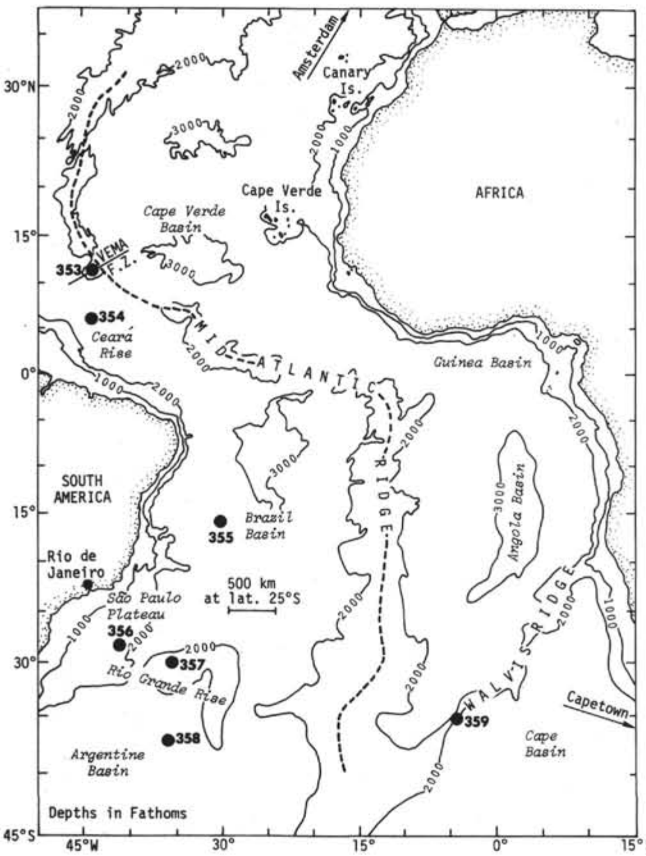
4. SITE 355: BRAZIL BASIN

The Shipboard Scientific Party[1]



SITE DATA

Date Occupied: 8 November 1974 (1858Z)

Date Departed: 12 November 1974 (1028Z)

Time on Site: 3 days, 15 hours, 30 minutes

Position: 15°42.59'S, 30°36.03'W

Accepted Water Depth: 4886 meters (drill pipe measurement)

Penetration: 460 meters

Number of Holes: 1

Number of Cores: 22

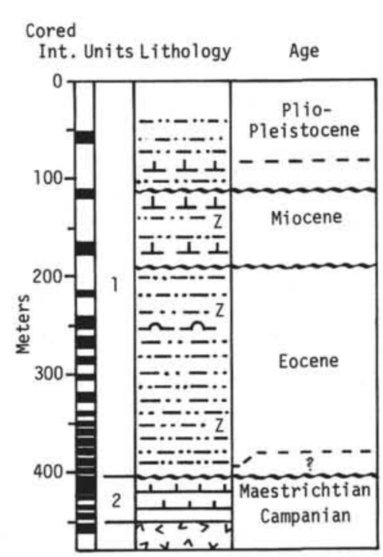
Total Length of Cored Section: 207.5 meters

Total Core Recovered: 118.1 meters

Principal Results: At Site 355, sediment 449 meters thick overlies a typical oceanic tholeiite basalt basement. The Tertiary section comprises muds, mudstones, and zeolitic muds. Silt and sand laminae indicate that much of the section was deposited by turbidity currents. Biogenic material is rare, except for bioclastic turbidites in the Miocene and an Eocene radiolarian mud. Zeolites are particularly common below 150 meters. At 405 meters, the muds and zeolitic muds unconformably overlie Campanian to lower Maestrichtian calcareous cores containing veins of sparry calcite. Hiatuses occur in the intervals from the middle to upper Miocene, from middle Eocene to lowermost Miocene, and from Maestrichtian to Paleocene. K-Ar dating of the basalt gives an age of 78.1 ±9 m.y., which is in excellent agreement with the Campanian age of the basal sediment determined by coccoliths, and provides an accurate date for the ocean crust between anomalies 33 and 34.

BACKGROUND AND OBJECTIVES

Site 355 is in the west central Brazil Basin at latitude 15°43'S, longitude 30°36'W, in accordance with recommendations of the JOIDES Atlantic Advisory Panel (Figure 1). A primary objective at this site was to date the basement (presumably oceanic basalt), in order to date the older end of the magnetic reversal time scale of Heirtzler et al. (1968). This site is between the recently determined positions of anomalies 33 and 34 in the Brazil Basin (Figure 2). Up to now, the oldest



[1]K. Perch-Nielsen, Eidg. Technische Hochschule, Zürich, Switzerland (Co-chief scientist); P.R. Supko, Scripps Institution of Oceanography, La Jolla, California (Co-chief scientist); A. Boersma, Lamont-Doherty Geological Observatory, Palisades, New York; R.L. Carlson, University of Washington, Seattle, Washington; M.G. Dinkelman, The Florida State University, Tallahassee, Florida; R.V. Fodor, University of New Mexico, Albuquerque, New Mexico; N. Kumar, Lamont-Doherty Geological Observatory, Palisades, New York; F. McCoy, Lamont-Doherty Geological Observatory, Palisades, New York; J. Thiede, Oregon State University, Corvallis, Oregon; H.B. Zimmerman, Union College, Schenectady, New York.

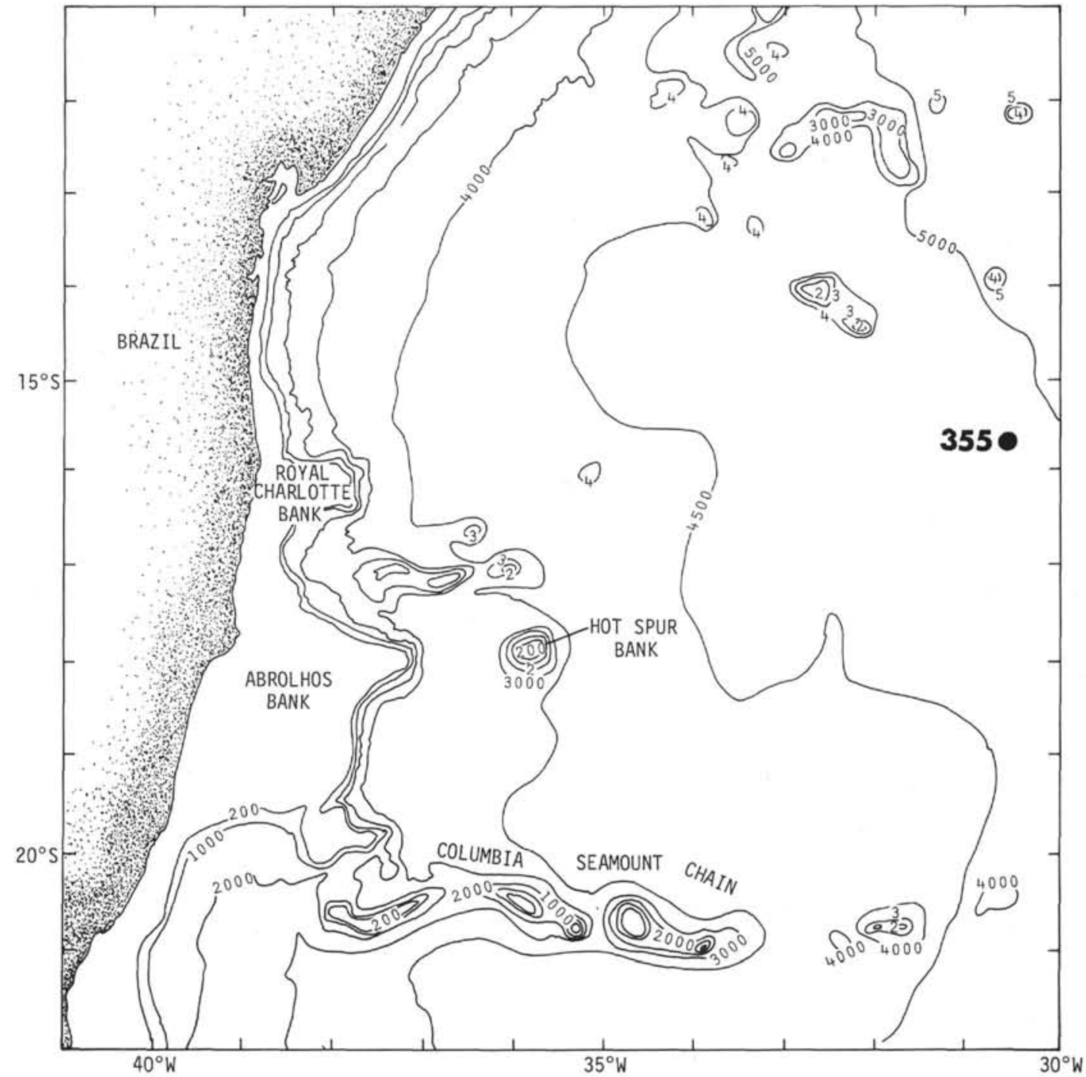


Figure 1. *Base map, Site 355. Contours are 200, 1000, 2000, 3000, 4000, 4500, and 5000 m. Numbers 1, 2, 3, 4, 5 are in thousands of meters. From Connary and Moody, 1975, Bathymetry of the continental margin of Brazil (unpublished).*

reliable date for the reversal time scale is probably the Maestrichtian age (67 ±1 m.y., Maxwell, Von Herzen, et al., 1970) obtained by drilling on anomaly 30 in the South Atlantic.

A second major objective was to delineate sediment facies as a function of time, in order to aid in compiling a circulation history for the South Atlantic. Seismic profiles in the area (Figure 3) show about 0.5 sec of sediment near the proposed site. Sections of the records (e.g., 1900-2000 hr, 22 November, Figure 3) show stratified sediment to basement. The more typical section, however, as at the proposed site (2010 hr, Figure 3), is transparent, with only slight apparent layering in the upper layers. We had estimated about 300 meters of Cretaceous and Paleogene biogenic sediments, overlain by about 200 meters of Oligocene and Neogene pelagic clays and occasional fine silts; we obtained these figures by using an estimated basement age of 80 m.y.B.P., the sea-floor spreading crustal subsidence curve of Sclater et al. (1971), the average Atlantic accumulation rates for clay, marl, and calcareous ooze facies (Berger and von Rad, 1972), and an estimated carbonate compensation level for the middle and early Tertiary.

We planned to spot core the pelagic clays and silts, core more closely the lower biogenic section, and core continuously beginning at least 60 meters above calculated basement, in order to ensure coring of the sediment-basalt contact.

OPERATIONS

We approached Site 355 from Recife, Brazil, on a heading of 154°T (Figure 4). At 1605Z on 8 November 1974, at a point 15°42'S, 30°48'W, we changed course to 077°T to follow the reference profile (Figure 3), and slowed to 6 knots. A good satellite navigation fix at 1626Z showed us to be exactly on the Lamont track, and our approach profile (Figure 5) matched the reference profile. We decided to pinpoint the site in a small depression in the basement (passed at 1812Z), in

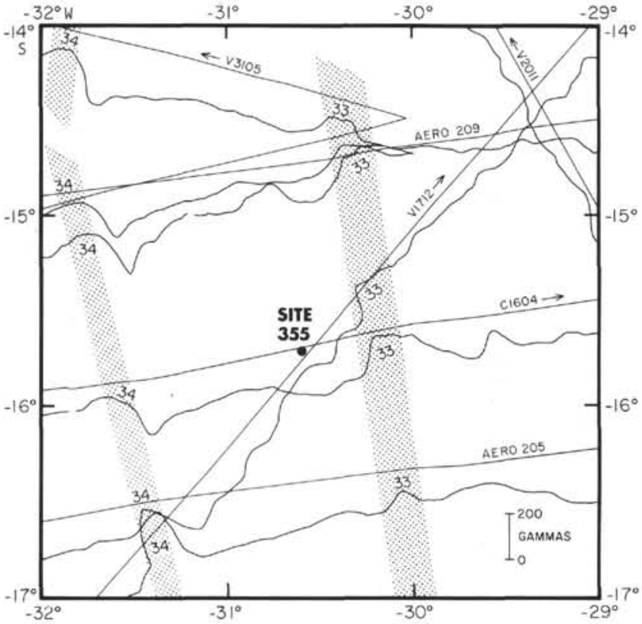


Figure 2. *Location of Site 355 in relation to anomalies 33 and 34 in the Brazil Basin. Position of anomalies identified by Roger Larson (personal communication). Track C1604 is the reference seismic reflection profile.*

order to sample the oldest possible sediments. At 1825Z we executed a Williamson turn, and came back onto a reciprocal heading of 259°T at 1837Z. We dropped the beacon under way at 1858Z, retrieved gear, and came back over the beacon.

Coring was intermittent to a depth of 338 meters, and continuous below that (Table 1). The entire section cut quickly; fluctuations in coring and drilling rates resulted mostly from stickiness of the clay formations.

We did not use the heave compensator because (1) the sediment cover was fairly thin and we expected no hard layers, (2) we needed to penetrate basement only shallowly, and (3) the weather was fine. We were therefore able to drill double joints of pipe and reduce the time required for connections. We lost six hours because the positioning computer malfunctioned.

No survey seemed necessary after we finished at the site; we left Site 355 at 1028Z, 12 November 1974, and headed toward Site 356 on course 218°T.

LITHOLOGY

We took 21 cores in the 449-meter-thick sedimentary section overlying basalt in the Brazil Basin. The lowermost core contains basalt and the sediment/basalt contact. The upper 338 meters (Cores 1-9) were discontinuously cored, but the remainder of the sediment section (Cores 10-22) was continuously cored.

Two sedimentary units have been defined: muds, mudstones, and zeolitic muds in the upper portion (Unit 1), unconformably overlying a nannofossil ooze (Unit 2); the latter is in apparently conformable contact (see Fodor and McKee, this volume) with tholeiitic basalt.

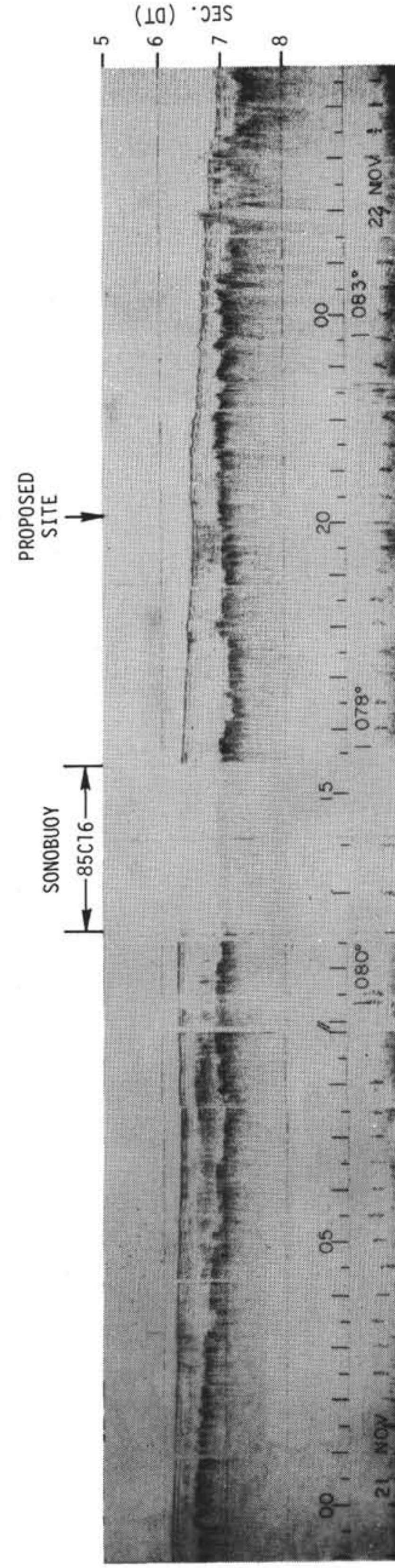


Figure 3. *Reference seismic reflection profile obtained by Lamont-Doherty Geological Observatory,* Robert D. Conrad *cruise C1604.*

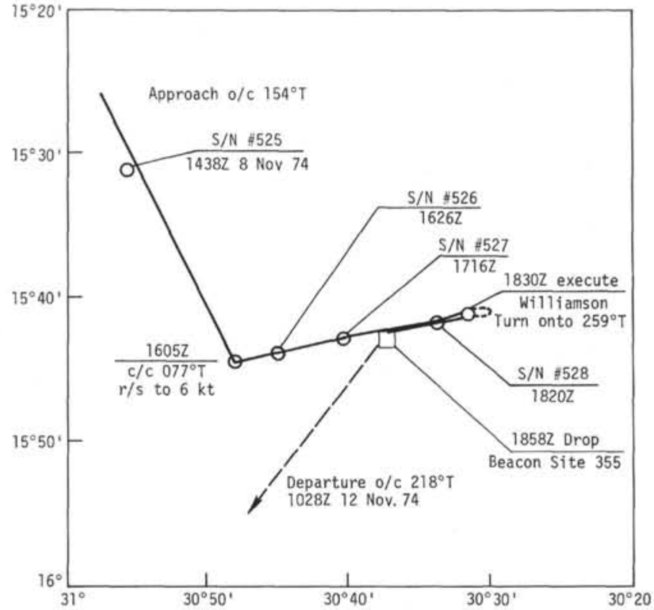


Figure 4. Glomar Challenger *track in the vicinity of Site 355.*

In general, the entire Tertiary here (represented by Unit 1) seems to have been characterized by pelagic and turbidity current sedimentation below the carbonate compensation depth (CCD), after a Late Cretaceous regime of deposition of calcareous material (represented by Unit 2) when this site was above the CCD. The units are summarized in Table 2; the general variation in dominant sediment components is given in Figure 6; detailed variations and changes in these components from smear-slide analyses are graphed in Figure 7.

TABLE 1
Coring Summary, Site 355

Core	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
1	53.0-62.5	9.5	9.3	98
2	110.0-119.5	9.5	6.9	73
3	167.0-176.5	9.5	7.6	80
4	214.5-224.0	9.5	3.3	35
5	243.0-252.5	9.5	9.5	100
6	262.0-271.5	9.5	9.5	100
7	281.0-290.5	9.5	4.2	44
8	300.0-309.5	9.5	3.0	32
9	319.0-328.5	9.5	6.9	73
10	338.0-347.5	9.5	2.0	21
11	347.5-357.0	9.5	5.6	59
12	357.0-366.5	9.5	6.4	67
13	366.5-376.0	9.5	3.7	39
14	376.0-385.5	9.5	6.3	66
15	385.5-395.0	9.5	5.7	60
16	395.0-404.5	9.5	2.1	22
17	404.5-414.0	9.5	8.0	84
18	414.0-423.5	9.5	4.6	48
19	423.5-433.0	9.5	3.3	35
20	433.0-442.6	9.5	2.0	21
21	442.5-452.0	9.5	1.5	16
22	452.0-460.0	8.0	6.7	84
Total		207.5	118.1	57

Unit 1

The upper 405 meters of the Brazil Basin sedimentary sequence forms Unit 1 (assuming that it extends up-section to the sediment-water interface), which consists of low-carbonate unconsolidated muds, zeolitic muds, and some mudstones near the base of the section. Colors, generally brown, become an alternating sequence of yellow-brown and green-gray in the middle

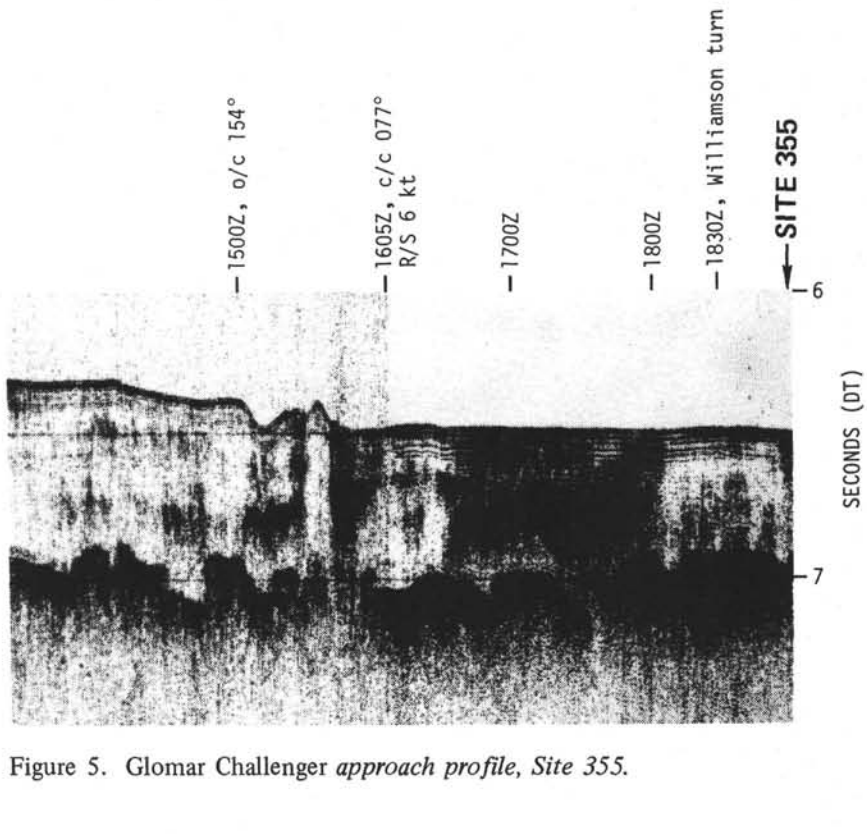


Figure 5. Glomar Challenger *approach profile, Site 355.*

TABLE 2
Lithologic Summary, Site 355

Unit	Cores	Depth Below Sea Floor (m)	Thickness (m)	Age	Description
1	1-17 (Section 2)	0-405	405	Pleistocene to Eocene	Unconsolidated mud, zeolitic mud, mudstone (brown, red-brown, green-gray); with turbidites in upper portion; increasing zeolite content downsection; mudstones only near base.
1A	5 (Section 1-2)	234 (?)-245	11 (?)	Middle Eocene	Unconsolidated radiolarian mud (olive-gray).
1B	6, CC-7	271-284 (?)	13 (?)	Early Eocene	Unconsolidated dolomite mud-zeolitic dolomite mud (green-gray).
2	17 (Section 2) -21	405-449	44	Late Cretaceous (Maestrichtian-Campanian)	Nannofossil ooze (pale brown); with numerous thin calcite veins, lower portion altered in contact with basalt.
3	21-22	449-	11+	Cretaceous (Campanian) (78.1±9 m.y., K/Ar))	Aphyric tholeiitic basalt with numerous calcite veins.

of the unit (Cores 3-11), then an alternating sequence of dark red-brown and brown near the base (Cores 12-17). Except for one hiatus (see Biostratigraphy and Sediment Accumulation Rates), the entire Tertiary, from the Eocene to the Plio-Pleistocene, is represented by this unit.

