2. SITE 494: MIDDLE AMERICA TRENCH LOWER SLOPE[1]

Shipboard Scientific Party[2]

HOLE 494

Date occupied: 16 May 1979

Date departed: 17 May 1979

Time on hole: 34.5 hr.

Position: 12°43.00′N; 90°55.97′W

Water depth (sea level; corrected m, echo sounding): 5472

Water depth (rig floor; corrected m, echo sounding): 5482

Bottom felt (m, drill pipe): 5529

Penetration (m): 37.5

Number of cores: 4

Total length of cored section (m): 37.5

Total core recovered (m): 30.32

Core recovery (%): 80.85

Oldest sediment cored:
Depth sub-bottom (m): 37.5
Nature: Mud
Age: Quaternary

Basement: Not reached

HOLE 494A

Date occupied: 17 May 1979

Date departed: 25 May 1979 (includes HIG experiment)

Time on hole: 12 days

Position: 12°43.01′N; 90°55.97′W

Water depth (sea level; corrected m, echo sounding): 5472

Water depth (rig floor; corrected m, echo sounding): 5482

Bottom felt (m, drill pipe): 5529

Penetration (m): 366.5

Number of cores: 35

Total length of cored section (m): 329.0

Total core recovered (m): 100.31

Core recovery (%): 30.49

Oldest sediment cored:
Depth sub-bottom (m): 310
Nature: Nannofossil ooze and claystone
Age: Late Cretaceous
Measured velocity (km/s): 3–4

Basement:
Depth sub-bottom (m): 336
Nature: Pebbles of altered igneous rocks
Velocity range (km/s): 4

Principal results (Holes 494 and 494A): The recovered section casts doubt on the concept of simple, orderly accretion along the seaward edge of the Guatemala convergent margin. Site 494, on the lower slope, is about 3 km from the trench axis and 580 meters above it and is situated on a small terrace that is about 2 km wide (Fig. 1).

On the basis of site survey data obtained prior to drilling at Site 494, this terrace was thought to be at least 18 km long and to have been formed by emergence of a large imbricate thrust. The bathymetry collected during a deep-tow survey (Moore et al., this volume) shows, however, that this terrace extends only about 4 km along the trench. Reentrants separate this small terrace from similar-sized terraces to the northwest and southeast, terraces that are at depths about 100 meters shallower and 100 meters deeper, respectively. Thus the bathymetry gathered from conventional reflection profiles suggests that the terrace at Site 494 is one of a series of benches that might be individual features, perhaps slump blocks. Seabeam bathymetry of Aubouin et al. (this volume) indicates that the terrace is a relatively continuous feature and that reentrants are of minor importance. A major objective of the drilling at Site 494 was to test if the terraces are related to proposed imbricate thrusts or to smaller slump blocks.

The recovered lithologies (Fig. 2) are:

1) 0 to 223 meters: Holocene to Pliocene dark gray diatomaceous mud containing abundant fauna displaced from 1000 to 2000 meters water depth; sedimentation rate—55 m/m.y.

2) 223 meters: Unconformity, contact observed.

3) 223 to 241 meters: Blue gray hemipelagic clay, 18 meters thick, with early Miocene to late Oligocene nannofossil assemblages typical of open-ocean environments rather than areas of coastal upwelling; deposited near the calcite compensation depth (CCD) at about 3000 meters; sedimentation rate—3 m/m.y.

4) 241 meters: Unconformity, contact observed.

5) 241 to 294 meters: Dark, sandy, middle Eocene mudstone, 53 meters thick, in which one undisturbed and very complete section has many closely spaced faults with small displacement; fauna deposited below the foraminiferal CCD but above the nannofossil CCD; sedimentation rate—10 m/m.y.

6) 294 meters: Unconformity or fault, contact not observed.

7) 294 to 313 meters: Dark gray mudstone, 19 meters thick, mixed by faulting or drilling disturbance with blue gray micritic limestone, middle Eocene and Upper Cretaceous, respectively.

8) 313 to 322 meters: Medium gray Upper Cretaceous mudstone, 9 meters thick, with an open-marine fauna containing abundant *Globotruncana;* deposited above the CCD.

9) 322 to 367 meters: Five cores with a total recovery of 1 meter of altered mafic igneous rock atypical of ocean-floor basalts.

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[1] Aubouin, J., von Huene, R., et al., *Init. Repts. DSDP*, 67: Washington (U.S. Govt. Printing Office).

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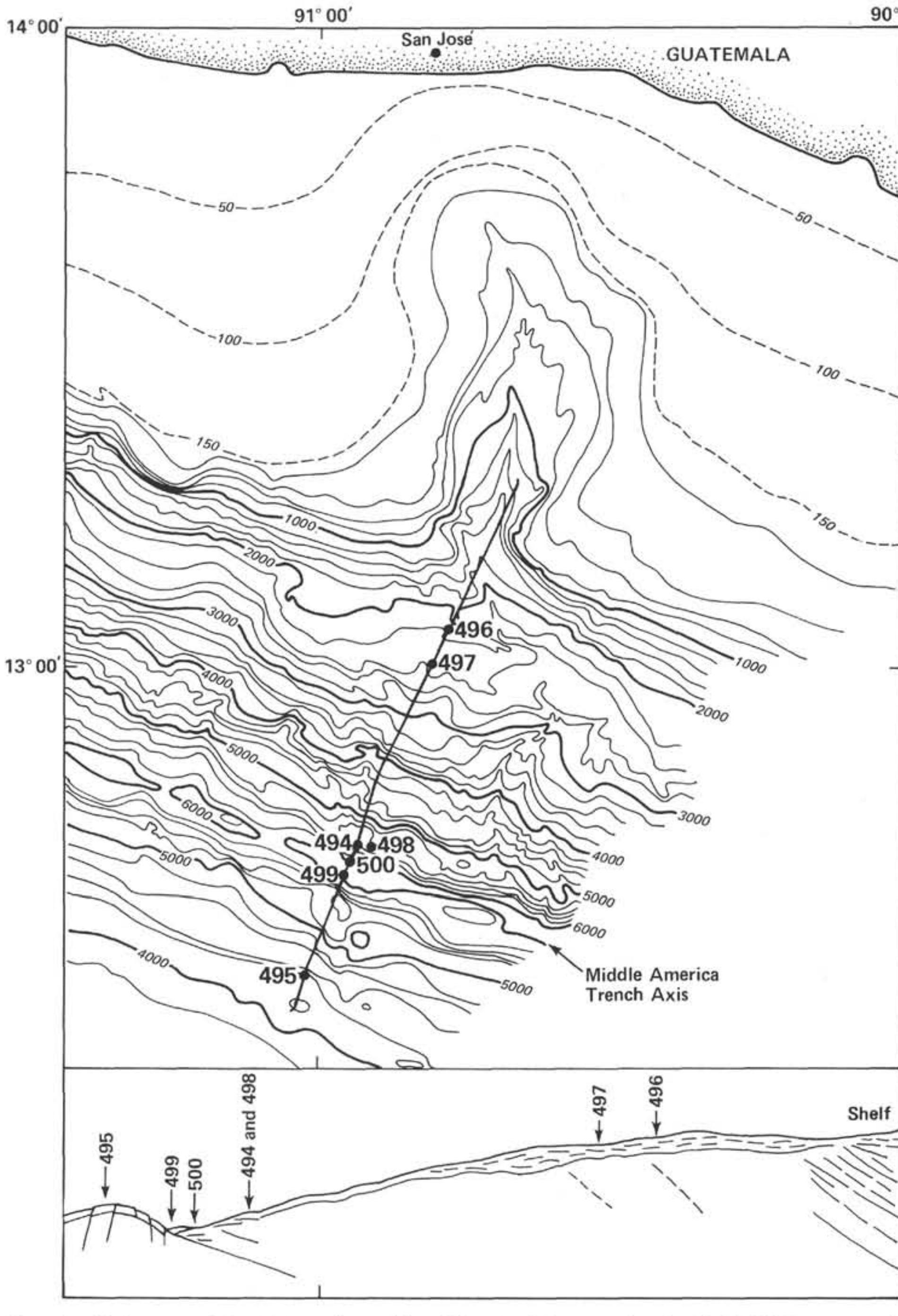


Figure 1. Bathymetry of the Guatemala margin and San José Canyon, showing the UTMSI survey tracks and the location of Leg 67 sites.

Gaseous hydrocarbons in the section are mainly methane, and only minor amounts of ethane were detected.

BACKGROUND AND OBJECTIVES

On the landward slope of the Middle America Trench in about 5520 meters of water, Site 494 is located on a narrow terrace about 580 meters above and 3 km from the adjacent trench axis (Fig. 1). The multichannel seismic records off Guatemala show strong reflections dipping to the north-northeast under the outer continental shelf and the upper and middle slope, which might represent an extension of the Nicoya Complex that crops out in Costa Rica. For Site 494, located on the lower slope, seismic records are highly obscured by diffractions. Nevertheless, three reflections may be traced across the trench and perhaps under the landward slope—the uppermost, possibly marking the lower boundary of the sedimentary apron on the slope; the second, a boundary between the sediments filling the trench and the deep ocean basin sediment; and the third reflection, the top

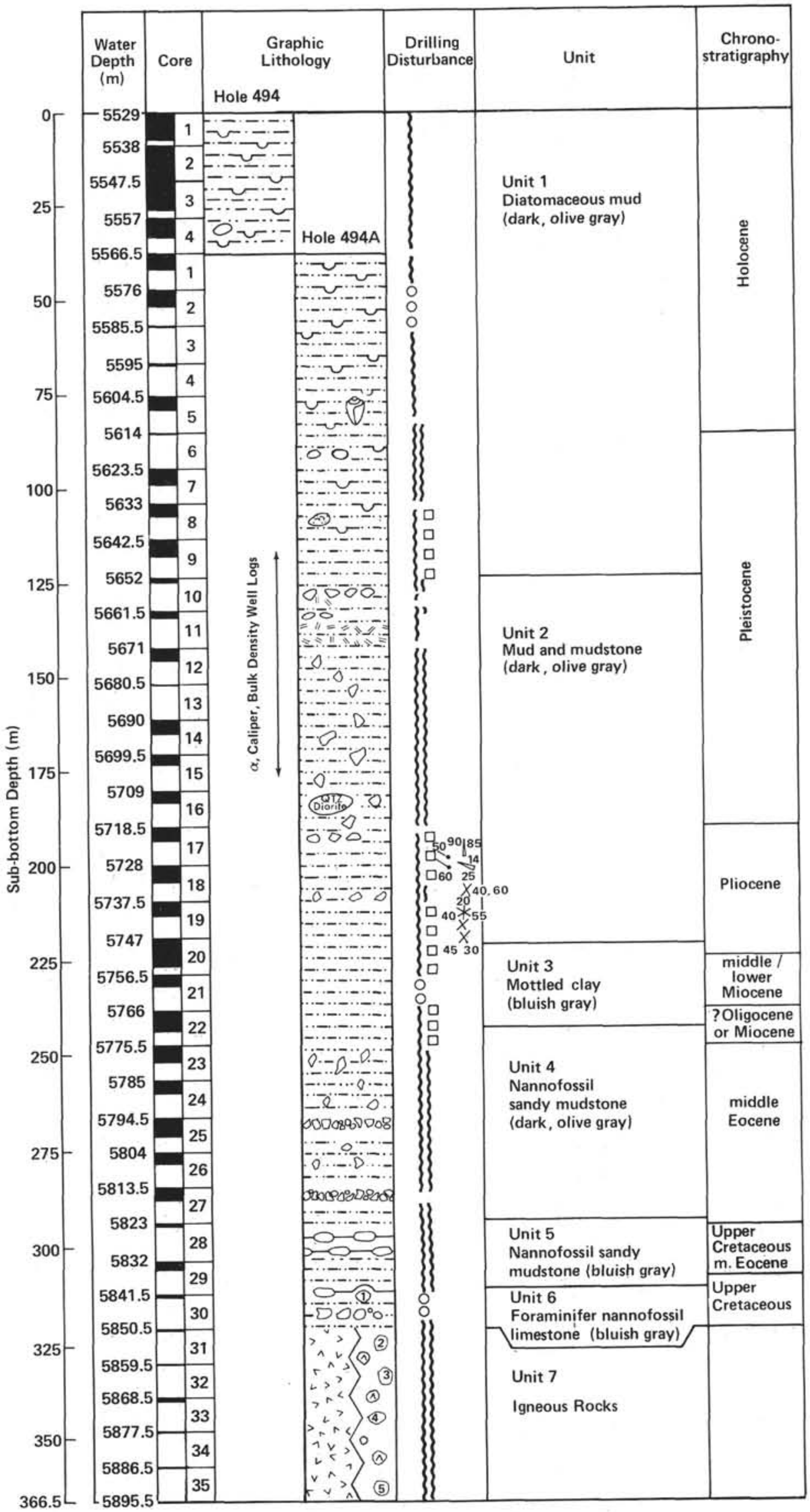


Figure 2. Summary lithologic column for Site 494.

of the igneous ocean crust that can be traced a short distance under the continental margin. Thus Site 494 is situated in a zone where the model of an accretionary prism could be tested, if the drilling were sufficiently deep to penetrate through the slope deposits. Likewise, it would be possible to sample the underlying deposits inferred to be trench and perhaps deep ocean basin sediment. Another goal of Leg 67 was to test if the terraces are related to proposed imbricate thrusts or to smaller slump blocks.

OPERATIONS

The *Glomar Challenger*, operating its underway seismic reflection, magnetic, and 12-Khz and 3.5-Khz, transducer geophysical instruments, was in transit for four days from Manzanillo to the Middle America Trench transect off Guatemala. The trench transect was intersected from the last transit course of 110° at 1449 Local Time (L) 13 May when the ship came to 200° (Fig. 1). That approach gave a 14-km track across the trench lower slope on the transect and allowed recognition of bathymetric features for positioning of the beacon. A series of satellite fixes received prior to the turn insured relatively good positioning along the transect, however, a 10- to 15-knot south wind tended to set *Challenger* north of course. The bathymetry taken by *Challenger* matched the bathymetric profile of seismic record GUA-18 to within a 10-meter depth and a 0.25-km horizontal position. A fairly reliable satellite position, received just as the desired position for Site 494 was reached, indicated that *Challenger* had drifted 1.5 nm off course, and a left turn to 110° was initiated. The decision to drop the beacon was made shortly after turning, because the depth matched site depth to within 11 meters; upon review, the satellite position was possibly suspect. The *Challenger* came to position at Site 494 on 13 May at 1600L.

The initial lowering of the drill stem resulted in discovery of a series of problems with the drilling rig. About 10 hr. were spent trying to repair the Bowen-Sub, and after recovery of the first core barrel, devoid of sediment about 8 hr. were spent trying to retrieve the second core barrel. Rust and thick grease from a new sand line had apparently collected around the latching head of the core barrel, preventing retrieval. After four attempts and extensive circulation to wash out line grease, the drill string was pulled to avoid spending more time in recovery attempts. A firmly lodged blockage prevented latching of the overshot.

Upon retrieval of the drill collars and removal of the core barrel, no sign of a blockage could be found. At the time it was thought that perhaps the blockage had washed away during retrieval of the drill string. While the drill string was aboard, the ship was offset about 3000 ft. (914 m) south to stay clear of an area of rough seafloor, possibly slump debris from the adjacent slope.

Once the string was lowered, the Bowen-Sub malfunctioned. Similar problems with the "sub" had been reported during the previous leg. After 8 hr., a broken check valve was removed, but parts of this valve had already entered and damaged the drive motor.

The initial attempts to core resulted in five water cores between the precision-depth-recorder (PDR) determined depth of 5482 meters and the mud line at 5529 meters; thus the first three and one-half days were spent on site without core recovery.

After cutting the fourth core at Hole 494, the Bowen-Sub again needed repair and the drill string was pulled out of the hole. Hole 494A was washed down to the total depth (T.D.) of Hole 494—37.5 meters. After one core, the overshot would not retrieve the barrel, and after 6 hr. it was retrieved using another core barrel. This problem recurred on the next core, but change of the latch mechanism on one core barrel eliminated the latching problem in subsequent coring attempts.

Drilling proceeded routinely through the remainder of the 18th until the 21st of May (Table 1). Igneous rock slowed drilling considerably; eventually 2 hr. were required to cut a core, and the recovery was only a core-catcher (CC) sample. It became obvious that the bit was damaged despite only 27 hr. of rotation. During retrieval of the last core the bottom-hole assembly stuck but was worked free in about 3 hr.

Logging began the afternoon of 21 May and was abandoned 1.5 days later with no success because all the logging tools were malfunctioning. During this period, *Kana Keoki* proceeded with a detailed site survey begun on 20 May while standing by for the emplacement of the downhole seismometer.

After completion of the downhole seismometer experiment and deployment of the recording package, *Glomar Challenger* departed the site on May 25.

LITHOSTRATIGRAPHY

Sedimentary Rocks

Site 494 is located at 5529 meters depth, about 4 km north of the axis of the Middle America Trench. The site lies on a narrow terrace on the landward trench slope.

Holes 494 and 494A were cored continuously except in their intervals of overlap; the samples obtained provide a good record of the stratigraphy and a fair indication of the primary fracturing within the major lithologic units. The sediment and sedimentary rocks can be divided into seven units on the basis of their lithology (Fig. 2).

Unit 1 (Hole 494, Cores 1 to 4, 0–37.5 m; Hole 494A, Cores 1 to 9, 0–115 m sub-bottom depth, Quaternary)

Diatom frustules in abundances of 10% or more characterize this relatively uniform dark olive gray to olive gray sediment (5Y 3/2 to 5Y 4/2). Calcareous benthic foraminifers, ostracode, pelecypod fragments, and plant remains provide abundant evidence for the reworking of deposits downslope and attest to a provenance far upslope of the present 5529-meter water depth, i.e., less than a 2000-meter depth (see the section on Biostratigraphy).

Medium- and fine-grained, drilling deformed, sandy beds up to 5 cm thick occur within Cores 1 and 2 of Hole 494, but below 18.5 meters sub-bottom depth, sandy

Table 1. Coring summary for Holes 494 and 494A.

Core No.	Date (May, 1979)	Local Time (L)	Depth from Drill Floor (m; top-bottom)	Sub-bottom Depth (m; top-bottom)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 494							
1	17	0127	5529.0-5538.0	0.0-9.0	9.0	8.4	93
2	17	0310	5538.0-5547.5	9.0-18.5	9.5	9.5	100
3	17	0445	5547.5-5557.0	18.5-28.0	9.5	8.3	87
4	17	0800	5557.0-5566.5	28.0-37.5	9.5	5.12	54
Hole 494A							
H1	17	0930	5529.0-5566.5	0.0-37.5			
1	17	1113	5566.5-5576.0	37.5-47.0	9.5	4.8	50
2	17	1330	5576.0-5585.5	47.0-56.5	9.5	5.7	60
3	17	1929	5585.5-5595.0	56.5-66.0	9.5	0.20	2
4	17	2142	5595.0-5604.5	66.0-75.5	9.5	0.35	3
5	18	0133	5604.5-5614.0	75.5-85.0	9.5	3.74	39
6	18	0345	5614.0-5623.5	85.0-94.5	9.5	0.05	>1
7	18	0600	5623.5-5633.0	94.5-104.0	9.5	4.55	47
8	18	0800	5633.0-5642.5	104.0-113.5	9.5	3.03	32
9	18	1024	5642.5-5652.0	113.5-123.0	9.5	4.03	42
10	18	1225	5652.0-5661.5	123.0-132.5	9.5	0.60	6
11	18	1440	5661.5-5671.0	132.5-142.0	9.5	0.90	9
12	18	1625	5671.0-5680.5	142.0-151.5	9.5	2.77	29
13	18	1850	5680.5-5690.0	151.5-161.0	9.5	0.01	>1
14	18	2112	5690.0-5699.5	161.0-170.5	9.5	3.59	38
15	18	2345	5699.5-5709.0	170.5-180.0	9.5	2.46	26
16	19	0230	5709.0-5718.5	180.0-189.5	9.5	2.41	25
17	19	0430	5718.5-5728.0	189.5-199.0	9.5	3.05	32
18	19	0659	5728.0-5737.5	199.0-208.5	9.5	4.52	47
19	19	0930	5737.5-5747.0	208.5-218.0	9.5	2.91	31
20	19	1137	5747.0-5756.5	218.0-227.5	9.5	7.85	83
21	19	1433	5756.5-5766.0	227.5-237.0	9.5	3.92	41
22	19	1640	5766.0-5775.5	237.0-246.5	9.5	6.02	65
23	19	1852	5775.5-5785.0	246.5-256.0	9.5	3.58	38
24	19	2108	5785.0-5794.5	256.0-265.5	9.5	2.59	27
25	19	2343	5794.5-5804.0	265.5-275.0	9.5	5.35	56
26	20	0345	5804.0-5813.5	275.0-284.5	9.5	3.60	38
27	20	0745	5813.5-5823.0	284.5-294.0	9.5	3.51	37
28	20	1020	5823.0-5832.0	294.0-303.0	9.5	1.0	10
29	20	1317	5832.0-5841.5	303.0-312.5	9.5	2.20	23
30	20	1620	5841.5-5850.5	312.5-321.5	9.5	1.0	10
31	20	1941	5850.5-5859.5	321.5-330.5	9.5	0.20	2
32	20	2344	5859.5-5868.5	330.5-339.5	9.0	0.10	1
33	21	0414	5868.5-5877.5	339.5-348.5	9.5	0.42	4
34	21	0747	5877.5-5886.5	348.5-357.5	9.5	0.23	
35	21	1222	5886.5-5896.0	357.5-366.5	9.5	0.24	

Note: Core number prefaced by H is a wash core.

beds are rare, with the exception of a few layers of volcanic glass shards and isolated concentrations of sponge spicules. A fragment of serpentinized peridotite was recovered in the deformed, soupy residue of Section 494A-2-2. For Unit 1 the average sand-silt-clay percentages are 16%, 36%, and 47%, respectively.

Core 3 of Hole 494A marks the first appearance of calcareous, ashy, micritic cobbles within the lithostratigraphic section. Cobbles of similar composition reappear in the uppermost sections of Cores 7, 8, 9, 10, 13, 17, 19, 24, and 28. Those subangular to subrounded rocks are retrieved as disoriented clasts, probably derived from uphole caving. When the bit is lifted from the bottom during core retrieval, clasts may collect with other caved material, and because of their large size, they may not be washed out during pumping prior to drilling of the next core.

The style of fracturing and drilling-induced swirling indicates that most of the sediment of Unit 1 is incompetent; only Sections 2 and 3 of Core 5, Hole 484A are sufficiently consolidated and fractured to form disaggregated drill cuttings, so characteristic of the immediately underlying unit. The primary fabric of Unit 2 may be preserved between 115 cm and 135 cm of Section 2, Core 9. That interval contains a loosely consolidated breccia that passes downward into drill cuttings.

Unit 2 (Cores 9 to 20, 115-224 m sub-bottom depth: Pleistocene to Pliocene)

The unit is differentiated from overlying sediment only by the absence or rarity of diatoms. A major depositional contact at 70 cm of Section 4, Core 20 defines the base of the unit and the base of the Pliocene. The dark olive gray (5Y 3/2) mud and granules of the semi-indurated mudstone dominating Unit 2 contain few biogenic remains. Pale, blue gray (5G 7/1 to 5BG 7/1) granules rich in volcanic glass and glauconite are a secondary constituent, and white to light gray (5Y 8/1 to 5Y 7/1) granules of micritic limestone are a third major constituent. Minor occurrences include ash layers in Core 11 and a quartz diorite cobble at the top of Section 1, Core 16. The average sand-silt-clay percentages for the combined, major lithologies are 17%, 30%, and 52%, respectively.

Unit 3 (Core 20, Section 4 to Core 22, Section 3, 224-241 m sub-bottom depth; lower Miocene to upper Oligocene)

The upper boundary of this unit is well defined at the Pliocene contact and the lower boundary is marked by a gradual color change beginning at 40 cm of Section 3, Core 22 and ending at a sharp contact in the OG (organic geochemistry) sample. Unit 3 contains bluish gray, mottled clay (5G 4/1 to 5BG 4/1). Smear slides indicate that nannofossils are the most important biogenic components of this sediment. The sand-silt-clay percentages are 1%, 28%, and 71%, respectively.

Core 22, Sections 1 and 2 contain subrounded granules and cobbles of calcareous chalk and limestone that must have been part of the undisturbed primary sediment, but the cause of deformation within the plastic sediment of that core is a subject of considerable discussion. Some judge this core to be mainly clay that has flowed plastically into the core liner. Others believe that the interior of core segments between horizontal twist-off fractures (biscuits) show original structure (see the Structure section). Other fabric, for example, Core 25, Section 1, surely reflects primary fracturing in those more consolidated sedimentary rocks.

Unit 4 (Core 22, Sections 3 and 4 to Core 27, Section 3, 241–294 m sub-bottom depth; middle Eocene)

The color and age boundary in Core 22 define the top of this unit of very dark gray (5Y 3/1) mudstone. The first appearance of foraminifer-bearing micrite marks the base. The sand–silt–clay percentages for this interval are 16%, 37%, and 47%, respectively. Core 27, Section 1 represents one of the most remarkable intervals recovered at Hole 494A. This is the first interval of brittlely fractured sedimentary rock preserved without much drilling deformation (Fig. 3). Simple offsets, conjugate fractures, and healed fractures are clearly outlined by light colored bands rich in volcanic glass.

Unit 5 (Cores 28 and 29, 294–313 m sub-bottom depth; middle Eocene to Upper Cretaceous)

This nannofossil-rich, dark olive gray (5Y 3/2) mudstone contains bluish gray (5G 6/1) micritic limestone and minor amounts of reddish black (10R 2.5/1) mudstone. Grain sizes are generally finer than within the overlying units, the sand–silt–clay percentages for Unit 5 being 7%, 28%, and 65%, respectively. The first occurrence of medium gray (5Y 6/1) pebbles of light greenish gray, altered igneous rock in the core catcher of Core 29 marks the base of the unit. Unit 5 is composed of middle Eocene sediment and rocks with some admixture of Upper Cretaceous sediment in Cores 28 and 29.

Unit 6 (Core 30, 313–322 m sub-bottom depth; Upper Cretaceous)

This unit is identified by medium gray (5Y 6/1) pebbles containing healed fractures and tests of *Globotruncana* abundant and large enough to be seen with a hand lens. Analysis of smear slides suggests that sand–silt–clay occur in proportions of 9%, 46%, and 45%, respectively.

Unit 7 (Cores 31–35, 322–366.5 m sub-bottom depth)

This unit includes the deepest sediment and rock cored at Hole 494A. Only 3% of the interval was actually recovered, and most of that consisted of drill cuttings. It is, therefore, difficult to reconstruct the appearance of the primary sediment and rock. The rocks, however, do represent an assortment of igneous types and offer a range of provenance.

Igneous Petrology

Several fragments of hard, very fine-grained igneous rocks were included in muddy drilling breccia in Cores 29, 31, 33, 34, and 35. Total recovery in the cores was very low. Nine representative samples are briefly described below. Most fragments are light greenish gray and locally contain .5 mm to 2 mm filled vesicles; Samples 494A-29,CC and 494A-31,CC (15–17 cm) are representative of the few percent of fragments that are very dark gray to brown. The core catcher in Core 31 also contained a 1-cm fragment of compact "epidote-rock" with druses of calcite.

Samples 494A-29,CC (0–3 cm), 494A-33,CC, 494A-34-1, 148–150 cm, 494A-35-1, 125–130 cm

This suite is characterized by 70% to 95% groundmass consisting of felted microlites of plagioclase .1 mm to .3 mm in length and interstitial material comprising brown clay, optically irresolvable phyllosilicates, and pale green chlorite (Sample 494A-29,CC). This interstitial material probably represents altered glass or originally fine-grained ferromagnesian minerals. Samples contain 5% to 15% locally clustered, subhedral to euhedral phenocrysts of colorless to very pale tan augite ($+2V = 45$–50) up to .6 mm in diameter. Sample 494A-29,CC may contain a few grains of olivine. Plagioclase grains are incipiently to moderately altered and contain tiny grains and patches of phyllosilicates and epidote. Tiny (.03 mm) clots of epidote(?) are scattered through the groundmass. Sample 494A-29,CC (0–3 cm) has a vesicle filled with sheaves of pleochroic pumpellyite, clay, and zeolite and a 2-mm vein of zeolite as well. Vesicles in Sample 494A-33,CC contain quartz, pumpellyite, and epidote. Vesicles in Section 494A-34-1 contain zeolite plus quartz; rare epidote and pumpellyite were noted in the groundmass.

Samples 494A-29,CC, 494A-31,CC, 494A-31,CC (12–15 cm)

Rocks in this suite all contain altered plagioclase laths, charged with and invaded by clay minerals and chlorite, and up to 20% quartz. In samples from Core 31, the quartz is in irregular patches up to .4 mm large and is probably a secondary mineral. In Sample 494A-29,CC, many quartz grains are subhedral, have sharp outlines, and may represent primary phenocrysts of bipyramidal volcanic quartz. Augite grains compose 10% of Samples 494A-29,CC and 494A-31,CC. Secondary epidote–clinozoisite is abundant (up to 7%) in both samples from Core 31; it also occurs in vesicles and veinlets (Sample 494A-31,CC [12–15 cm]) and as clots and crystal sheaves.

