 0.52 | 52 | 0.27 | 7.5<br>(indet) | 0.055 | 0.21 | 0.25 |
| 65–67.5 | 32-5–38 | 2.2 | 1.94 | 1.46 | 3.2 | 74 | 2.38 | 4.2<br>(indet) | 0.18 | 2.2 | 0.83 |

sus depth in Fig. 13). It yielded the usual trend of increasing wet-bulk density and thermal conductivity and decreasing water content, porosity, and shrinkage with depth, as at Sites 525 and 528. In the lower part of Unit I these properties are constant, as are grain density, sonic velocity, and shear strength. Vane shear strength is very low. Needle penetration shows a distinct trend of increasing strength with increasing depth.

Unit II, which contains considerable amounts of clay, is distinct from the units above and below. The gravimetric data do not reveal major differences except in having a slightly wider variation, but shrinkage and especially shear strength are markedly different. Owing to the clay content, which is documented by a sharp decrease of carbonate content, shrinkage reaches its highest values (32.5% of volume) in this unit. Layers with

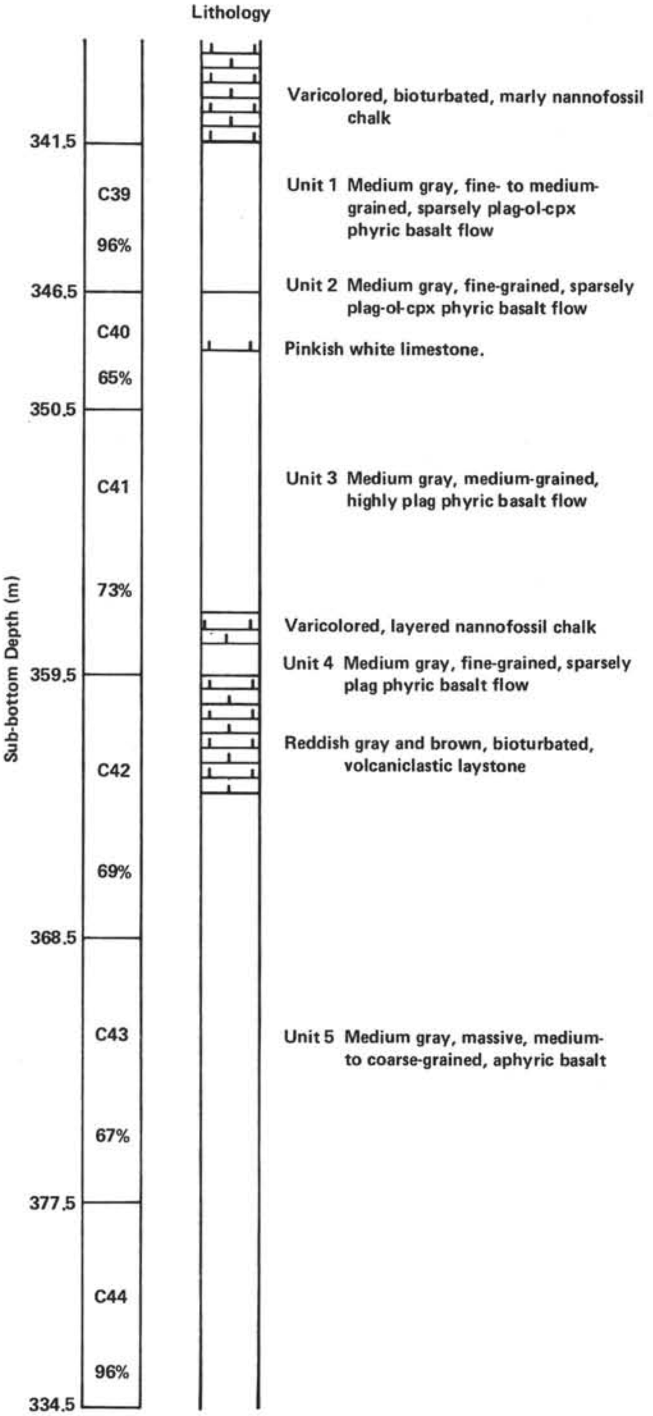


Figure 12. Hole 527 basalt lithology.

less clay content (top, bottom, and middle of Unit II) show lower shrinkage (7% of volume). As the cohesion of the sediment increases with its clay content, the shear strength increases. The wide scattering of the shear strength values in this unit is due to cyclic lithological changes. Pure clay layers reveal the highest shear strengths—up to 1320 g/cm$^2$ (≙132 kPa)—whereas pure carbonate oozes have the lowest shear strength. According to the percentages of clay and carbonate, the other shear strength values of this unit vary between these extremes. Needle penetration shows its lowest values in this unit. Sonic velocity is not affected by the clay content, and its value is rather uniform at about 1.55 km/s.

Unit III is characterized by a transition from calcareous ooze to chalk. Whereas Unit I did not show major trends (except the upper part), this unit shows distinct trends that are due to diagenetic processes and sediment lithology. Bulk density increases gradually from about 1.57 g/cm$^3$ at the top of this unit to about 1.9 g/cm$^3$ at a depth of 250 m below seafloor. Below this depth, there is a slight decrease of bulk density, which corresponds with the decrease of carbonate content, and the lowest bulk densities (approx. 1.8 g/cm$^3$) occur at the same depth (278 m sub-bottom) as the lowest carbonate contents (30%) at the top of Unit IV. The same trend appears in the water content and porosity data, although it is somewhat obscured by scatter in the data. Both decrease from the top of the unit down to about 250 m below seafloor and increase below that depth to the bottom of the unit. Grain density does not show these trends and increases slightly throughout Unit III. Shrinkage and shear strength of the sediment could be measured only in the upper part of Unit III. In the lower part, the sediments were lithified and indurated, making these measurements impossible. The data from both kinds of measurements show a trend of increasing diagenesis with depth. Shrinkage decreases clearly, and it may be assumed that there is no shrinkage at depths below 200 m. Shear strength increases with depth, its maximum being about 660 g/cm$^2$ (=66 kPa). Sonic velocity shows a slight increase with depth throughout the unit.

In Unit IV, which is characterized by volcanic material together with the dominant chalk component, the general trends continued. Bulk density, which is relatively low at the top of the unit (1.8 g/cm$^3$), increases to about 1.95 g/cm$^3$ at 300 m below seafloor and then remains constant throughout the lower part of Unit IV. The same trend is found in water content and porosity, both decreasing from the top of the unit down to about 300 m sub-bottom and then showing a slight increase with depth in the lower half of the unit. These trends parallel the increase of carbonate content in the upper part of Unit IV and the slower decrease in the lower part of the unit. Both grain density and sonic velocity are relatively constant throughout Unit IV.

Unit V is basaltic basement with a few interrelated sedimentary layers. The physical property data of the basalt do not vary as widely as at Sites 525 and 528, perhaps because of a more homogeneous sequence and lower alteration, and the mean values range between those of the basalts of Sites 528 and 527 (see Table 7).

Thermal conductivity was measured in all units, and the data show a large scatter around a mean value of about 1.5 W/m °C (≙3.59 mcal/cm °C s), so that there is only a slight trend of increasing conductivity with depth.

The GRAPE density obtained from 2-min. special counts appears somewhat higher than the gravimetric

Table 6. Physical properties summary, Site 527.

| Core/Section (interval, level in cm) | Sub-bottom Depth (m approx) | 2-min. Count GRAPE Density (g/cm³) | | Gravimetric Data | | | | | Vane Shear Strength ( ) = remolded (g/cm³) | Penetrometer (mm) Fall Height | | Sonic Velocity | | Acoustic Impedance | | Thermal Conductivity (W/m°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ∥ To Bedding | ⊥ | Wet-Bulk Density (g/cm³ approx.) | Grain Density | Salt-Corrected Wet Water Content (%) | Salt-Corrected Porosity (%) | Shrinkage (vol.%) | | 0 cm | 1 | ∥ to Bedding (km/s) | ⊥ (km/s) | ∥ to Bedding ($10^5$g/cm$^2$ s) | ⊥ | |
| 1-1, 146–149 | 1.5 | | | | | 40.6 | | | | | | | | | | |
| 1-3, 122–149 | 4.3 | | | 1.63 | 2.69 | 40.0 | 63.5 | 11.5 | 35 | 10.4 | 14.4 | 1.54 | | 2.52 | | 1.40 |
| 1-4, 83–86 | 5.3 | | | | | 38.5 | | | | | | | | | | |
| 1-6, 37–40 | 6.4 | | | | | 42.2 | | | | | | | | | | |
| 2-1, 120–123 | 10.2 | | | 1.66 | 2.61 | 37.3 | 60.4 | 13.8 | | | | | | | | |
| 3-2, 20–31 | 20.2 | 1.75 | | | | | | | 60 | 7.75 | 12.55 | 1.53 | | 2.67 | | 1.39 |
| 3-3, 6–9 | 21.6 | | | 1.65 | 2.70 | 38.9 | 62.6 | 13.6 | | | | | | | | |
| 3-4, 130–133 | 24.3 | | | | | 34.4 | | | | | | | | | | |
| 4-1, 43–53 | 28.4 | | | | | 35.3 | | | 4 | 12.7 | 11.55 | 1.54 | | | | 1.14 |
| 5-1, 73–76 | 38.2 | | | | | | | | 23 | 10.9 | 13.0 | | | | | |
| 5-1, 87–100 | 38.4 | | | 1.75 | 2.71 | 33.0 | 56.5 | 8.3 | 29 | 10.1 | 7.75 | 1.53 | | 2.67 | | 1.50 |
| 5-3, 1–4 | 40.5 | | | | | 33.4 | | | | | | | | | | |
| 6-1, 142–145 | 48.4 | | | | | 32.9 | | | | | | | | | | |
| 6-3, 132–149 | 51.3 | 1.83 | | | | | | | 49 | 6.6 | 6.45 | 1.55 | | | | 1.63 |
| 6-5, 117–120 | 54.2 | | | | | 32.0 | | | | | | | | | | |
| 6-6, 139–149 | 55.9 | | | 1.76 | 2.71 | 32.5 | 56.0 | 6.9 | 8 | 9.1 | 9.5 | 1.55 | | 2.73 | | 1.73 |
| 7-2, 40–43 | 58.4 | | | | | 31.7 | | | | | | | | | | |
| 8-1, 135–147 | 67.5 | 1.77 | | | | | | | 18 | 8.7 | 8.75 | 1.54 | | 2.73 | | 1.49 |
| 8-3, 115–118 | 70.2 | | | | | 32.9 | | | | | | | | | | |
| 8-5, 144–147 | 73.5 | | | | | 32.0 | | | | | | | | | | |
| 12-2, 116–118 | 96.7 | | | | | 36.1 | | | | | | | | | | |
| 12-4, 32–36 | 98.8 | | | | | | | | 130 | 4.7 | 8.6 | | | | | |
| 12-4, 116–118 | 95.8 | | | | | 34.4 | | | | | | | | | | |
| 12-4, 120–135 | 95.8 | | | 1.73 | 2.73 | 34.4 | 58.2 | 12.9 | 75 | 7.2 | 12.15 | 1.53 | | 2.64 | | 1.97 |
| 13-2, 104–106 | 106.5 | | | | | 32.4 | | | | | | | | | | |
| 13-4, 104–106 | 109.5 | | | | | 37.4 | | | | | | | | | | |
| 13-6, 35–98 | 112.5 | 1.80 | | | | | | | | | | | | | | |
| 13-6, 104–115 | 112.6 | | | | | 38.1 | | | 1314 (239) | 1.15 | 3.55 | 1.55 | | 2.79 | | 1.19 |
| 14-1, 126–128 | 114.8 | | | | | 33.5 | | | | | | | | | | |
| 14-2, 121–130 | 116.3 | | | 1.76 | 2.74 | 32.9 | 56.6 | 1.5 | 784 | | | 1.55 | | 2.72 | | |
| 14-2, 133–140 | 116.4 | | | | | | | | | 1.3 | 4.3 | | | | | 1.30 |
| 14-3, 29–31 | 116.8 | | | | | 32.7 | | | | | | | | | | |
| 14-4, 130–145 | 119.4 | 1.76 | | | | | | | 721 | 1.55 | 4.6 | 1.50 | 1.56 | 2.64 | 2.74 | 1.26 |
| 14-6, 18–35 | 121.3 | | | 1.73 | 2.62 | 33.0 | 55.6 | 8.3 | 314 | 2.5 | 4.9 | 1.55 | | 2.69 | | |
| 14-7, 84–87 | 123.0 | | | | | 34.7 | | | | | | | | | | |
| 15-1, 125–128 | 124.3 | | | | | 32.9 | | | | | | | | | | |
| 15-2, 100–121 | 125.7 | | | 1.83 | 2.76 | 29.9 | 53.4 | 19.5 | 447 | 1.75 | 5.0 | 1.58 | | 2.90 | | 1.55 |
| 16-1, 119–133 | 133.8 | | | | | 35.5 | | | 1359 (831) | | | | | | | |
| 16-1, 133–146 | 133.9 | | | 1.69 | 2.67 | 35.8 | 59.1 | 32.6 | 1082 | | | 1.57 | 1.56 | 2.65 | 2.64 | 1.27 |
| 16-2, 130–133 | 135.3 | | | | | 38.1 | | | | | | | | | | |
| 16-3, 130–133 | 136.8 | | | | | 41.9 | | | | | | | | | | |
| 16-4, 115–118 | 138.2 | 1.79 | | | | | | | | | | | | | | |
| 16-5, 90–104 | 139.5 | | | 1.71 | 2.69 | 35.4 | 58.9 | 7.0 | 52 | 6.25 | 10.15 | 1.52 | | 2.60 | | 1.58 |
| 17-1, 121–124 | 143.2 | | | | | 33.6 | | | | | | | | | | |
| 17-4, 90–92 | 147.4 | | | 1.72 | 2.58 | 32.8 | 55.0 | 6.0 | | | | | | | | |
| 17-4, 92–106 | 147.5 | 1.84 | | | | | | | 122 | 4.6 | 10.4 | 1.52 | | 2.79 | | 1.53 |
| 18-1, 137–140 | 152.9 | | | | | 30.4 | | | | | | | | | | |
| 18-2, 138–147 | 154.4 | | | 1.81 | 2.68 | 29.9 | 52.8 | 2.0 | 314 | 2.7 | 4.9 | 1.58 | | 2.85 | | 1.50 |
| 18-3, 98–101 | 155.5 | | | | | 30.1 | | | | | | | | | | |
| 19-1, 58–62 | 161.6 | | | | | | | | 192 | 2.8 | 3.9 | | | | | |
| 19-1, 103–113 | 162.1 | 1.92 | | | | | | | 151 | 10.25 | 7.75 | 1.57 | | 3.01 | | 1.82 |
| 19-3, 146–149 | 165.1 | | | | | 31.5 | | | | | | | | | | |
| 19-2, 61–64 | | | | | | 29.8 | | | | | | | | | | |
| 19-7, 61–64 | 170.5 | | | | | 29.8 | | | | | | | | | | |
| 20-1, 110–112 | 171.6 | | | 1.83 | 2.72 | 29.4 | 52.5 | 5.3 | | | | | | | | |
| 20-1, 113–125 | 171.6 | | | 1.78 | 2.55 | 29.1 | 50.5 | 0.3 | 64 | 5.0 | 6.05 | 1.60 | | 2.84 | | 1.69 |
| 20-2, 110–112 | 173.1 | | | | | 29.9 | | | | | | | | | | |
| 20-4, 74–77 | 175.2 | | | | | 29.8 | | | | | | | | | | |
| 22-1, 85–95 | 185.4 | | | 1.78 | 2.55 | 29.1 | 50.4 | 2.2 | 145 | 2.6 | 3.3 | 1.62 | | 2.88 | | |
| 22-1, 110–115 | 185.6 | | | | | | | | | | | | | | | 1.65 |
| 23-2, 55–60 | 191.6 | | | | | 25.2 | | | 668 | | | | | | | |
| 23-2, 78–87 | 191.8 | | | | | | | | 296 | 2.6 | 3.85 | 1.61 | | | | 1.53 |
| 24-3, 26–30 | 202.3 | | | | | | | | | | | | | | | 1.49 |
| 24-3, 122–147 | 203.3 | 1.97 | | | | 30.0 | | | 178 | 3.8 | 4.4 | 1.58 | | 3.12 | | |
| 25-2, 4–24 | 210.1 | | | | | 32.6 | | | | | | 1.59 | | | | 1.29 |
| 26-2, 117–118 | 220.7 | | | | | 30.1 | | | | | | | | | | |
| 26-2, 132–146 | 220.9 | 1.89 | 1.90 | 1.86 | 2.72 | 27.9 | 50.7 | | 151 | 4.1 | 4.05 | 1.59 | | 2.96 | | 1.53 |
| 27-1, 50 | 228.0 | | | | | 39.4 | | | | | | | | | | |
| 27-3, 41–42 | 230.9 | | | | | 39.0 | | | | | | | | | | |
| 27-3, 51–55 | 231.0 | | | 1.84 | 2.73 | 28.7 | 51.7 | | | | | 1.63 | 1.64 | 3.00 | 3.03 | 1.54 |
| 28-1, 108–110 | 238.1 | | | 1.90 | 2.72 | 25.9 | 48.1 | | | | | | | | | |
| 28-1, 111–120 | 238.1 | 1.96 | 1.96 | 1.90 | 2.75 | 25.6 | 49.2 | | | | | 1.64 | 1.65 | 3.12 | 3.14 | 0.95 |
| 28-3, 108–110 | 241.1 | | | 1.94 | 2.75 | 24.9 | 47.1 | | | | | | | | | |
| 28-5, 141–144 | 244.4 | | | 1.88 | 2.74 | 27.0 | 49.7 | | | | | | | | | |
| 29-1, 95–97 | 247.5 | | | 1.89 | 2.75 | 26.9 | 49.7 | | | | | | | | | |
| 29-2, 80–89 | 248.9 | 2.06 | 2.04 | 1.99 | 2.75 | 22.5 | 43.7 | | | | | 1.75 | 1.75 | 3.48 | 3.47 | 1.47 |
| 29-2, 91–94 | 248.9 | | | 1.96 | 2.75 | 23.8 | 45.5 | | | | | | | | | |
| 30-1, 51–54 | 256.5 | | | 1.88 | 2.75 | 27.5 | 50.4 | | | | | | | | | |
| 30-2, 35–38 | 257.9 | | | 1.90 | 2.76 | 26.5 | 49.2 | | | | | | | | | |
| 30-2, 41–52 | 258.0 | 2.46 | 1.86 | 1.86 | 2.76 | 28.7 | 52.0 | | | | | 1.62 | 1.93 | 3.02 | 3.60 | 1.48 |
| 30-4, 40–42 | 260.9 | | | 1.85 | 2.80 | 29.6 | 53.5 | | | | | | | | | |
| 31-1, 138–150 | 266.9 | 1.91 | 1.92 | 1.86 | 2.76 | 28.5 | 51.2 | | | | | 1.67 | 1.67 | 3.10 | 3.11 | 1.41 |
| 31-3, 143–146 | 270.0 | | | 1.83 | 2.74 | 29.5 | 52.7 | | | | | | | | | |
| 31-4, 10–12 | 279.1 | | | 1.86 | 2.77 | 28.8 | 52.3 | | | | | | | | | |
| 31-6, 0–11 | 273.1 | 1.95 | 1.95 | 1.89 | 2.74 | 27.0 | 49.6 | | | | | 1.69 | 1.68 | 3.15 | 3.19 | 1.25 |
| 32-2, 129–132 | 277.8 | | | 1.79 | 2.80 | 32.5 | 56.8 | | | | | | | | | |

Table 6. (Continued).

| | | 2-min. Count GRAPE Density ($g/cm^3$) | | Gravimetric Data | | | | | | | Sonic Velocity | | Acoustic Impedance | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Salt-Corrected | | | | | | | | | |
| Core/Section (interval, level in cm) | Sub-bottom Depth (m approx) | ∥ To Bedding | ⊥ To Bedding | Wet-Bulk Density ($g/cm^3$ approx.) | Grain Density ($g/cm^3$ approx.) | Wet Water Content (%) | Porosity (%) | Shrinkage (vol.%) | Vane Shear Strength ( ) = remolded ($g/cm^3$) | Penetrometer (mm) Fall Height 0 cm 1 | ∥ to Bedding (km/s) | ⊥ to Bedding (km/s) | ∥ to Bedding ($10^5 g/cm^2$ s) | ⊥ to Bedding ($10^5 g/cm^2$ s) | Thermal Conductivity (W/m°C) |
| 32-4, 0–13 | 279.6 | 1.91 | 1.87 | 1.82 | 2.76 | 30.4 | 54.0 | | | | 1.79 | 1.77 | 3.25 | 3.23 | 1.37 |
| 32-5, 129–132 | 282.3 | | | 1.91 | 2.75 | 25.8 | 48.2 | | | | | | | | |
| 33-1, 18–20 | 284.7 | | | 1.95 | 2.72 | 24.3 | 45.4 | | | | | | | | |
| 33-2, 92–102 | 287.0 | 1.65 | 1.65 | 1.85 | 2.66 | 27.6 | 49.7 | | | | 1.68 | 1.67 | 3.11 | 3.09 | 1.45 |
| 33-4, 30–32 | 289.3 | | | | | 26.8 | | | | | | | | | |
| 34-1, 12–14 | 294.1 | | | | | 25.3 | | | | | | | | | |
| 34-3, 116–126 | 298.2 | 1.74 | 2.02 | 1.97 | 2.73 | 23.3 | 44.7 | | | | 1.74 | 1.75 | 3.43 | 3.44 | 1.56 |
| 34-6, 0–12 | 301.6 | 1.99 | 1.96 | 1.96 | 2.76 | 24.1 | 46.0 | | | | 1.73 | 1.73 | 3.40 | 3.40 | 1.49 |
| 35-1, 77–91 | 304.3 | 1.38 | 2.02 | 1.94 | 2.74 | 24.6 | 46.5 | | | | 1.66 | 1.70 | 3.22 | 3.30 | 1.67 |
| 35-3, 35–37 | 306.9 | | | 1.93 | 2.75 | 25.1 | 47.4 | | | | | | | | |
| 35-5, 36–43 | 309.9 | 1.98 | 2.02 | 1.96 | 2.75 | 24.0 | 45.8 | | | | 1.70 | 1.69 | 3.32 | 3.32 | 1.63 |
| 36-2, 24–34 | 314.8 | 1.98 | 2.01 | 1.98 | 2.75 | 23.1 | 44.6 | | | | 1.76 | 1.70 | 3.48 | 3.36 | |
| 36-4, 0–13 | 317.6 | 2.00 | 2.00 | 1.94 | 2.74 | 24.7 | 46.7 | | | | 1.75 | 1.79 | 3.40 | 3.48 | 1.57 |
| 37-2, 104–116 | 325.1 | 2.15 | 2.01 | 1.93 | 2.76 | 25.2 | 47.5 | | | | 1.66 | 1.68 | 3.21 | 3.23 | 1.55 |
| 38-2, 72–86 | 334.3 | 2.01 | 1.98 | 1.85 | 2.79 | 29.2 | 53.1 | | | | 1.67 | 1.67 | 3.22 | 3.22 | 1.34 |
| 38-2, 80–82 | 334.3 | | | 1.93 | 2.78 | 25.6 | 48.2 | | | | | | | | |
| 42-2, 55–68 | 361.6 | 2.08 | 2.10 | 2.05 | 2.80 | 21.0 | 42.0 | | | | 1.88 | 1.86 | 3.86 | 3.81 | 1.45 |
| 42-4, 96–105 | 365.0 | 2.70 | 2.69 | 2.69 | 2.91 | 4.6 | 11.9 | | | | 4.53 | 4.50 | 12.20 | 12.09 | 1.69 |
| 43-1, 54–67 | 369.1 | 2.70 | 2.68 | 2.70 | 2.93 | 4.7 | 12.4 | | | | 4.48 | 4.58 | 12.10 | 12.36 | 1.65 |
| 43-3, 0–10 | 371.6 | 2.70 | 2.69 | 2.71 | 2.90 | 3.7 | 9.2 | | | | 4.71 | 4.69 | 12.76 | 12.72 | 1.76 |
| 43-5, 7–16 | 374.6 | 2.69 | 2.72 | 2.71 | 2.96 | 4.8 | 12.7 | | | | 4.64 | 4.57 | 12.58 | 12.38 | 1.64 |
| 44-1, 0–10 | 377.6 | 2.47 | 2.50 | 2.49 | 2.79 | 6.8 | 16.6 | | | | 3.93 | 3.94 | 9.79 | 9.81 | 1.64 |
| 44-3, 4–14 | 380.6 | 2.61 | 2.68 | 2.67 | 2.94 | 5.3 | 13.8 | | | | 4.49 | 4.53 | 11.99 | 11.27 | 1.46 |
| 44-4, 140–150 | 383.5 | 2.52 | 2.50 | 2.49 | 2.76 | 6.4 | 15.6 | | | | 3.95 | 3.94 | 9.83 | 9.80 | 1.38 |

Table 7. Physical properties summary for the basement complex, Site 527.

| | Basalt (mean of 7 samples) | Sediment (Sample 527-42-2, 55–68 cm) |
|---|---|---|
| Wet-bulk density (gravimetric) | 2.64 $g/cm^3$ | 205 $g/cm^3$ |
| Wet-water content | 5.2% | 21.0% |
| Porosity | 13.2% | 42.0% |
| Approximate grain density | 2.88 $g/cm^3$ | 2.80 $g/cm^3$ |
| Sonic velocity: horizontal | 4.39 km/s | 1.88 km/s |
| vertical | 4.39 km/s | 1.86 km/s |
| Thermal conductivity | 1.60 W/m°C<br>(=3.83 mcal/cm°C s) | 1.45 W/m°C<br>(=3.47 mcal/cm°C s) |

bulk density throughout the whole sedimentary sequence. In the basalt, GRAPE density and gravimetric density data are about the same.

## DOWNHOLE INSTRUMENTS

(No heat flow measurements were attempted at this site.)

### Logging

We logged Hole 527 after completion of rotary drilling. Density logs were obtained. The hole caved in before sonic velocity, resistivity, and final temperature could be logged.

The density log (Fig. 14) agrees well with predictions and measurements from lithology. Major negative spikes (density decreases) are observed in Unit II, corresponding to the layers with low carbonate content (clayey layers). There is a general increase in density from top to bottom of Unit III (~1.85–1.97 $g/cm^3$), corresponding to the increasing ratio of chalk to ooze with depth. Near the Unit III/IV boundary (Cretaceous/Tertiary boundary), there is a negative spike in the density plot, corresponding to a decrease in the carbonate content of the sediment at the same location. Unit IV is also characterized by increasing density with depth (~2.00–2.07 $gm/cm^3$). In basalt basement (Unit V), the density increases to values greater than 2.5 $g/cm^3$.

We are unsure at the present time of the origin of the negative spikes at the low carbonate content levels. It is generally believed that spikes arise as a result of layers washing out or caving in. It is also tempting to speculate that the sediments in other areas where large negative spikes exist (e.g., ~4605 m) are also low carbonate (clayey) sediments that were either not recovered or not identified. However, the gamma ray trace (which shows positive fluctuations in the regions where the negative spikes are known to occur and where there is a clay lithology) does not fluctuate in these other areas.

## SUMMARY AND CONCLUSIONS

Site 527 is on crust of Magnetic Anomaly 31 age (middle Maestrichtian) and located at the base of the western slope of a NNW-SSE-trending block on the Walvis Ridge. It is the deepest site of a transect across the Walvis Ridge into the Angola Basin. One hole was rotary-drilled, which gives a complete section from the seafloor through the sedimentary layers and into a basement complex consisting of basaltic rocks with intercalated sediments.

Forty-four cores were drilled with a total penetration of 384.5 m below the seafloor. The basement complex was first encountered at 341.0 m sub-bottom. We thus cored 341.0 m of sediment (recovery rate 62%) and 43.5 m of basement (recovery rate 76%).

### Lithology: Sediment

Five major sedimentary lithologic units are observed. One of these units occurs within the basement complex.

*Unit I* extends from the mud line to 104.0 m sub-bottom (late Miocene) and consists primarily of very homo-

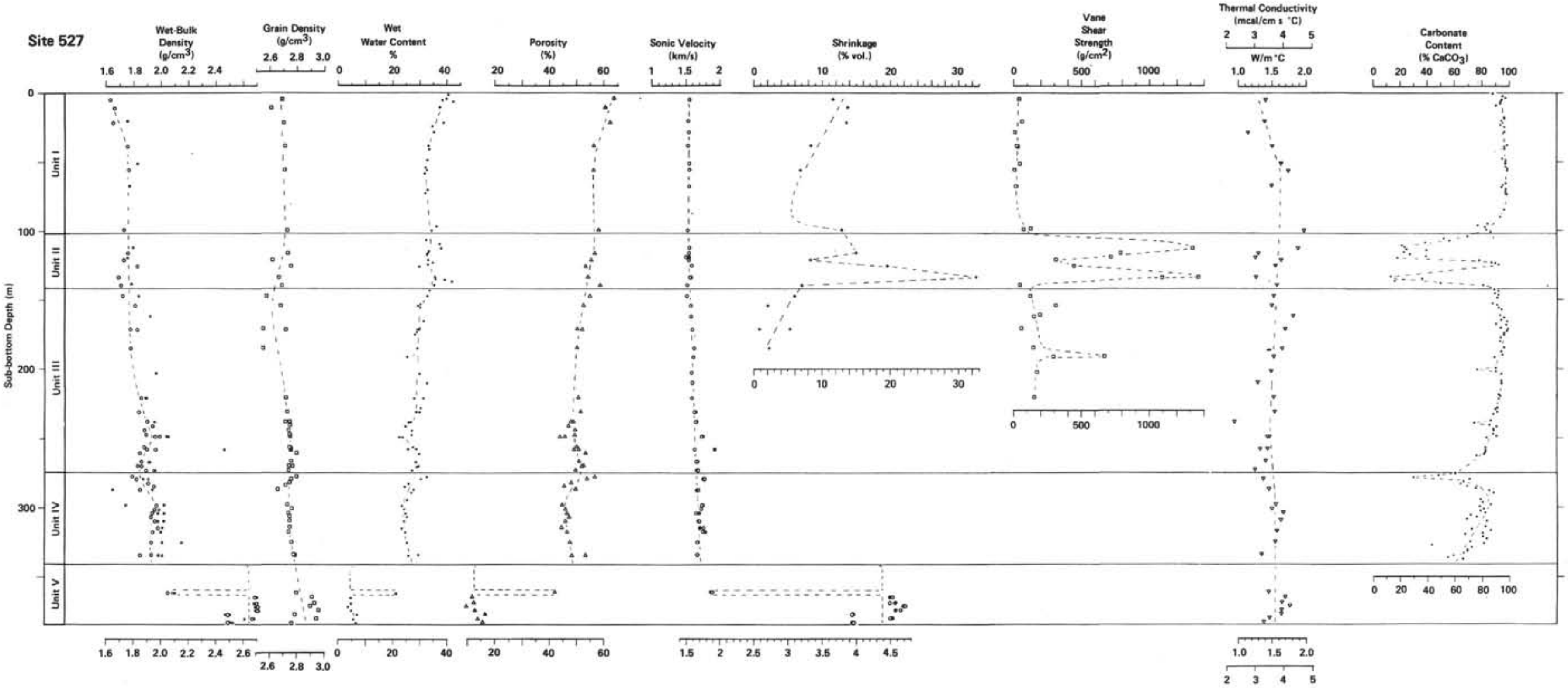


Figure 13. Summary of physical properties versus depth at Site 527.

