3. BAJA CALIFORNIA PASSIVE MARGIN TRANSECT: SITES 474, 475, AND 476[1]

Shipboard Scientific Party[2]

INTRODUCTION

In the previous chapter, we briefly discussed current thought on the origin and evolution of passive continental margins, the geological problems that may be resolved by a combination of marine geology, geophysics, and scientific deep-sea drilling, and the philosophy and advantages of drilling in a youthful, passive continental margin. Current ideas on the origin and geological history of the Gulf of California were also reviewed and will not be repeated here.

Present tectonics of the Gulf are shown in Figure 1. The East Pacific Rise enters the mouth of the Gulf and extends to the triple junction at the first major transform, the Tamayo Fracture Zone. Of concern here is the geological history of the youthful passive or intraplate continental margin of the tip of Baja California (Fig. 2). Drilling this youthful continental margin was proposed early in the JOIDES and IPOD planning phases of scientific deep-sea drilling, because the margin's structure can be determined geophysically, and the sediment section overlying the crustal rocks is thin enough to be penetrated by drilling.

Subaerial geology of the southern end of the Baja California peninsula is shown in Figure 3. The crystalline basement rocks consist of probable Paleozoic metamorphics, mainly metasediments and metavolcanics, intruded by Cretaceous diorites, tonalites, and granodiorites. Ages of the intrusives range from 54 to 88 m.y. (Gastil et al., 1976). The tip of the peninsula is uplifted relative to the Isthmus of La Paz by the north–south-trending La Paz Fault system. Other faults east of, and parallel to, the La Paz Fault have formed a graben, in which early Miocene, Pliocene, and Quaternary sedimentary rocks have been deposited. These sedimentary rocks are mainly continental, but with some shallow marine facies, and generally contain considerable volcaniclastic material. West of the La Paz Fault, more of the section is shallow marine.

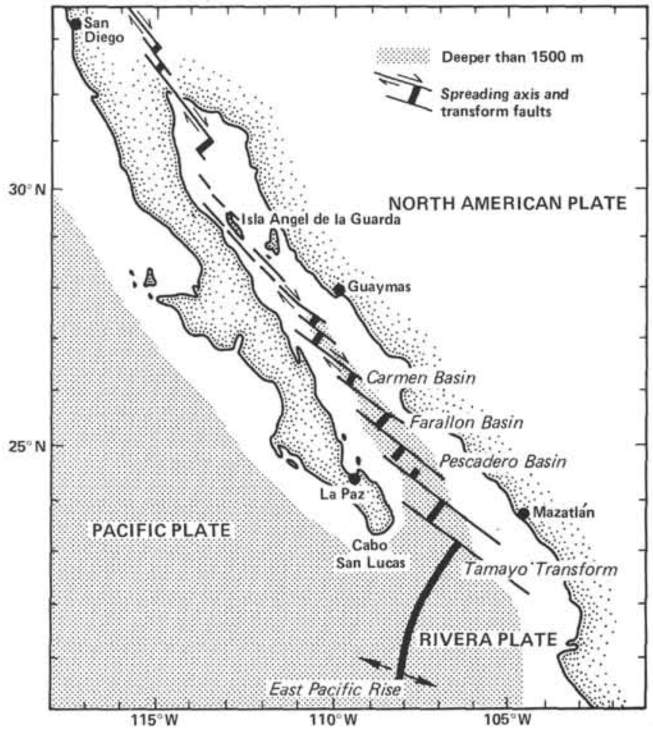

Figure 1. Simplified tectonic map, Gulf of California.

Normark and Curray (1968) were the first to map the offshore structure of the tip of Baja California. Their work was based on seismic reflection records, one seismic refraction station from Phillips (1964), and dredge hauls, mainly collected and reported by Shepard (1964). Their map of "basement rocks" (Fig. 4) shows a delineation of continental-versus-oceanic basement and a series of northeast–southwest-trending, normal and/or listric faults, dividing the offshore geology into a series of horst and grabens and rotated fault blocks. These faults approximately parallel the trend of the East Pacific Rise in the mouth of the Gulf (Fig. 1) and the faults

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[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

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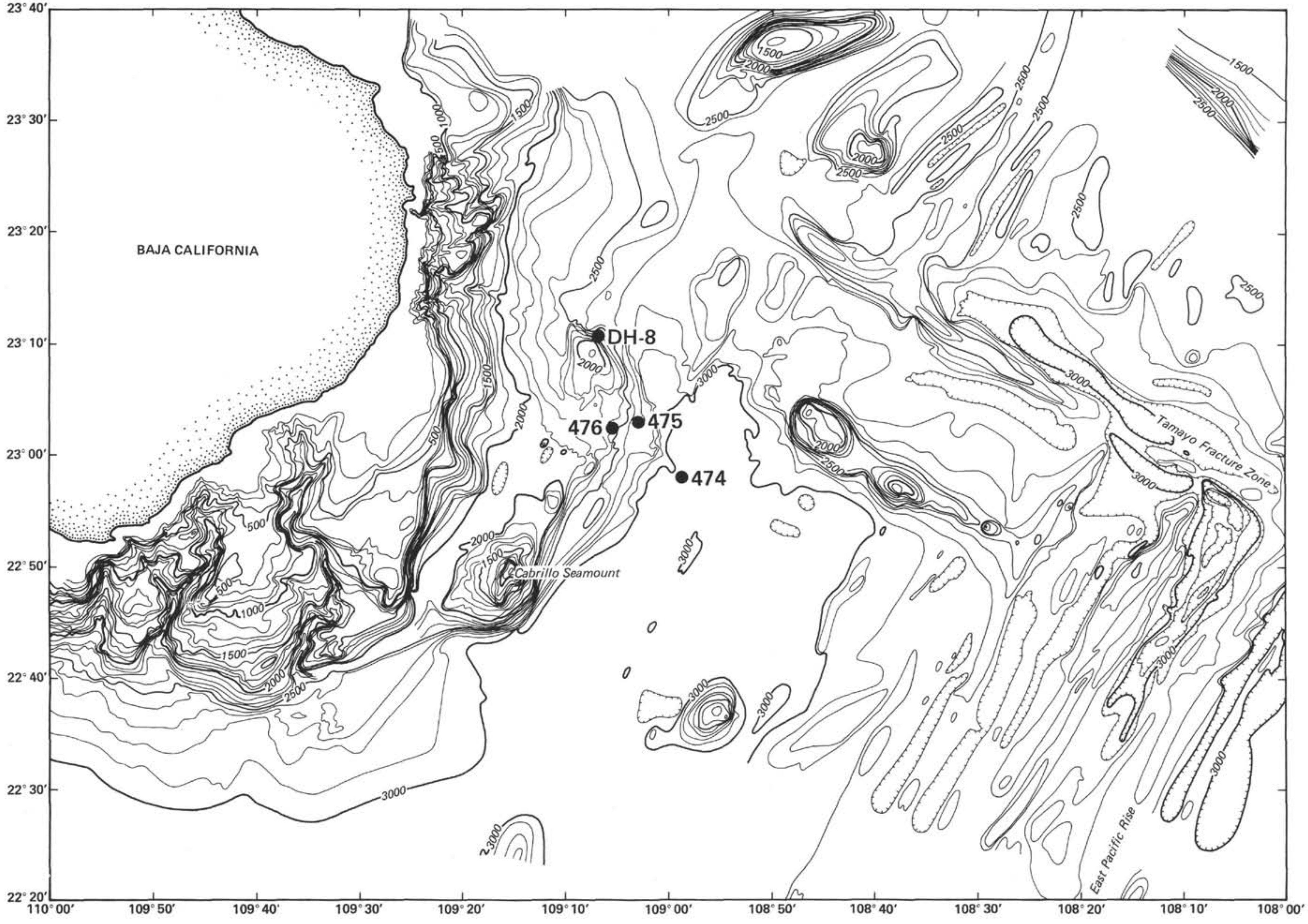

Figure 2. Regional bathymetry of the Baja California passive-margin transect (contours are in uncorrected meters, assuming 1500 m/s; drilling sites and one selected dredge sample are also shown).

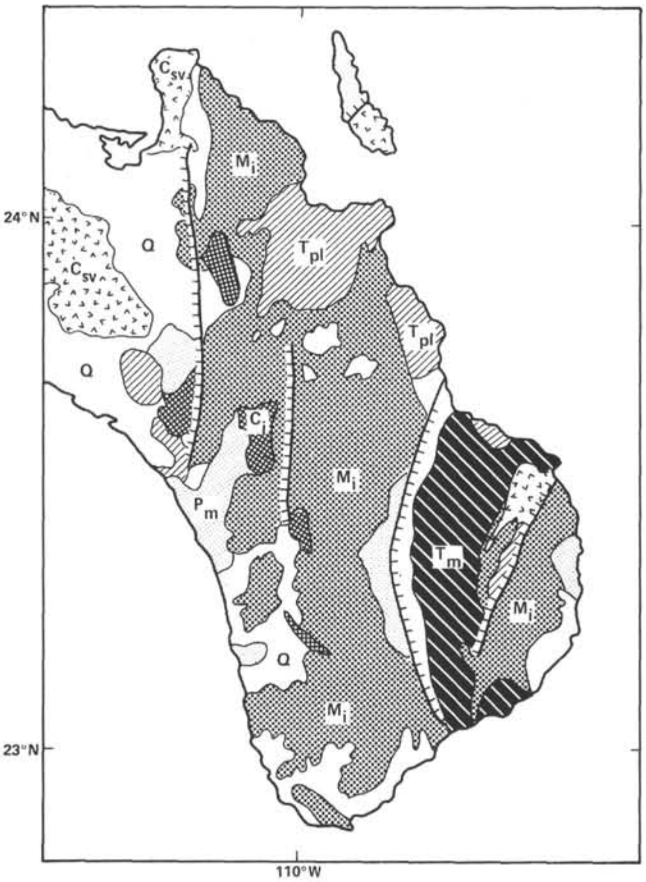

Figure 3. Simplified geology of the tip of Baja California (after Lopez Ramos, 1976; Q = Quaternary, principally alluvium; T_{pl} = Pliocene coastal alluvium and marine deposits; T_m = upper Miocene marine deposits; C_{sv} = Miocene-to-Recent continental volcanics and pyroclastics, principally Comondu Formation in this area; C_i = Cenozoic intrusives; M_i = Mesozoic intrusives, principally late Cretaceous granite and granodiorite; P_m = Paleozoic metasediments and metavolcanics).

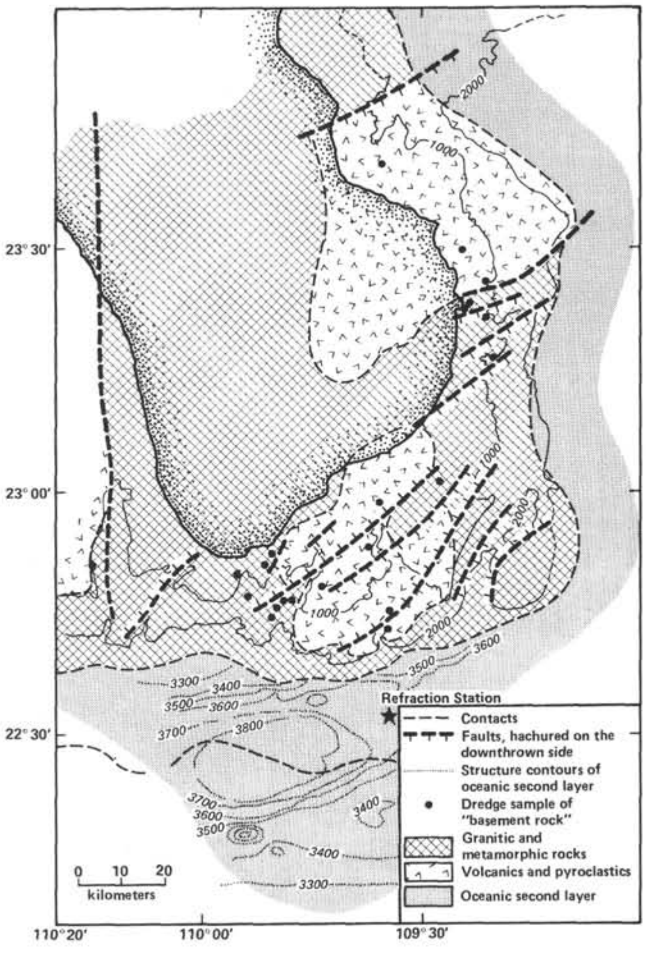

Figure 4. Configuration of "basement rocks" with sediments removed (Normark and Curray, 1968, with permission from the Geological Society of America).

forming the graben on land; they are probably the result of the extension or thinning of continental crust associated with opening of the Gulf. They also attempted to identify the onshore sedimentary formations in their offshore seismic reflection records.

Larson (1972), Larson et al. (1968), and Moore and Buffington (1968) delineated the magnetic anomalies in the mouth of the Gulf. They also identified the oldest anomaly at the foot of the continental slope off the tip of Baja California as approximately 3.5 m.y. Lewis et al. (1975) further refined the correlation of the anomalies (Fig. 5).

The geophysical, geological, and drilling objectives of studying a young passive margin such as this are to determine the structure of the continental crust associated with rifting and drifting, to delineate the precise contact between continental and oceanic crust, to determine the nature of the oldest oceanic crust adjacent to the continental crusts, to determine the nature and age of the sediments overlying the subsided continental crust and the oldest crust, and to determine rates of subsidence and geological history that occurred during the rifting and drifting periods. The specific objectives of each site in this three-site transect will be discussed as background and objective for each site.

Our plan in drilling this transect was to ensure that we located the transition from continental to oceanic crust. We chose the first site (474; Planning Site GCA-5) such that drilling would penetrate the oldest oceanic crust at the foot of the continental slope (Figs. 5, 6). If we penetrated oceanic crust (as predicted), the next site or sites chosen (Sites 475, 476; Planning Sites GCA-6, GCA-7A, respectively; Fig. 6) would be those presumed to be the lowermost continental crust immediately landward of Site 474. If drilling at the first site had bottomed in subsided continental crust, then a second attempt to find the oldest oceanic crust would be made at a site farther seaward (Planning Site GCA-3).

BAJA CALIFORNIA MARGIN TRANSECT: PRINCIPAL RESULTS (Fig. 7)

Drilling at Site 474 (Figs. 2, 7) penetrated about 500 meters of (mostly) mud turbidites, rich in diatoms; but the first 100 meters included a 66-meter debris flow of cobbles and sand, fining upward to silty clay. The deep-

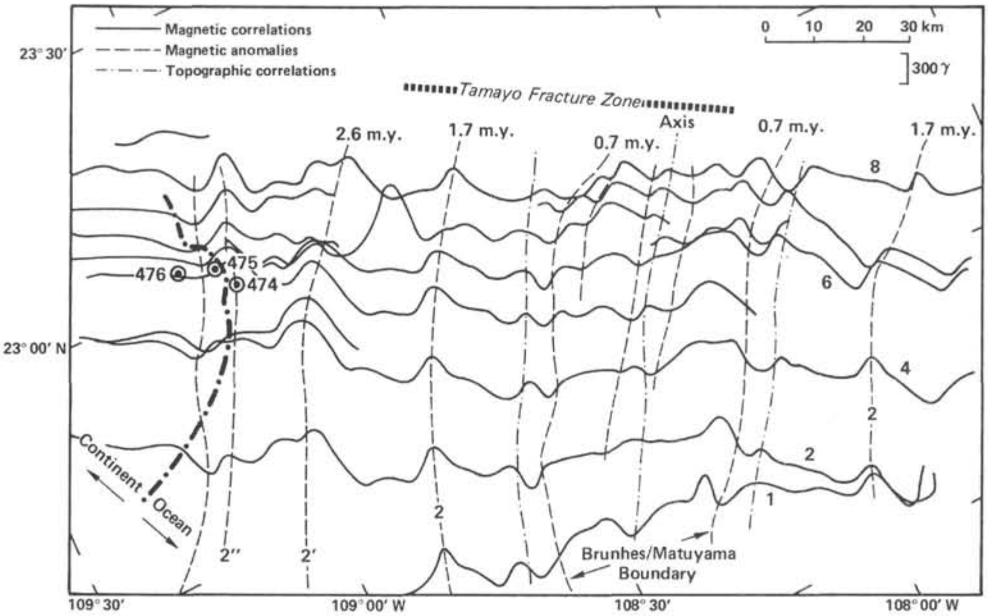

Figure 5. Magnetic anomaly correlations. (From Lewis et al., 1975, with permission of the authors.)

est hole bottomed in late Pliocene sediments between dolerite sills and a pillow lava.