Sample 494A-29,CC

This is the texturally least-altered sample; the fragment is dark brown and aphanitic. Randomly oriented plagioclase laths and microlites .1 mm to .5 mm are in

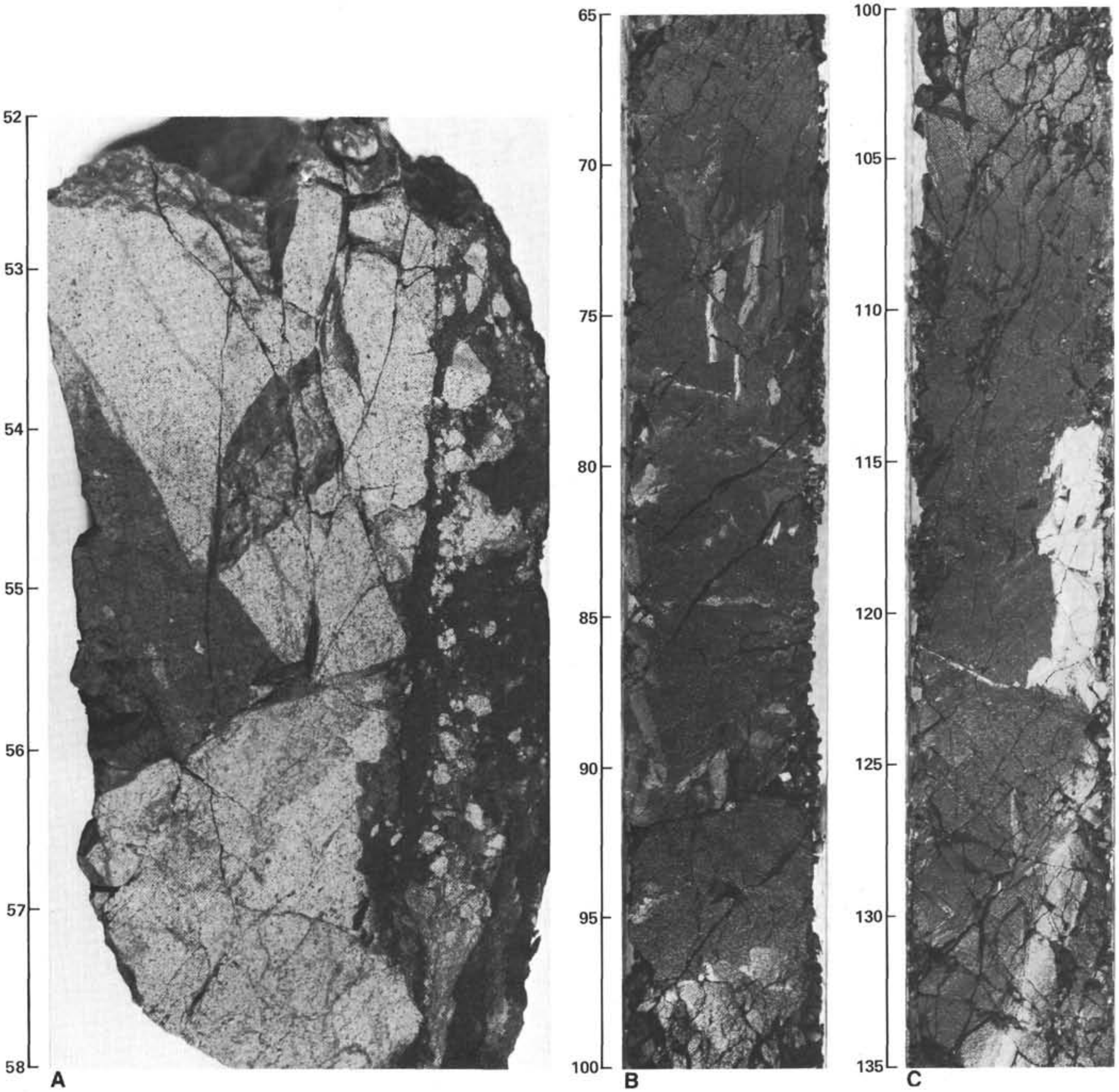


Figure 3. Deformation fabric of dark gray Eocene mudstones. (Off-sets, conjugate fractures, and healed fractures are outlined by light colored bands rich in volcanic glass.) A. Sample 494A-27-3, 52–58 cm; B. Sample 494A-27-1, 65–100 cm; C. Sample 494A-27-1, 100–135 cm.

an intersertal brown matrix of greenish brown very fine-grained phyllosilicates. Very rare relict ferromagnesian phenocrysts are nearly totally replaced by calcite. The matrix also includes chlorite, and it may represent altered glass. Plagioclase is sodic and charged with inclusions of phyllosilicates and epidote(?).

Sample 494A-31,CC

This is the coarsest-grained sample examined. It is composed of 55% strongly zoned laths of plagioclase (average length .5 mm but rare phenocrysts up to 1 mm long) and 23% fresh euhedral to subhedral augite (very pale tan, $+2V \sim 45°$). Twenty-percent of the rock is pale green intersertal chlorite filling interstices of plagioclase and pyroxene and probably representing altered glass. Almost all feldspars contain wisps, patches, and veinlets of chlorite and a medium brown mineral (smectite?). Rims are possibly as calcic as An 48–52. Lastly, it contains 2% well-formed but locally skeletal sphene intergrown with opaque minerals (ilmenite?) and has rare veinlets and patches of calcite.

Comments

These samples are all fragments or clasts of altered, fine-grained, mafic and possibly intermediate igneous rocks. Their original, primary constituents were typically microlitic plagioclase, phenocrysts of clinopyroxene (augite) and interstitial glass or very fine-grained ferromagnesian minerals. All samples record varying degrees of alteration, which in most cases has moderately to severely affected plagioclase and matrix. Original textures and mineralogy in most samples are reminiscent of diabases. Pervasive alteration precludes meaningful determination of plagioclase compositions, and the possibility that some samples have bulk compositions more silicic than diabase (basalt) cannot be excluded at present. Key secondary minerals are: chlorite, clinozoisite-epidote, pumpellyite, and zeolite. These assemblages record a static, pervasive, thermal metamorphic overprint, approximately corresponding to prehnite-pumpellyite-zeolite facies and probably the result of burial. These rocks are definitely atypical of "ocean-floor" basalts presently being consumed at the Middle America Trench.

It should be noted that the texture and primary and secondary mineralogy of the fragments do not in themselves provide much information on the type of volcanic deposits or body that the drill sampled. They could be fragments of flows, hypabyssal intrusive bodies, or clasts in volcanic conglomerates, and so on.

Structural Analysis

This section is divided into two parts. The first part generally interprets the consolidation history of the sedimentary section on the basis of systematic changes in drilling-induced structures and behavior. The second part contains a detailed analysis of more controversial structures in Cores 17, 22, and 27 and a discussion of whether they originated *in situ* or were formed during drilling.

Consolidation—Depth Relations

Although many cores from Hole 494A are characterized by sparse recovery of intact, whole pieces, there are systematic and progressive changes in material behavior that may be compared with those encountered at other DSDP sites at convergent plate margins. Core 1 and one and one-half sections of Core 2 consist of soft, plastic mud displaying the convex-upward swirling typically caused by drilling in this type of material. Part of Core 2 and all of Cores 3 and 4 consist of drilling fragments. In Core 5, however, firmer mud is divided into "biscuits" averaging 5 cm in thickness; these biscuits are separated by horizontal "drilling laminations" that generally hook downward within a few millimeters of the core liner. Laminations simply represent localized zones of intense drilling-induced shear separating less-deformed domains of original sediment in biscuits. Part of Core 5 consists of drill cuttings composed of mudstone fragments, Core 6 comprises only two fragments of hard micrite, and Core 7 contains three sections of angular mudstone cuttings. Core 8 (104 m) has the first good recovery of whole core below Core 2. Core 8 and the first one and one-half sections of Core 9 consist of stiff, flaky mudstone in discrete biscuits separated by 1-mm drilling laminations or equivalent zones up to 1 cm thick containing more pliant, drilling-remolded ("sheared") sediment. Mudstone biscuits in Cores 8 and 9 commonly display nonopened ("healed") shear fractures. Some have been locally intruded by mobilized remolded mud. Faint veining, possibly formed during dewatering, was observed in Sample 494A-9-2, 12-26 cm. With the possible exception of Core 22 (discussed in more detail in the following part of this section), similar features—including drilling laminations, biscuits, shear fractures, angular drill cuttings, and intermittent poor recovery—characterize cores below 9.

Taken together, these features indicate that an important change in material response, or deformational behavior, takes place from Core 5 (first biscuits; approximately 76 m sub-bottom depth) to Core 8 (distinctly firm, locally fractured biscuits; 104 m sub-bottom depth). In essence, the sediments begin responding by showing more localized strain (laminations) or brittle behavior (extensional shear fractures) rather than the more homogeneous, macroscopically ductile flow typical of less-consolidated material uphole. In fact, this change in behavior can be arbitrarily chosen to mark the onset of lithification and, as such, can be identified at other DSDP sites. If all other variables are equal or unimportant, the behavioral change may be a function of the degree of consolidation of the sediment. Even though there is some debate about whether fractures such as those in Cores 8 and 9 are caused by drilling (see the next section), the fact that they are first noted in an interval marked by the onset of unequivocally drilling-induced structures (biscuits and laminations) suggests that they may be used as an index of lithification regardless of their origin.

Lithification, as defined above, begins at a shallow sub-bottom depth in Hole 494A (approximately 80–100 m) compared to other sites in similar geologic environments. At Site 488 (Leg 66), about 8 km landward of the Middle America Trench off Oaxaca, stiff mud was first noted at 181 meters and the first healed fractures at depths below 220 meters. At Sites 434 and 441 (Legs 56 and 57), on the lower slope of the Japan Trench, the first veining and fracturing begin at 132 meters. At this depth, drill cuttings resemble the mudstone-chip drill cuttings that dominate the cores from Hole 494A below 75 meters. At Site 459 (Leg 60), at the top of the landward slope of the Marianas Trench, fracturing was first noted below 200 meters. Sediments cored on the landward walls of trenches at Sites 434, 441, 459, and 488 all become lithified at shallower depths than sediments in nearby reference sites (on the downgoing oceanward plate or landward slope), which have not been affected by any tectonism associated with crustal convergence. Sediments at these reference sites have been normally and lithostatically consolidated. In contrast, shallow sediments in Sites 434, 441, 459, and 488 have been overconsolidated by tectonic stresses in excess of lithostatic stresses. The upper Pleistocene sediments at Site 494 may be tectonically overconsolidated as well, because lithification features are noted at even shallower depths than at Sites 434, 441, 459, and 488. Measurements of physical properties (following section) also indicate that sediment at Hole 494A becomes overconsolidated at approximately 40 to 80 meters.

The tectonic stresses responsible for this overconsolidation and anomalously shallow onset of lithification may be related broadly to crustal convergence—the subduction of one lithospheric plate beneath another. Deformation caused directly or indirectly by plate convergence on a large scale probably occurs in a variety of distinct, smaller-scale tectonic environments on and within the inner slopes of trenches. For example, packets of sediment scraped off the descending plate and plastered onto the landward trench slope might be tectonically compressed, consolidated, dewatered, and uplifted soon after deposition. Preliminary data suggest, however, that drilling at Hole 494A penetrated slope sediments that were not scraped from the descending plate. Perhaps the generally observed overconsolidation of young sediments from Hole 494A and holes near other active trenches indicates that silts and clays at the foot of the inner slope undergo some convergence-related strains, regardless of whether they originated as ocean-plate or slope sediments and even if they lie structurally above the hypothetical zone of offscraping and underplating.

Origin of Small-scale Structures

There are differences of opinion among the Shipboard Scientific Party regarding whether some interesting structures in Cores 17, 22, and 27 formed during drilling or *in situ* deformation. Because one of the goals of Leg 67 was the characterization of deformational styles broadly associated with convergence, we have tried to develop criteria for distinguishing the two types of structures. The following remarks briefly summarize pertinent observations and some working hypotheses. Analysis is hampered because of poor core recovery, lack of marker horizons, and local severe drilling disturbance (laminations and biscuits).

Although shallower cores contain fractures and biscuits, these features are particularly well developed in Core 17. The entire core is dominated by drilling biscuits separated by laminations and zones of more pliant, plastic mud. Two types of fractures were noted. Above 50 cm in Core 17, Section 1, most fractures occur wholly within biscuits and only locally do they cross laminations. The fracture pattern in these biscuits is basically a shear set (with each shear fracture oriented at a maximum of 30°–40° from the core axis) and a less well-developed fracture set oriented almost parallel to the core axis. Both of these fracture sets may be drilling-induced because of their consistent symmetrical orientation with respect to the core axis. Both patterns are enhanced by opening as the core dried. Another type of feature occurs in larger (5–7 cm long) biscuits from 80 to 100 cm in Section 494A-17-1. At 82 to 88 cm, a set of sigmoidal dark veins up to 1.5 mm wide progressively offsets thin, light-colored layers, which may be bedding laminae, in a left-lateral sense. In the next lower biscuit at 90 cm, a 1 to 2 mm dark vein is offset by <1 mm fractures. Most veins and fractures in this part of the core are healed and have not been opened or intruded with mud during drilling. They can be interpreted as *in situ* deformational features.[3]

[3] Note that the result is a shortening parallel to the core axis.

The unusual structure of Sections 494A-22-1 and 494A-22-2 is difficult to resolve. Core 22 recovered a lower Miocene blue gray pebbly mudstone. Upon drying, dessication cracks accentuated the internal structure. The lower half of Section 494A-22-2 is punctuated by horizontal to convex upward drilling laminations spaced every 2 to 5 cm. Similar, more widely spaced fractures occur through Section 494A-22-1 and the remainder of Section 494A-22-2. These are concentrically striated with respect to the core axis and were clearly produced by drilling. Biscuits between laminations display intricate, swirled patterns defined by variably colored but generally bluish mudstone. Tiny dessication cracks .2 to .3 mm wide mimic the swirling. On a smaller scale, the mudstone has a penetrative fabric best described as "microflaky" or microscaly." Tiny polished scales of mudstone are easily visible by a hand lens; their parallel orientation defines a foliation that is reflected by the dessication cracks. The microscaliness is probably a record of the cataclastic flow that accommodated the mesoscopic swirling flow on a smaller scale. Scattered limestone fragments up to 4 cm long have slickensided and striated rinds of mudstone, which indicate they rotated with respect to the mudstone matrix.

We do not yet agree regarding how much of the observed structure in Core 22 could have formed *in situ*. The flow structure, defined by microflakiness, color variations, and tiny cracks, is locally axially symmetrical; the impression is one of small convex-inward convective cells within biscuits. This symmetry argues that at least some of the flow was drilling-induced. However, adherents to this hypothesis are unsure of whether *all* of the micro- and mesostructure was due to drilling or whether some could have been inherited from a predrilling, *in situ* deformation. The possibility of a remobilized deformed sediment cannot be refuted. Another opinion holds that some of the structures in the centers of biscuits is inherited from an *in situ* fabric. Locally, flow patterns are chaotic and do not have any apparent symmetrical relation to core-barrel geometry. The fabric of *in situ* mudstone may also be random, perhaps it records deformation along a major fault. The *Kana Keoki* survey has defined a topographic offset in the lower trench wall that trends toward and projects through the site. This feature may be a major, near-vertical fault zone.

All observers were impressed by the peculiar behavior of the mudstone of Core 22, which has deformed by a combination of mesoscopic cataclastic flow and more localized horizontal fractures. If the flow is drill-induced, an unusual mineralogy may be a factor; if it is *in situ*, fluid overpressures or fault-related deformation might have been responsible. Typical olive gray mudstones in shallower cores (e.g., Core 17) have deformed predominantly by fracturing. It should be pointed out that 20 cm of Upper Cretaceous black mudstone in Core 29, Section 1 has an apparently identical fabric.

Section 494A-27-1 consists predominantly of firm, dark gray Eocene mudstone with irregularly distributed layers and wisps of lighter gray, more clay-rich, slightly calcareous mudstone (Fig. 3). There is general agreement that this sedimentary rock has undergone two distinct types of deformation. The earlier, "soft" deformation is recorded by the irregular shapes and chaotic distribution of some of the light gray material. That event, which disrupted sedimentary layering, probably occurred while the rock was less consolidated and thus able to flow mesoscopically; thin-section observations indicate no microfracturing at all. The process (e.g., gravitational sliding; tectonic consolidation) responsible for this deformation is unknown. During the second stage of deformation, the rock responded in brittle, rather than ductile, fashion. Healed (nonopen) shear fractures are marked by <1-mm-thick zones of dark, cohesive, "gouge," which may consist of remolded sediment or finely granulated rock. Both healed and open fractures are inclined $>30°$ to the core axis and some extend completely across the core. Fractures at 70 to 80 cm form a conjugate set, and displacements recorded by offset light gray layers have resulted in extension normal to the core axis. This symmetry suggests that some displacements <1 cm could be related to drilling. However, several healed fractures, parallel to open fractures of this set, have offsets that exceed several cm, because the continuations of offset layers do not occur within the core. Thus some healed fractures must have existed prior to drilling, but other parallel fractures with small displacement may have been reactivated or induced by drilling. Microscopic observations of Section 494A-27-1 show features, such as fractures truncating at sharp corners, which are compatible with brittle deformation.

The cause of this brittle, *in situ* fracturing is not known. It could be related to topographic offsets, interpreted as faults from seismic lines obtained by *Kana Keoki;* or other unknown, convergence-related tectonic stresses might have been responsible.

Summary

Fossil remains and rock types allow some conjecture as to the provenance of units cored at Holes 494 and 494A. The affinity of rocks cored at the base of Hole 494A is probably something other than ocean-floor basalts, but because they occur as drill cuttings, their stratigraphic relation to the overlying *Globotruncana* clasts of Unit 6 is not firmly established. Unit 6 is representative of an open ocean environment, the absence of detrital grains indicating that deposition occurred far from the influence of hemipelagic sedimentation. Foraminifers disappear from Unit 5, and the nannofossils of Unit 5 disappear upwards towards Unit 4. The sequence: clays, then nannofossils, followed by nannofossils plus foraminifers is reminiscent of a pelagic section deposited on a subsiding and aging seafloor. This explanation seems untenable, however, in view of the lagoonal aspect of the nannofossils of Unit 5. Rapid vertical movements must be involved to account for the presence of an open-water assemblage in Unit 6 overlain by a lagoonal facies in Unit 5.

Sedimentary Units 3 to 1 suggest the progressive deepening of the site in combination with the increasing importance of sediment transport downslope from shallow water. Calcareous grains of Unit 3 give way to clay minerals in Unit 2, a series of cores represented by drill cuttings. A subrounded quartz dioritic cobble recovered in Core 16 suggests continental influence.

On the basis of structural evidence and paleontologic depth indicators (see the section on Biostratigraphy), Unit 1 consists of redeposited sediment derived from higher up on the slope, less than 2000 meters water depth. The microfossils within the mud are clearly out of place at the locality from where they were recovered, present water depth 5529 meters. Although drilling disturbance makes structural interpretation difficult and ambiguous, displaced microfossils are evidence for down-slope mass transport of the sediment of Unit 1. The relatively high organic matter content of the dark muds indicates a depth of origin between 500 and 2000 meters on the slope. The oxygen minimum level presently intersects the slope within that depth range and may have done so during earlier episodes of the Pleistocene. Terrigenous sand layers rich in volcanogenic material are derived from areas landward from the shelf break, ultimately from the Quaternary volcanic belt of Guatemala.

PHYSICAL PROPERTIES

Wet-Bulk Density, Water Content, and Porosity

Figure 4 shows the vertical distribution of these parameters with depth and defines four distinct stratigraphic units. Bulk density and water content vary inversely with each other and show large variability with depth.

Unit 1: Extends from the mud line to approximately 80 meters (corresponding with upper Quaternary diatomaceous sandy mud and muddy clay). Water content decreases from slightly more than 100% (dry weight) in Hole 494, Core 1, Section 1 to slightly less than 50% at 80 meters in Hole 494A, Core 5.

Unit 2: Extends from 80 to 190 meters and shows significant variation in water content and one low value for bulk density. No data is available for the interval between 120 to 190 meters due to extreme brecciation of the Pleistocene mudstone and calcareous siltstone.

Unit 3: Begins with a clustering of GRAPE (continuous and 2-minute measurements) densities between 190 to 240 meters, varying between 1.65 to 1.80 Mg/m^3, through the mudstones of the Pliocene/Pleistocene transition and including the upper Oligocene/lower Miocene claystone.

Unit 4: Begins at 295 meters where Upper Cretaceous mudstones occur and extend to the base of the hole, their continuity interrupted by a thin (approximately 10 m) section of middle Eocene claystone. These interbedded lithologies are most clearly shown by the water content variations (Fig. 4A). At 300 meters, Cretaceous sediment with low water content is followed by middle Miocene sediment with higher water content (310–320 m), again followed by Cretaceous sediment with low water content. The same interval is marked by porosity and bulk density changes (Fig. 4A).

Sound Velocity

Compressional-wave velocity shows a remarkably uniform pattern from the mud line down to 300 meters, varying narrowly within 1.5 to 2.0 km/s (Fig. 4B). The data are not likely to be representative of *in situ* velocity conditions until Cretaceous rock is reached, because the entire sediment column for about 300 meters was alternately very gassy and/or very strongly fractured. Attenuation of the signal was generally very high and often made valid readings on the oscilloscope impossible.

Impedance variation shows the possibility of at least two reflectors in the sediment column above the Cretaceous. They occur at 150 and 240 meters (Fig. 4B). The Cretaceous rocks may serve as a significant reflector inasmuch as their impedance is two to three times the impedance of the rocks above (with the exception of the two data points at 150 and 240 m, as noted). No downhole sonic log was available for comparison.

Shear Strength

The upper 20 meters at Hole 494 consist of deformed, clay-rich sediments possessing a consistently low shear strength (approximately 10 kPa) (Fig. 5). Below 20 meters, shear strength increased regularly with depth to 80 meters, where, due to induration, testing could no longer be performed. Several tests made on the sediments from Cores 17, 18, and 19 indicated very high shear strengths.

Table 2 summarizes Site 494 physical properties.

GEOPHYSICS

Introduction

Hole 494A is located 3 km landward of the trench axis on the lowest of a series of narrow bathymetric terraces that characterize the Middle America Trench landward slope. The hole is 580 meters above the floor from the trench in 5529 meters of water. The "steep" slope from the seaward edge of the terrace to the trench floor dips approximately 7°. The terrace extends at least 15 nautical miles along the slope parallel to the trench and terminates about 10 nautical miles southeast of the drill site. Hole 494A is located on a portion of the terrace that has a more irregular, broken topography than to the southeast or northwest, where the mile-wide terrace is broken only by occasional steps (Fig. 6).

Seismic Surveys

Before drilling, the site was surveyed by seismic shooting on a 3- to 10-mile grid. The 24-fold Common Depth Point (CDP) seismic profiles recorded low-frequency sound sources with energy concentrated in the 10 to 50 Hz band. During the drilling the site was surveyed with a single-channel seismic-reflection survey using a sound source with energy spread across the 100 to 500 Hz band. The single-channel survey is gridded at a half-mile line spacing and shows that the surface of the terrace is generally an irregular series of small steps. In many cases the boundaries of the steps may be associated with near-vertical faults. Near-vertical faulting may also be associated with breaks in the slope above and below the terrace.

The high-resolution survey suggests that Hole 494A is located at the intersection of two faults. A north-trending fault is indicated by an S-curve in the bathymetric contours between the terrace and the trench floor. An east-trending fault on the terrace through Hole 494A is indicated by the alignment of fault offsets noted on three high-resolution seismic lines that cross the terrace.

The high-frequency survey shows reflections in the upper 200 to 300 meters of section that are discontinuous in lateral extent, but it indicates that in many areas the slope both above and below the terrace is represented by horizontal reflectors. In most cases these reflections cannot be traced more than 0.5 miles. It is not clear whether the reflections terminate because of local faulting or because the overlying topography causes irregular scattering, which produces variable amplitudes of deeper reflections. Under the terrace on which Site 494 is located, many reflections appear subhorizontal and some of them may even crop out on the slope below the site. In the immediate vicinity of Hole 494A there are minor faults with a small but indeterminate vertical offset.

The multichannel CDP seismic survey indicates deeper, more persistent reflections. At about 8 s on the time section (Figs. 6 and 7), or about 800 meters ± 100 meters into Hole 494A, a reflection is seen that extends at least 20 km parallel to the trench and 5 km landward from the trench. This reflection is at an appropriate depth to represent the top of ocean crust extending landward beneath the lower slope. The section beneath the mudline and above this 8-s reflection can be divided into two units on the basis of the low-frequency seismic data (Fig. 7). The upper unit between the seafloor and about 0.4-s sub-bottom consists of weak, irregular reflections. The details of this upper section show in the high-frequency data. At about 0.4 s sub-bottom, a strong, irregular reflection occurs that marks the top of a series a strong, irregular reflections. Southeastward along the trench the upper trench unit pinches out, possibly exposing the lower unit at the seafloor.

Laboratory measurements indicate that the rock at Hole 494A has sonic velocities of about 1.7 km/s in the first 300 meters and about 4.0 km/s below that to the bottom of the hole. This velocity structure indicates that the top of the 4-km/s unit ought to be 0.35 s sub-bottom on the seismic section, coinciding within reasonable limits with the strong reflection at 0.4 s sub-bottom. The 0.4-s reflection is, therefore, probably the top of the Upper Cretaceous claystone and igneous rock obtained from the hole.

Northwest–southeast trending magnetic anomalies of the ocean crust seaward of the trench terminate along the trench axis. The slope and shelf coincide with an irregular series of anomalies that generally parallel the trench. Regional analysis of the seafloor magnetics suggests that deposition of the ocean crust just seaward of Hole 494A took place in the Eocene.

A postdrilling bathymetric survey (Aubouin et al., this volume) shows that the terrace where Site 494 is located parallels the trench axis for 15 nautical miles. The straight boundary between the trench floor and the slope below the trench suggests an origin other than slumping for the terrace, because slumps are usually associated with lobate bathymetric contours.

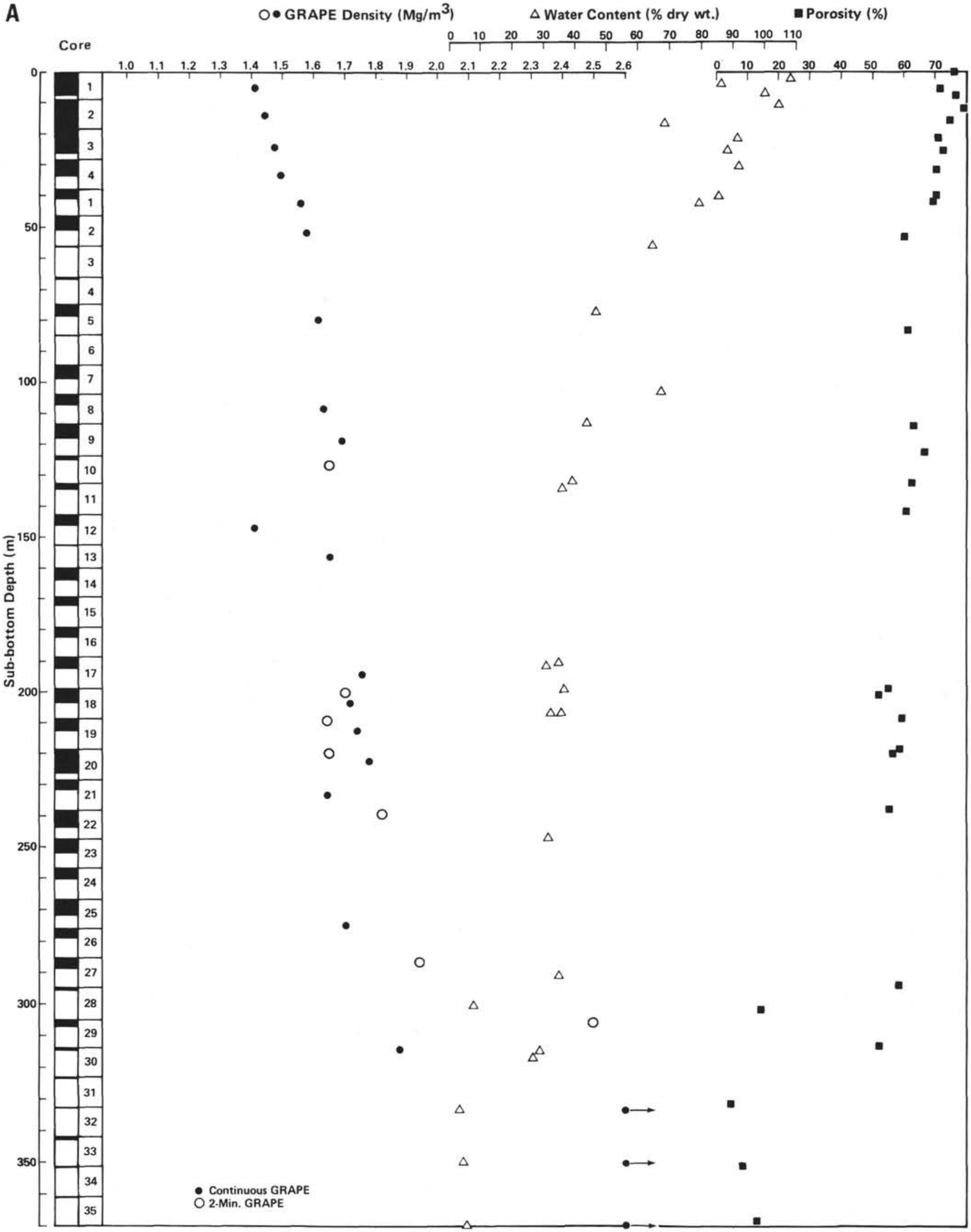


Figure 4. A and B. Physical properties of the lithologic section at Site 494. (A. Arrows denote points outside the range of the graph for GRAPE density data.)