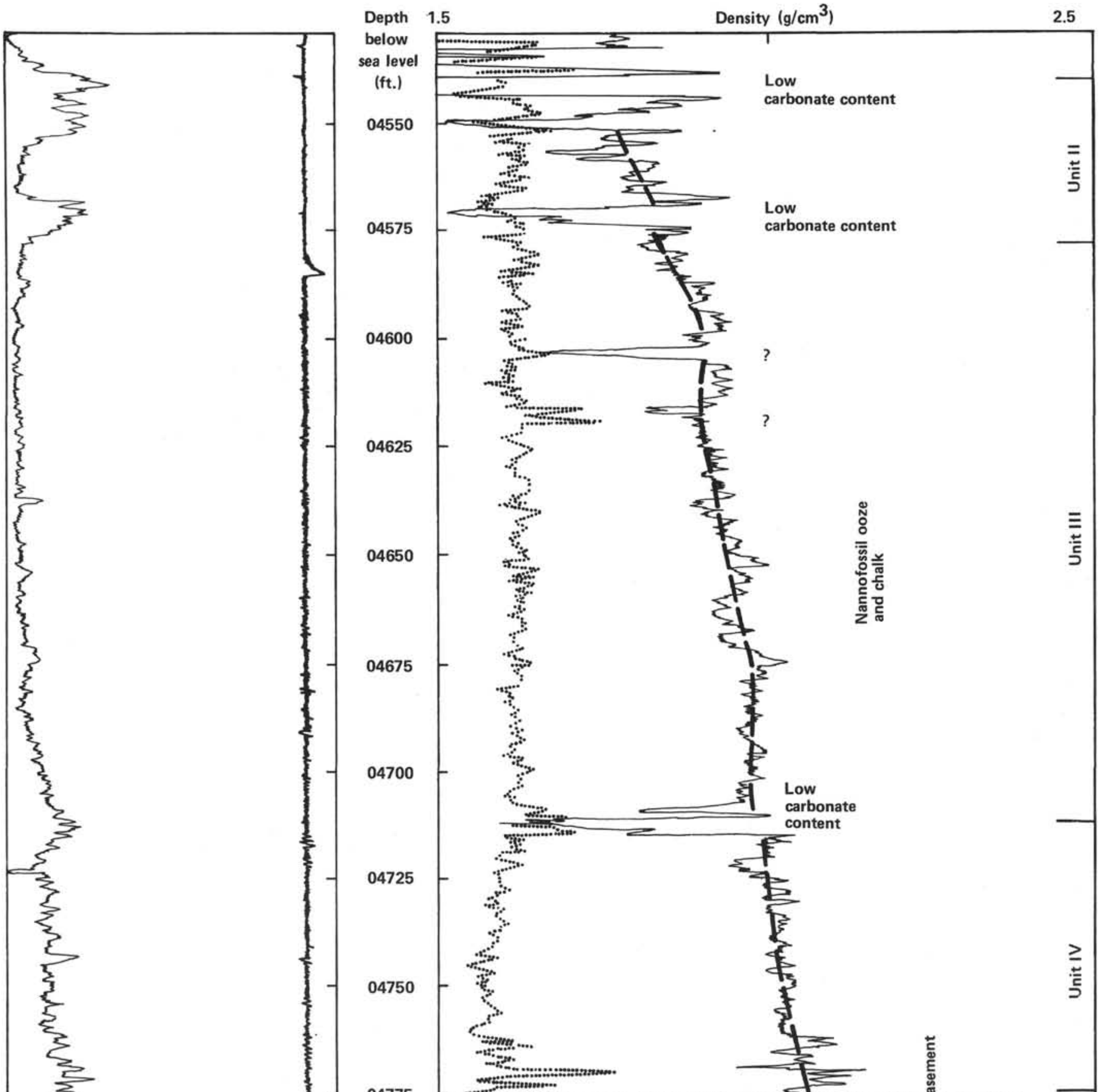


Figure 14. Density log and gamma ray trace compared to sediment and rock lithology, Site 527.

geneous white to pale orange nannofossil ooze. The calcium carbonate content is greater than 90%. Near the base of the unit, the carbonate content decreases to ~80% and is associated with a color change and slight increase in clay content. Bioturbation is present but less abundant in the upper part of the unit.

*Unit II* extends from 104.0 (late Miocene) to 142.0 m sub-bottom (middle–late Eocene) and consists of pale to dark yellowish brown nannofossil oozes and pale to dark brown pelagic nannofossil clays. A cyclic sedimentation pattern, which ranges in width from 15 to 240 cm, is indicated by distinct color changes. Changes in the calcium carbonate content within these cycles may indicate major dissolution events. Bioturbation is present throughout the unit, with *Planolites* predominating and with occasional *Chondrites* and *Zoophycos*. There is a dramatic slowdown in sedimentation rates from upper Miocene to middle Miocene and a hiatus from middle Miocene to lower Oligocene within this unit.

*Unit III* extends from 142.0 (middle upper Eocene) to 275.0 m sub-bottom (lowermost Paleocene, near the Cretaceous/Tertiary boundary) and consists of alternating layers of very pale orange and yellow to light gray nannofossil ooze and chalk, the ratio of ooze to chalk decreasing with depth. A distinct color change to very pale brown, observed at 256 m sub-bottom, is associated with an increased clay content and a decrease of carbonate content. Bioturbation (primarily *Planolites*, with lesser abundant *Chondrites, Zoophycos*, and *Teichichnus*) is slight but increases significantly below the color change.

*Unit IV* extends from near the well-preserved Cretaceous/Tertiary boundary (275.0 m) to the basaltic basement complex at 341.5 m sub-bottom and consists primarily of reddish brown muddy nannofossil chalks characterized by volcanic glass and palagonite increasing in amount with depth. Carbonate content decreases with depth from ~80 to 60%. Color changes are abundant in this unit. Sedimentary structures (horizontal and inclined laminations, convolute bedding, and cross-laminations) are common. Bioturbation is moderate to strong, with *Planolites* in greatest abundance and *Chondrites* and *Zoophycos* also present.

*Unit V* consists of highly altered sedimentary rocks interlayered within the basaltic basement complex. They consist of nannofossil chalks and carbonate mudstone, both with high amounts of volcanic material. Burrows are also present. The age of the sediments is the same as those recovered just above the basement complex—middle Maestrichtian.

### Lithology: Basalt

Forty-three meters were drilled in the basaltic basement complex with a recovery rate of 77%. The intercalated sediment (Unit V) and two glassy chilled upper margins (suggestive of a subaqueous extrusion) are the basis for dividing the massive basalt flows into five units. In general, vesicles are not observed in the basalts. Thin smectite-filled, and often pyrite-lined, veins occur at 20 to 50 cm intervals throughout most of the units. As at Site 525, it cannot be ascertained whether these are alkali or tholeiitic basalts until shore-based studies are performed. The shipboard interpretation is that the basalts were formed at a mid-ocean ridge spreading center.

The following are the five basalt units:

*Unit 1* is a 5-m-thick, medium gray, fine- to medium-grained, slightly altered, plagioclase, olivine, clinopyroxene phyric basalt with intergranular texture.

*Unit 2* is 2 m thick, similar to Unit 1, with a chilled upper margin with glass rind, and underlain by a single limestone fragment.

*Unit 3* is a 9-m-thick, medium gray, medium-grained, highly plagioclase (2 cm diameter phenocryst) phyric basalt with sparse clinopyroxene and olivine phenocrysts. It is underlain by a 60+-cm-thick nannofossil chalk.

*Unit 4* is a 40-cm-thick, medium gray, fine-grained, sparsely plagioclase phyric basalt with subophitic texture. There is altered glass rind in contact with upper chalk. The unit is underlain by carbonate mudstone.

*Unit 5* is a 21+-m-thick, massive fine- to coarse-grained aphyric basalt with subophitic to intergranular texture.

### Relationship between Lithology and Seismic Reflection Profile

The seismic stratigraphy is shown in Figure 15. The basal, very smooth, dark reflector is interpreted (as at Site 525) as the top of the basaltic basement complex. The top of the prominent reflector observed ~0.05 s above basement is probably related to the top of Unit IV (near the Cretaceous/Tertiary boundary) and to the change from nannofossil oozes and chalks to marly-muddy nannofossil chalks. This reflector appears to be continuous with the reflector observed near the Cretaceous/Tertiary boundary at Site 525. Higher in the section (at ~0.22 s above basement) there is a prominent reflector that may relate to the mid-Miocene- early Oligocene hiatus (or slowdown in sedimentation rates) in Unit II and to lithologic change from oozes to oozes mixed with chalks. If this reflector is continuous with that at Site 525, it is time-transgressive. The prominent reflector observed at 525 was interpreted to be the late Oligocene-mid-Eocene hiatus.

### Paleomagnetics

Paleomagnetic analyses of samples were performed for Cores 14-38 (~120 m to the basement complex at 341 m sub-bottom; early Oligocene to middle Maestrichtian). Owing to poor recovery and core disturbance, the record is not complete above the lower Paleocene, but below, a good reversal stratigraphy was obtained. The sedimentation rates calculated from the paleomagnetics suggest an increase in rates from the Eocene to the late Paleocene, followed by a decrease near the Cretaceous/Tertiary boundary and a sharp rise to about 40 m/m.y. in the Cretaceous.

The reversal sequence is consistent with the biostratigraphy and surface ship magnetic field measurements in that the crust at Site 527 was formed at Magnetic Anomaly 31 time.

### Physical Properties and Logging

In general, except for Unit II, the physical properties at Site 527 are similar to those at Site 525.

Sediment Unit I does not reveal major trends, except perhaps in the uppermost 30 m. Unit II, which contains considerable amounts of clay, is clearly distinct from the units above and below, particularly in shrinkage and shear strength. Unit III, characterized by a transition from ooze to chalk, shows distinct trends—increase in bulk density, grain density, sonic velocity, shear strength; decrease in water content, porosity, shrinkage—that are probably related to diagenesis. The trends in Unit III continue in Unit IV. Within the basement, the basalt is not as altered as at Site 525 and hence its physical properties do not vary as widely.

Only density was logged before the hole collapsed. The density log agrees well with the major lithologic

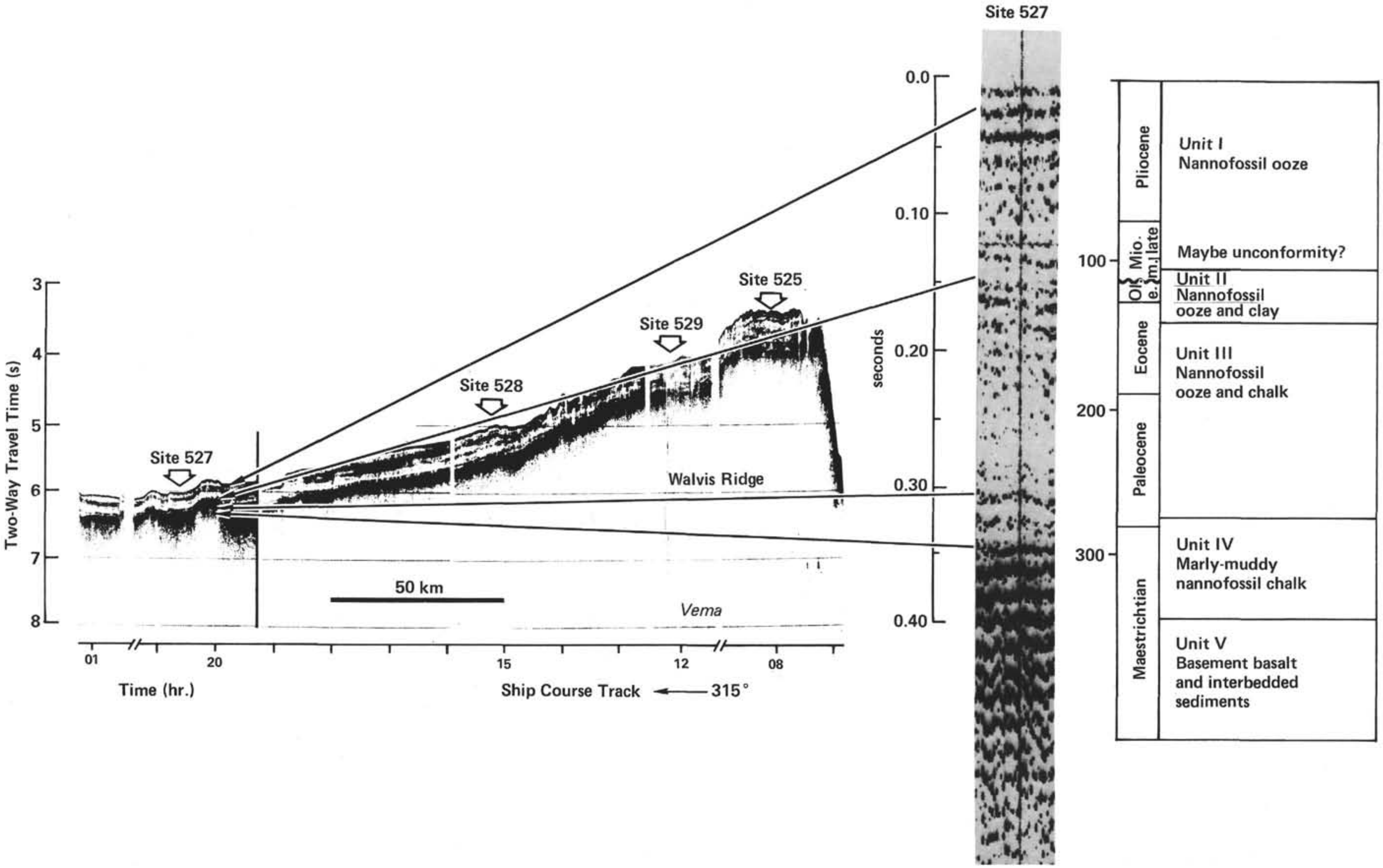


Figure 15. Correlation between seismic records and lithostratigraphic column, Site 527.

changes and may pick up other unrecognized or unrecovered formations.

### Accumulation Rates

Basement at Site 527 is only a few million years younger than at Site 525, yet the total sedimentary section is 234 m thinner. This difference in thickness is caused primarily by very low accumulation rates and hiatuses through the Miocene. Sedimentation rates in the late Cretaceous were actually higher at the deeper site (527), and the total accumulation for the early Paleogene was comparable (with sedimentation rates varying in a similar manner and ranging between 0.5 cm/$10^3$ y. and 1.3 cm/$10^3$ y.). Most of the Oligocene is missing from both Sites 525 and 527, but whereas the Miocene is well represented at Site 525, it is nearly absent from the section at 527. In the Plio–Pleistocene part of the record, both sites show a maximum in sedimentation rates in the lower Pliocene; however, the rates in this (527), the deeper, site are distinctly higher. Overall section thickness for the Plio–Pleistocene at Site 527 is over 90 m, whereas at Site 525 it is only 65 m.

### Biostratigraphy and History of the Walvis Ridge

A continuous section was drilled from the seafloor through the upper 43 m of basement at the base of the western slope of a NNW–SSE-trending block of the Walvis Ridge. The morphology of this segment of the Walvis Ridge is parallel to the observed magnetic lineations and normal to the fracture zone trends (as at Site 525).

The age of the crust (early late Maestrichtian), as determined from identification of the fossils within the sediments above basement and within the basement complex as well as from paleomagnetic measurements, is in agreement with the surface ship magnetic anomaly identification (Anomaly 31) and thus suggests further that this part of the Walvis Ridge was formed at a mid-ocean ridge spreading center. Unlike Site 525, Site 527 shows initial extrusion of ocean crust not near sea level but at bathyal depths.

The section recovered at Site 527 is marked by a very slow sediment accumulation between the lower Pliocene–uppermost Miocene and a hiatus in the lower Miocene through lower Oligocene. These diminished or missing intervals correspond roughly to mid–upper Miocene hiatuses found at several other South Atlantic sites (but not at 525) and in part to the lower Miocene to middle Eocene hiatus at Site 525. There are, however, differences in the pattern of hiatus occurrence: (1) Most of the upper Miocene is usually identified at other South Atlantic sites, whereas at Site 527 it is poorly preserved, and (2) the upper middle Miocene is frequently missing at other South Atlantic sites and is present here. The sparsely fossiliferous upper middle Miocene section recovered at Site 527 is approximately equivalent in time to a maximum in sediment accumulation at Site 525. The sediments at the lower and upper bounds of the mid-Tertiary hiatus at 527 are younger than those at 525; however, the presence of the poorly preserved, clayey section on either side of the hiatus at Site 527 clearly indicates that carbonate dissolution is associated with the creation of this break in the fossil record. At Site 525 no such low carbonate interval is encountered, and the break in sedimentation appears to be erosional in origin. Thus the upper Eocene sediments that are poorly preserved at this site are entirely missing at Site 525, and the sequence of events associated with this mid-Tertiary interval appears to have been as follows: (1) Increased carbonate dissolution in the upper Eocene in the deep site was associated with erosion at the shallow site; (2) erosion and/or dissolution removed most of the Oligocene section at both sites; and (3) continued dissolution removed the lower Miocene section at Site 527, whereas reduced erosion allowed sediment to accumulate at the shallower Site 525. If the mid-Tertiary hiatus at 525 is entirely due to erosion, it is completely spanned by an interval of increased dissolution at 527.

Other, shorter intervals appear to be missing near the Eocene/Oligocene boundary and the upper/middle Eocene boundary. These may represent either breaks in sediment accumulation or inadequate core recovery.

Preservation of calcareous microfossils ranges from moderate to poor in the section and is generally poor near the breaks in sediment accumulation. In the Pliocene, there are several intervals of poor preservation, particularly in the lowermost Pliocene. Foraminifers are generally absent from the highly dissolved Oligocene and upper Eocene sections and are not well preserved in the middle Eocene. Here, however, the poor preservation is due largely to recrystallization and calcite precipitation. Such early diagenetic alteration has been noted in many other middle Eocene sections in the South Atlantic. The foraminifers in the Paleocene are somewhat chalky but are in general better preserved at this site than at the shallower site, 525. This is also true for the basal Tertiary–uppermost Cretaceous sequences. Even though some effects of dissolution and a decrease in carbonate content are noted near this important boundary, the section does appear to be complete. The improved carbonate preservation in this lower part of the section compared to that at Site 525 may be due in part to the decreased overburden at this deeper site.

The planktonic biota represented in this section indicates temperate climatic conditions throughout most of the Tertiary and Late Cretaceous. In some intervals of poor preservation, dissolution effects tend to give the fauna a cooler aspect, and changes in the floral assemblages may be predominantly the effects of dissolution. Only in the early Eocene fauna is there a clear indication of warmer surface waters.

The benthic fauna shows several important relationships. First, in the basal sediments benthic foraminifers indicate a bathyal depth at the time of crustal formation. This is an important constraint on models of formation of the Walvis Ridge. For the ridge to have been formed at a spreading center, the crestal height of this center had to be lowered 1500 m in less than 5 m.y. (the maximum age difference in basement at the two sites). Second, the benthic populations found in close association with basalts (both here and at Site 525) appear unique in their species makeup, great abundance, and large size of individual specimens. This may suggest a rather different environment in this region during the time of basement formation. Finally, benthic foraminifers are not as abundant at this deeper site and, moreover, do not tend to be enriched in the more dissolved samples. Rather, they too appear to be dissolved and fragmented. This may be a result of the rather robust tests of the mid-latitude planktonic fauna, which resist dissolution almost as readily as some benthic forms, and indicates the very strong effect of dissolution on the character of both planktonic and benthic assemblages preserved at this site. It may also indicate a link between the low rain rate of organic debris (giving rise to low benthic productivity) and the presence of very corrosive deep waters (rich in carbon dioxide) within the Angola Basin.

The overall character of the section recovered at Site 527, including the preservation of microfossils, is dominated by the effects of carbonate dissolution. This is particularly true for the mid-to late Cenozoic, when carbonate content varied between 13 and 98%, roughly paralleling the preservation of calcareous fossils.

Preservation of calcite was moderate in the basal (late Maestrichtian) part of the section. This, combined with the addition of volcanogenic material, gave rise to the moderately high sedimentation rate of 2 cm/k.y. Near the top of the Maestrichtian, both the input of ash and the sedimentation rate dropped. Sediment accumulation rates increased with carbonate preservation in the upper Paleocene and lower Eocene but then dropped again in the mid- to upper Eocene. The next maximum in accumulation rate occurs in the lower Pliocene and coincides in time with accumulation rate maxima at Site 525 and at the Angola Basin sites of Leg 73. It is interesting to note, however, that the magnitude of the peak accumulation rate at 527 is at least 50% higher than at 525, even though the rain of pelagic debris must have been nearly identical at the two sites. This suggests the importance of winnowed and laterally transported fine-grained carbonate at Site 527. A careful analysis of the accumulation rates of various-sized components with different susceptibilities to solution allows us to distinguish the effects of winnowing and/or dissolution in our depth transect.

## REFERENCES

Bischoff, J. L., and Dickson, F. W., 1975. Sea water-basalt interaction at 200°C and 500 bars: Implications for origin of sea-floor heavy metal deposits and regulation of sea water chemistry. *Earth Planet. Sci. Lett.*, 25:385-397.

Diester-Haas, L., 1978. Influence of carbonate dissolution, climate, sea level changes, and volcanism on Neogene sediments off northwest Africa (Leg 41). *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP*, 41: Washington (U.S. Govt. Printing Office), 1033-1048.

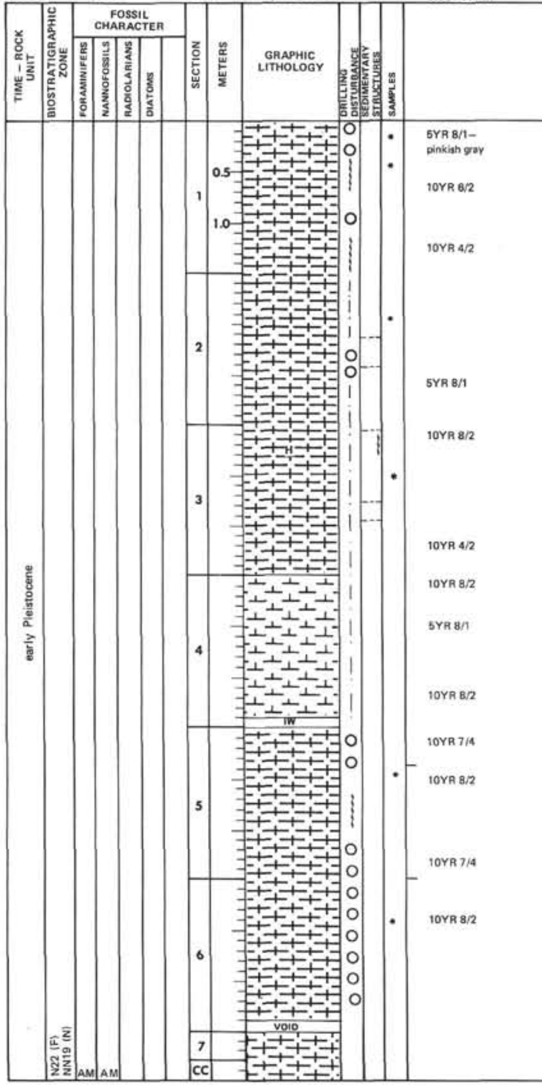
Glasby, G. P., 1977. *Marine Manganese Deposits:* New York (Elsevier).

Ness, G., Levi, S., and Couch, R., 1980. Marine magnetic anomaly time scales for the Cenozoic and Late Cretaceous: A precis, critique and synthesis. *Rev. Geophys.*, 18:753-770.

Perch-Nielsen, K., 1977. Albian to Pleistocene calcareous nannofossils from the Western South Atlantic, DSDP Leg 39. *In* Supko, P. R., Perch-Nielsen, K., et al., *Init. Repts. DSDP*, 39: Washington (U.S. Govt. Printing Office), 699-824.

Rabinowitz, P. D., and Simpson, E. S. W., 1979. Results of IPOD site surveys aboard R/V *Thomas B. Davie:* Walvis Ridge Survey. *L-DGO Tech. Rept.*, JOI Inc.

SITE 527 HOLE CORE 1 CORED INTERVAL 0.00–9.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE

A highly disturbed multicolored dark yellowish brown (10YR 4/2) to grayish orange (10YR 7/4) to very pale orange (10YR 8/2) foraminiferal nannofossil ooze was recovered.

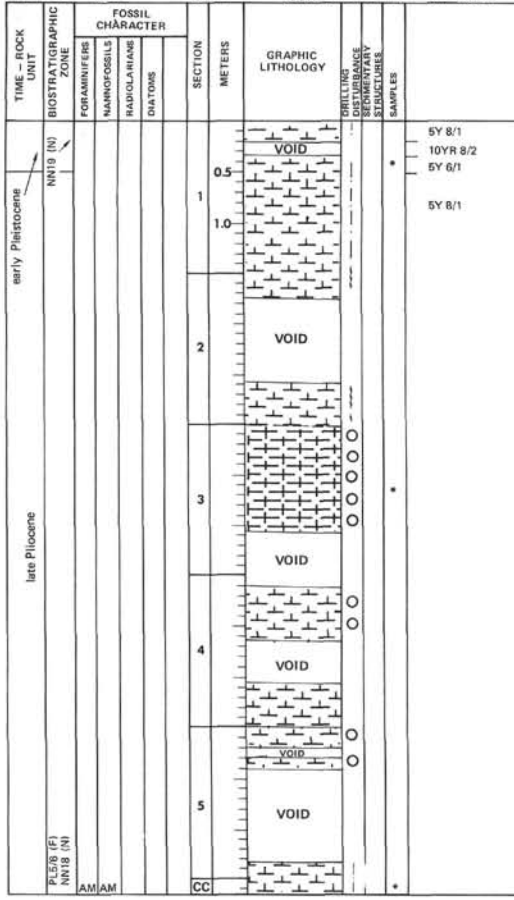
Alternating colors which may represent cycles are recognized. They are persistent throughout the core. The cycles which consist of a dark and light layer are approximately 20–70 cm thick. Except for one halo burrow no sedimentary structures are found.

SMEAR SLIDE SUMMARY:

| | 1-20<br>D | 2-50<br>D | 3-50<br>D | 5-50<br>D | 6-50<br>D |
|---|---|---|---|---|---|
| Composition: | | | | | |
| Quartz | TR | TR | TR | TR | – |
| Heavy minerals | 1 | TR | TR | – | – |
| Clay | 1 | TR | TR | – | – |
| Volcanic glass | – | – | – | TR | TR |
| Palagonite | – | – | – | TR | TR |
| Carbonate unspecified | – | – | – | TR | – |
| Foraminifers | 15 | 15 | 15 | 7 | 15 |
| Calcareous nannofossils | 83 | 85 | 85 | 93 | 85 |

---

SITE 527 HOLE CORE 2 CORED INTERVAL 9.0–18.5 m



LITHOLOGIC DESCRIPTION

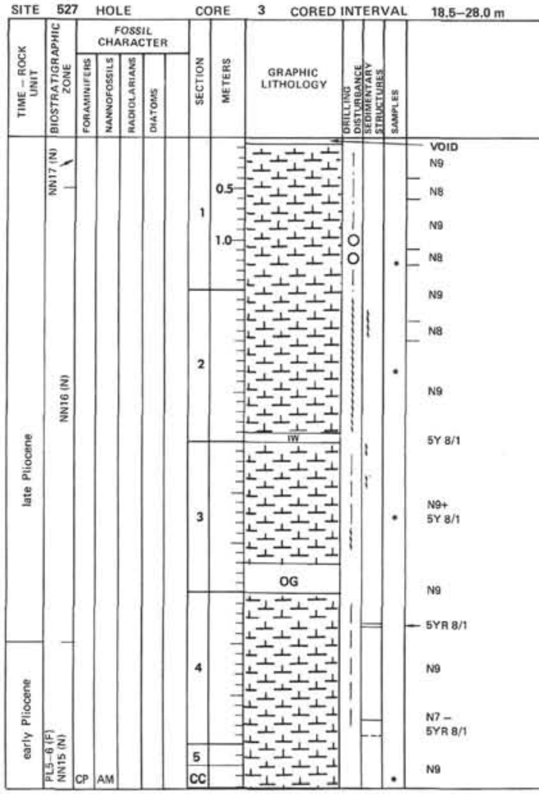
NANNOFOSSIL OOZE

This core contains a highly disturbed yellowish gray (5Y 8/1) to light olive gray (5Y 6/1) nannofossil ooze. Black wisps are present and may represent pyrite and/or darker areas (layers?). Some biogenic mottles are observed. They are not found in the lighter areas.

SMEAR SLIDE SUMMARY:

| | 1-45<br>D | 3-60<br>D | CC<br>D |
|---|---|---|---|
| Composition: | | | |
| Heavy minerals | 3 | TR | TR |
| Volcanic glass | TR | TR | TR |
| Palagonite | TR | TR | TR |
| Carbonate unspecified | 3 | – | – |
| Foraminifers | 4 | 20 | 3 |
| Calcareous nannofossils | 90 | 80 | 97 |

SITE 527 HOLE CORE 3 CORED INTERVAL 18.5–28.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

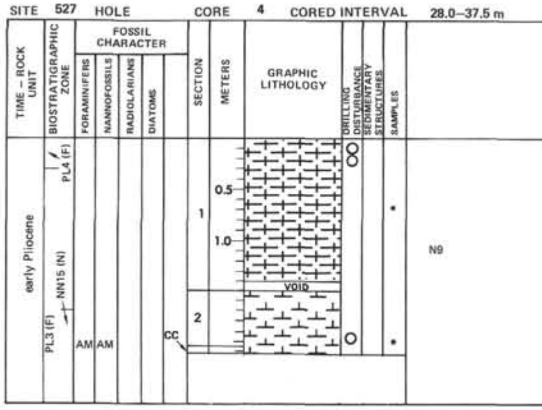
This core contains a highly disturbed white (N9), very light gray (N8) to pinkish gray (5YR 8/1) nannofossil ooze. Although highly disturbed the colors alternate and thus sedimentation appears to be cyclic in nature.