At Site 475, drilling penetrated mostly diatom-rich hemipelagic mud through early Pliocene dolomitic mud and glauconite; drilling was abandoned in a conglomerate of metavolcanic cobbles. Hole 476 penetrated essentially the same section as at Site 475 and bottomed in deeply subaerially weathered granite.

HOLE 474

Date occupied: 2 December 1978

Date departed: 4 December 1978

Time on hole (hr.): 22.23

Position: 22°57.72′N; 108°58.84′W

Water depth (sea level; corrected m, echo-sounding): 3023

Water depth (rig floor; corrected m, echo-sounding): 3033

Bottom felt (m, drill pipe): 3043

Penetration (m): 182.5

Number of cores: 20

Total length of cored section (m): 182.5

Total core recovered (m): 77.63

Oldest sediment cored:
Depth sub-bottom (m): 182.5
Nature: Nannofossil clayey silt
Age: Quaternary (NN19)

Basement: Not reached

Principal results: Hole 474 is 55 km southeast of the tip of Baja California. Three sedimentary units are recognized in the Quaternary section. The uppermost unit (0–21 m) is hemipelagic diatomaceous mud and ooze. The second comprises a 66-meter-thick sequence of cobbles, gravel, and sand, fining upward to nannofossil-rich silty clay, probably a debris flow of older sediments from a shallower depth. It lies between the younger, deeper-water muddy diatom ooze of Unit I (above) and the younger deeper-water clayey silts, silty clays, nannofossil marls, and mud turbidites of Unit III (below).

HOLE 474A

Date occupied: 4 December 1978

Date departed: 10 December 1978

Time on hole (hr.): 152.37

Position: 22°57.56′W; 108°58.68′N

Water depth (sea level; corrected m, echo-sounding): 3022

Water depth (rig floor; corrected m, echo-sounding): 3032

Bottom felt (m, drill pipe): 3043

Penetration (m): 626

Number of cores: 50

Total length of cored section (m): 465.6

Total core recovered (m): 283.8

Core recovery (%): 61

Oldest sediment cored:
Depth sub-bottom (m): 572
Nature: Mudstone between flows
Age: Late Pliocene (NN16)

Basement:
Depth sub-bottom (m): 562.5
Nature: Basalt flows and doleritic sills
Measured velocity (km/s): 4.80–6.27

Principal results: Hole 474A was washed to 163.5 meters and then continuously cored to a total sub-bottom depth of 626 meters. The lowermost of the three sedimentary units of Hole 474 continued to 240 meters. Two other underlying units are recognized in this hole: Unit 4, a continuing Quaternary section of silty claystone to clayey siltstone and mudstone turbidites (to 480 m); and Unit 5, early Pliocene to Quaternary clayey siltstone, sands, mud flows, calcite-cemented sandstone, and silty claystones, intercalated between dolerite sills (to 553.2 m). The oldest sediment, late Pliocene (NN16), is beneath the first basalt flow of the basement at just over 572 meters. A complete logging program followed the drilling.

SITE 474: BACKGROUND AND OBJECTIVES

Site 474 is east of the tip of the Baja California peninsula in a basin filled with deep-sea fan sediments (Figs. 2, 7). It is on what was presumed to be the oldest ocean-

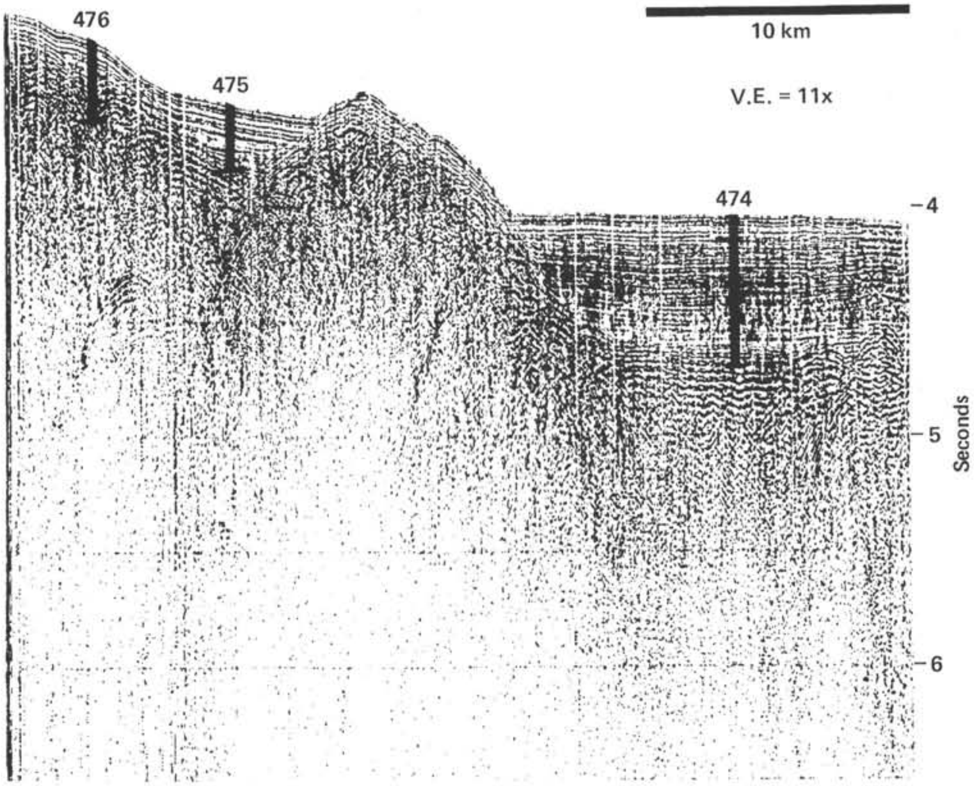

Figure 6. Single-channel analog seismic reflection record from *Glomar Challenger* across Sites 474 and 475, with Site 476 projected into this section.

ic crust and closely adjacent to what was, presumably, the most deeply subsided continental crust of the peninsula. The site is seaward of the edge of continental crust as interpreted by Normark and Curray (1968) (Fig. 4) and is on the landwardmost correlatable magnetic anomaly from Larson et al. (1968) and Lewis et al. (1975) (Fig. 5). Its interpreted age is approximately 3.2 m.y.

Our specific drilling objectives for this site—in the context of the transect objectives outline in the previous chapter—included the following:

1) Basement rocks
    a) Confirming that this site lies seaward of the continent/ocean crust transition
    b) Determining the composition and character of the basement rocks, presumably the oldest created in this present phase of opening of the mouth of the Gulf, for comparison with progressively younger oceanic rocks to be drilled during Leg 65 on its transect to the crest of the East Pacific Rise
2) Nature of the sedimentary section
    a) Determining general lithologic and biostratigraphic facies distributions
    b) Determining the age of the oldest sediments on oceanic basement rocks for comparison with interpreted ages from magnetic anomalies
    c) Determining water depth indicator changes downward in the section as a record of subsidence history
    d) Obtaining a record of Pleistocene sea-level fluctuations
    e) Determining the diagenesis of organic and inorganic matter
3) Evidence for climatic and/or oceanic circulation changes

OPERATIONS

After lowering hydrophones and testing thrusters off Mazatlán harbor, we departed on 1 December 1978 at 2010Z for Site 474, the first of three sites where we planned to study the early rifting history at the mouth of the Gulf of California. Our approach to the proposed site paralleled the *Thomas Washington* Guaymas 01 profile (Fig. 8) and continued beyond it to the lower continental slope southeast of the tip of Baja California; we then came about, returned, and dropped the beacon (1447Z on 2 December) about 1.8 km ENE of the proposed site. The quality of the seismic reflection collected on our approach (Fig. 30) enabled us to select a preferred site 900 meters northwest of the beacon in 3020 meters water depth. After returning to this site, the ship's dynamic positioning system was actuated, and we began running into the hole at 1630Z. We spudded at 2150Z and located the mudline in the first core at 3043 meters, corresponding to the (PDR) depth of 3033 meters.

We cored continuously to a depth of 182.5 meters. Recovery was 47 to 99% to 68.5 meters, where we encountered probable boulders, cobbles, and loose sand. Only one cobble was recovered to 87.5 meters. Thereafter, recovery was 35 to 71%, except in apparent coarse-sand and cobble zones at 125.5 to 135 meters and

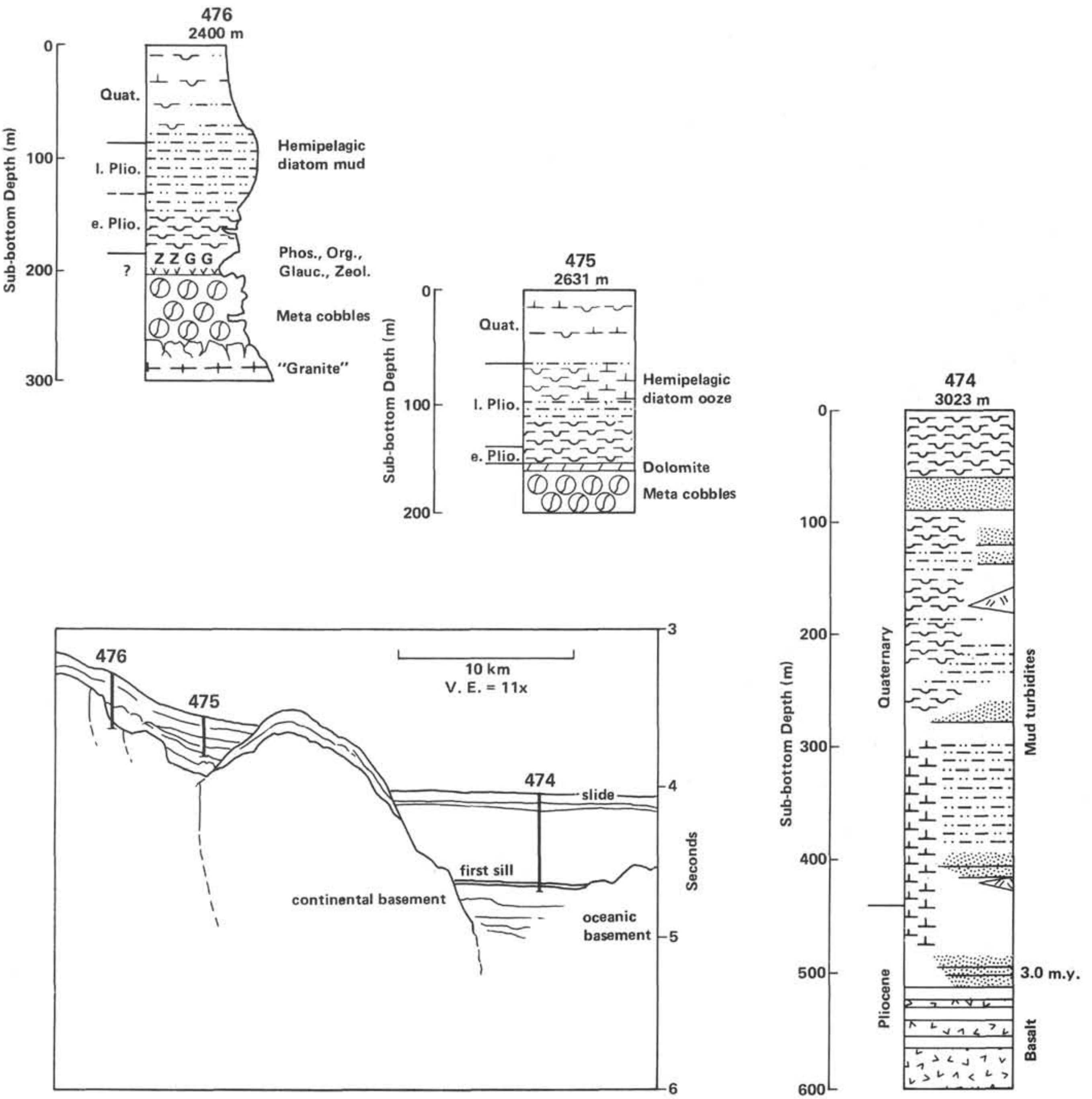

Figure 7. Simplified principal lithological results and line drawing through Baja California passive-margin transect sites.

173 to 182.5 meters, where only few pebbles were recovered. Overall recovery was 42.5% (Table 1).

Our principal operational problems occurred in deploying the heat-probe/pore-water sampler tool. The timing of the pore-water sampler and the caving of loose material around the bit from above caused failures on the first two attempts. A final attempt with the tool, after raising Core 474-20, resulted in our abandoning the hole: After latching, the tool could not be inserted into formation without first retracting, washing down, and then relatching. This bent the sampling tool; it could not be withdrawn, and we pulled the drill string to recover the tool.

At 1355Z, we moved 300 meters to the south of Hole 474 while lowering pipe. We used the mudline depth of 3043 meters established at Hole 474, because we planned to wash this hole (474A) to the equivalent depth of 161 meters before coring. This was accomplished routinely, and our first core from Hole 474A was on deck at 2310Z. The next core was much the same as Core 474-20 (clayey silt, like the intervals above), confirming our suspicion that problems with the heat probe at Core 474-20 were the result of sand and pebbles caving in from uphole.

For the remainder of this hole, coring operations were routine, and our recovery was mostly in the 50–75% range. Drilling times increased sharply when we

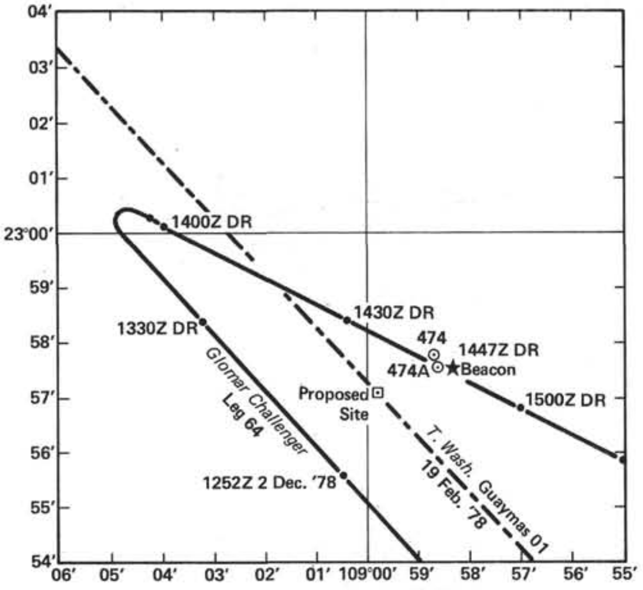

Figure 8. Track of *Glomar Challenger:* Approach and departure, Site 474.

encountered our first dolerite sill at 521 meters. A potentially serious problem developed at Core 474A-44, when the core barrel stuck in the pipe and circulation was lost. After six hours' work, circulation was regained, and the core barrel was recovered. Thereafter, the hole was drilled to completion at 626 meters sub-bottom with more than 100 meters penetration below the top of the first sill at 521 meters.

On 9 December, after drilling ceased at 0350Z, we unsuccessfully attempted to operate the hydraulic-bit-release mechanism; the drill pipe was also stuck in the hole. After the drill string was freed, a second go-devil was pumped down very slowly (four strokes on pump), and at 0900Z on 9 December, the bit released. The hole was prepared for logging and the drill string was pulled to 135 meters below the mudline.

Logging began at 0645Z and ended at 0830Z on 10 December; it consisted of four runs with eight tools:

1) density (gamma-ray back scatter), natural gamma radiation, caliper, temperature;

2) sonic (compressional wave velocity over 61-cm interval), natural gamma radiation, caliper;

Table 1. Coring summary, Site 474.