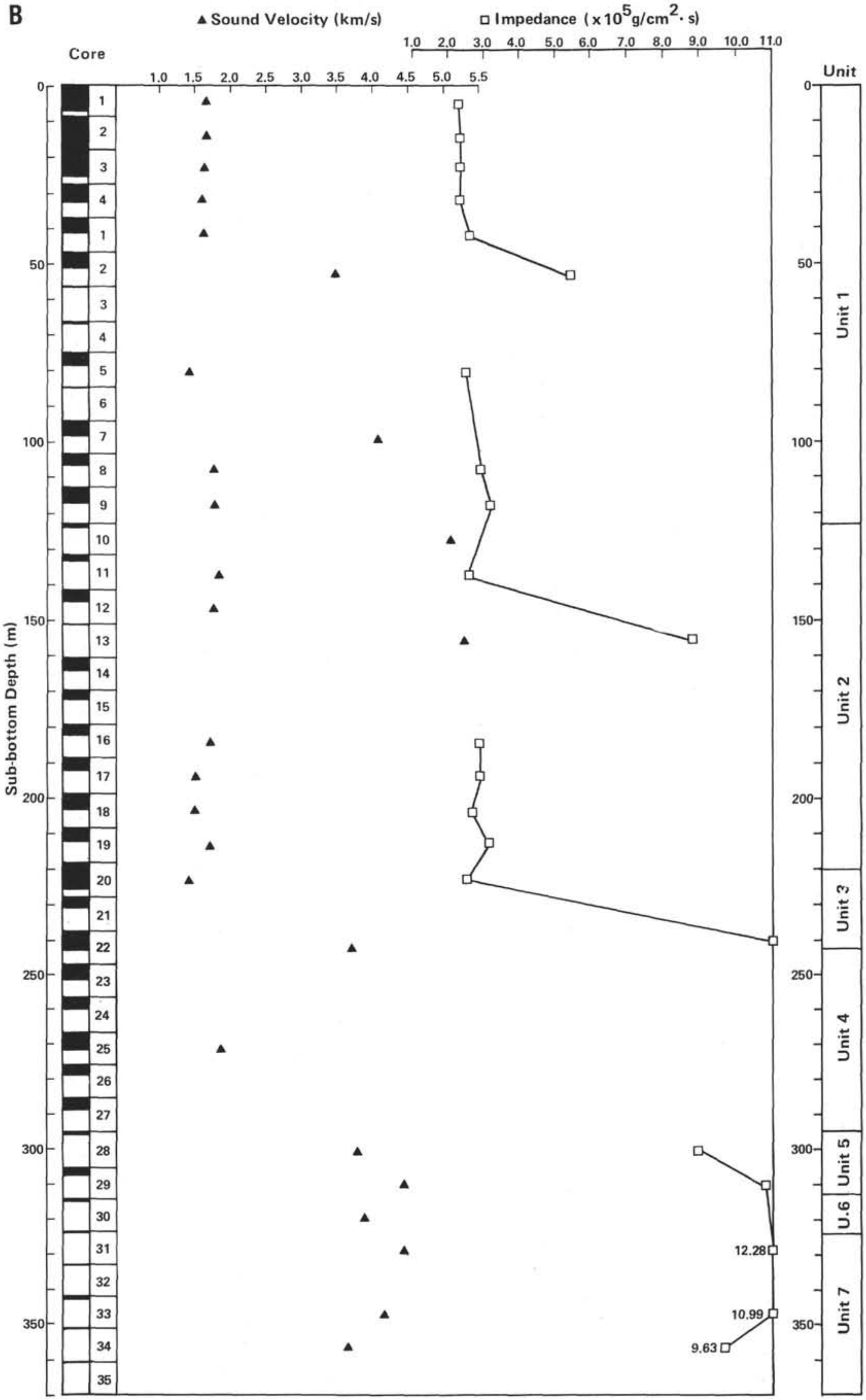


Figure 4. (Continued).

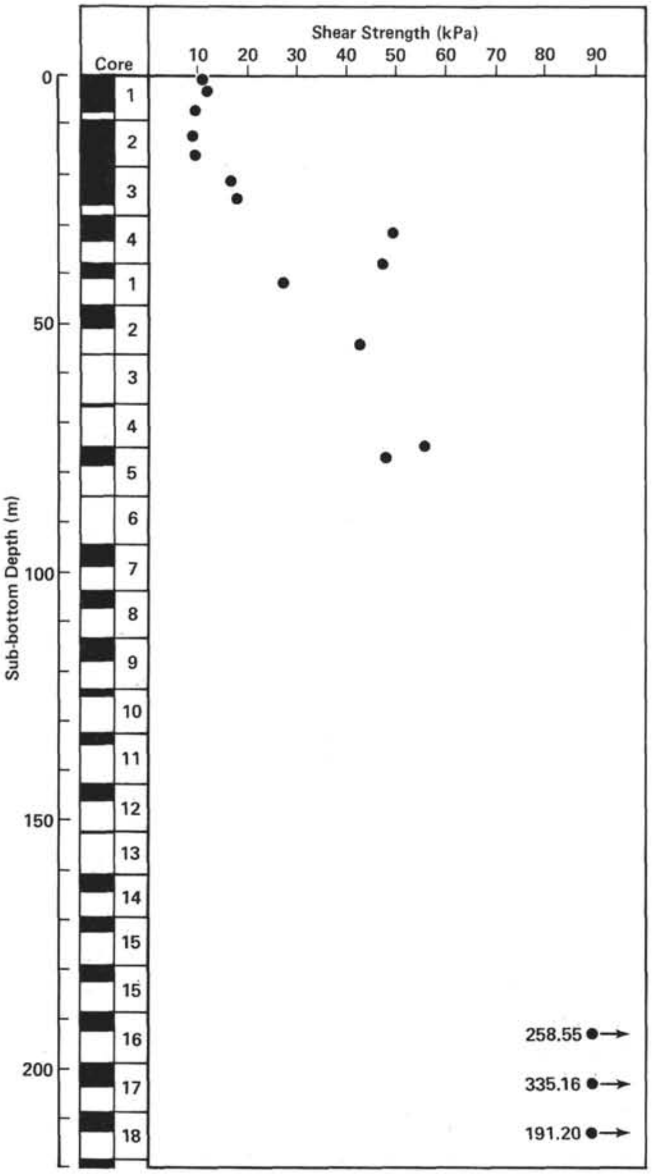


Figure 5. Shear strength of sediment from Site 494. (Arrows denote points outside the range of the graph.)

DOWNHOLE EXPERIMENT

Site 494 was chosen for installation of a three-component, short-period seismometer developed by the Hawaii Institute of Geophysics for use in drill holes. The downhole sensor was placed in Hole 494A at a sub-bottom depth of 297 meters on 24 May 1979. The downhole system is composed of three parts: the sensor package, the recording package, and the recovery assembly (Fig. 8). Only 29 in. long and 3⅝ in. in diameter, the downhole package contains tilt, temperature, and seismic sensors as well as the electronics necessary to send the data up the wire to the recording package. It is mounted on the retractable arm of a standard logging tool that holds the package against the side of the hole. Well-logging equipment on board the drilling ship is used to install the instrument.

Table 2. Physical properties, Site 494.

Sample (core-section, interval in cm)	GRAPE Wet-bulk Density (Mg/m^3)	*P*-Wave Velocity (km/s)	Acoustic Impedance ($\times 10^5 g/cm^2 \cdot s$)	Shear Strength (kPa)	Water Content (% dry wt.)	Porosity (vol. %)
Hole 494						
1-1, 58	1.39	1.62	2.25	—	—	—
1-1, 77	1.41	1.61	2.27	—	—	—
1-1, 93	1.43	1.63	2.33	—	—	—
1-1, 133–135	1.42	—	—	10.72	108.4	75.7
1-2, 56	1.43	1.72	2.46	—	—	—
1-3, 78	1.41	1.61	2.27	—	—	—
1-3, 109–111	1.47	—	—	11.10	86.6	72.6
1-4, 106	1.46	1.59	2.32	—	—	—
1-5, 69–71	1.41	—	—	9.96	100.0	76.3
1-5, 92	1.42	1.63	2.31	—	—	—
2-3, 46	1.36	1.63	2.22	—	—	—
2-3, 103–105	1.36	—	—	9.19	104.6	79.4
2-4, 69	1.44	1.62	2.33	—	—	—
2-5, 54	1.40	1.60	2.24	—	—	—
2-6, 81	1.48	1.64	2.43	—	—	—
2-6, 119–121	1.45	—	—	9.58	68.2	73.8
2-7, 83	1.39	1.62	2.26	—	—	—
3-1, 129	1.46	1.55	2.26	—	—	—
3-3, 88	1.47	1.65	2.43	—	—	—
3-3, 99–101	1.50	—	—	16.65	91.2	70.8
3-5, 131	1.39	1.68	2.34	—	—	—
3-6, 118–120	1.47	—	—	18.38	88.6	72.0
4-2, 41	1.50	1.61	2.42	—	—	—
Hole 494A						
1-1, 82	1.49	1.64	2.44			
1-1, 133–135	1.50			10.72	108.4	75.7
1-2, 36	1.42	1.63	2.31			
1-3, 70–72	1.51			26.81	79.3	69.5
1-3, 77	1.52	1.42	2.16	—	—	—
2-1, 57	—	3.49	—	—	—	—
2-7, 37–39	—	—	—	43.09	64.2	60.3
5-1, 40–42	1.64	—	—	55.54	46.5	61.5
5-1, 81–83	1.62	—	—	47.88	—	—
5-1, 85	1.62	1.45	2.35	—	67.4	63.3
8-1, 124–126	1.62	—	—	—	—	—
8-2, 104	1.60	1.76	2.82	—	—	—
8-2, 111	1.60	1.51	2.42	—	—	—
9-2, 11	—	1.48	—	—	—	—
9-2, 21	—	1.81	—	—	—	—
9-2, 99–101	—	—	—	—	42.9	66.1
10-1, 104	—	5.18	—	—	—	—
10-1, 143–145	—	—	—	—	39.1	62.1
11-1, 91	1.64	1.85	3.03	—	—	—
11-1, 119–121	1.66	—	—	—	37.6	60.3
12,CC	—	1.76	—	—	—	—
13-1, 100	1.66	5.30	8.80	—	—	—
17-1, 76–79	—	1.57	—	258.55	33.4	54.4
17-1, 137–139	—	1.55	—	—	—	—
17-2, 82–84	1.70	1.67	2.84	—	30.5	51.4
18-1, 79–81	1.70	—	—	335.16	36.7	59.5
19-1, 10–12	1.30	1.72	2.24	—	32.0	57.4
19-1, 109–111	1.52	—	—	191.52	32.1	55.7
20-2, 17	1.78	1.38	2.46	—	—	—
20-3, 9	1.76	1.54	2.71	—	—	—
22-1, 140–142	1.83	—	—	—	30.5	54.5
22-3, 9	1.80	3.59	6.46	—	—	—
25-1, 64	—	1.86	—	—	—	—
27,CC	—	—	—	—	33.5	56.9
28-1, 49–51	—	—	—	—	5.6	13.4
28,CC	—	3.51	—	—	—	—
29-2, 9–12	—	—	—	—	27.1	—
29-2, 30–33	—	—	—	—	27.1	50.6
31,CC	—	—	—	—	1.4	3.9
33,CC	—	—	—	—	2.7	7.1

Note: — indicates no data available.

The recording package consists of two 6-ft. cylinders that remain on the seafloor but are attached by logging cable to the downhole sensor (Fig. 8). Power is sent from the recording package down the wire to the sensor package, and the signal returned is recorded on cassette tapes.

Although the seismometer sensors did not perform as well as hoped (due to a partial failure of a data digitizing circuit), many earthquakes, explosion–refraction data, temperature, and tilt data were recorded during a 24-hr. period when the sensors were monitored on the *Challenger* during installation of the ocean–sub-bottom seismometer (OSS) in the hole and during the four-week deployment. The five conventional ocean-bottom seismom-

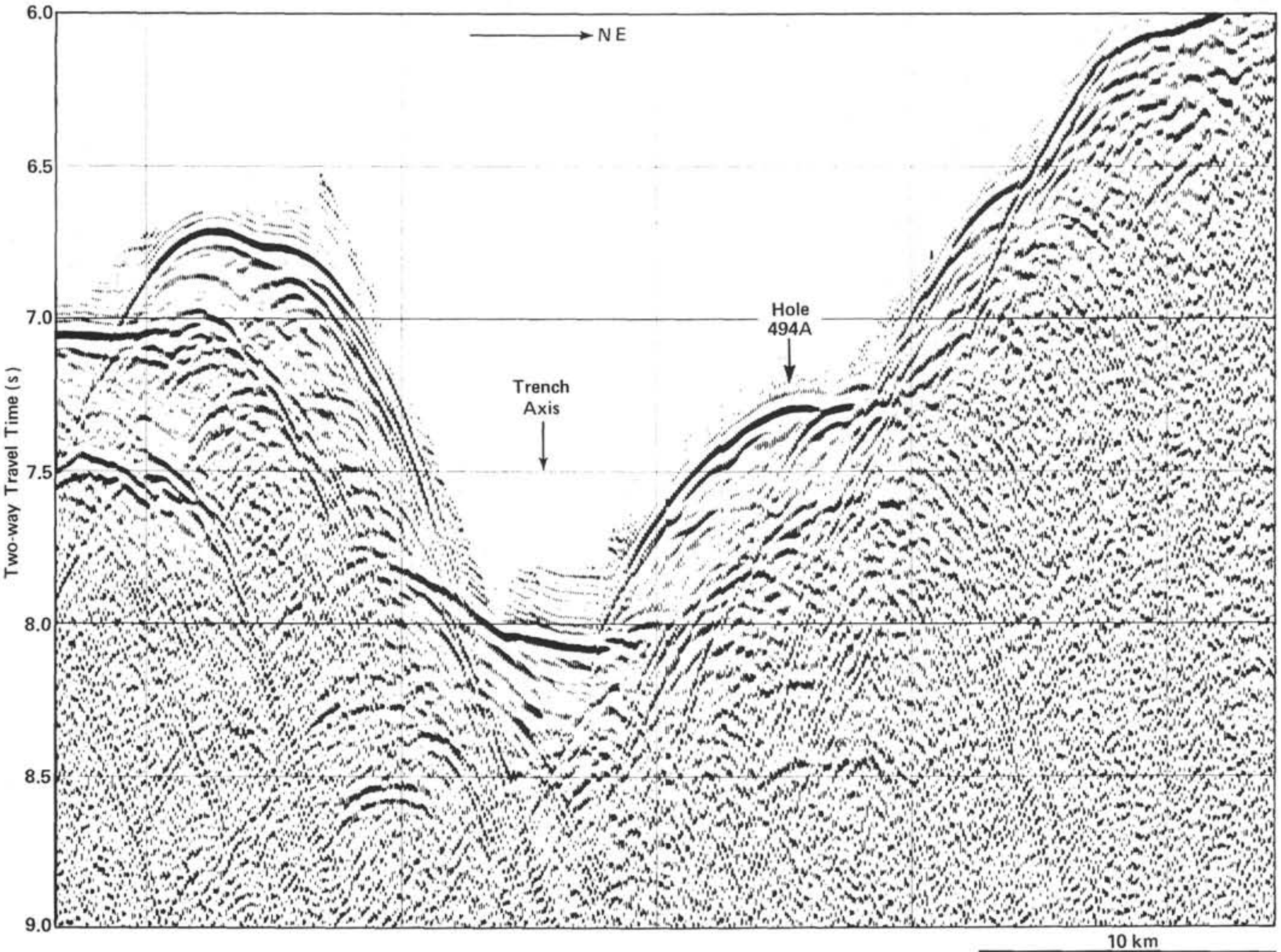


Figure 6. A 10 to 50 Hz seismic-reflection record (GUA-18) representative of the records collected during the UTMSI site survey of the Guatemalan margin.

eters (OBS) were all recovered, and all contained excellent data.

After recovery of the first data set, the OSS system was refurbished and redeployed to record two additional months' data. The entire system, and the two-month data set, were recovered in February 1980.

Analysis of the seismic data is not complete. On the basis of the excellent quality of the OBS and some of the OSS data, useful structural and tectonic information should be obtained from the experiment. The temperature and tilt data are available, and these are of some interest.

Temperature

Because of the floating-point scheme used to record temperature, the digital step sizes of these data are very large. Each step represents about 3°C, and there are only two steps during the entire recording period. A few hours after emplacement, the temperature was measured to be 2.45 ± 1.5°C. Then, as the effects of drilling became negligible over the next ten days, the temperature increased to 8.45 ± 1.5°C. Thermal equilibrium was approached at a slow rate.

An estimate of heat flow can be made using the temperature at the ocean floor and the temperature measured by the downhole package (297 m sub-bottom depth). Assuming a thermal conductivity of 2 units and a bottom temperature of 0°C, we compute a heat flow of 0.57 ± 0.10 hfu (heat-flow units).

Tilts

Two perpendicular bubble tiltmeters with a sensitivity of 3 V/rad within ±0.2 radians of vertical are mounted in the downhole sensor. The sensor package, after being clamped in Hole 494A, is approximately 32.3 milliradians from vertical in the parallel tiltmeter direction and 49.4 milliradians from vertical in the perpendicular tiltmeter direction. The step size on both of the tilt channels this far from the upright position is 0.215 milliradians. Figure 9 shows both components of tilt during the first OSS deployment.

The actual orientation of the tilts with respect to the edge of the hole is calculated on the basis of the charac-

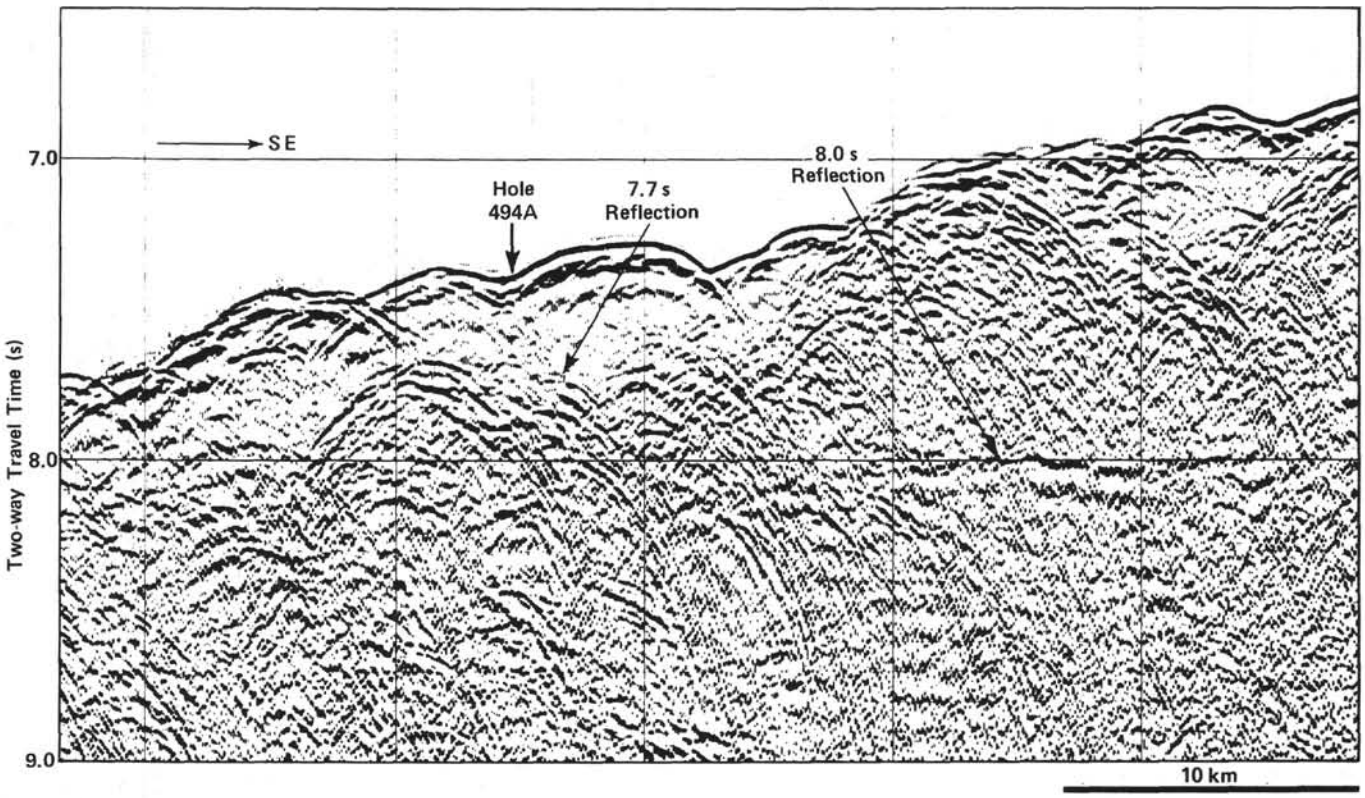


Figure 7. Portion of a multichannel record (GUA-9) perpendicular to and crossing GUA-18 at Site 494, which shows reflections beneath the seaward extremity of the Guatemalan margin. (The reflection at 7.7 s occurs 0.4 s below the seafloor.)

ter of seismic arrivals on the horizontal geophones from shots with known locations. The tiltmeters were oriented relative to the horizontal geophones.

One full milliradian of tilt change was observed in the first seven days of recording. At that time the direction of tilt change reversed, and its rate of change decreased. This is too much tilt change to be tectonic in origin. The tilt may be an effect of slow strain induced by drilling, temperature change in the hole, or some settling of the sensor against the wall of the hole. The fact that the direction of tilt change is fairly smooth and reverses itself with time suggests that the effect involves the drill hole, rather than being just the result of the instrument settling against the wall or the interaction of the logging cable settling in the hole. The two months' tilt data still to be recovered may clarify the tilt interpretation.

BIOSTRATIGRAPHY

Drilling at base-of-the-slope Holes 494 and 494A recovered a succession of Upper Cretaceous mudstones, middle Eocene siltstones, and lower Miocene to Quaternary mudstones (Fig. 10). Upper Quaternary unconsolidated diatomaceous muds, rich in organic matter, fecal pellets, plant debris, upper bathyal foraminifers, and frequent clasts bearing Miocene radiolarians characterize Hole 494, Cores 1 to 4, and Hole 494A, Cores 1 to 5; in contrast, lower Quaternary diatomaceous mudstones are poorly fossiliferous, but also bear Miocene clasts (Hole 494A, Cores 6–16). Upper Oligocene or lower Miocene claystones through Pliocene mudstones (Hole 494A, Cores 17–22) occasionally bear middle Eocene clasts. Middle Eocene siltstones in Hole 494A, Cores 23 to 27, bearing some radiolarians and poorly preserved nannofossils and lacking foraminifers, are interpreted as having been deposited below the CCD. Hole 494A, Cores 28 to 30, terminates in Upper Cretaceous (Maestrichtian) mudstones with strongly recrystallized foraminifers and radiolarians.

Three major hiatuses are evident at Holes 494 and 494A (Fig. 11). The youngest hiatus is shown as a lithologic contact between lower/middle Miocene claystones and lower Pliocene mudstones in Core 20, Section 4. A second gap occurs between the middle Eocene drill breccia and upper Oligocene/lower Miocene claystone (Hole 494A, Cores 23 and 22, respectively). The third hiatus separates the Upper Cretaceous (Maestrichtian) calcareous mudstones from middle Eocene radiolarian siltstones (Hole 494A, Cores 28 and 27, respectively). Contact relations for either hiatus reveal no information about their sedimentary or tectonic origins.

Foraminifers

Cores 1 through 4 (Hole 494) and Cores 1 through 5 (Hole 494A) contain common to abundant, well preserved planktonic and benthic foraminifers deposited in the late Pleistocene or Holocene. Typical planktonic forms include *Neogloboquadrina eggeri, N. subcretacea, Globorotalia menardii, Globigerinoides ruber, G. sacculifer* and *Globigerinita glutinata;* benthic forms include *Bolivina* spp., *Bulimina* spp., costate and finely

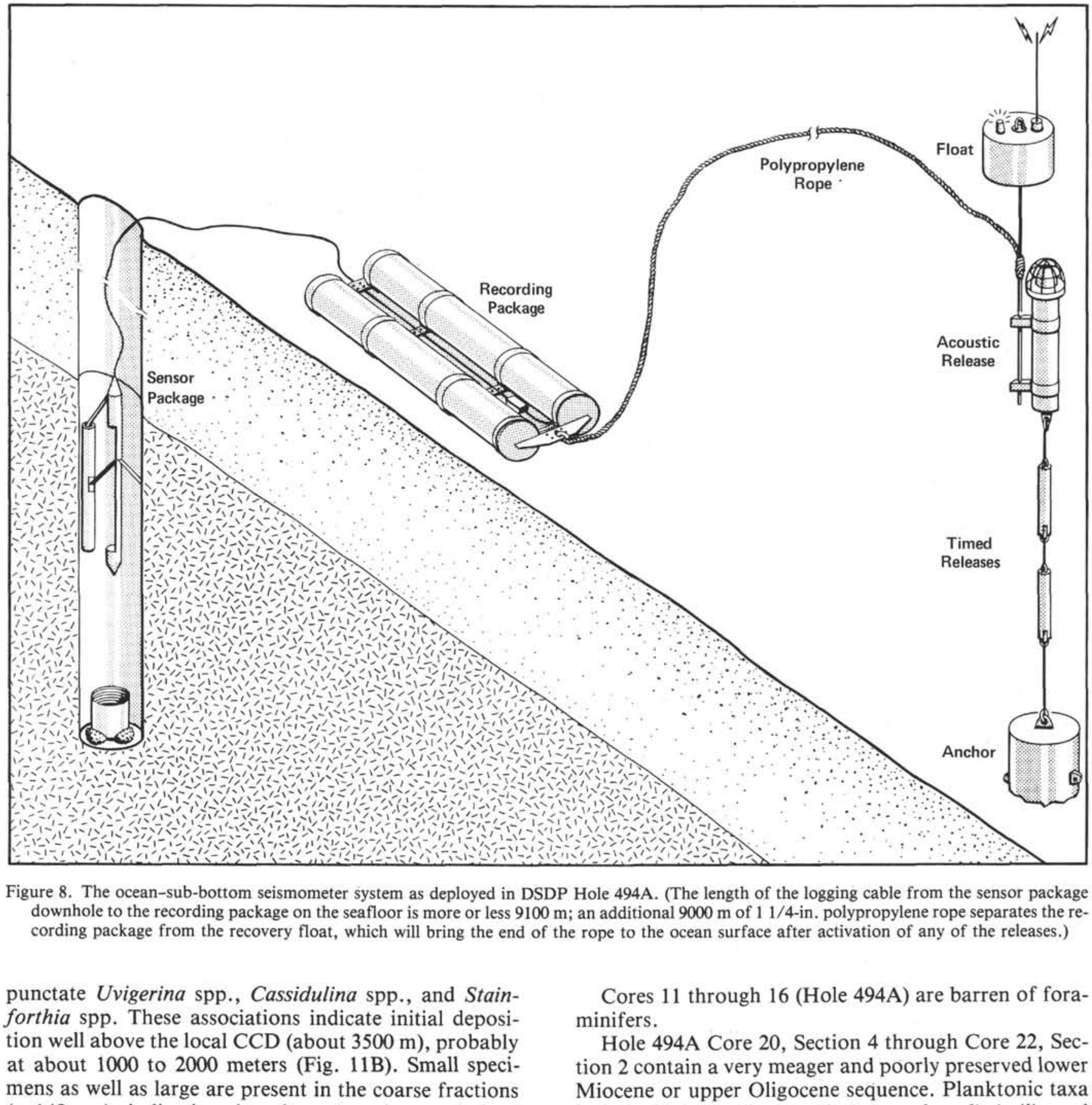


Figure 8. The ocean-sub-bottom seismometer system as deployed in DSDP Hole 494A. (The length of the logging cable from the sensor package downhole to the recording package on the seafloor is more or less 9100 m; an additional 9000 m of 1 1/4-in. polypropylene rope separates the recording package from the recovery float, which will bring the end of the rope to the ocean surface after activation of any of the releases.)

punctate *Uvigerina* spp., *Cassidulina* spp., and *Stainforthia* spp. These associations indicate initial deposition well above the local CCD (about 3500 m), probably at about 1000 to 2000 meters (Fig. 11B). Small specimens as well as large are present in the coarse fractions (> 149 μm), indicating that these deposits are derived from upslope areas by mass movement (unsorted) rather than turbidites (graded).

Cores 6 to 10 (Hole 494A) contain planktonic assemblages suggesting that deposition took place earlier in the Pleistocene than those just referred to; these assemblages are found in more indurated sediments. Specimens of *N. eggeri* are primitive. Section 494A-8-1, has poorly preserved *N. acostaensis, Globigerinoides subquadratus*, and *Globorotalia* cf. *plesiotumida*, suggesting reworked lower Pliocene or upper Miocene sediment. Section 494A-8-2 has left-coiling *Pulleniatina obliquilocata*, along with the lower bathyal (ca., 2000 m) benthic taxa *Pyrgo* sp., *Melonis pompilioides, Ehrenbergina* sp., *Pullenia bulloides*, and *Uvigerina senticosa.*

Cores 11 through 16 (Hole 494A) are barren of foraminifers.