Some mottles which may have been biogenic are present. However, they are highly distorted.

SMEAR SLIDE SUMMARY:

| | 1-125 | 2-80 | 3-80 | CC |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Quartz | – | 1 | TR | TR |
| Feldspar | TR | TR | TR | – |
| Carbonate unspecified | TR | 1 | – | 2 |
| Foraminifers | 2 | 3 | 5 | 5 |
| Calcareous nannofossils | 98 | 95 | 94 | 84 |
| Discoasters | – | – | 1 | 10 |

SITE 527 HOLE CORE 4 CORED INTERVAL 28.0–37.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE

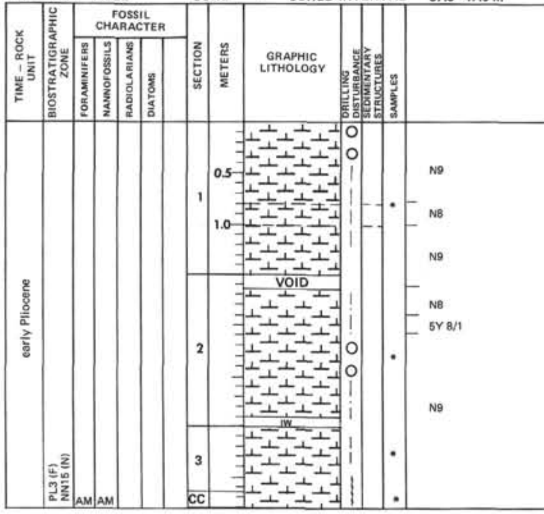
A highly disturbed, homogeneous white (N9) foraminifer nannofossil ooze is present.

Drilling disturbance has obliterated any structure which may have been present.

SMEAR SLIDE SUMMARY:

| | 1-70 | 2-52 |
|---|---|---|
| | D | D |
| Composition: | | |
| Quartz | – | TR |
| Feldspar | – | TR |
| Palagonite | TR | TR |
| Foraminifers | 15 | 10 |
| Calcareous nannofossils | 85 | 90 |

SITE 527 HOLE CORE 5 CORED INTERVAL 37.5–47.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

A white (N9) to very light gray (N8) moderately disturbed to soupy, homogeneous nannofossil ooze is observed.

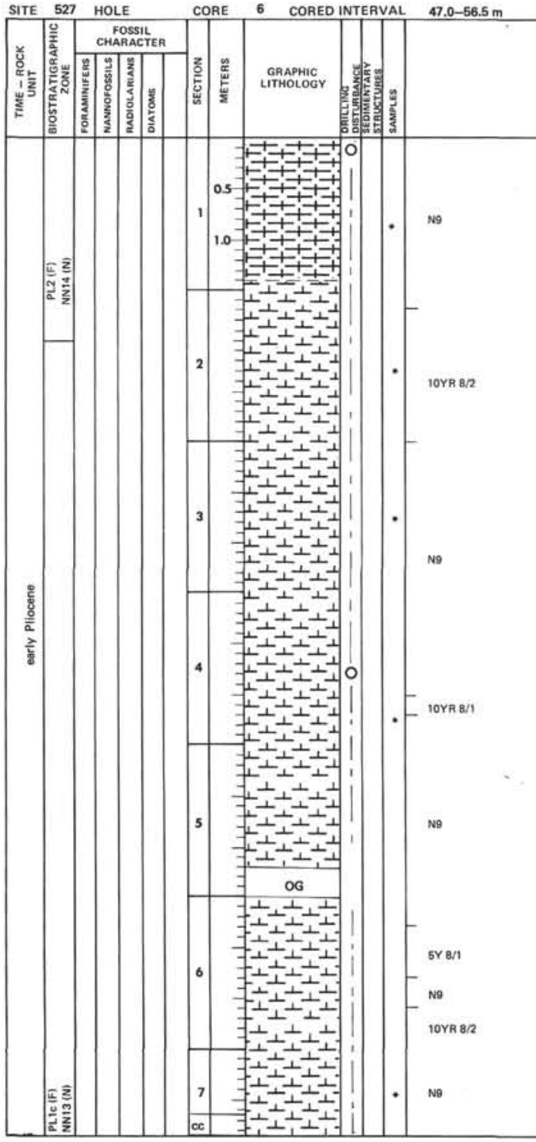
No sedimentary structures are recognized.

A vague trace of a cyclic sedimentation pattern is present in Section 1.

SMEAR SLIDE SUMMARY:

| | 1-83 | 2-80 | 3-30 | CC |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Quartz | TR | TR | – | – |
| Feldspar | – | – | TR | – |
| Volcanic glass | – | – | TR | TR |
| Palagonite | TR | TR | – | – |
| Carbonte unspecified | 2 | TR | TR | 2 |
| Foraminifers | 2 | 7 | 1 | 2 |
| Calcareous nannofossils (coccoliths) | 66 | 78 | 64 | 71 |
| Discoasters | 30 | 15 | 35 | 25 |

SITE 527 HOLE CORE 6 CORED INTERVAL 47.0–56.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL AND FORAMINIFER
NANNOFOSSIL OOZE

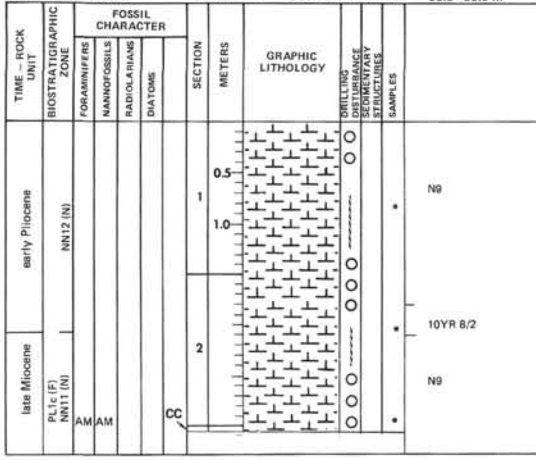
A moderately deformed white (N9) to very pale orange (10YR 8/2) nannofossil ooze was recovered.

No sedimentary structures are preserved.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-80 | 3-80 | 4-130 | 7-40 |
|---|---|---|---|---|---|
| | D | D | D | D | D |
| Composition: | | | | | |
| Feldspar | TR | TR | – | TR | – |
| Clay | – | TR | – | – | – |
| Volcanic glass | TR | TR | TR | – | TR |
| Palagonite | – | – | – | TR | – |
| Carbonate unspecified | TR | – | – | TR | – |
| Foraminifers | 15 | TR | TR | 3 | TR |
| Calcareous nannofossils | 85 | 100 | 100 | 97 | 100 |

SITE 527 HOLE CORE 7 CORED INTERVAL 56.5–66.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

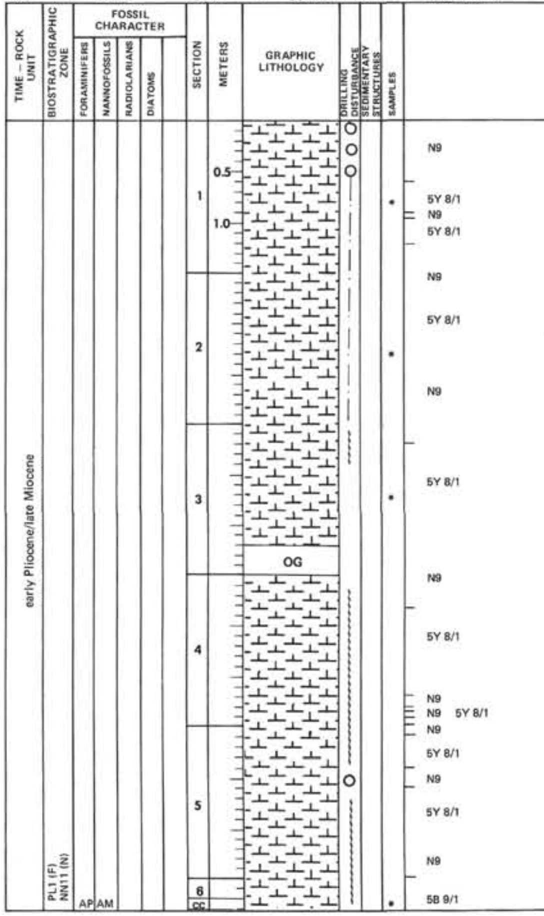
A white (N9) to very pale orange (10YR 8/2) highly disturbed by drilling, nannofossil ooze was recovered.

No sedimentary structures are observed.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-50 | CC |
|---|---|---|---|
| | D | D | D |
| Composition: | | | |
| Quartz | TR | – | TR |
| Mica | – | TR | – |
| Volcanic glass | TR | – | TR |
| Palagonite | – | TR | – |
| Carbonate unspecified | TR | – | – |
| Foraminifers | TR | TR | TR |
| Calcareous nannofossils | 65 | 60 | 65 |
| Discoasters | 35 | 40 | 35 |

SITE 527 HOLE CORE 8 CORED INTERVAL 66.0–75.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

This core contains a soupy to moderately deformed white (N9) to yellowish gray (5Y 8/1) nannofossil ooze.

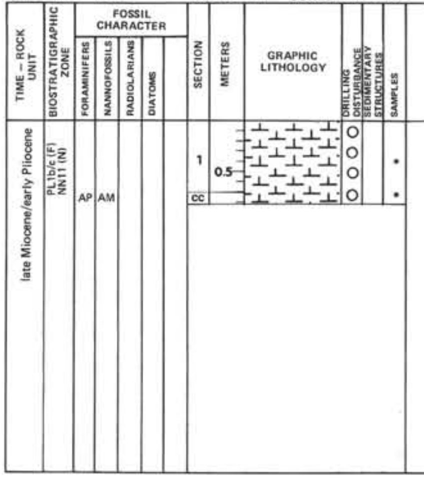
Section 3 contains a homogeneous white ooze which has a sharp upper contact with a yellowish gray ooze. The lower contact of the yellowish gray ooze and a white ooze is gradational.

SMEAR SLIDE SUMMARY:

| | 1-80<br>D | 2-80<br>D | 3-80<br>D | CC<br>D |
|---|---|---|---|---|
| Composition: | | | | |
| Quartz | TR | – | TR | TR |
| Feldspar | TR | TR | TR | TR |
| Clay | 3 | – | – | – |
| Volcanic glass | TR | – | – | TR |
| Palagonite | – | TR | TR | TR |
| Carbonate unspecified | – | – | TR | – |
| Foraminifers | – | TR | TR | TR |
| Calcareous nannofossils | 97 | 100 | 100 | 100 |

---

SITE 527 HOLE CORE 9 CORED INTERVAL 75.5–85.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

A soupy, white (N9) nannofossil ooze is present. No primary or secondary sedimentary structures are preserved.

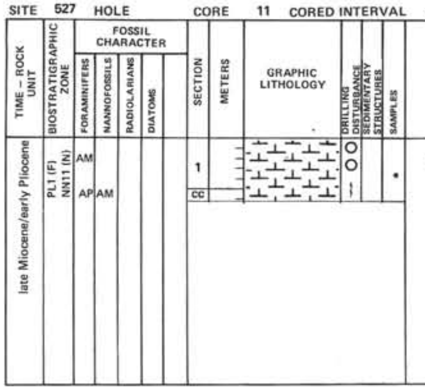
SMEAR SLIDE SUMMARY:

| | 1-40<br>D | CC<br>D |
|---|---|---|
| Composition: | | |
| Quartz | – | TR |
| Feldspar | – | TR |
| Heavy minerals | TR | – |
| Volcanic glass | TR | TR |
| Carbonate unspecified | TR | TR |
| Foraminifers | TR | TR |
| Calcareous nannofossils | 55 | 85 |
| Discoasters | 40 | 15 |

NOTE: Core 10, 85.0–89.5 m: No recovery.

---

SITE 527 HOLE CORE 11 CORED INTERVAL 89.5–94.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE

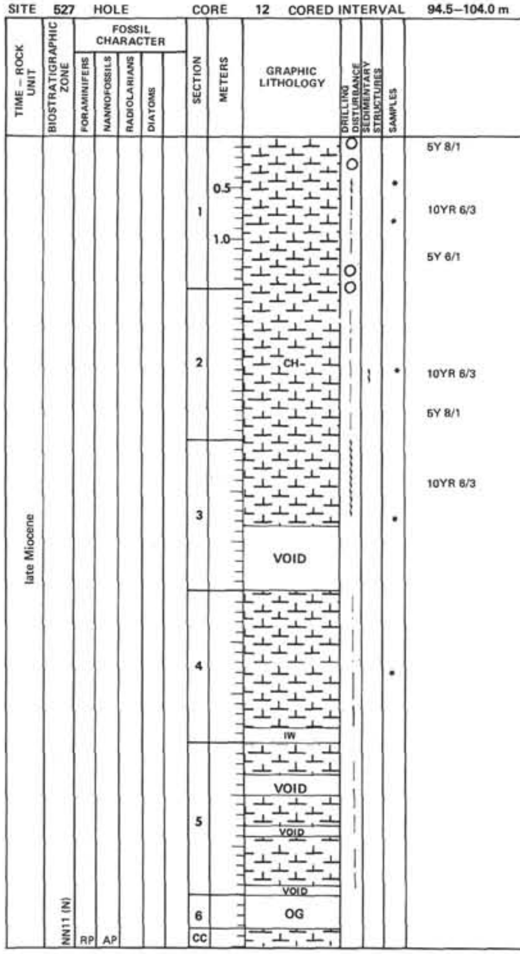
A highly disturbed to soupy, very pale orange (10YR 8/2) nannofossil ooze is present.

Drilling has obliterated any sedimentary structures which may have been present.

SMEAR SLIDE SUMMARY:

| | 1-40<br>D |
|---|---|
| Composition: | |
| Volcanic glass | TR |
| Foraminifers | 5 |
| Calcareous nannofossils | 95 |
| Fish remains | TR |

SITE 527 HOLE CORE 12 CORED INTERVAL 94.5–104.0 m



LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE

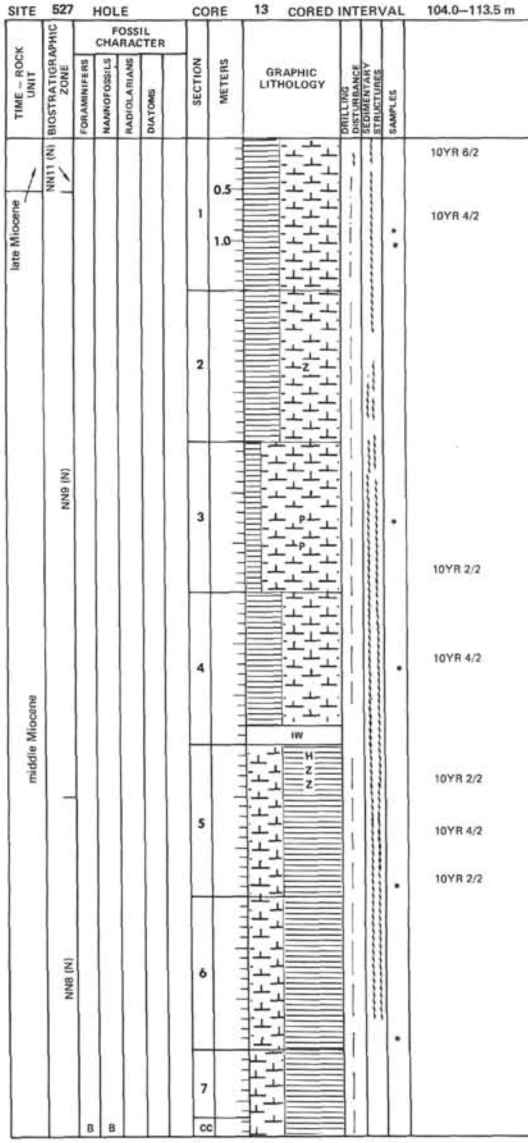
This core contains a pale brown (10YR 6/3) to yellowish gray (5Y 8/1) moderately deformed clayey nannofossil ooze. The color change is distinct from the previous core and marks the beginning of a different lithologic (or at least color) unit. Trace fossil (halo burrows) are observed, but their preservation is somewhat distorted because of drilling. The mottles are usually a very pale orange (10YR 8/2).

Discoasters (calcareous nannofossils) are very abundant in smear slides.

SMEAR SLIDE SUMMARY:

| | 1-40 | 1-80 | 2-80 | 3-80 | 4-80 |
|---|---|---|---|---|---|
| | D | D | D | D | D |
| Composition: | | | | | |
| Heavy minerals | 1 | 2 | 2 | TR | 1 |
| Clay | TR | 5 | 5 | 5 | 5 |
| Volcanic glass | TR | 1 | TR | – | TR |
| Palagonite | – | – | – | TR | – |
| Pyrite | – | – | – | – | TR |
| Carbonate unspecified | – | 1 | 2 | 1 | 2 |
| Foraminifers | TR | – | 5 | 5 | 2 |
| Calcareous nannofossils | 99 | 86 | 86 | 89 | 90 |

SITE 527 HOLE CORE 13 CORED INTERVAL 104.0–113.5 m



LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE TO
NANNOFOSSIL CLAY

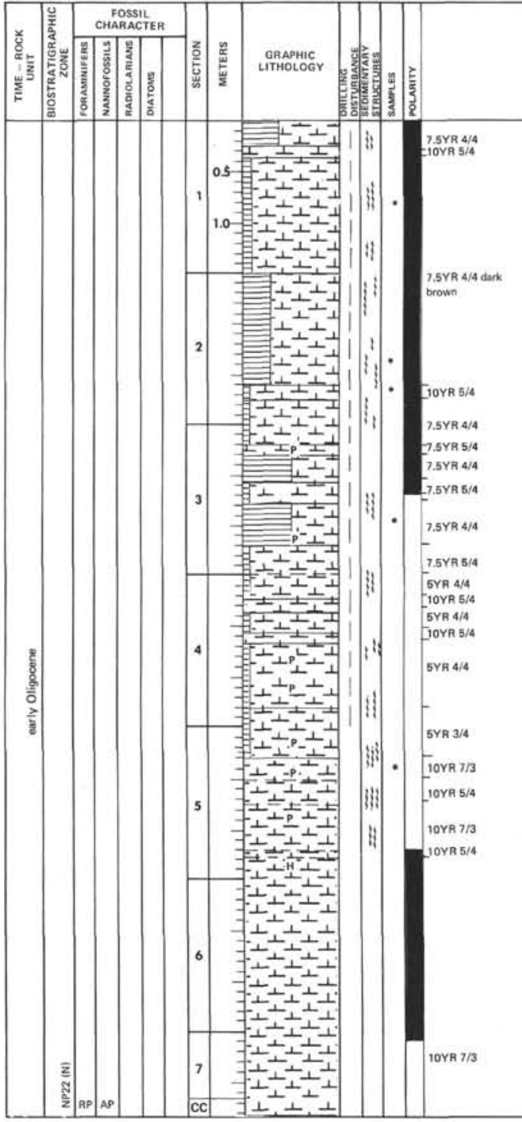
A highly variegated, dark yellowish brown (10YR 4/2) grading to a dusky yellowish brown (10YR 4/2) clayey nannofossil ooze to nannofossil clay. Biogenic sedimentary structures are present. Very pale orange mottles are nannofossil oozes. The increase in darkness of the core with depth is associated with an increase in clay content. Zoophycus crosscuts both light and dark mottled areas indicating that the mottling is mostly due to biologic activity.

Note: discoasters are majority of nannofossils.

SMEAR SLIDE SUMMARY:

| | 1-91 | 1-101 | 3-80 | 4-80 | 6-140 |
|---|---|---|---|---|---|
| | D | M | D | D | D |
| Composition: | | | | | |
| Clay | 40 | 10 | 20 | 40 | 60 |
| Foraminifers | – | 2 | 5 | 2 | TR |
| Calcareous nannofossils | 60 | 88 | 75 | 58 | 40 |

SITE 527 HOLE CORE 14 CORED INTERVAL 113.5–123.0 m



LITHOLOGIC DESCRIPTION

### CLAYEY NANNOFOSSIL OOZE ALTERNATING THEN GRADING INTO A NANNOFOSSIL OOZE

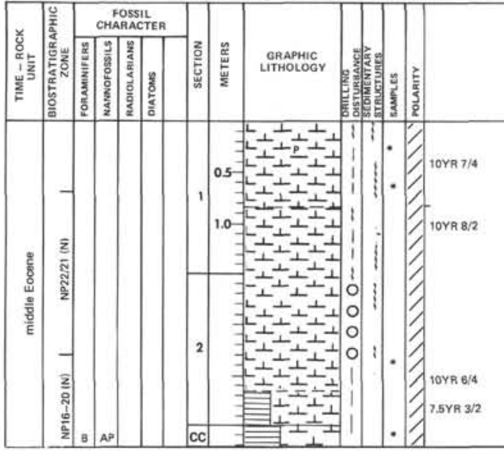
This core contains a dominant moderately yellowish brown (10YR 5/4) to dark brown (7.5YR 4/4) highly bioturbated clayey nannofossil ooze. Cyclic sedimentation patterns are present. Two units to each cycle exist. The lighter unit is nannofossil ooze and the dark unit is clayey nannofossil ooze. Each cycle ranges from 15–240 cm in length. From the bottom of Section 4 and top of Section 5 to 30 cm of Section 6 exists a very dark clayey nannofossil ooze. Below this zone nannofossil ooze is present with very little clay. This is a gradational contact.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-80 | 2-115 | 3-100 | 5-40 |
|---|---|---|---|---|---|
| | D | D | D | D | D |
| Composition: | | | | | |
| Heavy minerals | TR | TR | – | 10 | – |
| Clay | 30 | 30 | 40 | 30 | 5 |
| Volcanic glass | – | – | – | 10 | – |
| Zeolites | – | – | – | 10 | – |
| Carbonate unspecified | 10 | 10 | – | 10 | 5 |
| Calcareous nannofossils | 60 | 60 | 90 | 30 | 90 |

---

SITE 527 HOLE CORE 15 CORED INTERVAL 123.0–132.5 m



LITHOLOGIC DESCRIPTION

### NANNOFOSSIL OOZE GRADING TO CLAYEY NANNOFOSSIL OOZE

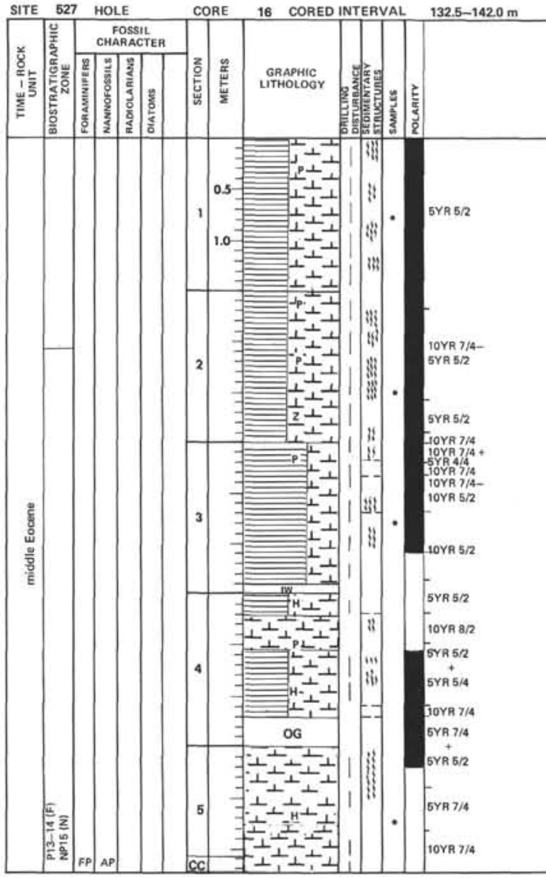
This core contains a moderately bioturbated very pale orange (10YR 8/2) nannofossil ooze. This ooze grades over a 40 cm interval into a dark clayey nannofossil ooze.

The dark layer may mark the beginning of a new lithologic unit.

SMEAR SLIDE SUMMARY:

| | 1-30 | 1-70 | 2-90 | CC |
|---|---|---|---|---|
| | M | D | D | D |
| Composition: | | | | |
| Heavy minerals | – | 1 | – | 2 |
| Carbonate unspecified | – | 1 | – | 2 |
| Calcareous nannofossils | 98 | 98 | – | 95 |
| Fish remains | 2 | – | – | 1 |
| Calcareous dinoflagellates | TR | – | – | – |

SITE 527 HOLE CORE 16 CORED INTERVAL 132.5–142.0 m



LITHOLOGIC DESCRIPTION

### MARLY NANNOFOSSIL OOZE

This core contains a highly variegated pale brown (5YR 5/2) to grayish orange (10YR 7/4) marly nannofossil ooze.

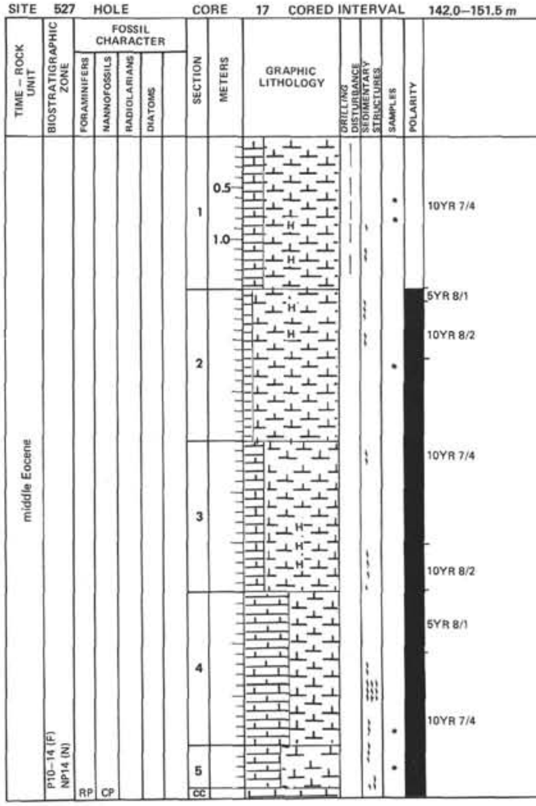
The core is intensely burrowed. Cyclic sedimentation is present and is distinguished mostly on color and clay content in smear slides.

The contacts between lithotypes within a sequence is gradational. The cycles are about 1 meter.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-100 | 3-80 | 5-80 |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Quartz | 1 | 1 | 1 | 1 |
| Feldspar | 1 | – | – | – |
| Mica | – | – | – | – |
| Clay | 48 | 53 | 68 | 5 |
| Volcanic glass | – | – | TR | – |
| Palagonite | TR | 1 | – | 1 |
| Pyrite | TR | – | 1 | 1 |
| Foraminifers | – | – | – | – |
| Calcareous nannofossils | 20 | 20 | 29 | 87 |
| Discoasters | 30 | 25 | 1 | 5 |

SITE 527 HOLE CORE 17 CORED INTERVAL 142.0–151.5 m



LITHOLOGIC DESCRIPTION

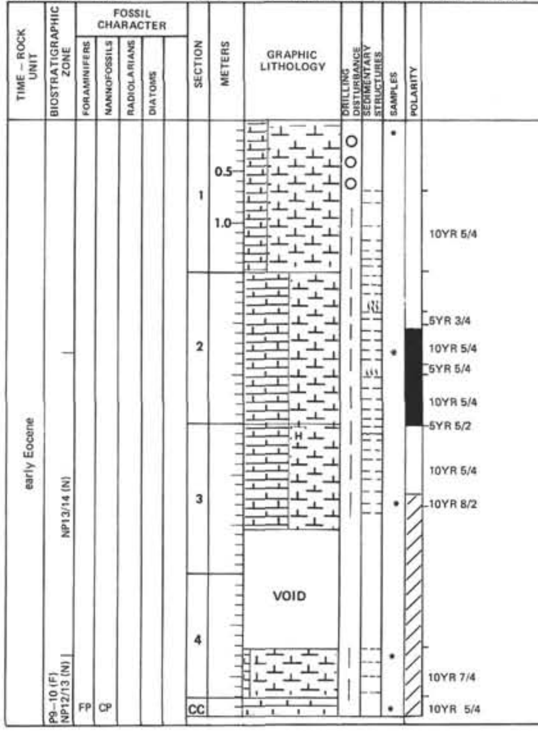
### ALTERNATING LAYERS OF NANNOFOSSIL OOZE AND CHALK

The core contains a grayish orange (10YR 7/4) to very pale orange (10YR 8/2) nannofossil ooze/chalk. Bioturbation is moderate with well preserved halo burrows. It is possible that the chalk/ooze sequences represent cycle. The cycles repeat about every 50 cm in the upper sections, with cycles becoming more frequent (every 10 cm) in the lower sections.

SMEAR SLIDE SUMMARY:

| | 1-60 | 1-78 | 2-80 | 4-140 | 5-20 |
|---|---|---|---|---|---|
| | D | D | D | D | D |
| Composition: | – | – | | | |
| Quartz | TR | – | – | TR | 2 |
| Feldspar | TR | 1 | TR | – | – |
| Mica | | | TR | – | – |
| Clay | 10 | 10 | 10 | 1 | 5 |
| Volcanic glass | TR | – | TR | – | TR |
| Palagonite | – | 1 | – | TR | TR |
| Foraminifers | – | TR | 1 | TR | – |
| Calcareous nannofossils | 90 | 88 | 89 | 99 | 93 |

SITE 527 HOLE CORE 18 CORED INTERVAL 151.5–161.0 m



LITHOLOGIC DESCRIPTION

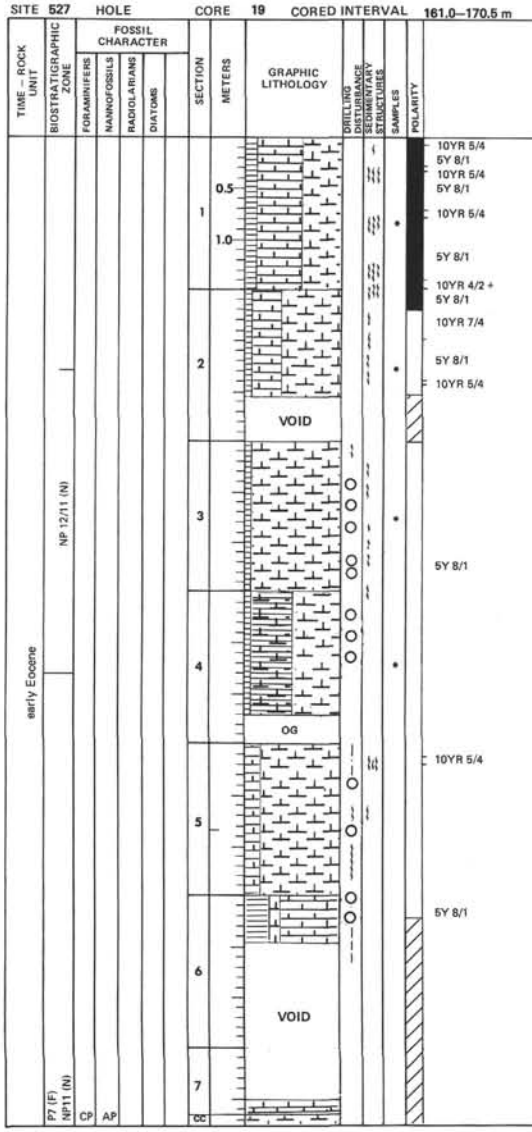
MARLY NANNOFOSSIL OOZE/CHALK

A grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4) alternating (cyclic) sequence of marly nannofossil oozes and chalk is present. The chalk, ooze beds repeat themselves approximately every 10 cm. Contacts between the ooze and chalk are gradational. Bioturbation is more intense in the chalk with halo burrows the most noticeable.