Core	Date (December, 1978)	Time (Z)	Depth from Drill Floor (m; top-bottom)	Depth below Sea Floor (m; top-bottom)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 474							
1	2	1550	3043.0–3045.0	0.0–2.0	2.0	1.89	95
2	2	1640	3045.0–3054.5	2.0–11.5	9.5	5.15	54
3	2	1742	3054.5–3064.0	11.5–21.0	9.5	4.46	47
4	2	1840	3064.0–3073.5	21.0–30.5	9.5	4.44	47
5	2	2105	3073.5–3083.0	30.5–40.0	9.5	5.79	61
6	2	2215	3083.0–3092.5	40.0–49.5	9.5	9.42	99
7	2	2340	3092.5–3102.0	49.5–59.0	9.5	9.42	99
8	3	0132	3102.0–3111.5	59.0–68.5	9.5	8.44	89
9	3	0310	3111.5–3121.0	68.5–78.0	9.5	0.00	0
10	3	0552	3121.0–3130.5	78.0–87.5	9.5	0.10	1
11	3	0652	3130.5–3140.0	87.5–97.0	9.5	3.05	32
12	3	0757	3140.0–3149.5	97.0–106.5	9.5	0.52	6
13	3	1053	3149.5–3159.0	106.5–116.0	9.5	1.6	17
14	3	1142	3159.0–3168.5	116.0–125.5	9.5	5.83	61
15	3	1252	3168.5–3178.0	125.5–135.0	9.5	0.05	1/2
16	3	1600	3178.0–3187.5	135.0–144.5	9.5	3.96	42
17	3	1717	3187.5–3197.0	144.5–154.0	9.5	6.27	66
18	3	1820	3197.0–3206.5	154.0–163.5	9.5	3.90	41
19	3	1919	3206.5–3216.0	163.5–173.0	9.5	3.33	35
20	3	2020	3216.0–3225.5	173.0–182.5	9.5	0.01	<1
Hole 474A							
0	4	1517	3190.0–3190.2	147.0–147.2	—	0.24	—
1	4	1610	3206.5–3216.0	163.5–173.0	9.5	6.16	65
2	4	1710	3216.0–3225.5	173.0–182.5	9.5	7.27	77
3	4	1811	3225.5–3235.0	182.5–192.0	9.5	6.74	71
4	4	1912	3235.0–3244.5	192.0–201.5	9.5	6.52	69
5	4	2013	3244.5–3254.0	201.5–211.0	9.5	1.96	21
6	4	2115	3254.0–3263.5	211.0–220.5	9.5	3.18	33
7	4	2213	3263.5–3273.0	220.5–230.0	9.5	4.28	45
8	4	2322	3273.0–3282.5	230.0–239.5	9.5	7.09	75
9	5	0031	3282.5–3292.0	239.5–249.0	9.5	6.45	68
10	5	0141	3292.0–3301.5	249.0–258.5	8.5	7.38	78
11	5	0246	3301.5–3311.0	258.5–268.0	9.5	5.54	58
12	5	0350	3311.0–3320.5	268.0–277.5	9.5	7.31	77
13	5	0458	3320.5–3330.0	277.5–287.0	9.5	9.12	96
14	5	0614	3330.0–3339.5	287.0–296.5	9.5	8.39	88
15	5	0733	3339.5–3349.0	296.5–306.0	9.5	0.00	0
16	5	0852	3349.0–3358.5	306.0–315.5	9.5	7.94	84
17	5	1012	3358.5–3368.0	315.5–325.0	9.5	7.08	75
18	5	1140	3368.0–3370.0	325.0–327.0	2.0	1.70	85
19	5	1338	3370.0–3377.5	327.0–334.5	7.5	3.35	45
20	5	1436	3377.5–3387.0	334.5–344.0	9.5	0.22	2
1	5	1552	3387.0–3396.5	344.0–353.5	9.5	7.78	82
22	5	1712	3396.5–3406.0	353.5–363.0	9.5	8.67	91
46	8	0205	3624.0–3633.0	581.0–590.0	9.0	3.20	34
47	8	0647	3633.0–3642.0	590.0–599.0	9.0	5.15	57
48	8	1038	3642.0–3651.0	599.0–608.0	9.0	4.87	54
49	8	1533	3651.0–3660.0	608.0–617.0	9.0	3.74	42
50	8	2050	3660.0–3669.0	617.0–626.0	9.0	4.00	44

3) guard (electric), natural gamma radiation, porosity (neutron back scatter);

4) temperature.[3]

After logging, the hole was plugged with cement from 3234.0 to 3134.0 meters and the remainder of the hole filled with mud. We left the site at 2320Z on 10 December.

SEDIMENTARY LITHOLOGY

Introduction

Holes 474 and 474A were drilled only 300 meters apart, and their stratigraphic sections are complementary (Fig. 9). A dolerite sill was encountered at 521 meters sub-bottom (see section on igneous petrology). Approximately 11 more meters of sediment were cored below this sill, and we recovered a small amount of claystone 553 meters below a second sill. The bottom of the sediment is defined as the top of the first basalt flow in Core 474A-44 at 562 meters. It is possible to correlate Holes 474 and 474A by the presence of a thin layer of rhyolite ash at about 169 meters sub-bottom in Cores 474-19 and 474A-19 (Fig. 9). The oldest sediment (572 m) is a small fragment of late Pliocene (NN16) intercalated claystone from below the first pillow basalts.

The site's lithology partly reflects its location at the outer fringe of a fan girdle that drains the rapidly denuding batholith terrain of southern Baja California (Figs. 3, 4). This site thus presents an opportunity to study distal fan sedimentation over time. The sediment section is predominantly hemipelagic mud and a thick sequence of mud turbidites and their more lithified counterparts. Nannofossils persist to the basement, but siliceous fossils disappear below 275 meters.

The five depositional units chosen for this section (Table 2) are based on diatom abundance for Unit I; a displaced fauna and lithology with coarse sand for Unit II; abundant muddy turbidite layers for Unit III; the change to lithified mudstone turbidites for Unit IV; and the Pleistocene/Pliocene transition for Unit V. Most of the section was deposited rapidly during the early Quaternary (NN19), although the last vestiges include evidence of late Pliocene (NN16, 3.0–2.3 m.y.) in claystones between flows.

Unit I (Cores 474-1–474-3, 0–21 m, late Pleistocene). Unit I sediments are highly disturbed but appear to comprise decimeter layers of grayish olive green (5GY 3/2) muddy diatomaceous ooze to olive-gray (5Y 5/3) hemipelagic muds. Nannofossils are present throughout and prominent (20–30%) in alternating dusky yellow green (5GY 5/2) nannofossil diatomaceous clayey silts. These beds have a sharp basal contact but darken gradationally upward, suggesting episodic redeposition as turbidites. A thin arkosic sand (474-4-1, 89 cm) contains displaced shell fragments from shallower water. Angular, silt-size quartz and feldspars are equally common terrigenous components in sands and silts. Glitter from abundant mica flakes is visible on the cut sediment sur-

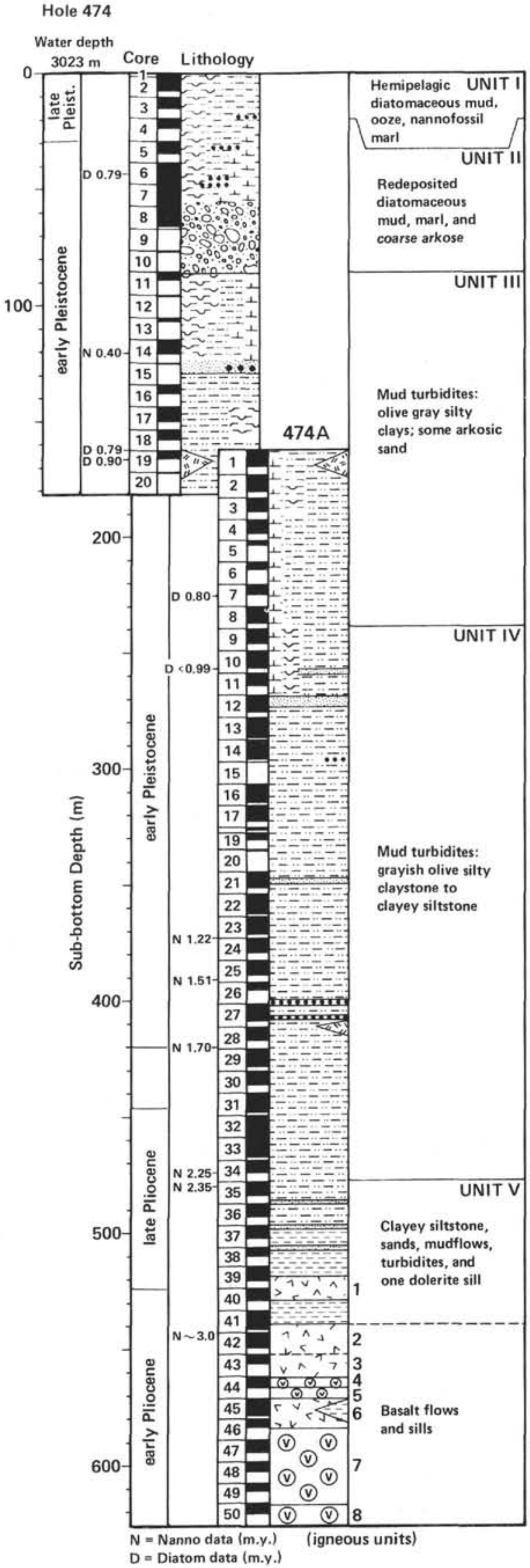

Figure 9. Lithology, lithologic units, and core recovery (shown in black), Site 474.

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[3] The induction tool intended for the last run was inoperative.

Table 2. Sedimentary lithological units, Site 474.

Unit	Interval	Sub-bottom Depth (m)	Lithology	Sediment Environment	Age	Estimated Sedimentation Rate (m/m.y.)	Thickness (m)	Contact
I	Cores 474-1–474-3	0.0–21.0	dusky yellow green to grayish olive diatomaceous muds to oozes and diatomaceous nannofossil marls with downward increasing clayey silts	hemipelagic distal fan	to NN21/20	47	30.5	transitional
II	Core 474-4–Section 474-10,CC	21.0–87.5	olive brown to grayish olive; firm nannofossil diatomaceous muds and a coarse arkose sand to conglomerate	redeposited slump-debris flow	(NN19)	very high(?)	76.0	top = transitional; bottom = sharp, abrupt
III	Sections 474-11-1–474A-8,CC	87.5–239.0	clayey silts to silty clays, nannofossil diatomaceous muds, nannofossil marls, and scattered arkose muds	hemipelagic mud and mud turbidites on outer fan	NN20	395	142.0	top = sharp; bottom = transitional to Core 474-12
IV	Sections 474A-8,CC–474A-28,CC	239.0–420.0	grayish olive silty claystone to clayey siltstone		early Pleistocene	395→86	181.0	top and bottom transitional
IVA	Sections 474-9-1–474A-10,CC	(239.0–285.5)	mostly uniform silty claystones with siliceous fossils and nannofossils	hemipelagic with some mud turbidites	NN19	395		
IVB	Sections 474A-10,CC–474A-28,CC	(258.5–420.0)	mostly cycles of thick, clayey quartzose siltstone beds and some arkose sands; mud flows; siliceous fossils diminished	middle fan and mud turbidites		395→86	(161.5)	gradational
V	Sections 474A-28,CC–474A-41-5 (25 cm) and 474A-45-1	420.0–533.0	olive gray clayey siltstone with thick mass flows and cemented arkose silty claystones between dolerite sills	middle fan, mud turbidites, and hemipelagic mud	late Pliocene	86	(~95.0)	interflow claystones

face. Apatite, hornblende, and zircons from a granitic terrain compose a conspicuous heavy mineral suite. Coarse fractions from mud contain abundant fecal pellets; coarse fractions from silt contain mostly arkosic mineral suites.

The sediments are reducing and, when cut, released a permeating odor of H_2S. Pyrite is an ubiquitous auxiliary mineral accompanied by considerable woody organic matter.

Pelagic components (10–50%) are well preserved. Siliceous fossils are dominated by diatoms (20–40%) but also include many silicoflagellates, radiolarians, and sponge spicules. Sponge-spicule clusters occur as small white spots, visible on the core surface in more clayey zones. Smear slides indicate that, toward the base of Unit I (210.0 m), there is a gradual increase in the proportion of these sandy silts and opaque components.

The contact with Unit II is gradational and accompanied by an increase in coccolith abundance.

Unit II (Cores 474-4–474-10, 21–87 m, late Pleistocene [NN19]). Unit II is a redeposited section. Its upper part consists of drab, olive gray hemipelagic mud and mud turbidites, initially similar to Unit I but with a marked increase in the number of coarse silt to sandy beds (Fig. 10). The most prominent feature of the unit is a thick layer (~ 30 m) of coarse, greenish gray, peppered arkosic sand to conglomerate (Section 474-7-5–474-10, CC). Recovery was poor: only three granodiorite cobbles occur in Core 474-10 (Fig. 11); but seismic evidence suggests that this is a single bed, with lateral continuity across the basin. Drilling disturbance was intense, but it appears that the arkose unit is an upward-fining bed of grain-supported clasts, little matrix, and moderate sorting. The direction of transport and the mechanism for this mass flow are discussed elsewhere in this volume (see Moore, Curray and Einsele, this volume, Pt. 2). Again, however, the seismic geometry suggests a more northerly source, because the bed appears to abut the nearest slopes to the northwest. Clasts are rounded and polished; biotite, feldspars, and rock fragments appear fresh. They include common mollusk debris, bryozoan fragments, benthic foraminifers, a snail shell, and calcareous algae, indicating a near-shore source. Some nannofossils occur in the fine matrix.

The overlying hemipelagic mud and sandy mud turbidites of Cores 474-4 to 474-8 are not contiguous with the arkosic sand layer. They are included nonetheless in Unit II, because they apparently contain a warmer- or shallower-water displaced nannofossil flora (NN19). Below the conglomerate contact, sediments are again

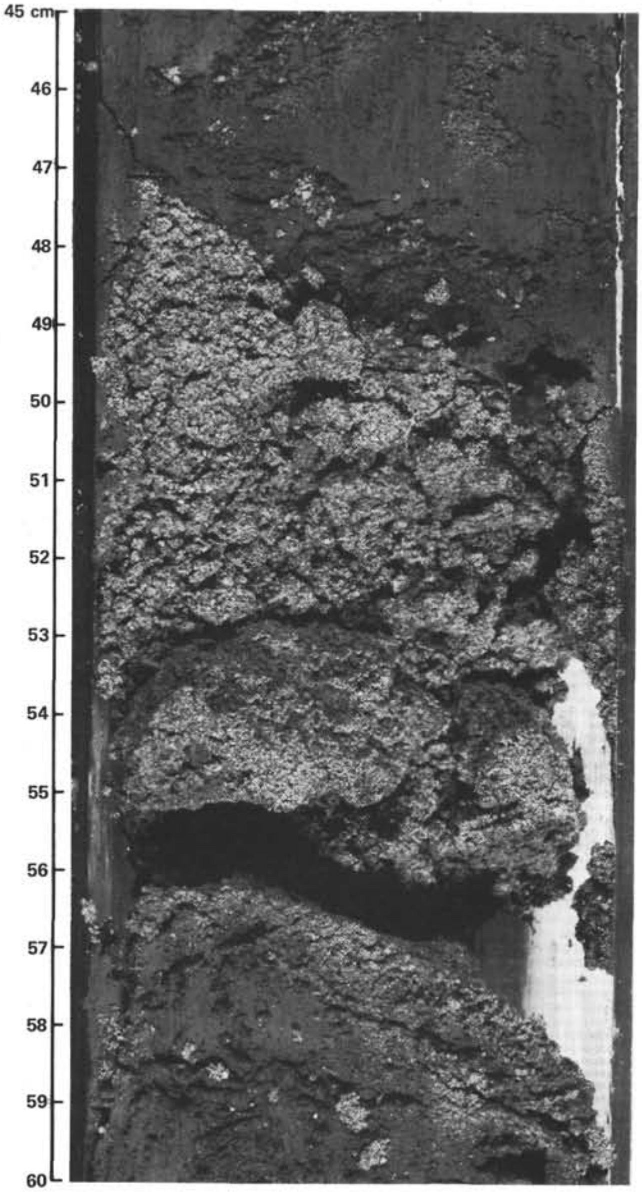

Figure 10. Sample 474-6-6, 45–60 cm, Unit II: Coarse, well-sorted, massively oxidized, yellow-brown arkosic sand with small mud pebbles and some pyroclastic components. (Contacts appear sharp, and grading is ill defined, including fragments of pecten and bryozoa.)

younger (NN20). Possibly, the upper section was redeposited during a lowered sea-level period, or as older sediments—laid bare by a mass-flow event—were further excavated.

These sediments are characterized by an interlayering of nannofossil-bearing diatomaceous clayey silt to diatomaceous nannofossil mud (dusky yellow green [5GY 5/2] to moderate olive brown [5Y 4/4]) that grades downward into thin, grayish olive (10Y 4/4), sandy mud. Sediments become firm below Core 474-5, where nannofossils also become predominant (20–60%) over siliceous components (5–15%). Nannofossil-rich zones are closely related to numerous, interspersed silty sand layers, and the zones and layers may be part of multiple mud turbidite cycles. Clayey silts have much lower carbonate content. Many of the sandier layers contain small, reworked shell fragments or matrix-supported pebbles, including quartz-feldspar porphyry and basalt (Section 474-6-1) or cemented sandstone (Section 474-7-3, 130 cm). Most sandy beds are poorly sorted, but a few discrete, well-washed, rounded-and-sorted yellow gray sands similar to beach sands are present (e.g., in Sample 474-6-5, 110–130 cm). Except in these sand layers, the sediments are reducing. There is an intense odor of H_2S in Cores 474-4 and 474-5, diminishing below Core 474-6. Wood bits and pyrite are common (1–5%). Clayey beds may show surface pimples (after cutting) caused by intense degassing. Tiny spiculite blebs dot the surface of some beds.