Hole 494A Core 20, Section 4 through Core 22, Section 2 contain a very meager and poorly preserved lower Miocene or upper Oligocene sequence. Planktonic taxa include *Globorotalia mayeri, Catapsydrax dissimilis*, and *Globigerina praebulloides*, recrystallized specimens referred to *Globoquadrina* sp., *Globorotalia opima, Globigerina ciperoensis*, and *G. sellii*. Benthic foraminifers are rare in these samples; *Lenticulina* and *Stilostomella* sp. were present in Core 20, Section 4, suggesting lower bathyal deposition (3000 m). Hole 494A Core 22, Section 3 has a very rare fauna tentatively assigned to the uppermost lower Miocene because of the presence of *Globigerinoides* cf. *sicanus* (one specimen).

Hole 494A Cores 23 to 27 have been dated by nannofossils and radiolarians as middle Eocene, but only long-ranging Paleogene foraminifers were observed in Core 27, Section 1: *Chiloguembelina* sp. and cf. *Pseudohastigerina* sp. These appear to be replaced by silica, and the

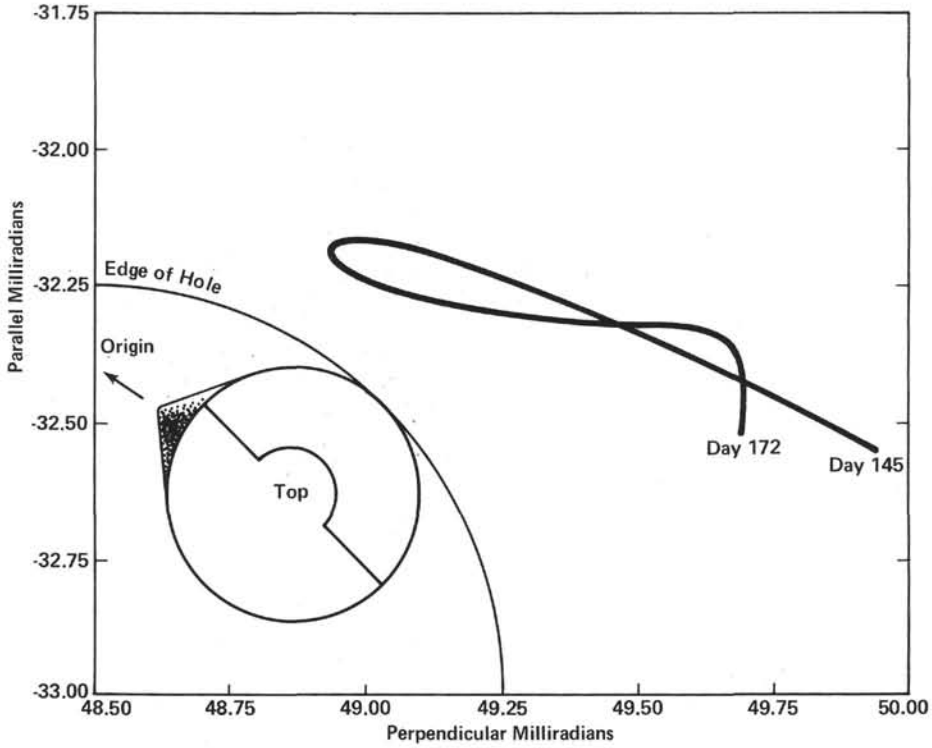


Figure 9. Downhole sensor tilt during the first one-month deployment. (Each point on the curve represents one hour. On the basis of the seismic arrival characteristics, the sensor package orientation is estimated to be north-south in the parallel tilt direction and east-west in the perpendicular tilt position. Thus the tilt motion is mainly in a direction along the strike of the trench.)

entire interval is considered to have been deposited below the CCD due to the almost complete absence of calcareous planktonic or benthic foraminifers.

Hole 494A Core 28 belongs in the Upper Cretaceous because of its abundant but recrystallized *Globotruncana* spp., *Abathomphalus mayaroensis, Raceguembelina fructicosa, Pseudotextularia elegans, Planoglobulina glabrata, Rugoglobigerina* sp., and *Heterohelix* sp., indicating deposition in the Maestrichtian in the *Abathomphalus mayaroensis* Zone. These are faunas typical of the Late Cretaceous, and similar assemblages have been noted in warm-water units throughout the Caribbean (e.g., Premoli-Silva and Bolli, 1973).

Although Sample 494A-29-1, 0–75 cm was identified as having been deposited in the early to middle Eocene on the basis of poorly preserved *Morozovella* sp. and *Globigerapsis* sp., it is believed that this matter caved from shallower levels during drilling. Below Core 29, Section 1 (75 cm) and Core 30 are Upper Cretaceous samples, indicated by the presence of abundant *Globotruncana*, including *G. arca* and *G. fornicata, Heterohelix globulosa*, and *Pseudotextularia elegans*; from these species, an early Maestrichtian or Campanian deposition is inferred. Few if any benthic species occur in these samples, and the resulting high planktonic to benthic ratios indicate open ocean sedimentation; small planktonic shells are abundant, suggesting minimal dissolution and deposition in warm waters less than 3000 meters deep.

Radiolarians

Cores 1 through 4 (Hole 494) and 1 through 16 (Hole 494A) contain rare to few Quaternary radiolarians with moderate preservation, along with occasional reworked, poorly preserved Miocene and Eocene forms. Drill cuttings from Sample 494-2-8, 21–23 cm contain a moderately preserved lower to middle Miocene assemblage. Blue pebbles from Section 494A-4-1 and Sample 494A-7,CC also contain Miocene radiolarians, but these are very fragmented. A few Eocene forms are reworked into the Quaternary assemblage of Samples 494-2,CC and 494A-14-3, 12–24 cm.

The first appearance of a species restricted to the Pliocene is *Spongaster pentas* in Sample 494A-17-2, 64–66 cm. However, the next sample, 494A-18-4, 64–66 cm contains both one specimen of *S. pentas* and one specimen of *Theocorythium trachelium*, which, according to Nigrini, has a first appearance in the lower Quaternary. *Stichocorys peregrina*, which ranges from upper Miocene to Pliocene, is found in Samples 494A-18-1, 90–92 cm. Its morphotypic top indicates the top of the *Spongaster pentas* Zone in the Pliocene.

The blue clay of Section 494A-20-5 contains a sparse lower Miocene radiolarian assemblage. In Core 21 the radiolarians are extremely rare and indeterminate.

A sample from the blue gray mudstone of Sample 494A-22-2, 102–104 cm contains very rare, recrystallized Oligocene to lower Miocene forms, *Theocorys spongo-*

Series	Sample (hole-core-section, interval in cm)	Approximate Sub-bottom Depth of Boundary(m)	Basis for Boundary Position
Quaternary	494-1 → 494-4 494A-1 → 494A-16	152	Top of *D. brouweri* Zone
Pliocene	494A-17 → 494A-20-4, 70 cm	185.7	
middle Miocene or lower Miocene	494A-20-4, 77 cm → 494A-21, CC	Nannofossil data show middle Miocene through 494A-22-3 Radiolarians show lower Miocene 494A-20-4 → -22-3	
		202.9	
? Oligocene or lower Miocene	494A-22-1 → 494A-22-3, 40 cm	206	
middle Miocene	494A-22-3, 40 cm → 494A-22, CC	209	*N. quadrata* Zone Presence of *P. mitra* zonal assemblage
middle Eocene	494A-23 → 494A-27, CC and 494A-29-1, 0–60 cm	256.5	Presence of *Globotruncana*
Upper Cretaceous	494A-28, and 494A-29-1, 60 cm → 494A-30, CC	T.D. 366.5	

Figure 10. Stratigraphic series at Site 494.

conus, Artophormis gracilis, and *Theocyrtis annosa*. However, the next sample, 494A-22-3, 91–93 cm, which is greenish gray mudstone, contains the Pliocene form *S. pentas* and one specimen of *Stichocorys wolffii* (which ranges from lower to middle Miocene).

A middle Eocene assemblage is found in Cores 23 through 27: *Calocyclas hispida, Eusyringium fistuligerum, Lithocyclia ocellus* grp., *Lithochytris vespertilio, Podocyrtis papalis, P. mitra* (in Sections 494A-24-1 and -25-1, only), *Sethochytris babylonis* grp., and *Theocampe mongolfieri*. These are few in abundance and moderately preserved in Core 23, but in the fractured mudstones of Cores 24, 25, and 27 they are very fragmented and rare.

In Section 494A-28-1, radiolarians are rare and recrystallized, probably Cretaceous. The dark mudstone at the top of Section 494A-29-1 contains the same Eocene assemblage just described for Cores 23 through 27, but the chalk and dark mudstone from the lower part of Section 494A-29-1 contains Upper Cretaceous forms. Very rare Eocene species were found in two samples from lower Section 494A-29-1, along with the rather abundant Upper Cretaceous species. There is little doubt that these rare occurrences of Eocene forms are a result of drilling contamination.

Nannoplankton

Diatomaceous sandy muds of Cores 1 to 4 of Hole 494 and 1 to 2 of Hole 494A include Holocene/upper Pliocene *Emiliania huxleyi/Geophyrocapsa oceanica* Zones, small *Gephyrocapsa* and *Emiliania, Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Cyclococcolithina leptopora, E. ovata, E. annula*. Cores 4 to 16 of Hole 494A contain the same assemblage minus *G. oceanica* and are assigned to the lowest Pleistocene *Crenalithus doronicoides* Zone.

Nannoplankton are absent in Core 19. A sample from Core 20, Section 4, 125 cm contains Miocene nannoplankton but includes no Miocene index-species. Nevertheless co-occurrence of *Sphenolithus moriformis, Reticulofenestra pseudoumbilica, Discoaster* aff. *bollii, Cyclococcolithina macintyrei* are possible only in the *Discoaster exilis* Zone of the lower part of the middle Miocene.

The assemblage with *C. leptopora, Coccolithus pelagicus, Reticulofenestra pseudoumbilica, Sphenolithus*

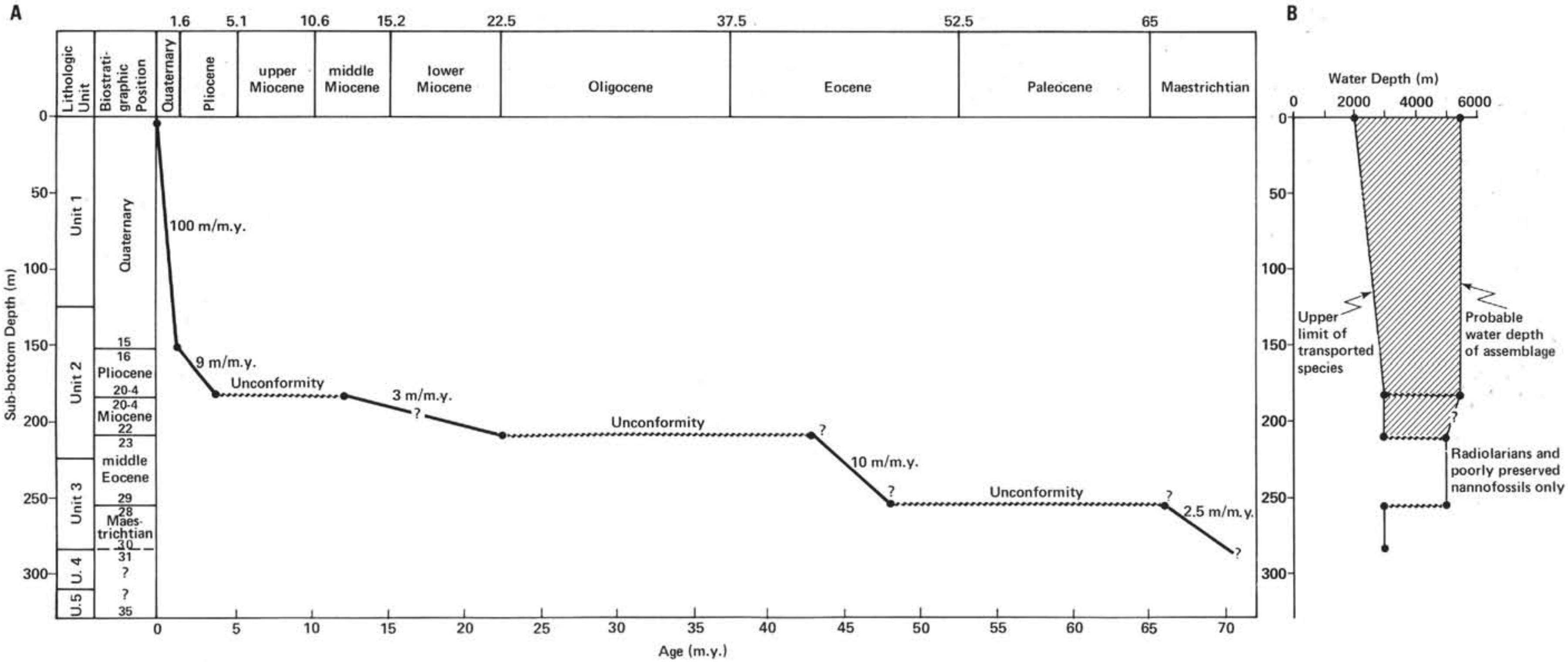


Figure 11. A. Sedimentation rate for Hole 494A. (Numbers in Biostratigraphic Position column refer to cores and sections of Hole 494A.) B. Paleobathymetry is based on benthic foraminifers.

moriformis, Discoaster aff. *bollii, D.* cf. *challengeri* was found in Samples 494A-22-1, 70 cm and 494A-22-2, 75 cm. The age of this interval is the same as that of Sample 494A-20-4, 125 cm, i.e., middle Miocene.

The interval from Samples 494A-22-4, 7 cm to 494A-29-1, 85 cm is Eocene. The taxa includes: *Discoaster barbadiensis, Discoaster* aff. *binodosus, Discoaster* cf. *lodoensis, Discoaster saipanensis, Reticulofenestra umbilica, Coccolithus eopelagicus, Cyclococcolithina formosa, Chiasmolithus grandis, C. expansus, C.* aff. *solitus, S. obtusus, S. radians, Zygrhablithus bijugatus.* Again, the assemblage includes no index-species, nevertheless, it can be assigned to the middle Eocene *Nannotetrina quadrata* Zone. In this sample and in that from Core 29, Section 1, 85 cm, reworked Upper Cretaceous *Micula staurophora* (very rare) and *M.* aff. *mura* (rare) also occur. Finally, Sample 499A-29-1, 102 cm contains Upper Cretaceous (Maestrichtian) nannoplankton: *M. staurophora, M.* aff. *mura, Arkhangelskiella* sp., *Watznaueria barnesae.*

The sample from Core 29, Section 1, 102 cm is the deepest one we found containing nannoplankton; Cores 30 to 35 are devoid of nannoplankton.

GEOCHEMISTRY

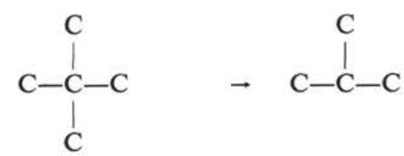
Organic Geochemistry

Gaseous hydrocarbons were analyzed at Holes 494 and 494A using both the Carle and Hewlett Packard gas chromatographs. The Carle unit requires approximately 7 min. to analyze gas samples for C_1 (methane), CO_2, and C_2 (ethane) content. This analysis provides rapid information concerning the possible origin of gaseous hydrocarbons. The Carle gas chromatograph is not very sensitive and requires individual components to be present in concentrations on the order of .1 to .2 of a percent. The Hewlett-Packard gas chromatograph is capable of detecting gaseous hydrocarbons in the sub-parts-per-million range, but sample processing and analysis time is about 25 to 30 min. The more detailed analysis, however, provides data on the higher molecular-weight hydrocarbon species that indicate a petroleum (rather than biogenic) origin.

Figure 12 shows the variation in the C_1/C_2 ratio with depth at Holes 494 and 494A; the ratio is currently being used as an indicator of petroleum hydrocarbons. Low values for the ratio may indicate proximity to a petroleum accumulation and possibly hazardous conditions for *Glomar Challenger* drilling operations. The range of C_1/C_2 ratios for Holes 494, and 494A was from 3600 to 690,000; these ratios are of such magnitude to suggest a lack of petroleum-type hydrocarbons. In addition, higher molecular-weight species, which almost invariably accompany petroleum deposits, are present in only trace (usually sub-ppm) quantities. The C_1/C_2 ratios have values that decrease with increasing depth to a minimum at Core 27. Two deeper samples have considerably higher ratios.

Core 27 marks the top of a calcareous nannoplankton–sandy mudstone lithologic unit. The fact that Core 27 is immediately overlain by a clay provides an interesting lithologic situation for speculation. If organic material deposited in the nannoplankton–sandy mudstone had suitable characteristics, it may have been capable of providing a source for the ethane that affected the C_1/C_2 ratio. The overlying clay may have provided a relatively effective barrier for dissemination processes by means of its sorptive capacity and low permeability. Immediately above the clay are mudstones, muddy clays, and sandy muds. These lithologies are probably more suitable for processes such as diffusion and result in relatively high values for the C_1/C_2 ratios. Thus one explanation for the observed pattern of C_1/C_2 ratios might be that C_1 (methane) exists in relatively uniform concentrations throughout the penetrated section and C_2 (ethane) is concentrated in a specific stratigraphic interval. The dispersal of C_2 throughout the overlying section may be controlled by lithologic characteristics.

Concentrations of gaseous hydrocarbons are shown in Figure 13. Methane content remains fairly constant from about 150 meters to 305 meters (except for a sample at 294 m where poor core recovery resulted in a gas sample of questionable quality). Figure 13 also indicates the progressive increase of ethane concentrations. Isobutane (iso-C_4) and neopentane (neo-C_5) are also shown on Figure 13 because of the potential relation between these two species. Neopentane is relatively rare in petroleum, whereas iso-C_4 is more common. The structural configuration of both species is as follows: Degradation involving the loss of any one of the four methyl groups from neo-C_5 results in the formation of iso-C_4.



neopentane isobutane

A reaction such as this might normally be considered a thermally controlled process; however, lack of shipboard maturity data precludes any definite conclusions. The structural similarities between these two hydrocarbon species warrants additional study.

Inorganic Geochemistry

Figure 14 shows the results of the shipboard interstitial water program. Chlorinity and *p*H values remained fairly constant through the entire section penetrated. Alkalinity values are relatively high for the first 50 meters and then decrease with increasing depth. Personnel involved in the handling of core on the drilling floor noted that the upper 50 meters contained hydrogen sulfide (H_2S). After an initial decrease, calcium concentrations increase with depth, whereas the magnesium content decreases. At about 230 meters, calcium content is greater than magnesium content, and plots of concentrations of the two species cross at that point. This situation often exists when there is an underlying basalt or more reactive sedimentary sequence.

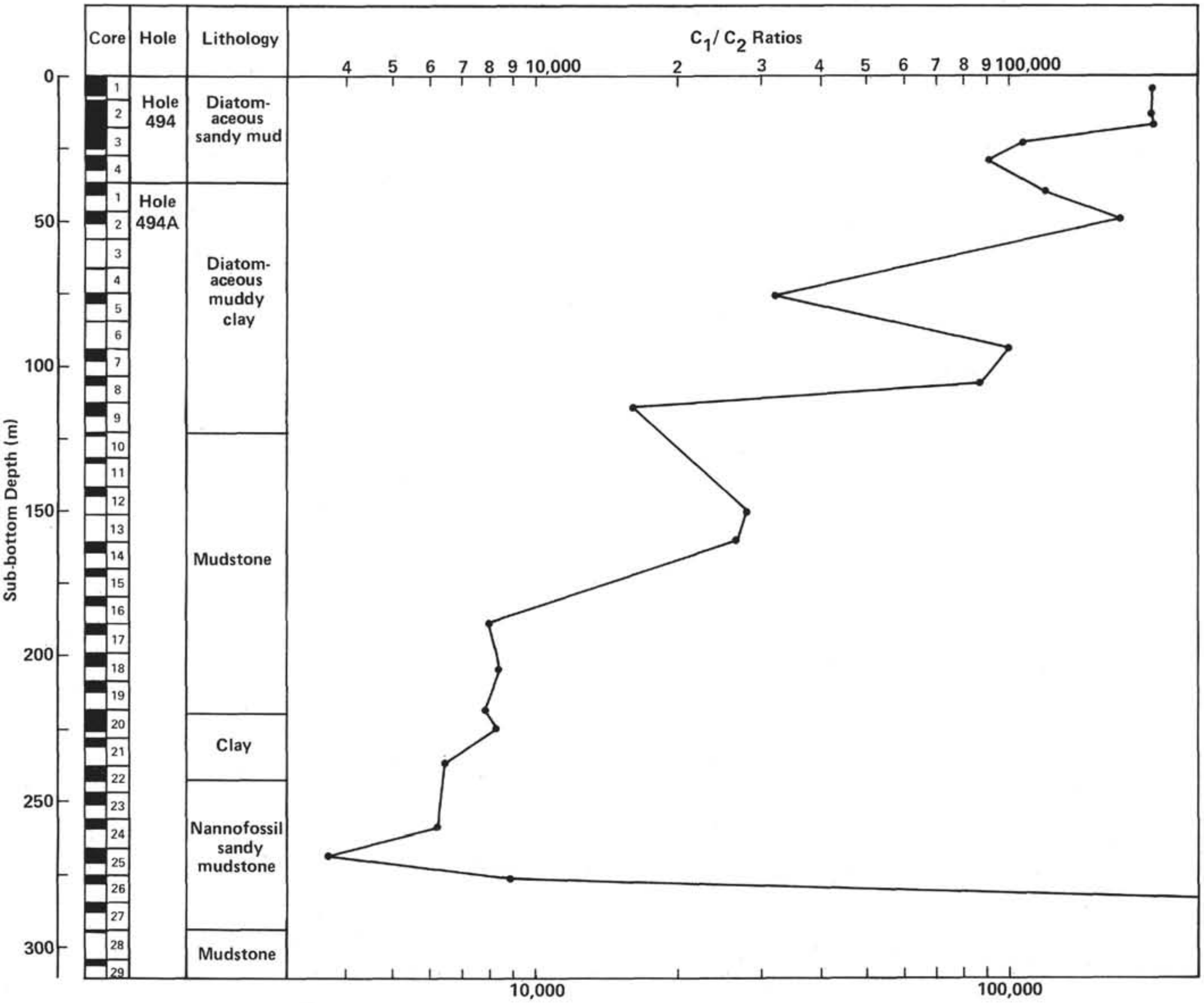


Figure 12. Methane/ethane ratios at Site 494.

SUMMARY AND CONCLUSIONS

Site 494 is about 3 km from and 580 meters above the trench axis. It is situated on a terrace that is about 2 km wide and at least 18 km long. A large imbricate thrust may have formed this terrace. A major objective of the drilling at Site 494 was to test if the terraces are related to proposed imbricate thrusts or to smaller slump blocks.

This site was chosen for the downhole seismometer experiment in order to determine the distribution of low-magnitude earthquakes in the uppermost subduction shear zone. Land seismic stations can detect only the few earthquakes of a magnitude greater than 3 that occur in this region, and those cannot be located with any precision. We suspect that many low magnitude (≤ 3) earthquakes should be relieving local stress that is generated by the initial contact of the converging plates. The hypocenter distribution in the lower trench wall may indicate whether the area is subject to compressive thrusting of imbricate thrust sheets or to normal faulting and slumping if the edge of the continent is being subjected to erosion and tectonic subsidence.

Seismic records (Seely et al., 1974; Ladd et al., 1978; Ibrahim et al., 1979) show strong reflections from the igneous oceanic crust beneath the front of the margin. Above the oceanic crust, other reflections suggest a landward-dipping section. Above the landward-dipping section, at 0.3 s and 0.4 s below the seafloor, there are some relatively strong subhorizontal reflections. Drilling at the site penetrated 367 meters through the section of weak discontinuous reflections, perhaps to the underlying strong ones, but lack of accurate velocity data precludes precise determination of the depth of the seismic reflectors.

Below the Pleistocene sediment, the average core recovery was less than 30%. Nonetheless, recovery was sufficient to determine that the strata occur in an orderly stratigraphic sequence of young over old. A relatively complete sequence of microfossil assemblages was recovered at the site, but with the exception of Quaternary diatoms, representatives of most groups are sparse. Ben-

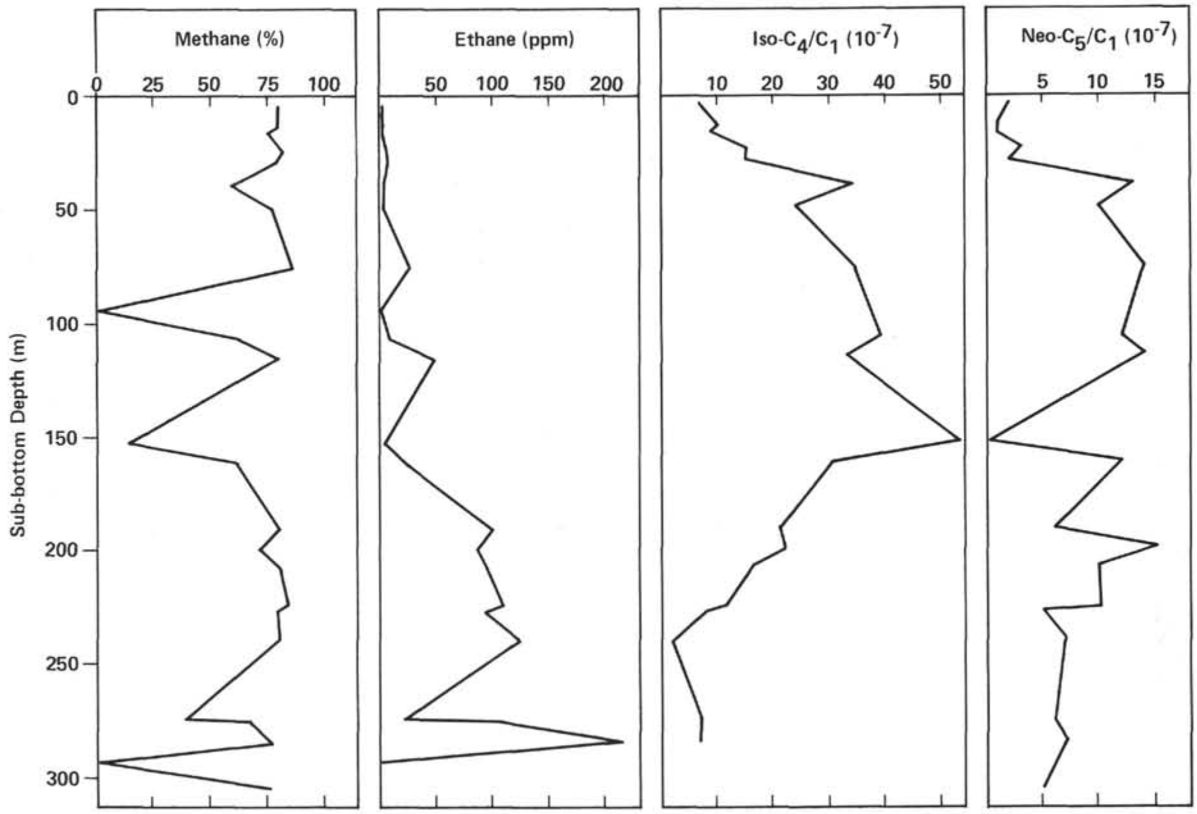


Figure 13. Concentrations of gaseous hydrocarbons at Site 494.

thic foraminiferal assemblages are displaced downslope, especially in the post-Miocene and perhaps post-Cretaceous interval. Nannofossil assemblages lack index species and diversity because of dissolution that is related to water depth. Radiolarian assemblages are less than abundant, often fragmented, and lack certain index species. Radiolarians are found in older clasts throughout the Pliocene/Pleistocene section. The microfossils indicate three long sedimentation hiatuses separating sections of different age and provenance. The recovered lithologies are:

1) 0 to 223 meters: Holocene to Pliocene dark gray diatomaceous mud, 223 meters thick, containing abundant fauna displaced from 1000 to 2000 meters water depth; sedimentation rate—55 m/m.y.

2) 223 meters: Unconformity, contact observed.

3) 223 to 241 meters: Blue gray hemipelagic clay, 18 meters thick, with lower Miocene/upper Oligocene nannofossil assemblages typical of open-ocean environments rather than areas of coastal upwelling; deposited near the CCD at about 3,000 meters; sedimentation rate—3 m/m.y.

4) 241 meters: Unconformity, contact observed.

5) 241 to 294 meters: Dark, sandy, middle Eocene mudstone, 53 meters thick, in which one undisturbed and very complete section has many closely spaced faults with small displacement; fauna deposited below the foraminiferal CCD but above the nannofossil CCD; sedimentation rate—10 m/m.y.

6) 294 meters: Unconformity or fault, contact not observed.

7) 294 to 313 meters: Dark gray mudstone, 19 meters thick, mixed by faulting or drilling disturbance with blue gray micritic limestone; middle Eocene and Upper Cretaceous, respectively.

8) 313 to 322 meters: Medium gray, Upper Cretaceous mudstone, 9 meters thick, with an open-marine fauna containing abundant *Globotruncana;* deposited above the CCD.

9) 322 to 367 meters: Five cores with a total recovery of 1 meter of altered mafic and intermediate igneous rock atypical of ocean floor basalts.

Below this sequence, seismic records indicate a continuation of layered material.