SMEAR SLIDE SUMMARY:

| | 1-5<br>D | 2-80<br>D | 3-80<br>D | 4-80<br>D | CC<br>D |
|---|---|---|---|---|---|
| Composition: | | | | | |
| Quartz | TR | – | – | – | TR |
| Feldspar | – | – | – | TR | – |
| Clay | 64 | 10 | – | – | 2 |
| Volcanic glass | TR | – | – | – | TR |
| Palagonite | 1 | TR | TR | – | – |
| Pyrite | – | – | – | – | TR |
| Zeolites | – | – | 1 | TR | – |
| Carbonate unspecified | TR | – | TR | – | TR |
| Foraminifers | – | – | – | TR | 48 |
| Calcareous nannofossils | 20 | 20 | 59 | 65 | – |
| Discoasters | 15 | 70 | 40 | 35 | 50 |

SITE 527 HOLE CORE 19 CORED INTERVAL 161.0–170.5 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK AND OOZE

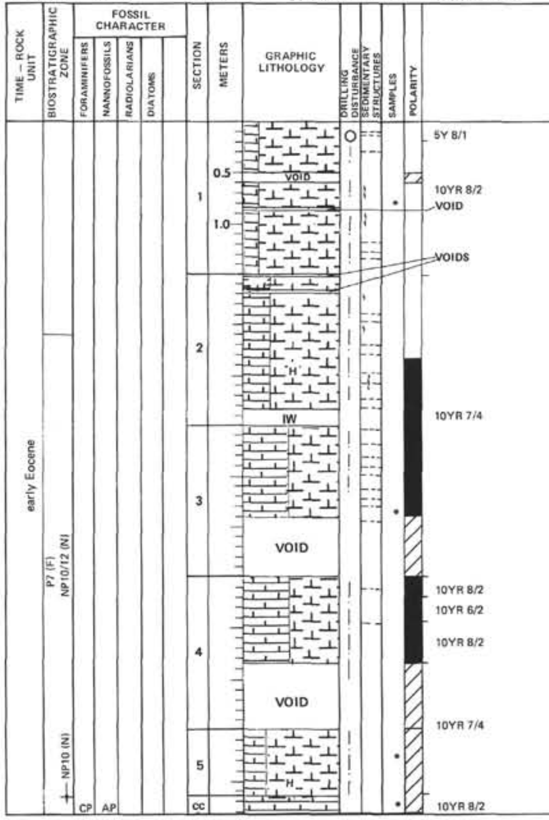
A cyclic pattern of alternating beds of marly nannofossil chalk and ooze is present. Where the cores are undisturbed biogenic sedimentary structures are present. Planolites and halo burrows are the most common with some vertical burrows 5 mm wide by 2–3 cm long at the bottom of Section 1.

The cyclic pattern repeats on the order of every 5 cm up to 1 meter.

SMEAR SLIDE SUMMARY:

| | 1-80<br>M | 2-80<br>D | 3-80<br>D | 4-80<br>D |
|---|---|---|---|---|
| Composition: | | | | |
| Quartz | – | – | TR | TR |
| Feldspar | TR | TR | TR | – |
| Mica | TR | – | – | – |
| Clay | 40 | 10 | 20 | 50 |
| Volcanic glass | TR | – | – | – |
| Palagonite | TR | 5 | 3 | TR |
| Carbonate unspecified | TR | TR | TR | – |
| Foraminifers | TR | – | TR | TR |
| Calcareous nannofossils | 60 | 85 | 77 | 50 |

SITE 527 HOLE CORE 20 CORED INTERVAL 170.5–180.0 m



LITHOLOGIC DESCRIPTION

ALTERNATING LAYERS OF
NANNOFOSSIL CHALK AND OOZE

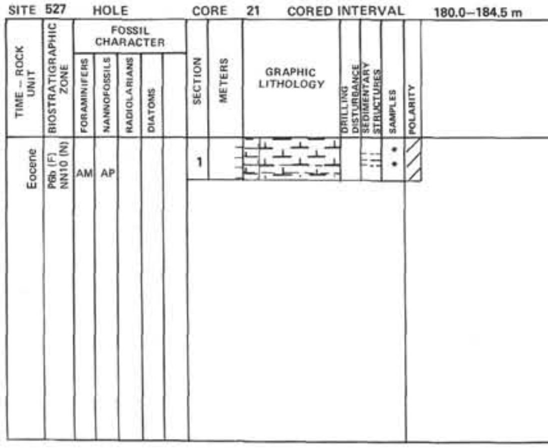
This core contains a predominantly very pale orange (10YR 8/2) sequence of alternating beds of nannofossil chalk and ooze. Bioturbation is difficult to distinguish from drilling disturbance. A few white (N9) patches are found which were halo burrows.

The frequency of repeating beds varies from 10–50 cm.

SMEAR SLIDE SUMMARY:

| | 1-80 | 3-93 | 5-20 | CC |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Quartz | TR | TR | TR | – |
| Feldspar | 1 | – | – | – |
| Palagonite | – | TR | – | TR |
| Carbonate unspecified | 1 | TR | – | – |
| Foraminifers | 2 | 1 | 1 | 2 |
| Calcareous nannofossils | 95 | 89 | 79 | 88 |
| Discoasters | 1 | 10 | 20 | 10 |
| Dolomite | – | – | TR | – |

SITE 527 HOLE CORE 21 CORED INTERVAL 180.0–184.5 m



LITHOLOGIC DESCRIPTION

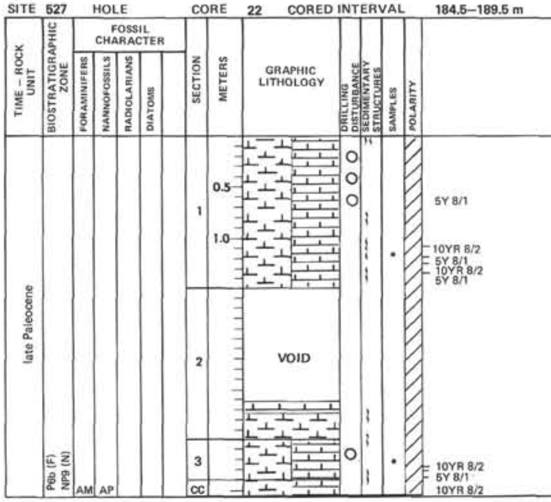
NANNOFOSSIL OOZE/CHALK

A very pale orange (10YR 8/2) to greyish orange nannofossil ooze and chalk is found. A thin marly nannofossil chalk is also observed.

SMEAR SLIDE SUMMARY:

| | 1-10 | 1-29 |
|---|---|---|
| | D | D |
| Composition: | | |
| Quartz | 1 | – |
| Heavy minerals | – | TR |
| Clay | – | 50 |
| Volcanic glass | – | TR |
| Palagonite | TR | TR |
| Foraminifers | – | TR |
| Calcareous nannofossils | 99 | 50 |
| Dolomite | TR | – |

SITE 527 HOLE CORE 22 CORED INTERVAL 184.5–189.5 m



LITHOLOGIC DESCRIPTION

ALTERNATING BEDS OF
NANNOFOSSIL CHALK AND OOZE

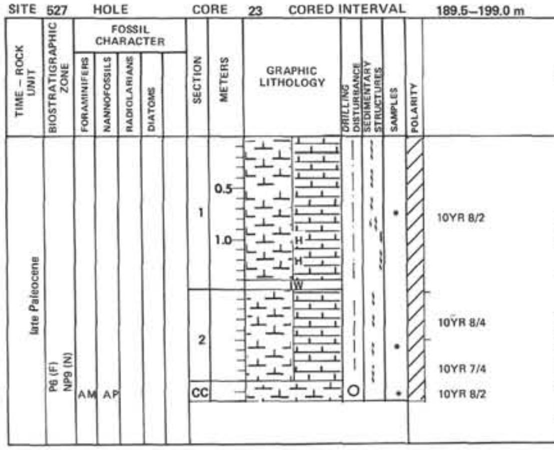
This core contains alternating beds of nannofossil ooze and chalk. The dominant colors are yellowish gray (5Y 8/1) and very pale orange (10YR 8/2). Biogenic mottling is slight, but some white (N9) burrows are observed.

The cyclic sequence repeats approximately every 5–50 cm.

SMEAR SLIDE SUMMARY:

| | 1-115 | 3-28 |
|---|---|---|
| | D | D |
| Composition: | | |
| Quartz | TR | – |
| Clay | 5 | 5 |
| Volcanic glass | TR | TR |
| Foraminifers | 7 | 1 |
| Calcareous nannofossils | 88 | 94 |

SITE 527 HOLE CORE 23 CORED INTERVAL 189.5–199.0 m



LITHOLOGIC DESCRIPTION

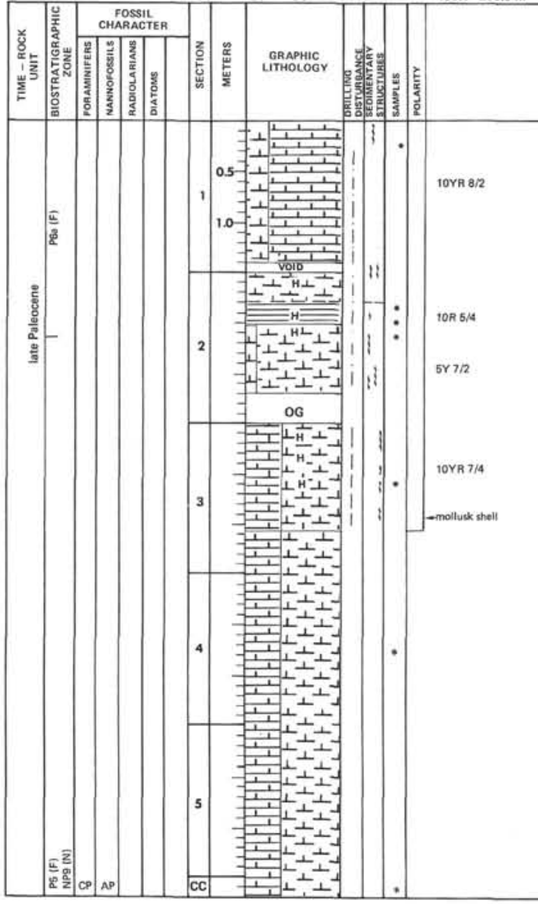
ALTERNATING LAYERS OF
NANNOFOSSIL OOZE AND CHALK

This core contains a very pale orange (10YR 8/2) mixture of nannofossil chalk and ooze. Drilling disturbance has eliminated any pattern of sedimentation. A couple of halo burrows are noticed.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-65 | CC |
|---|---|---|---|
| | D | D | D |
| Composition: | | | |
| Quartz | TR | TR | – |
| Clay | – | 2 | – |
| Palagonite | TR | TR | TR |
| Foraminifers | 2 | 5 | 5 |
| Calcareous nannofossils | 98 | 90 | 95 |
| Calcareous dinoflagellates | – | 5 | – |

SITE 527 HOLE CORE 24 CORED INTERVAL 199.0–208.5 m



LITHOLOGIC DESCRIPTION

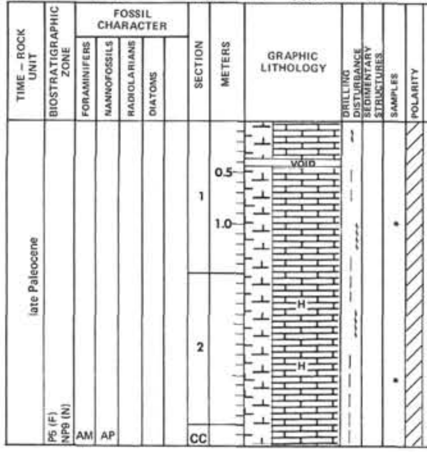
NANNOFOSSIL OOZE/CHALK TO NANNOFOSSIL CLAY TO NANNOFOSSIL OOZE/CHALK

This core contains a moderately disturbed very pale orange (10YR 8/2) to yellowish gray (5Y 7/2) intercalated nannofossil ooze and chalk. The top of Section 2 is nannofossil chalk which grades into a pale reddish brown (10R 5/4) nannofossil clay. Trace fossils are well preserved in this section. The lower contact is sharp with intraclasts of the "red" clay included into the underlying nannofossil ooze. Load casts are also present. Black wisps and mottles are present in the upper part of Section 2 (MnO?). A large mollusk fragment is present in Section 3.

SMEAR SLIDE SUMMARY:

| | 1-27<br>D | 2-47<br>D | 2-58<br>D | 3-66<br>D | 4-66<br>D |
|---|---|---|---|---|---|
| Composition: | | | | | |
| Heavy minerals | – | 5 | 2 | 1 | 1 |
| Clay | – | 74 | 2 | 1 | 1 |
| Carbonate unspecified | 1 | 1 | 1 | – | 1 |
| Foraminifers | – | – | – | 1 | – |
| Calcareous nannofossils | 97 | 20 | 94 | 97 | 97 |
| Fish remains | 2 | – | 1 | – | – |

SITE 527 HOLE CORE 25 CORED INTERVAL 208.5–218.0 m



LITHOLOGIC DESCRIPTION

10YR 7/3

INTERCALATED NANNOFOSSIL OOZE AND CHALK

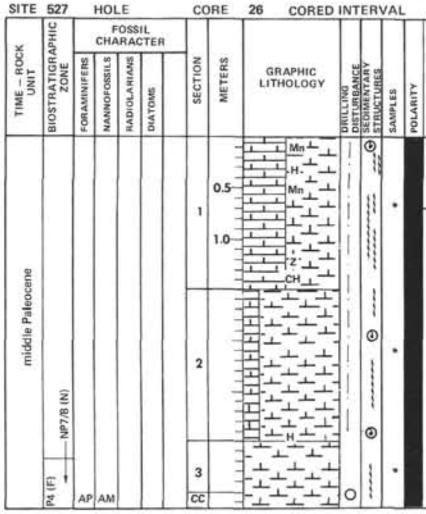
A moderate to highly disturbed very pale brown (10YR 7/3) intercalated nannofossil chalk and ooze was cored. Preservation of ichnofossil is poor.

No pattern in sedimentation exists.

SMEAR SLIDE SUMMARY:

| | 1-95<br>D | 2-108<br>D |
|---|---|---|
| Composition: | | |
| Clay | TR | TR |
| Calcareous nannofossils | 99 | 99 |
| Fish remains | 1 | – |
| Calcium dinoflagellates | – | 1 |

SITE 527 HOLE CORE 26 CORED INTERVAL 218.0–227.5 m



LITHOLOGIC DESCRIPTION

5Y 8/1

5YR 8/1

5Y 8/1

5YR 8/1

5Y 8/1

5YR 8/1

NANNOFOSSIL OOZE/CHALK

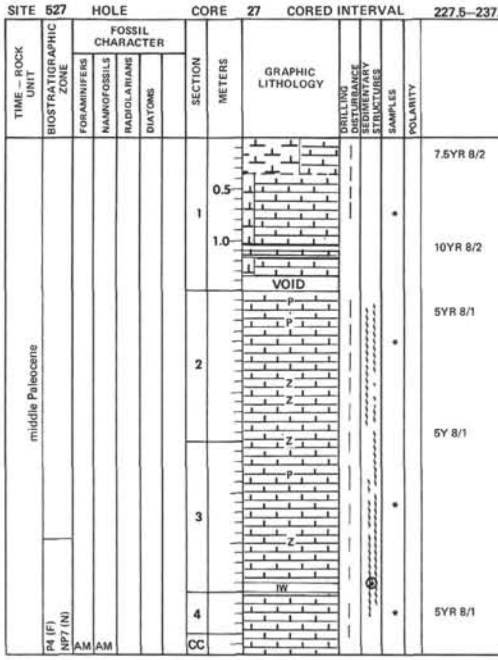
This core contains a *nannofossil ooze* (5Y 8/1 – yellowish gray) which is intercalated with nannofossil chalk (5YR 8/1 – pinkish gray). Black (MnO?) micronodules are present through the core. Bioturbation is slight with halo burrows preserved in the chalk layers.

Whether the chalk/ooze sequence represents cyclic sedimentation cannot be determined due to drilling disturbance. If they represent cycles they are 10–50 cm in thickness.

SMEAR SLIDE SUMMARY:

| | 1-70<br>D | 2-61<br>D | 3-37<br>D |
|---|---|---|---|
| Composition: | | | |
| Heavy minerals | TR | 1 | TR |
| Clay | 2 | 1 | 2 |
| Volcanic glass | – | 1 | 1 |
| Carbonate unspecified | 2 | 2 | 2 |
| Foraminifers | – | – | TR |
| Calcareous nannofossils | 96 | 95 | 95 |
| Fish remains | TR | TR | TR |

SITE 527 HOLE CORE 27 CORED INTERVAL 227.5–237.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK

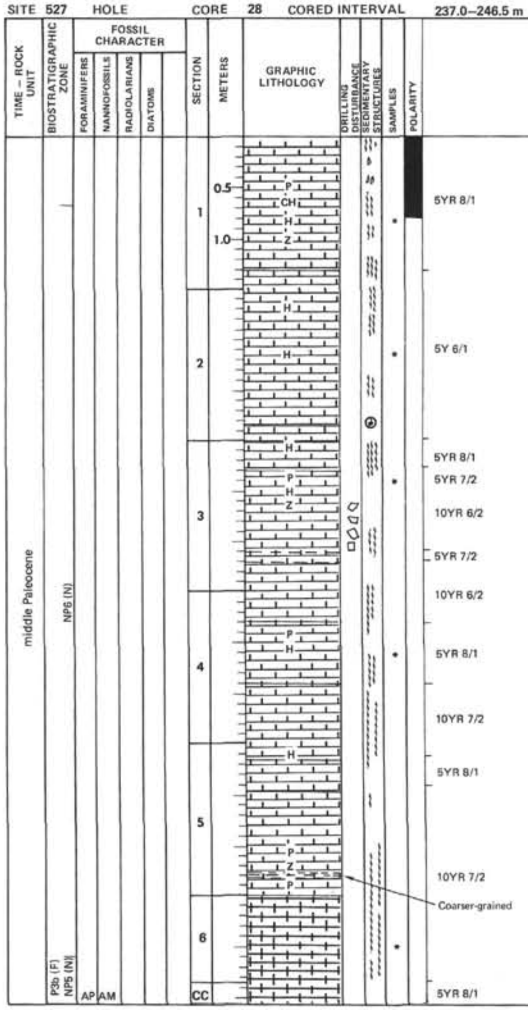
This core contains a pinkish white (7.5YR 8/2) to yellowish gray (5Y 8/1) highly bioturbated nannofossil chalk. Black Mn? concretions or nodules are present throughout.

Areas of more than one burrow cross-cutting other burrows are labeled composite burrows.

SMEAR SLIDE SUMMARY:

| | 1-78<br>D | 2-55<br>D | 3-70<br>D | 4-28<br>D |
|---|---|---|---|---|
| Composition: | | | | |
| Heavy minerals | – | TR | 1 | TR |
| Clay | TR | 1 | – | – |
| Volcanic glass | – | – | 1 | TR |
| Palagonite | TR | – | – | |
| Foraminifers | 5 | 2 | TR | 2 |
| Calcareous nannofossils | 92 | 97 | 98 | 98 |
| Calcareous dinofl-gellates | 3 | – | – | – |

SITE 527 HOLE CORE 28 CORED INTERVAL 237.0–246.5 m



LITHOLOGIC DESCRIPTION

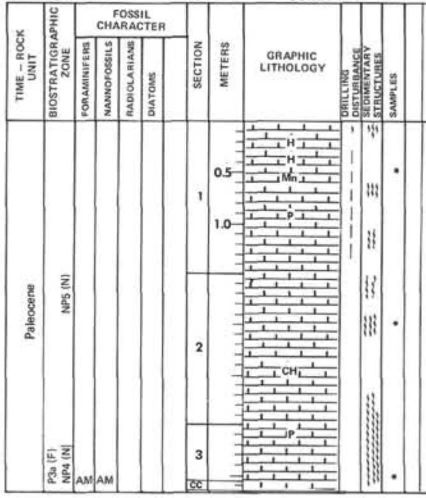
NANNOFOSSIL CHALK

This core contains an alternating colored sequence (cyclic) of nannofossil chalks. Cycles are approximately 50–100 cm thick and consist of a light gray (10YR 7/2) (darker) layer and pinkish gray (5YR 8/1) (lighter) layer. Bioturbation is intense with halo burrows, planolites, zoophycus, and chrondrites being present. Some dark (opaque) and brown (high clay content) centers of halo burrows are noticed. Slightly coarser grained areas are observed at the base of one contact.

SMEAR SLIDE SUMMARY:

| | 1-80<br>D | 2-70<br>D | 3-40<br>D | 4-70<br>D | 6-60<br>D |
|---|---|---|---|---|---|
| Composition: | | | | | |
| Quartz | – | 1 | – | – | – |
| Heavy minerals | 1 | – | – | 1 | 1 |
| Clay | 5 | 5 | 2 | 2 | 2 |
| Volcanic glass | – | 2 | – | 1 | – |
| Palagonite | 1 | – | 1 | – | TR |
| Foraminifers | TR | 1 | 2 | 1 | 5 |
| Calcareous nannofossils | 92 | 90 | 93 | 94 | 90 |
| Calcareous dinoflagellates | 1 | 1 | 2 | – | 2 |

SITE 527 HOLE CORE 29 CORED INTERVAL 246.5–256.0 m



LITHOLOGIC DESCRIPTION

10YR 7/2
10YR 8/2
5YR 8/1
10YR 8/2
10YR 7/2
10YR 7/1

NANNOFOSSIL CHALK

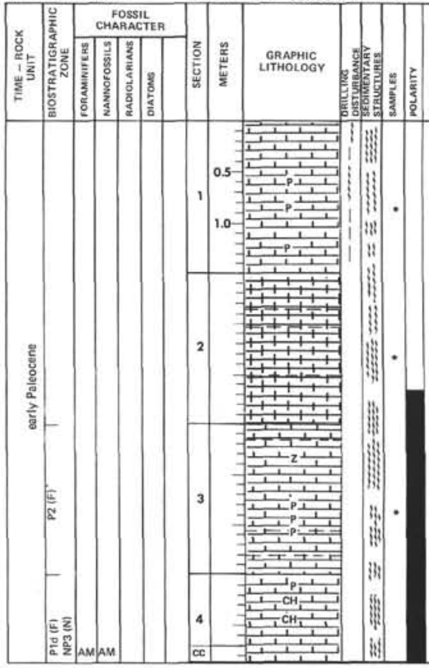
This core contains a hgihly mottled nannofossil chalk. The dominant color is light gray (10YR 7/1). Numerous trace fossils are present.

Some black possibly MnO micronodules or concretion are observed. The cyclic alternation of color is present, but the lighter colored (very pale orange – 10YR 8/2) layer are much thinner than the dark (light gray) layers. Cycles are repeated every 60–100 cm.

SMEAR SLIDE SUMMARY:

|  | 1-50<br>D | 2-50<br>D | 3-50<br>D |
|---|---|---|---|
| Composition: |  |  |  |
| Heavy minerals | – | 1 | 1 |
| Clay | – | – | 1 |
| Carbonate unspecified | 95 | 98 | 98 |
| Foraminifers | 5 | – | – |
| Fish remains | – | 1 | – |

SITE 527 HOLE CORE 30 CORED INTERVAL 256.0–265.5 m



LITHOLOGIC DESCRIPTION

10YR 7/3
10YR 6/4
10YR 7/3
10YR 6/6
10YR 6/4
10YR 7/3
10YR 6/4
7.5YR 7/4

NANNOFOSSIL CHALK

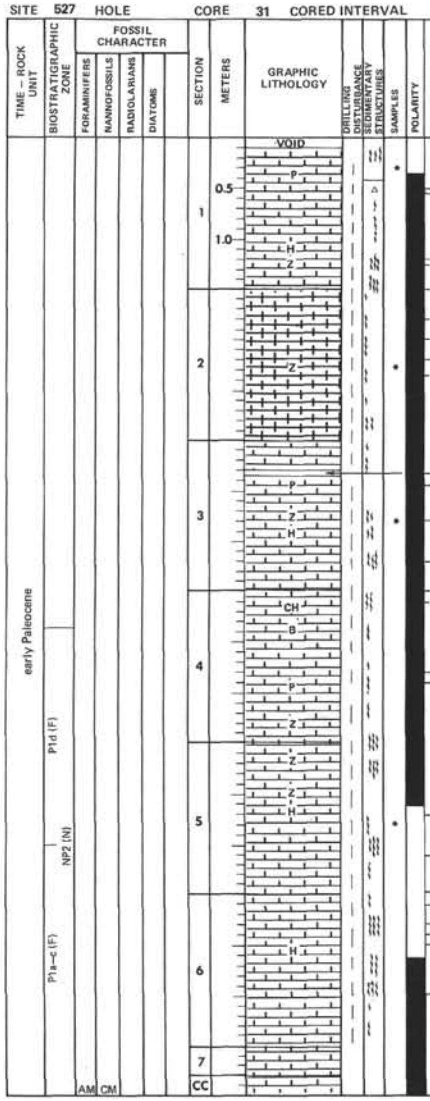
A very pale brown (10YR 7/3) to light yellowish brown (10YR 6/4) very highly bioturbated nannofossil chalk was cored.

Beautifully preserved ichnofossils are present. Planolites is the most abundant. A large vertical branching burrow is present in Section 2. Sections 2 and 3 show a cyclic sedimentation pattern which is indicated by color change.

SMEAR SLIDE SUMMARY:

|  | 1-80<br>D | 2-80<br>D | 3-80<br>D |
|---|---|---|---|
| Composition: |  |  |  |
| Heavy minerals | TR | TR | – |
| Clay | TR | TR | – |
| Volcanic glass | 1 | – | – |
| Palagonite | TR | TR | TR |
| Foraminifers | 8 | 12 | 5 |
| Calcareous nannofossils | 91 | 87 | 95 |

SITE 527 HOLE CORE 31 CORED INTERVAL 265.5–275.0 m



LITHOLOGIC DESCRIPTION

10YR 6/3
10YR 7/4
10YR 6/3
10YR 7/4
10YR 6/3
10YR 5/3
10YR 6/3
10YR 5/3
5YR 7/2
10YR 6/3
VOID
10YR 7/4
10YR 6/3
10YR 7/4
5YR 8/4
10YR 6/3
5YR 7/2
10YR 6/3
5YR 7/2
10YR 5/2
10YR 6/3
5YR 7/4
10YR 6/2
10YR 7/4
10YR 7/3

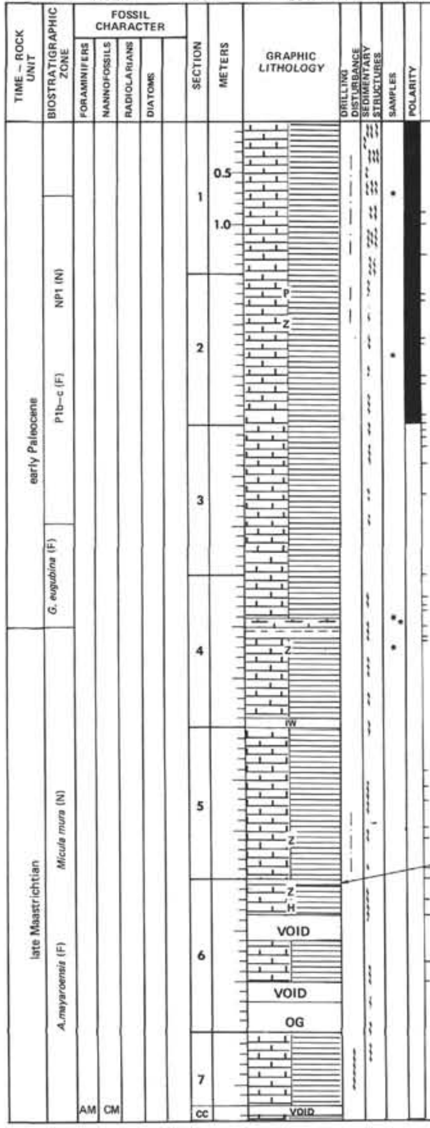
NANNOFOSSIL CHALK

A multicolored, but dominantly pale brown (10YR 6/3), indurated nannofossil chalk, is present. The core is intensely bioturbated. Sections 3–6 show an alternation of colors which is suggestive of cyclic sedimentation.

SMEAR SLIDE SUMMARY:

|  | 1-30<br>D | 2-80<br>D | 3-80<br>D | 5-80<br>D |
|---|---|---|---|---|
| Composition: |  |  |  |  |
| Quartz | 1 | TR | TR | 1 |
| Heavy minerals | – | – | TR | – |
| Clay | 64 | TR | – | 3 |
| Volcanic glass | 10 | TR | – | – |
| Palagonite | – | – | – | TR |
| Zeolites | TR | TR | – | – |
| Foraminifers | – | 15 | 1 | 1 |
| Calcareous nannofossils | 25 | 85 | 99 | 94 |
| Dinoflagellates | – | – | 1 | 1 |

SITE 527 HOLE CORE 32 CORED INTERVAL 275.0–284.5 m



LITHOLOGIC DESCRIPTION

10YR 4/2
5YR 6/4
10YR 4/2
5YR 6/4
10YR 4/2
5YR 6/4
10YR 4/2
5YR 5/6
5YR 6/4
10YR 4/2
5YR 6/4
10YR 6/2
5YR 6/4
10YR 4/2
with
5YR 6/4
10YR 4/2
5YR 7/2
10YR 4/2
5YR 7/2
5YR 4/4
N7
5YR 8/4
5YR 6/4
5YR 6/1
5YR 6/4
10YR 4/2
5Y 6/1
5YR 6/4
VOID
5Y 7/2
5YR 6/4
10YR 7/4
5YR 7/2
5YR 4/4,
10YR 4/2,
and 5Y 7/2

MARLY NANNOFOSSIL CHALK

This core contains a light brown (5YR 6/4) to pale yellowish brown (10YR 6/2), highly bioturbated marly nannofossil chalk. Trace fossils are abundant and are responsible for the multicolored appearance. Planolites and zoophycus are most noticeable.