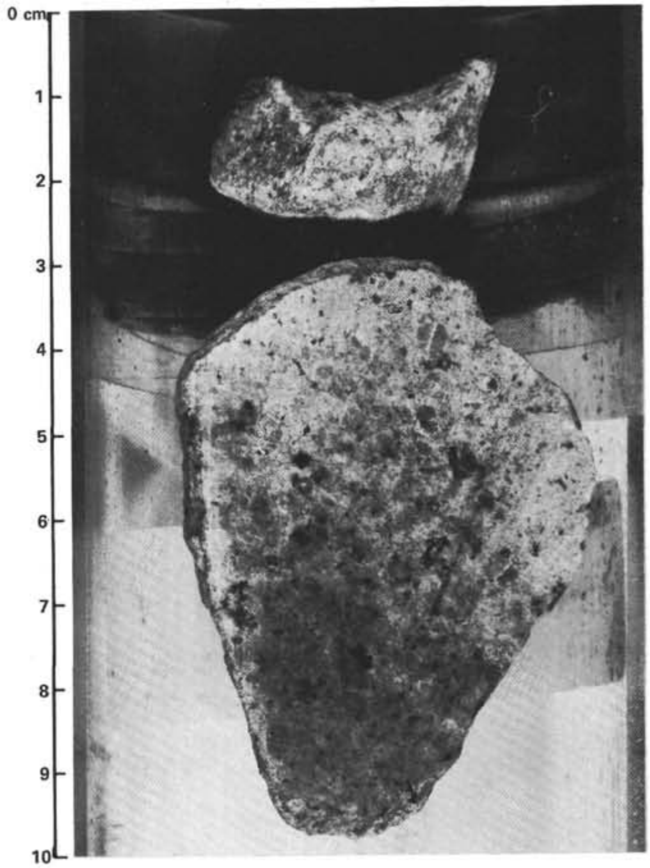

Figure 11. Sample 474-10,CC, Unit II: Large rounded pebbles of altered granodiorite.

The contact with Unit III is sharply defined by the base of the coarse gravel.

Unit III (Sections 474-11-1–474A-8,CC, 87.5–239.0 m, early Pleistocene [NN20–19]). Below the redeposited Unit II, siliceous fossils occur with renewed vigor (10–40%) and, initially, diatoms are more common than coccoliths. This part may even repeat the section from Cores 474-4 through 474-5. Sediments are mainly firm-to-hard, nannofossil-bearing, siliceous clayey silts to hard silty clays, with some nannofossil marls (Core 474-13) and scattered silty sand layers. Thin silty sands generally mark the base of numerous thick mud turbidite cycles.

Colors are generally grayish green (10GY 5/2; 10Y 4/2), changing to dusky yellow green (10GY 3/2) where more carbonate is found. Mica flakes glisten on much of the surface.

Cores 474-14, 474-15, 474-16, and 474-17 (116–154 m) contain numerous coarser mud turbidites; Cores 474-18 and 474-19 (114.5–163.5 m) are mainly uniform hemipelagic mud. The pebbles in Core 474-20 are probably caused by hole cavings, because none was recovered when this interval was recored in Hole 474A. Cores 474A-1 to 474A-8 (163–239.5 m), again, mostly comprise mud turbidites; more than 67 have thicknesses ranging from 40 to 60 cm.

The two holes are correlated with the help of a single, centimeter-thin layer of white, vitric, rhyolitic ash at Section 474-19-2, 123 cm (~166.2 m) and again at Section 474A-1-4, 28 cm (~168.3 m).

Better induration enabled us to see evidence of burrowing and subtly upward-fining silt from the intermittent mud turbidites. They are best recognized by a thin, well-sorted sand at the base. Coarse fractions from sand show mainly quartz-feldspar-mica and weathered granitic rock fragments. A few sands are rich in heavy minerals (apatite, zircon, pyroxene, and hornblende). Pebbles of metavolcanics, a porphyrite, and a feldspar acid tuff in the core catcher of Core 474-15 may indicate another thick conglomerate layer (see thin-section descriptions on the barrel sheets and Fig. 12). Other coarse layers contain bryozoan fragments, shallow water carbonates, pelecypods (no coral!), and wood debris.

Unit IV (Core 474A-9–Section 474A-28,CC; 239.0–420.0 m, early Pleistocene). The character of this thick unit is similar to that of Unit III. Downhole, the preservation of siliceous fossils becomes poorer and sediments firmer. The contact with Unit IV is gradational and based on the change in lithification to clayey siltstone and silty claystone; carbonate content decreases (~10%). These sediments mainly consist of rapidly deposited mud turbidites, typically 20 to 60 cm thick, with minor hemipelagic mud. The color of most of the section is grayish olive (10Y 4/2), and textures vary from claystones to clay siltstones and some sandy siltstones. The extent of bioturbation separates mud turbidites from background hemipelagic mud (Fig. 13). But, possibly, bioturbated claystones partly include lutite portions of the mud turbidites. The mudstones, which are burrowed by *Planolites* and meniscate types, are considered representative of the hemipelagic mud, whereas *Chondrites* are considered an indicator of turbidite lutite. Carbonate content varies with grain size; it is highest in siltier beds but remains low throughout the unit (5–15%).

Sub-unit IVA (Cores 474-9 and 474A-10, 239–258 m). A predominantly finer-grained, slightly calcareous sequence of diatomaceous silty claystones containing nannofossils comprises this sub-unit. Siliceous microfossils diminish rapidly below it and disappear around 270 meters sub-bottom. These claystones have decimeter-scale cyclic development, visible by variations in burrowing intensity and color shades.

Sub-unit IVB (Cores 474A-11–474A-34, 258.5–420.0 m). The remainder of Unit IV is uniformly characterized by many thick turbidite mudstones and other diverse resedimented beds, including some massive sands and minor debris flows. More than 200 turbidite units are recognized, forming beds typically 40–60 cm thick but which may exceed 320 cm. Most cores consist of more than 50% turbidite cycles (Einsele and Kelts, this volume, Pt. 2). Toward the base of the section, some thicker units and debris-flow deposits (Fig. 14) occur, although the sediment composition remains a uniform, terrigenous quartz-feldspar-mica assemblage. Land-derived wood fragments appear to increase downhole. Sediments are reducing but give off no H_2S. Pyrite is common. Some sands have pyrite grain concentrations (commonly pyritized foraminifers) of more than 10%. Some very hard layers occur in Cores 474A-17 and 474A-25. One ash bed was noted at 474A-28 (411 m).

Some 200-cm-thick beds have pebbly sand basal sections; others are only slightly graded, poorly sorted sandy silt. A few of the clasts have oxide coatings. There is no prominent change in lithologic continuity between Units IV and V. The boundary was selected to coincide closely with the Pleistocene/Pliocene boundary. Gradational changes will be discussed later.

Unit V (Section 474A-28,CC–Core 474A-41, 420–572.0 m; late Pliocene [NN18/16]). The sediments are generally olive gray (5Y 3/2), hard, silty claystones to clayey siltstones. Mud turbidites continue and include several thick beds (80 cm or more), some sandy layers with pelecypod shells, and cemented arkose with basalt clasts.

Calcareous nannofossils are rare, and siliceous fossils are absent; but carbonate content is about 5–10%, and some rare beds of siltstone or sandstone are cemented by carbonate. Clay minerals (50–60%) and quartz and feldspar (~30%) are predominant.

At 521 meters, a 4.5-meter-thick dolerite sill was encountered (see section on igneous rocks). On the upper and lower contacts, we recovered pieces of the same hard, coarse, carbonate-cemented arkose (Fig. 15). The sill had been injected along a single, coarse layer in a zone with numerous sandy beds.

Graded mud turbidite cycles continue below the upper dolerite, but grain size and thickness of the coarser layers decrease. Bioturbation is extensive, and sediments are harder. Diagenetic effects are as follows: pyrite-filled burrows, some graded, calcite-cemented beds, barite concretions, and dark, vermillion olive, pyritic claystones near the lower dolerite contact. The oldest sediment is a fragment of late Pliocene (NN16?) claystone (at 572 m) beneath the uppermost pillow basalts.

Depositional Environment

The overwhelming feature of the sedimentation at this site is the impressive thickness of rapidly sedimented, poorly graded mud turbidites. Throughout the sequence, they exhibit similar development. Silt sizes predominate. The main body of the thick bed (20–320 cm) is structureless grayish olive clayey silt, which would be overlooked were it not for the generally bioturbated hemipelagic mud.

An idealized cycle begins at the base with a thin (1–10-mm), clean, moderately well-sorted sand that may erode into the substratum. The lower contact is sharp. A

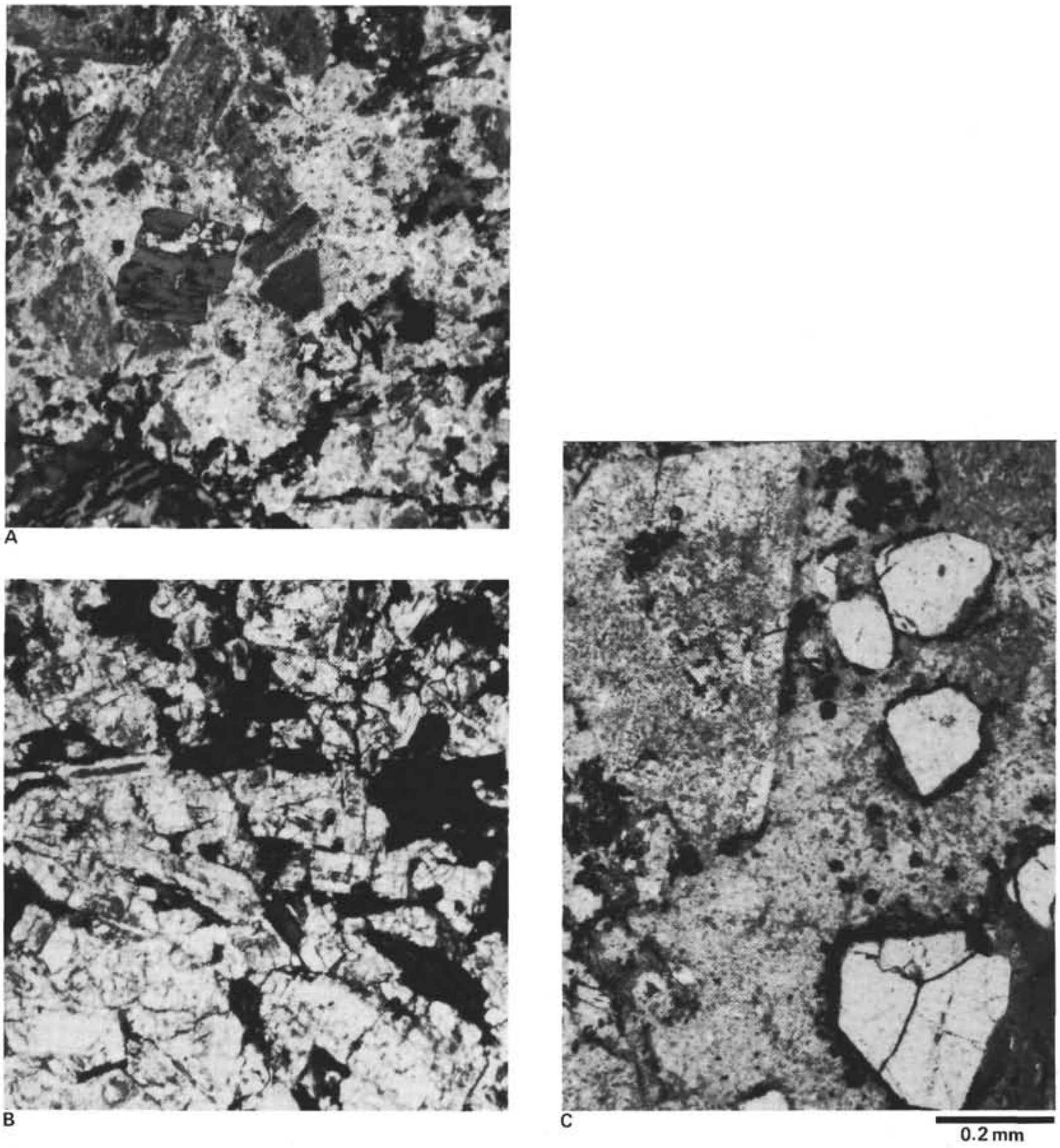

Figure 12. Thin-section photomicrographs of pebbles from Core 474A-15, Unit IV. A. Metamorphic quartzite with microcrystalline groundmass containing zoisite, green mica, phlogopite, and altered feldspars. B. Diorite with abundant, fresh-looking, zoned plagioclase and common hornblende. C. Metaignimbrite with euhedral plagioclase and quartz supported in a microcrystalline groundmass.

zone of poorly sorted silty sand, with some shallow-water debris, changes gradationally to the structureless silt of the mud section. Some scattered, large, round, sand-filled burrows from large, deep-scavenging individuals may occur in the homogeneous midsection. The classic Bouma sequence of sedimentary structures could not be observed in the freshly cut cores. Laminations are very rare. Near the top, the thin, silty lutite fraction is almost invariably burrowed by *Chondrites* below a heavily bioturbated zone, which is sometimes a lutite part of the mud turbidite (see Fig. 13). Carbonate, caused mostly by shelf carbonate but also by nannofossils, increases downward with grain size. Terrestrial plant matter is ubiquitous in the smear slides. Grayish olive colors also tend to be lighter in the sandy silt and darker in the basal sand and upper lutite (see Einsele and Kelts, this volume, Pt. 2).

In the silty basal third of the unit, floating clasts and pebbles may occur. A series of smear slides over a 250-cm-thick siltstone section confirms the presence of a subtle grading. This type of bed has been interpreted as indicating a distal fan—interchannel areas bordering abyssal plains (cf. Piper, 1978). The lack of clear grading may result from the formation of a stable clay floc (Piper, 1978), which behaves much as the silt particles. There are few detailed studies on the mechanism of transport of these beds, but rafted clasts and a close association with mud flow deposits suggest a rather quick deposition from a high-density flow. Similar mud turbidites are also known to be generated by slumping,

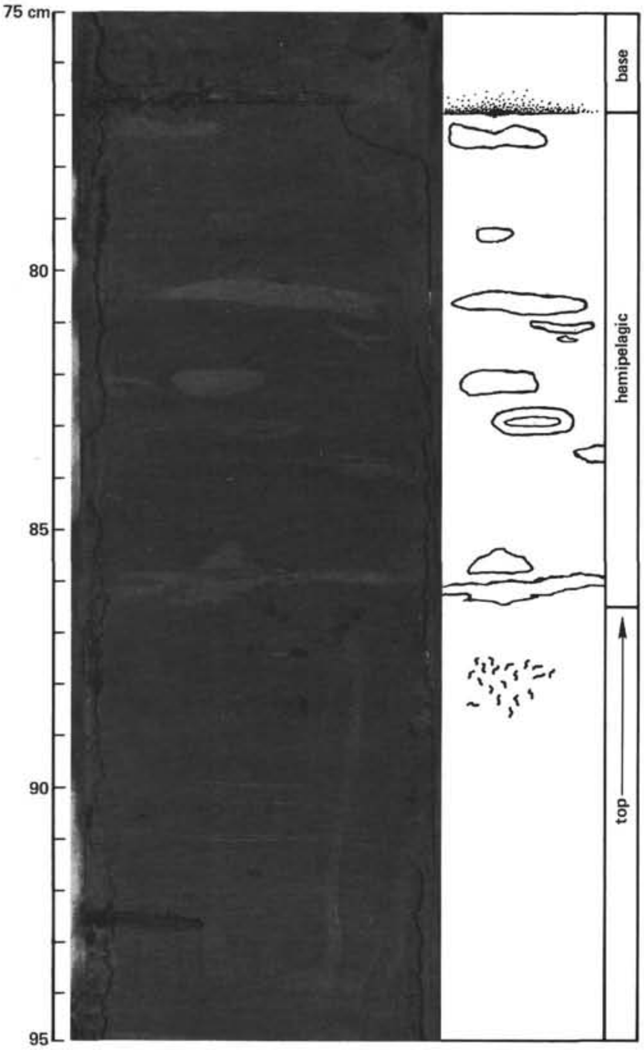

Figure 13. Sample 474A-13-3, 75–95 cm, Unit IV: An example of criteria for recognizing mud turbidite units (thin, basal sand layer; top marked by a few chondrite burrows; and the host hemipelagic sediment is generally spotted with meniscate or *Planolites*-type burrows [midsections are massive mud]).

from rapidly deposited deltaic regions in deep lakes. The sediments accumulating around southern Baja California today show a lack of clay fraction and a preponderance of arkose sands to silts characterized by abundant mica flakes (van Andel, 1964).