Carbonate content varies from 0 to about 10%; locally higher values up to 80% are associated with bioclastic turbidite sequences in the Miocene and Plio-Pleistocene (Cores 2 and 3), discussed below. Foraminifers, calcareous nannofossils, and biosiliceous tests are rare, except in the bioclastic turbidites and in the Eocene radiolarian mud forming Subunit 1A, also discussed below. Abundant coarse micarb occurs locally. Dolomite is abundant only in the dolomite mud of Subunit 1B (see below).

In general, Unit 1 is a silty clay with local sand and silt laminae, and contains substantial amounts of quartz and feldspar. Zeolites are abundant (5%-60% from smear-slide estimates), particularly in the lower 250 meters of the section.

The upper portion of this predominantly terrigenous sequence is brown mud (Core 1), in which color variations produce a series of pale yellow-brown, light brown, and dark brown. Silt content varies from 5% to 50% (all values are from smear-slide estimates); average is between 5% and 10%. Clays vary from 40% to 95%, averaging 80%. Calcium carbonate values are low (6%). Biogenic debris comprises 5% or less radiolarians, foraminifers, and nannofossils. Dolomite (0-5%) occurs with micronodules (0-5%), ferruginous material (0-5%), and zeolites (1-15%); zeolites become more abundant down section. Terrigenous detritus, in addition to the characteristically high clay content, is present as quartz (0-15%), feldspar (0-10%), and heavy minerals and mica (both usually in trace amounts). More silt-sized components occur in thin laminae, as a result of the higher concentrations of manganese micronodules and anhedral iron oxides (limonite), along with some quartz, feldspar, and biosiliceous material.

Bioclastic turbidite sequences are interbedded and are apparent (Cores 2 and 3) by their light gray and white colors. We sampled only a 65-cm-thick undisturbed portion of these turbidites; the remainder occurs in a drilled breccia. Individual units appear to be thin (2-8 cm). Compositional and textural variations within each unit (Figure 8), and the generally fine-grained sediment texture and the thinness of individual units, imply a distal turbidite sequence. Thin bluish zeolitic muds (containing up to 5% pyrite) at the tops of the sequences may represent pelagic brown muds reduced by rapid burial under successive bioturbidites. Biogenic material is predominantly calcareous nannofossils (up to 60%), coarse micarb (up to 40%), and foraminifers (up to 15%). In some drilling breccia clasts, disturbed foraminifer sands apparently formed basal portions of some bioclastic turbidite sequences. Many benthic foraminifers and other invertebrate fossils, as well as calcareous nannofossils in these units, are also displaced. (See Biostratigraphic Summary.)

Beneath the turbidite sequence, Unit 1 is characterized by a higher zeolite content (10%-55%; average about 23%), and is alternately red-brown and green-gray. As elsewhere in this unit, calcareous and biosiliceous material, except the bioclastic turbidites, does not form a significant component of these zeolitic muds. The bulk of the sediment is clay (montmorillonite with some illite and kaolinite; see Zimmerman, this volume); quartz and feldspar are present, but in small quantities. Where dolomite is

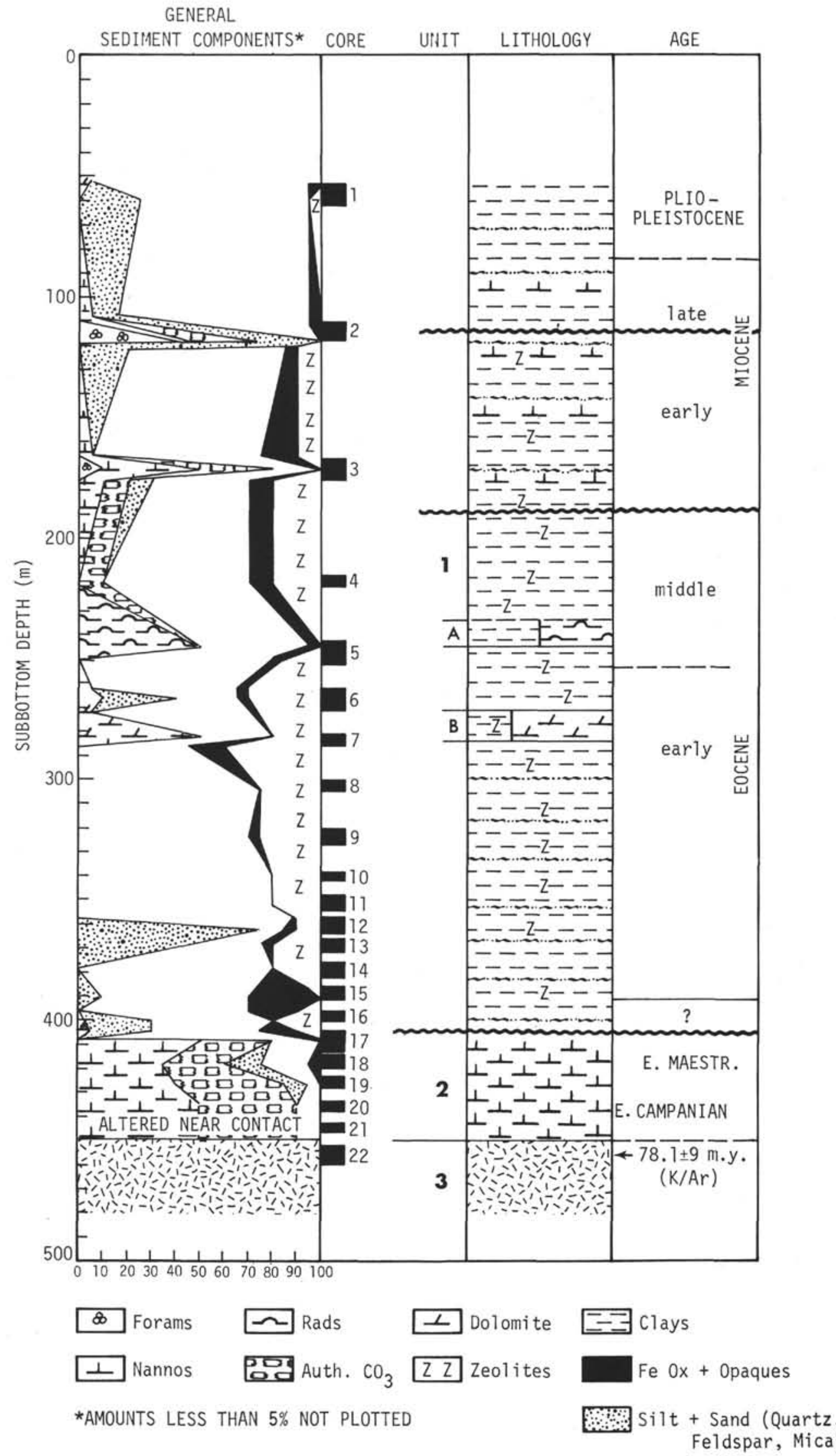


Figure 6. *Lithologic summary, Site 355.*

present, it occurs as rhombs with central cores containing coarse micarb grains similar to those found elsewhere in the mud.

We define two subunits of the lower to middle Eocene: a radiolarian mud (Unit 1A) and a dolomite mud (Unit 1B) (Table 2). The radiolarian mud (40% radiolarians) forms the upper 1.5-meter portion of Core 5. The actual thickness of this biogenic mud may be 8 meters, if the decreased drilling rate at 234 meters marks the top of the unit. Dolomite mud sampled in the core catcher of Core 6 is interbedded with the siliceous muds in Core 7. Assuming continuity of the sediment between cores, this dolomite-rich sequence (average 50% dolomite) is about 13 meters thick. Above the dolomitic unit, a fragment of dolomite rock (2 by 4 mm) occurs in Core 6.

Intercalated in the zeolitic mud sequence (from about 246 m to the base of Unit 1 at 405 m) are numerous thin laminae of quartz-zeolite sands, silts, and muds. Their number increases markedly toward the base of the unit. They may contain up to 70% sand-sized or silt-sized grains; an average texture would be about 25% sand, 25% silt, 50% clay, or a sandy mud. Typically, these laminae contain between 2% and 60% quartz (average 40%), between 2% and 50% zeolite (average 25%), up to 10% feldspar (average 5%), and less than 5% of heavy minerals, mica, and micronodules. Zeolites tend to be untwinned and larger than those common in the surrounding zeolitic muds. They are clinoptilolite (see McCoy et al., this volume), and appear to have grown authigenically in contact with quartz grains (see Krinsley and McCoy, this volume). We regard the quartz-zeolite laminae as basal portions of individual turbidites, on the basis of their displaced biogenic material (see Biostratigraphy), the surface morphologies of some quartz grains (Krinsley and McCoy, this volume), and ratios of clay minerals (Zimmerman, this volume).

At 357 meters (Core 12), Unit 1 becomes an alternating sequence of greenish-gray and brown mud containing some mudstones. The thin sand and silt laminae here appear to be less sandy (average 3%) and less clayey (average 30%), but contain considerably more silt (average 65%). Within a 48-meter interval, at least 60 of these laminae occur; each is only about 0.5 to 2 mm thick.

Unit 2

A calcareous Upper Cretaceous sequence (Unit 2) lies beneath the muds and zeolitic muds of Unit 1. It is a light gray-brown nannofossil ooze, 44 meters thick (Cores 17 through 21), in contact with tholeiitic basalt. The lower contact is altered in large degree to micritic limestone and may have been baked.

Calcium carbonate is high (44% to 84%); nannofossils range from 20% to 70% (average 40%) and coarse micarb ranges from 25% to 80% (average 50%). Terrigenous components are relatively scant: 0-20% silt-size detritus (average about 6%), most of which is quartz (0-20%, average about 6%). Clay minerals form an equally sparse constituent (0-20%, average 8%). Trace amounts of micronodules, mica, heavy minerals, limonite, and zeolites are present.

Within Unit 2, 21 veins of sparry calcite occur (X-radiography suggests that more veins may be present but extensively broken by drilling). Vein thicknesses range from 3 to 13 mm. Thirteen veins are within and associated with reddish-brown ferruginous nannofossil oozes. This suggests an intimate relationship; perhaps metalliferous components were transferred to the host sediment by hydrothermal solutions that (may have) formed the calcite veins. These calcite veins also occur in the underlying tholeiitic basalt.

Basalt

Basalt was first cored at a subbottom depth of 449 meters, and a total of 7.5 meters was recovered. The upper 10 cm of the basalt core is yellowish-gray to dark gray, owing to extreme seawater alteration. Below the weathered zone, the basalt is medium to dark gray and in general is aphyric in texture.

The basalt is highly fractured and veined with calcite, particularly at the top; one vein, however, is deep green, and consists of prochlorite. Local areas, generally along fractures, contain reddish iron staining. Glassy zones are uncommon and may or may not represent tops of separate flows. Where present, they are thin (< 1 cm) and often mixed with calcite. Local brecciated zones also occur.

Thin-section examination shows phenocrysts and microphenocrysts of plagioclase and clinopyroxene, sometimes as glomerocrysts, in an intergranular groundmass of the same phases. Titaniferous magnetite is also present in the lowermost sections, and relict olivine crystals (highly oxidized) occur infrequently in the uppermost core. Alteration is most apparent in the replacement of clinopyroxene by clay minerals.

Discussion

Three findings are particularly significant in the sediments and sediment associations from this section: (1) the general paucity of calcareous sediments, (2) the high concentration of zeolites in the section, particularly in the middle and lower portions of Unit 1, and (3) the numerous thin laminae of bioclastic detritus, and zeolites and quartz within the zeolite muds of Unit 1.

The absence of a thick calcareous sediment unit at the base of the section (the calcareous sequence of Unit 2 is only 44 m thick) implies that the sea-floor depositional environment in the Brazil Basin has been beneath the CCD since Late Cretaceous time. Piston core data and information from other DSDP sites in this area reinforce this implication (see McCoy and Zimmerman, this volume).

Thus, the depositional history in the Brazil Basin began during the Late Cretaceous (Campanian) with accumulation of nannofossil oozes (Unit 2) in contact with basalt of similar age (see Fodor and McKee, this volume). This calcareous material now forms only a thin veneer over the basaltic basement, and is separated from the overlying muds of Unit 1 by a hiatus. Biogenic material indicates dissolution of calcareous components as a result of dissolution since the Brazil Basin passed beneath the CCD during the Maestrichtian. The large variation in carbonate concentrations

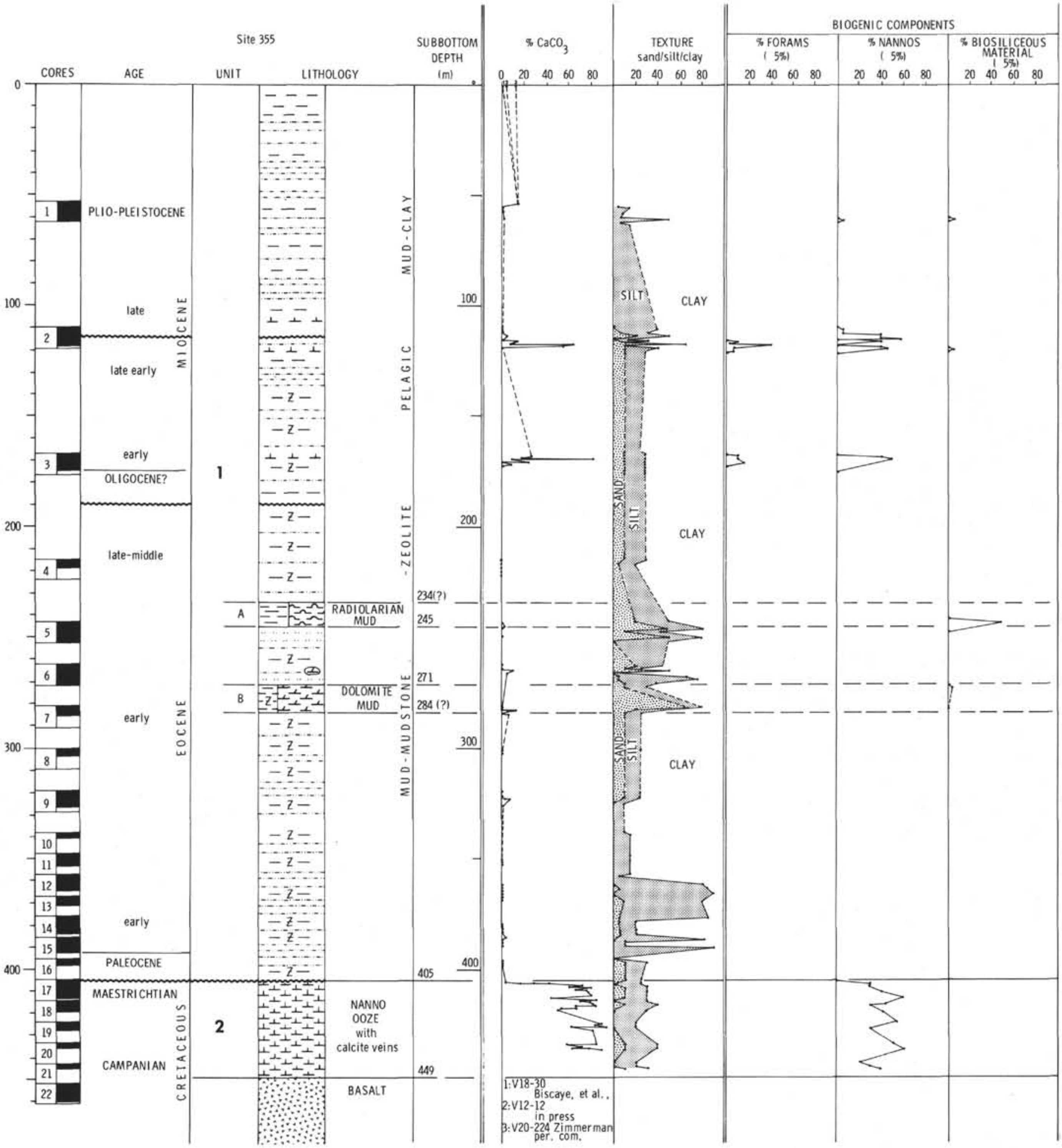


Figure 7. *Sedimentary components of Site 355 cores. Data are from smear-slide estimate, except $CaCO_3$ percentages, which are based on laboratory analysis.*

(see Figure 7) may also reflect differing degrees of dissolution.

During the Late Cretaceous, hydrothermal solutions enriched in CO_3^{-2} and metalliferous cations—perhaps implying proximity to the spreading center—migrated up through the calcareous oozes and produced metasomatic calcite veins and their associated red-brown ferruginous (?) zones.