Physical properties point to overconsolidation for the section below 80 meters, a pattern consistent with the response of the section to drilling. Average drilling time in the first 200 meters was more than four times longer than the drilling time required at equivalent depths in Hole 495, the ocean reference site. Below 80 meters, the drill cuttings were lithic chips rather than the drill slurry normally produced by drilling mudstone. Such lithic chips have been observed at previous DSDP sites (434, 441) when drilling took place in microfractured rock (von Huene, Nasu et al., 1978). Despite the microfractured rock at 290 meters, poor recovery precludes establishing the beginning of microfracturing. On the basis of core recovery and drilling character, however, it appears at abnormally shallow depths.

Gaseous hydrocarbons in the section are mainly methane, and only minor amounts of ethane were detected.

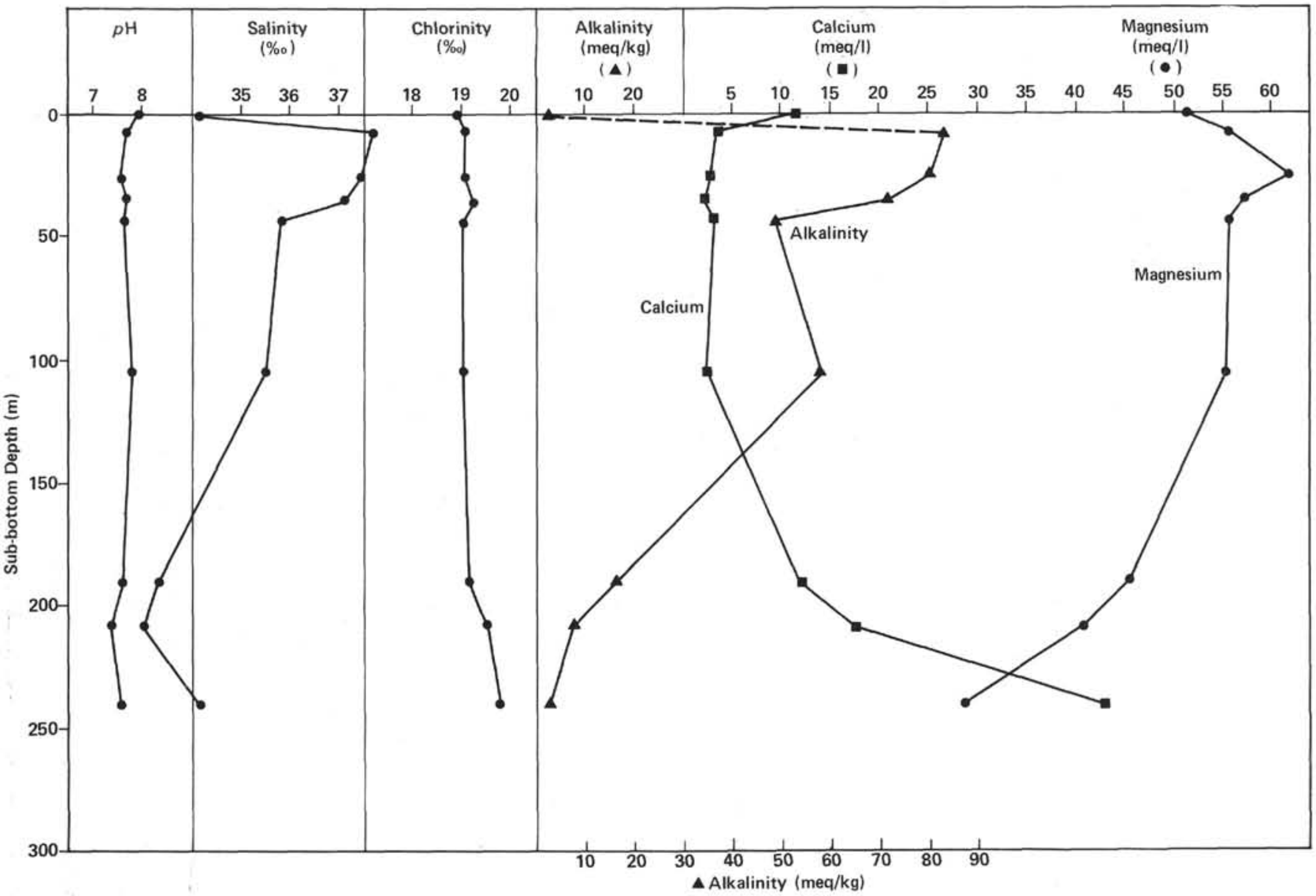


Figure 14. Interstitial water data at Site 494.

Study of the cores from Site 494 indicates that the imbricate-wedge, accretionary-prism model is not representative of the seaward portion of the Guatemalan margin. First, in terms of that model, the discovery of rock as old as Late Cretaceous within 3 km of the trench, which is apparently underlain by subducting early Miocene ocean crust, is unexpected. Second, the regular increase in rock age with depth over an interval of 360 meters and 70 m.y. time at the foot of a convergent margin indicates that the drilled section is not cut by thrust fault. We should caution that this conclusion is based on minimal data, because the overall core recovery was less than 30%. Nonetheless, the sequence is similar to that reported by Seely (1979) from the edge of the continental shelf. Thus the sequence drilled could have been transported as a large block from a location landward of the site, or part of it may have been deposited seaward, or it might have originated near its present position with respect to a continental sediment source.

The environments representated by the listed sequence, the nature of the hiatuses between them, and their relation to the stratigraphy of the shelf (Seely, 1979) are interpreted from top to bottom as follows:

1) A Pliocene and Pleistocene deposit consisting principally of sediment transported from the shelf and upper slope to the site.

2) An upper Miocene unconformity coincident with the widespread upper Miocene unconformity on the shelf.

3) A sequence of distal, terrigenous, hemipelagic clay that accumulated during the early Miocene on seafloor near the CCD and at rates an order of magnitude less than age-equivalent deposits on the adjacent shelf (3 m/m.y. versus 100 m/m.y.).

4) An upper Eocene to Oligocene hiatus, which is the age equivalent of a widespread unconformity in the adjacent shelf section but of unknown origin in the section drilled.

5) An Eocene hemipelagic clay deposited below the foraminiferal CCD but above the nannofossil CCD at rates at least five times less than age-equivalent shelf deposits.

6) A hiatus of unknown origin but of an age represented by thick, widespread Paleocene sediments on the adjacent shelf.

7) An Upper Cretaceous claystone that accumulated in an open-ocean environment above the CCD at depths about equivalent to, but at rates apparently less than, age-equivalent rocks on the present shelf.

8) A contact of unknown origin between claystone and igneous rocks.

9) Igneous rock originally of basaltic and andesitic

composition and atypical of igneous oceanic crust; the type of body sampled is unknown.

Immediately below is an undrilled sequence of layered rock, 500 to 800 meters thick, as indicated by seismic records, resting on probable Miocene igneous ocean crust.

The sequence shows signs of tectonic stress beginning between the Pleistocene and the Pliocene, but the imprint of prior episodes of deformation in rock older than Pliocene is unknown. Any major thrust faults must be confined to the undrilled section. However, the fractured condition of the pre-Pliocene section is similar to that recovered from other convergent margins—for instance, the Japan Trench slope (von Huene, Nasu, et al., 1978), the slope off Oregon (Carson, 1977), and the Aleutian Trench slope (Kulm, von Huene, et al., 1973).

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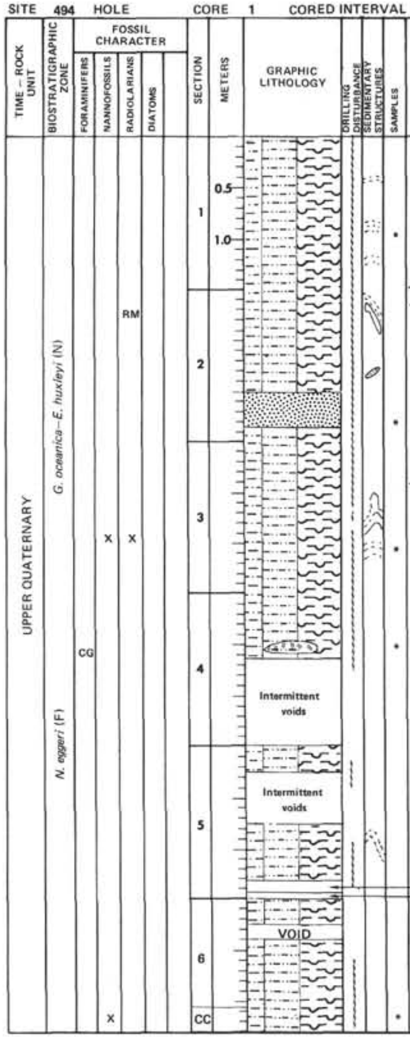
SITE 494 HOLE CORE 1 CORED INTERVAL 0.0–9.0 m



LITHOLOGIC DESCRIPTION

5Y 4/2

5GY 4/1

5GY 5/1

5GY 4/1

Sandy stringers

Deformed fine layer 5G 5/1–6/1

Sandy stringers

5GY 4/1

Sandy stringers

5Y 4/2

Sandy stringers

5GY 4/1

Ash

5GY 4/1

Intermittent voids

IW

DIATOMACEOUS SANDY MUD

Color: olive gray to dark greenish gray. Primary bedding disturbed but size grading obvious in spite of drilling. Section becomes finer downward.

SMEAR SLIDE SUMMARY

	1-96	2-130	3-108	4-55	CC
TEXTURE:					
Sand	2	50	5	7	40
Silt	25	10	25	18	15
Clay	73	40	70	75	45
COMPOSITION:					
Quartz	12	25	20	12	20
Feldspar	2	5	1	2	3
Mica	5	15	7	3	5
Other heavy minerals	2	5	2	1	2
Clay minerals	25	7	10	5	15
Volcanic glass	–	–	–	45	–
Glauconite	–	2	2	–	3
Zeolite	2	–	–	1	2
Foraminifers	–	–	1	–	1
Diatoms	50	40	55	30	48
Sponge spicules	2	1	1	–	1
Silicoflagellates	–	–	1	1	–

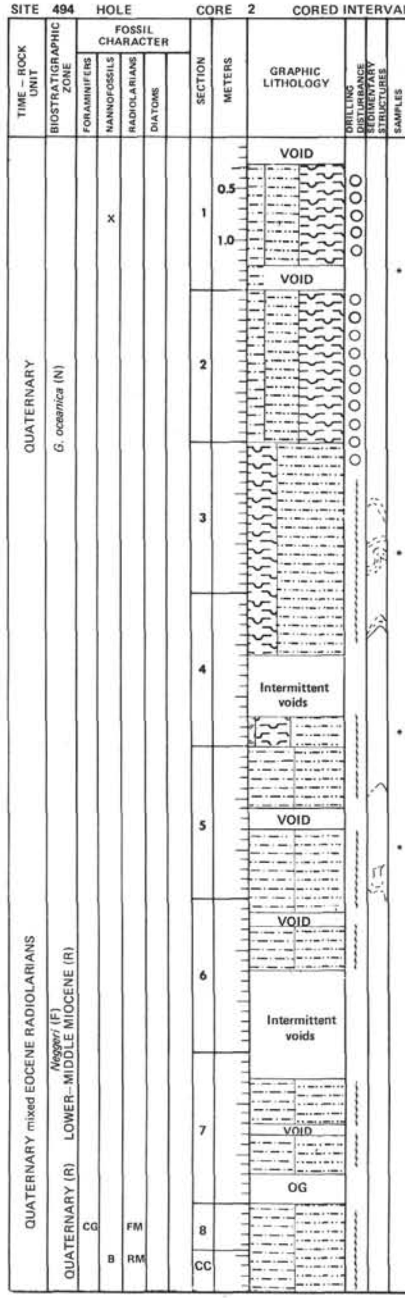
CARBONATE BOMB (%)

1, 19–21 = 2.5

CARBON-CARBONATE (%)

	1, 133–135	3, 109–111	5, 79–81
Organic Carbon	2.54	1.65	2.25
Total Carbonate	5	2.5	2.5

SITE 494 HOLE CORE 2 CORED INTERVAL 9.0–18.5 m



LITHOLOGIC DESCRIPTION

5GY 4/1

Sandy stringers

5GY 4/1

Sandy stringers

Drilling deformation

Drilling deformation

5Y 4/1

5GY 5/1

5GY 4/1

DIATOMACEOUS MUD

Color: dark greenish gray. Extra sections due to gas expansion. Lower-middle Miocene Radiolarians in "shaly chips".

SMEAR SLIDE SUMMARY

	1-122	3-105	4-138	5-95
TEXTURE:				
Sand	10	1	1	25
Silt	30	44	64	45
Clay	60	55	35	30
COMPOSITION:				
Quartz	20	3	4	30
Feldspar	2	5	5	20
Mica	6	–	–	–
Pyrite	1	2	3	3
Other heavy minerals	–	1	1	5
Clay minerals	15	47	33	27
Volcanic glass	5	2	10	3
Glauconite	1	2	2	2
Zeolite	1	2	3	3
Calc.-Dolo.-Arag.	–	3	1	TR
Foraminifers	1	TR	–	TR
Calc. nannofossils	–	1	TR	TR
Diatoms	46	30	35	5
Sponge spicules	1	TR	TR	1
Silicoflagellates	1	–	1	–
Plant debris	–	2	–	1

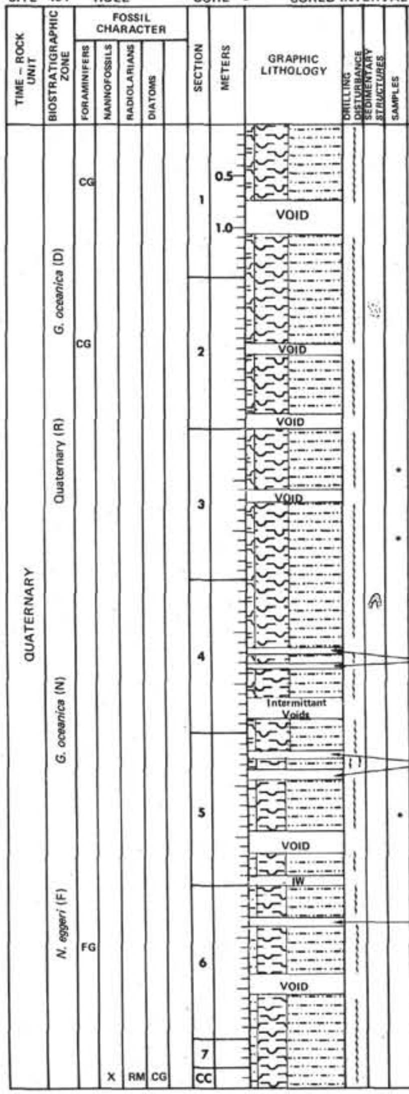
CARBONATE BOMB (%)

3, 93–95 = 2.5

CARBON-CARBONATE (%)

	3, 95–101	6, 123–125
Organic Carbon	2.12	2.5
Total Carbonate	1.43	2.5

SITE 494 HOLE CORE 3 CORED INTERVAL 18.5–28.0 m



5G 4/1

5GY 4/1

Sandy layer worked downward by drilling process

5GY 4/1

Stretched out whitish blotches

5GY 4/1

10YR 8/1

5GY 4/1

Pelecypod valve (2.5 cm long)

5GY 4/1

Deformed sandy layer

5Y 4/2

VOIDS

VOIDS

5Y 3/1 to 3/2

5Y 3/2

VOID

5Y 3/2

5Y 3/2

DIATOMACEOUS MUDDY SILT
Color: dark greenish gray to olive gray. Primary bedding disturbed, rarely obvious.
Core-Catcher: semi-consolidated pebble – has Pliocene nannofossils.

SMEAR SLIDE SUMMARY

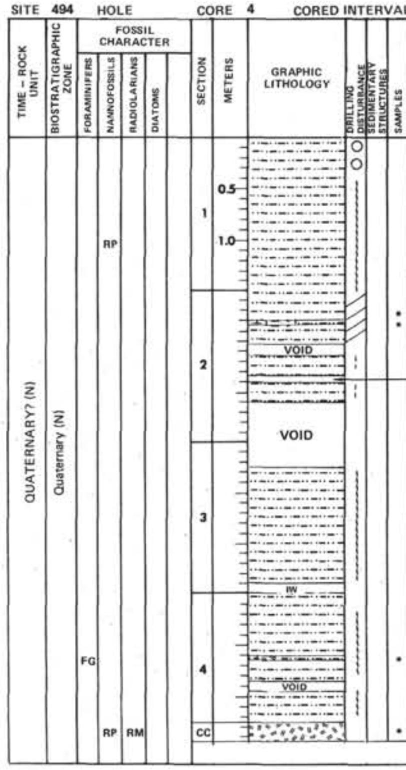
	3-46†	3-110	5-80
TEXTURE:			
Sand	23	20	20
Silt	50	50	35
Clay	27	30	45
COMPOSITION:			
Quartz	10	–	7
Feldspar	5	–	5
Mica	–	5	–
Pyrite	20	1	5
Other heavy minerals	1	15	2
Clay minerals	15	20	40
Volcanic glass	–	–	2
Glauconite	3	5	3
Zeolite	–	–	1
Diatoms	20	35	30
Radiolarians	–	5	–
Sponge spicules	25	2	1
Others	1	12	1
Plant debris	–	–	3

† Smear slide of white blotch

CARBON-CARBONATE (%)

	3, 98–100	6, 118–120
Organic Carbon	2.32	2.42
Total Carbonate	2.5	2.5

SITE 494 HOLE CORE 4 CORED INTERVAL 28.0–37.5 m



5Y 3/2

Pebble/cut: shows offsets of primary structure

Mottled during drilling

VOID

5Y 3/2 to 2/2

DIATOMACEOUS MUD
Color: dark olive gray.
Section 3: mottled by drilling disturbance.
Section 4: diatomaceous muddy silt, as above. Vague streaks due to drilling disturbance. Very dark gray (5Y 2/2) streaks contain concentrated heavy minerals (*ilmenite and limonite*).
Core-Catcher: muddy silt (5Y 4/2) grades downward to gray (5Y 5/2) silt-size vitric volcanic ash, sharp contact, 5Y 3/2 diatomaceous muddy silt.

SMEAR SLIDE SUMMARY

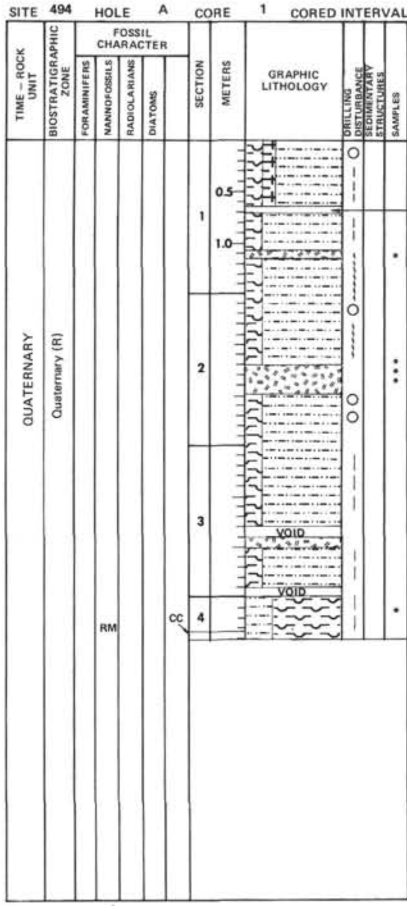
	2-28	2-32	4-64	CC
TEXTURE:				
Sand	10	15	8	5
Silt	6	30	80	95
Clay	84	55	12	–
COMPOSITION:				
Quartz	1	–	2	2
Feldspar	1	1	12	2
Mica	–	–	TR	–
Pyrite	1	5	48	–
Other heavy minerals	1	1	7	TR
Clay minerals	76	28	5	–
Volcanic glass	–	–	20	94
Glauconite	5	15	1	–
Zeolite	5	–	4	–
Calc.-Dolo.-Arag.	4	–	–	–
Foraminifers	–	TR	–	–
Calc. nannofossils	1	20	–	–
Diatoms	4	15	TR	1
Sponge spicules	1	15	–	1
Others	TR	–	1	–

CARBONATE BOMB (%)
3, 56–58 = 2.5

CARBON-CARBONATE (%)

	4, 77–79
Organic Carbon	2.77
Total Carbonate	2.5

SITE 494 HOLE A CORE 1 CORED INTERVAL 37.5–47.0 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS SILTY MUD
Dark gray (5Y 3/2), partly homogenized and swirled by drilling.
Section 1, 0–20 cm: contains 2 pebbles: 1 cm – light gray hard siltstone and 2 cm – rounded oblate harder pebble with <1 mm thick dark laminations.
Section 1, 108–115 cm: 5Y 7/2 well sorted coarse silt-size vitric ash, 8% total quartz and feldspar. Swirled into predominant lithology (mud).
Section 2: variably mottled and disturbed by drilling. Some soupy intervals. 70–97 cm: some swirls of 5Y 5/2 sandy diatomaceous vitric ash.
Section 3: dark olive gray (5Y 3/2) disturbed, firm, flaky diatomaceous silty mud, irregular drilling mottling.
Section 4, 14 cm: Proportion of diatomaceous debris varies – 70% diatoms and 22% volcanic ash.
Core-Catcher: 4 cm mud, as above.

SMEAR SLIDE SUMMARY

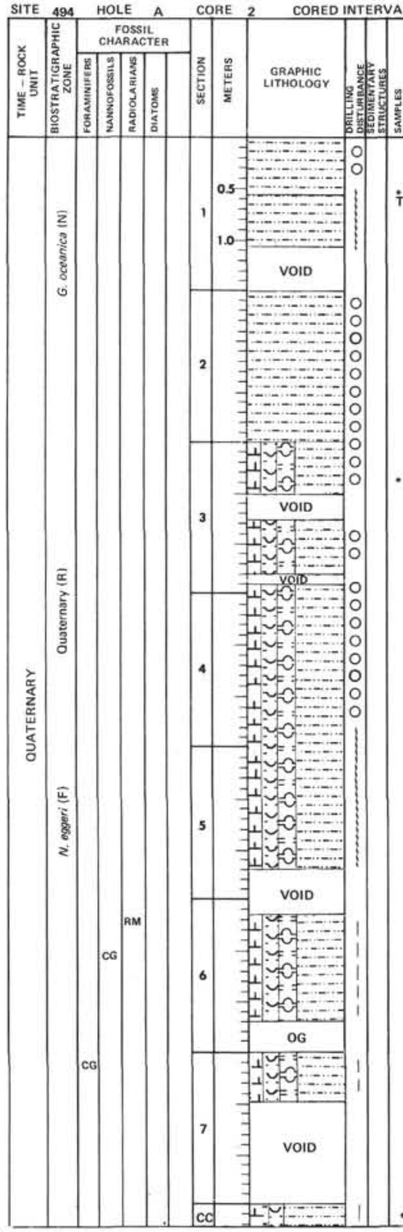
	1-110	2-62	2-75	2-85	4-14
TEXTURE:					
Sand	1	30	45	65	1
Silt	99	35	35	20	79
Clay	–	35	20	15	20
COMPOSITION:					
Quartz	3	1	1	1	2
Feldspar	3	5	7	3	1
Mica	–	–	–	–	TR
Pyrite	–	4	25	2	–
Other heavy minerals	TR	4	3	1	TR
Clay minerals	–	18	30	12	5
Volcanic glass	94	–	21	64	22
Glauconite	TR	15	1	2	TR
Zeolite	–	1	–	3	–
Calc.-Dolo.-Arag.	–	15	5	2	–
Foraminifers	–	8	–	–	–
Calc. nannofossils	–	4	2	TR	–
Diatoms	–	20	4	10	70
Radiolarians	–	–	TR	–	TR
Sponge spicules	TR	5	1	–	–

CARBONATE BOMB (%)
1, 45–47 = 3.0

CARBON-CARBONATE (%)

	1, 102–104	3, 68–70
Organic Carbon	2.27	2.12
Total Carbonate	2.5	2.5

SITE 494 HOLE A CORE 2 CORED INTERVAL 47.0–56.5 m



LITHOLOGIC DESCRIPTION

Drilling laminations

DIATOMACEOUS SILTY MUD
Soupy mud (5Y 3/2) with scattered firmer lumps 2–10 mm diameter of predominant lithology as in Core 1.
Section 1, 58–150 cm: Pebbly mudstone? Matrix of typical diatomaceous silty mud with >5 cm fragments light gray (5Y 5/2) hard calcareous vitric ash chalk. Pebbles are flat (oblate).
Section 1, 63–65 cm: Thin Section of pebble: approximately 50% very fine-grained sand and coarse silt-sized vitric ash, with 5% quartz, feldspar, and heavy minerals, and 45% very fine-grained carbonate matrix.
Section 2: Completely soupy. Unsure of original lithology, probably pebbly mudstone. A few <1 cm fragments of hard chalk as in Section 1. Also, 2 cm subrounded slickensided fragment (pebble?) of serpentinized peridotite, with bastite pseudomorphs and disseminated sulfides.
Section 3: Probably a pebbly mudstone(?) disrupted by drilling. Broken fragments of light gray (5Y 5/3) siltstone (chalk) pebbles in 5Y 3/2 typical sandy silty mud. Fragments platy to subangular to subrounded.
Section 4: All soupy mud.
Section 5: Firm 5Y 3/2 diatomaceous silty mud, disturbed throughout by drilling. Abundant fragments of light gray hard calcareous silty ash.
Section 6: Drilling disturbed, swirled, firm, diatomaceous silty mud.
Section 7: Disturbed, swirled 5Y 3/2 diatomaceous silty mud; swirled fine sand layer 1 cm thick at 40 cm (drilling laminations).
Core-Catcher: Diatomaceous calcareous silty mud, 5Y 3/2. Firm but swirled, deformed, and disaggregated by drilling.

SMEAR SLIDE SUMMARY

	1-58	3-40	CC
TEXTURE:			
Sand	30	20	5
Silt	25	30	25
Clay	45	50	70
COMPOSITION:			
Quartz	7	1	3
Feldspar	10	5	5
Pyrite	3	5	8
Other heavy minerals	5	5	2
Clay minerals	45	44	40
Glauconite	20	5	2
Calc.-Dolo.-Arag.	5	3	8
Foraminifers	2	1	2
Calc. nannofossils	3	12	10
Diatoms	–	15	15
Sponge spicules	–	14	5

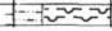
CARBONATE BOMB (%)
6, 68–70 cm = 2.5

CARBON-CARBONATE (%)

	7, 37–39
Organic Carbon	2.15
Total Carbonate	3

SITE 494 HOLE A CORE 3 CORED INTERVAL 56.5–66.0 m

TIME – ROCK UNIT: QUATERNARY
BIOSTRATIGRAPHIC ZONE: Quaternary (R)
FOSSIL CHARACTER (Foraminifers, Nannofossils, Radiolarians, Diatoms): Radiolarians FM
SECTION: CC



LITHOLOGIC DESCRIPTION

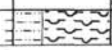
DIATOMACEOUS SILTY MUD
Core-Catcher only: 5Y 3/2, crumbly, drilling-disturbed diatomaceous silty mud. Also: One 5 cm subrounded light gray hard pebble of calcareous tuff.

SMEAR SLIDE SUMMARY

	CC	CC (pebble)
TEXTURE:		
Sand	5	0
Silt	30	40
Clay	65	60
COMPOSITION:		
Quartz	10	–
Feldspar	–	TR
Mica	5	–
Other heavy minerals	1	TR
Clay minerals	5	TR
Volcanic glass	–	1
Zeolite	1	–
Calc.-Dolo.-Arag.	3	–
Foraminifers	1	–
Calc. nannofossils	–	99
Diatoms	70	–
Radiolarians	2	–
Sponge spicules	1	TR

SITE 494 HOLE A CORE 4 CORED INTERVAL 66.0–75.5 m

TIME – ROCK UNIT: QUATERNARY
BIOSTRATIGRAPHIC ZONE: L. Pleistocene (N); *G. doronicoides* (N)
FOSSIL CHARACTER (Foraminifers, Nannofossils, Radiolarians, Diatoms): Nannofossils RM; Radiolarians RP
SECTION: 1



LITHOLOGIC DESCRIPTION

DIATOMACEOUS SILTY MUD
5Y 3/2, typical lithology in cores above, occurs as matrix and cohesive lumps. Contains abundant 1–2 mm coarse sand and granules of 2 distinctive rock types:
80% – grayish green (10G 4/2) firm radiolarian clay, probably zeolitized
20% – olive gray hard silty chalk (calcareous)
Miocene radiolarians in blue clasts.
Core-Catcher: 5 cm of material. Granules and pebbles of both pebble types above up to 2 cm diameter, with cohesive lumps of mud (5Y 3/2). Probably a drilling-disaggregated pebbly mudstone.

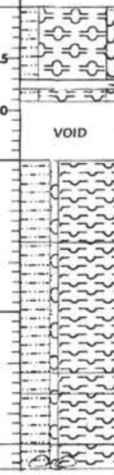
SMEAR SLIDE SUMMARY

	1-15†	1-15††	1-15†††
TEXTURE:			
Sand	1	5	3
Silt	4	93	37
Clay	95	2	60
COMPOSITION:			
Quartz	60	3	10
Feldspar	2	1	1
Mica	1	3	1
Other heavy minerals	–	–	2
Clay minerals	–	2	10
Glauconite	–	1	–
Zeolite	–	–	1
Calc.-Dolo.-Arag.	–	90	–
Diatoms	–	–	70
Radiolarians	30	–	1
Sponge spicules	7	–	3

† grayish green pebbles
†† light gray pebbles
††† mud matrix

SITE 494 HOLE A CORE 5 CORED INTERVAL 75.5–85.0 m

TIME – ROCK UNIT: QUATERNARY
BIOSTRATIGRAPHIC ZONE: L. Pleistocene (N); *N. eggeri* (F)
FOSSIL CHARACTER (Foraminifers, Nannofossils, Radiolarians, Diatoms): Foraminifers CG; Radiolarians FM; Nannofossils RM
SECTION: 1, 2, 3, CC
METERS: 0.5, 1.0



5G 4/1
VOID
5GY 4/1
5Y 3/2

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUD
Section 1–Section 2, 80 cm: Olive green with isolated concentrations of sponge spicules. Drill biscuits and laminations.
Section 2, 80 cm–base of core: DRILL CUTTINGS, dark olive gray diatomaceous muddy claystone. Scaphopod and pyrite crystal section totally disturbed. (Possible explanation: only one bumper sub in hole, swell sufficient to lift drill string, cuttings fall into hole, ship falls, cores graded sequence from walls of hole.
Core-Catcher: Contains pebbles.