Paleoenvironment

When drilling ceased at Core 474A-50, the petrologic evidence suggested that this site was floored by oceanic crust. When rifting opened the area approximately 3.5 Ma, it was already at bathyal depths. Coarse volcanogenics or continental conglomerates were not encountered. Although poorly recovered, late Pliocene sediments overlying the basement and the lower sill already indicate a distal-fan-to-hemipelagic character. During the early late Pliocene (NN17/18), a sedimentation pattern of mud turbidites, hemipelagic mud, and sporadic mud flows was established and continues to the present.

Although some sandy basal layers contain redeposited shallower-water material, the flora and the char-

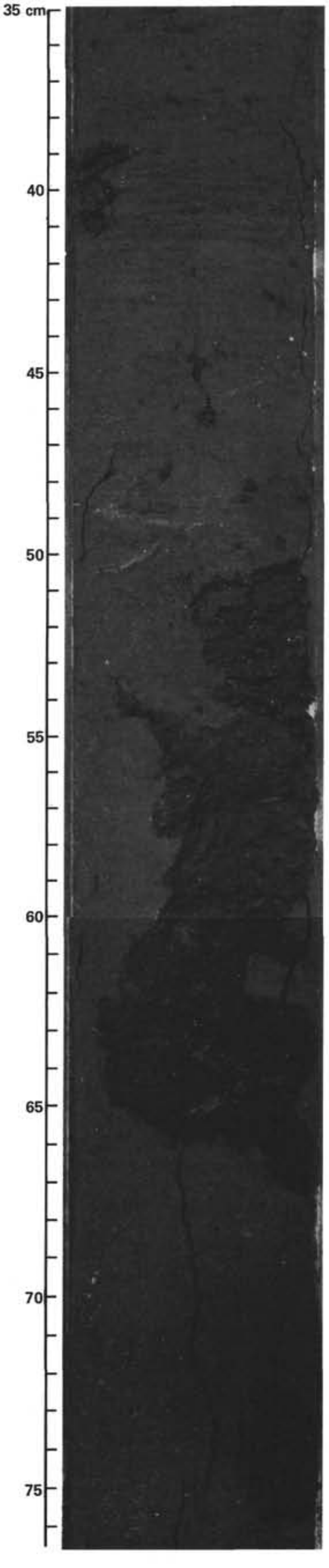

Figure 14. Sample 474A-21-5, 35–75 cm, Unit IV: example of large, fractured mud clast in a thick debris-flow bed.

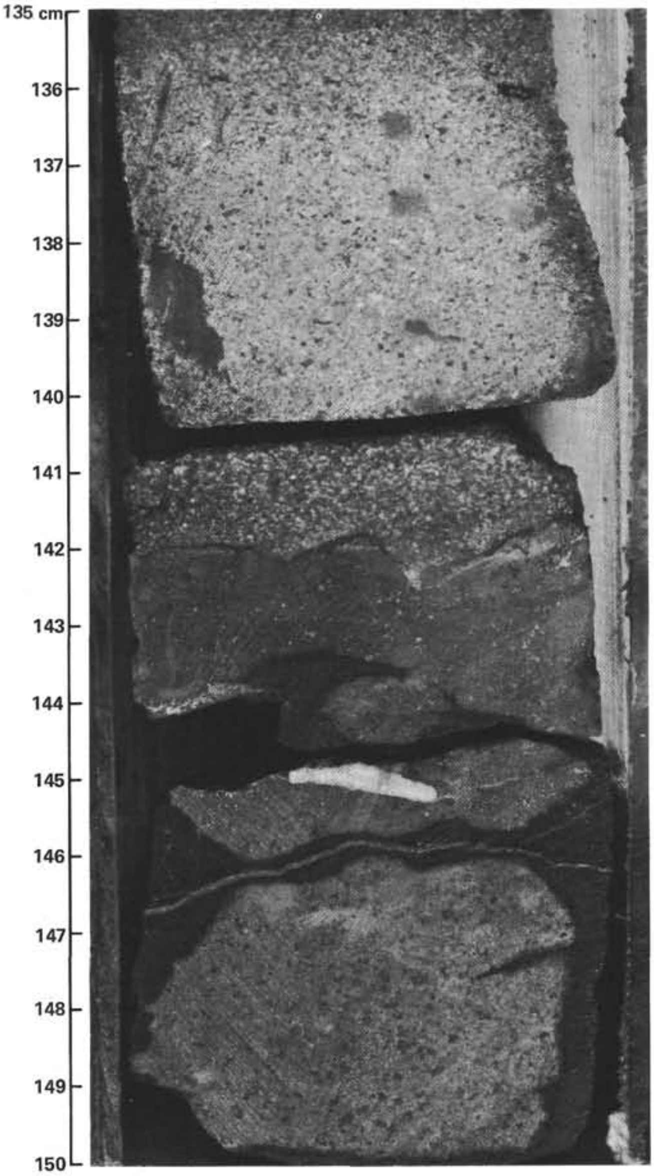

Figure 15. Sample 474A-39-3, 135–150 cm, Unit V: Contact of dolorite sill (Igneous Unit 1) with hard, carbonate-cemented, coarse basal sand of a turbidite. (Clasts are mainly arkosic but include weathered volcanic rock fragments.)

acter of burrowing indicate a prolonged depth and environment similar to that of the present environment. No linear development pattern was evident in the sediments. Coarsening and upward-fining cycles do occur in the sediment column, and fluctuations in thick and thin turbidites, coarse and fine sediment, and mass-flow deposits may derive from sea-level changes that moved more or less sediment into shelf-edge canyon heads. They may reflect tectonic control (growth faulting), produce multiple pathways to feeder channels in the distal fan environment. They may also reflect frequency of tectonic movement. Sedimentation rates of 300 to 400 m/m.y. suggest that pelagic sediments between mud turbidite events are comparatively thin.

The likely sources of this region's sandy material today are the Los Frailes, Salado, and Vinorama canyons. Dredging and coring in these canyons (Shepard, 1964) mainly produced weathered granitic cobbles, typical Pecten mollusk fragments, and fine micaceous sand. These components also characterize most of the coarser basal turbidite layers in Hole 474A (Units I–V).

During the latest Pleistocene, terrigenous sedimentation rates decreased, and less diluted pelagic nannofossil diatom ooze was deposited. This may reflect a sinking margin, rising sea level, or a diversion of sediment transport paths.

Volcanic Sediments

Most of the coarse fractions do not contain clasts from young volcanic rocks. One exception is the cemented sandstone that accompanies the sill at 521 meters sub-bottom. The source of these sands is unknown. In addition to granitic components, they contain many, apparently fresh, plagioclase clasts, rock fragments of basalt, and metamorphics. We recognized two thin ash layers derived from Quaternary rhyolite eruptions—most likely from the mainland side of the Gulf. The upper portion (Core 474-19) retained fresh glass and sanidine shards, whereas in the lower portion (Core 474A-28), glass was completely altered to montmorillonite.

Diagenesis

Pleistocene mud at this site was surprisingly well indurated. The hard mud-to-mudstone transition occurs at approximately 239 meters, parallel with increasingly poor preservation of siliceous fossils and their disappearance below 275 meters. This suggests that active silica diagenesis contributes to early lithification.

Cobbles of calcite-cemented sand to gravel are associated with the upper dolerite sill. They have apparently been cemented *in situ* as a result of the dolerite intrusion. Calcitic-graded siltstone layers in Core 474A-41, below the sill, also provide evidence for *in situ* cementation of coarser layers. Perhaps the barite, pyrite, and calcite below the sill are evidence of some hydrothermal effects.

Pyrite is the most common diagenetic mineral in the section. Near the top (Units I, II), it occurs as framboids and octahedra, commonly filling diatom frustules. It is less conspicuous in Unit III, where the permeating H_2S odor disappears. In Unit IV, pyrite grains may comprise 10% of some sandy silts, occurring commonly as coatings and replacements of foraminifers and, perhaps, wood debris. In Unit V, pyrite-filled burrows, pyrite sands, and pyrite-rich claystones are present.

ORGANIC GEOCHEMISTRY

C_1–C_5 Hydrocarbon Analyses

As drilling proceeded, methane and ethane were monitored on a Carle gas chromatograph (GC), and C_2–C_5 hydrocarbons were measured intermittently on a Hewlett-Packard GC. The method for rapid gas analyses was evaluated on Leg 47 (von Rad, Ryan, et al., 1977; Whelan, 1979). Samples from core gas pockets were collected through the core liner in "vacutainers" immediately after the cores were brought on deck. Analyzing these samples for hydrocarbons of a molecular weight higher than C_5H_{12} was not possible because of contamination from the rubber stopper in the vacutainer.

Shipboard analysis of C_1–C_5 hydrocarbons was conducted routinely on two gas chromatographs: C_1 and C_2 analysis on a Carle GC (3 min. analysis time) and C_2-to-C_5 analyses on a dual-column Hewlett-Packard 5711A instrument equipped with temperature programming and dual flame ionization detectors used in the compensation mode (15 min. analysis time). Analyses of both C_1 and C_2 to C_5 on the same sample were not possible in a reasonable time because of the appearance of the small C_2-to-C_5 peaks on the tail of the much larger methane peak. Amounts were obtained by measuring peak areas with an electronic integrator (CSI 38) for C_1 to C_5.

Sample introduction into the Hewlett-Packard GC was accomplished with a ⅛″ × 8″ loop packed with 60/80-mesh alumina (Analabs, Activated Alumina F-1) attached to a Carle sampling valve (microvolume valve 2014 or minivolume valve 2818; Whelan, 1979). A stream of dry helium, with the flow rate adjusted to 15 cc/ min. with a fine-metering valve, was passed through the alumina-filled loop. The sample to be analyzed (1–5 ml, depending on CH_4 content) was withdrawn from the vacutainer and injected through a silicone-rubber septum into the helium stream flowing through the sample loop. The loop had been cooled in a propan-2 bath cooled to between −72°C and −68°C with a portable refrigeration unit (FTS Systems 80). Before analysis methane was stripped from the sample by allowing helium to flow through the loop (1 cc/3 s) for 2 min. After stripping, the sample loop was shut off with toggle valves from helium flow and injection port and heated for 1 min. in a 90-to-100°C water bath; the sample was injected by turning the sample valve. The GC analysis was carried out on a column of ⅛″ × 6′ spherosil (40/100 mesh; Supelco) attached to ⅛″ × 12′ 20% OV-101 on Analabs AS (100/110 mesh), with temperature programming from 60 to 200°C at 8°/min. We left the loop in the carrier gas stream during GC analysis.

Sampling and GC separated methane, ethane, ethylene, propane, propylene, isobutane, *n*-butane, neopentane, isopentane, *n*-pentane, and cyclopentane in order of increasing retention time. The absolute sensitivity of the system was as determined by Whelan (1979).

At Site 474, gas pockets and gas pressure appeared in the core liners from about 10 to 450 meters sub-bottom. They appeared less frequently in the more indurated sediments from about 275 to 500 meters; gas was absent from 270 to 310 meters. About 30 min. after sealing, we also collected gas samples from the core caps of the more indurated sediments. High gas pressures occurred at about 150 to 175 and 220 to 270 meters. Poor core recovery, with no gas recovery, occurred in the sand sequence (about 75–100 m), and we observed no gas pressure above and below the first sill.

The results of the GC analyses are presented as the normalized concentrations of methane (CH_4) and ethane (C_2H_6) and are plotted versus depth in Figure 16. Most of the CH_4 values are between 90 and 100%, indicating an essentially constant CH_4 component of the interstitial gas, whereas the C_2H_6 shows a distinct increase to a maximum, followed by a decrease. This decrease in the C_2H_6 content reflects the slower diffusion of ethane from more indurated sediment. The ratios of C_2H_6 to CH_4 are plotted in Figure 17. They show a normal linear increase (semilog scale) to about 300 meters and then a decrease from a maximum value of 8.5×10^{-4}. Sediment lithology indicates increasing lithification below 239 meters.

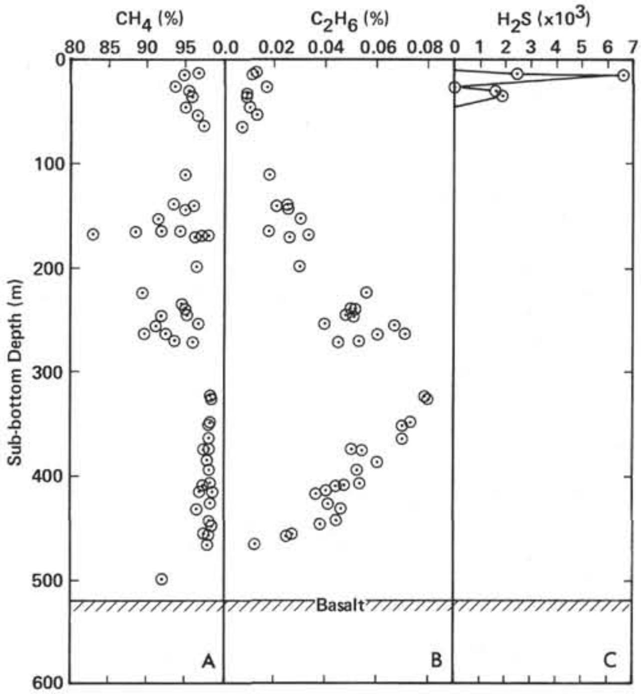

Figure 16. Results of gas chromatographic analyses for methane (A), ethane (B), and hydrogen sulfide (C) versus depth, Site 474. (Units of H_2S are arbitrary counts.)

Carbon dioxide (CO_2) and hydrogen sulfide (H_2S) were also detected. We observed H_2S only in the upper sediment (about 10–40 m), and it was not quantified but is expressed in arbitrary counts (Fig. 16C). The CO_2 (normalized data; Fig. 18) exhibited a scattered distribution to about 300 meters and, at greater depths, a lower, more linear concentration.

The higher-weight hydrocarbon gases (C_2–C_4) were analyzed to complement the CH_4 data. The concentrations of ethane and propane (assuming 100% CH_4 by volume) are plotted in Figure 19; they increase to about 300 meters and then decrease. Isobutane and, to a certain extent, isopentane also follow this trend. The maximum amounts of C_2–C_4 hydrocarbons on an air-free basis are as follows: $C_2 = 0.08\%$, $C_3 = 0.017\%$, and $C_4 = 0.007\%$. The absence of thermogenic hydrocarbon gases (e.g., cyclopentane, neopentane, and 2,2-dimethylbutane), and the low concentrations of *n*-butane and *n*-pentane indicate that the C_2–C_5 hydrocarbons of these sediments have a biogenic origin. Nevertheless, it has not been unequivocally demonstrated that the methanogenic or other types of bacteria produce ethane, propane, and isobutane, although that has often been inferred. The C_2/C_1 data from the Carle GC were con-

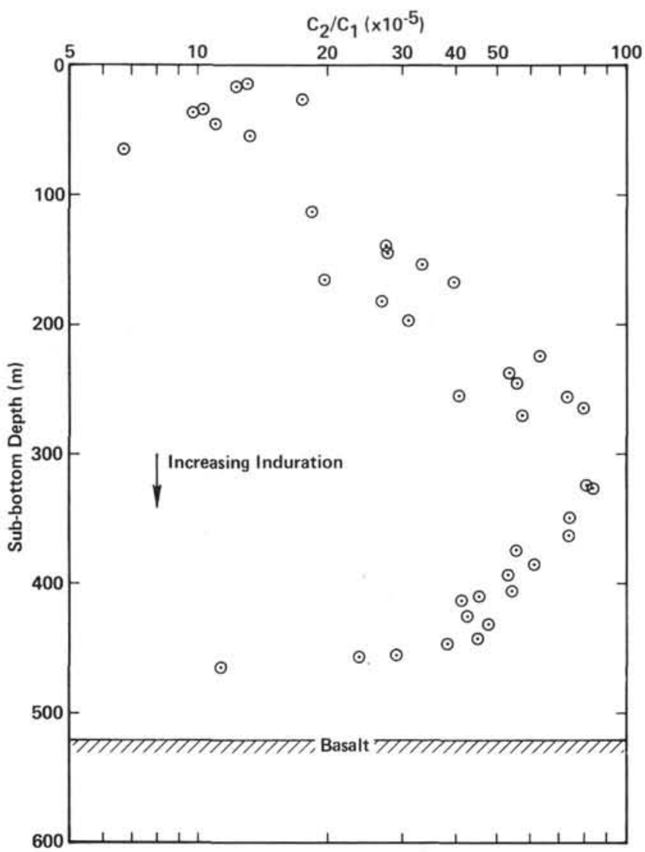

Figure 17. Ethane/methane ratios versus depth, Site 474.