With the absence in sediments of a significant carbonate component, the muds of Unit 1 became the dominant sediment type in the Brazil Basin. By the Campanian, significant influx of terrigenous detritus had already occurred in the northern Brazil Basin (see Sites 23 and 24 in Bader, Gerard, et al., 1970); and by the Eocene, this influx had also occurred farther south, at Site 355. Our drilling results indicate that the influx

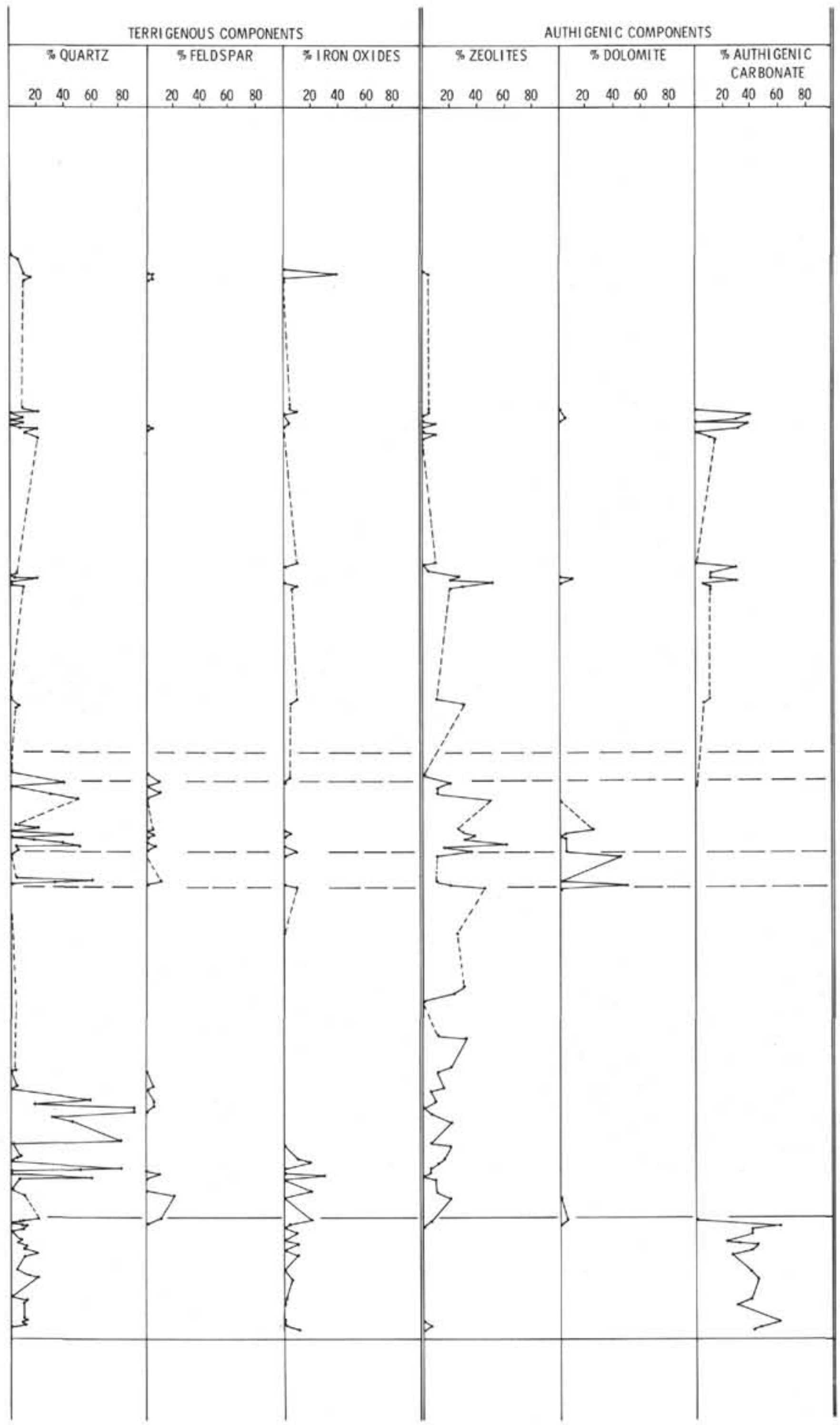


Figure 7. *Continued.*

was strong during the early Eocene (lower portion of Unit 1) and decreased significantly by the middle Eocene (middle portion of Unit 1), as shown by the smaller number of sand and silt laminae up-section. X-radiography supports this contention. Distal clay turbidite sequences are not apparent, so the decrease in the number of sand-silt laminae does not reflect dilution by finer materials. Textural data, in fact, imply that there may have been a progressive increase of coarser detritus as turbidity current processes diminished (note that the laminae become sandier up-section). The material forming the laminae was apparently derived from continental shelf and upper slope areas, as indicated by biogenic components (see

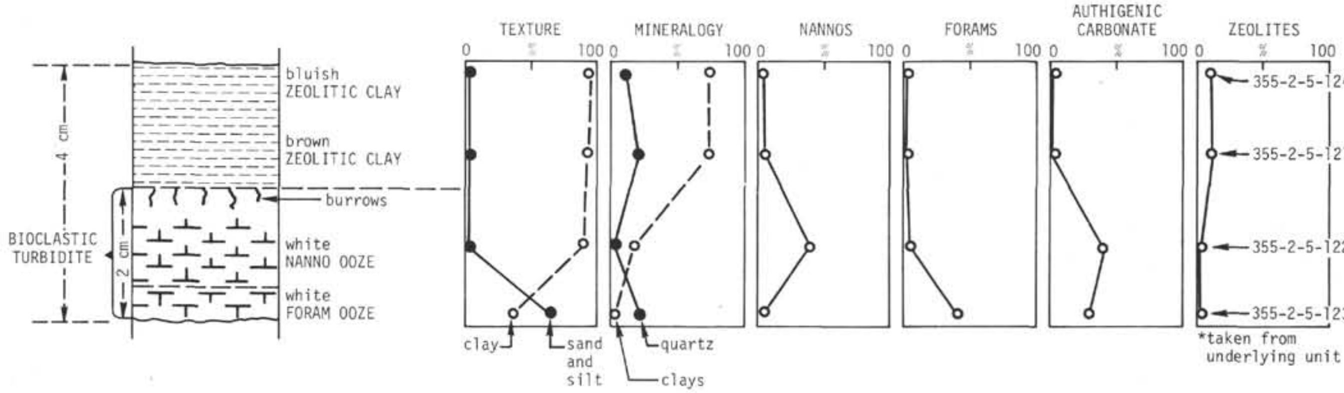


Figure 8. *Compositional variations in a bioclastic turbidite, subunit 1A Sample 355-2-5, 121-124 cm.*

Biostratigraphy) and quartz grain surface-morphological characteristics (see Krinsley and McCoy, this volume). Sediment accumulation rates were correspondingly high (see Sediment Accumulation Rates).

Detrital mineral assemblages of the turbidites suggest a chiefly volcanic rock source. Quartz grains contain vacuoles and some microlites as inclusions, and show straight extinction. The predominant feldspar appears to be twinned plagioclase. There is evidence of both extrusive and intrusive vulcanism in Brazilian marginal basins during the Late Cretaceous-Tertiary (Asmus and Ponte, 1973); erosion of these volcanics and the lower Cretaceous Paraná and the Serra Geral basalts in Brazil, as well as possible erosion of the Columbia Seamount Chain, may have provided a source. Orthoclase, hornblende, and micas, present in small amounts (see Emelyanov and Trimonis, this volume), imply some contribution from the Brazilian Shield.

Later diagenesis in the muds of Unit 1 led to growth of zeolites. The basal sand-and-silt laminae of turbidites seem to have been especially conducive to their formation.

Accumulation rates decreased with the decrease in turbidite deposition, until renewed bioclastic turbidite deposition during the Miocene. Since this calcareous material was emplaced below the CCD (foraminifers and nannofossils suggest dissolution; see Biostratigraphic Summary), rapid burial must have occurred. This is also indicated by bluish muds that suggest a reducing environment consequent to rapid burial of the underlying muds by the bioclastic deposits.

There is some evidence for continued turbidity current deposition in the upper portion of Unit 1 in the Plio-Pleistocene. Although X-radiography does not indicate turbidite structures here, displaced foraminifers occur (see Biostratigraphic Summary) in the core-catcher sample of Core 1, where the quartz content increases markedly (see Emelyanov and Trimonis, this volume). Deposition rates also appear to increase (see Sediment Accumulation Rates). Some volcanic components occur as volcanic ash or are represented by the higher feldspar content (see Emelyanov and Trimonis, this volume); perhaps they were derived from the Columbia Seamount Chain or from continued erosion of the Brazilian mainland.

GEOCHEMISTRY

We measured *p*H, alkalinity, salinity, and Ca^{++}, and Mg^{++} contents of 10 interstitial water samples onboard ship. Data are presented in Table 3 and Figure 9.

PHYSICAL PROPERTIES

The sediments recovered from Site 355 were in very poor condition for physical properties determinations. Most of the material consisted of "biscuits" of clay-rich material, about one inch thick, and appeared to have been compressed in the coring process. The matrix was mud, presumably derived from drill cuttings. Because of the mud surrounding the harder material, we abandoned velocity measurement on materials in split liners and resorted to the more time-consuming procedure of cutting and trimming individual pieces of

TABLE 3
Summary of Shipboard Geochemical Data

Sample (Interval in cm)	Subdepth (m)	*p*H	Alkalinity (meq/l)	Salinity (°/₀₀)	Ca++ (mmoles/l)	Mg++ (mmoles/l)
1-5, 144-150	60	7.27	2.78	35.2	14.88	49.44
2-4, 144-150	115	7.31	2.71	34.6	17.82	46.94
3-3, 144-150	170	7.12	3.17	34.1	24.43	41.98
4-2, 144-150	216	6.82	2.89	35.2	27.44	44.06
5-5, 144-150	250	7.35	3.76	33.6	33.09	46.26
9-4, 144-150	325	7.70	3.14	34.1	38.72	33.58
11-2, 144-150	350	7.54	2.18	34.2	40.61	31.20
15-3, 144-150	390	4.17	2.08	34.1	50.76	27.13
16-2, 144-150	398	7.12	2.10	34.1	45.29	31.57
17-4, 140-150	412	7.01	3.34	35.2	44.29	29.78

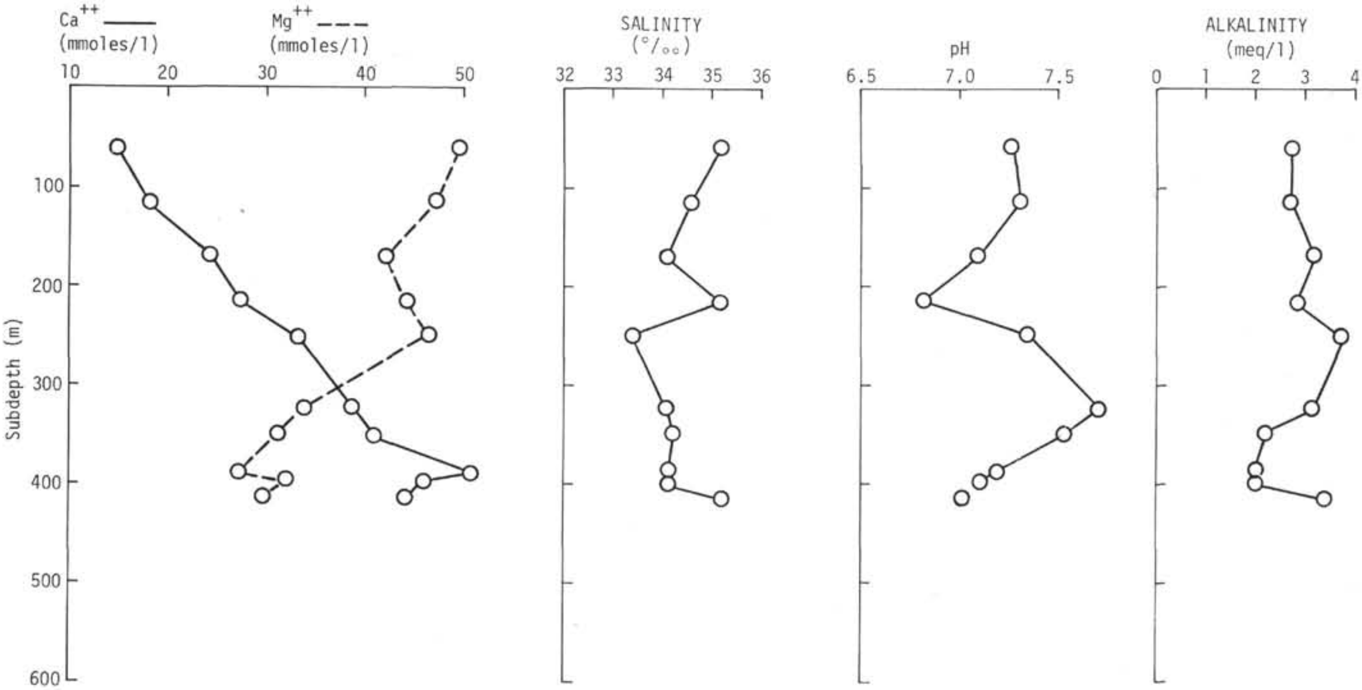


Figure 9. *Geochemical parameters (pH, salinity, alkalinity, Ca++, and Mg++ content) of interstitial waters versus depth, Site 355.*

hard sediment. The unusually pronounced fissility of these sediments posed another difficulty. Many promising samples were destroyed in trimming, and sampling took a long time. Cut samples were also used for 2-minute GRAPE and immersion density determinations. Because of the condition of the samples, the physical properties measured aboard ship (Table 4) are probably not representative of conditions in situ.

Downward through the sequence, some correlations between physical properties and lithology are possible (see Figure 10). The transition from mud/clay to zeolite mud at about 150 meters is not apparent, but the zeolite mud shows distinct gradients in velocity (1.54 to 1.80 km/sec) and in water content (40% to 26%). That no gradient is apparent in the widely scattered density data may be a consequence of the poor condition of the samples.

The mudstone bottom section of Unit 1 and the nannofossil ooze of Unit 2 both show strong gradients in velocity, density, and water content. The scattered velocity data for the mudstone are consistent with observations for mudstones recovered at other sites (see Sites 356 and 358). The water content of the ooze is distinctly lower than that of the mudstone unit.

In general, the measured physical properties for Site 355 indicate a moderate compaction trend, as shown by the marked increase in acoustic velocity below about 200 meters. A similar trend occurs in water content, and density values increase abruptly below 360 meters.

BIOSTRATIGRAPHIC SUMMARY

At Site 355 we penetrated 449 meters of sediment which ranges in age from Plio-Pleistocene to Campanian; hiatuses apparently occur between the upper and middle Miocene, between the lower Miocene and the middle Eocene, and between the lower Eocene and the lower Maestrichtian-upper Campanian. The hole terminated in very fractured and weathered basaltic basement. Figure 11 shows the biostratigraphic units encountered at this site.

The sediments of the first three cores range from the lower Miocene to the Plio-Pleistocene. Planktonic foraminifers and calcareous nannofossils are the most common microfossils; lesser amounts of radiolarians and both larger and smaller benthic foraminifers also occur, together with traces of pteropods, ostracodes, diatom remains, sponge spicules, and bryozoan and fish debris.

The nature and associations of these assemblages strongly suggest deposition by turbidity currents originating at relatively shallow depths on the Brazilian continental margin, since Site 355 lay well below the CCD throughout the Tertiary. Mixed with these bioclastic turbidites are layers of pelagic and hemipelagic sediment, but because the cores were intensely disturbed we could not determine exactly the depth of these layers.

Considering the nature of the sedimentary sequence—pelagic sediment interbedded with turbidity current deposits—it is surprising that the data from both the planktonic foraminifers and the calcareous nannofossils suggest the middle to upper Miocene hiatus, which also occurs at Site 354 and at several other South and equatorial Atlantic sites (Leg 3 and Leg 14).

From the top of Core 4 to the bottom of Core 15, radiolarians are essentially the only microfossils

TABLE 4
Physical Properties Data, Site 355

Sample	Depth	Velocity	Density (g/cc)				Porosity (%)			Acoustic Impedance		
(Interval in cm)	(m)	(km/sec)	S	I	G	Wt %	S	I	G	S	I	G
1-4, 58	58.08	1.487	–	–	–	–	–	–	–	–	–	–
2-5, 98	116.98	1.528	1.671		1.719	37.33	61.43	–	58.57	2.55	–	2.63
2-5, 102	117.02	1.571	1.845	–	1.992	43.37	51.04	–	42.27	2.90	–	3.13
3-4, 65	172.15	1.539	–	–	1.656	–	–	–	62.33	–	–	2.55
3-4, 110	172.60	1.542	–	–	1.655	–	–	–	62.39	–	–	2.55
3-5, 55	173.55	1.557	–	–	1.698	–	–	–	59.82	–	–	2.64
3-5, 108	174.08	1.559	–	–	1.675	–	–	–	61.19	–	–	2.61
4-3, 120	218.70	1.587	–	1.700	1.760	–	–	59.70	56.12	–	2.70	2.79
4-3, 135	218.85	1.578	–	1.690	1.771	–	–	60.30	55.46	–	2.67	2.79
5-3, 21	246.21	1.642	–	–	–	33.94	–	–	–	–	–	–
5-4, 130	248.80	1.641	–	1.610	1.771	–	–	65.07	55.46	–	2.64	2.91
5-6, 141	251.91	1.575	–	–	–	40.15	–	–	–	–	–	–
6-2, 75	264.25	1.655	–	1.640	1.647	–	–	63.28	62.87	–	2.71	2.73
6-3, 60	265.60	1.629	1.840	–	–	31.37	51.34	–	–	3.00	–	–
7-2, 34	282.84	1.682	–	–	–	–	–	–	–	–	–	–
8-2, 95	302.45	1.681	–	1.640	–	–	–	63.28	–	2.76	2.76	–
8-2, 95	302.45	1.725	1.640	–	–	–	63.28	–	–	2.83	–	–
9-1, 112	320.12	1.714	–	1.670	1.727	–	–	61.49	58.09	–	2.86	2.96
9-2, 65	321.15	1.735	1.650	–	–	–	61.69	–	–	2.86	–	–
9-3, 95	322.95	1.716	–	–	–	–	–	–	–	–	–	–
9-4, 75	324.25	1.759	–	–	–	–	–	–	–	–	–	–
10-1, 142	339.42	1.759	–	–	–	33.33	–	–	–	–	–	–
10-2, 91	340.31	1.746	–	1.650	–	28.32	–	62.69	–	–	2.88	–
11-1, 121	348.71	1.803	–	1.610	–	30.08	–	65.07	–	–	2.90	–
12-5, 126	364.26	1.674	–	1.690	–	30.97	–	60.30	–	–	2.83	–
14-3, 103	380.03	1.781	–	1.70	–	–	–	54.93	–	–	3.17	–
14-4, 87	381.37	1.719	–	–	–	–	–	–	–	–	–	–
14-5, 149	383.49	1.806	–	1.890	–	26.91	–	48.36	–	–	3.41	–
15-2, 72	387.72	1.614	1.840	–	–	26.28	51.34	–	–	2.97	–	–
15-3, 24	288.74	1.651	1.760	–	–	37.84	56.12	–	–	2.91	–	–
17-1, 120	405.70	1.644	–	–	–	13.28	–	–	–	–	–	–
17-2, 132	407.32	1.743	2.000	–	–	20.33	41.79	–	–	3.49	–	–
17-3, 126	408.76	1.731	–	–	–	17.17	–	–	–	–	–	–
17-4, 63	409.63	1.754	1.970	–	–	18.10	43.58	–	–	3.46	–	–
17-5, 60	411.10	1.775	1.950	–	–	17.65	44.78	–	–	3.46	–	–
18-1, 8	414.08	1.900	2.030	–	–	17.98	40.00	–	–	3.86	–	–
18-1, 90	414.90	5.791	–	–	–	–	–	–	–	–	–	–
18-2, 15	415.65	1.844	–	–	–	17.99	–	–	–	–	–	–
19-1, 137	424.87	1.868	–	–	–	–	–	–	–	–	–	–
19-3, 65	427.15	1.745	–	–	–	17.07	–	–	–	–	–	–

NOTE: S = syringe technique, I = immersion technique, G = GRAPE.

present. Small numbers of diatom remains occur in the upper part of the section, and fish teeth and fish debris are common in Cores 14 and 15. Preservation of the radiolarians is generally poor and indicates that remobilization of opaline silica has occurred. The sediment ranges from upper middle Eocene in Core 4 to lower Eocene in Core 15. Deposition in this interval was continuous and rapid (see Sediment Accumulation Rates). The abundant to common radiolarians and the high deposition rates agree with the contention of Ramsay (1971) that parts of the Eocene Atlantic were areas of high productivity, with consequent deposition of siliceous sediments, and that no significant deposition of siliceous sediments has occurred since.

Radiolarians are absent below Core 15. Fish teeth and fish debris are the principal biogenic components in the red clays of Cores 15 and 16, and are still important constituents of the biogenic fraction in Cores 17 and 18. Cores 17 to 21 contain calcareous nannofossils and benthic foraminifers of early Maestrichtian to Campanian age. We cannot be certain whether the absence of any datable upper Maestrichtian-Paleocene material is a consequence of a hiatus or of the very slow accumulation of the zeolitic and ferruginous clays.

Foraminifers

In this area of the Brazil Basin, sediments containing calcareous foraminifers consist of (1) clay-rich turbidites in Core 1, (2) Neogene clay-rich layers interbedded with foraminifer sands in Cores 2 and 3, and (3) Cretaceous clay-rich nannofossil ooze, with very small percentages of calcareous foraminifers, in Cores 17 through 20. Foraminifers were not found in the predominately green clay of Cores 4-15 and in the brick red clay of Core 16, most of which contains siliceous microfossils.