SMEAR SLIDE SUMMARY

	1-47	2-20
TEXTURE:		
Sand	70	15
Silt	15	15
Clay	15	70
COMPOSITION:		
Quartz	TR	13
Feldspar	–	1
Mica	–	3
Pyrite	2	–
Other heavy minerals	–	1
Clay minerals	15	12
Glauconite	–	1
Zeolite	–	1
Diatoms	10	60
Radiolarians	TR	–
Sponge spicules	70	6
Silicoflagellates	TR	1

SITE 494 HOLE A CORE 6 CORED INTERVAL 85.0–94.5 m

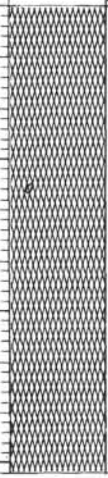
FOSSIL CHARACTER (Foraminifers, Nannofossils, Radiolarians, Diatoms): Nannofossils B
SECTION: CC

LITHOLOGIC DESCRIPTION

Core-Catcher: Consists of 3 pebbles.

SITE 494 HOLE A CORE 7 CORED INTERVAL 94.5–104.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
QUATERNARY	L. Pleistocene (N)	RP	RM, B, B	RP FM; Miocene in blue (R) Quaternary in gray (R)		1, 2, 3, CC	0.5, 1.0					



Olive gray (5Y 3/1) pebbles

Bluish (5G 5/1) pebbles

← Pumaceous fragment

DRILL BRECCIA

Lithology:

Dominant: very dark gray pebbles of diatomaceous muddy siltstone

Secondary: blue gray pebbles of zeolitic mudstone

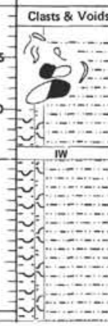
Size is gravel now; however the primary lithology was diatomaceous muddy claystone with secondary zeolitic claystone.

SMEAR SLIDE SUMMARY

	1-80	1-145
TEXTURE:		
Sand	4	TR
Silt	26	5
Clay	70	95
COMPOSITION:		
Quartz	2	2
Feldspar	4	1
Mica	2	–
Other heavy minerals	TR	1
Clay minerals	60	–
Volcanic glass	2	3
Glauconite	2	1
Zeolite	10	84
Calc.-Dolo.-Arag.	1	–
Calc. nannofossils	1	TR
Diatoms	10	–
Radiolarians	2	2
Sponge spicules	1	5
Palagonite	1	–

SITE 494 HOLE A CORE 8 CORED INTERVAL 104.0–113.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
QUATERNARY	L. Pleistocene (N); *N. eggeri* (F)	CP, AG	RP, RP, CG			1, 2, CC	0.5, 1.0	Clasts & Voids; IW				



DIATOMACEOUS MUDDY CLAY AND MUDSTONE

Color: Dark, olive-gray, fractured. Clasts: Calcareous, micritic cobbles. Larger representation of 55–80 cm interval on Visual Core Description Form. Biscuits dominant below 90 cm and in Section 2. Subtle difference between darker, indurated clasts and softer, lighter-colored matrix. Section 2, 117 cm (smear slide): Not representative of core in general, sampled light colored clast.

SMEAR SLIDE SUMMARY

	1-67	1-101	1-105	2-117
TEXTURE:				
Sand	3	30	3	50
Silt	60	15	30	20
Clay	37	55	67	30
COMPOSITION:				
Quartz	4	4	4	3
Feldspar	12	3	4	–
Pyrite	5	5	10	5
Other heavy minerals	1	1	1	2
Clay minerals	21	51	31	–
Volcanic glass	10	4	2	25
Glauconite	1	5	2	5
Zeolite	10	2	15	30
Calc.-Dolo.-Arag.	3	20	5	–
Foraminifera	1	1	1	–
Calc. nannofossils	2	TR	2	TR
Diatoms	25	3	20	5
Radiolarians	5	1	1	5
Sponge spicules	–	–	2	20
Ostracods	–	–	–	TR

CARBONATE BOMB (%)

1, 72–74 = 4.0

CARBON-CARBONATE (%)

	1, 133–135
Organic Carbon	2.61
Total Carbonate	2

SITE 494 HOLE A CORE 9 CORED INTERVAL 113.5–123.0 m

TIME – ROCK UNIT: QUATERNARY
BIOSTRATIGRAPHIC ZONE: L. Pleistocene (N); *N. eggeri* (F)
FOSSIL CHARACTER: FORAMINIFERS: RP; NANNOFOSSILS: B, B, FM; RADIOLARIANS: RM; DIATOMS
SECTION: 1, 2, 3, 4
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: VOID; VOID
DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUD AND MUDSTONE
Three 3x3 cm pebbles of calcareous siltstone at top of core.
Section 1–Section 2, 120 cm: Section consists of approximately 2x5 cm firm drilling biscuits, surrounded by more pliant mud. Predominant color is dark olive gray (5Y 3/2–5GY 4/1. Biscuits are fractured, probably from drilling, and fracture surfaces show incipient polish from displacements. Locally, mud has flowed into these fractures. Disturbed 1–3 mm vitric ash layers at Section 1, 30–35 cm; swirled ash at Section 1, 85 cm. Shell fragments at 135 cm. Some extensional fractures in biscuits.
Section 2, 120–128 cm: This material may represent undisturbed pebbly mudstone. Firm conglomeratic mudstone, with granule-size clasts of bluish-gray clay and light gray calcareous siltstone (hard) (calcareous ash).

DRILL BRECCIA
Section 3: Disaggregated by drilling: consists of 2–4 mm fragments of 1) bluish gray firm clay as above; 2) 5Y 3/2 firm diatomaceous silty mud; and 3) 10% light gray hard calcareous siltstone. Variable amounts of soupy mud matrix of sandy and silty clay with diatoms – essentially a soupy version of predominant lithology (mud) above this section in 494A.

SMEAR SLIDE SUMMARY

	1-33	1-88	1-88	2-41	3-80
TEXTURE:					
Sand	5	1	30	3	30
Silt	50	2	35	20	42
Clay	45	97	35	77	28
COMPOSITION:					
Quartz	1	1	2	2	12
Feldspar	2	2	3	5	15
Mica	TR	–	–	–	–
Pyrite	1	2	3	2	2
Other heavy minerals	TR	TR	TR	2	2
Clay minerals	41	91	11	63	35
Volcanic glass	50	–	72	15	5
Glauconite	2	1	1	1	8
Zeolite	1	–	6	3	1
Calc.-Dolo.-Arag.	–	–	TR	TR	–
Foraminifers	–	–	–	–	2
Calc. nannofossils	–	TR	–	TR	–
Diatoms	TR	–	TR	2	15
Radiolarians	1	1	TR	3	TR
Sponge spicules	1	2	1	1	2

CARBONATE BOMB (%)
2, 5–7 = 2.5

SITE 494 HOLE A CORE 10 CORED INTERVAL 123.0–132.5 m

TIME – ROCK UNIT: QUATERNARY
FOSSIL CHARACTER: NANNOFOSSILS: B; RADIOLARIANS: RM
SECTION: 1
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: VOID; Clasts & Voids

LITHOLOGIC DESCRIPTION

HEMIPELAGIC MUD
Clasts and fragments up to 2x5 cm of firm dark gray mudstone and pale hard chalk. Completely broken up by drilling. Disturbed firm, flaky, sandy, and silt mudy, 5Y 3/1–5Y 3/2.

SMEAR SLIDE SUMMARY

	1-120
TEXTURE:	
Sand	18
Silt	12
Clay	70
COMPOSITION:	
Quartz	12
Feldspar	3
Pyrite	5
Other heavy minerals	1
Clay minerals	68
Volcanic glass	2
Glauconite	1
Zeolite	2
Diatoms	1
Radiolarians	1
Sponge spicules	1

CARBON-CARBONATE (%)

	1, 124–126
Organic Carbon	2.75
Total Carbonate	1

SITE 494 HOLE A CORE 11 CORED INTERVAL 132.5–142.0 m

TIME – ROCK UNIT: QUATERNARY
BIOSTRATIGRAPHIC ZONE: L. Pleistocene (N)
FOSSIL CHARACTER: FORAMINIFERS: B; NANNOFOSSILS: RM; RADIOLARIANS: FM
SECTION: 1
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: VOID; Drill breccia; Void & drill breccia

LITHOLOGIC DESCRIPTION

HEMIPELAGIC MUD
All disturbed by drilling–irregular swirling and mottling to complete brecciation. Consists of 5Y 3/1–3/2, silty-sandy mud, firm with 10–15% volcanic glass shards. Swirled layers of 5Y 4/3 ashy clay–vitric ash in lighter layers at 85–90 cm and 100–105 cm.

SMEAR SLIDE SUMMARY

	1-106	1-108
TEXTURE:		
Sand	–	15
Silt	30	45
Clay	70	40
COMPOSITION:		
Quartz	2	10
Feldspar	2	15
Pyrite	1	10
Other heavy minerals	1	1
Clay minerals	70	38
Volcanic glass	24	13
Glauconite	–	8
Calc.-Dolo.-Arag.	–	1
Foraminifers	TR	–
Diatoms	TR	1
Radiolarians	–	1
Sponge spicules	–	1
Limonite	–	1

CARBONATE BOMB (%)
1, 124–126 = 2.5

SITE 494 HOLE A CORE 12 CORED INTERVAL 142.0–151.5 m

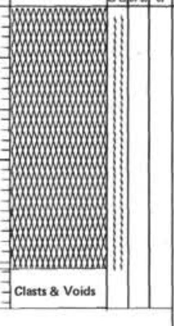
TIME-ROCK UNIT: QUATERNARY

BIOSTRATIGRAPHIC ZONE: Pleistocene (N); Early–Middle Miocene (Blue chips) (R)

FOSSIL CHARACTER (FORAMINIFERS / NANNOFOSSILS / RADIOLARIANS / DIATOMS): B; RM; B, RM; RM

SECTION: 1, 2, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

DRILL BRECCIA

Entire core is drilling breccia. Consists of subrounded to subangular fragments 2–5 mm in size of pale greenish blue firm clay, dark gray firm mud, and calcareous siltstone (limy ash/tuff); in ratio 5:4:3.5. Calcareous siltstone fragments are 1–2 mm. Interpreted as a drilling disaggregated pebbly mudstone.

Core-Catcher: Fragments of very hard calcareous siltstone as above, firm bluish gray clay as above, and dark olive gray mudstone. One blue fragment 3 cm diameter. Dark gray mudstone chips are Pleistocene. Calcareous siltstone is carbonate-cemented ash. Blue chips have early–middle Miocene radiolarians.

CARBON-CARBONATE (%)

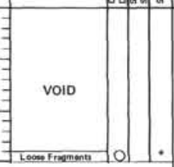
	2, 90–118
Organic Carbon	1.58
Total Carbonate	4

SITE 494 HOLE A CORE 13 CORED INTERVAL 151.5–161.0 m

FOSSIL CHARACTER: B

SECTION: 1 — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



SAMPLES: *

LITHOLOGIC DESCRIPTION

MICRITIC LIMESTONE AS COBBLES IN DRILL BRECCIA

Section 1: Several pebbles and fragments of light olive gray (5Y 6/2) very hard chalk (0.5–6 cm). Smear slide consists of very fine-grained carbonate and glass shards; ashy limestone.

SMEAR SLIDE SUMMARY

	1, 140–150
TEXTURE:	
Sand	–
Silt	40
Clay	60
COMPOSITION:	
Quartz	TR
Feldspar	TR
Volcanic glass	40
Calc.-Dolo.-Arag.	60

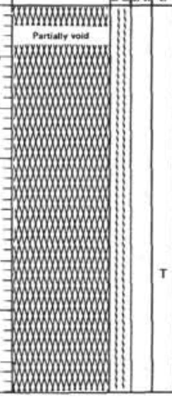
SITE 494 HOLE A CORE 14 CORED INTERVAL 161.0–170.5 m

BIOSTRATIGRAPHIC ZONE: Quaternary (R); Pleistocene (N)

FOSSIL CHARACTER: B; B; B; FM; B; RM

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



SAMPLES: T ← Bivalve fragment

LITHOLOGIC DESCRIPTION

DRILL BRECCIA

All the core is a drilling breccia. Consists of fragments subrounded 0.5–50 mm. Dark olive gray (5Y 3/2) hard mud. Pale greenish blue (5G 7/1–5BG 7/1) granule to pebble. Light olive gray (5Y 6/2) granule to pebble (calcareous siltstone). Rare white–light gray (5Y 8/1–7/2) pebbles. Thin section: Silty micrite (calcareous). Core-Catcher: 1 black pebble.

CARBON-CARBONATE (%)

	3, 0–10
Organic Carbon	1.29
Total Carbonate	16.5

SITE 494 HOLE A CORE 15 CORED INTERVAL 170.5–180.0 m

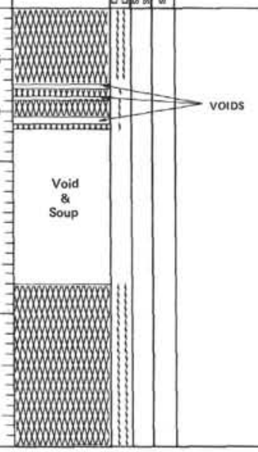
TIME-ROCK UNIT: QUATERNARY

BIOSTRATIGRAPHIC ZONE: Pleistocene (N)

FOSSIL CHARACTER: FG; B; B; B

SECTION: 1, 2, 3 — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



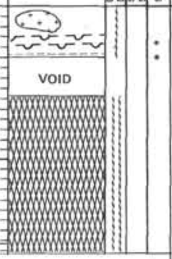
LITHOLOGIC DESCRIPTION

DRILL BRECCIA

All the core is a drilling breccia. Consists of fragments subrounded size (3.5 cm). Dark olive gray (5Y 3/2) hard mud. Pale greenish blue (5G 7/1–5BG 7/1) granule to pebble. Light olive gray (5Y 6/2) granule to pebble (calcareous).

SITE 494 HOLE A CORE 16 CORED INTERVAL 180.0–189.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
QUATERNARY	L. Pleistocene (N)	B	FM	RM		1, 2, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

DRILL BRECCIA

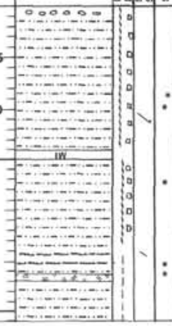
Drill cuttings – liner badly imploded, looks as if sediment was sucked up to the top. 0–50 cm: diatomaceous muddy clay–claystone (Section 1).
Section 1 (top): subrounded cobble acid igneous intrusive rock: 50–50% light–dark grains coarse-grained quartz diorite.
Section 1, 87 cm–base of core: drill breccia.
Core-Catcher: 10 cm; drill breccia as above.
Smear slide 1-42: Not representative of section in general – taken from bluish chips in gray matrix.

SMEAR SLIDE SUMMARY

	1-30	1-42
TEXTURE:		
Sand	15	40
Silt	35	40
Clay	50	20
COMPOSITION:		
Quartz	5	–
Pyrite	10	5
Other heavy minerals	5	2
Clay minerals	5	5
Volcanic glass	10	20
Glauconite	2	40
Zeolite	50	15
Diatoms	10	10
Radiolarians	–	2
Sponge spicules	2	1
Bryozoans	TR	–
Ostracods	1	–
Echinoderm	–	TR

SITE 494 HOLE A CORE 17 CORED INTERVAL 189.5–199.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
PLIOCENE	*G. altispira* (F); *D. brouweri* (N)	CM	AG, RM	RM		1, 2, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

SILTY MUD AND FRACTURED MUDSTONE
(local hackly fracture)
Section 1, 0–12 cm: pebbles, light olive gray, subround-subangular.
Dominant lithology: silty mud and mudstone.
Secondary lithology: sandy mud (5Y 5/2) with glass.
Minor lithology: sandy ash (5Y 6/1).

SMEAR SLIDE SUMMARY

	1-83	1-109	2-29	2-108	2-118
TEXTURE:					
Sand	7	25	10	55	40
Silt	48	25	15	30	20
Clay	45	50	75	15	40
COMPOSITION:					
Quartz	4	3	2	3	5
Feldspar	7	7	–	–	–
Pyrite	3	3	TR	–	1
Other heavy minerals	TR	1	–	2	2
Clay minerals	43	46	2	–	5
Volcanic glass	20	10	10	50	50
Glauconite	1	1	2	2	1
Zeolite	8	8	74	15	34
Calc.-Dolo.-Arag.	1	–	5	10	–
Foraminifers	–	–	–	17	–
Diatoms	10	4	2	–	1
Radiolarians	1	1	2	1	1
Sponge spicules	2	1	1	–	–

CARBONATE BOMB (%)
1, 90–92 = 5

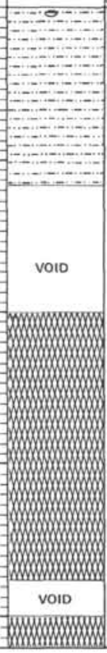
CARBON-CARBONATE (%)

	1, 76–78
Organic Carbon	2.8
Total Carbonate	4.0

SITE 494 HOLE A CORE 18 CORED INTERVAL 199.0–208.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
PLIOCENE	S. pentas (R)	B				1	0.5, 1.0
						2	
						3	
		B		RM		4	
						CC	

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

← Pebble 5x2 cm, light colored

Slickensides
← 40°, 60°
← 40°, 70°
← 30°, 85°
← 25°, 55°, 90°

5Y 3/1

MUDSTONE
Section 1–Section 2, 22 cm: Very dark, olive gray.

DRILL CUTTINGS
Section 3–base of core: 5Y 3/1. Very dark gray mudstone, 2–5 mm. Pale greenish blue granules, 2–5 mm. Pale olive gray sand, >1 mm.

SMEAR SLIDE SUMMARY

	1-86
TEXTURE:	
Sand	5
Silt	30
Clay	65
COMPOSITION:	
Quartz	5
Mica	1
Other heavy minerals	5
Volcanic glass	10
Glauconite	5
Zeolite	60
Foraminifers	1
Diatoms	10
Radiolarians	2
Sponge spicules	1

CARBONATE BOMB (%)
1, 92–94 = 2.5

CARBON-CARBONATE (%)

	1, 78–80
Organic Carbon	1.97
Total Carbonate	2.5

SITE 494 HOLE A CORE 19 CORED INTERVAL 208.5–218.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
PLIOCENE	S. pentas (R)			RM		1	0.5, 1.0
	G. altispira (F)	CP	B			2	
						CC	

GRAPHIC LITHOLOGY

LITHOLOGIC DESCRIPTION

← Possible burrow filled with light yellow zeolitic clay

MUDSTONE
Dark gray.
Section 1, 0–22 cm: Clasts and void: black mudstone pebble; bluish gray claystone; light olive gray (probably hard ashy micrite). Dark gray sandy mudstone, locally glassy, 2x5 cm thick drilling biscuits 60–140 cm in Section 1. Clots of 5Y 6/2 zeolitic clay at 55 cm. Biscuits typically affted by hackly fractures throughout.
Section 2, 0–59 cm: Probably interlayered 5Y 6/2 zeolitic clay and dark gray (5Y 2/2) sandy mudstone, all disturbed and swirled by drilling.
Section 2, 59 cm–base of core: 5Y 2/2 biscuits of fractured sandy mudstone and drilling laminations.
Core-Catcher: 15 cm, firm drilling disturbed. 5Y 2/2 dark mudstone.

SMEAR SLIDE SUMMARY

	1-10	1-56	1-105	2-18
TEXTURE:				
Sand	7	–	20	3
Silt	10	–	20	10
Clay	83	–	60	87
COMPOSITION:				
Quartz	3	10	–	1
Feldspar	4	–	–	1
Mica	1	–	–	–
Pyrite	3	6	8	2
Other heavy minerals	1	1	2	1
Clay minerals	76	20	–	83
Volcanic glass	5	15	30	5
Glauconite	1	3	–	1
Zeolite	3	37	57	5
Calc.-Dolo. Arag.	–	–	–	1
Foraminifers	–	–	1	–
Diatoms	1	2	1	–
Radiolarians	TR	1	1	TR
Sponge spicules	2	2	TR	–
Plant debris	–	3	–	–
Ostracod	–	–	TR	–

CARBONATE BOMB (%)
2, 46–48 = 26.0

CARBON-CARBONATE (%)

	CC, 10–12
Organic Carbon	1.05
Total Carbonate	2.5

SITE 494 HOLE A CORE 20 CORED INTERVAL 218.0–227.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER PLIOCENE	*S. pentas* (R)	AG				1	0.5, 1.0
	G. tumida (F)	FP				2	
	?*D. exilis* (N)	RP		RM		3	
LOWER TO MIDDLE MIOCENE	Middle Miocene	FM	FM			4	
	C. tetrapera (R)	B	RM			5	
		B				6	

GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

LITHOLOGIC DESCRIPTION

5Y 3/2

SANDY SOFT MUDSTONE
Section 1: Drilling laminations separate internally fractured drilling biscuits, dark olive gray (5Y 3/2).

SANDY MUD AND MUDDY SANDSTONE
Section 2–Section 4, 70 cm: dark olive gray (5Y 3/2). Pervassive fracturing 125–150 cm in Section 2.

CLAY AND CLAYSTONE
Major Lithologic Contact · 7 cm drilling disturbed (swirled) mixed zone (Section 4, 70 cm and below). Bluish gray (5G 4/1–5BG 4/1), clay, firm to flaky, brecciated and swirled by drilling. At Section 5, 10–20 cm fragments of light gray hard ashy micrite.

Drilling laminations

Major lithologic contact

SMEAR SLIDE SUMMARY

	1-45	1-73	1-73	2-66	3-104	4-126	5-10	5-141
TEXTURE:								
Sand	10	10	35	25	1	2	–	5
Silt	25	26	15	45	21	13	10	28
Clay	65	64	50	30	78	85	90	72
COMPOSITION:								
Quartz	5	5	18	9	1	1	–	3
Feldspar	8	10	14	10	3	1	–	5
Pyrite	–	1	–	45	2	2	–	5
Mag. hematite	2	–	–	–	–	–	–	–
Other heavy minerals	TR	TR	8	5	TR	TR	TR	1
Clay minerals	63	57	17	15	77	82	–	68
Volcanic glass	5	7	4	5	7	5	10	12
Glauconite	1	TR	8	1	1	TR	–	1
Zeolite	3	3	4	8	–	2	–	5
Calc.-Dolo.-Arag.	6	1	27	1	1	3	90	1
Foraminifers	–	TR	–	–	–	–	–	–
Calc. nannofossils	1	–	–	–	–	–	–	2
Diatoms	2	10	TR	1	6	1	–	TR
Radiolarians	2	1	–	–	–	1	–	1
Sponge spicules	2	4	TR	–	2	2	–	–
Others	–	1	–	–	–	–	–	–

CARBONATE BOMB (%)
5, 136–137 = 2.5

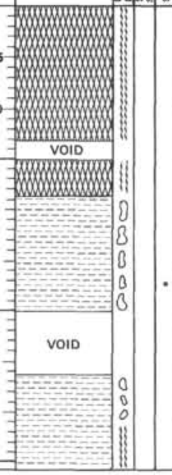
CARBON-CARBONATE (%)

	2, 40–42	3, 134–136	5, 75–77	5, 108–110	5, 53–55
Organic Carbon	1.6	1.88	0.54	0.42	2.73
Total Carbonate	2.5	4.0	2.5	2.5	1

SITE 494 HOLE A CORE 21 CORED INTERVAL 227.5–237.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER TO MIDDLE MIOCENE	M. Miocene	B				1	0.5, 1.0
		RP				2	
	?*D. exilis* (N)	RP				3	
					CC		

GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

5GY 4/1

CLAYSTONE
Bluish gray (5GY 4/1). Totally brecciated by drilling(?). Sediment locally reduced to soupy breccia. Origin: in situ or drill induced?
In Section 2, soupy breccia below 40 cm.
Section 3, 130 cm: fragments of whitish gray ashy micrite, probably brecciated by drilling.
Core-Catcher: Breccia.

SMEAR SLIDE SUMMARY

	2-125
TEXTURE:	
Sand	–
Silt	–
Clay	100
COMPOSITION:	
Calc.-Dolo.-Arag.	100

SITE 494 HOLE A CORE 22 CORED INTERVAL 237.0–246.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
OLIGOCENE TO MIOCENE	P22 (F)–N4; Oligocene? (R)	FP, CP		RM, RP		1, 2	0.5, 1.0	VOID			*
	?D. exilis (N); Miocene (R)	FM	FM	RM		3		OG			
MIDDLE MIOCENE	N7 (F); Middle Eocene (R)	RP	CG			4, CC					*
	N. fulgens (N)										

5G 5/1

5Y 3/2?

← Contact observed in frozen sample

Blue gray (5G 6/2)

Greenish gray

Light green gray

LITHOLOGIC DESCRIPTION

CLAY AND CLAYSTONE

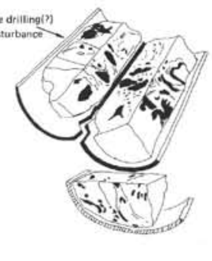
Bluish gray.

Section 1, 35 cm–Section 3, 40 cm: All sticky, adobe-like blue-gray (5G 5/1) mudstone with scattered granules and pebbles (<5%–50 mm diameter) of calcareous chalk and limestone. Thoroughly disturbed by drilling. Diagram below shows interval flow patterns. Mudstone is a microbreccia of finely scaly clay.

Section 3, 40 cm to base of core: Color change from blue-gray to greenish gray mudstone. Color change marks very important lithologic change into very dark olive gray mud typical of section in higher cores. Also represents marked paleontological change from Oligocene back into Miocene.

Section 4, 0–20 cm: blue gray (5G 6/2) mudstone; 20–104 cm: greenish gray claystone (drill breccia); 104–130 cm: drill breccia of light greenish gray claystone with <1 cm white granules.

Core-Catcher: drill breccia.



SMEAR SLIDE SUMMARY

	1-112	4-106
TEXTURE:		
Sand	–	2
Silt	90	60
Clay	10	38
COMPOSITION:		
Quartz	–	5
Feldspar	–	1
Mica	–	1
Other heavy minerals	–	1
Clay minerals	–	25
Volcanic glass	–	10
Zeolite	–	1
Calc.-Dolo.-Arag.	100	–
Calc. nannofossils	–	55
Sponge spicules	–	1

CARBONATE BOMB (%)

2, 6–8 = 2.5

SITE 494 HOLE A CORE 23 CORED INTERVAL 246.5–256.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
MIDDLE EOCENE	Middle Eocene (R); N. fulgens (N)	B, RP		FM		1, 2	0.5, 1.0				*
	P. mitra(?) (R)	B	CG		CM	3, CC					

LITHOLOGIC DESCRIPTION

DRILL BRECCIA

1–4 mm fragments of dark olive gray (5Y 3/2) sandy mudstone, of bluish gray (5B 7/1) claystone, of olive gray (5Y 4/2) silty mudstone.

Below 100 cm of Section 1: light gray (5GY 6/1) compact but breakable siltstone. Size fragments = 20 mm; average <5 mm, light gray (5Y 4/2) siltstone 90% and dark gray (5GY 6/1) mudstone.

Section 3: 95% light gray (5Y 4/2) siltstone as above and 5% light gray (5Y 4/2) claystone.

Core-Catcher: as above.

SMEAR SLIDE SUMMARY

	1-120
TEXTURE:	
Sand	1
Silt	70
Clay	29
COMPOSITION:	
Quartz	5
Feldspar	1
Mica	1
Clay minerals	25
Zeolite	1
Calc. nannofossils	60
Radiolarians	2
Sponge spicules	5

CARBONATE BOMB (%)

1, 120–122 = 36.0

CARBON-CARBONATE (%)

	1, 98–100
Organic Carbon	0.61
Total Carbonate	22

SITE 494 HOLE A CORE 24 CORED INTERVAL 256.0–265.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
MIDDLE EOCENE	P. mitra (R); N. fulgens (N)	B, B	CG	RP		1, 2, CC	0.5, 1.0				

←3 pebble fragments

LITHOLOGIC DESCRIPTION

DRILL BRECCIA

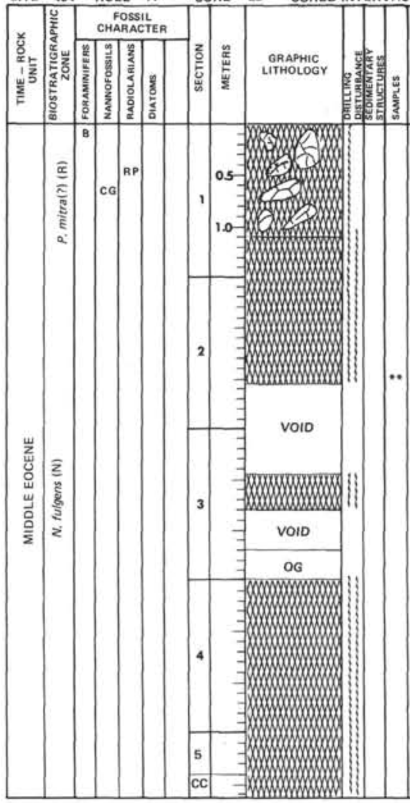
All drilling breccia composed of mudstone (5Y 3/2), siltstone (5GY 6/1), and locally ashy micrite (5Y 7/1). Grain size = average 3–5 mm. Three pebble fragments = one mudstone and two calcareous siltstone.