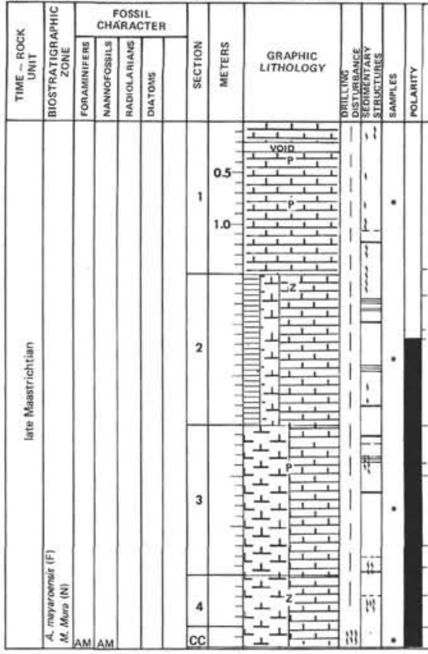
The cretaceous tertiary boundary is located in Section 4.

SMEAR SLIDE SUMMARY:

| | 1-70 | 2-80 | 4-50 | 4-53 | 4-80 |
|---|---|---|---|---|---|
| | D | D | D | D | D |
| Composition: | | | | | |
| Quartz | – | – | – | – | TR |
| Feldspar | TR | – | TR | – | – |
| Mica | – | – | TR | – | – |
| Heavy minerals | 2 | 2 | TR | – | 1 |
| Clay | 50 | 30 | 30 | – | 79 |
| Volcanic glass | 5 | 5 | – | TR | 3 |
| Palagonite | – | – | 2 | – | – |
| Zeolites | 5 | 10 | 2 | – | 2 |
| Carbonate unspecified | – | – | – | 1 | – |
| Foraminifers | 38 | 20 | 10 | – | 5 |
| Calcareous nannofossils | – | 33 | 56 | 99 | 10 |
| Dinoflagellates | TR | – | – | – | TR |

---

SITE 527 HOLE CORE 33 CORED INTERVAL 284.5–294.0 m



LITHOLOGIC DESCRIPTION

10YR 7/4
10YR 6/4
10YR 7/3
10YR 6/4
10YR 7/4
10YR 5/4
10YR 7/4
10YR 6/4
10YR 7/4
10YR 6/4

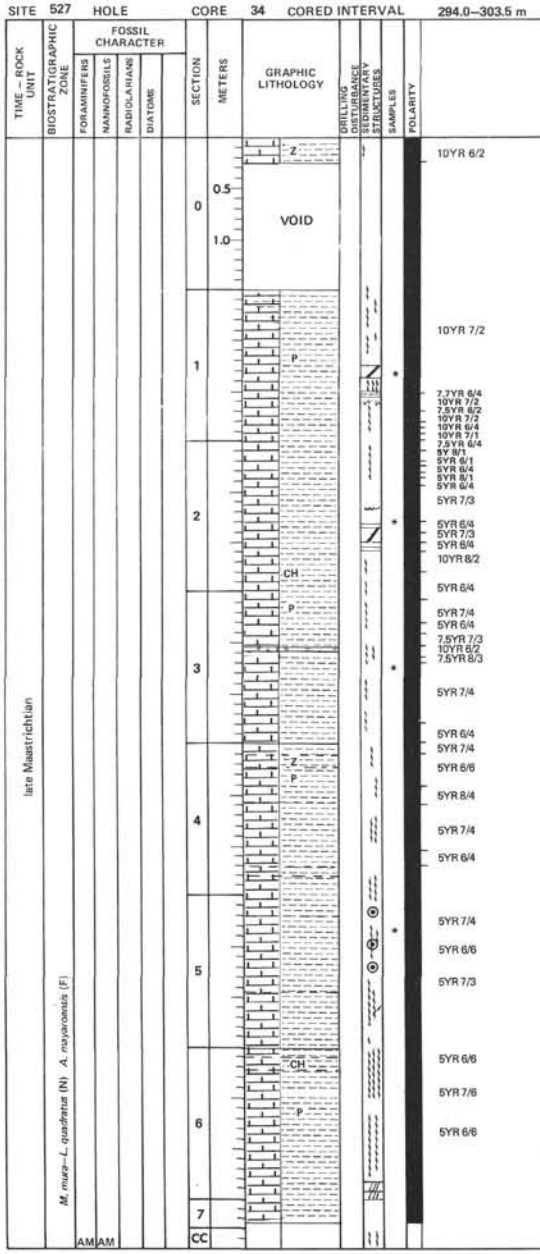
NANNOFOSSIL CHALK/OOZE

This core contains a light yellowish brown (10YR 6/4) to very pale brown (10YR 7/4) moderately bioturbated nannofossil chalk/ooze. Inclined and horizontal parallel laminations are present in Sections 2 and 3. The chalk and ooze layers alternate suggesting a cyclic sedimentation pattern.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-80 | 3-33 | CC |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Quartz | TR | 1 | 2 | 1 |
| Feldspar | – | – | TR | – |
| Heavy minerals | – | – | – | TR |
| Clay | – | 10 | 5 | 5 |
| Volcanic glass | – | – | – | 1 |
| Palagonite | 1 | TR | – | – |
| Pyrite | TR | TR | – | TR |
| Carbonate unspecified | TR | – | – | 1 |
| Foraminifers | 1 | 2 | 2 | 3 |
| Calcareous nannofossils | 98 | 87 | 91 | 89 |

SITE 527 HOLE CORE 34 CORED INTERVAL 294.0–303.5 m



LITHOLOGIC DESCRIPTION

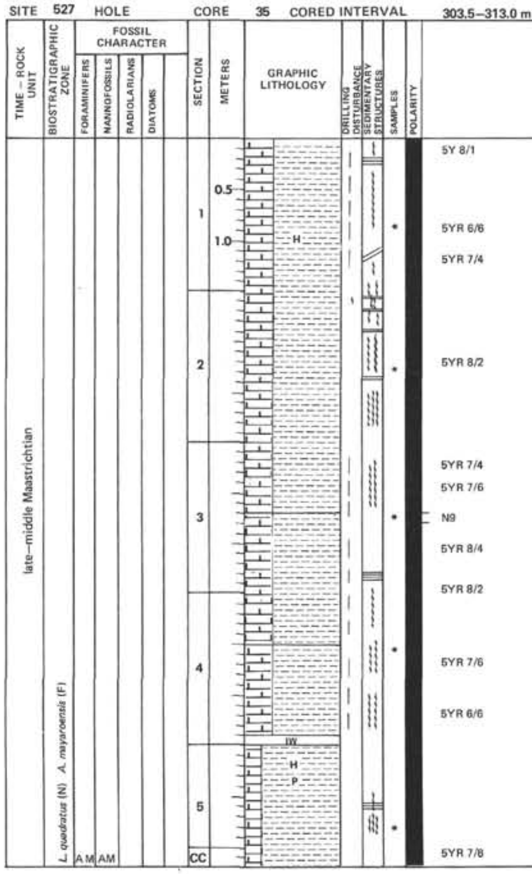
NANNOFOSSIL MUDSTONE

This core contains a multicolored, dominantly pink (5YR 7/4), light reddish brown (5YR 6/4) and reddish yellow (5YR 6/6), nannofossil limestone. Black micronodules which give an amorphous x-ray diffraction pattern are present. Cross and parallel laminations are observed. Wavy bedding is also present in Section 2.

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-80 | 3-80 | 5-33 |
|---|---|---|---|---|
| | D | D | D | D |
| Composition: | | | | |
| Feldspar | TR | – | – | – |
| Heavy minerals | 1 | TR | TR | – |
| Clay | 70 | 80 | 50 | 80 |
| Volcanic glass | TR | TR | TR | – |
| Palagonite | TR | TR | – | TR |
| Foraminifers | – | – | TR | – |
| Calcareous nannofossils | 29 | 20 | 50 | 20 |

SITE 527 HOLE CORE 35 CORED INTERVAL 303.5–313.0 m



LITHOLOGIC DESCRIPTION

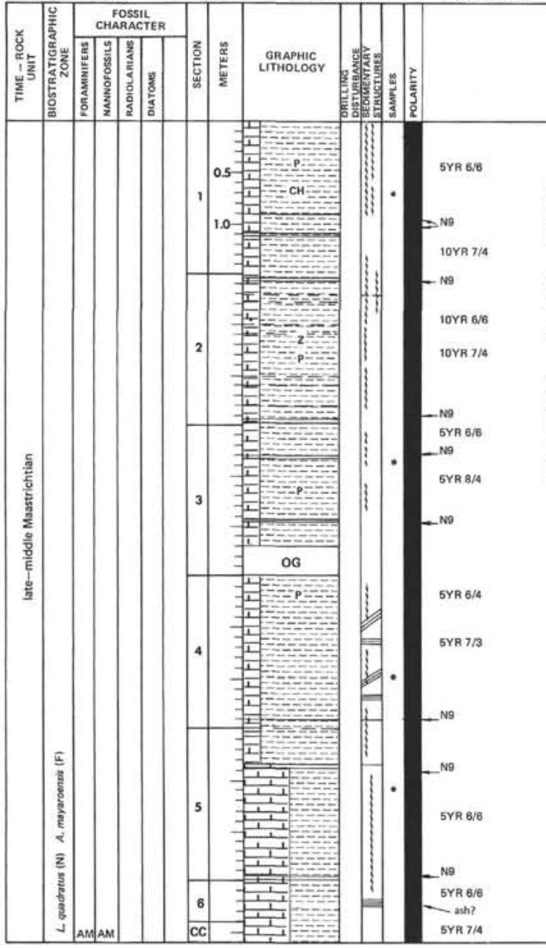
NANNOFOSSIL MUDSTONE

The core contains a multicolored, moderately bioturbated nannofossil mudstone. Bioturbation is slight to moderate. The dominant colors are a yellowish red (5YR 6/6) and pink (5YR 7/4). Inclined and horizontal parallel lamination are present. A possible ash alyer exists at 52 cm, Section 4. It has a very sharp contact and contains a high amount of volcanic glass (30%).

SMEAR SLIDE SUMMARY:

| | 1-80 | 2-80 | 3-73 | 4-52 | 5-80 |
|---|---|---|---|---|---|
| | D | D | D | M | D |
| Composition: | | | | | |
| Quartz | 1 | 1 | – | – | – |
| Heavy minerals | – | TR | – | – | – |
| Clay | 60 | 74 | 20 | 68 | 83 |
| Volcanic glass | – | – | TR | 30 | – |
| Palagonite | TR | TR | – | – | – |
| Pyrite | TR | – | – | – | – |
| Foraminifers | TR | – | TR | – | – |
| Calcareous nannofossil | 39 | 25 | 80 | 2 | 15 |

SITE 527 HOLE CORE 36 CORED INTERVAL 313.0–322.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL MUDSTONE

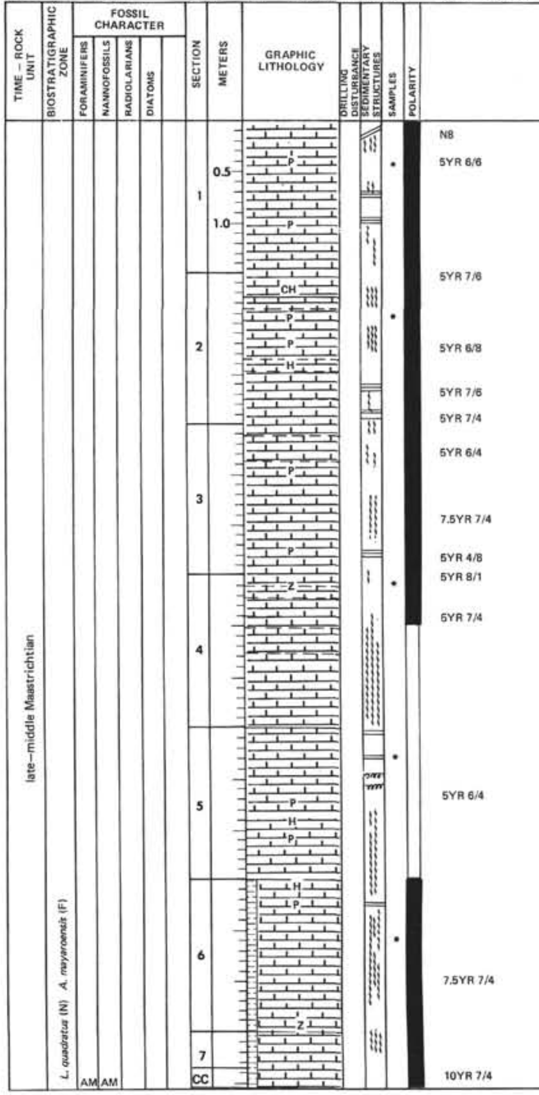
The core contains a reddish yellow (5YR 6/6) to pink (5YR 7/4) nannofossil mudstone. Bioturbation is moderate, with zoophycos, halo, and planolites. Trace fossils present. Color changes are abundant suggesting changing environments. Horizontal and inclined lamination also indicate current activity.

Very thin white (N9) layers are present throughout the cores. They are mostly nannofossil chalks but one in Section 6 contains high amounts of altered glass and may be an ash layer.

SMEAR SLIDE SUMMARY:

| | 1-70 | 3-32 | 4-100 | 5-53 |
|---|---|---|---|---|
| | D | M | D | D |
| Composition: | | | | |
| Heavy minerals | 2 | TR | – | – |
| Clay | 68 | 48 | 75 | 49 |
| Volcanic glass | 4 | 25 | 5 | TR |
| Palagonite | – | 25 | – | – |
| Zeolites | – | – | – | TR |
| Foraminifers | – | TR | – | 1 |
| Calcareous nannofossils | 26 | 21 | 20 | 50 |

SITE 527 HOLE CORE 37 CORED INTERVAL 322.5–332.0 m



LITHOLOGIC DESCRIPTION

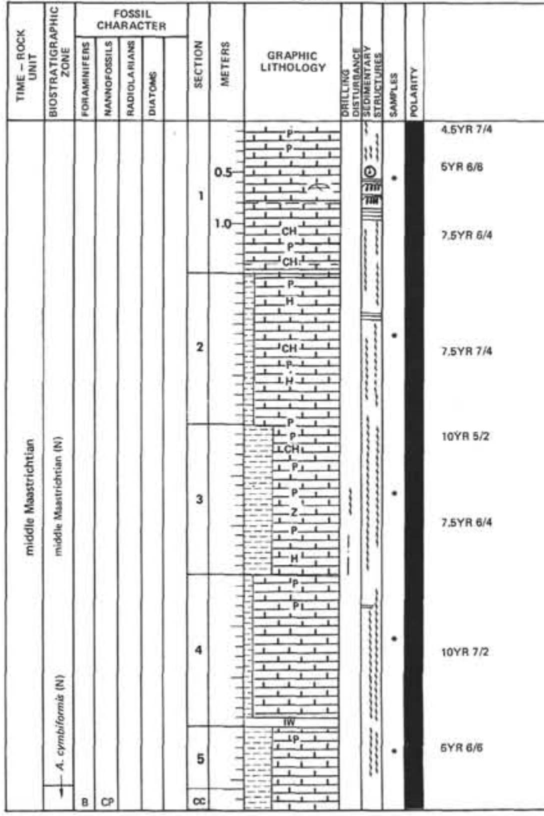
NANNOFOSSIL TO MUDDY
NANNOFOSSIL CHALK

This core consists of a predominantly reddish yellow (5YR 6/6), pink (5YR 7/4), to light reddish brown (5YR 6/4) nannofossil chalk. Within the more reddish layers are high amounts of silt and clay grains of most volcanic origin. Biogenic sedimentary structure are ubiquitous. The upper part of Section 4 contain white lamination beds and mottles. Well preserved cross laminations, horizontal lamination, and convolute bedding is present (e.g. Section 5). Small scale current activity followed by intense biologic activity is evident.

SMEAR SLIDE SUMMARY:

| | 1-41 | 2-40 | 4-15 | 5-34 | 6-60 |
|---|---|---|---|---|---|
| | D | D | M | D | D |
| Composition: | | | | | |
| Quartz | – | 1 | – | – | – |
| Heavy minerals | – | 2 | 1 | 3 | – |
| Clay | TR | 10 | 5 | – | – |
| Volcanic glass | 2 | 10 | 5 | 5 | 5 |
| Palagonite | 1 | 5 | – | – | – |
| Carbonate unspecified | – | 1 | – | 2 | – |
| Foraminifers | 1 | 5 | 8 | – | 3 |
| Calcareous nannofossils | 96 | 64 | 80 | 90 | 92 |
| Calcareous dinoflagellates | – | 2 | 1 | TR | – |

SITE 527 HOLE CORE 38 CORED INTERVAL 332.0–341.5 m



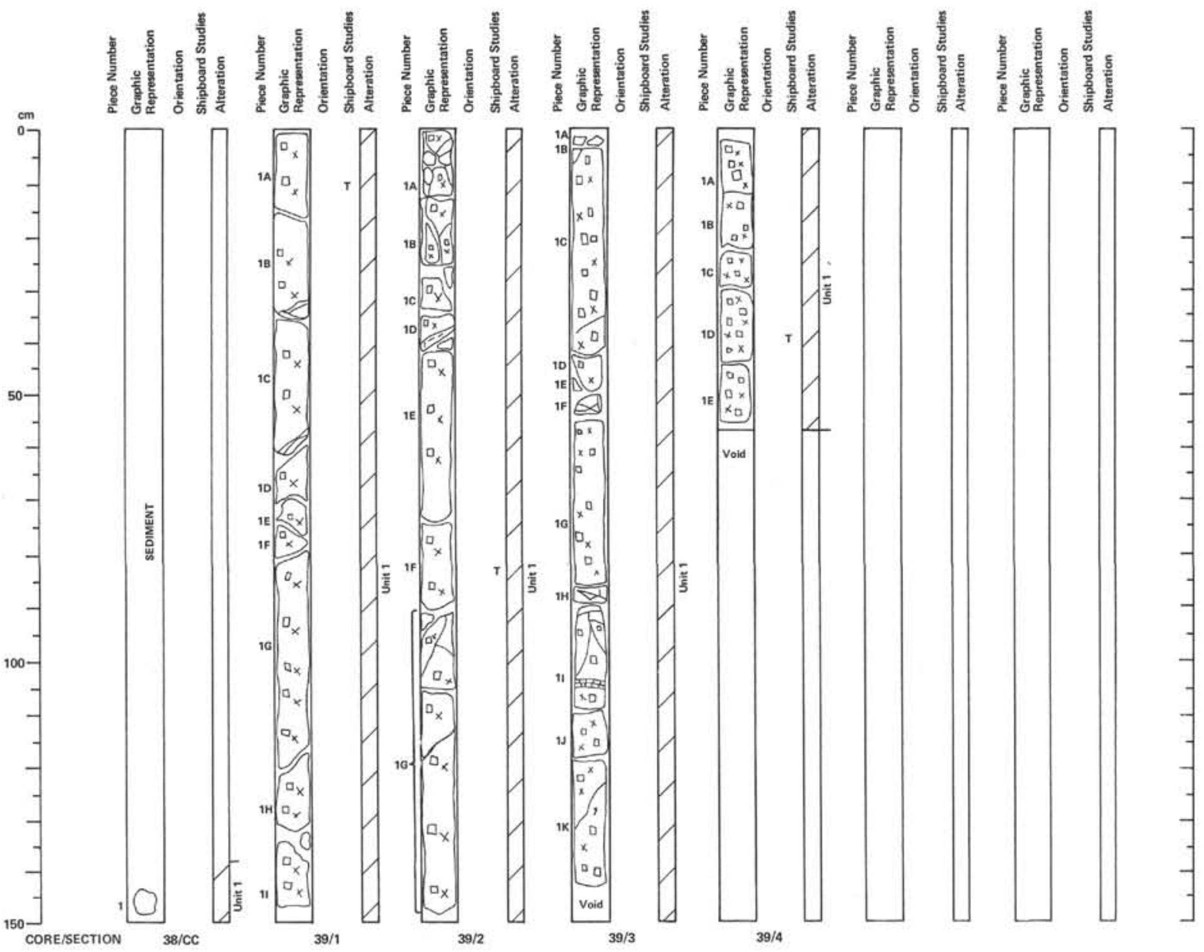
LITHOLOGIC DESCRIPTION

MUDDY NANNOFOSSIL CHALK

The core consists of a moderate to highly bioturbated muddy nannofossil chalk. Volcanically derived grains are silt to sand in size and comprise from 10–35% of the chalks. The dominant colors are a pink (7.5YR 7/4), light brown (7.5YR 6/4), and grayish brown (10YR 5/2). Horizontal laminations and convolute laminations are present indicating either minor current activity or deformation due to loading. Shell fragments are present at 88 cm in Section 1.

SMEAR SLIDE SUMMARY:

| | 1-68 | 2-69 | 3-69 | 4-69 | 5-22 |
|---|---|---|---|---|---|
| | D | D | D | D | M |
| Composition: | | | | | |
| Heavy minerals | 5 | – | 5 | – | – |
| Clay | 5 | 10 | 10 | 5 | – |
| Volcanic glass | 5 | 15 | 15 | 10 | 3 |
| Palagonite | – | 5 | 5 | – | – |
| Foraminifers | 5 | – | 3 | 10 | 5 |
| Calcareous nannofossils | 80 | 70 | 62 | 75 | 92 |



**74-527-38 through 39** **Depth: 341.4–346.5 mbsf**

Core 38, Section Core-Catcher and Core 39, Sections 1–4 (Unit 1)

Dominant Lithology: Moderately to sparsely plagioclase, olivine, clinopyroxene phyric basalt.

Macroscopic Description: Medium gray, fine- to medium-grained, sparsely to moderately plagioclase, olivine, clinopyroxene phyric basalt. The uppermost basalt fragment has an aphanitic margin suggestive of original glassy texture. Alteration is slight.

Thin Section Descriptions:

39-1, 10–13 cm (Piece 1A):

Name: Plagioclase, olivine, clinopyroxene, phyric basalt.

Texture: Subophitic/intergranular.

Phenocrysts: 15% total rock. Olivine, 15%, 2.0x1.0 mm, euhedral–subhedral, highly altered; plagioclase, 80%, 4.0x3.0 mm, subhedral, zoned, twinned with altered clinopyroxene inclusions; clinopyroxene, 5%, 1.1x0.3 mm subhedral.

Groundmass: 75%, olivine, 15%, 0.12x0.16 mm, subhedral; plagioclase, 50%, 0.64x0.08 mm, laths; clinopyroxene, 30%, 0.4x0.3 mm, anhedral; and magnetite, 5%, 0.03x0.04 mm, subhedral, irregular.

Vesicles: None.

Alteration: Interiors of olivines, grain boundaries, and groundmass clinopyroxene are highly altered to clay minerals (~16% of thin section).

39-2, 69–73 cm (Piece 1E):

Name: Sparsely plagioclase–clinopyroxene phyric basalt.

Texture: Intergranular.

Phenocrysts: Plagioclase, 2%, 1.5x5.0 mm, stubby laths, zoned, twinned; clinopyroxene, <1%, 0.5x0.3 mm, augite, subhedral.

Groundmass: Plagioclase, 50%, 0.5x0.15 mm, euhedral laths, twinned; clinopyroxene, 45%, 0.15x0.15 mm, subhedral; and magnetite, 3%, 0.1x0.05 mm, skeletal.

Vesicles: None.

Alteration: Approximately 5% groundmass altered to brown ferromagnesian minerals.

39-4, 35–39 cm (Piece 1D):

Name: Sparsely plagioclase–olivine phyric basalt.

Texture: Intergranular.

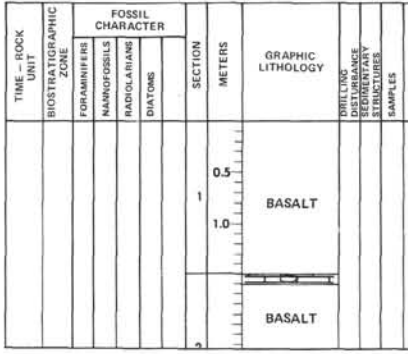
Phenocrysts: Olivine, <1%, 0.5x0.5 mm, euhedral, totally altered to clay; plagioclase, 2%, 5.0x3.0 mm, glomerocrysts, twinned, zoned, and surrounded by quench sheaf textured zone.

Groundmass: Plagioclase, 50%, 0.6x0.2 mm, euhedral laths, twinned; clinopyroxene, 45%, 0.2x0.1 mm, subhedral; and magnetite, 30%, 0.1x0.05 mm, skeletal.

Vesicles: None.

Alteration: Clays, 5%, replacing groundmass ferromagnesian minerals.

SITE 527 HOLE CORE 40 CORED INTERVAL 346.5–350.5 m



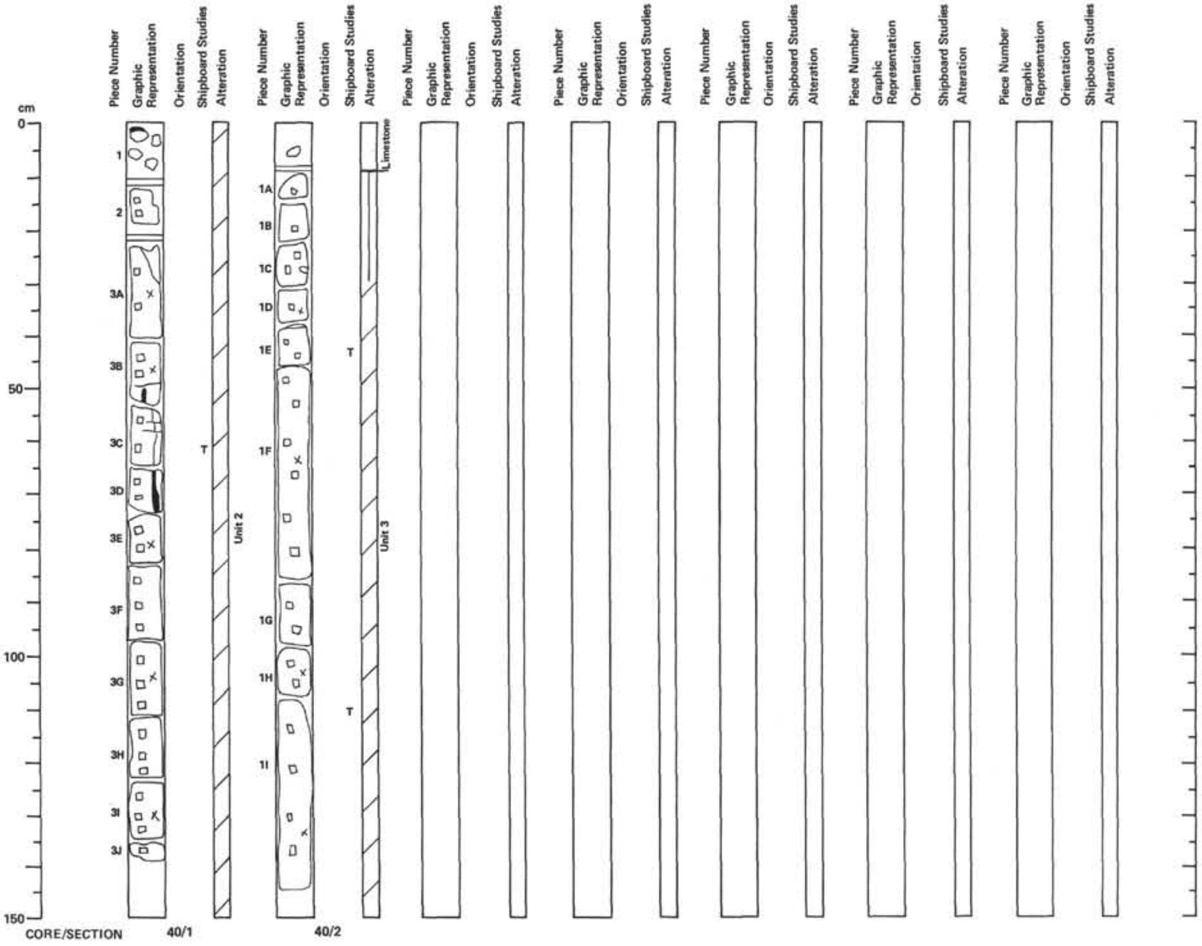
LITHOLOGIC DESCRIPTION

NANNOFOSSIL LIMESTONE

A nannofossil limestone fragment sandwiched between basalt was cored. The color is pinkish white to white (N9).

SMEAR SLIDE SUMMARY:

| | 2-5<br>D |
|---|---|
| Composition: | |
| Volcanic glass | 4 |
| Carbonate unspecified | 90 |
| Calcareous nannofossils | 6 |



**74-527-40** **Depth: 346.5–348.0 mbsf**

Core 40, Section 1 (Unit 2)

Dominant Lithology: Sparsely plagioclase-olivine-clinopyroxene phyric basalt.

Macroscopic Description: Medium gray, fine- to medium-grained, sparsely to moderately plagioclase, olivine and clinopyroxene phyric basalt. Some fine-grained chilled margins. Slight alteration.

Thin Section Description:
- 40-1, 53–55 cm (Piece 3C):
  - Name: Sparsely plagioclase-clinopyroxene phyric basalt.
  - Texture: Intergranular.
  - Phenocrysts: Plagioclase, 2%, 2.0x1.0 mm, stubby laths, twinned, zoned; clinopyroxene, 4%, 1.5x1.0 mm, augite, subhedral, with small inclined plagioclase laths.
  - Groundmass: Plagioclase, 50%, 0.5x0.1 mm, euhedral laths, twinned; clinopyroxene, 45%, 0.2x0.1 mm, subhedral; and magnetite, 3%, 0.05x0.05 mm, skeletal.
  - Vesicles: None.
  - Alteration: ~5% groundmass ferromagnesian minerals are altered to brown clays.