Clay-Rich Turbidites

Core 1 contains a small assemblage of planktonic foraminifers, including *Globigerinoides ruber*, *G.*

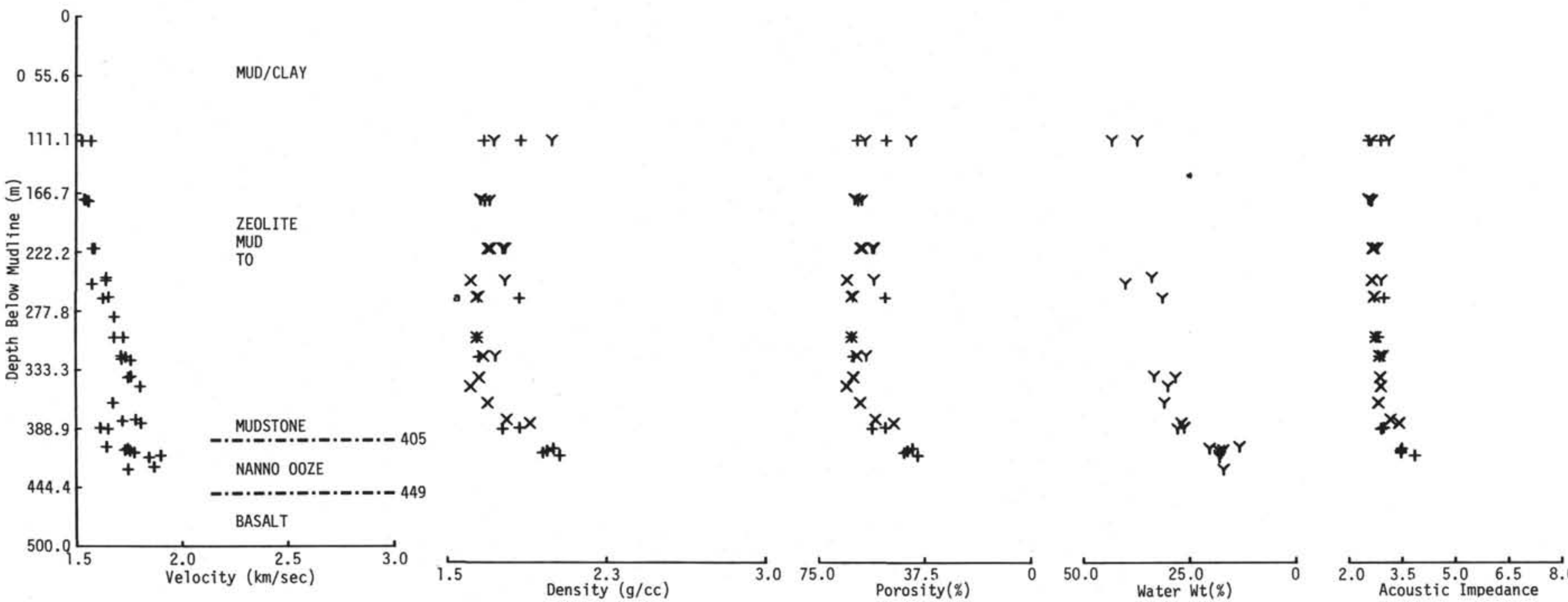


Figure 10. *Physical properties versus depth; +, x, and y represent syringe, immersion, and GRAPE values, respectively.*

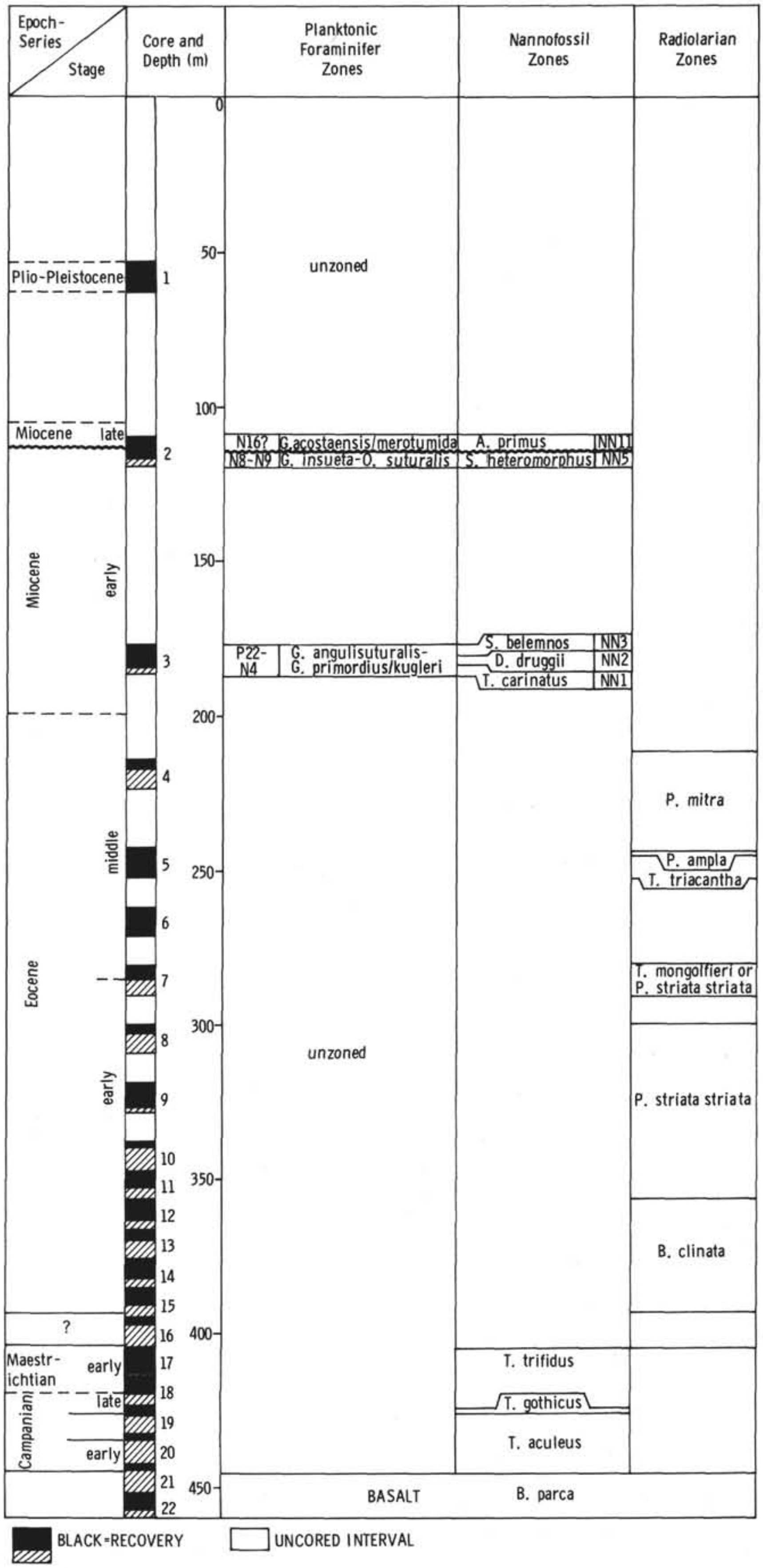


Figure 11. *Biostratigraphic summary, Site 355.*

trilobus, *Globorotalia scitula*, *G. tumida*, *Globigerinita glutinata*, *Globigerina pachyderma*, and *Candeina nitida*. Most foraminifers, including the benthic species, are fragmented and dissolved. Those that remain are generally small and some are very fragile. Along with the foraminifers there are sponge spicules, radiolarians, echinoid fragments, fish debris, and several pteropods.

Since the core was taken from water depths close to 5000 meters, and the CCD in this area of the South Atlantic is estimated at 4600 meters, calcareous material did not seem likely in this core. The presence of foraminifers and particularly of pteropods indicates rapid redeposition.

Although not indicative of an age more precise than Pliocene to Pleistocene, the planktonic foraminifers appeared "young"; we assign them tentatively to the Pleistocene. The presence of *Globigerinoides ruber* and absence of *G. obliquus* support this age assignment.

Neogene Oozes

Most residues are composed of about 70% quartz silt and 30% calcareous foraminifers. The foraminifers are often broken and corroded, planktonic and benthic species alike. The assemblages of planktonic foraminifers are dominated by the fragile globigerinids and *Globigerinoides* sp.; globorotaliids are rare and often fragmented.

The index species include *Globigerina nepenthes*, *Orbulina universa*, *Globigerinoides obliquus*, *Sphaeroidinellopsis seminulina*, *S. subdehiscens*, *G. bulloides*, and *Globorotalia menardii*. The benthic fauna indicates a deep environment, and contains smooth and hispidocostate uvigerinids, some rotalids, *Bulimina*, and *Bolivina*. Also present are cancellate ostracodes and echinoid and fish debris.

The age of the samples is late Miocene. The fauna implies tropical open marine conditions and apparent flooding with turbidite sands that also may have brought the ostracodes.

Below approximately 120 cm in Section 2-2, there is a lithologic change, reflected also by a change in the foraminifer fauna. Quartz silt is still abundant and foraminifers are fragmented. However, the planktonic fauna now consists of *O. universa*, *Globoquadrina altispira*, *Praeorbulina transitoria*, *Biorbulina* sp., and *G. praebulloides*. In addition to the deep benthic foraminifers, smooth, cancellate, and ridged ostracodes, sponge spicules, radiolarians, and diatom remains are present.

This fauna belongs to the lower to middle Miocene. A middle to upper Miocene hiatus is indicated in Section 2 of Core 2, around 120 cm.

The residue from Sample 2, CC, however, contains an older fauna, but does not contain the quartz silt. Planktonic foraminifers are small. The larger globorotaliids and globoquadrinids are absent. The fauna does contain *Praeorbulina glomerosa*, *P. transitoria*, *G. praebulloides*, *Globorotalia peripheroronda*, and *Globigerinoides diminutus*. Ostracodes are punctate and smooth, and benthic foraminifers are rare, but of deep-water origin. Echinoid fragments and sponge spicules are also present.

Because *Orbulina* is absent and its predecessor *Praeorbulina* is present, we assign this sample to the lower Miocene, top N7-N9. The fauna indicates open marine, deep-water conditions and a turbidite origin.

Core 3 contains clay-rich oozes with interbedded coarse-grained foraminifer sands. We examined both the oozes and the sands.

Oozes

The clay-rich oozes from Sections 1-5 of Core 3 contain a planktonic foraminifer fauna rich in tiny globigerinids and *Globigerinoides* sp. The expected globorotaliids and globoquadrinids, typical of this part of the column, are rare to absent. The planktonic species include *Globoquadrina altispira*, *Globigerinoides primordius*, *Globigerina praebulloides*, *Globorotalia* (*T.*) *kugleri*, *Globigerinoides trilobus*, *Globigerina ciperoensis*, and *Globoquadrina sellii*. The benthic foraminifers are deep-water species of *Nonion*, *Angulogerina*, *Nuttallides*, *Lagena*, and *Nodosaria*.

The ooze from Sample 3, CC, contains *Globorotalia* (*Turborotalia*) *opima nana*. Thus, the core apparently ranges in zone from N5-N6 in the top sections to N4/P22 in the core-catcher sample. The benthic species indicate a deep-water origin for this sediment.

Coarse Foraminifer Sands

These sands contain a surprising fauna of larger benthic foraminifers and other invertebrate fossils, mixed with the oozes described above. Included in this coarse material are *Miogypsina*, *Gypsina*, *Sphaerogypsina*, *Amphistegina*, large rotalids, large sections of bryozoans, and possibly calcareous algae.

Such fossil debris is usually associated with a reef or carbonate platform environment. Depths indicated are substantially less than 200 meters. These are presumably turbidite sands derived from very shallow waters and intercalated into the ooze sequence.

Cores 4 through 16 contain zeolitic pelagic clays and mudstones which lack foraminifers.

Cretaceous Clay-Rich Oozes

The calcareous component of residues of Cores 17 to 20 is minor and consists almost entirely of benthic foraminifers. Although the percentages of the genera vary, the faunas are similar and are dominated by *Reussella*, *Semivulvulina dentata*, *Pullenia*, *Dorothia*, and species of the key genera *Ammodiscus*, *Aragonia*, *Pleurostomella*, and *Buliminella*. Notably absent is the genus *Gavelinella*. In these samples the planktonic species are entirely dissolved; only a few pieces attest to their previous existence. The benthic species are corroded and fragmented. Outer chambers in the rotalids have been dissolved, leaving only the umbilical areas thickened by umbilical nodes. *Inoceramus* is present in Core 19.

This fauna is typical of the Upper Cretaceous and contains abyssal benthic foraminifers (see Sliter, this volume).

Calcareous Nannofossils

Three Neogene (Cores 1-3) and six upper Cretaceous cores (Cores 17-22) contain calcareous nannofossils. The remainder of the cores, all probably of middle to early Eocene age, consist mainly of zeolitic pelagic clays and are barren of coccoliths. The distribution of species is shown in tables in Perch-Nielsen (this volume). The distribution of coccolith zones is summarized in Figure 11.

Pleistocene-Pliocene (Core 1)

The seven samples of brown clay studied from Core 1 are barren or contain very few coccoliths. A few *Gephyrocapsa* sp. without visible bridges and scarce *Sphenolithus neoabies* indicate a Pliocene rather than Pleistocene age for this core, which was taken at 53 meters.

Miocene (Cores 2 and 3)

The Miocene material in Core 2 includes rich and well-preserved assemblages of the upper Miocene *Discoaster quinqueramus* Zone (NN 11) in the upper part of Section 2. In the lower part of this section, below 120 cm and down to the core-catcher portion, assemblages of the lower to middle Miocene *Sphenolithus heteromorphus* (NN 5) Zone occur. This indicates that a hiatus of about 7 m.y. is present in this section. Caution is necessary, however, in interpreting this sequence. The interval from 62.5 meters to 110 meters, where Core 2 was taken, was drilled with the core barrel in place, so the recovered sediment could have been "picked up" anywhere within this interval.

The assemblages in Cores 2 and 3 contain rare to few *Braarudosphaera bigelowi* and *Micrantholithus* sp., neither of which is usually found in open ocean sediments. Since part of Core 2 consists of clays deposited below the CCD and barren of coccoliths, the presence and relatively good preservation of the coccoliths may indicate a turbidite origin for the calcareous layers. The number of reworked older coccoliths, however, is very small.

Although the core-catcher sample and samples from Sections 4 and 5 of Core 3 are barren, the three upper sections contain common to a few fairly well preserved coccolith assemblages of the *Sphenolithus belemnos* Zone (NN3), the *Discoaster druggi* Zone (NN2), and possibly the *Triquetrorhabdulus carinatus* Zone (NN1), all lower Miocene. Since we do not know exactly where the core was taken, we cannot be sure whether the proximity of these three zones, which span some 7 m.y., is a result of very slow accumulation or a hiatus, or is a drilling artifact.

Late Cretaceous

Lower Maestrichtian and Campanian coccolith assemblages of the *Tetralithus trifidus*, *T. gothicus*, and *T. aculeus* zones occur in Cores 17-21. An early Campanian age can be assigned to a slightly indurated pink chalk sample recovered from the core catcher of Core 22 (*Broinsonia parca* Zone of Perch-Nielsen, this volume).

The coccolith assemblages are generally poorly preserved and of low diversity, and solution-resistant species dominate. *Kamptnerius magnificus* is absent and *Arkhangelskiella cymbiformis* is extremely rare. Both were relatively common in the slightly younger chalk of comparable age at Site 354 on the Ceará Rise.

The oldest datable sediment recovered at this site is 76 to 80 m.y., according to Bukry's (1974) correlations of coccolith zones, stages, and ages.

Radiolarians

Radiolarians are present only in the sediment recovered between 170 and 390 meters below the sea floor (Section 3-3 to Sample 15, CC). The sediments are zeolitic pelagic clays between Section 3-3 and Sample 11, CC, and silty claystones between Core 12 (top) and Sample 15, CC. In most samples, radiolarians make up the bulk of the coarse fraction, except in the lower part of the section (bottom of Core 14 and Core 15), where fish debris and mineral grains are more abundant. Preservation of the radiolarians is in general rather poor, owing to dissolution and remobilization of the biogenic silica. At several intervals this makes species identification difficult and age assignment uncertain. In spite of the poor preservation consequent to dissolution, the diversity is surprisingly high, which indicates that perhaps remobilization of the opaline silica has affected the assemblages for a relatively short period. Fish debris is a constituent of the coarse fraction throughout, and increases in abundance in Cores 14 and 15.

Miocene-Oligocene

Few specimens of *Cannartus prismaticus*, *Cannartus* sp., *Calocycletta* sp., and *Dorcadospyris* sp. occur in very poorly preserved assemblages of Sections 3-4 and 3-5 and the core-catcher sample. They indicate a late Oligocene to early Miocene age for this interval.

Eocene

A moderately well preserved assemblage of the middle Eocene *Podocyrtis mitra* Zone is present in Sample 4, CC, and in Section 5-1. The assemblage is diverse, and the presence of *Sethochytris triconiscus* indicates that the upper part of the *P. mitra* Zone is represented. The presence of sediments of this age only about 40 meters below the lower Miocene in Sample 3, CC, suggests that a hiatus is probable somewhere in this interval. In Cores 5, 6, and 7, preservation of the radiolarians deteriorates considerably. Section 5-2 belongs to the short *P. ampla* Zone, and Sections 3, 4, and 6 and Sample 5, CC, can be assigned to the *Thyrsocyrtis triacantha* Zone. Samples from Core 6 cannot be assigned to a zone because the assemblages are poorly preserved, but *Podocyrtis sinuosa* suggests a middle Eocene age for this core. The assemblage of Core 7 belongs to the *Theocampe mongolfieri* Zone of the lowermost middle Eocene, or to the lower Eocene *Phormocyrtis striata striata* Zone, assemblages of which occur down to the bottom of Core 11. Cores 12 through 15 can be assigned to the lower Eocene *Buryella clinata* Zone. No radiolarians occur in the sediments below Sample 15, CC.

Palynomorphs

Ioannides and Colin (this volume) studied palynomorphs from Sections 15-1, 15-2, 15-3, and 15-4, of early Eocene age; Sections 16-1, 16-2, and 17-1, of unknown age; and Sections 17-2, 17-3, 17-4, 17-5, and 17-6, of early Maestrichtian-late Campanian age. Most samples are devoid of any acid insoluble microfossils. The two questionable records of the dinoflagellate *D. phosphoritica*—a species confined to Eocene and Oligocene sediments—in Sample 17-1, 135-40 cm, seem insufficient evidence for dating the ferruginous zeolitic claystone as early Eocene. It is uncertain whether there is a hiatus between the lower Eocene and the lower Maestrichtian-Campanian in Section 17-1, or whether a period of slow, more or less continuous sediment accumulation occurred.

SEDIMENT ACCUMULATION RATES

Drilling results confirm earlier speculation on the history of sediment accumulation at this site, and confirm particularly the likelihood of one or more hiatuses, although only intermittent coring was possible in the upper part of the sequence and biostratigraphic control is lacking in a few cores. A hiatus probably occurs in Section 2-2 between the upper Miocene and the lower to middle Miocene; a hiatus including most of the Oligocene and the upper Eocene is also highly probable. Another major hiatus or sequence of extremely slow accumulation seems to represent most of the Paleocene and the upper Maestrichtian.

The accumulation rate was about 2 cm/1000 yr during the Pleistocene and the Pliocene. This rather high rate for a brown pelagic mud was probably caused by the contribution of turbidity currents. The same is true for the lower to middle Miocene sequence, which seems to have been deposited at about the same rate.

Miocene Hiatus

This hiatus occurs at about 120 cm in Section 2-2, a section highly disturbed by drilling. A major change in lithology occurs at about this depth in the section. Foraminifers and coccoliths indicate an age of late Miocene and early to middle Miocene for calcareous sediment lumps floating in the non-calcareous brown clays. It is unlikely that this hiatus is a drilling artifact, since the core barrel was not full when recovered and the sediment seemed soft enough to wash away easily.

Oligocene Hiatus

Core 3 contains foraminifer zones (N4, P22) and coccolith zones (NN3, 2) which indicate that the oldest sediment in this core is of early Miocene or possibly latest Oligocene age. Core 4 was taken at 215-224 meters, 38 meters below Core 3, and was dated by radiolarians to be of late middle Eocene age (about 42 to 45 m.y., *Podocyrtis mitra* Zone).

This suggests either (1) continuous accumulation at an average rate of only 0.2 cm/1000 yr or (2) more plausibly, a higher rate just above Core 4 and a hiatus spanning most of the Oligocene and possibly the latest Eocene, since the lithology in Core 4, with accumulation rate of about 1 cm/1000 ur (Figure 12, accumulation rate in the middle Eocene, between Core s 4 and 5), may continue on up to about 190 meters, where a drilling break occurs.

The accumulation rate of the lower Eocene zeolitic muds was high, presumably because of contribution of terrigenous material by turbidity currents.