Core-Catcher: as above.

CARBON-CARBONATE (%)

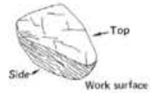
	2, 34–37
Organic Carbon	0.99
Total Carbonate	13

SITE 494 HOLE A CORE 25 CORED INTERVAL 265.5–275.0 m



LITHOLOGIC DESCRIPTION

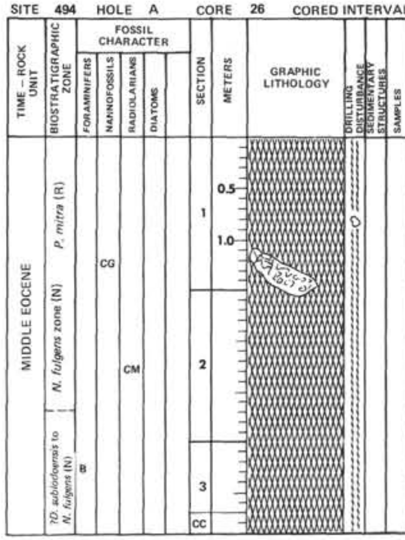
DRILL BRECCIA
Primary lithology was probably a mudstone with incipient fracture. Drilling has made a gravel deposit out of that. Top of Section 1 is truly a drilling breccia. No fracture angles because cobbles have been reoriented during coring. Large chunks are obviously brecciated during drilling. Fracture within cobbles is primary. Bottom of Section 2–Core-Catcher is gravel size, homogeneous drill cuttings.



SMEAR SLIDE SUMMARY

	2-100A (blue granule)	2-100B (gray granule)
TEXTURE:		
Sand	40	3
Silt	15	60
Clay	45	37
COMPOSITION:		
Quartz	1	12
Feldspar	2	1
Mica	–	1
Pyrite	5	1
Other heavy minerals	–	1
Clay minerals	19	35
Volcanic glass	30	12
Glauconite	2	1
Zeolite	25	5
Foraminifers	1	–
Calc. nannofossils	2	1
Diatoms	1	25
Radiolarains	5	–
Sponge spicules	7	5

SITE 494 HOLE A CORE 26 CORED INTERVAL 275.0–284.5 m



LITHOLOGIC DESCRIPTION

DRILL BRECCIA
Mixture of elements (2–3 cm), gray (5Y 3/1), blue gray (5G 4/2), and buff brown (5Y 4/2).

Initial sediment with fractures (fragmentation)

SITE 494 HOLE A CORE 27 CORED INTERVAL 284.5–294.0 m

TIME – ROCK UNIT: MIDDLE EOCENE

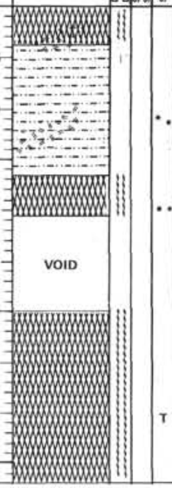
BIOSTRATIGRAPHIC ZONE: ?D. sublodoensis to N. fulgens (N); P. mitra (R)

FOSSIL CHARACTER: FORAMINIFERS RP; NANNOFOSSILS CG; RADIOLARIANS RP; DIATOMS

SECTION: 1, 2, 3, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: VOID



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES: T

LITHOLOGIC DESCRIPTION

DRILL BRECCIA

Very dark gray nannofossil sandy mudstone with nannofossil rich layers, all of which is brecciated as primary, not drilling-induced structure.

Section 1, 40–145 cm:

Open and healed fractures.
The light colored laminae open fracture, parallel healed fracture.

SMEAR SLIDE SUMMARY

	1-113[†]	1-116[††]	2-50	2-50
TEXTURE:				
Sand	22	40	8	19
Silt	30	20	11	32
Clay	48	40	81	53
COMPOSITION:				
Quartz	5	–	TR	10
Feldspar	2	2	2	8
Pyrite	10	2	2	10
Other heavy minerals	–	2	TR	TR
Clay minerals	15	10	1	23
Volcanic glass	15	40	1	8
Glauconite	–	–	TR	1
Zeolite	–	–	1	2
Calc.-Dolo.-Arag.	8	9	68	12
Calc. nannofossils	25	20	10	10
Radiolarians	10	5	9	10
Sponge spicules	10	8	1	1
Plant debris	–	2	5	5

† Dark gray matrix
†† Light gray ash layer

SITE 494 HOLE A CORE 28 CORED INTERVAL 294.0–303.0 m

TIME – ROCK UNIT: MAASTRICHTIAN

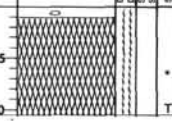
BIOSTRATIGRAPHIC ZONE: G. gansseri (F); Upper Cret. and M. Eocene (N); Upper Cret. and Eocene (R)

FOSSIL CHARACTER: FORAMINIFERS AP, AP; NANNOFOSSILS CM; RADIOLARIANS RP; DIATOMS

SECTION: 1

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES: T

LITHOLOGIC DESCRIPTION

One fragment (6 cm) of silty limestone

DRILL BRECCIA

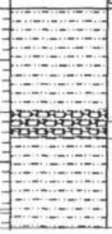
Top of Section 1 – one fragment of silty limestone. Remainder of core is drill breccia with 65–80 cm intact but fractured light gray (5G 6/1) firm silty micritic chalk (10% silt).

SMEAR SLIDE SUMMARY

	1-70
TEXTURE:	
Sand	–
Silt	10
Clay	90
COMPOSITION:	
Quartz	4
Feldspar	3
Pyrite	1
Other heavy minerals	1
Clay minerals	57
Volcanic glass	1
Zeolite	5
Calc.-Dolo.-Arag.	28

SITE 494 HOLE A CORE 29 CORED INTERVAL 303.0–312.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
MIDDLE EOCENE	Middle Eocene (N and R)			FP							
UPPER CRETACEOUS	Upper Cretaceous (N and R)		CM	CP		1	0.5				
			FM	RP			1.0				
				FP		2					
						CC					



LITHOLOGIC DESCRIPTION

5Y 3/2

5Y 6/1
↓
5GY 7/1

10R 2.5/1

MUDSTONE
Section 1, 0–50 cm: Sandy siliceous-calcareous mudstone.
50–75 cm: Mixed zone micro-breccia, sandy mudstone.
75–130 cm: Calcareous siliceous chalk.
Section 1, 130 cm–Section 2, 45 cm: Very dark gray (dusty red tint) carbonaceous-silty mudstone, 3–5 hard calcareous pebbles.
Section 2, 45 cm and Core-Catcher: pebbles (largest 4x6 cm), lower half very hard light greenish gray altered mafic volcanic rock.

SMEAR SLIDE SUMMARY

	1-34	1-83	2-13
TEXTURE:			
Sand	15	8	4
Silt	20	57	27
Clay	65	35	69
COMPOSITION:			
Quartz	4	2	2
Feldspar	7	3	4
Pyrite	4	1	7
Other heavy minerals	1	TR	1
Clay minerals	22	20	65
Volcanic glass	6	2	4
Glauconite	TR	1	9
Zeolite	4	4	6
Calc.-Dolo.-Arag.	16	30	1
Calc. nannofossils	5	3	TR
Diatoms	TR	–	–
Radiolarians	20	20	TR
Sponge spicules	1	2	TR
Siliceous and plant fragments	9	10	1

CARBONATE BOMB (%)
2, 14–16 cm = 2.5

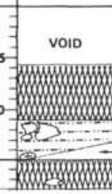
CARBON-CARBONATE (%)

	2, 6–8	2, 9–12
Organic Carbon	0.97	0.92
Total Carbonate	0.92	1

NOTE: Radiolarian biostratigraphy indicates: Section 1, 100–102 cm, 135–137 cm and Section 2, 30–32 cm all have small amounts of Eocene-probably the same age as the assemblage in Section 1, 14–16 cm. However, the Eocene is very rare and the Upper Cretaceous radiolarians are common.

SITE 494 HOLE A CORE 30 CORED INTERVAL 312.5–321.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
MAASTRICHTIAN	*G. contusa* (F)	FP	B	B		1	0.5	VOID			
							1.0				
						CC					



LITHOLOGIC DESCRIPTION

VOID

DRILLING BRECCIA
All the core highly disturbed by drilling, light gray (5Y 6/1).
Section 1, 0–110 cm: 5Y 6/1 pebble with fractures, *Globotruncana* (Upper Cretaceous) thin section.
Section 1, 110–150 cm: Very dark gray (5Y 3/1) mudstone with fractures involved by drilling?
At the bottom Section 1 pebble 12 mm igneous rock.
Core-Catcher: Mudstone (5Y 3/1) with fractures and drilling breccia 5Y 3/1–5G 5/2.

SMEAR SLIDE SUMMARY

	1-100	1-135
TEXTURE:		
Sand	15	3
Silt	75	17
Clay	10	80
COMPOSITION:		
Quartz	7	6
Feldspar	1	1
Mica	1	TR
Pyrite	1	–
Other heavy minerals	1	1
Clay minerals	60	80
Volcanic glass	?	–
Calc.-Dolo.-Arag.	24	–
Calc. nannofossils	3	10
Others	1	–

SITE 494 HOLE A CORE 31 CORED INTERVAL 321.5–330.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
						CC					

LITHOLOGIC DESCRIPTION

DRILL BRECCIA
5Y 3/1–5G 5/2 with pebbles of igneous rocks.

SITE 494 HOLE A CORE 32 CORED INTERVAL 330.5–339.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
			B			CC					•	

MUDDY CLAYSTONE
5BG 6/1 muddy claystone highly disturbed by drilling – drilling breccia.

SMEAR SLIDE SUMMARY

	CC-2
TEXTURE:	
Sand	10
Silt	80
Clay	10
COMPOSITION:	
Quartz	5
Feldspar	TR
Pyrite	TR
Clay minerals	85
Glauconite	TR
Calc. nannofossils	10

SITE 494 HOLE A CORE 33 CORED INTERVAL 339.5–348.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
			B			CC					• •	

DRILL BRECCIA
Soupy sand of igneous and carbonate material. Sticky clayey silt (zeolitic clay). Pebbles of green rocks, 8 subangular, 2–3 cm in size altered fine-grained volcanic rocks.

SMEAR SLIDE SUMMARY

	CC	CC
TEXTURE:		
Sand	40	3
Silt	40	67
Clay	20	30
COMPOSITION:		
Quartz	5	1
Feldspar (altered)	15	7
Mica	–	TR
Pyrite	2	–
Other heavy minerals	30	1
Clay minerals	10	20
Volcanic glass (altered)	–	3
Zeolite	10	67
Calc.-Dolo.-Arag.	20	1
Calc. nannofossils	5	–
Diatoms	TR	–
Sponge spicules	TR	–
Organic material	3	–

SITE 494 HOLE A CORE 34 CORED INTERVAL 348.5–357.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
						1	0.5 1.0	VOID				

DRILL BRECCIA
5BG 6/1

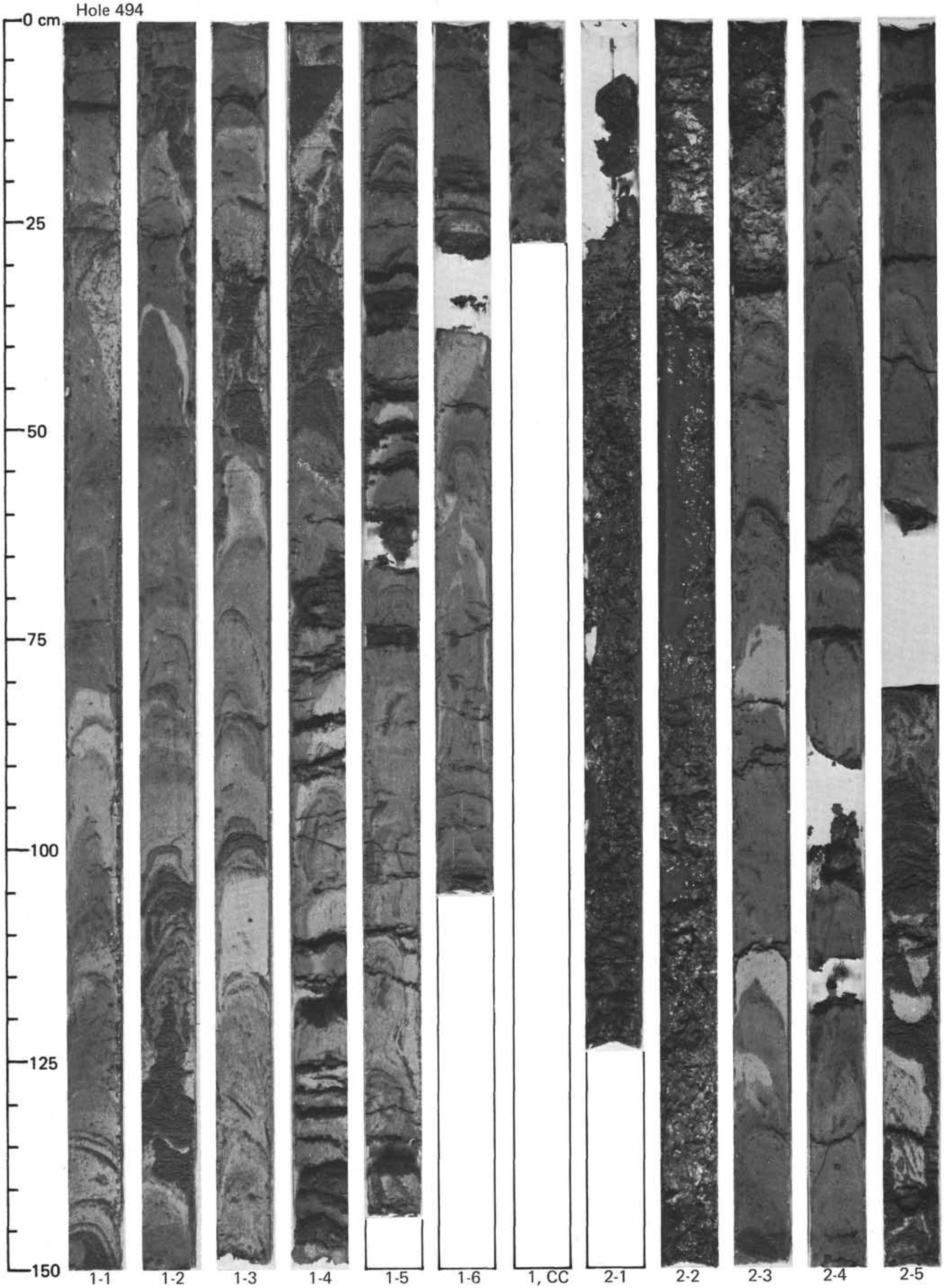
SITE 494 HOLE A CORE 35 CORED INTERVAL 357.5–366.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
						CC					•	

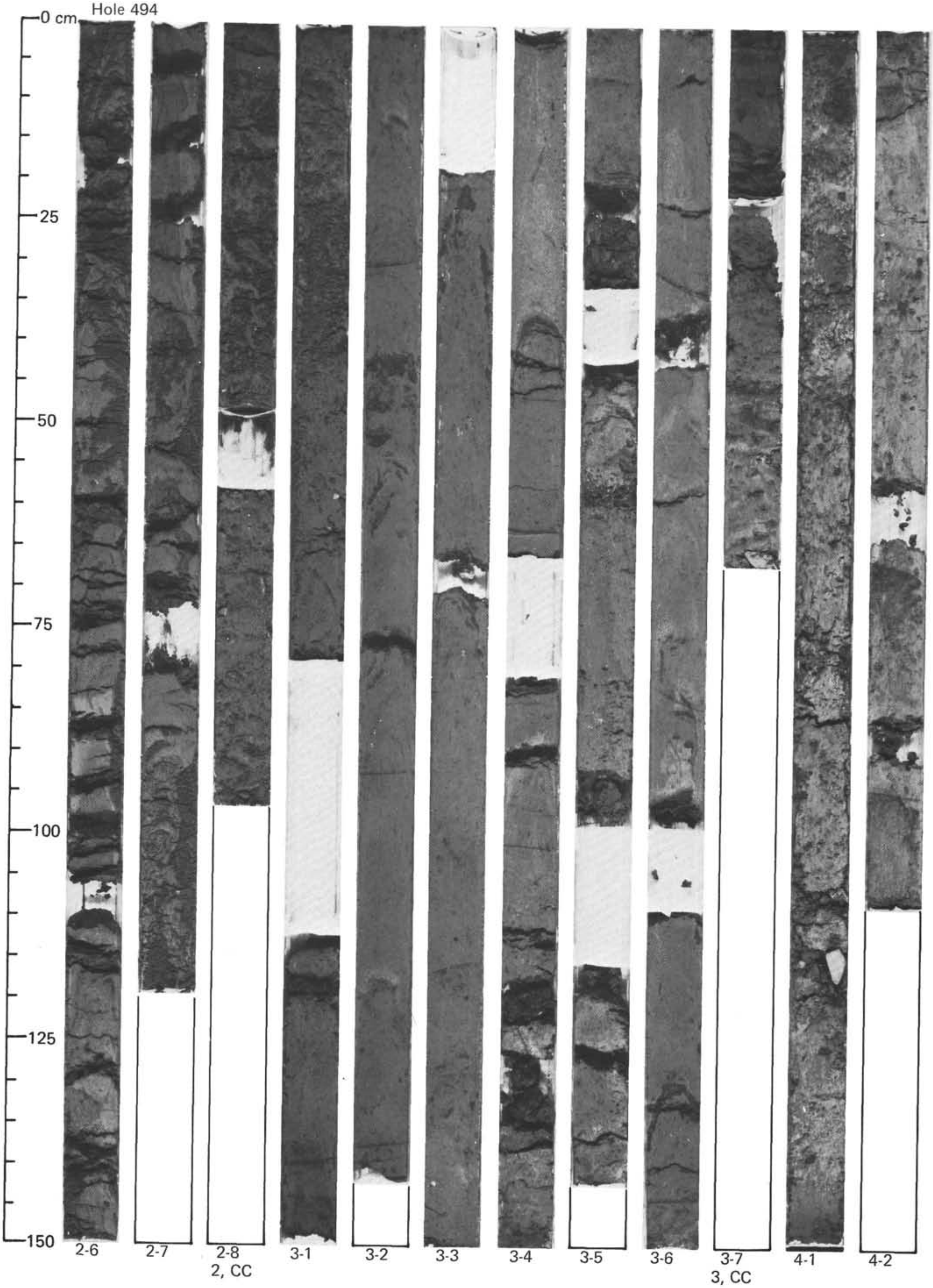
SANDY ZEOLITIC MUD
5G 5/2–5G 6/2 with granule – pebble (largest 5x4x4 cm, green rock with zeolite? druse). Quartz, feldspar, glass fossils highly altered.

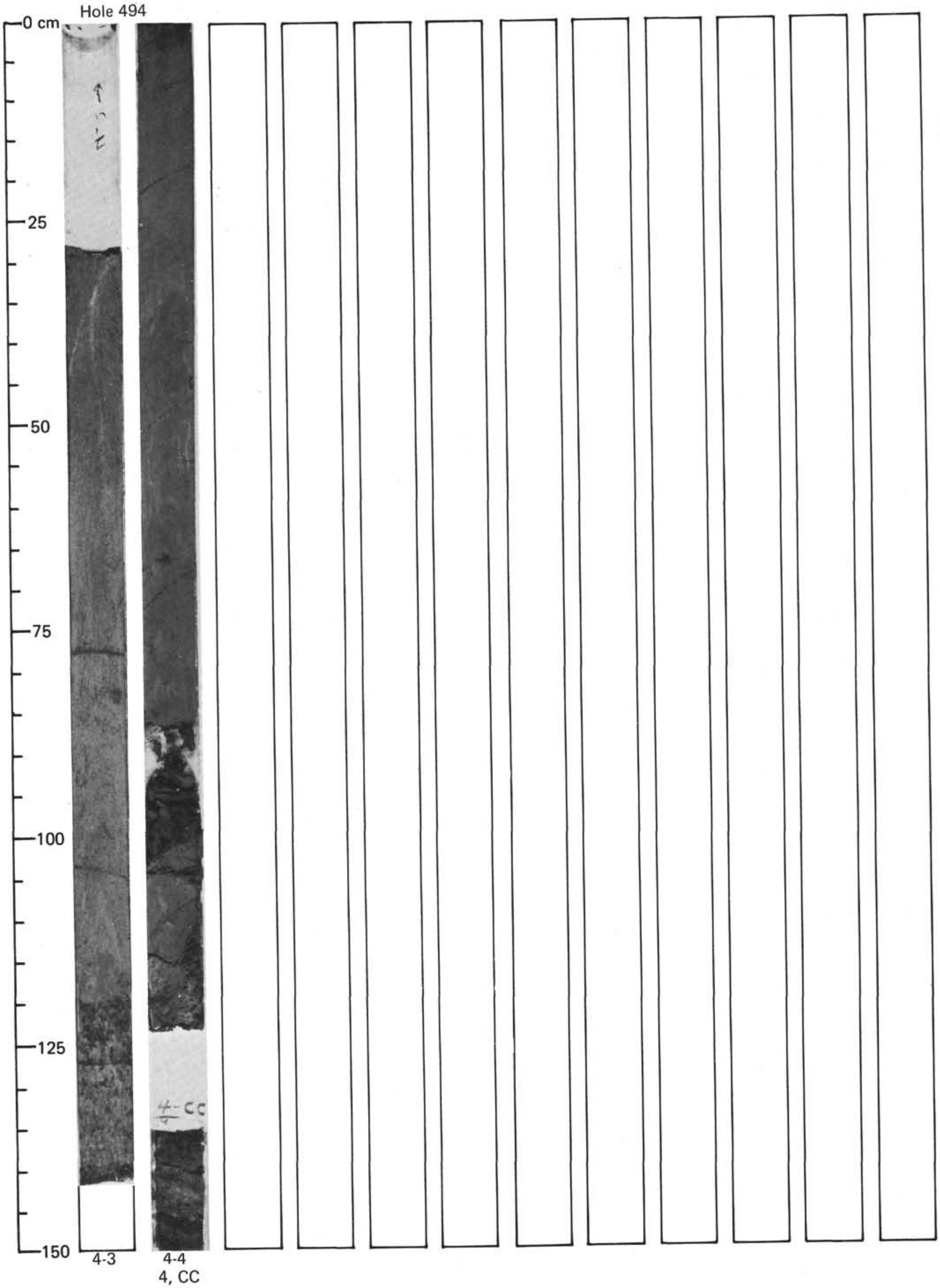
SMEAR SLIDE SUMMARY

	CC
TEXTURE:	
Sand	20
Silt	30
Clay	50
COMPOSITION:	
Quartz	1
Feldsper	18
Mag. hematite, etc.	2
Other heavy minerals	2
Clay minerals	8
Glauconite	1
Zeolite	66
Calc.-Dolo.-Arag.	2



0 cm
Hole 494
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1, CC
2-1
2-2
2-3
2-4
2-5