**74-527-40 through 41** **Depth 348.1–356.5 mbsf**

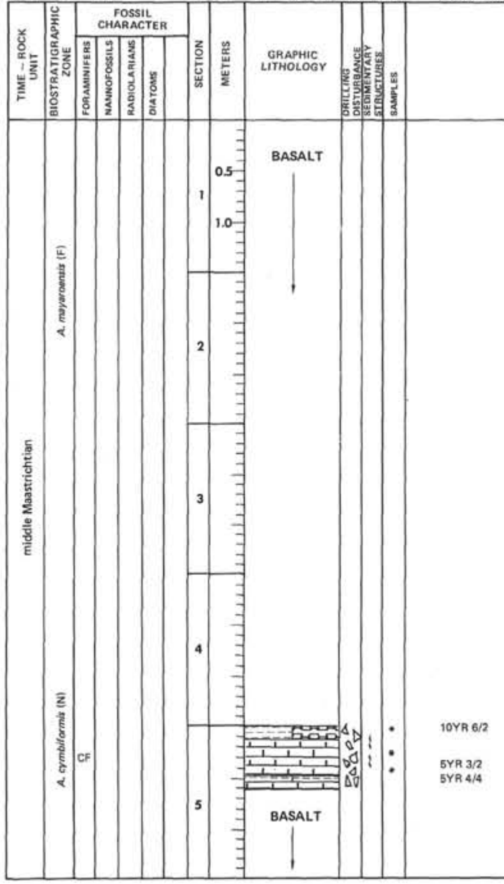
Core 40, Section 2 and Core 41, Sections 1–4 (Unit 3)

Dominant Lithology: Highly plagioclase phyric basalt.

Macroscopic Description: Medium gray, medium-grained, highly plagioclase phyric basalt. Plagioclase phenocrysts are up to 2 cm in diameter and comprise 20–30% of the rock. Very sparse clinopyroxene and olivine phenocrysts are also present. Slight alteration.

Thin Section Descriptions:
- 40-2, 36–39 cm (Piece 1E):
  - Name: Highly plagioclase-clinopyroxene-olivine phyric basalt.
  - Texture: Phyric with subophitic groundmass.
  - Phenocrysts: Olivine, 1%, 0.6x0.3 mm, euhedral, totally altered to clays; plagioclase, 20%, 10.0x5.0 mm labradorite with stubby laths; zoned, twinned; and clinopyroxene, 2%, 1.0x1.5 mm, augite, subhedral associated with plagioclase phenocrysts.
  - Groundmass: Plagioclase, 37%, 0.6x0.1 mm laths, twinned; clinopyroxene, 37%, 0.3x0.2 mm, subhedral; and magnetite, 3%, 0.06x0.06 mm, subhedral.
  - Vesicles: None.
  - Alteration: Clays replace ~1% olivine.
- 40-2, 105–110 cm (Piece 1I):
  - Name: Highly plagioclase-olivine phyric basalt.
  - Textures: Phyric with subophitic groundmass.
  - Phenocrysts: Plagioclase, 25%, 12.0x5.0 mm, labradorite, stubby laths, twinned, zoned; and clinopyroxene, 1%, 0.6x0.6 mm, augite, subhedral.
  - Groundmass: Plagioclase, 35%, 0.6x0.1 mm, twinned, laths; clinopyroxene, 35%, 0.3x0.2 mm, subhedral; and magnetite, 4%, 0.06x0.06 mm, subhedral.
  - Vesicles: None.
  - Alteration: Brown clay minerals have replaced the groundmass, clinopyroxene forming about 2% total thin section alteration.
- 41-3, 28–32 cm (Piece 1B):
  - Name: Highly plagioclase-clinopyroxene phyric basalt.
  - Texture: Phyric with subophitic groundmass.
  - Phenocrysts: Plagioclase, 25%, 12.0x5.0 mm, labradorite, stubby laths, zoned, twinned; and clinopyroxene, 1%, 0.8x1.0 mm, augite, subhedral, partially altered to brown clay.
  - Groundmass: Plagioclase, 35%, 0.6x0.1 mm, twinned, laths; clinopyroxene, 35%, 0.3x0.2 mm, subhedral; and magnetite, 4%, 0.06x0.06 mm, subhedral.
  - Vesicles: None.
  - Alteration: Groundmass is about 5% altered with clinopyroxene being replaced by brown clays.

SITE 527 HOLE CORE 41 CORED INTERVAL 350.5–359.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK AND
MARLY CALCAREOUS CHALK

The sediment interlayered with basalt was predominantly a nannofossil chalk. Marly calcareous chalks are also present. The carbonate is recrystallized. Highly amounts of volcanogenic sediments were recognized in the marly sediments. The dominant colors are pinkish gray (10YR 6/2) and reddish brown (5YR 4/4).

SMEAR SLIDE SUMMARY:

|  | 5-1<br>D | 5-30<br>D | 5-48<br>D |
|---|---|---|---|
| Composition: |  |  |  |
| Quartz | 5 | 2 |  |
| Clay | 35 | 10 | 83 |
| Volcanic glass | 30 | 1 | 5 |
| Palagonite | TR | – | – |
| Pyrite | – | TR | – |
| Zeolites | – | – | 10 |
| Carbonate unspecified | 30 | TR | 1 |
| Calcareous nannofossils | – | 87 | 1 |

74-527-41

Depth:357.1–357.6 mbsf

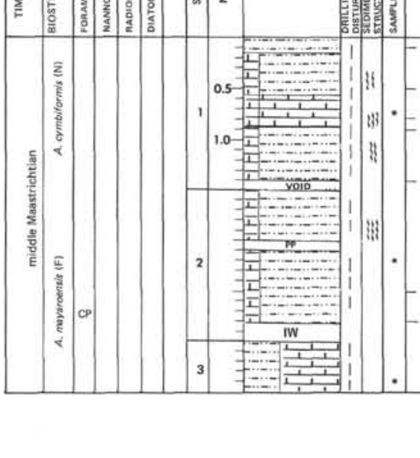
Core 41, Section 5 (Unit 4)

Dominant Lithology: Sparsely plagioclase phyric basalt.

Macroscopic Description: Medium gray, fine-grained, sparsely plagioclase phyric basalt. Unit consists of a single flow with upper chilled margin.

Thin Section Description:
- 41-5, 103–105 cm (Piece 4A):
  - Name: Sparsely plagioclase phyric basalt.
  - Texture: Subophitic.
  - Phenocrysts: Plagioclase, 1%, 4.0x1.0 mm, euhedral laths, twinned, zoned.
  - Groundmass: Plagioclase, 50%, 0.5x0.1 mm, twinned euhedral laths; clinopyroxene, 48%, 0.2x0.2 mm, augite, subhedral; magnetite, <1%, 0.02x0.02 mm.
  - Vesicles: None.
  - Alteration: The groundmass is about 3% altered with green and brown clays replacing clinopyroxene.

SITE 527 HOLE CORE 42 CORED INTERVAL 359.5–368.5 m



LITHOLOGIC DESCRIPTION

5YR 6/2

N9

5YR 5/4

5YR 6/2

5YR 5/2

5YR 5/4

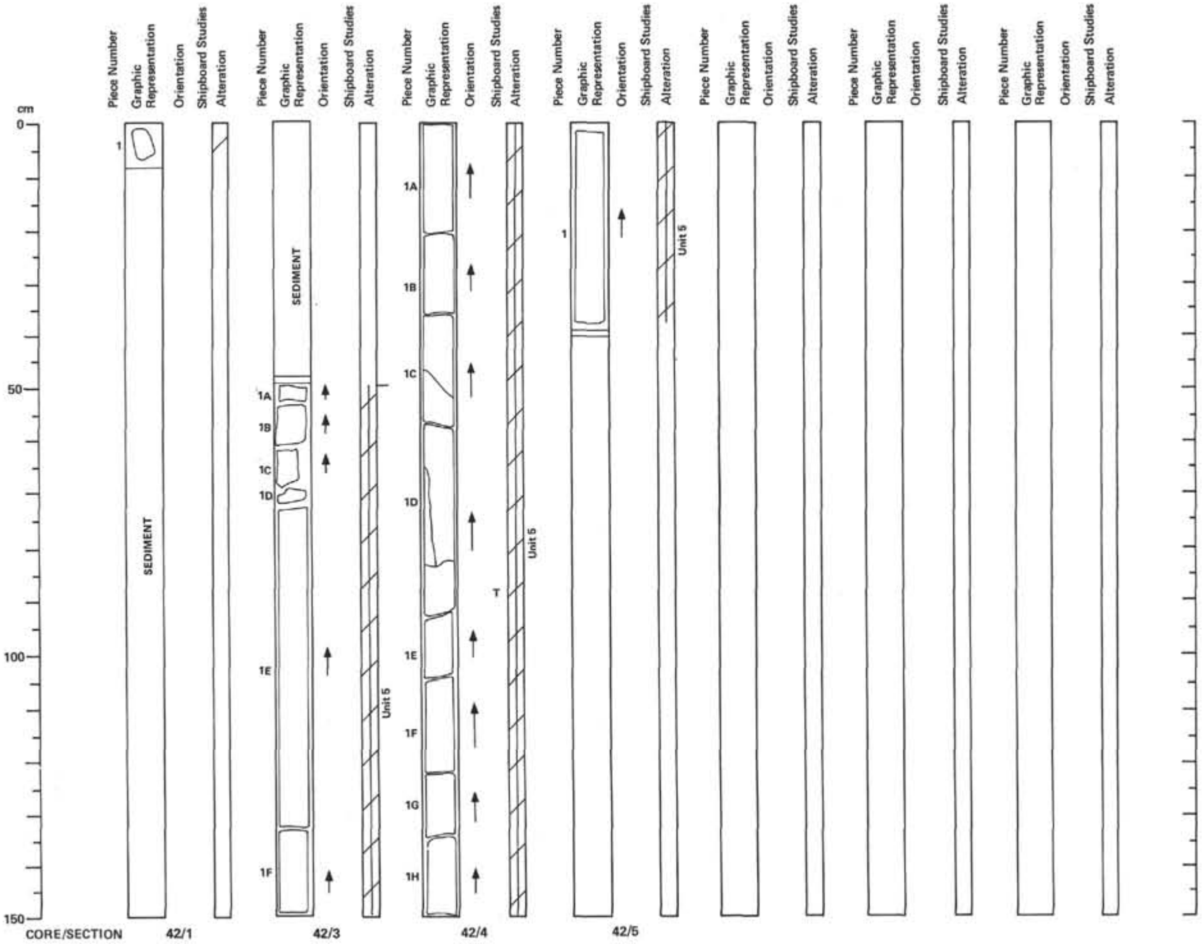
5YR 5/2

CARBONATE MUDSTONE

This sediment, located between basalt layers, is a pinkish gray to reddish brown highly bioturbated carbonate mudstone. Large vertical and horizontal burrows are present. The clay and silt mineral fraction consists mainly of volcanogenic sediment.

SMEAR SLIDE SUMMARY:

| | 1-70<br>M | 2-70<br>D | 3-40<br>D |
|---|---|---|---|
| Composition: | | | |
| Quartz | – | 1 | – |
| Feldspar | – | – | 1 |
| Heavy minerals | – | 1 | – |
| Clay | 27 | 70 | 45 |
| Volcanic glass | 1 | – | – |
| Palagonite | 1 | TR | – |
| Pyrite | – | 1 | – |
| Carbonate unspecified | – | 1 | TR |
| Foraminifers | 1 | TR | TR |
| Calcareous nannofossils | 70 | 25 | 54 |



**74-527-42 through 44** **Depth 363.0–384.5 mbsf**

*Core 42, Sections 3–5; Core 43, Sections 1–5; and Core 44, Sections 1–5 (Unit 5)*

Dominant Lithology: Aphyric basalt.

Macroscopic Description: Massive, fine- to coarse-grained, aphyric basalt. Patchy development of very coarse-grained "pegmatitic" scattered dark green smectite. Veins are lined with pyrite, and pyrite emplaced in the basalt matrix. Moderate alteration.

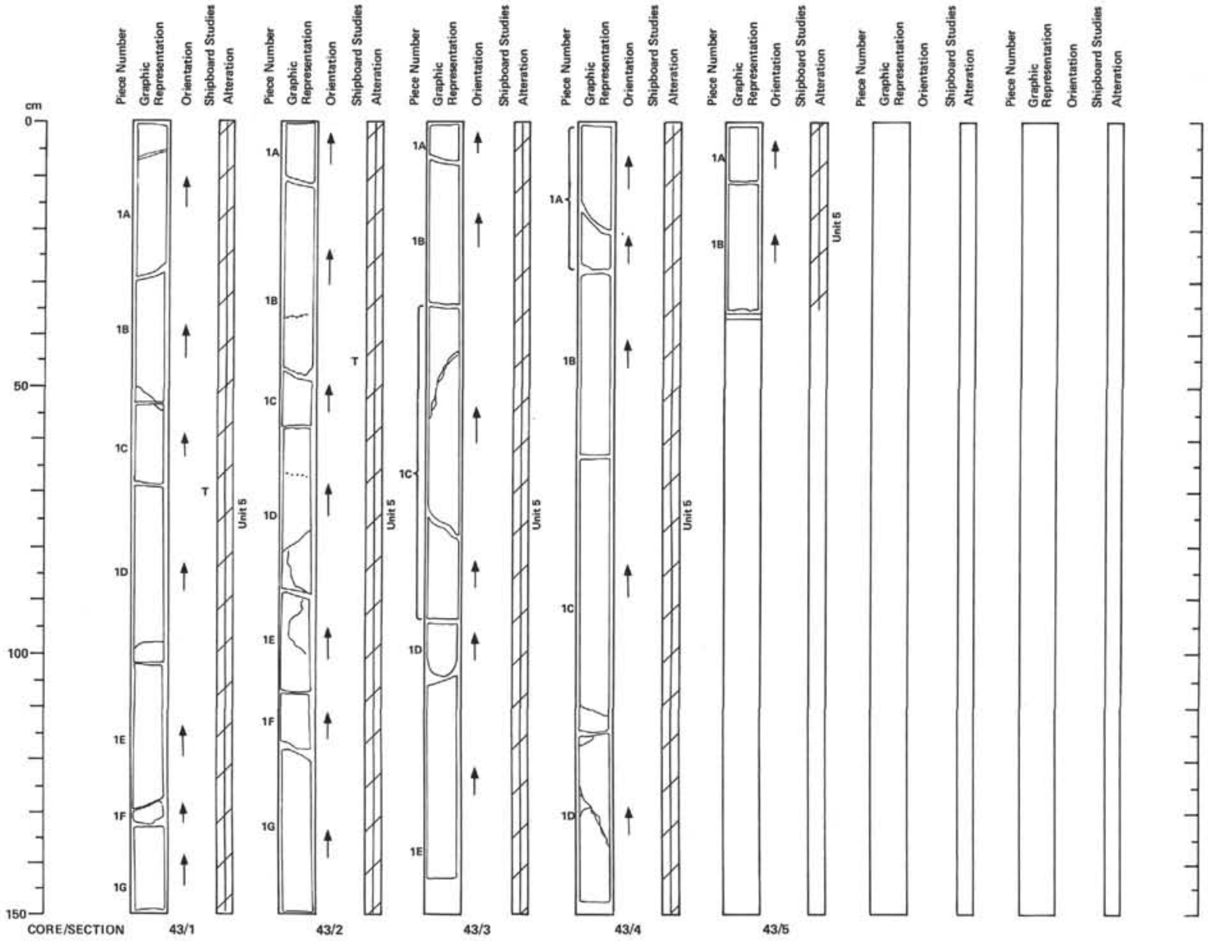
Thin Section Descriptions:

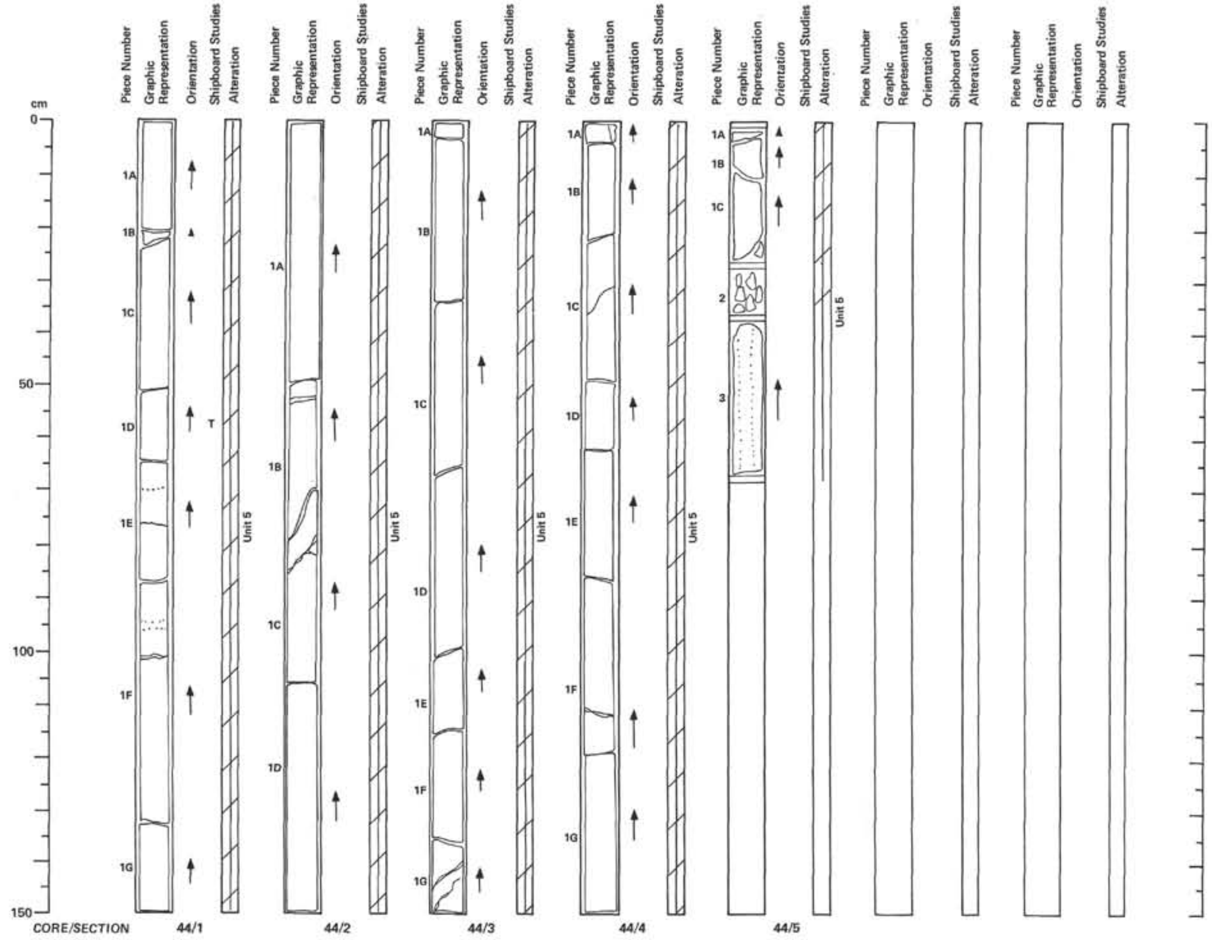
42-4, 89–92 cm (Piece 1D):
Name: Aphyric basalt.
Texture: Subophitic.
Phenocrysts: Plagioclase, <1%, 3.0x2.0 mm, stubby laths, partially altered.
Groundmass: Plagioclase, 55%, 0.5x0.2 mm, stubby laths; clinopyroxene, 40%, 0.1x0.1 mm, anhedral; and magnetite, 5%, 0.15x0.1 mm, subhedral, skeletal.
Vesicles: None.
Alteration: ~15% groundmass is altered, pale brown clays replace clinopyroxene.

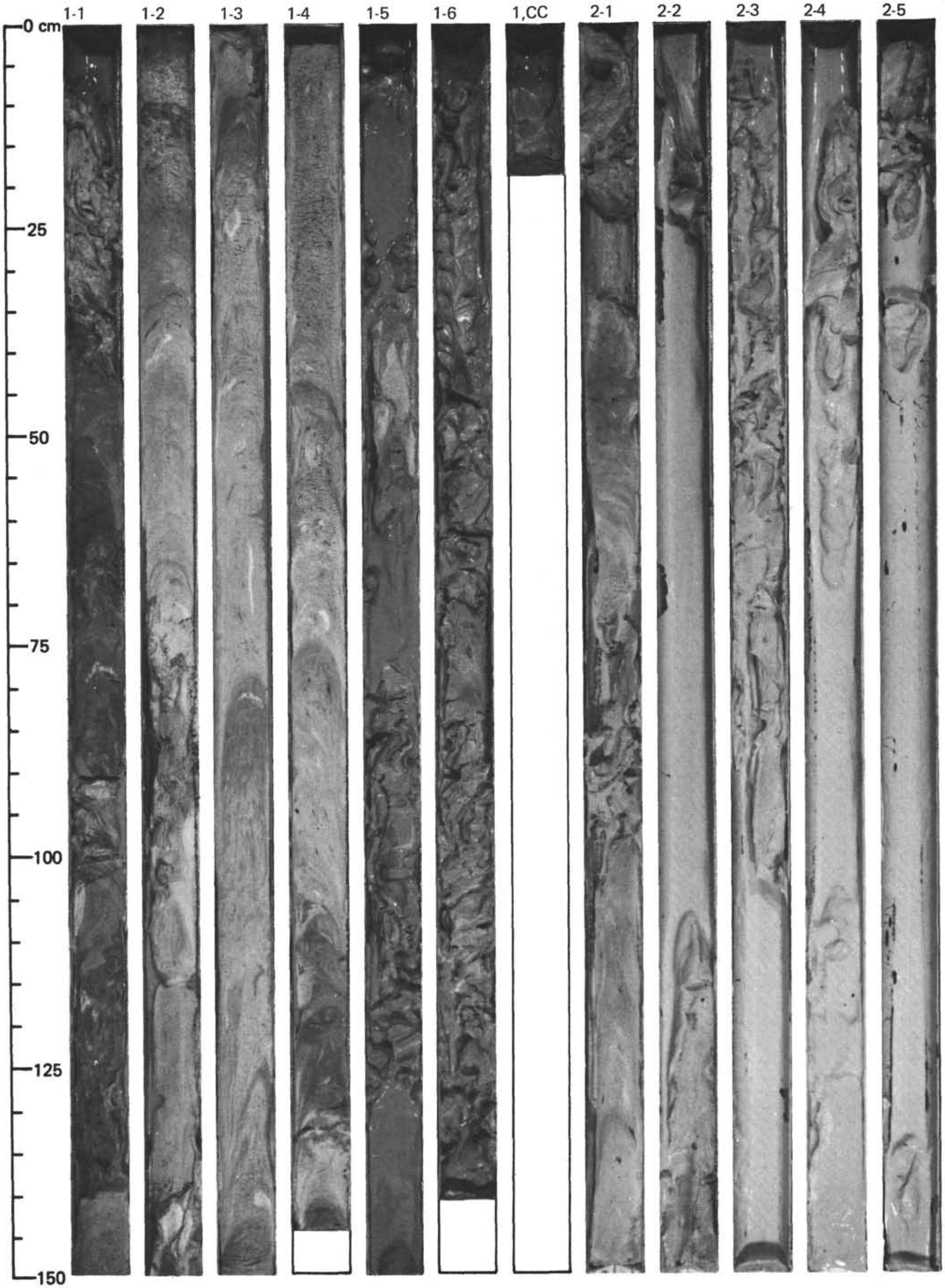
43-1, 68–72 cm (Piece 1D):
Name: Aphyric basalt.
Texture: Pegmatitic.
Phenocrysts: None.
Groundmass: Plagioclase, 55%, 3.0x1.0 mm, laths; clinopyroxene, 40%, 10.0x1.0 mm, elongate, extensively altered; magnetite, 3%, 0.2x0.2 mm, skeletal; pyrite, >2%, 0.3x0.3 mm, euhedral in triangular and hexagonal cross-sections; and apatite, <0.5%, 1.5x0.02 mm, needles.
Vesicles: None.
Alteration: Groundmass 10% altered, clinopyroxene replaced by clay minerals.

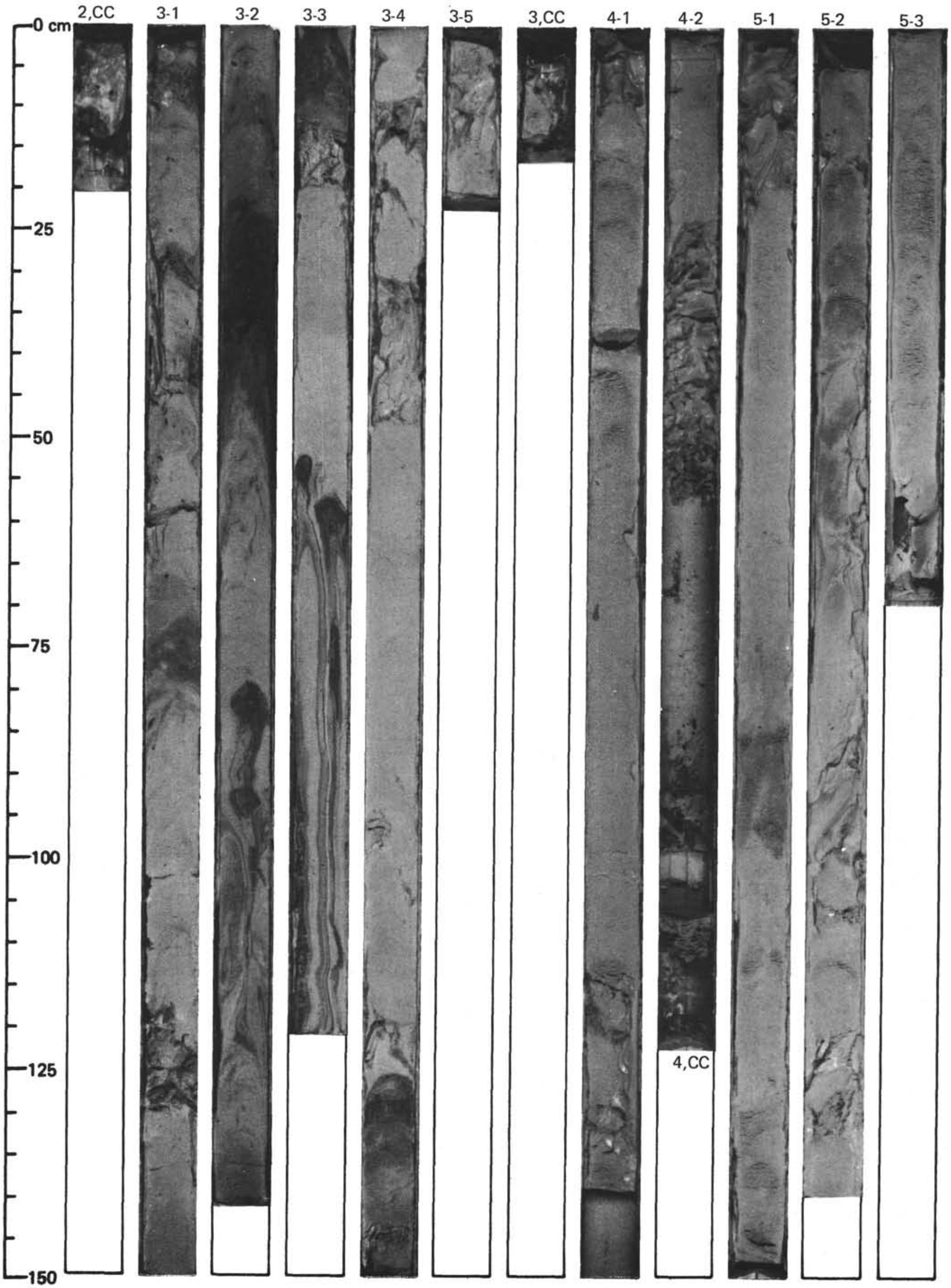
43-2, 45–47 cm (Piece 1B):
Name: Aphyric basalt.
Texture: Subophitic/intergranular.
Phenocrysts: None.
Groundmass: Plagioclase, 50%, 0.6x0.3 mm, stubby laths; clinopyroxene, 40%, 0.1x0.1 mm, anhedral; magnetite, 5%, 0.15x0.1 mm, subhedral/skeletal; apatite, 0.5%, 0.6x0.01 mm, tiny prisms associated with mesostosis; and mesostosis, 5%, 0.3x0.2 mm, interstitial, altered to rich-brown material.
Vesicles: None.
Alteration: Groundmass 10% altered clay minerals replace clinopyroxene.