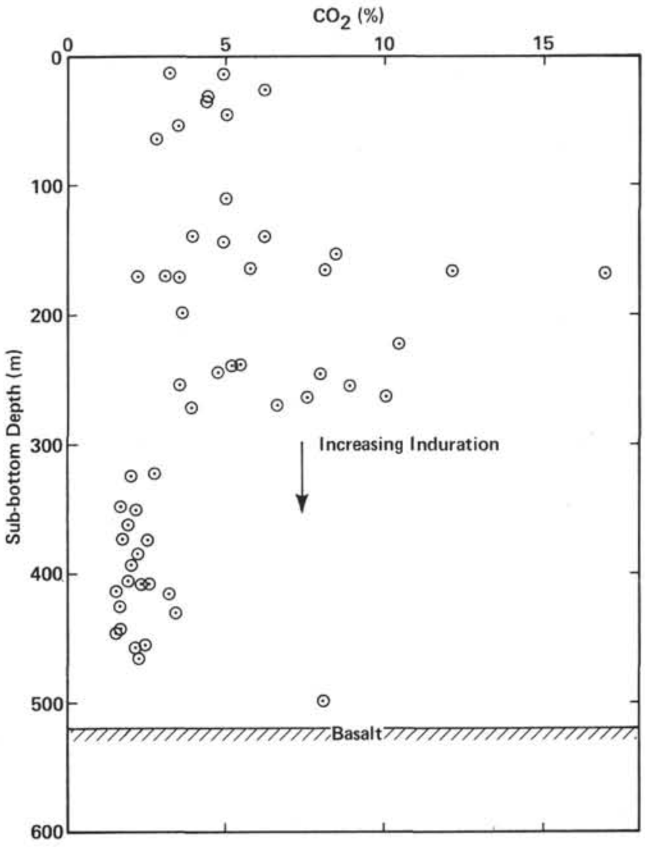

Figure 18. Carbon dioxide concentration versus depth, Site 474.

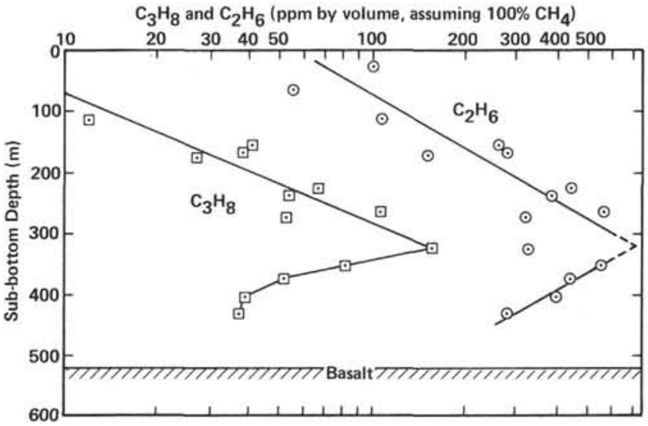

Figure 19. Ethane and propane concentrations versus depth, Site 474.

firmed by the ethane concentrations obtained on the Hewlett-Packard GC.

In general, the hydrocarbon gas of this sediment sequence is of biogenic origin and within safety and pollution limits.

Fluorescence

Fluorescence measurements can indicate the presence of aromatic compounds in, for example, petroleum and its products (e.g., Wyman and Castaño, 1974). Fluorescence in pyrolysis products is an approximate indicator of the petrogenic potential of a sediment. Fluorescence data were measured on raw sediment samples, trichloroethane extract solutions of raw samples, and pyrolized samples: All exhibited only faint, yellow fluorescence for the extract and yellow-to-blue or no-fluorescence for the pyrolysis extract. These sediments do not contain petroleum, nor do they appear to have a high potential for petrogenesis.

Organic Carbon and Nitrogen

The organic carbon and nitrogen content was determined aboard ship by the standard DSDP method (see Hays et al., 1972; Kulm, von Huene, et al., 1973) and plotted in Figure 20 (cf. Appendix I, this volume, Pt. 2, for data listing).

Shipboard analysis of cores for organic carbon and organic carbon versus total nitrogen atomic ratio was performed using a CNH analyzer. Samples containing as little as 0.1% organic carbon could be analyzed reproducibly.

Aboard ship, a sample weighing 0.5 to 1 g was refrigerated immediated after collection. Prior to analysis the sample was homogenized, and 3 ml of 6*N* HCl was added to remove carbonate carbon. The acid was evaporated on a hot plate, and the acidified sample was dried for at least 2 hr. at 105°C. The sample was cooled in a desiccating cabinet and then weighed on a Cahn electrobalance, mounted on a gimballed table. We used a sample weight from 8 to 25 mg, depending on the suspected carbon content.

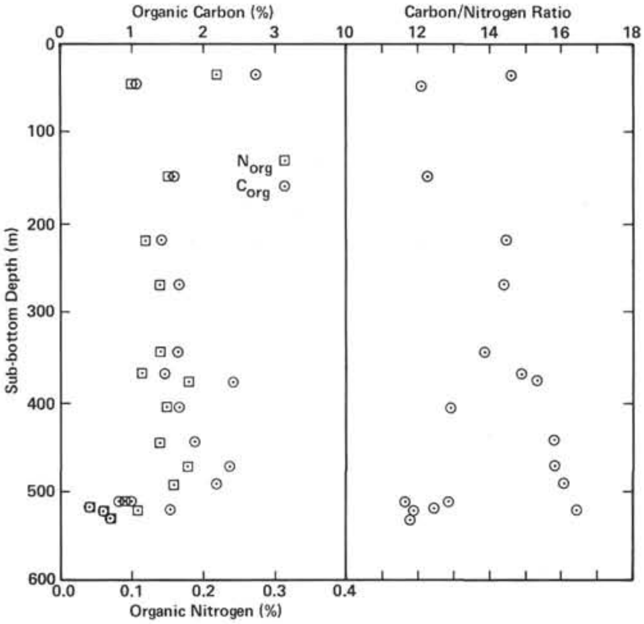

Figure 20. Organic carbon and nitrogen: content and ratios versus depth, Site 474.

The sample (in an aluminum boat) was oxidized in the presence of a metal oxide catalyst at 1100°C in a Hewlett-Packard 185B CHN analyzer. Copper turnings reduced nitrogen oxides to nitrogen gas. The gas products were separated by a Porapack Q column attached to a thermal conductivity detector. Detector response, as measured by peak height, was calibrated daily with standard samples of cystine. Multiplying the ratio of weight percentages by 1.167 converted the weight ratio to atomic C/N ratio.

Additional organic carbon and carbonate determinations were made by the Scripps Institution of Oceanography (Appendix I, this volume, Pt. 2).

The organic carbon ranges from 1 to 3% throughout the core; it drops, in the proximity of the dolerite, to about 1%. Organic nitrogen ranges from about 0.1 to 0.25%, and the plot, also dropping in the sill proximity to <0.1%, parallels that of organic carbon. The C/N ratio is also plotted in Figure 20, and the values, with some scatter, range from 11 to 17. The C/N ratios for Recent sediments usually cluster around 12 (Ryther, 1956), which accords with data for the upper section of this sequence. Maturation of organic matter increases the C/N ratio, and this trend is slightly discernible below about 200 meters. Both higher and lower values are observed near the dolerite sill, which values may indicate more altered (thermally) organic matter from various contributions.

Conclusion

The organic matter in this sediment sequence is of biogenic origin and immature (based on gas, fluorescence, and C/N analyses). Despite the high thermal gradient, no typical petrogenic hydrocarbons occur, and the origin of the methane, ethane, propane, and isobutane is probably biogenic. Nevertheless, the increase in these C_2–C_4 hydrocarbons with depth may also indicate an onset of low-temperature (<120°C) thermal decomposition of biogenic organic matter. This same increase was observed near a diorite intrusion into the Cretaceous black shales at Site 368 (Leg 41; about 600–900 m) and at depth in Hole 369A (Leg 41; below about 400 m; Doose et al., 1978).

The decrease in C_2–C_4 hydrocarbon concentrations below about 300 meters is caused by the increasing induration of the sediment and the associated slower outgassing of the lighter-weight hydrocarbons. This induration is also confirmed by the silica concentration in the interstitial water, which drops to a value of <400 μM (see section on inorganic chemistry for additional confirming data). The overall amounts of hydrocarbon gas are well within safety and pollution limits.

INORGANIC GEOCHEMISTRY

Interstitial Water Chemistry (Fig. 21)

High values of alkalinity, ammonia, and phosphate in the upper 100 to 200 meters indicate the importance of bacterial oxidation of organic matter. High concentrations of dissolved ammonia have led to significant ion exchange with the clay matrix, thus yielding an intermediate maximum in dissolved magnesium at about 100 meters sub-bottom.

Profiles of dissolved calcium and magnesium below 200 meters indicate a zone of reaction near 300 meters, which can be understood in terms of alteration processes of igneous material associated with a silicification front. The latter front is clearly delineated by the sharp drop in silica concentrations below 250 meters. The intermediate maximum in salinity reflects the sharp increase in bicarbonate concentration (alkalinity).

BIOSTRATIGRAPHY

Nannofossil and diatom datum planes indicate that the Quaternary/Pleistocene boundary occurs between Cores 474-28 and 474-29. On the basis of a few nannofossils in claystones between igneous units, the basement age is placed at the lower boundary of upper Pliocene (between 2.3 and 3.0 m.y.).

Coccoliths

Although the frequency and preservation of the nannofossils vary greatly at Site 474, a good biostratigraphic control was possible. The upper Pliocene assemblages are sparse, mainly composed of those forms most resistant to solution. A thin, upper Pleistocene section (Cores 474-1–474-14) was recovered, followed by a 360-meter-thick lower Pleistocene section (Cores 474-16–474A-28) and a 40-meter-thick section of upper Pliocene (Cores 474A-29 through 474A-41). A few mudstone pebbles in Core 474A-45 were also assigned to the late Pliocene. The Pleistocene/Pliocene boundary is sharply marked between Cores 474A-28 and 474A-29. *Pseudoemiliania lacunosa* first occurs in Core 474-16; *Helicosphaera sellii* in Sample 474A-23-3, 122–123 cm; and *Cyclococcolithus macintyre* in Sample 474A-25-1, 16–17 cm. *Discoaster brouweri* becomes abundant at the top

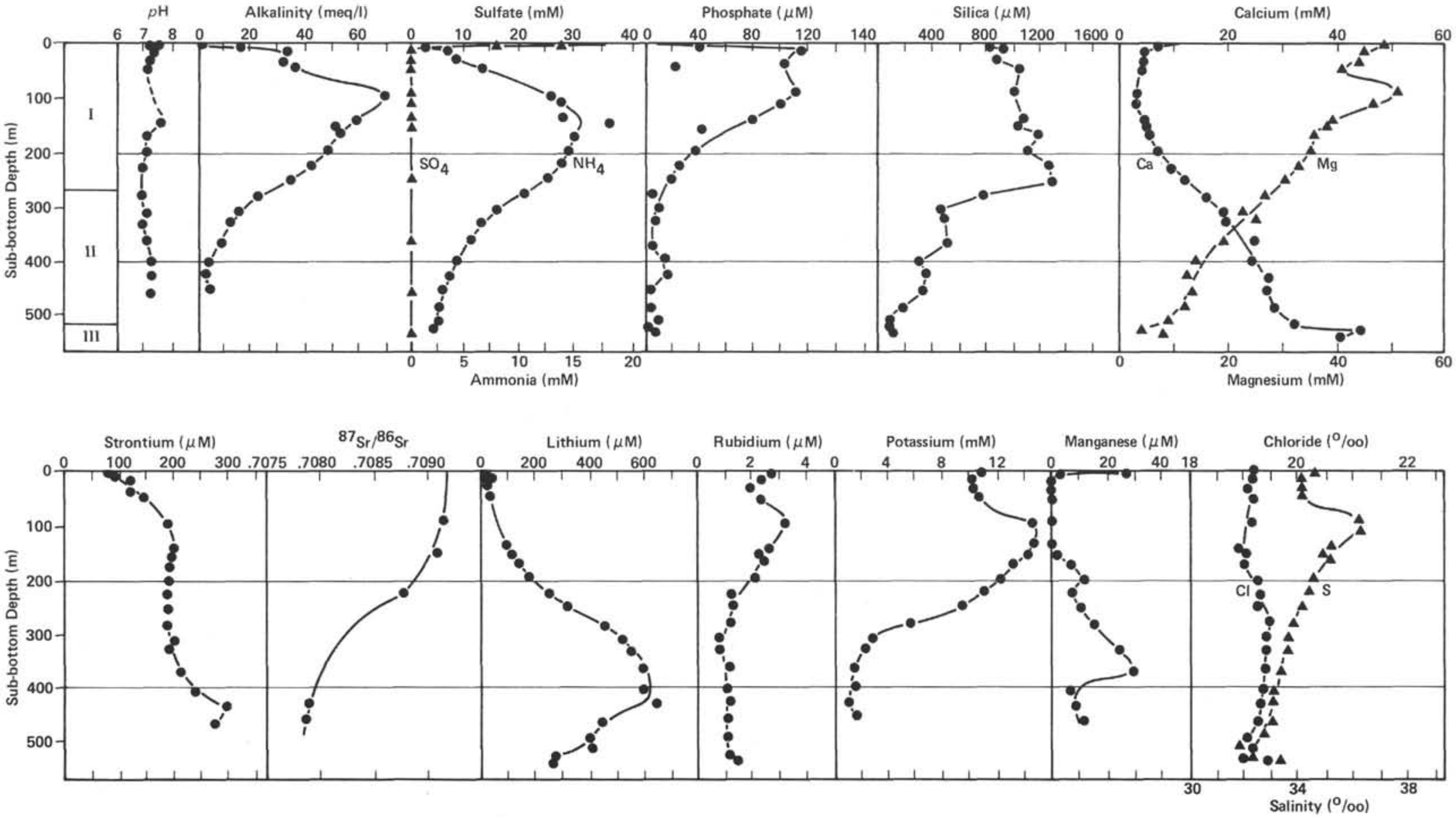

Figure 21. Interstitial water chemistry, Site 474.

of Core 474A-29 and is ubiquitous downhole. *Discoaster pentaradiatus* first occurs in Sample 474A-35-1, 72–73 cm, *D. surculus* in Sample 474A-35-4, 28–29 cm.

Diatoms

Open marine tropical to subtropical planktonic diatoms are abundant to rare and generally well to moderately preserved in the hemipelagic sediment from Cores 471-1 through 474-11. The mixture of marine benthic species is highly variable but never exceeds 1 to 2% of the total diatom assemblage. Samples below Core 474A-11 contain no diatoms. The following important diatom biostratigraphic species occurred at Site 474. *Nitzschia reinholdii* (Sample 474-6-2, 36–38 cm); *Mesocena quadrangula* (Sample 474-6-3, 56–58 cm; both species were found in Samples 474-7-1, 77–79 cm and 474-7-5, 114–116 cm); *N. reinholdii* (Samples 474-11-1, 64–66 cm to 474-17-2, 17–19 cm); *M. quadrangula* (Sample 474-18-1, 125–127 cm; since these species are absent in Samples 474-18-3, 8–10 to 474-19-2, 102–104 cm, these occurrences are interpreted as reworking); common *M. quadrangula* and *N. reinholdii* associated with *Rhizosolenia barboi* (Sample 474A-1-1, 107–109); *R. matuyama* (Samples 474-7-3, 53–55 cm to 474-10-1, 30–32 cm.