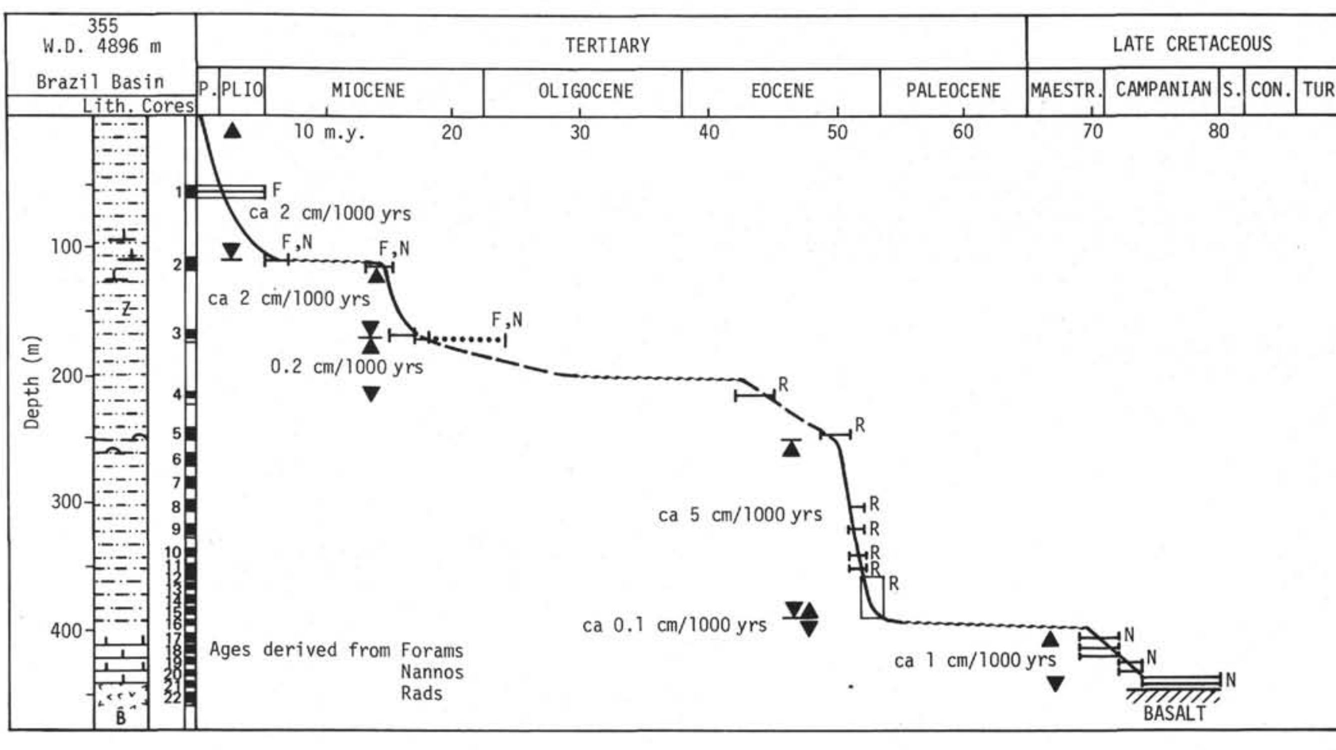


Figure 12. *Sediment accumulation history, Site 355.*

Paleocene-Maestrichtian Hiatus

The lowermost datable Tertiary sediments occur at 390 meters in Core 15; on the basis of radiolarians (*Buryella clinata* Zone), we assign them an age of 52 to 52.5 m.y. The uppermost datable Cretaceous sediments occur in Core 17; coccoliths (*T. trifidus* Zone) indicate an age of 69 to 72 m.y. Thus, the approximately 16 meters of red-brown mudstones, for which no age can be assigned, represent an interval of some 15-20 m.y., and if sedimentation was uninterrupted, would probably have been deposited at an average rate of less than 0.1 cm/1000 yr. This is unlikely in view of the high accumulation rate of the overlying sediments, whose lithology is basically the same as that found at the top of Core 17. The upper Maestrichtian and at least part of the Paleocene is probably represented by a hiatus.

Late Cretaceous

The coccolith zones in the Maestrichtian and Campanian are too long for more accurate calculation of the accumulation rate for the nannofossil ooze and chalk recovered in Cores 17-21. A rate of 1 cm/1000 yr seems reasonable, on the basis of the age ranges of the zones encountered (*Tetralithus trifidus*, *T. gothicus*, *T. aculeus*, and *Broinsonia parca*.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The reference reflection profile at Site 355 (LDGO profile 570 from R/V *Conrad* Cruise 16-04, Figure 3) shows an acoustically transparent sedimentary column, about 0.47 sec thick, overlying basement. A sonobuoy near the site (Figure 3, sonobuoy #85C16) indicated that the average velocity of sediments overlying basement is approximately 2.0 km/sec. On the basis of this information, a basement depth of 470 meters subbottom was predicted.

Like the reference profile, the approach profile (Figure 5) shows no well-defined continuous intermediate reflectors. The patchily distributed reflections are of unknown nature and significance; they may indicate lateral inhomogeneities in sediment type, or may be artifacts of acoustics or electronics. Basement is clearly evident, particularly under the transparent sediment sections.

The sonic velocities measured in the first few cores range from 1.5 to 1.7 km/sec. The measured velocities indicated that the basement might be present at a shallower depth than anticipated, i.e., within 380 to 400 meters subbottom. The basement was cored at 448 meters subbottom. The actual depth to basement suggests that the average velocity for the column is closer to that indicated by the sonobuoy than to velocities measured in the cores (see Table 4). The 0.47-sec two-way time through the sedimentary column and 448-meter thickness gives an average velocity for the entire column of 1.91 km/sec, which is close to the 2.0 km/sec measured with the sonobuoy. The discrepancy between the velocities measured in cores and those measured in situ by sonobuoy probably results from the relatively high degree of disturbance in the cores.

The sedimentary section at Site 355 appears to be acoustically homogeneous; most of it is composed of brown mud and clay and zeolitic pelagic clay. The interbedded layers of gravity-displaced sediment are probably too thin and too infrequent to create reflectors on the seismic record. Although the clay changes to claystone near the bottom of the section, and the claystone overlies nannofossil ooze, even these contrasts are apparently not sufficient to register as continuous reflectors on the seismic profile record.

SUMMARY AND CONCLUSIONS

The basalt cored at Site 355 is a typical ocean-ridge tholeiite (Fodor et al., this volume). It is assumed to be a surface flow, so its age is representative of the age of ocean crust at this distance from the present mid-ocean ridge. McKee and Fodor (this volume) have obtained a K/Ar age of 78.1 ±9 m.y. for the basalt, which is in excellent agreement with the early Campanian age determined by nannofossils. The position of the site with respect to magnetic anomalies 33 and 34 (Figure 2) provides a calibration point at the older end of the magnetic reversal time scale of Heirtzler et al. (1968).

Unconsolidated Campanian to lower Maestrichtian nannofossil ooze forms the basal sediment sequence, and numerous veins of calcite (satin spar) occur within the ooze. The veins are presumably the product of a diagenetic process associated with hydrothermal solutions which acted upon the sediments when the site was still within the region influenced by crustal generation. A hiatus probably separates the calcareous sediments from the overlying noncalcareous pelagic clays and terrigenous sediments. The lower Eocene sediments contain numerous laminae of sand and silt, which indicate a period when turbidity currents were contributing detritus. The laminae contain abundant zeolites, presumably authigenic. Siliceous organism remains occur in significant quantity in the middle Eocene. Bioclastic carbonate debris was introduced by turbidity currents in the Miocene.

A mid-Miocene hiatus occurs in Core 2, a middle Eocene hiatus is probable between Cores 3 and 4, and a middle Maestrichtian-lowermost Eocene hiatus or interval of very slow sediment accumulation exists between Cores 15 and 17. A mid-Miocene hiatus occurs on the Ceará Rise (Site 354, this volume; Site 142, in Hayes, Pimm, et al., 1972) and at other Atlantic DSDP sites (Pimm and Hayes, 1972). An Eocene-Oligocene hiatus was also found at Site 354 and at Site 144 on the Demerara Rise; Maxwell et al. (1970) report an Oligocene hiatus at the Rio Grande Rise. The Cretaceous-Tertiary hiatus (or at least period of nondeposition of carbonate) also occurs at both the Demerara Rise and the Ceará Rise sites, and is probably widespread. In a later chapter, Supko and Perch-Nielsen (this volume) discuss the significance of Leg 39 hiatuses in terms of broad paleooceanographic patterns.

Figure 13 is a plot of the average depth to basement in the South Atlantic versus age of the oceanic crust, after Sclater et al. (1971). It shows the present basement depth (corrected for isostatic effect of sediment load)

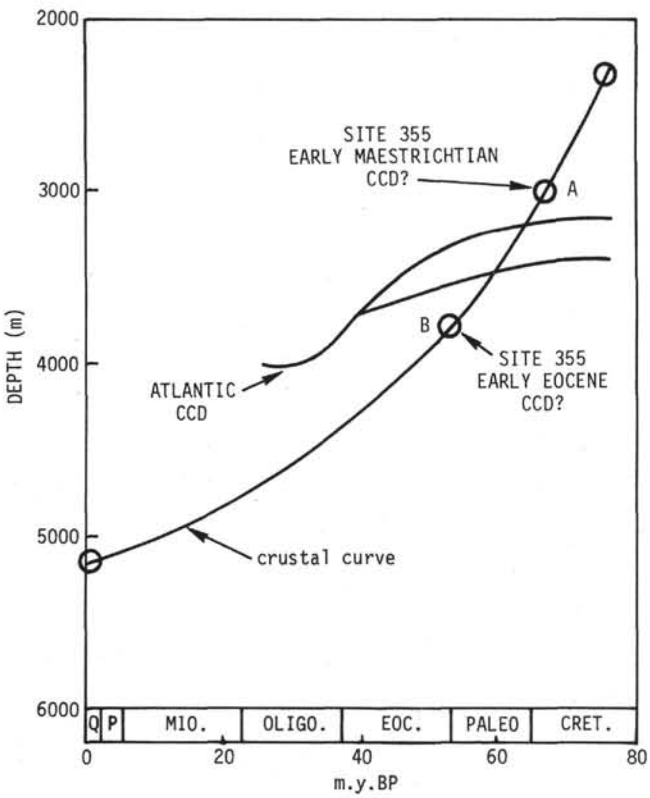


Figure 13. *Average depth to basement in the South Atlantic versus age of the oceanic crust, after Sclater et al. (1971)*

and determined crustal age at Site 355. If we assume that no subsequent vertical uplift has taken place and that subsidence was of the normal type described by Sclater et al. (1971), then back-tracking of the Site 355 data point (solid line, Figure 3) indicates the crust formed at a mid-ocean ridge at a water depth of about 2200 meters, as against the present average ridge crest depth of about 2700 meters.[2]

Still assuming normal basement subsidence, we may view the transition from calcareous to noncalcareous sediments in terms of its significance for the level of the CCD by considering two extreme examples. At one extreme, we assume that the depositional site accumulated 45 meters of carbonate in about 8 m.y. (early Campanian to early Maestrichtian), and that carbonate deposition ceased in the early Maestrichtian because the site subsided below the CCD. Normal subsidence rate would give an early Maestrichtian CCD level of about 3000 meters (Figure 13, Point A). In this case, the 16 meters of undated zeolitic and ferruginous clays between the chalk and the next younger sediments, dated early Eocene, could represent a period of very slow deposition at an average rate of ~0.1 cm/1000 yr, or could contain a hiatus.

At the other extreme, we may assume that the sediment directly above the carbonate is as young as lower Eocene, that carbonate deposition continued until the early Eocene at the latest, and that carbonate deposited after the early Maestrichtian was subsequently removed. The subsidence curve indicates an early Eocene CCD of ~ 3700 meters (Point B in Figure 13). The missing section in this extreme case would have to have been removed over a short period at the Paleocene-Eocene boundary; and since dissolution facies (pelagic clay) would be absent, the cause of the hiatus would have been current action instead of—or at least in addition to—dissolution.

The CCD for the Atlantic is shown by the dashed line in Figure 13, after van Andel (1975) and Berger and von Rad (1972). (Note that the envelope prior to late Eocene is a result of poor control.) Point A falls above the CCD curve, and so indicates that carbonate deposition should have continued after the early Maestrichtian. Point B falls considerably below the CCD envelope; this indicates that carbonate deposition probably ceased before the early Eocene.

Calcareous nannofossils in the uppermost part of the chalk sequence show dissolution effects (dominance of resistant species, solution, etc. but this may be a consequence of either synsedimentary processes or dissolution associated with erosional removal. Planktonic foraminifers are absent throughout the calcareous sequence.

[2]This is at odds with the conclusions of McCoy and Zimmerman (this volume), who interpret their data on the distribution of carbonates through time as indicating growth of the ridge as a positive feature only in the Cenozoic.

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APPENDIX A
Smear-slide Summary

	Sand	Silt	Clay	Quartz	Feldspar	Mica	Heavy Minerals	Clay	Iron Oxides	Pyrite	Opaques	Micro Nodules	Dolomite	Zeolite	Authigenic Carbonate	Foraminifers	Calcareous Nannofossils	Diatoms	Radiolarians	Sponge Spicules	Fish Remains	Remarks
Site 355																						
1-2, 50		5	95			1	1	85				5	5									
1-2, 55		15	85	5		2		90	1			1	1	1								
1-5, 135		50	50	10	5			40	40					5					5	1		
1-6, 125		5	95	15	5	1	1	75	1			1		5								
1, CC		15	85	10			5	75	1			5		5								
2-1, 139		40	60	10				80	5				1	5			5					
2-3, 111		30	70	20				60	10			1		5			5					
2-3, 138	5	25	70					20					1		40		40			1		
2-5, 90	20	30	50	10	1			5					5		30	10	40					
2-5, 110	10	20	70	1				20							15		60			5		
2-5, 121		10	90	10				75	5		1		1	10			1					
2-5, 122	10	20	30					15							40	1	40			5	1	
2-5, 123	65		35	20	5										30	40	5					
2-5-124	10	30	60	10				75		5			1	10			1					
2-5, 138	10	20	70	20				20		1		1		1	10	5	40					
2, CC	10	20	30	1				30				1	1		15	5	45			5		
3-1, 58	10	15	75					70	10			5		10			5					
3-1, 63	10	20	70					20	1					1	30	10	40					
3-2, 122	10	20	70	1				20						5	10	10	50			5	1	
3-2, 138	10	20	70					15						25	10	15	35					
3-3, 114	10	20	70	20		1		15					10	20	30	5						
3-3, 119	10	20	70					40				5		50	5		2					
3-5, 20	10	20	70					50	10					30	10		2					
3, CC	10	20	70	10				50	5			5		20	10							
4-1, 130	10	20	70					65	10			5		10	10							
4-3, 120	5	15	80					60	5				1	30	5							
5-1, 60	20	30	50					45	5										40	10		
5-3, 37	50	30	20	40	10			20						20						10		
5-4, 100	5	15	80					80		5				15				1				
5-6, 38	50	30	20	30	10			40		5				15								
5-6, 105		50	50	50		1			1			1	1	50								
6-1, 96	–	–	–	5	–	–							95									Dolomite Rock Fragment
6-3, 23	20	25	45	20	5	1		30				5	15	25					1			
6-3, 105	10	15	85					60	5				5	30								
6-4, 8	50		50	45	5							5		40								
6-4, 30		25	75					55		1		4	5	30								
6-5, 31	5	60	35	35									5	60								
6-5, 64	5	70	25	50	5		1	10			15		5	15								
6-5, 86	10	30	60	5		1		50	10			1	5	35							1	
6, CC	10	20	70					40		5			45	10								
7-2, 10	70	10	20	60	10	5	5	5		5			1	10								
7-2, 50	20	30	50					30					50	20			1					
7-3, 100	10	15	75					40	10			5		45								
8-2, 120	10	15	75			1		75						25				1				
9-1, 80	10	15	75					65				5		30				1				
9-2, 130	10	15	75					80						20								
9-3, 8		10	90	2		1		90				1	1	2					1			
10-2, 84		10	90					90				1		10								
10-2, 110		15	85					70						30					1			
11-1, 98		15	85					80	1					20					1			
11-2, 30		15	85					90						10								
12-2, 29		15	85	5	5	3		70				2		15								
12-3, 70		5	95					95						5					1			
12-5, 123		80	20	60	5	10	5	10						10								
12, CC	5	80	15	90	5	1	1	5						1								White Layer
13-2, 21	1	90	10	90		1	5					1	1	5								
13-2, 120	10	70	20	45		10		20			5			20								
14-2, 5	5	85	10	80			2	10					1	5								
14-2, 70	5	15	80	1				80			1			20								
14-4, 25	5	15	80	5				70	10					15								
14-5, 32	5	15	80					65	20		5			10								
15-1, 47		80	20	80		1	5	10						5							1	
15-1, 92		10	90			1		90	1		5			5								
15-2, 75		10	90		10			60	30			5									1	
15-2, 102		90	10	60		5	10	10			5			10								
16-1, 140			100	60				70	20					10								

APPENDIX A – *Continued*

16-2, 108	10	20	70	10	20	1		50				20			
17-1, 130	10	15	25	20	10			50	20		5	5			
17-2, 50		52	75				1		5	1	1		60	30	
17-3, 145	10	20	70	10				20			1		40	30	
17-4, 20	10	20	70					10	10		1		40	40	
17-4, 98								10	10				100		Vein
17-5, 37	10	20	70	5				20	1		1		20	60	
17-5, 80		30	70	5		1			10	1	1		45	45	
18-2, 65	10	30	60	10				20					40	30	
18-3, 27		30	70	20			1		10	5	1		25	40	
19-2, 91		20	80	5									40	55	
19-3, 105		20	80	20					5		1		45	30	
20-2, 72	10	30	60					10	1				40	50	
20-2, 147	10	30	60	10		5			1				30	60	
21-1, 12		20	80	10		1						1	60	20	
21-1, 28		20	80	10		1		10	1		1	5	45	30	
21-1, 60	10	20	70	1				10	10			1	40	40	
21-1, 71													100		Limestone at Sediment Basalt Contact

APPENDIX B
Carbonate and Quartz Determinations

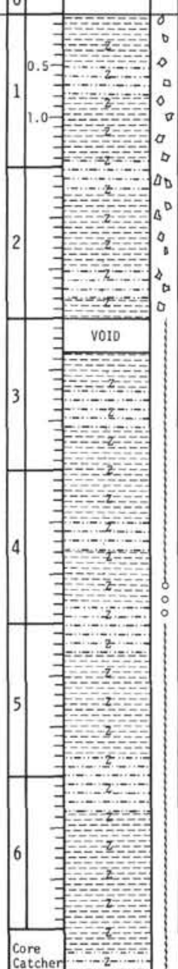
Section	Sediment Depth (cm)	$CaCO_3$ (%)	Org (%)	Total Carb (%)	Qtz (%)
1-2	5519	0.25	0.24		
1-3	5670	0.37	1.10	0.15	
1-6	6130	1.00	0.27		
2-2	11180	0.63	0.09	0.17	9.15
2-3	11370	3.67	0.12	0.56	
2-3	11430	1.25	0.30		
2-4	11520	13.60	0.10	1.73	
2-4	11570	12.97	0.40	1.96	6.65
2-5	11655	0.75	0.21		
2-5	11670	8.32	0.11	1.10	
2-5	11690	52.06	0.51	6.76	6.04
2-5	11710	63.77	0.08	7.74	
3-2	16900	16.98	0.13	2.17	
3-2	16938	8.50	0.51		
3-2	16957	80.57	0.42	10.09	5.31
3-3	17110	24.41	0.16	3.09	
3-4	17158	0.30	0.07	0.09	4.25
3-5	17358	0.75	0.54		
3-5	17390	0.00	0.09	0.09	
4-3	21860	0.00	0.36		
4-3	21870	0.30	0.05	0.09	5.15
4-3	21890	0.07	0.07	0.08	
4, CC	21925	0.19	0.10	0.12	4.47
5-1	24340	0.50	0.39		
5-1	24350	0.03	0.15	0.15	
5-4	24848	0.24	0.45		
5-5	25030	0.00	0.11	0.11	
6-2	26410	0.27	0.19	0.22	3.76
6-2	26410	0.85	0.17	0.27	
6-2	28450	5.00	0.63		
6-4	26660	0.20	0.11	0.13	15.05
6-6	26982	1.37	0.87	1.03	3.60
7-1	28170	0.27	0.18	0.22	4.48
7-2	28310	10.53	0.10	1.87	
7-2	28340	2.50	0.30		
7-3	28475	0.17	0.10	0.12	
7-3	28500	4.50	0.51		
8-2	30240	0.00	0.48		
8-2	30295	0.28	0.10	0.14	
9-2	32100	0.00	0.39		
9-3	32207	0.00	0.11	0.11	
9-5	32505	0.27	0.14	0.17	3.65
9-5	32618	1.03	0.11	0.23	
11-2	34991	0.00	0.21		
11-3	35055	0.12	0.09	0.10	3.56
11-3	35092	0.03	0.13	0.13	
12-4	36210	0.00	0.42		

APPENDIX B – *Continued*

Section	Sediment Depth (cm)	$CaCO_3$(%)	Org (%)	Total Carb (%)	Qtz (%)
12-4	36252	0.05	0.13	0.13	
12-5	36408	0.28	0.05	0.09	17.54
13-2	36820	0.57	0.04	0.11	29.54
13-2	36870	0.15	0.10	0.12	
13-3	36992	0.00	0.33		
14-3	37993	0.00	0.27		
14-5	38285	0.20	1.08	0.11	6.87
14-5	38287	0.00	0.30		
14-5	38340	0.17	0.09	0.11	
15-1	38634	1.50	0.63		
15-1	38648	0.00	0.14	0.13	
15-1	38677	0.00	0.51		
15-1	38680	0.03	0.13	0.13	
15-2	38802	0.16	0.12	0.14	46.65
15-3	38968	0.27	0.06	0.09	13.78
15-4	39085	0.20	0.08	0.10	6.30
17-2	40605	2.55	0.24	0.55	6.66
17-2	40609	14.60	0.05	1.80	
17-2	40625	27.25	0.50	3.77	6.90
17-2	40637	42.60	0.04	5.15	
17-3	40885	59.64	0.68	7.84	9.81
17-3	40890	69.80	0.30		
17-3	40896	80.34	0.03	9.68	
17-4	40905	66.51	0.93	8.91	10.38
17-4	40915	75.05	0.36		
17-4	40925	75.63	0.04	9.12	
17-6	41261	81.30	0.39		
17-6	41320	44.21	0.65	5.96	6.77
18-1	41432	83.05	0.03	10.00	
18-1	41515	74.78	0.51		
18-2	41568	69.67	0.32	8.68	11.85
18-2	41615	82.87	0.03	9.98	
18-3	41736	64.79	0.15		
18-3	41801	56.23	0.33	7.08	9.98
18-3	41820	50.44	0.04	6.10	
19-2	42527	60.79	0.66		
19-2	42588	92.74	0.03	11.16	
19-2	42591	81.83	0.87	10.69	10.49
19-3	42720	80.76	0.04	9.74	
20-2	43468	84.20	0.04	10.15	
20-2	43525	59.45	0.38	7.51	12.15
20-2	43565	89.12	0.48		
21-1	44277	71.05	0.65	9.18	10.66
21-1	44311	51.77	0.69	6.91	9.88

Site 355 Hole Core 1 Cored Interval: 53.0-62.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	LITHO. SAMPLE
PLIO.-PLEISTOCENE		No diagnostic species	RP		1	
			—		2	50, 55
			—		3	
			RP		4	
			—		5	135
					6	125
		RP	—	—	Core Catcher	CC



LITHOLOGIC DESCRIPTION

In general: CLAY/MUD, silty, pale yellowish brown (10YR 6/2) with light brown (5YR 6/4) mixed in.