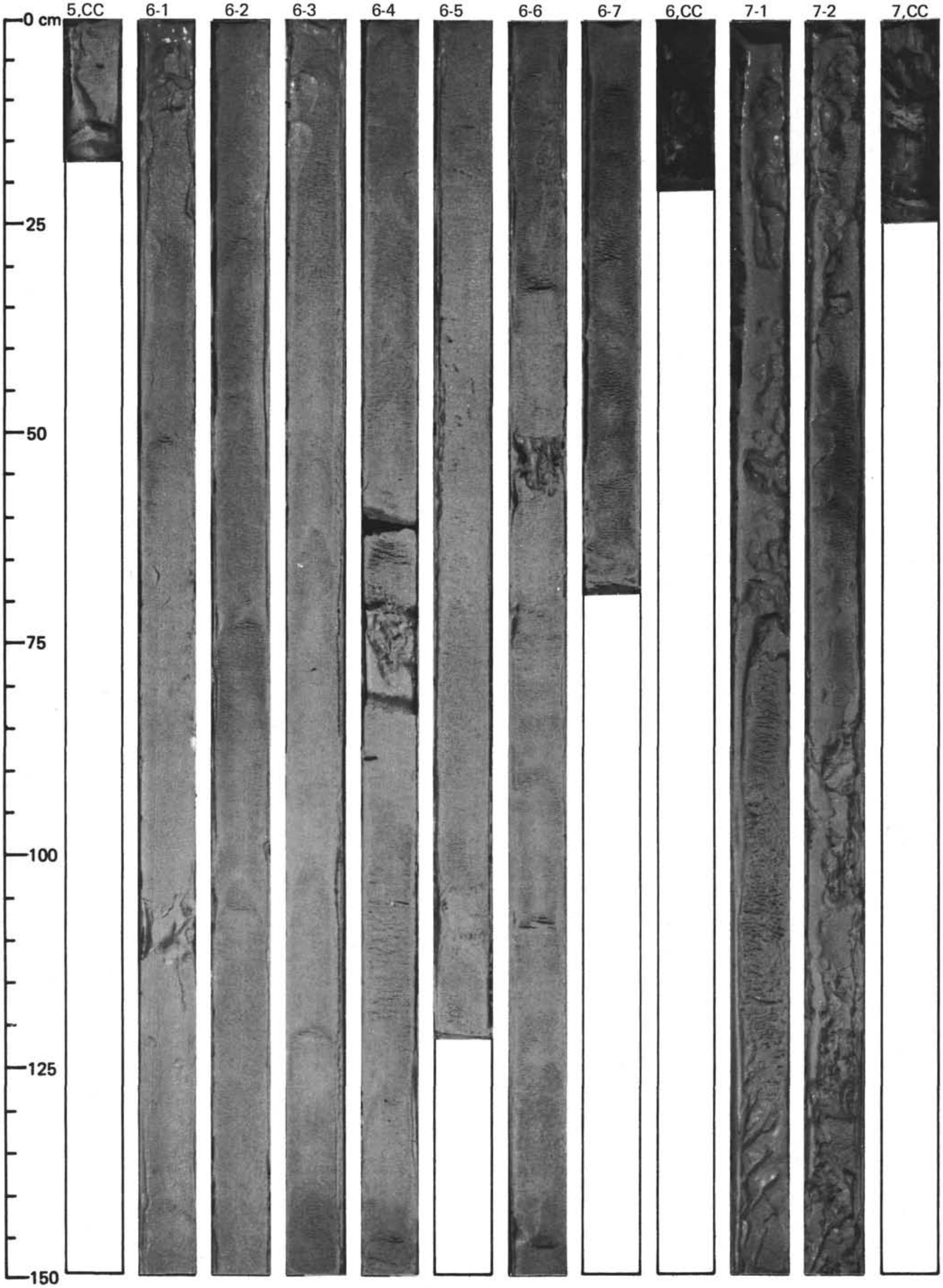
44-1, 49–52 cm (Piece 1D):
Name: Coarse-grained aphyric basalt.
Texture: Subophitic/intergranular.
Phenocrysts: None.
Groundmass: Plagioclase-clinopyroxene, 10%, very fine-grained groundmass intersticies.
Vesicles: None.
Alteration: Groundmass is 5% altered, clay minerals replace clinopyroxene in intersticies between feldspars.


cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
1A
1B
1C
1D
1E
1F
1G
T
Unit 5
CORE/SECTION
43/1
43/2
43/3
43/4
43/5

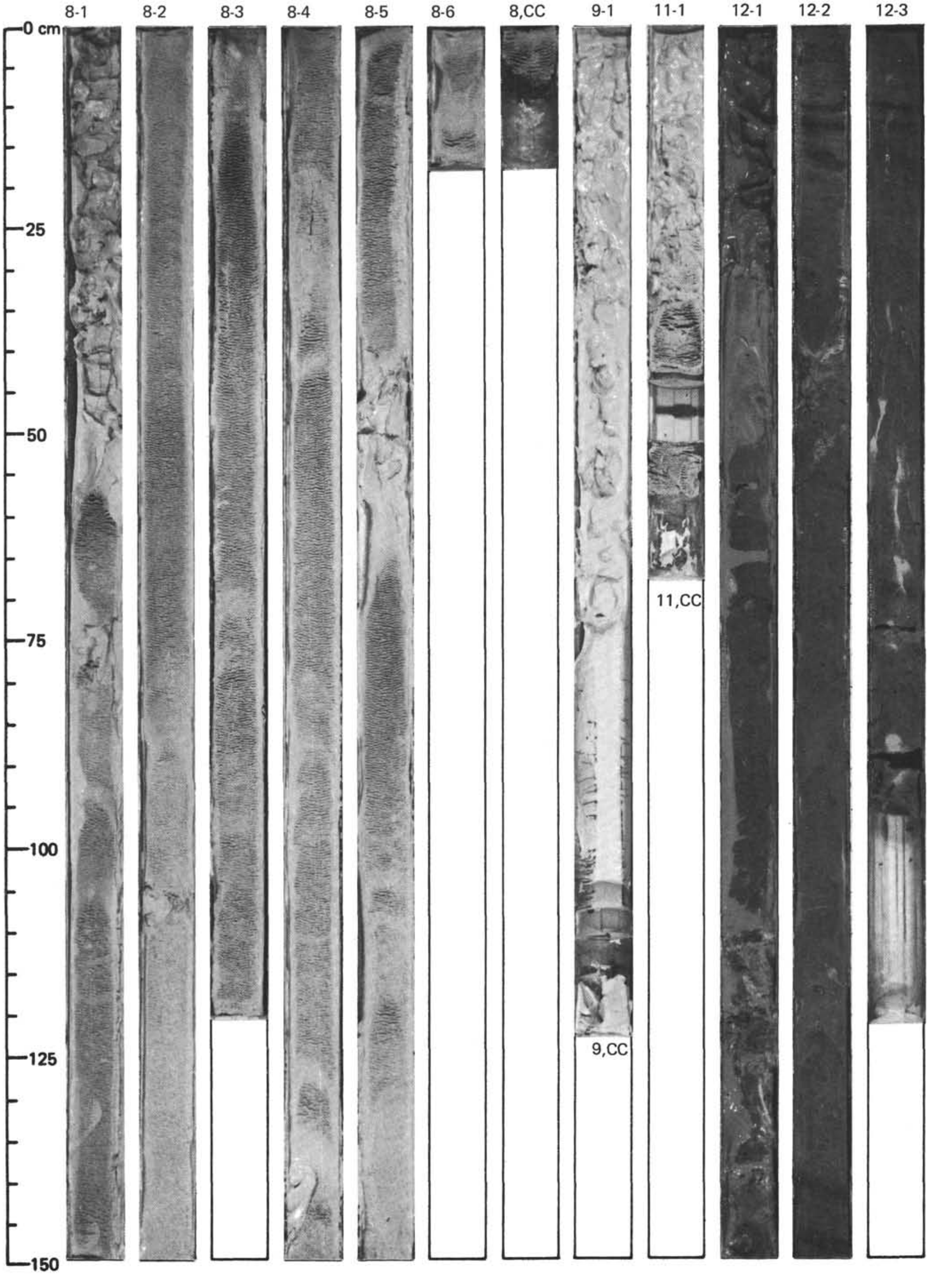

Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
cm
0
50
100
150
1A
1B
1C
1D
1E
1F
1G
T
Unit 5
2
3
CORE/SECTION
44/1
44/2
44/3
44/4
44/5

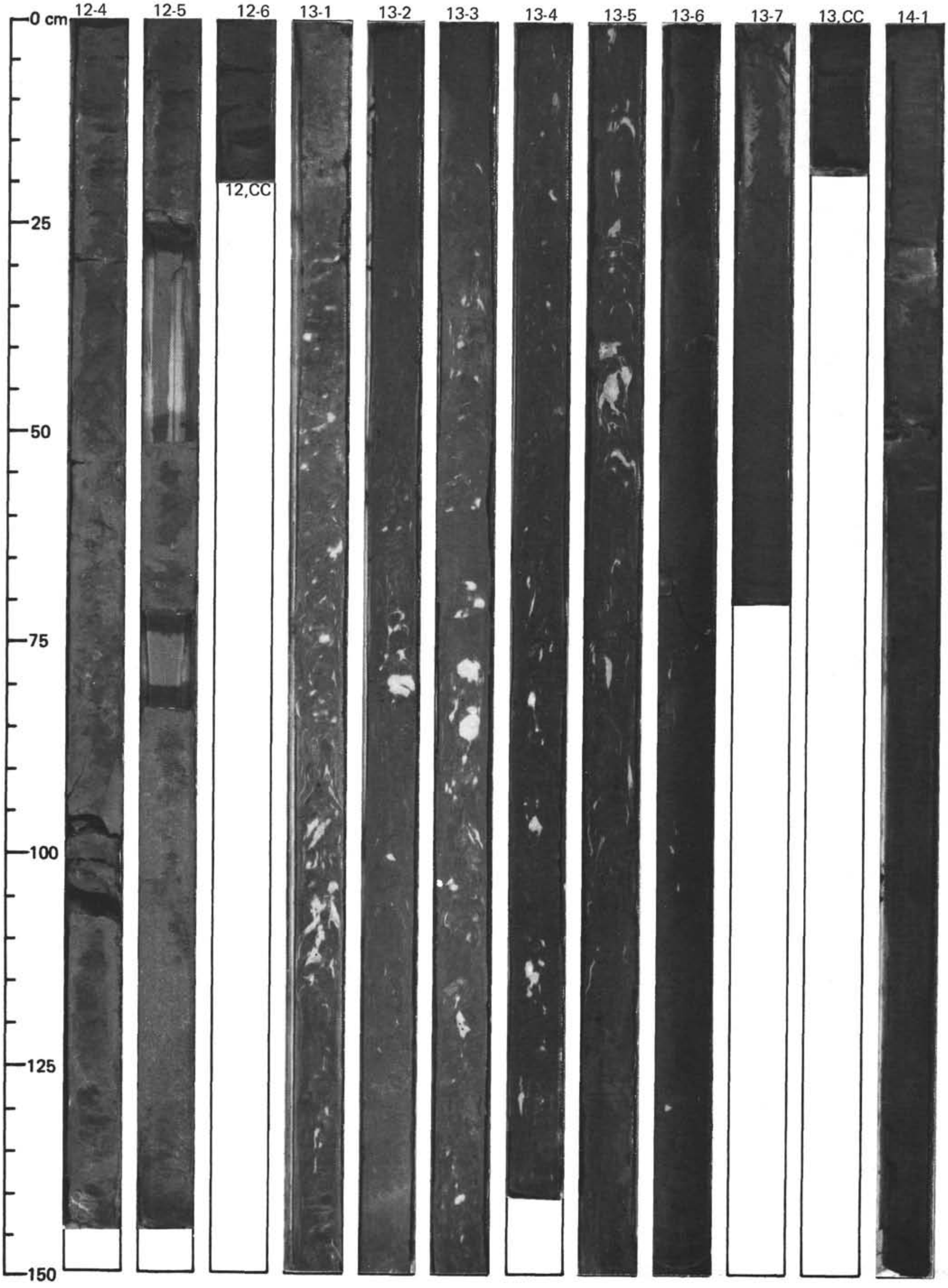

1-1
1-2
1-3
1-4
1-5
1-6
1,CC
2-1
2-2
2-3
2-4
2-5
0 cm
25
50
75
100
125
150


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

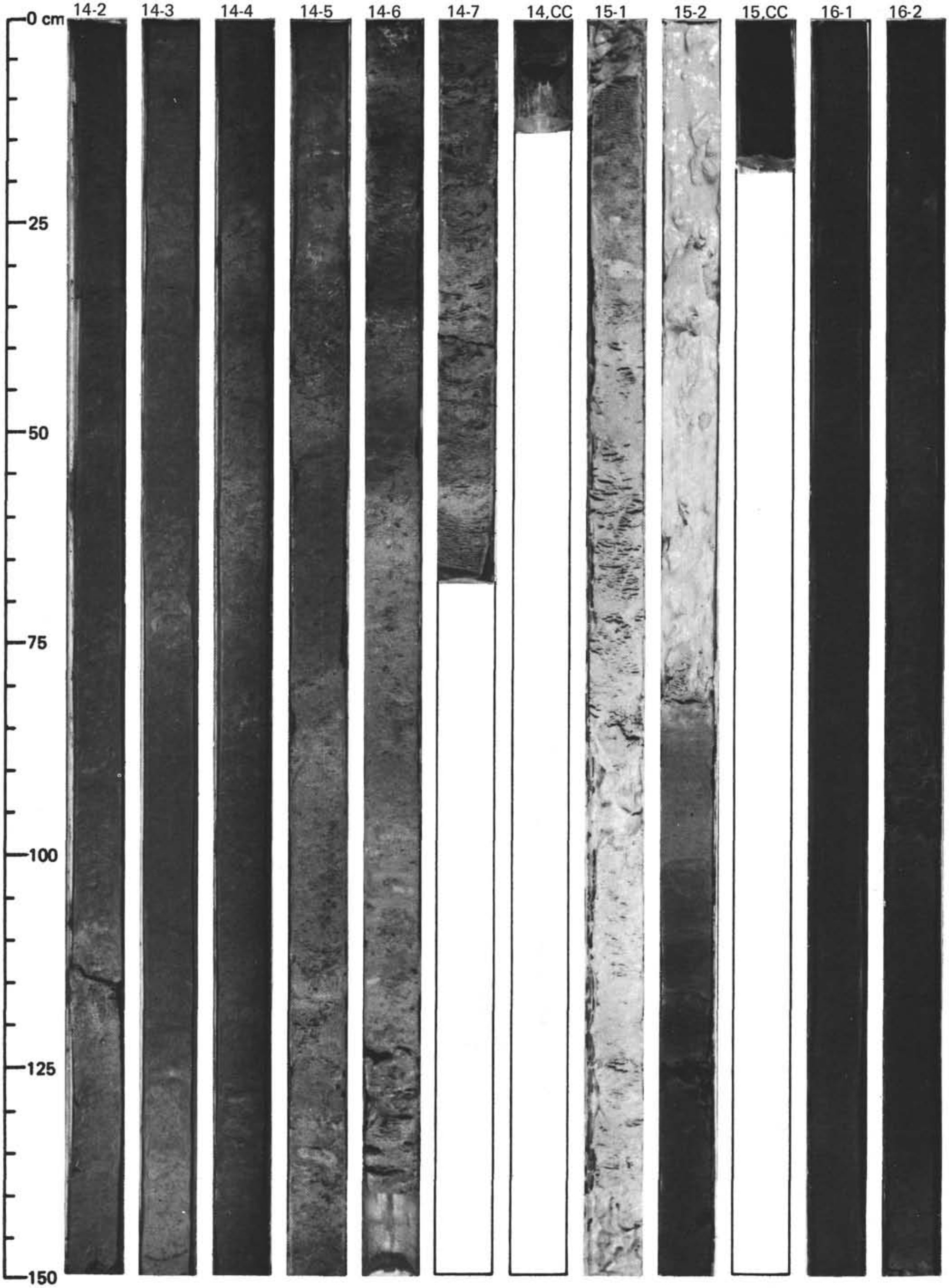


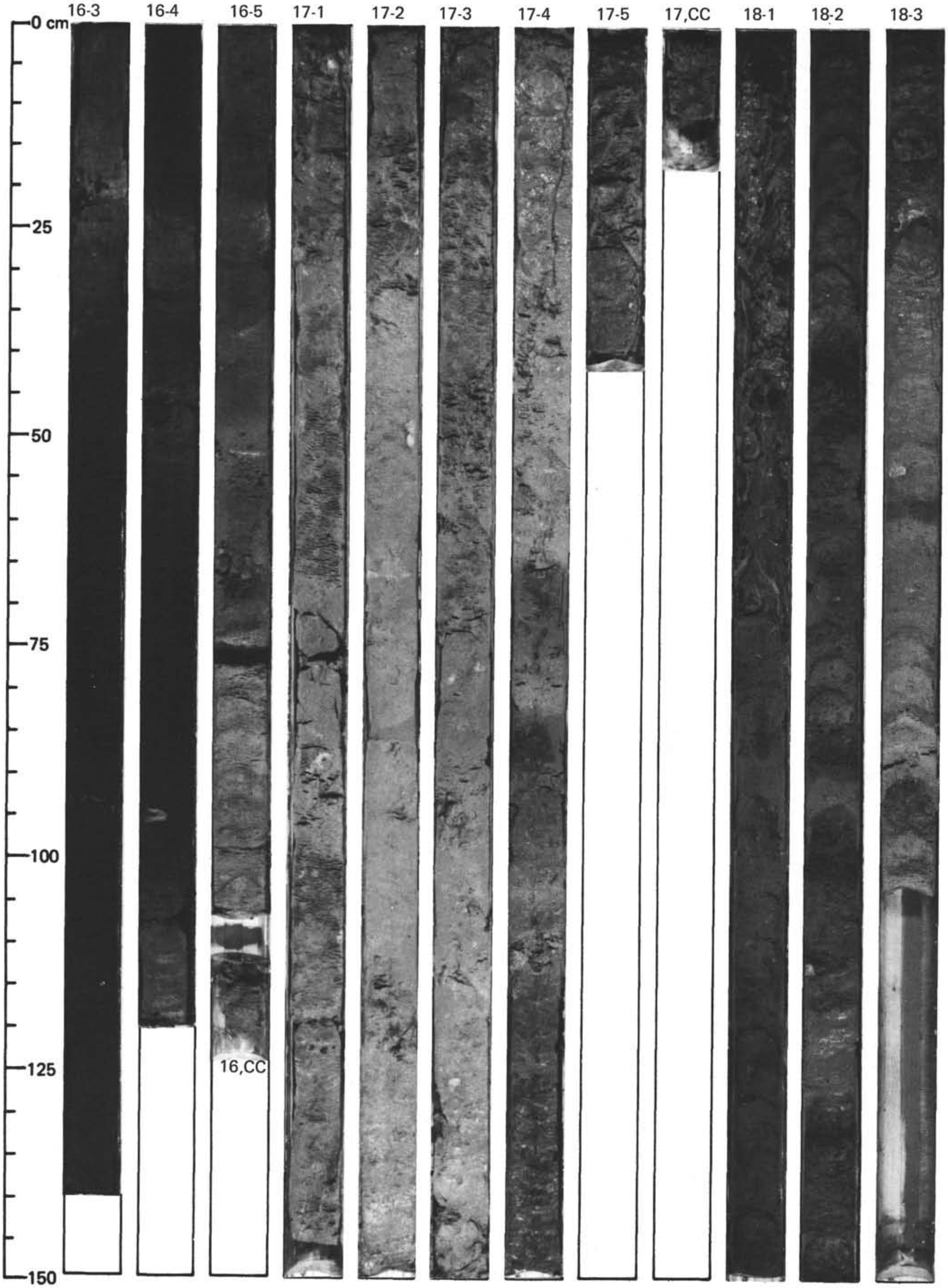
0 cm
25
50
75
100
125
150
5,CC
6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7,CC

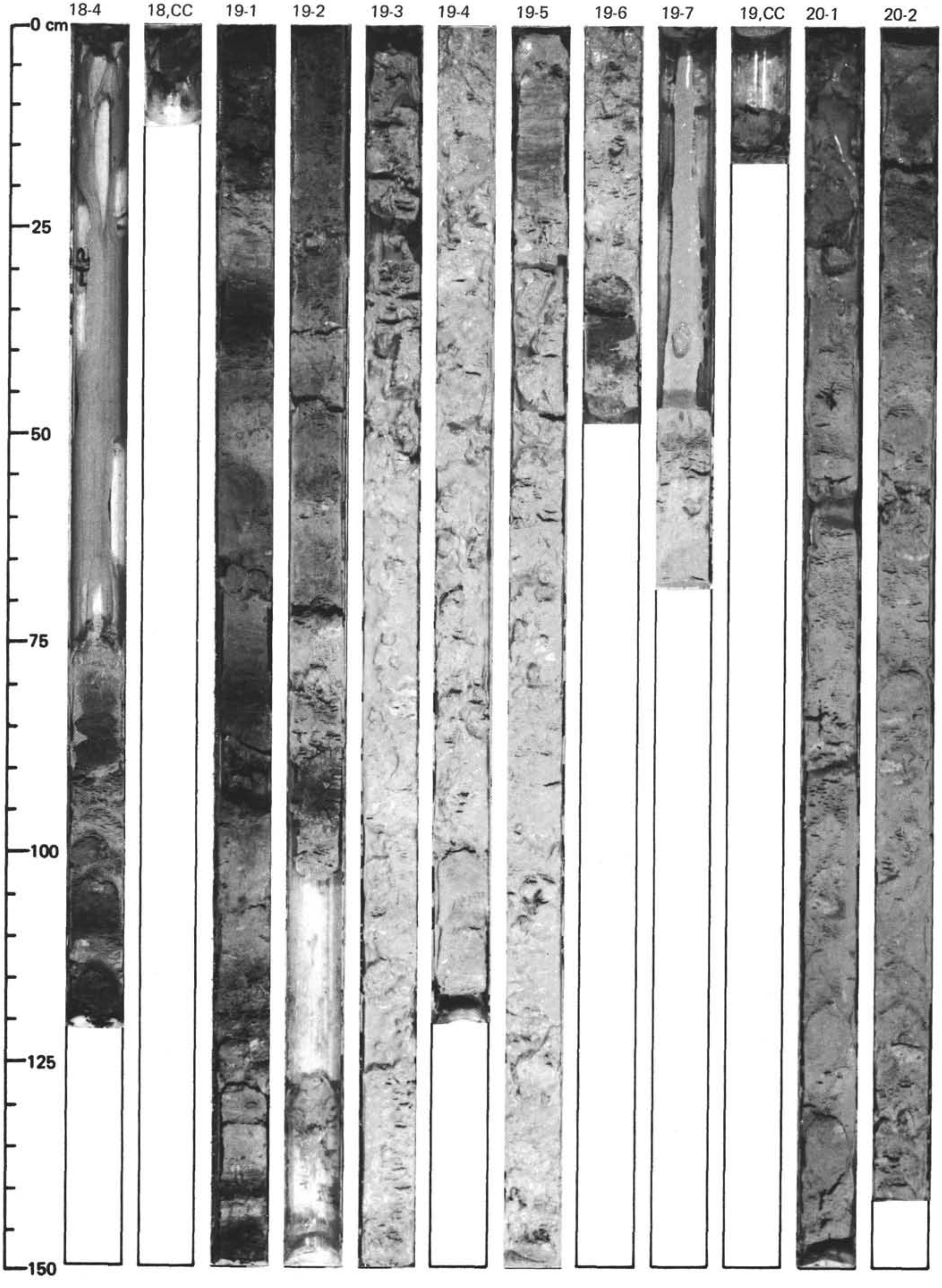

8-1
8-2
8-3
8-4
8-5
8-6
8,CC
9-1
11-1
12-1
12-2
12-3
0 cm
25
50
75
100
125
150
9,CC
11,CC

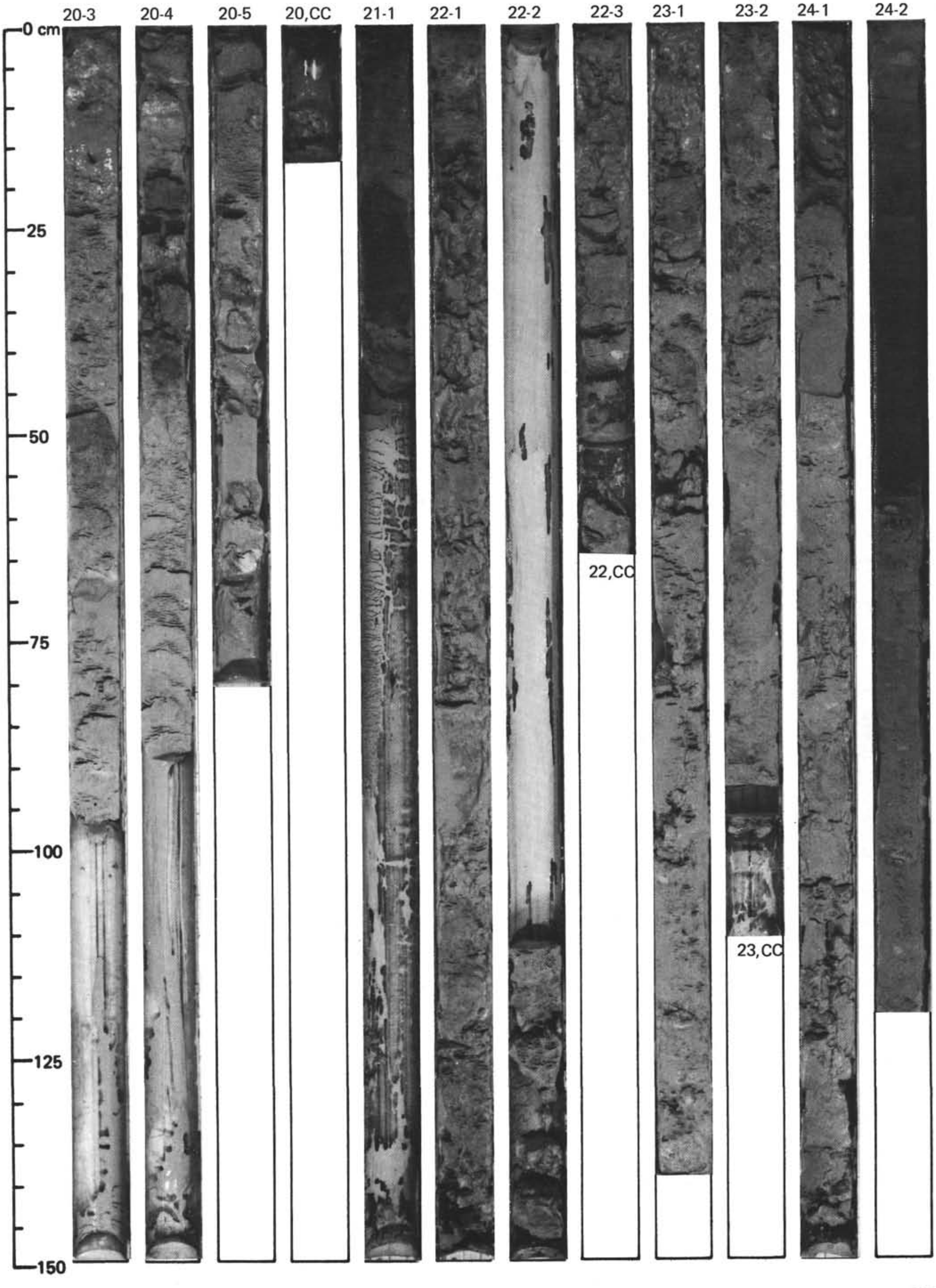


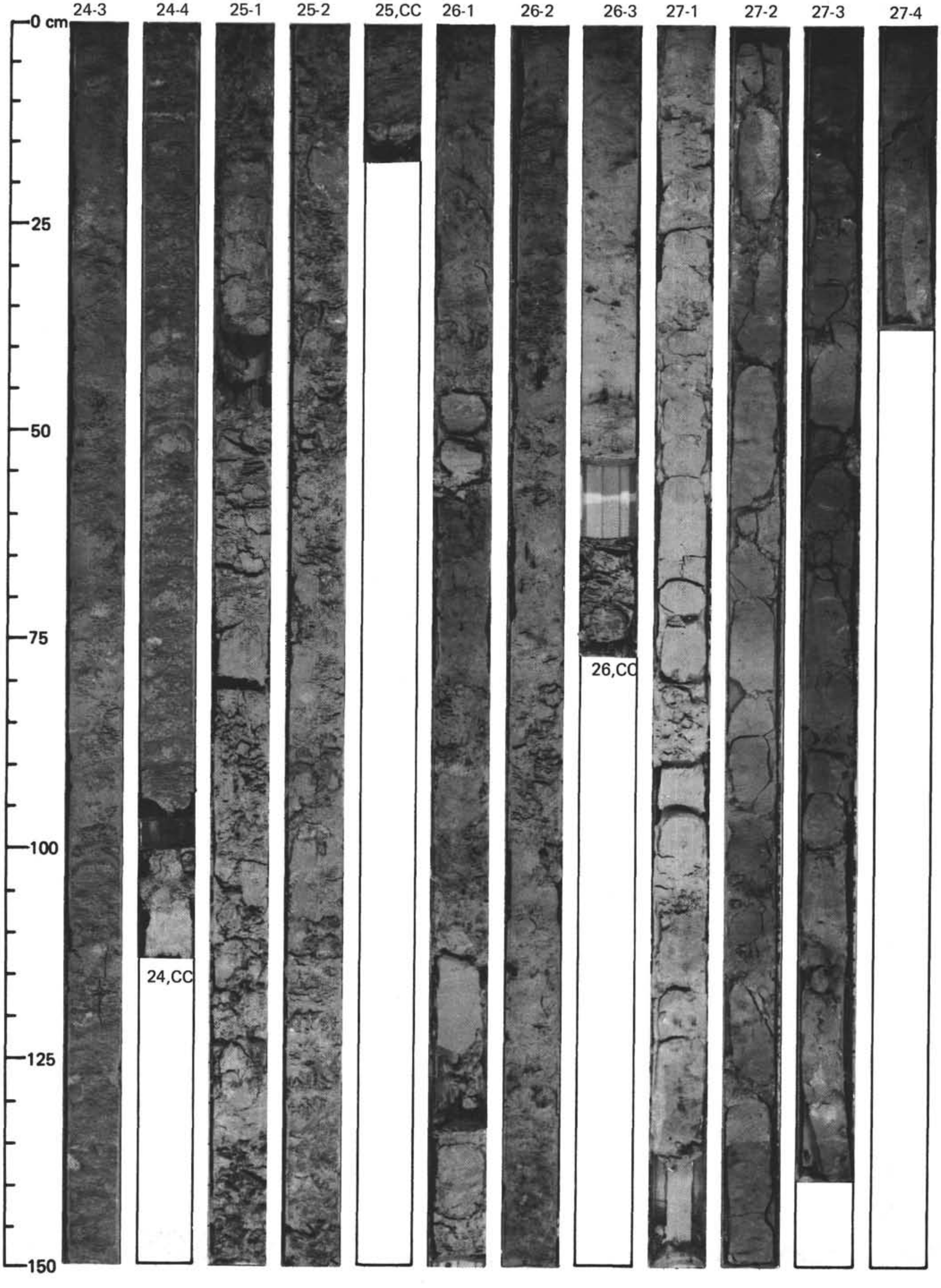
0 cm
25
50
75
100
125
150
12-4
12-5
12-6
12,CC
13-1
13-2
13-3
13-4
13-5
13-6
13-7
13,CC
14-1