Hole 494
0 cm
25
50
75
100
125
150
2-6
2-7
2-8
2, CC
3-1
3-2
3-3
3-4
3-5
3-6
3-7
3, CC
4-1
4-2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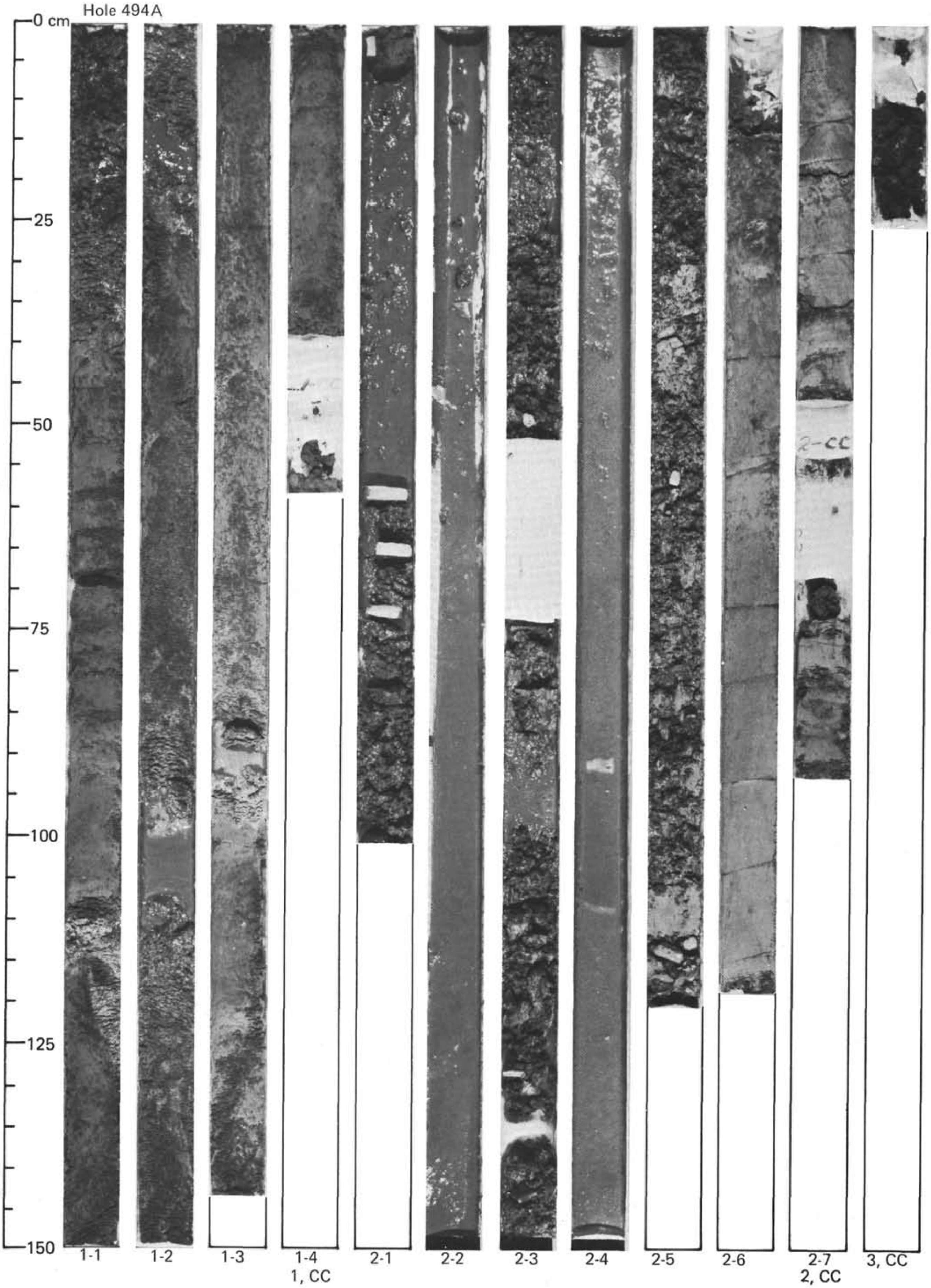
50
75
100
125
150
4-3
4-4
4, CC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75
100
125
150
1-1
1-2
1-3
1-4
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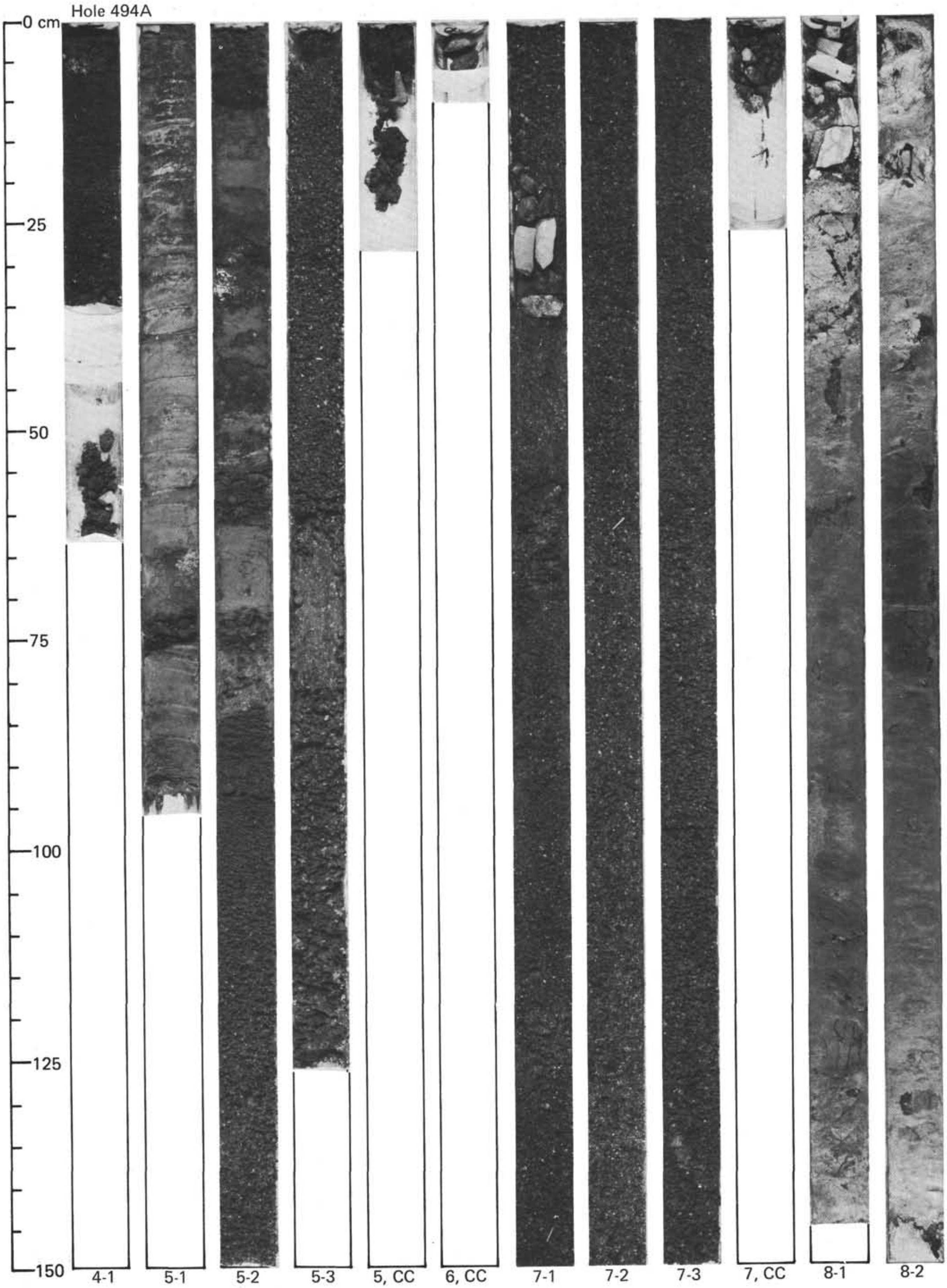
2-2
2-3
2-4
2-5
2-6
2-7
2, CC
3, CC
2-CC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125
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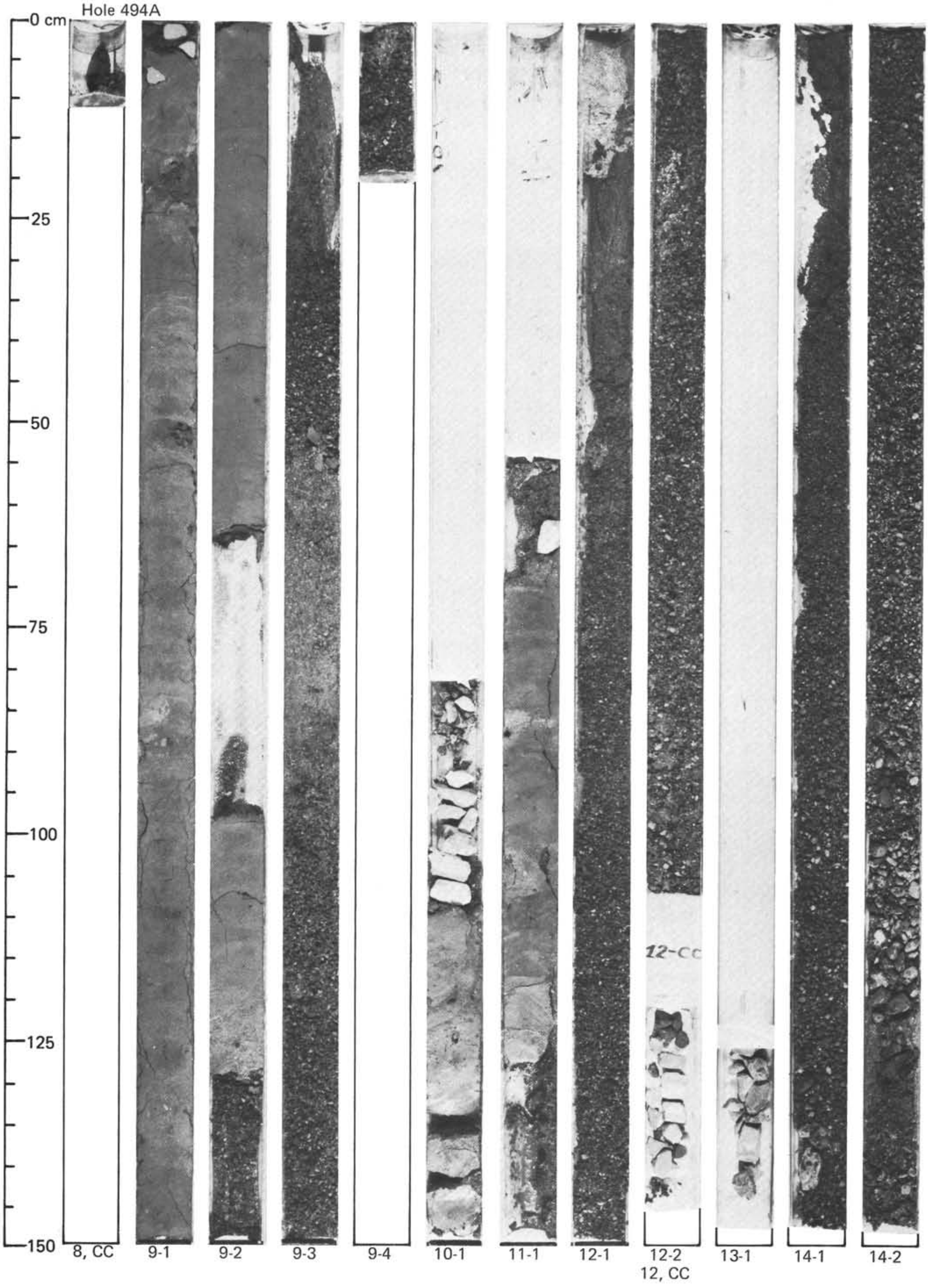
6, CC
7-1
7-2
7-3
7, CC
8-1
8-2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150
12-CC
8, CC
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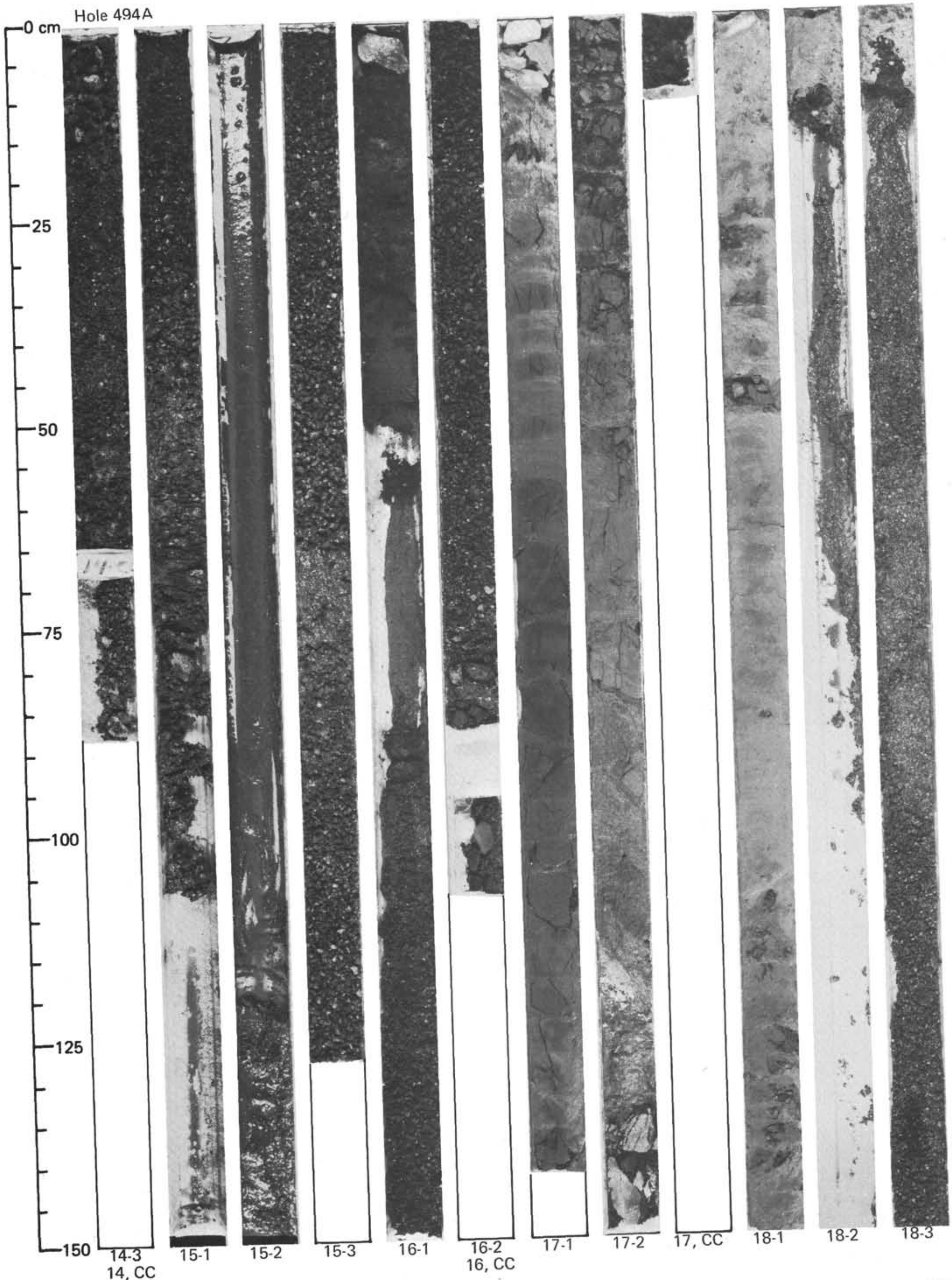
11-1
12-1
12-2
12, CC
13-1
14-1
14-2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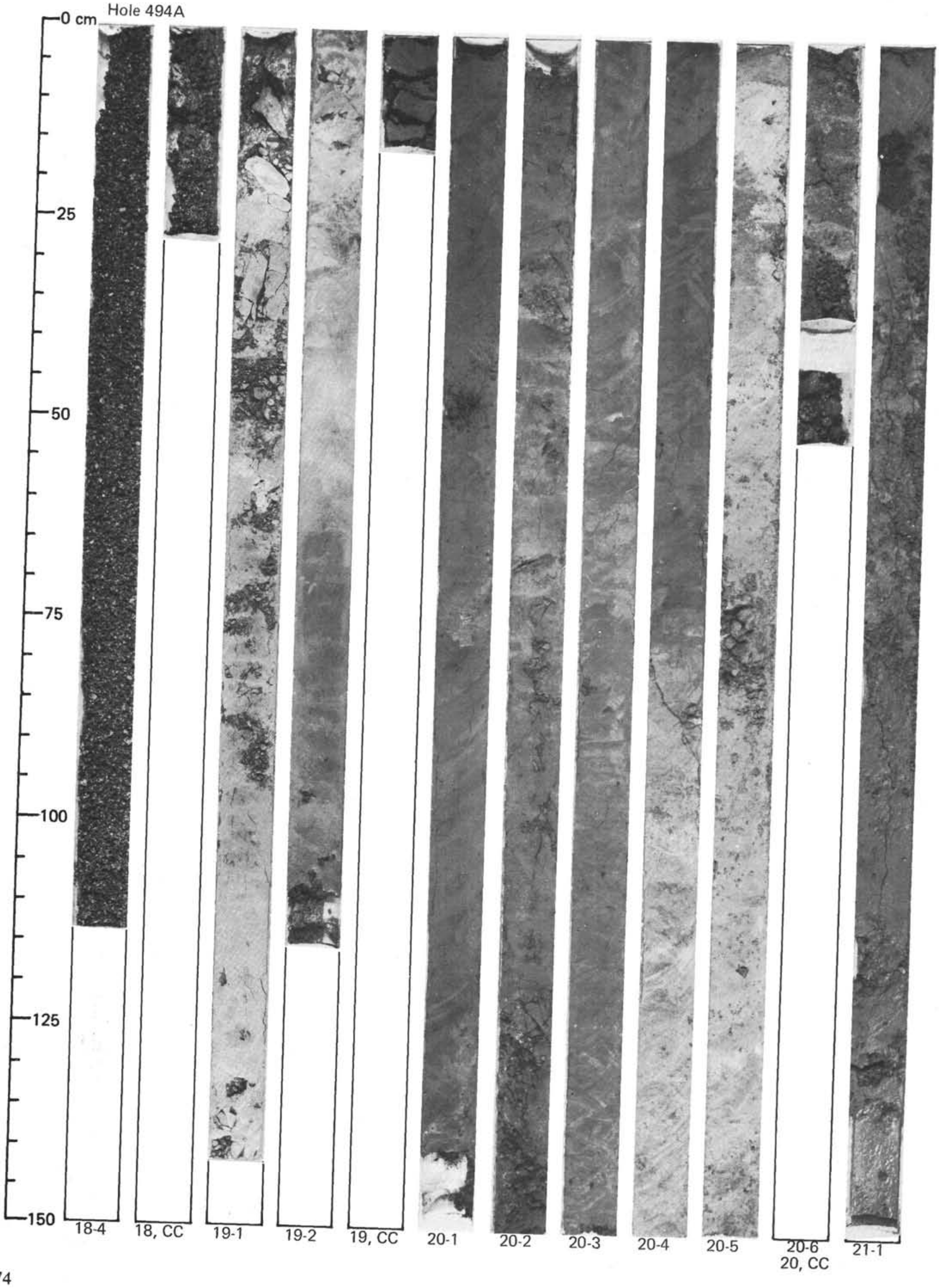
16, CC
17-1
17-2
17, CC
18-1
18-2
18-3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19-2
19, CC
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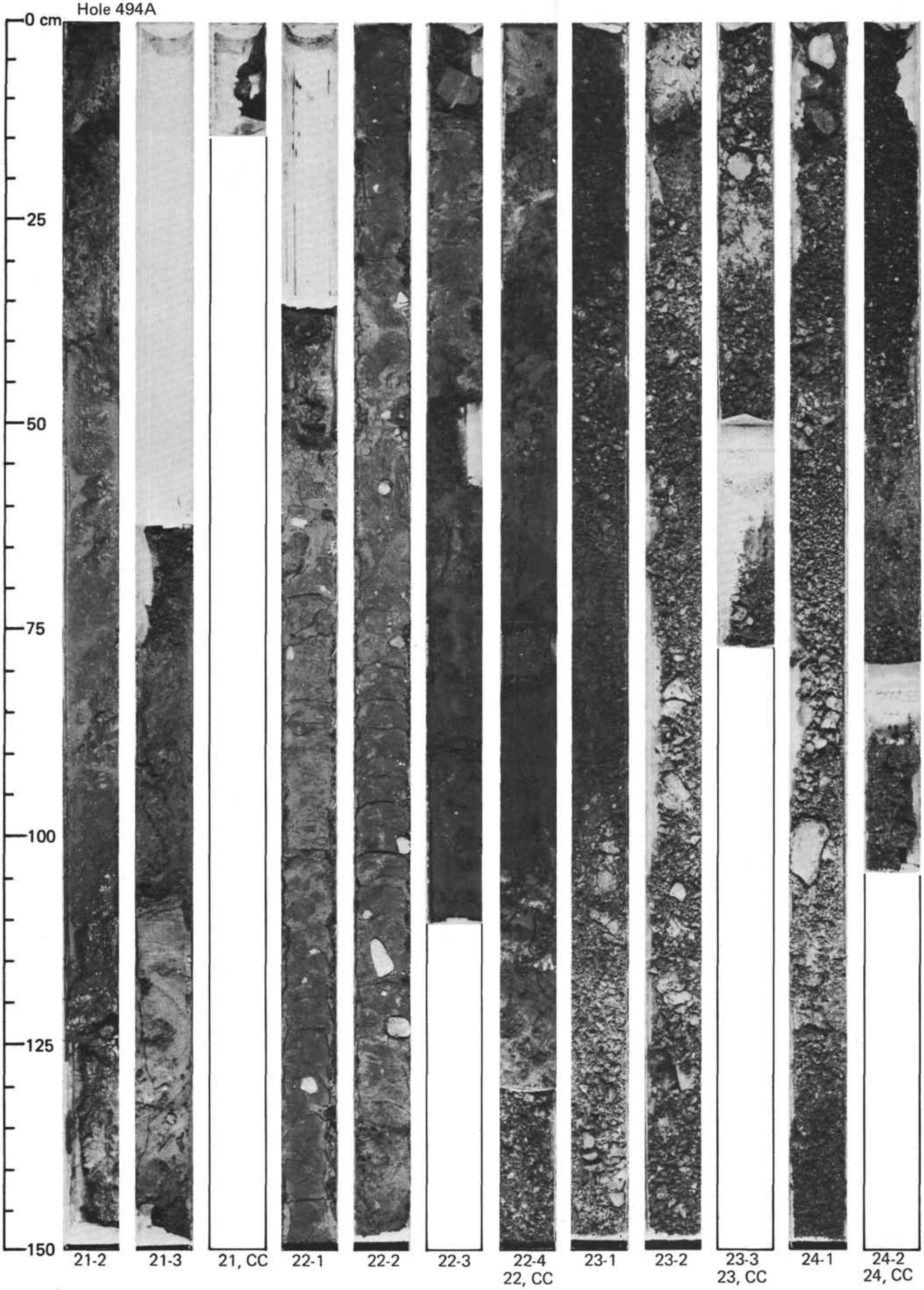
20-6
20, CC
21-1


Hole 494A
0 cm
25
50
75
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125
150
21-2
21-3
21, CC
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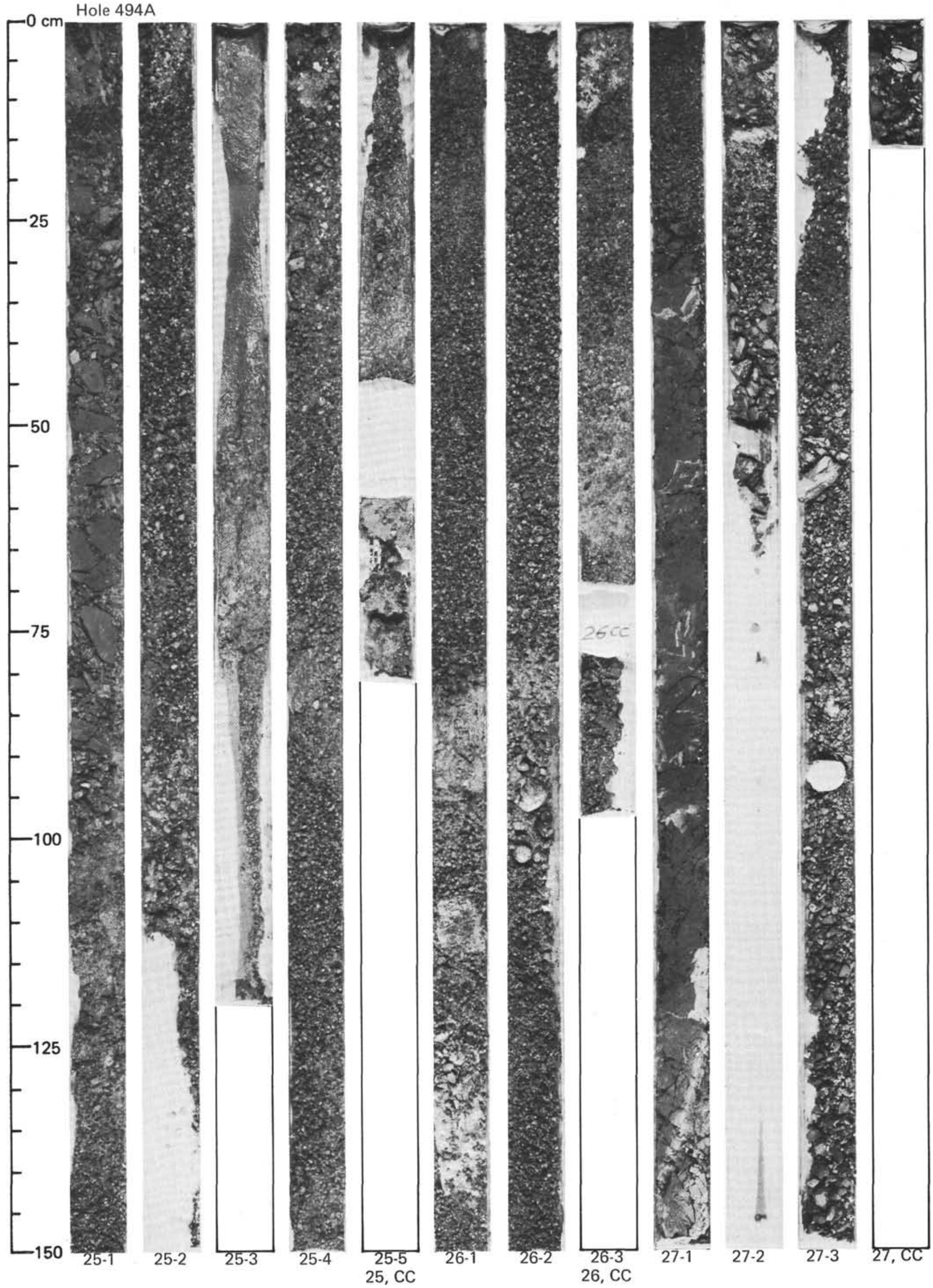
22-4
22, CC
23-1
23-2
23-3
23, CC
24-1
24-2
24, CC


Hole 494A
0 cm
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50
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150
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25-2
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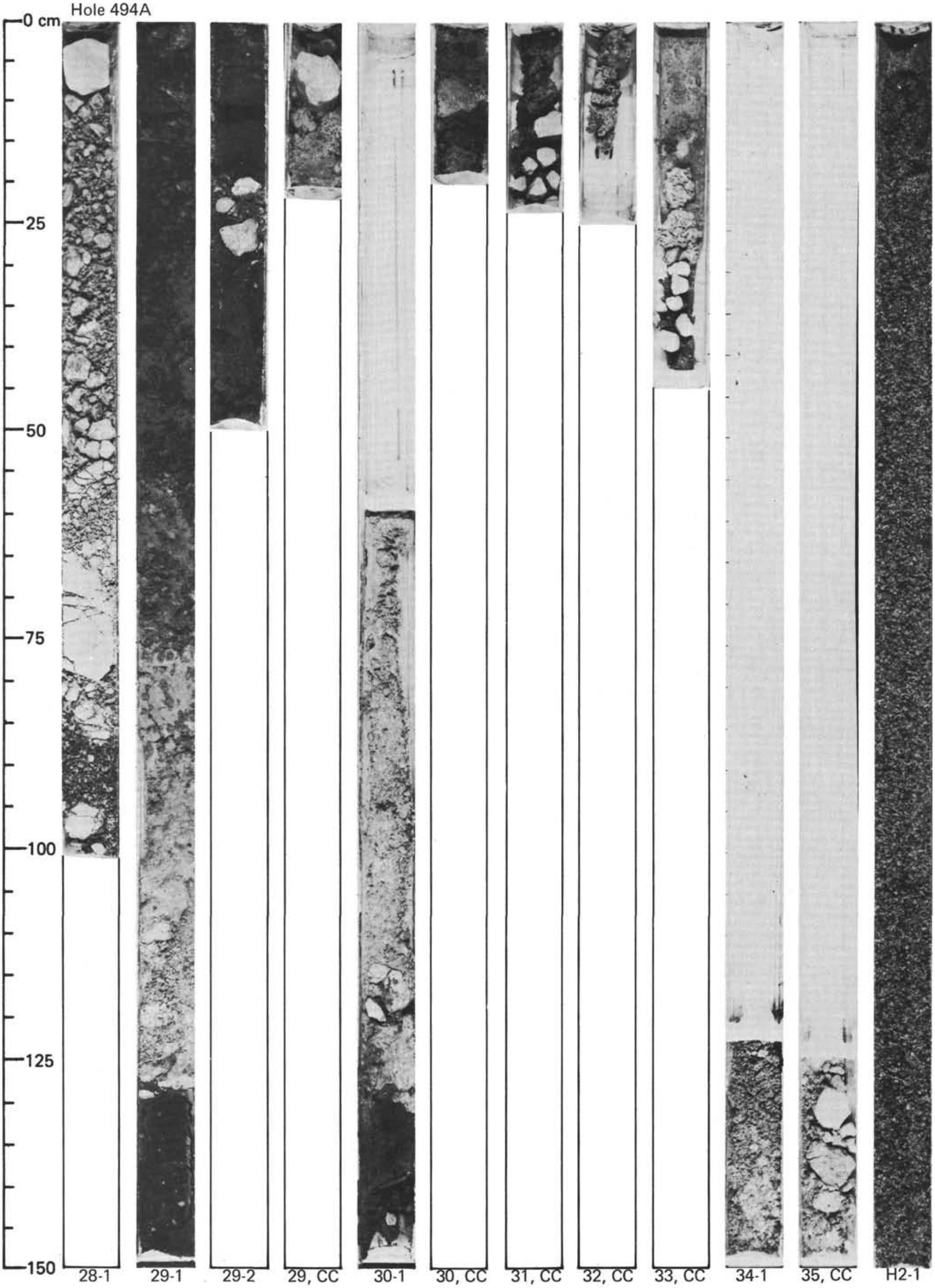
26-1
26-2
26-3
26, CC
27-1
27-2
27-3
27, CC
26CC


Hole 494A
0 cm
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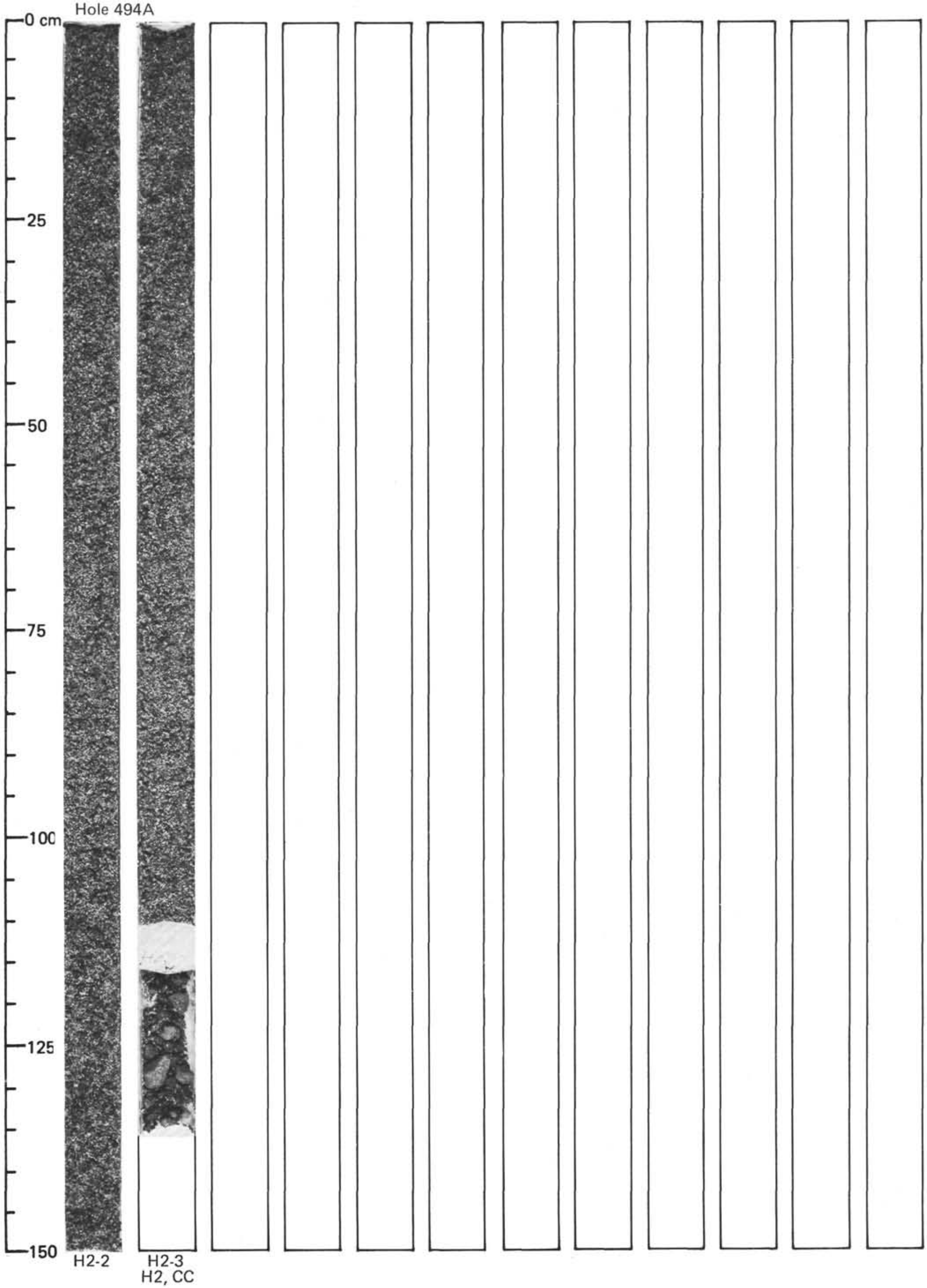
50
75
100
125
150
28-1
29-1
29-2
29, CC
30-1
30, CC
31, CC
32, CC
33, CC
34-1
35, CC
H2-1


Hole 494A
0 cm
25
50
75
100
125
150
H2-2
H2-3
H2, CC