Smear at 50 cm (Sec. 2) of light brown material:
ZEOLITIC CLAY [0, 5, 95] with:
TR% Mica
TR% Heavy minerals
85% Clays
5% Micronodules
TR- 5% Dolomite rhombs

Smear at 55 cm (Sec. 2) of darker brown material:
MUD, silty [0, 10-15, 85-90] with:
5% Quartz
2% Heavy minerals
80-90% Clay
1% Micronodules
1- 2% Zeolite
1- 2% Limonite

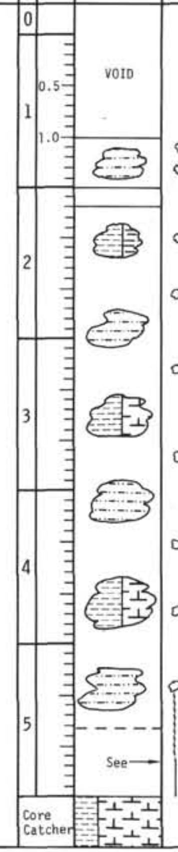
122-150 cm, black material mixed in; smear at 135: MANGANESE MUD, silty [0, 50, 50] with:
40% Clay
40% Micronodules + Limonite
5% Zeolites
5% Rads
10% Quartz
5% Feldspar

125 cm, some greenish gray (5GY 6/1) mixed in:
CLAY [0, 5, 95] with:
10% Feldspar
15% Quartz
70% Clay
5% Zeolite
TR% Limonite

CC: MUD, silty [0, 15, 85] with:
10% Quartz
5% Heavy minerals
5% Zeolite

Site 355 Hole Core 2 Cored Interval: 110.0-119.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	LITHO. SAMPLE
LATE MIOCENE	(N16?) G. acostaensis/merotumida; Amaurolithus primus NN11		RM		1	139
		CM	CM, CM, CM, CM		2	
	Hiatus; ?; turbidites		CM		3	111, 138
		CM	CP		4	
LATE EARLY MIOCENE	N8-N9 G. insueta-G. suturalis; Sphenolithus heteromorphus NN5	CM	CM, CP		5	121, 122, 123, 124
		AP	CP	—	Core Catcher	



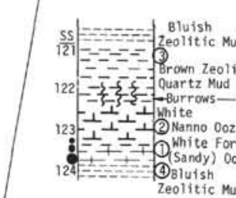
LITHOLOGIC DESCRIPTION

Drilling breccia composed of:

MUD, pale yellowish brown (10YR 6/2) and pale brown (5YR 5/2), silty [0, 40, 60] with:
smear slides at 139, Sec. 1, 111, Sec. 3:
10% Quartz, Silt
80% Clays
5% Calcareous Nannos
5% Limonite

Nanno ooze, very light gray (N8), smear slide at 138, Sec. 3:
20% Clay
40% Authigenic CO_3
40% Nannos
TR% Sponge spicules
Foram sand at 125, Sec. 4, disturbed.

MUD, pale brown (5YR 5/2) as above but containing a sequence of 8 bioclastic turbidites; typical sequence is as follows:



④ SS 124
10% Quartz, Silt
75% Clay
5% Pyrite
10% Zeolite
TR% Nannos
TR% Dolomite rhombs

③ SS 121
10% Quartz, Silt
75% Clay
10% Zeolite
5% Limonite
TR% Nannos
TR% Opaques
TR% Dolomite rhombs

② SS 122
15% Clay
40% Authigenic CO_3
40% Nannos
5% Sponge spicules
TR% Fish remains
TR% Forams

① SS 123
20% Quartz, Sand
5% Feldspar
30% Authigenic CO_3
40% Forams
5% Nannos

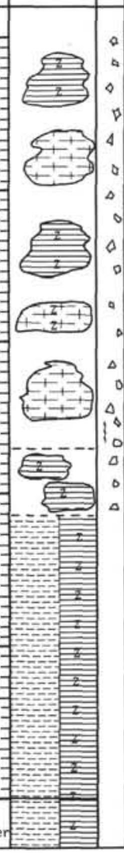
Nanno Ooze:
30% Clay
15% Authigenic CO_3
10% Forams and Sponge spicules
45% Nannos

Explanatory Notes in Chapter 1

Site 355 Hole Core 3 Cored Interval: 167.0-176.5 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHO. SAMPLE
EARLY MIOCENE	(P22-N4) G. angulisuturalis-G. prmordius/kugleri; N4-N5; turbidites; Triquetrorhabdulus carinatus? NN1; Discoaster druggi? NN2; S. belemnos NN3				0		
		CP	CM		1	0.5, 1.0	58
		CP	CM	—	2		122, 138
		CP	FM		3		114, 119
		CP	—	—	4		
		CP	—	—	5		20
		RP	—	RP	Core Catcher		CC

LITHOLOGY / DEFORMATION



LITHOLOGIC DESCRIPTION

Drilling breccia predomiantly composed of (exceptions noted below):
CALCAREOUS ZEOLITIC PELAGIC MUD, pale brown (5YR 5/2), with smear at 58 cm, Sec. 1:
70% Clay
5% Micronodules
10% Zeolite
10% Limonite
5% Calcareous nannos

FORAM-NANNO OOZE, light bluish gray (5B 7/1) and greenish gray (5G 6/1), with smear at 63 cm, Sec. 1:
20% Clay
TR% Zeolite
30% Authigenic carbonate
5-10% Forams
40-45% Calcareous nannos

At 122 cm (Sec. 2) and 136-142 cm (Sec. 2) local clumps of ZEOLITIC FORAM-NANNO OOZE, with:
15-20% Clay
5-15% Zeolite
10% Authigenic carbonate
10-15% Forams
45-50% Calcareous nannos
TR- 5% Sponge spicules
TR% Fish teeth

Drilling breccia of ZEOLITIC PELAGIC MUD, greenish gray (5G 6/1) and ZEOLITIC DOLOMITIC PELAGIC CLAY, light gray (N7); average composition:

SS 114	SS 119
30% Authigenic CO_3	40% Clay
20% Quartz	5% Micronodules
20% Zeolite	0% Dolomite
15% Clay	50% Zeolite
10% Dolomite rhombs	5% Authigenic carbonate
5% Forams	1- 2% Forams and Calcareous nannos

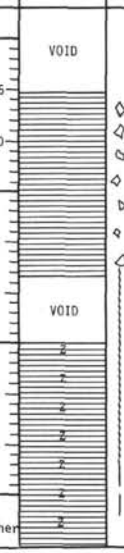
Note: dolomites

MARLY ZEOLITIC PELAGIC MUD, predominantly reddish brown (5YR 5/3) with some greenish gray (5G 6/1) (see above); smears at 20 cm (Sec. 5) and in core catcher:
0-10% Quartz
40-50% Clay
0- 5% Micronodules
10-20% Zeolite
10% Authigenic carbonate
5-10% Limonite
0-10% Calcareous nannos

Site 355 Hole Core 4 Cored Interval: 214.5-224.0 m

AGE	ZONE	FORAMS	COCCO-LITHS	RADS	SECTION	METERS	LITHO. SAMPLE
MIDDLE EOCENE	no planktonics; Podocyrtis mitra				0		
			—	—	1	0.5, 1.0	130
			—	—	2		
			—	—	3		120
		—	—	AM	Core Catcher		

LITHOLOGY / DEFORMATION



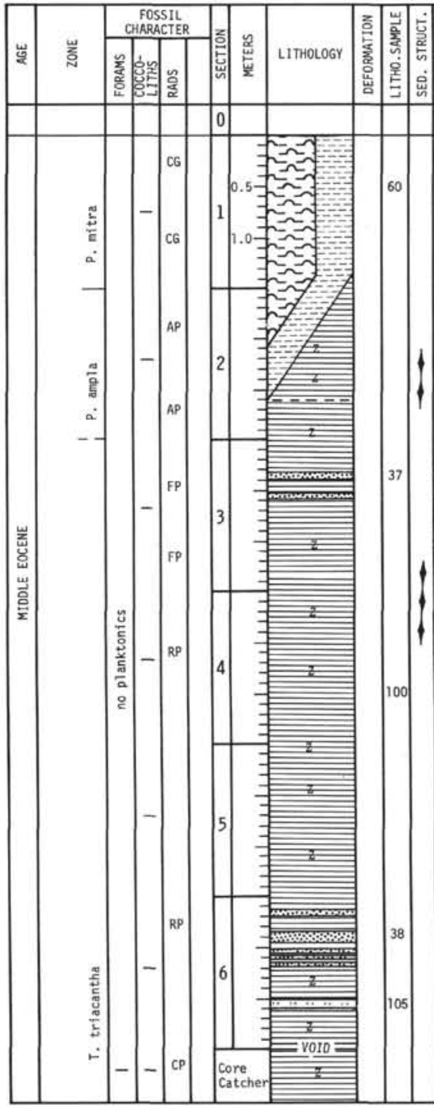
LITHOLOGIC DESCRIPTION

PELAGIC MUD, moderate yellowish brown (10YR 5/4) with minor grayish brown (5YR 3/2) mixed in, with:
75% Clay
10% Authigenic carbonate
10% Limonite
5% Micronodules
0-10% Zeolite

ZEOLITIC PELAGIC MUD, colors as above, with:
60% Clay
30% Zeolite
5% Authigenic carbonate
5% Limonite

Explanatory Notes in Chapter 1

Site 355 Hole Core 5 Cored Interval: 243.0-252.5 m



LITHOLOGIC DESCRIPTION

RADIOLARIAN MUD, light olive gray (5Y 6/1), with:
50% Clay
40% Rads
10% Sponge spicules
0- 5% Limonite

Transitional between RADIOLARIAN MUD and ZEOLITIC PELAGIC MUD; alternating light olive gray and greenish gray.

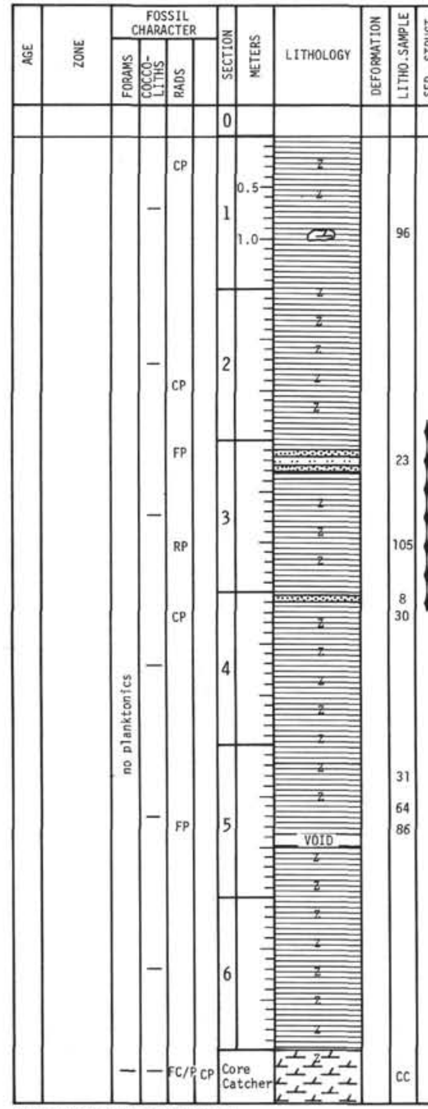
QUARTZ-ZEOLITE SAND [50, 30, 20] with: 40% Quartz, 20% Zeolite, 10% Feldspar, 10% Sponge spicules and 20% Clay; both quartz and feldspar are fresh and angular.

ZEOLITIC PELAGIC MUD, greenish gray (5G 6/1), with:
80% Clay
15% Zeolite
5% Pyrite

QUARTZ-ZEOLITE SAND [50, 30, 20] with: 40% Quartz, 15% Zeolite, 10% Feldspar, 5% Pyrite and 30% Clay; both quartz and feldspar are fresh and angular.

QUARTZ-ZEOLITE SILT [0, 50, 50] with: 50% Quartz, 50% Zeolite and Trace of Chlorite, Micronodules, Dolomite and Limonite;

Site 355 Hole Core 6 Cored Interval: 262.0-271.5 m



LITHOLOGIC DESCRIPTION

In general smear 105, Sec. 3 and Smear 30, Sec. 5: ZEOLITIC PELAGIC MUD, greenish gray (5G 6/1), some mottling but difficult to distinguish, with: 60% Clay, 30% Zeolite, 5% Dolomite and 5% Fe-oxide; scattered zones of brownish gray (5YR 4/1) Smear at 30 (Sec. 4) with same composition.

DOLOMITE ROCK fragment (~2 x 4 mm).

SANDY SILTY ZEOLITIC PELAGIC MUD [20, 24, 45], with 30% Clay, 25% Zeolite, 20% Quartz, 5% Feldspar, 5% Micronodules, 1% Mica and Rads, 10% Dolomite rhombs.

QUARTZ-ZEOLITE SAND [50, 0, 50], with 45% Quartz, 40% Zeolite, 5% Feldspar and 5% Micronodules.

QUARTZITIC ZEOLITIC PELAGIC MUD, silt [5, 60, 35] with 50% Zeolite, 35% Quartz, 5% Dolomite, 2% Mica, 3% Heavy minerals.

QUARTZITIC ZEOLITIC PELAGIC MUD, silty [5, 70, 25] with 50% Quartz, 15% Zeolite, 15% Opaques, 10% Clay, 5% Feldspar, 5% Dolomite, 1% Zircon.

ZEOLITIC PELAGIC MUD, sandy silty [10, 30, 60], 60% Clay, 35% Zeolite, 5% Quartz, 2% Dolomite, 1% Micronodules, 1% Fish remains, 5% Fe-oxides.

DOLOMITE MUD, greenish gray (5G 6/1), with 45% Dolomite, 40% Clay, 10% Zeolite, 5% Pyrite and rads, pyrite in radiolarian tests.

Explanatory Notes in Chapter 1

Site 355 Hole Core 7 Cored Interval: 281.0-290.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY/MIDDLE EOCENE	Phormocyrtis striata striata or Theocampe mongolfieri	no planktonics	—	FP	1	0.5, 1.0	VOID		10	Alternating sequences of: DOLOMITIC ZEOLITIC MUD, greenish gray (5G 6/1) with smear at 50 cm: 50% Dolomite 30% Clay 20% Zeolite
			—		2				50	ZEOLITIC PELAGIC MUD, dark yellowish brown (10YR 4/2) with smear at 100 cm: 45% Zeolite 40% Clay 10% Limonite 5% Micronodules
			—	PP	3				100	QUARTZ SAND [70, 10, 20] with 60% Quartz, 10% Feldspar, 10% Zeolite, 5% Mica, 5% Heavy minerals, 5% Clay, 3% Opaques, 2% Micronodules.
		—	—	CA/P	Core Catcher					

Site 355 Hole Core 8 Cored Interval: 300.0-309.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY EOCENE	Phormocyrtis striata striata	no planktonics	—		1	0.5, 1.0	VOID			ZEOLITIC PELAGIC MUD, greenish gray (5G 6/1), with some interbedded dark yellowish brown (10YR 4/2); considerably disturbed by coring; with: 75% Clay 25% Zeolite TR% Chlorite, Diatoms
			—	—	2				120	
		—	—	CP	Core Catcher					

Site 355 Hole Core 9 Cored Interval: 319.0-328.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY EOCENE	Phormocyrtis striata striata	no planktonics	—		1	0.5, 1.0	VOID		80	ZEOLITIC PELAGIC MUD, greenish gray (5G 6/1). with smears at 80 and 130 cm: 65-80% Clay 20-30% Zeolite 5% Micronodules TR% Diatoms and nannos. Some interlayering of dark yellowish brown (10YR 4/2) zeolitic pelagic clay in Secs. 3+6; fissile-like structure.
			—	FPM	2				130	
			—	—	3				8	MUD, pinkish gray (5YR 8/1), thin layers are outlined by a "blue" outline or "halo"; silty [0, 10, 90]; with: 90% Clay 2% Quartz 2% Zeolite 1% Mica 1% Micronodules 1% Dolomite 1% Rads
			—	RP	4					
			—	RP	5					
		—	—	CP	Core Catcher					

Explanatory Notes in Chapter 1

Site 355 Hole Core 10 Cored Interval: 338.0-347.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: COCCO-LITHS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY EOCENE	Phormocyrtis striata striata	no planktonics		RP	1	0.5, 1.0	VOID			
			—	RP	2				83, 110	ZEOLITIC PELAGIC MUD, in both greenish gray (5G 6/1) and brownish gray (5YR 4/1) alternating layers; moderate disturbances due to drilling but contacts between layers appear to be sharp; with: 70-90% Clays 10-30% Zeolite 1% Micronodules TR% Rads
		—	—	CP	Core Catcher					

Site 355 Hole Core 11 Cored Interval: 347.5-357.0 m

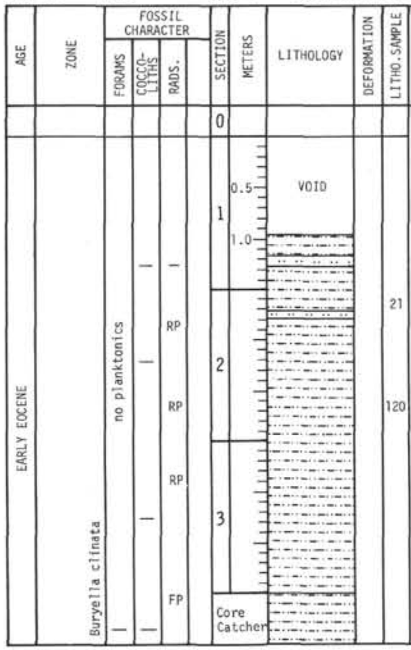
AGE	ZONE	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: COCCO-LITHS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY EOCENE	Phormocyrtis striata striata	no planktonics	—	—	1	0.5, 1.0	VOID		98, 30	Alternating sequences (in about equal amounts) of greenish gray (5G 6/1) and dark greenish brown (10YR 4/2) ZEOLITIC PELAGIC MUD with: 80-90% Clay 10-20% Zeolite TR% Limonite and Rads Appears to be finely laminated with fissile-like structure, laminae about 1 mm thick
			—	—	2					
			—	—	3					
			—	—	4					
		—		CP	Core Catcher					

Site 355 Hole Core 12 Cored Interval: 357.0-366.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	FOSSIL CHARACTER: COCCO-LITHS	FOSSIL CHARACTER: RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.	LITHOLOGIC DESCRIPTION
					0						
EARLY EOCENE	B. clinata	no planktonics		RP	1	0.5, 1.0	VOID				
			—	RP	2				29		ZEOLITIC MUD, light gray (N8), 2 mm thick laminae with 80% Clay, 5% Zeolite, 5% Quartz, 5% Feldspar, 3% Mica, 2% Micronodules; quartz and feldspar both fresh and angular. CLAY [0, 5, 95] greenish gray (5G 6/1), some fissile-like structure (drilling disturbance?), with: 95% Clay 10% Zeolite 1% Rads
			—	CPM	3				70		
			—	RP	4						
			—	RP	5				123		QUARTZ MUD, light gray (N8), silty [0, 80, 20] in 22 thin laminae from 2 to 0.5 mm thick, with 60% Quartz, 10% Mica, 10% Clay, 10% Zeolite, 5% Feldspar, 5% Heavy minerals; quartz and feldspar both fresh and angular. CLAY as above, but with some thin laminae of QUARTZ MUD [5, 80, 15] sandy silty, light gray, with 90% Quartz, 5% Feldspar, 5% Clay, TR% Zeolite, mica and heavy minerals.
		—	—	CP	Core Catcher				CC		

Explanatory Notes in Chapter 1

Site 355 Hole Core 13 Cored Interval: 366.5-376.0 m

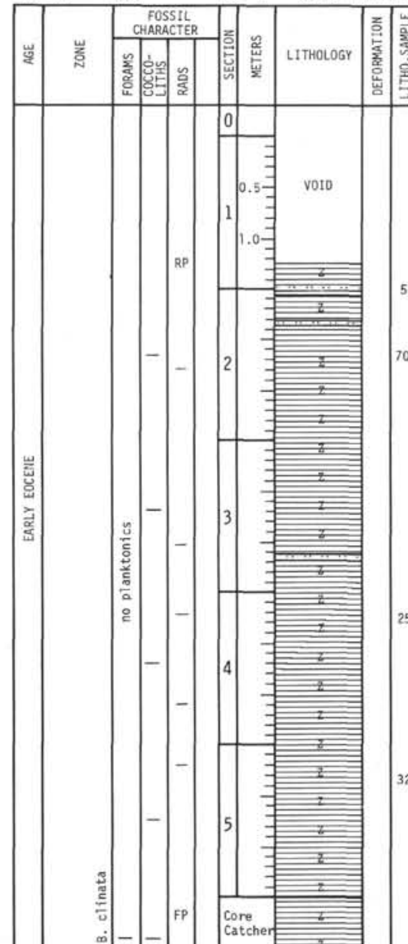


LITHOLOGIC DESCRIPTION

ZEOLITIC QUARTZ MUD, greenish gray (5G 6/1) with some layers of brownish gray (5YR 4/1); silty [0, 70, 30]; with:
45% Quartz
20% Clay
20% Zeolite
10% Chlorite
5% Opaques

QUARTZ SILT, very light gray (N8) [TR, 90, 10] containing 90% Quartz, 2-5% Heavy minerals, 1-5% Zeolite, 1% Mica, 1% Micronodules, 1% dolomite; these occur in a series of very thin laminae, 0.5-2 mm thick.