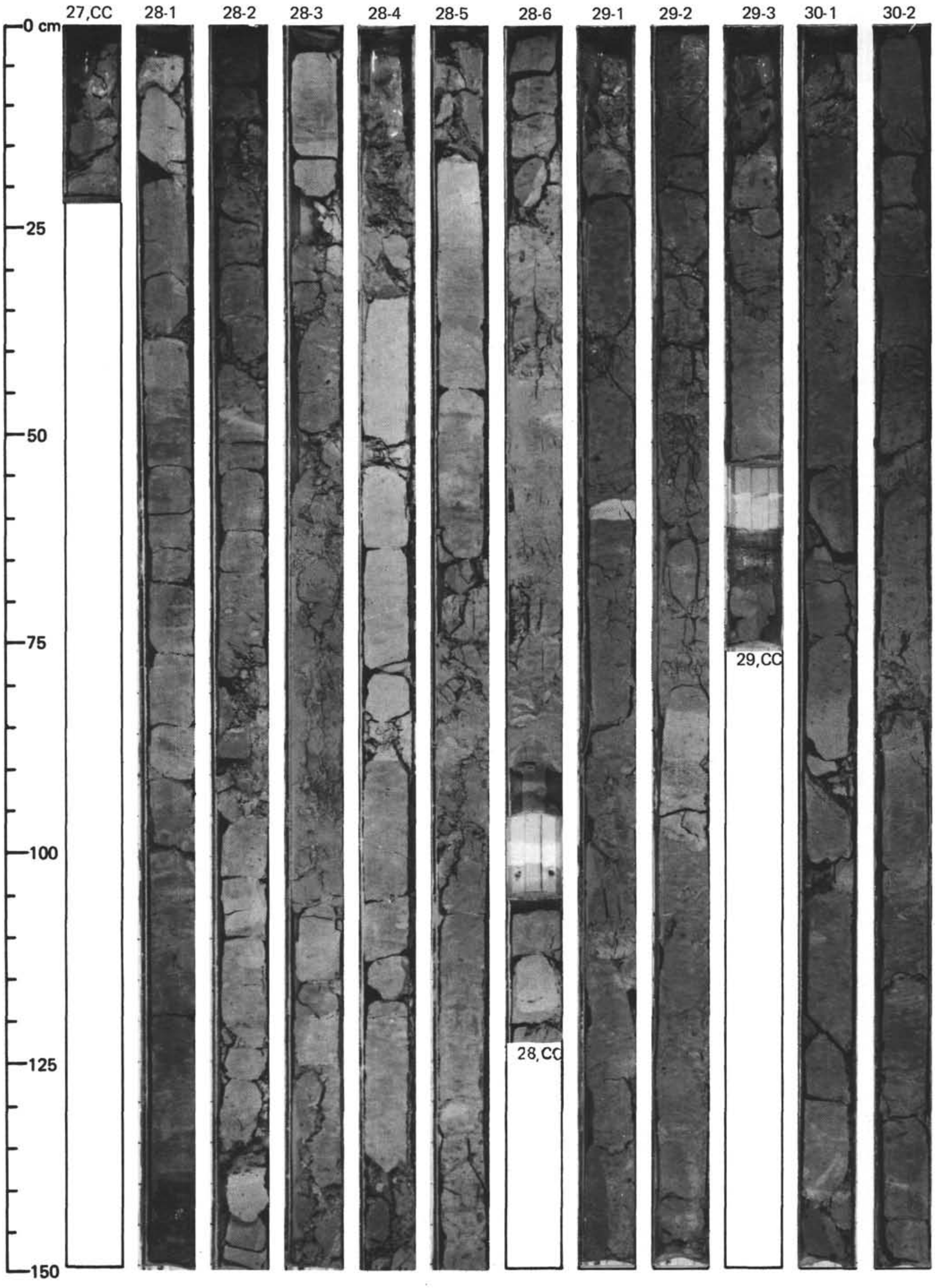

0 cm
25
50
75
100
125
150
14-2
14-3
14-4
14-5
14-6
14-7
14,CC
15-1
15-2
15,CC
16-1
16-2

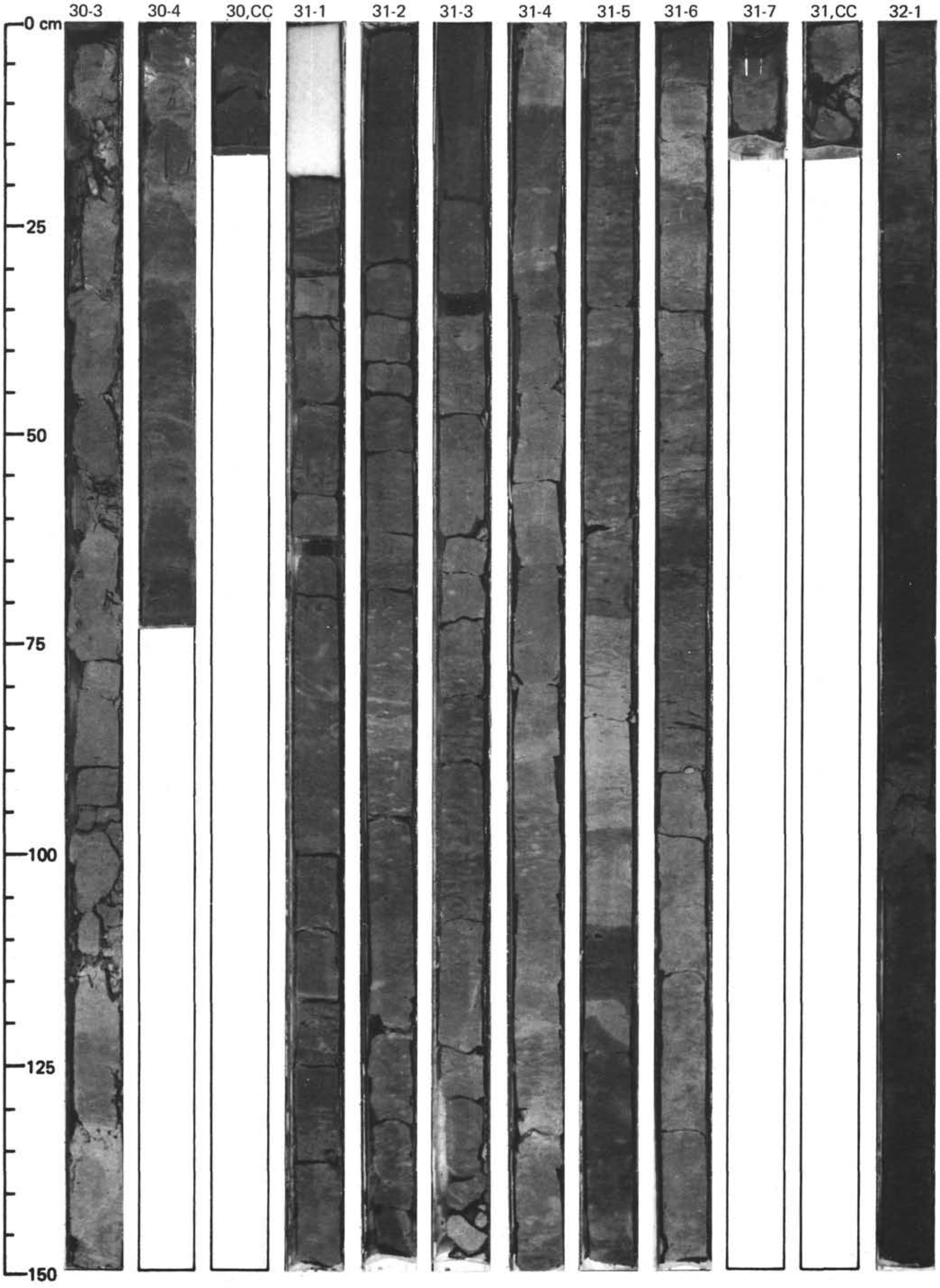

0 cm
25
50
75
100
125
150
16-3
16-4
16-5
16,CC
17-1
17-2
17-3
17-4
17-5
17,CC
18-1
18-2
18-3

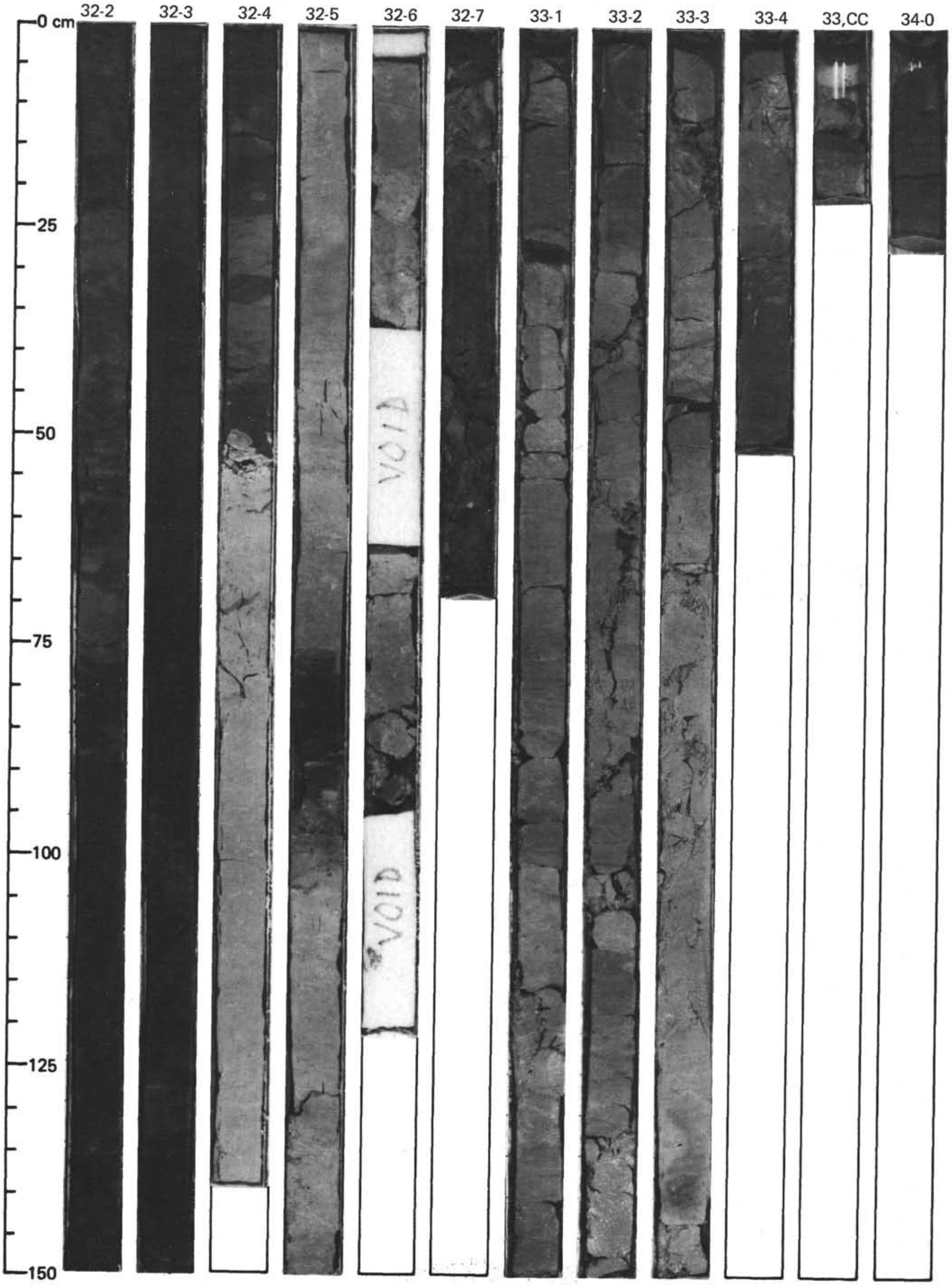

18-4
18,CC
19-1
19-2
19-3
19-4
19-5
19-6
19-7
19,CC
20-1
20-2
0 cm
25
50
75
100
125
150

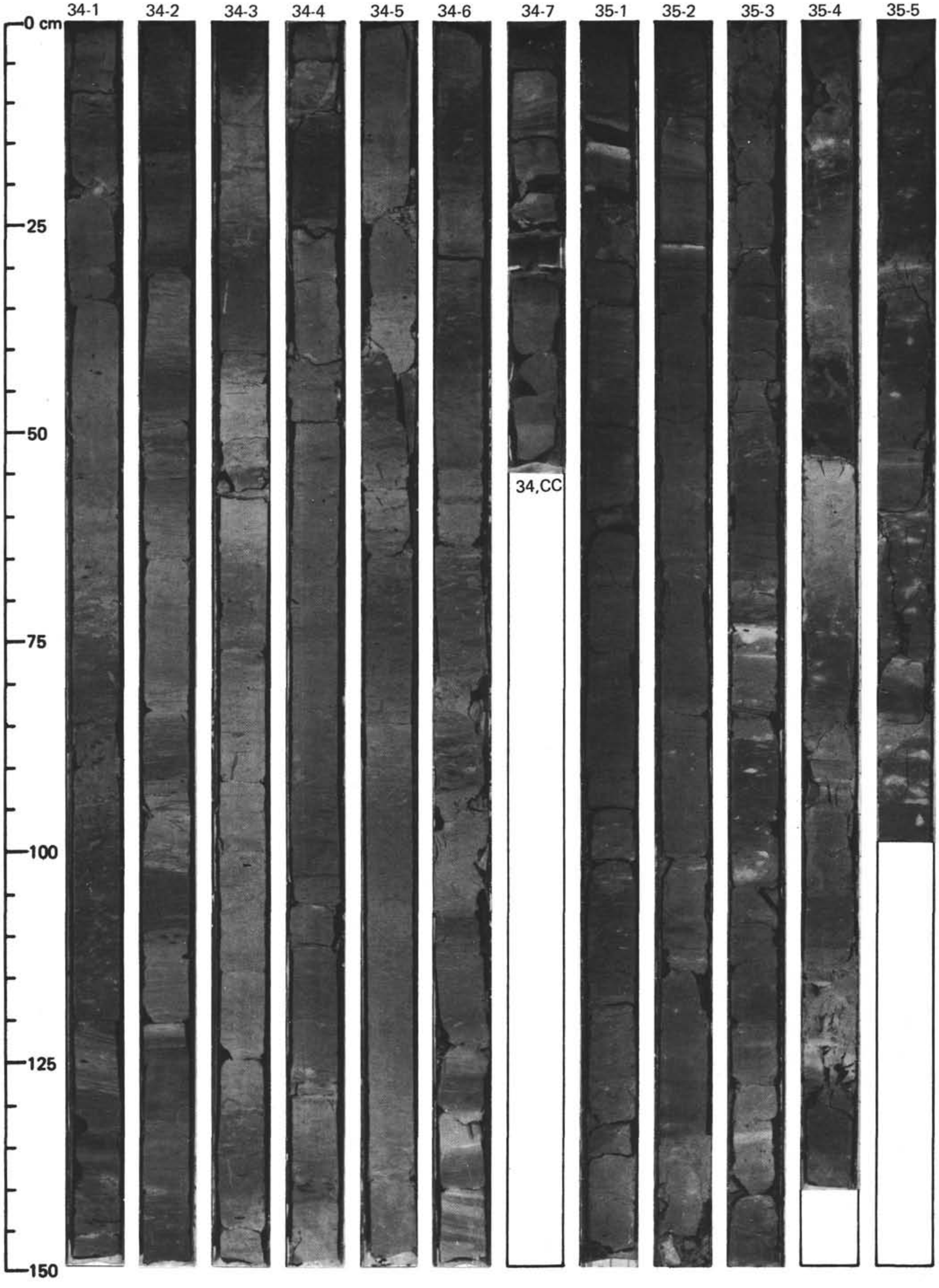

20-3
20-4
20-5
20,CC
21-1
22-1
22-2
22-3
23-1
23-2
24-1
24-2
0 cm
25
50
75
100
125
150
22,CC
23,CC

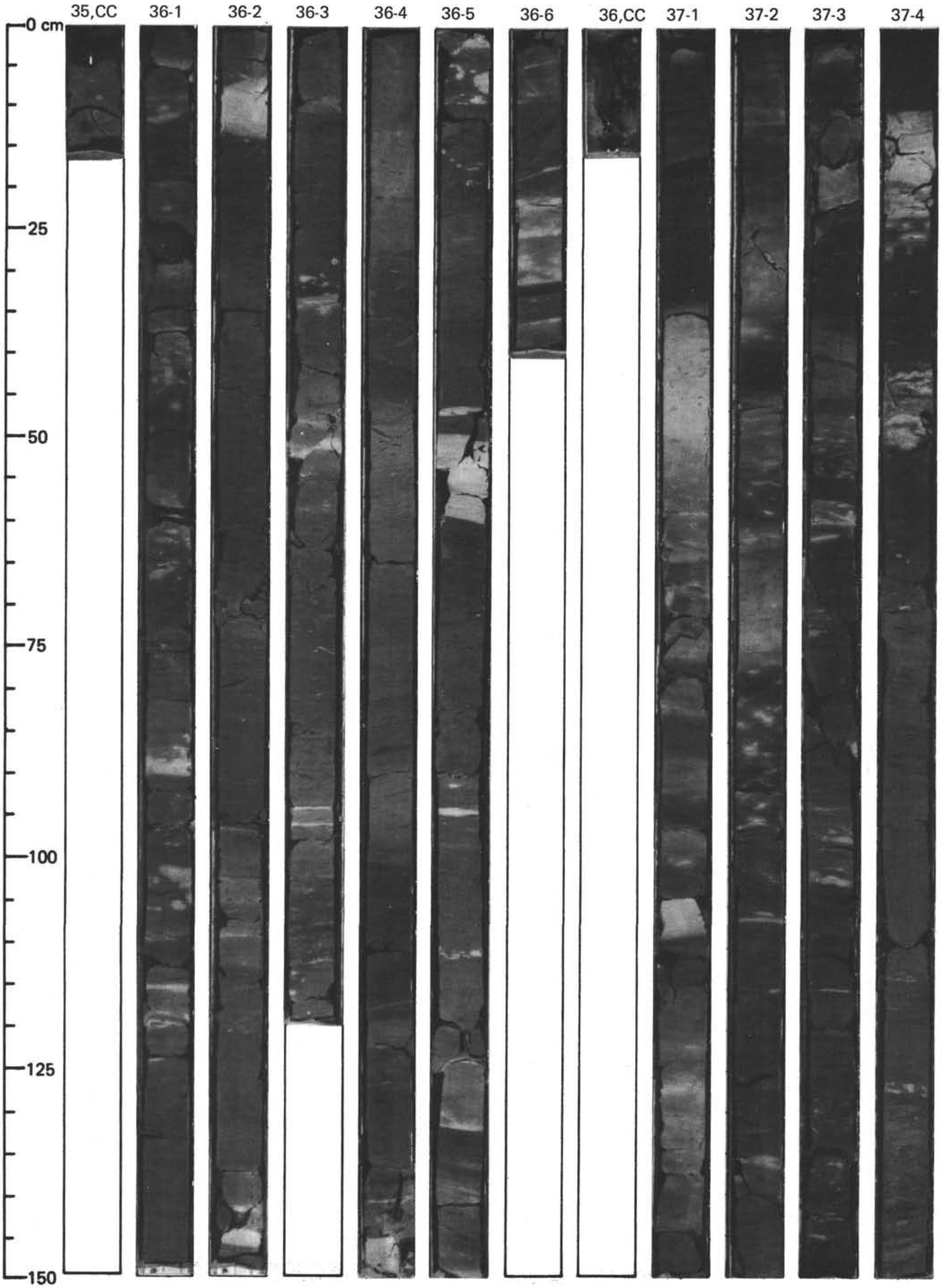

24-3
24-4
25-1
25-2
25,CC
26-1
26-2
26-3
27-1
27-2
27-3
27-4
0 cm
25
50
75
100
125
150
24,CC
26,CC

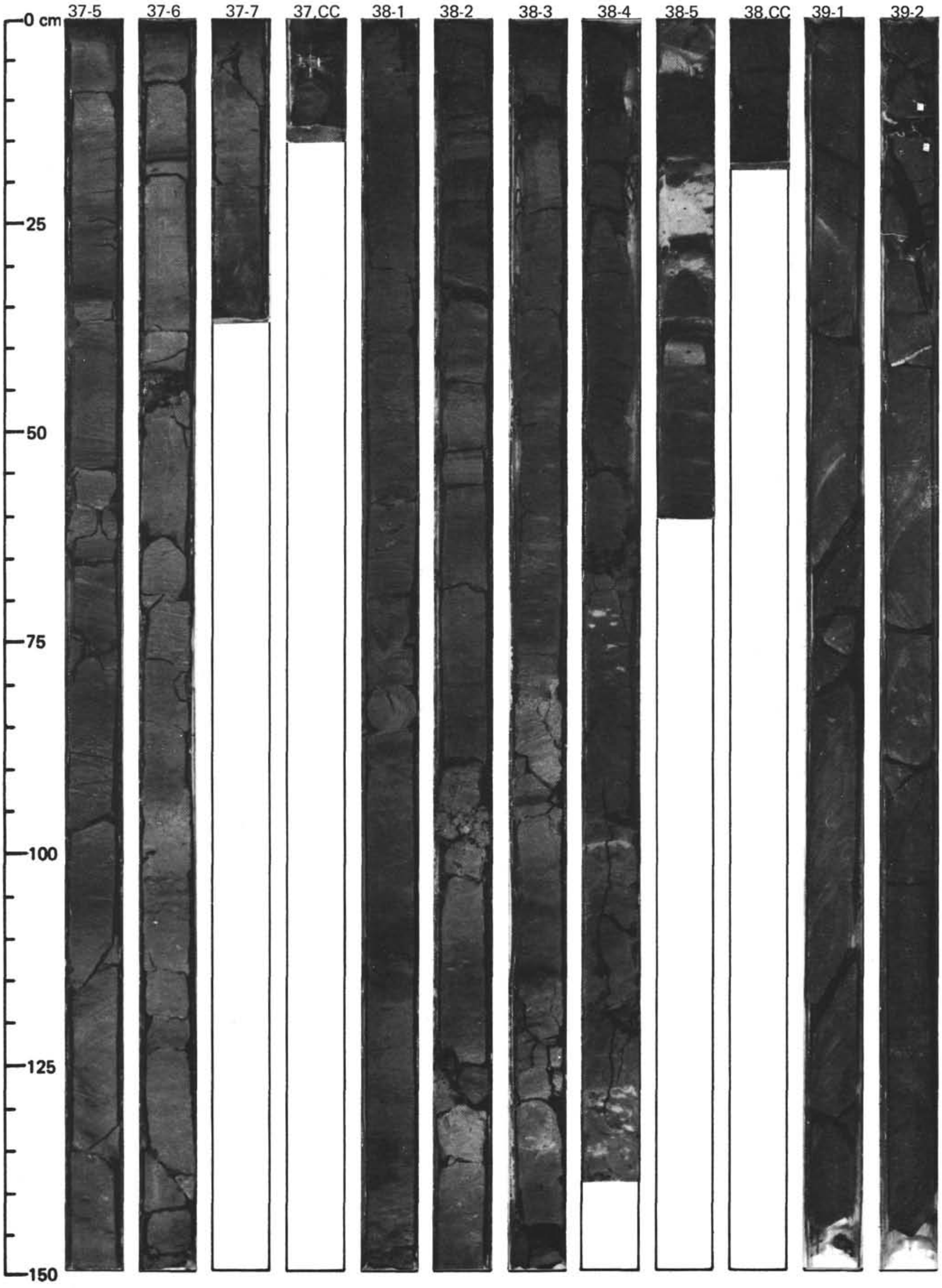

27,CC
28-1
28-2
28-3
28-4
28-5
28-6
29-1
29-2
29-3
30-1
30-2
0 cm
25
50
75
100
125
150
28,CC
29,CC

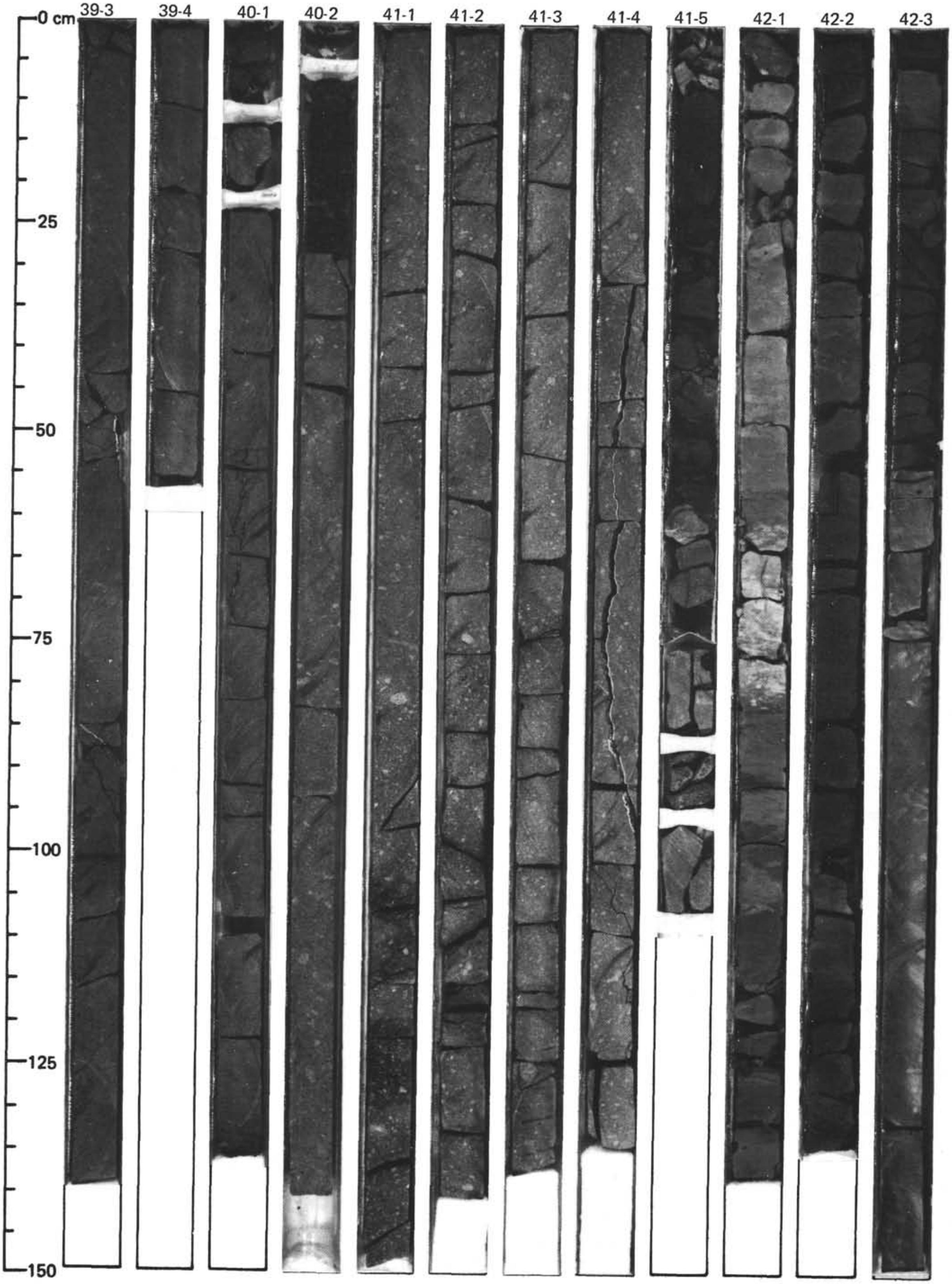

30-3
30-4
30,CC
31-1
31-2
31-3
31-4
31-5
31-6
31-7
31,CC
32-1
0 cm
25
50
75
100
125
150

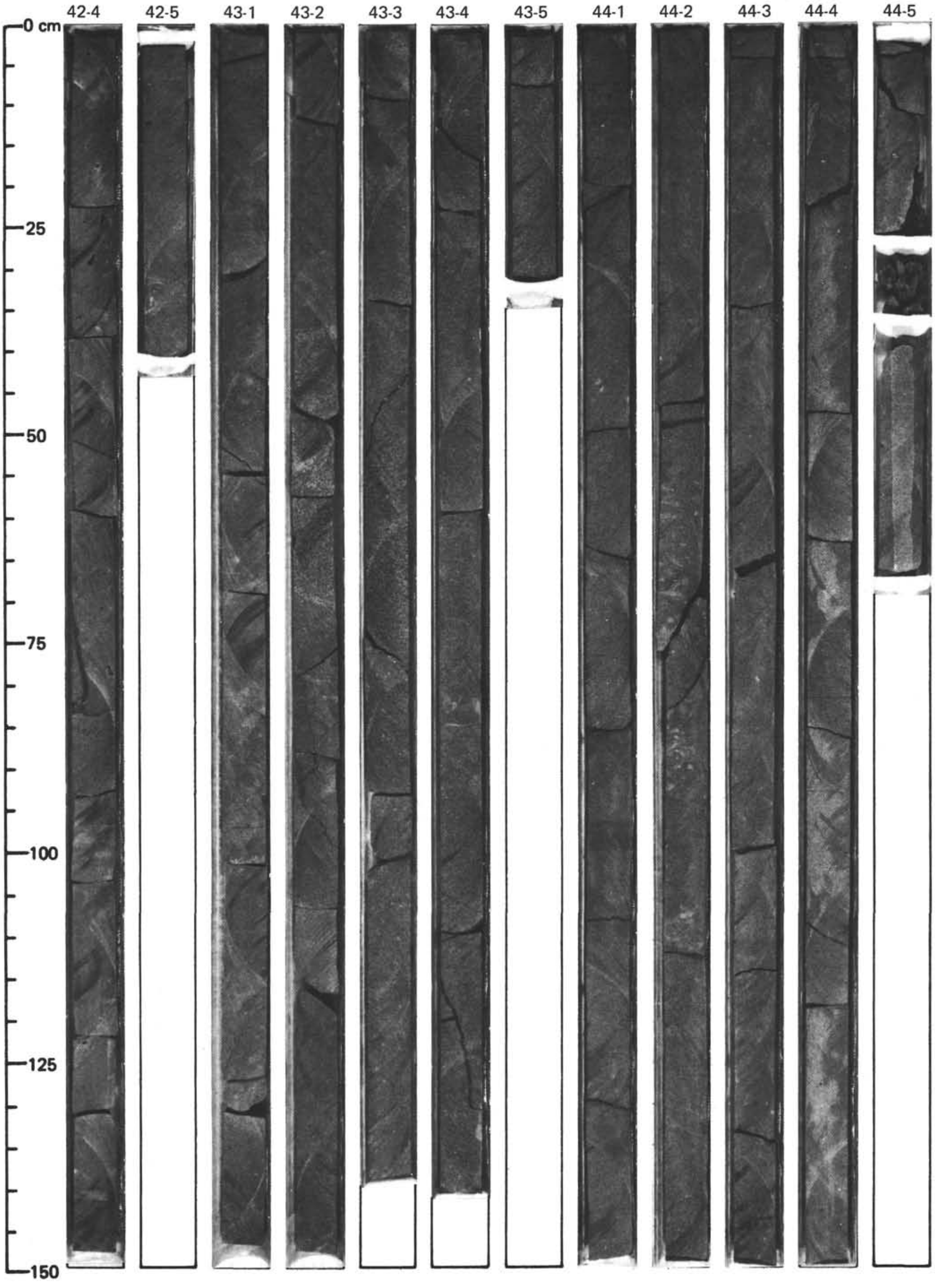

0 cm
25
50
75
100
125
150
32-2
32-3
32-4
32-5
32-6
32-7
33-1
33-2
33-3
33-4
33,CC
34-0
VOID
VOID


34-1
34-2
34-3
34-4
34-5
34-6
34-7
35-1
35-2
35-3
35-4
35-5
34,CC
0 cm
25
50
75
100
125
150


35,CC
36-1
36-2
36-3
36-4
36-5
36-6
36,CC
37-1
37-2
37-3
37-4
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
37-5
37-6
37-7
37,CC
38-1
38-2
38-3
38-4
38-5
38,CC
39-1
39-2


0 cm
25
50
75
100
125
150
39-3
39-4
40-1
40-2
41-1
41-2
41-3
41-4
41-5
42-1
42-2
42-3


42-4
42-5
43-1
43-2
43-3
43-4
43-5
44-1
44-2
44-3
44-4
44-5
0 cm
25
50
75
100
125
150