No key species were detected below the two remaining samples; diatoms are rare. Distinct cold-water intrusions into the Gulf were detected at the following levels (the occurrence of *R. barboi* is common to rare): 474A-1-1, 107–109 cm; 474A-9-1, 93–95 cm; 474A-9-3, 50–53 cm. Mass occurrences of *Thalassiothrix longissima* at 474-17-2, 17–19 cm and 474A-10-1, 30–32 cm also indicate colder surface-water temperatures during times of deposition.

Planktonic Foraminifers

No planktonic foraminifer zonation was established for Holes 474 and 474A, because neither *Globorotalia truncatulinoides* nor other stratigraphical diagnostic taxa were found along the cores. Furthermore, the sediments from Section 474-26,CC to the bottom of the hole are barren of planktonic foraminifers.

It appears that the planktonic foraminifers in these holes record geographical shifting of water masses. Most of the samples along the core sustain a "subtropical" population in which *Neogloboquadrina dutertrei* group B (Srinivasan and Kennett, 1976), *Globigerinoides ruber*, and *Orbulina universa* are the "dominant" species. In certain intervals, however, such as those corresponding to Sections 474-14,CC, 474-19,CC, 474A-10,CC, 474A-12,CC, 474A-14,CC, and 474A-16,CC, an apparent increase of the population, dwelling recently in the California Current, was observed. The "California Current" population is mostly *Globoquadrina pachyderma* right coiling and *Globigerina bulloides*.

The planktonic foraminifers were retained in the portion larger than 149 μm. The samples (about 3 cm^3) were treated only with distilled water.

Radiolarians

Slides to analyze radiolarian remains were prepared from core-catcher samples from Holes 474 and 474A. The preparation employed a special settling technique (Moore, 1973; Molina-Cruz, 1978) that yielded slides with evenly and randomly distributed grains.

In Holes 474 and 474A, radiolarian remains are common only in the top cores (474-1 and 474-2); rare to few in the subsequent cores (474-3–474-19 and 474A-1–474A-13); and absent in Core 474A-14 through the bottom; the remains are well to moderately preserved.

Radiolarians such as *Theoconus minythorax, Tetrapyle octacantha, Pterocanium praetextum, Ommatartus tetrathalamus, Theocorythium trachelium, Amphirhopalum ypsilon*, and *Liriospyris toxarium*, among others, clearly indicate the subtropical character of the Recent water mass.

Nigrini (1971) proposed a Quaternarian biozonation for the equatorial Pacific, and Hays (1970) and Kling (1973) proposed others for the North Pacific. None of these Quaternarian zonations, however, was used for Holes 474 and 474A, because index species such as *Anthocyrtidium angulare, Buccionosphaera invaginata, Collosphaera tuberosa*, and *Eucyrtidium matuymai* were not detected.

Radiolarian remains in Holes 474 and 474A have been preserved only during the Quaternary. Index species older than Quaternary were not found.

SEDIMENT ACCUMULATION RATES

We observed apparently continuous sedimentation at Site 474, without any suggestion of hiatuses. We assume the emplacement of the debris flow, Unit II, from 22 to 85 meters was essentially instantaneous on this time scale. The apparent rate of sediment accumulation (Fig. 22) averaged 86 m/m.y. from the base of the sediment section to about 375 meters, in early Pleistocene time. The rate then seems to have increased significantly during most of the Pleistocene to almost 400 m/m.y., but must have been much slower during the late Quaternary after emplacement of the debris flow.

IGNEOUS ROCKS

Igneous rocks were first encountered at 521 meters sub-bottom (Section 474A-36-3, 132 cm). The rocks were divided into eight units (Table 3; Fig. 23). The main rock types are olivine-rich dolerite and sparsely porphyritic to plagioclase-rich porphyritic varieties of basalt.

Unit 1

Unit 1 is a dolerite body with well-preserved chill zones at both its upper and lower contacts with sediment. A brecciated, thermally altered claystone above the upper contact indicates that the body is intrusive in origin. The dolerite contains variable quantities of olivine (5–30%), plagioclase (5–15%), and (minor) red chrome spinel phenocrysts; there is a noticeable concentration of olivine-rich dolerite in the lower one meter of the unit (Section 474-40-2). The groundmass comprises olivine (10%), plagioclase (30–40%, An_{60}) subophitically enclosed by pale brown augite (30–35%), and magnetite (<5%). The olivine (phenocryst and groundmass phases) has been variably altered to a green clay

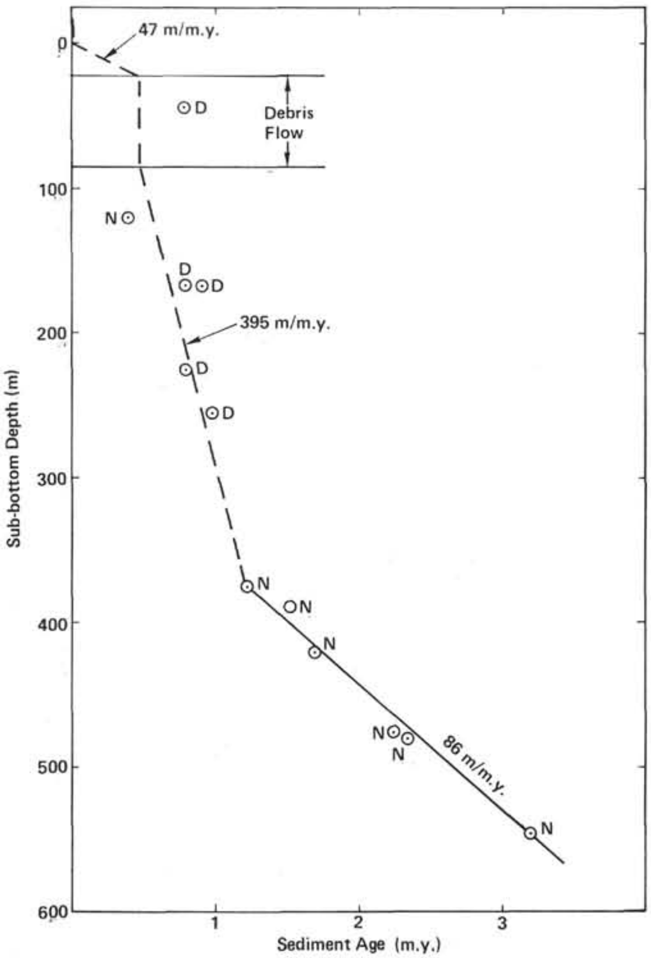

Figure 22. Sediment accumulation rates, Site 474. (Dotted lines indicate insecure sedimentation rates.)

mineraloid, particularly in areas adjacent to sporadic calcite veins, although neither the feldspars nor the pyroxene show evidence of alteration. Unit 1 intrudes sediments containing nannofossils, indicating a maximum age of emplacement of approximately 2.3 m.y.

Unit 2

Unit 2, a massive dolerite body, is separated from Unit 1 by about 15 meters of sediment. Thermally altered sediments adjacent to the upper contact indicate an intrusive origin for Unit 2, and petrographic studies show that it closely resembles Unit 1. The dolerite of Unit 2 is olivine rich, with occasional plagioclase phenocrysts and frequent olivine-rich segregations (up to 25% olivine phenocrysts). The groundmass is subophitic, comprising plagioclase, clinopyroxene (pale brown augite with a purplish tint indicating a titaniferous component), and opaques. Alteration is restricted to the olivines, which may be partly or completely replaced by green clay mineraloids, particularly in the vicinity of the abundant calcite- and zeolite-filled veins. Some vesicles are filled with expanding nontronite (see Fig. 24).

Unit 3

A small quantity of claystone at the top of Core 474A-43 suggests that Units 2 and 3 are separated by a thin sedimentary intercalation. The upper contact between the sediment and Unit 3 was not recovered, so we could not ascertain whether the unit is a sill or a flow. Petrographically, Unit 3 is distinct from Units 1 and 2. The rock is finer grained—almost basaltic—and contains as much as 5% equant- and lath-shaped plagioclase (An_{60-70}) phenocrysts and about 5% olivine microphenocrysts. The groundmass comprises olivine, plagioclase in variolitic clusters (40%), and an altered, sparsely vesicular mesostasis. Altered olivine pheno-

Table 3. Igneous lithological units, Hole 474A.

Unit	Core/Section (level in cm)	Top (m)	Base (m)	Thickness (m)	Recovery^b (m)	Cooling Unit	Phenocryst Assemblage
1	41-5, 142–40-2, 120	$520.5^a/522^b$	$526^a/526.5^b$	$5.5^a/4.5^b$	3.9	massive dolerite sill	Ol, Pl, Sp
sedimentary intercalation [NN15(?)]							
2	41-5, 127–42-5, 100	$543^a/542^b$	$551^a/550.5^b$	$8.0^a/8.5^b$	6.9	massive dolerite sill	Ol, Pl, Sp
sedimentary intercalation (barren)							
3	43-1, 3–43-4, 62	$552^a/550.5^b$	$558^a/561^b$	$6.0^a/10.5^b$	3.8	massive dolerite or coarse basalt	Ol, Pl
sedimentary intercalation (none recovered)							
4	44-1, 0–44-2, 10	$562.5^a/562.5^b$	$566.5^a/567^b$	$4.0^a/4.5^b$	1.5	pillow basalt	Pl
sedimentary intercalation(?)							
5	44-2, 11–44-5, 125	$567^a/567^b$	$571^a/571^b$	$4.0^a/4.0^b$	3.4	pillow basalt	Pl, Ol, Sp
sedimentary intercalation (≤3.2 m.y.)							
6	45-1, 0–46-2, 19	$572.5^a/574^b$	$584^a/585^b$	$11.5^a/11.0^b$	9.5	massive basalt	Pl, Ol
sedimentary intercalation(?)							
7	46-2, 20–50-2, 110	$589(?)^a/588^b$	$619.5^a/619^b$	$30.5^a/31.0^b$	15.6	pillow basalt	Pl, Ol, Sp
8	50-2, 111–50-4, 10	$619.5^a/619^b$	$626^a/626^b$	$6.5^a/7.0^b$	2.0	massive basalt	Ol, Pl

[a] Estimated from downhole log.
[b] Estimated from drilling rate and core logs.

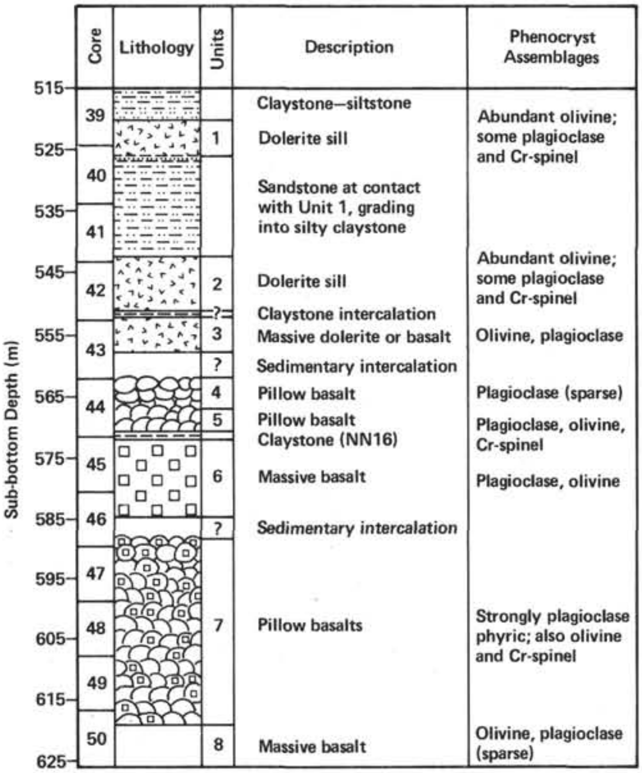

Figure 23. Igneous rock column, Site 474.

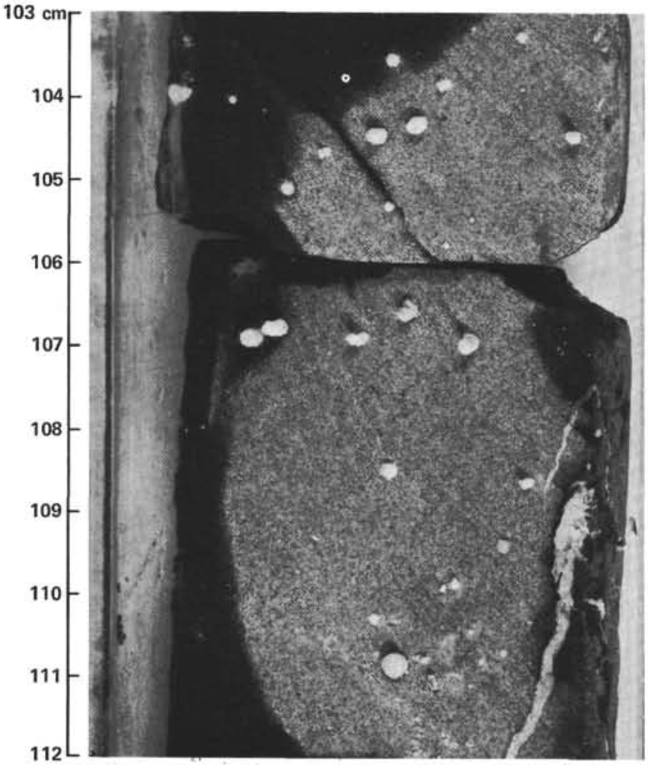

Figure 24. Sample 474A-42-2, 103–112 cm: alteration in Unit-2 dolerite.

crysts, however, are profuse (10–15%) at several intervals in Section 474A-43-1—a distribution similar to that observed in Units 1 and 2. Calcite veining occurs throughout Unit 3, frequently resulting in fragmentation of the basalt.

Fine-grained basalts with glassy chill zones and baked mudstone selvages were first encountered in Section 474A-44-1 at 562.5 meters sub-bottom. These are interpreted as being part of a pillow-lava sequence and probably represent the shallowest level of the true basement.

Unit 4

Unit 4 represents the upper 1.5 meters of the lava sequence and comprises moderately altered aphanitic basalts and sparsely plagioclase-phyric basalt. The basalt is cut by rare, thin calcite veins and is somewhat fractured. In thin section, the basalt contains less than 5% plagioclase phenocrysts (0.5–1.0 mm) in a quenched, variolitic groundmass of plagioclase, clinopyroxene, and disseminated magnetite. The mesostasis is partially replaced by yellow brown clay minerals, and the small, abundant (0.2–1.0 mm) vesicles (15–20%) are filled with clay minerals and zeolites.

Unit 5

Unit 5 comprises slightly altered plagioclase-phyric basalt. Glassy selvages as much as 2 mm wide are abundant, and the rock is considerably fractured. The basalt contains two generations of plagioclase phenocrysts. Large, tabular, subhedral, and zoned (An_{80-90}) plagioclase crystals, forming multicrystal aggregates as long as 5 mm across, compose about 5% of the rock. The second plagioclase phase consists of elongate lath-shaped crystals as much as 2.5 mm long (An_{70-80}), comprising as much as 30% of the rock. Other phenocryst phases include olivine (as much as 5%), which has been completely replaced by green clay mineraloids, and cubes of red chrome spinel lying in the groundmass and as inclusions in the plagioclase phenocrysts. The groundmass is generally very fine grained, containing olivine (5%), plagioclase microlites (20%), clinopyroxene (15%), and disseminated opaques. The mesostasis has been replaced by brown clay minerals, and occasional vesicles are filled with clay minerals, calcite, or zeolites.

Unit 6

Unit 6 appears to be overlain by a thin sediment intercalation containing nannofossil assemblage NN16. The absence of a recovered contact at the top of the unit, however, means that we could not ascertain whether Unit 6 represents an intrusive or extrusive body. The rock is a fresh, homogeneous, fine-grained dolerite; it has good recovery and an absence of fractures or quench zones, suggesting that it is either a thick flow or a sill. In thin section, the rock has a subophitic texture and is sparsely plagioclase phyric (5%, as wide as 2 mm across). The groundmass comprises olivine (5%), plagioclase (40%, An), pale brown augite (40%), and opaques. Alteration is restricted to the olivines, which are replaced by green clay mineraloids.

Unit 7

Unit 7 is part of a 36-meter sequence of fresh plagioclase-phyric basalts which, from the presence of numerous glassy selvages, probably represent successive submarine eruptions (pillow basalts). Approximately 5% of the rock consists of large (2–20 mm), partially resorbed, zoned (An), and glass-inclusion-filled plagioclase phenocrysts or megacrysts. In addition, smaller lath-shaped plagioclase (10%, 0.5–1.0 mm) and olivine (up to 5%) phenocrysts and euhedral red chrome spinel microphenocrysts lie in the pilotaxitic groundmass of plumose pyroxene, plagioclase microlites, and a glassy mesostasis containing approximately 5% clay minerals.