Site 355 Hole Core 14 Cored Interval: 376.0-385.5 m



LITHOLOGIC DESCRIPTION

Alternating sequences (in about equal amounts) of:
ZEOLITIC PELAGIC MUD, medium bluish gray (5B 5/1), with 80% Clay, 20% Zeolite, TR% Quartz, Silt and Opaques.

FERRUGINOUS ZEOLITIC PELAGIC MUD, moderate reddish brown (10R 4/6) with 65-70% Clay, 10-15% Zeolite, 10-25% Limonite and Opaques and 0-5% Quartz, Silt.

QUARTZ SILT, very light gray (N8), in packets of numerous thin (~1-2 mm thick) laminae, [5, 90-80, 10], with 80% Quartz, 10% Clays, 5% Zeolites, 1-2% Heavy minerals, 1% Dolomite.

Explanatory Notes in Chapter 1

Site 355 Hole Core 15 Cored Interval: 385.5-395.0 m

AGE: EARLY EOCENE

ZONE: no planktonics; Buryella clinata

Sections: 0, 1, 2, 3, 4, Core Catcher (Section 1: VOID at top)

Litho. samples: 47, 92, 75, 102

LITHOLOGIC DESCRIPTION

Alternating sequences (with red-brown layers more prevalent):
FERRUGINOUS CLAY-CLAYSTONE, dark reddish brown (10R 3/4), silty [0, 10, 90] containing:
60% Clay, 10% Feldspar and Quartz, 30% Limonite.

CLAY-CLAYSTONE, pale blue (5B 6/2), slightly mottled, containing:
90% Clay
5% Zeolite
5% Opaques
TR% Limonite and Mica

ZEOLITIC QUARTZ SILT, white (N9) [0, 80-90, 10-20], containing: 70-80% subangular Quartz, 10% Clays, 5-10% Zeolite, 2-10% Heavy minerals, 1-5% Micas, 0-5% Opaques, 0-1% Fish debris; occurring as thin (~0.5-2 mm) laminae.

Site 355 Hole Core 16 Cored Interval: 395.0-404.5 m

AGE: ?

Sections: 0, 1, 2, Core Catcher (VOID in Sections 1 and 2)

Litho. samples: 140, 108

LITHOLOGIC DESCRIPTION

FERRUGINOUS MUD-MUDSTONE, dark reddish brown (10R 3/4), [0, 0, 100], containing:
70% Clay
20% Limonite
10% Zeolite
and one lone large volcanic shard; some ZEOLITIC PELAGIC MUD-MUDSTONE occurs as a few ~1 cm thick layers that are distinctive by somewhat more brilliant red color of the ferruginous clay-claystone near the upper and lower contacts of the pelagic clay, the pelagic clay is medium bluish gray (5B 5/1), and contains:
50% Clay
15% Quartz
20% Zeolite
15% Feldspar
TR% Micarb

Site 355 Hole Core 17 Cored Interval: 404.5-414.0 m

AGE: LATE CAMPANIAN/EARLY MAESTRICHTIAN

ZONE: Tetralithus trifidus

Fossil character: Forams: no planktonics; Coccoliths: CP

Sections: 0, 1, 2, 3, 4, 5, 6, Core Catcher (Section 1: VOID at top)

Litho. samples: 130, 50, 145, 20, 98, 37, 80

LITHOLOGIC DESCRIPTION

FERRUGINOUS ZEOLITIC MUD-MUDSTONE, very dusky red (10R 2/2) containing: 45% clay, 25% Quartz and Feldspar, 15% Limonite, 10% Zeolite, 5% Dolomite.

NANNO OOZE, moderate yellowish brown (10YR 5/4), containing: 40% Authigenic carbonates ("micarb"), 30% Nannos, TR-1% Heavy minerals, Micronodules, Dolomite; with interbedded: also with 5-10% Quartz, Silt.

CALCITE VEINS, eight in all, thickness varying from 1 mm-5 mm (average ~3.5 mm), frequently broken by coring, composed of sparry calcite with numerous inclusions, [denoted by]:

NANNO CHALK, 124-130 cm (Sec. 2) and 139-9 cm (Secs. 3 and 4), white (N9), with 40% Nannos, 40% Authigenic carbonate, 20% Clay, TR% Dolomite.

FERRUGINOUS NANNO OOZE; pale reddish brown (10R 5/4) to reddish brown (2.5YR 5/4); which occurs in contact with, and both above and below the calcite veins and the white nanno chalk; [denoted by closely-spaced short dashes]; with: 40% Nannos, 40% Authigenic carbonate, 10% Clay, 10% Limonite.

NANNO OOZE, alternating grayish brown (10YR 5/2) and pale brown (10YR 6/3), with: 50-60% Nannos, 20-45% Authigenic carbonate ("micarb"), 20% Clay, TR-1% Dolomite, Mica, Micronodules and Limonite.

Explanatory Notes in Chapter 1

Site 355 Hole Core 18 Cored Interval: 414.0-423.5 m

AGE	ZONE	FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
					0					
LATE CAMPANIAN/EARLY MAESTRICHTIAN	Tetralithus trifidus	—	CP		1	0.5, 1.0				
			CP	—	2				65	
		—	CP	—	3				27	
		—	CP	—	Core Catcher					

LITHOLOGIC DESCRIPTION

NANNO OOZE, grayish brown (10YR 5/2) and pale brown (10YR 6/3) in Sec. 1, both colors alternate, in Sec. 2, grayish brown more prevalent, and in Sec. 3, the grayish brown predominates - with:
40-30% Nannos
10-20% Quartz Silt
25-40% Authigenic carbonates ("micarb")
20% Clay
5% Micronodules
TR% Dolomite
and with interbedded:

CALCITE VEINS (as described in Core 17), denoted by [IIIIIII], surrounded (only upper five veins) by FERRUGINOUS NANNO OOZE (also as described in Core 17).

Site 355 Hole Core 19 Cored Interval: 423.5-433.0 m

AGE	ZONE	FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
					0					
LATE CAMPANIAN	Tetralithus trifidus	—	CP		1	0.5, 1.0	VOID			
	T. gothicus		CP		2				91	
		—	FP		3				105	
	T. aculeus	no planktonics	CP	—	Core Catcher					

LITHOLOGIC DESCRIPTION

NANNO OOZE, thin zone of grayish brown (10YR 5/2) in upperportion of Sec. 1, but generally an alternating sequence (mixed) of pale yellowish brown (10YR 6/2), pale brown (10YR 6/3), and moderate brown (5YR 3/4) with:
30-50% Nannos (lower amount in lighter browns)
40-60% Authigenic carbonates
TR% Dolomite and Micronodules
5%-15% Quartz Silt , 5-10% Clay
with interbedded:
CALCITE VEINS, as described previously (Core 17), none noticed in Sec. 3 perhaps due to disturbed core; these veins not associated with ferruginous nanno oozes as in Cores 17 and 18; veins denoted by [IIIIIII].

Site 355 Hole Core 20 Cored Interval: 433.0-442.5 m

AGE	ZONE	FORAMS	COCCOLITHS	RADS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	SED. STRUCT.
					0					
CAMPANIAN	T. aculeus	—	CP		1	0.5, 1.0	VOID			
			CP		2				72	
									147	
		no planktonics	CM	—	Core Catcher					

LITHOLOGIC DESCRIPTION

NANNO OOZE, brown (10YR 5/3) with some scattered disturbed light brown (7.5YR 6/4), with:
50% Nannos
40% Authigenic carbonates
10% Clays

NANNO OOZE, light brown (7.5YR 6/4), with:
60% Nannos
30% Authigenic carbonates
10% Quartz Silt
TR% Limonite

Site 355 Hole Core 21 Cored Interval: 442.5-452.0 m

AGE	ZONE	FORAMS	COCCOLITHS		SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
					0				
EARLY CAMPANIAN	T. aculeus	—	CP		1	0.5			
			CP			1.0			

LITHOLOGIC DESCRIPTION

NANNO OOZE, altered dusky brown (5YR 2/2), with authigenic carbonates, nannos, micronodules, quartz silt, clays, limonite.

APHYRIC BASALT (rare phenocrysts of plagioclase, high Ca-pyroxene, and altered olivine). Top portion is highly altered, varying in color from grayish orange (10YR 7/4), to moderate yellowish brown (10YR 5/4), to medium dark gray (N4); calcite veins present. Remainder is medium dark gray to dark gray (N3); some glass present; mineralogy consists of plagioclase laths and high-Ca pyroxene in subophitic texture and as glomerocrysts. Much of groundmass highly altered. Olivine phenocrysts occur as highly altered and oxidized relicts. Plagioclase and pyroxene range from fresh to moderately altered. Oxides present as dust-sized material.

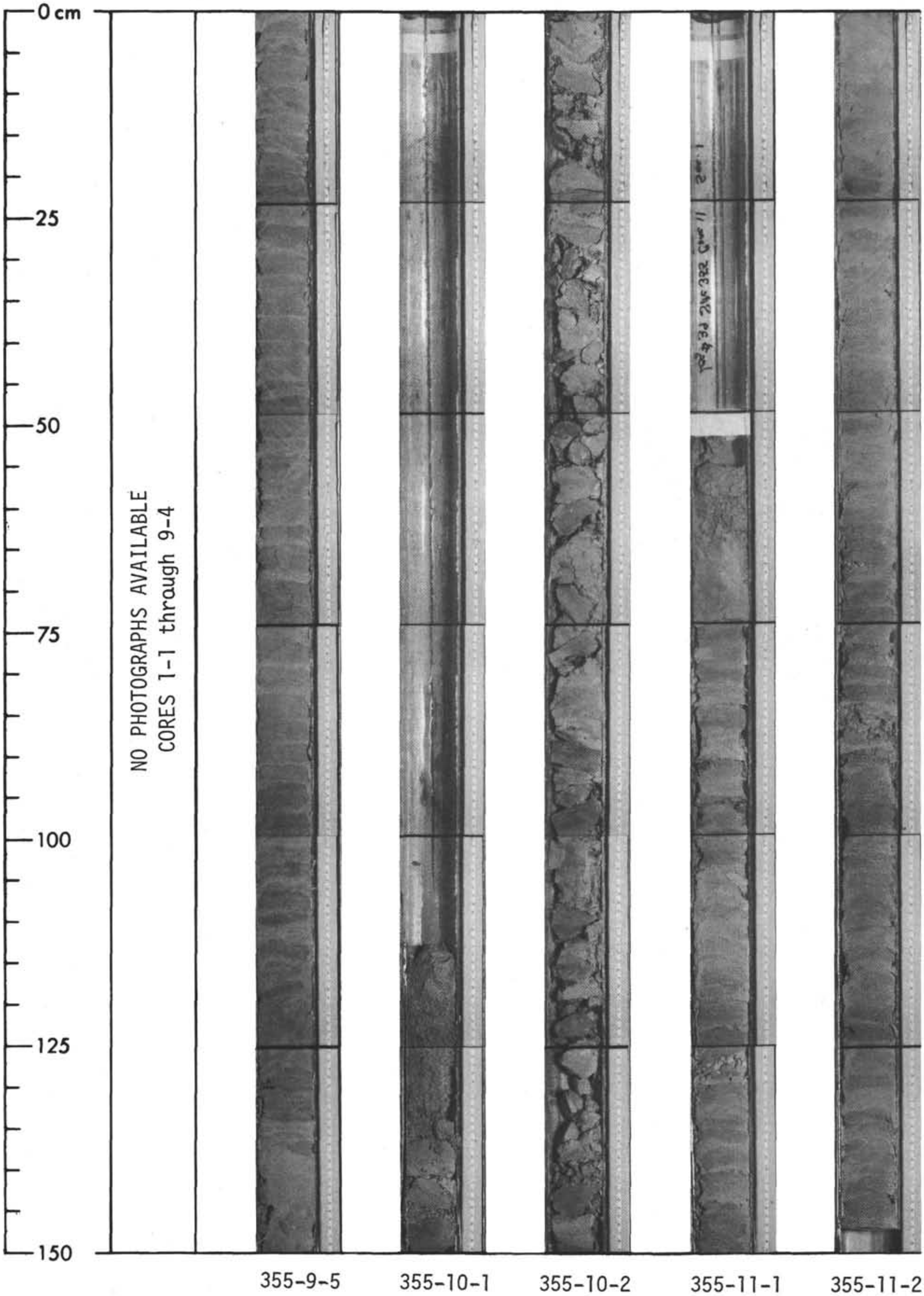
Plagioclase>pyroxene>altered olivine>oxides.

Explanatory Notes in Chapter 1

Site 355 Hole Core 22 Cored Interval: 452.0-461.5 m

AGE	ZONE	FOSSIL CHARACTER: COCCO-LITHS			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EARLY CAMPANIAN	B. parca	RP*			1 2 3 4 5	0.5 1.0				APHYRIC BASALT (rare phenocrysts of plagioclase, high Ca-pyroxene, and altered olivine). Medium dark gray (N3) to dark gray (N4) basalt; highly fractured and veined with calcite (green veins, possibly prochlorite, also present). Mineralogy consists of plagioclase laths, high-Ca pyroxene in subophitic texture and as glomerocrysts. Much of groundmass is highly altered. Olivine phenocrysts occur as highly altered and oxidized relicts. Plagioclase and pyroxene range from fresh to moderately altered. Oxides present and best displayed in lowermost portion. Plagioclase>pyroxene>altered olivine>oxides. Olivine (altered) absent from lower half. *lump of limestone

Explanatory Notes in Chapter 1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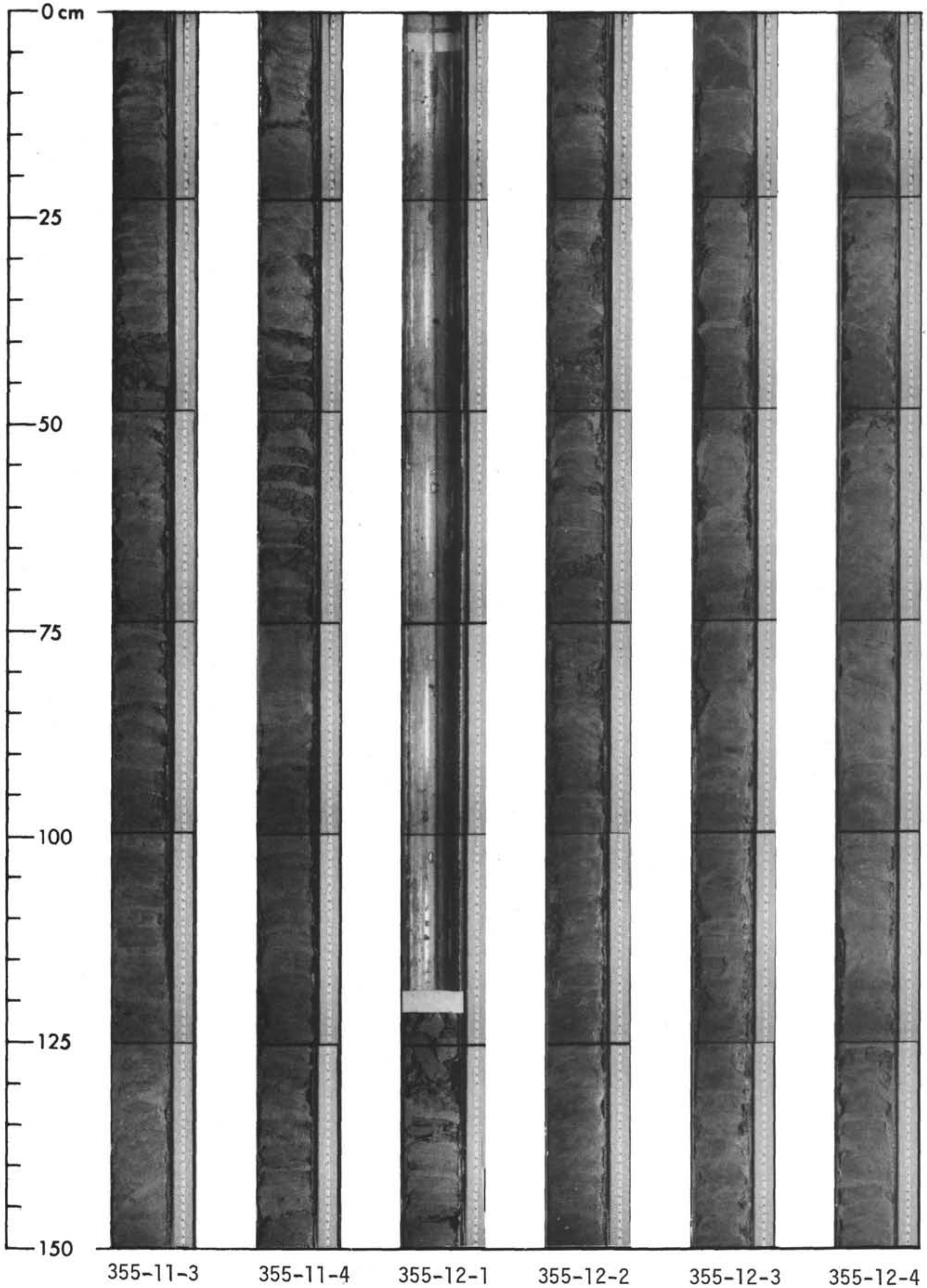
75
100
125
150
NO PHOTOGRAPHS AVAILABLE
CORES 1-1 through 9-4
355-9-5
355-10-1
355-10-2
355-11-1
355-11-2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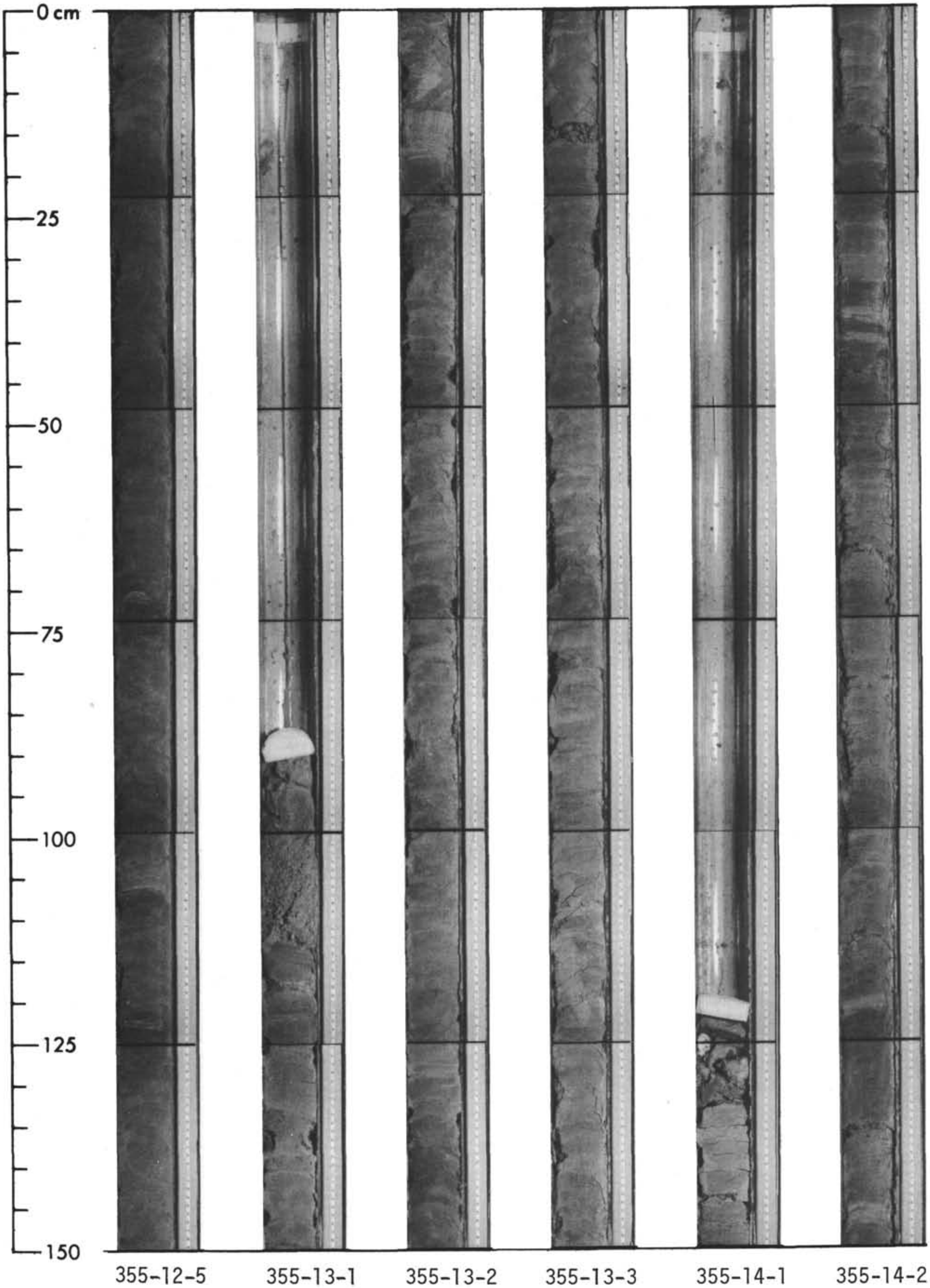
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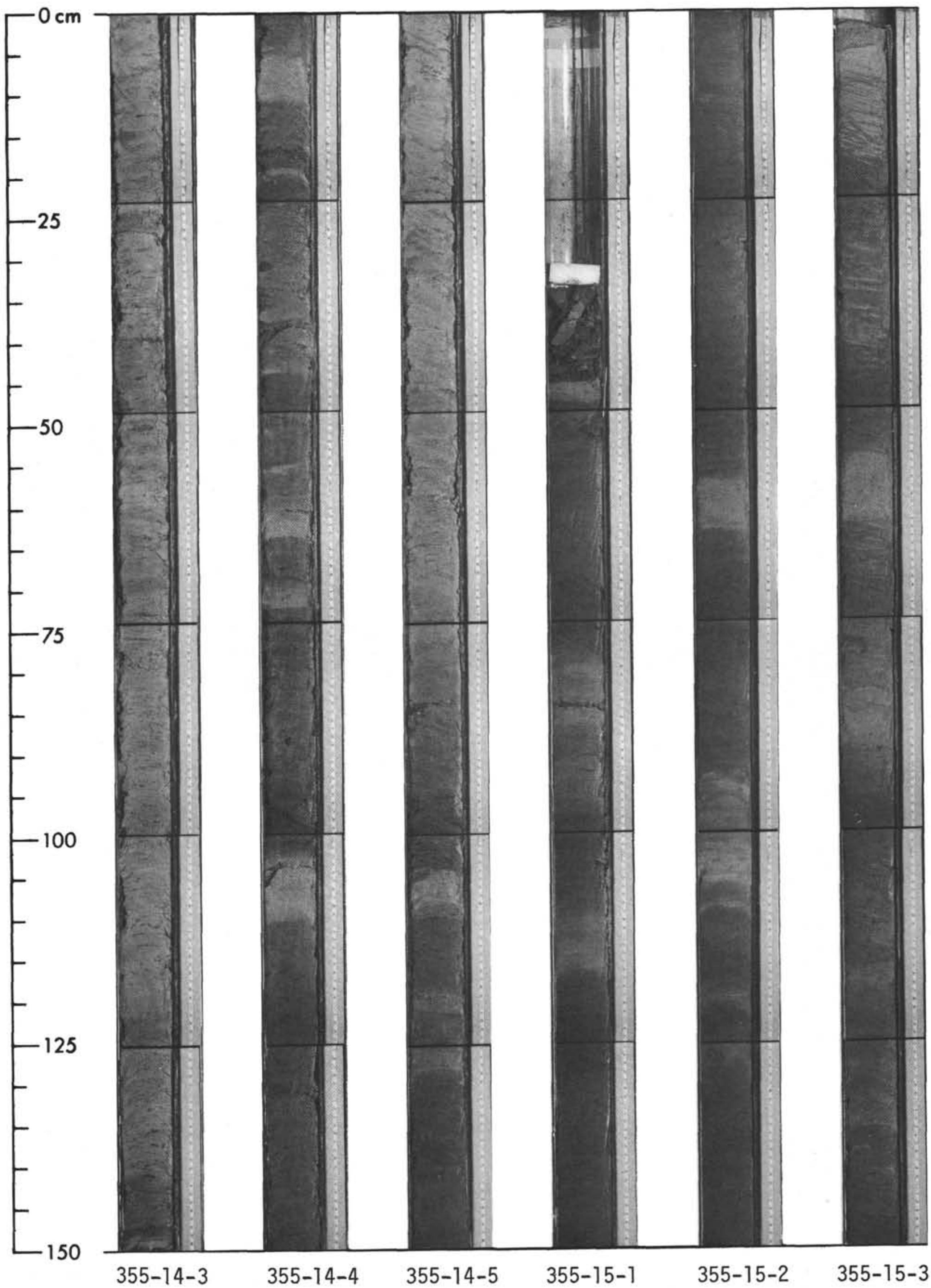
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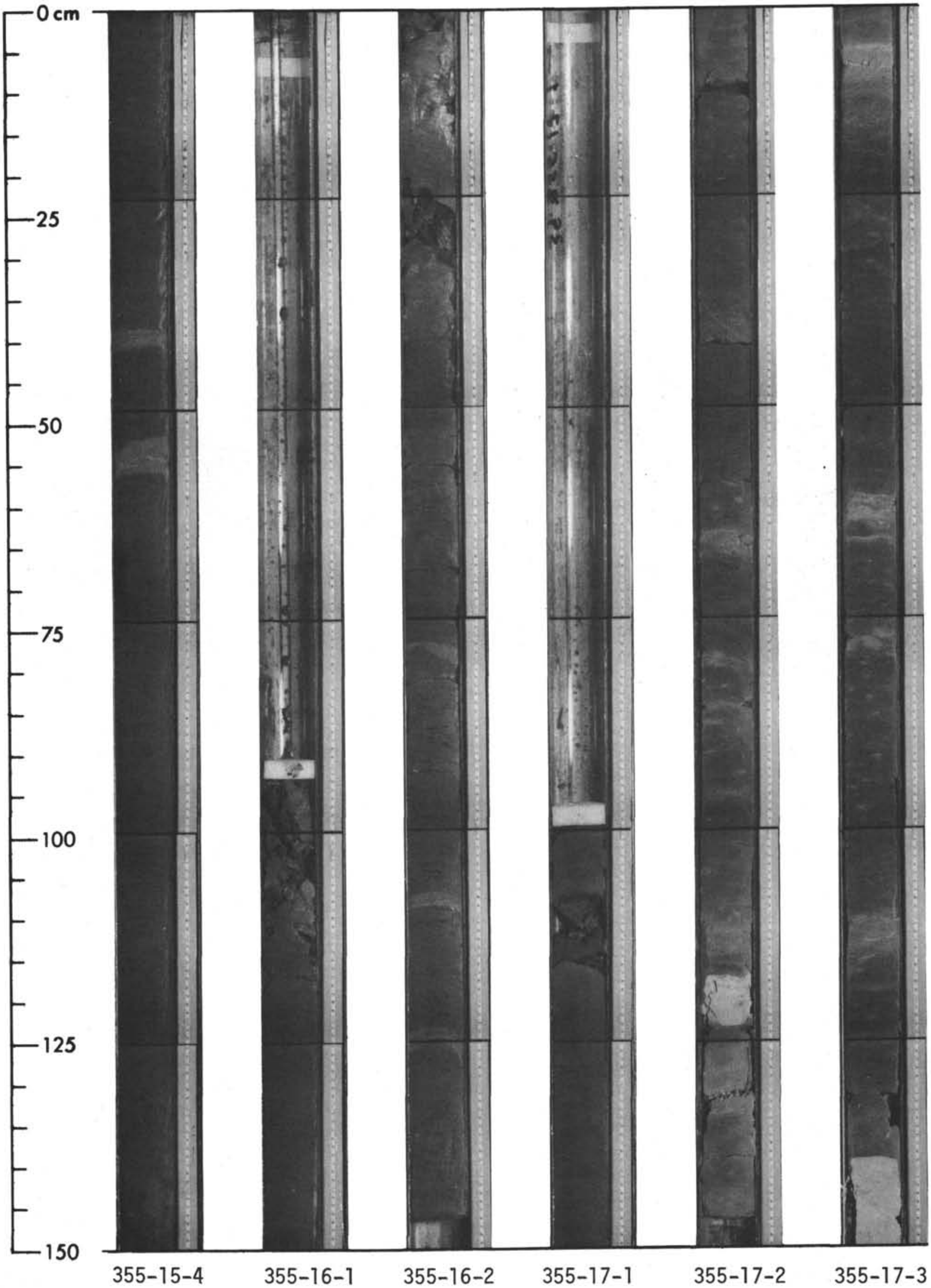
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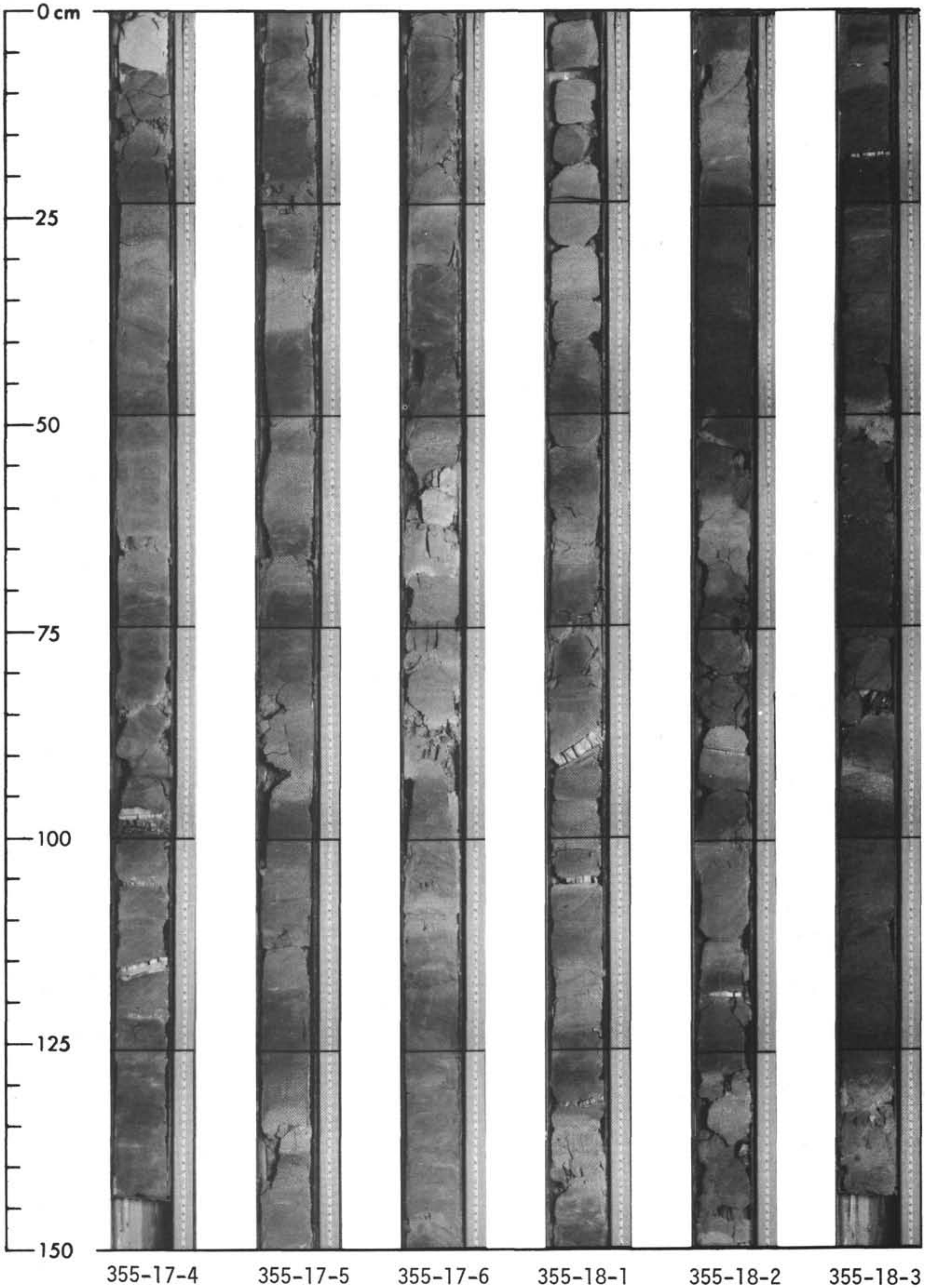
50
75
100
125
150
355-15-4
355-16-1
355-16-2
355-17-1
355-17-2
355-17-3


0 cm
25
50
75
100
125
150
355-17-4
355-17-5
355-17-6
355-18-1
355-18-2
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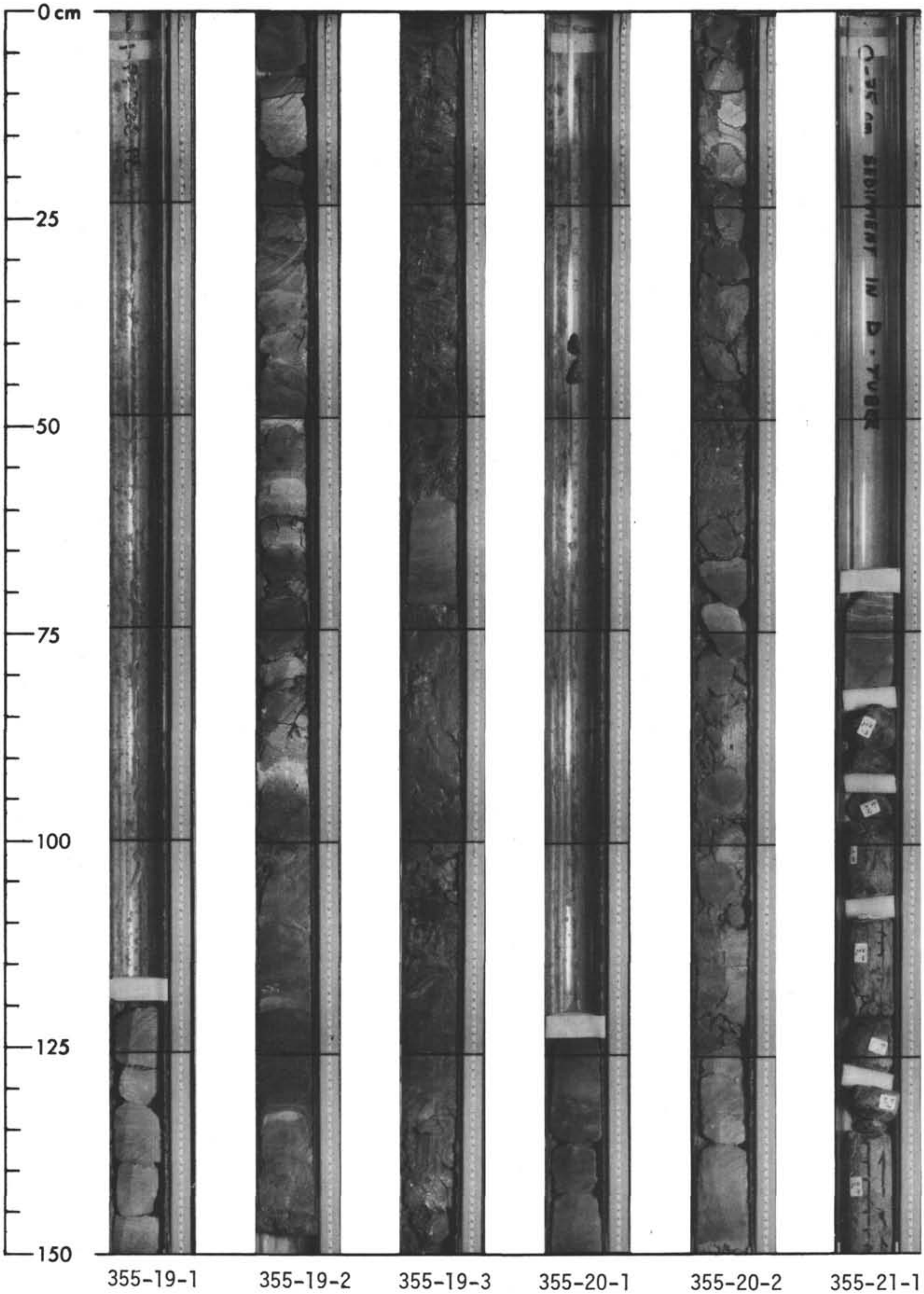
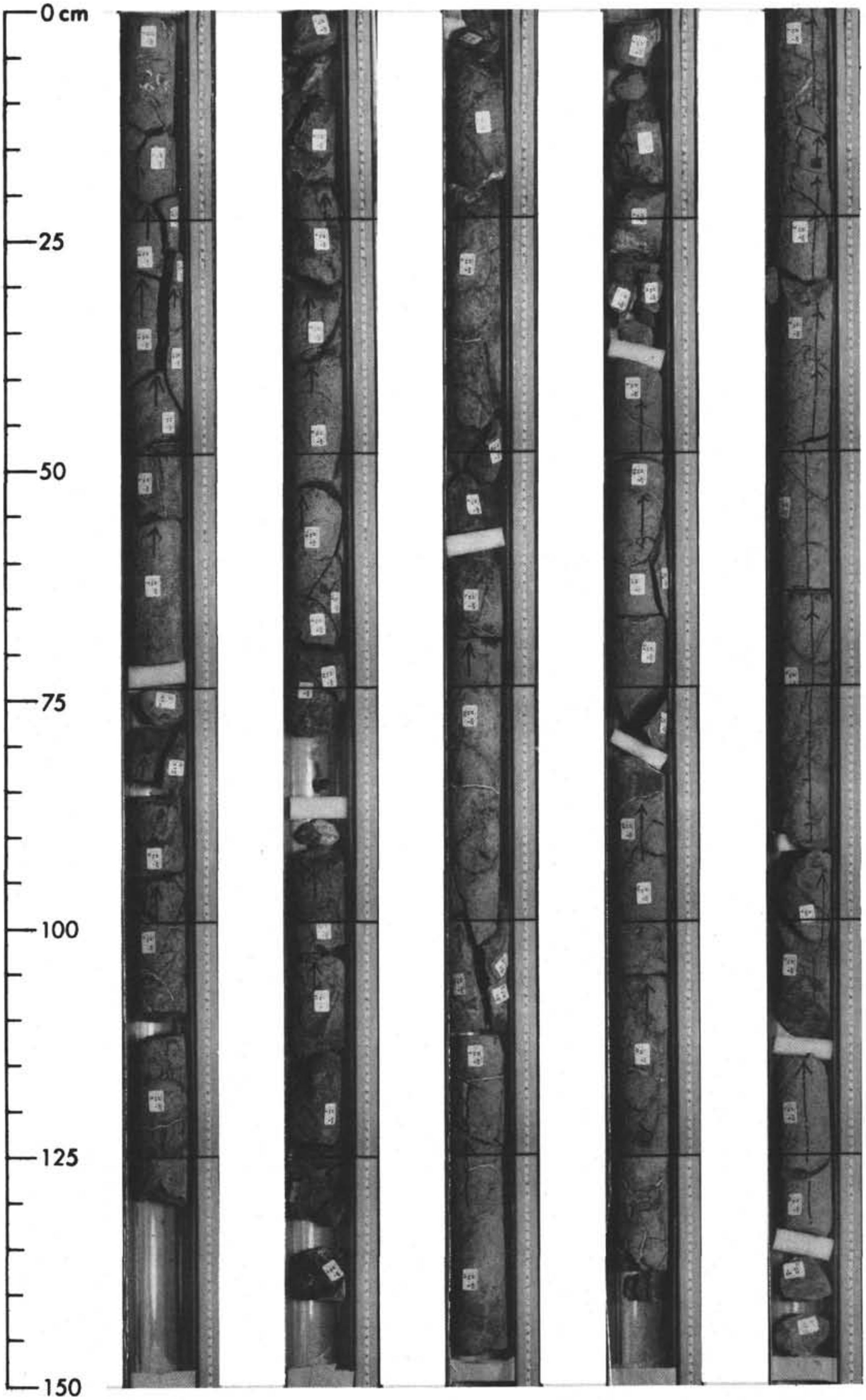

0 cm
25
50
75
100
125
150
355-19-1
355-19-2
355-19-3
355-20-1
355-20-2
355-21-1



355-22-1 355-22-2 355-22-3 355-22-4 355-22-5