Unit 8

Unit 7 grades downward through a narrow amygdular zone into Unit 8—2 meters of sparsely plagioclase (5%)- and olivine (5%)- phyric coarse-grained basalt. The phenocrysts lie in an intergranular-to-subophitic groundmass of approximately equal proportions of pale brown augite and plagioclase and about 15% olivine. The olivine in the rock has been altered to green clay mineraloids. Unit 8 contains no glassy selvages, indicating that it may be part of a massive flow.

The depth to true basement has been estimated by the glassy selvages in Unit 4 at 563 meters sub-bottom. A minimum age of about 3.0 m.y. for the basement rocks is suggested by a nannofossil-bearing claystone intercalation in Core 474A-45. This agrees with the magnetic lineation data showing that Hole 474A lies on anomaly 2″ (ca. 3.2 m.y.). Unit 1 is probably a sill, postdating the basement by at least 1.0 m.y. The petrographically similar Unit 2 is also intrusive in origin and probably of a similar age to Unit 1.

PALEOMAGNETISM

We collected 115 samples from Holes 474 and 474A for paleomagnetic examination. Of these samples, 79 were collected from sedimentary cores beginning at Core 474-11. Because the sediments were soft and greatly disturbed in the upper 150 meters, only a few samples were suitable for paleomagnetic studies. In Hole 474A, the density of sampling was greater, because the sediments were more compacted. We collected 36 additional samples from the igneous basement.

The routine shipboard sampling procedure was followed. Before sampling, an orientation arrow, pointing uphole, was traced on the rock. Igneous rocks were measured on shipboard with a Digico balanced-fluxgate spinner magnetometer, an alternating field (AF) GSD-1 demagnetizer, and a Bison magnetic susceptibility meter.

Basalts

Each igneous unit was sampled, and the natural remanent magnetization (NRM) and bulk susceptibility were measured. Rather than establishing the ideal range of AF demagnetization with a pilot set, the whole set was subjected to an alternating-field (AF) demagnetization procedure in increasing steps at 25, 50, 75, 100, 150, 200, 250, 300, and 350 Oe. By 350 Oe, most of the samples had lost more than 90% of their original NRM.

Results

The J_0 values range from 0.977×10^{-3} emu/cm^3 to 20.629×10^{-3} emu/cm^3, although two-thirds of them fall within 2 to 5×10^{-3} emu/cm^3. Curiously enough, some of the higher values come from samples in the uppermost part of the cores (474A-44, 474A-48, 474A-49, and 474A-50) and apparently bear no relation to the petrological or magnetic unit boundaries. Drilling may have caused this phenomenon. Negative and positive inclinations range from −61.2 to +60.2° (Fig. 25). Upon demagnetization, 7 samples remained positive and 15 negative; 12, which first showed a positive inclination, became negative as demagnetization proceeded. Two samples changed polarity from negative to positive. Usually these changes occurred within the first two or three steps (as far as 75 Oe), and then no major changes occurred in the declination or inclination values. In general, most of the samples remained very close to their stable inclination.

Unit 1 (three specimens) displays a normal polarity in two samples, but the third is reversed. This last sample is very close to the lower chilled margin of the sill. It may be that the sill intruded the sediments during a period of reversed polarity (which was "frozen" at the margins) shortly before a shift to normal polarity, which has registered in the inner parts of the sill. According to the age of the sediments above and below, the sill must have been emplaced sometime between 1.8 and 2.8 Ma, in the first half of the Matuyama Reversed

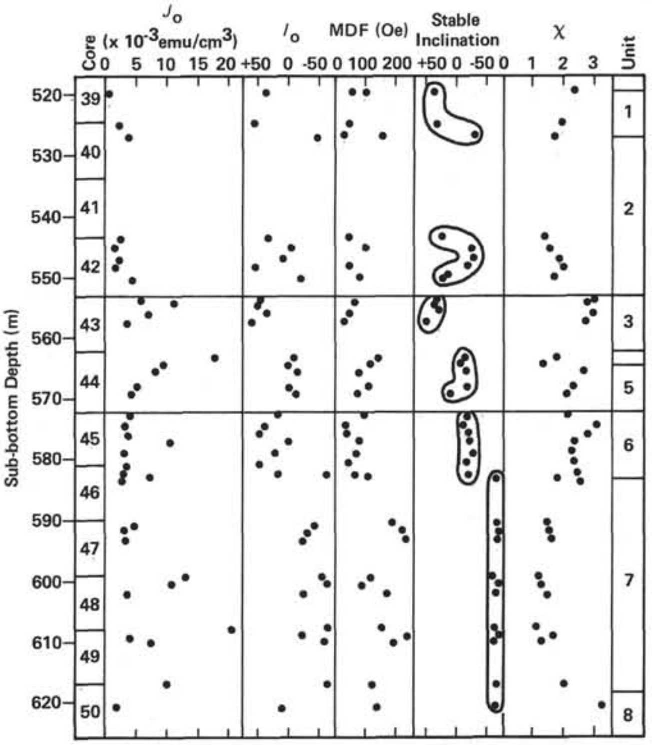

Figure 25. Paleomagnetism results, Site 474.

Epoch; several normal events occurred in that period. The stable inclination values agree with the expected values for this latitude (23°N).

Petrographically, Units 2 and 3 appear to be different. On paleomagnetic grounds (Table 4, Fig. 25), Units 2 and 3 display different polarities: Unit 3 shows a normal polarity throughout; the stable inclination for Unit 2 is −23.1°, somewhat shallower than expected, and Unit 3 has three samples with an average of 33° and one sample with a steeper positive inclination of 51.9°.

Units 4, 5, and 6 are magnetically similar; negative stable inclinations vary from −8.6 to −23.5. An abrupt change occurs between Units 6 and 7 (Table 4; Fig. 25). The stable inclination values of Units 7 and 8 are the steepest of this site: −59° to −66°. The median destructive field (MDF), varying from 90 to 250 Oe, is higher than in any other units. The x values are smaller than in other samples, and the Q_n values are therefore higher. All the samples increase in intensity during the first step of demagnetization, indicating that a normal component is being erased (Fig. 26).

Except for Units 1 and 3, which exhibit an inclination value agreeing with the one expected for this latitude (23°N), the units have inclinations either too shallow or too steep. Several alternatives include secular variation, tectonic disturbance, or some drilling remanence. Another puzzling fact is that Hole 474A was drilled on a positive magnetic anomaly, NR2, but most of the units have a reversed polarity. One reason for this may be that the source of the anomaly is deeper than 100 meters. Similar situations have been encountered in DSDP Legs 45, 37, and 39.

PHYSICAL PROPERTIES

Most of the methods and procedures that determine physical properties aboard *Glomar Challenger* have been described. References and some remarks on the validity and reliability of these determinations, as well as a description of some additional techniques, are presented in a summary of physical properties (Einsele, this volume, Pt. 2). For all measurements, we tried to choose the least-disturbed samples (generally from the lowermost core sections) from sediments representing the predominant sediment type. Special layers, such as mud turbidites, were, as far as possible, avoided or sampled separately. Sand layers were usually very much disturbed or completely lost in drilling. Therefore, all the data presented here are valid only for cohesive muds.

When the sediment was stiff enough, chunks were taken and weighed in air and under water to determine "wet" water content, wet-bulk density, and porosity. In soft sediments not stiff enough for the chunk method, we used special steel cylinders (about 5 cm³ volume) to remove undisturbed samples from the center of the split core. All porosity data were corrected for salt content. According to the chemical analyses on interstitial water,

Table 4. Paleomagnetism, Hole 474A.

Core/ Section (level in cm)	Sub-bottom Depth (m)	J_0 ($\times 10^{-3}$ emu/cm^3)	I_0	D_0	MDF (Oe)	Stable		Polarity	x ($\times 10^{-3}$ emu)	Q_n ($F = 0.45$)	Igneous Unit
						Inclination	Declination				
39-4, 55	520.05	0.977	38.1	96.2	65	37.2	83.8	N	2.364	0.91	
40-1, 70	525.20	2.432	56.2	121.6	50	34.3	112.8	N	1.945	2.77	1
40-2, 106	527.06	3.621	−51.0	347.7	40	−32.7	344.9	R	1.752	4.59	
42-1, 3	543.53	2.642	35.7	249.7	45	24.7	253.6	N	1.395	4.20	
42-2, 48	545.48	1.506	−1.9	168.8	100	−23.1	161.2	R	1.527	2.19	
42-3, 66	547.16	2.189	8.9	67.9	135	−25.8	65.5	R	1.821	2.67	2
42-4, 37	548.37	1.768	56.1	195.1	45	−17.8	183.6	R	1.935	2.03	
42-5, 98	550.48	4.538	−18.6	139.7	80	22.4	140.5	N	1.557	6.47	sediment
43-1, 110	554.10	5.644	49.7	172.9	65	33.1	174.9	N	2.962	4.23	
43-2, 13	554.63	11.251	49.3	34.4	62	35.7	40.8	N	2.727	9.16	
43-3, 19	556.19	7.467	36.8	239.5	50	31.9	233.9	N	2.894	5.73	3
43-4, 29	557.79	3.333	60.2	271.9	25	51.9	258.8	N	2.676	2.76	
44-1, 106	563.56	17.609	−6.3	212.3	140	−9.6	210.7	R	1.715	22.81	4
44-2, 56	564.56	9.525	1.2	269.6	115	−8.6	271.7	R	1.312	16.13	
44-3, 39	565.89	8.382	−12.8	351.8	80	−12.5	347.6	R	2.673	6.96	5
44-4, 124	568.24	5.230	2.3	134.6	105	−18.0	128.8	R	2.250	5.16	
44-5, 107	569.57	4.066	−12.2	84.5	75	14.5	80.8	N	2.081	4.34	sediment
45-1, 86	572.86	4.177	18.5	226.9	95	−13.9	225.8	R	2.113	4.39	
45-2, 121	574.71	3.188	39.5	57.8	35	−12.3	53.4	R	2.994	2.36	
45-3, 92	575.92	3.499	50.1	40.3	40	−15.8	32.1	R	2.771	2.80	
45-4, 67	577.17	10.515	3.9	98.0	80	−18.7	97.8	R	2.321	10.06	6
45-5, 101	579.01	2.764	25.4	142.1	65	−23.5	147.5	R	2.237	2.74	
46-1, 10	581.10	3.285	50.1	287.4	40	−15.4	301.6	R	2.295	3.18	
46-1, 124	582.24	2.577	−20.5	266.4	65	−14.8	267.6	R	2.509	2.28	
46-2, 68	583.18	7.122	−60.6	25.6	105	−65.4	19.3	R	1.174	13.48	
47-1, 116	591.16	4.715	−42.2	315.5	190	−63.5	322.7	R	1.495	7.00	
47-2, 51	592.01	2.955	−29.1	218.1	215	−66.0	223.9	R	1.522	4.31	
47-3, 32	593.32	2.915	−24.5	277.6	235	−63.0	289.7	R	1.537	4.21	
48-1, 69	599.69	13.108	−53.6	359.4	110	−59.2	1.3	R	1.161	25.08	7
48-2, 19	600.69	10.853	−57.7	96.6	95	−64.4	100.0	R	1.228	19.63	
48-3, 30	602.30	3.472	−23.9	138.1	160	−61.0	137.1	R	1.464	5.27	
49-1, 8	608.08	20.629	−60.6	248.5	150	−62.1	249.1	R	1.046	43.82	
49-2, 14	609.64	3.790	−20.4	168.4	225	−66.1	155.6	R	1.555	5.41	
49-2, 68	610.18	7.318	−54.0	121.7	190	−60.3	124.3	R	1.275	12.75	
50-1, 29	617.29	9.767	−61.2	327.8	115	−66.3	326.9	R	2.006	10.81	
50-3, 113	621.13	1.534	15.6	38.4	135	−61.1	9.4	R	3.282	1.03	8

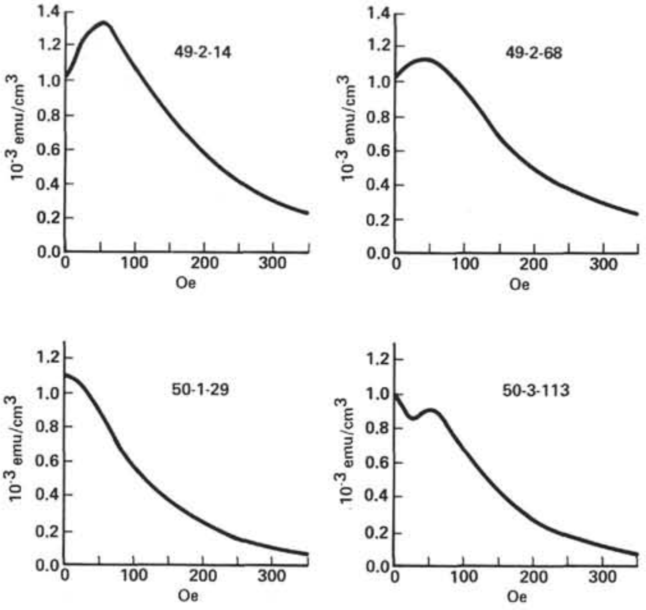

Figure 26. Demagnetization curves, Site 474.

the total salt content of the pore water—down to the oceanic crust—varies only slightly. Therefore, no further corrections for changing salt content were necessary. Loss of volume by shrinkage was determined on the dried samples from the cylinders and expressed in percentages of the original volume of the wet samples. In about 10 to 200 meters below the sediment surface—and to some smaller extent in deeper cores—part of the pore water was removed and cavities were formed by expanding methane gas. Since calculations for bulk density and porosity assume that the samples are water-saturated, the values in this part of the sequence are somewhat too low. This especially applies to the cylinder method, whereas the chunks could take up some of their lost water during weighing under water.

The Hamilton Frame could not measure sound velocity in the upper and middle part of the sediment sequence, probably (again) because of the gas content of the samples. We routinely determined GRAPE wet-bulk density on each or each second core section within the plastic liner. Vane shear tests, using the Wykeham Farrance apparatus and, in more consolidated sediment, the hand-operated, soil-test, high-capacity vane tester and a newly developed cone vane tester, were performed on the split cores. From Core 474-34 downward, the sediments became so hard that the coherent parts of the section cracked during penetration of the vane. Nevertheless, we finished the test by holding the split pieces together by hand. We took the highest value from several tests at the same core section.

Besides the well-known general relation between physical properties and depth in core, at Site 474 some special major trends can be recognized—trends mostly related to the composition of the sediments and the first stages of diagenesis. The data gained from the uppermost 60 meters of the hole show unusually strong gradients of all physical properties (Fig. 27), especially in Cores 474-1 and 474-2. "Wet" water content and porosity decrease from about 65 to 85% to about 45 and 65%, respectively. Bulk density increases from 1.3 to 1.55 g/cm^3, and vane shear strength versus depth appears to grow very fast. In the same interval, shrinkage of dried samples decreases from 40 to 50% to about 30%. These strong gradients in the upper 10 to 20 meters of a sedimentary column are to some extent normal, but at Site 474 they are amplified by the decrease of biogenic silica and the increase of the coccoliths as important constituents of the sediment. Biogenic silica (mainly in the form of delicate diatom frustules) tends to preserve high porosity, whereas the calcareous remnants of coccoliths do not prevent compaction to such an extent. The sediments of this depth range also have a comparatively high silt content. Thus, the dotted trend lines in Figure 27 are drawn somewhat apart from the actual data points.

In the sandy section from depths of about 60 to 90 meters, no physical properties could be determined. From about 90 to 250 meters, water content, porosity, and bulk density are changing slowly versus depth—as expected. The data, however, scatter considerably in this range, which is also true of the density log. This scattering is partly caused by expanded gas and the initial difficulties in distinguishing mud from the "background" sediments from mud from the upper part of mud turbidites.

Since biogenic silica (opal) and calcareous nannofossils are still present in considerable quantities, recrystallization appears hardly to have occurred in this interval. Shrinkage drops, however, from 30 to 5%. Why this great change falls into an interval of otherwise minor variations is not quite clear. It appears that first diagenetic bonds between single grains are being established within this depth range.

From about 260 to 360 meters, water content and porosity decrease fairly rapidly from 37 to 27 and 60 to 48%, respectively. In the same interval, bulk density increases from 1.67 to nearly 1.90 g/cm^3, whereas shear strength scarcely changes, and shrinkage remains very low. From 240 meters downward, the sediments are silty claystones or clayey siltstones. Beginning with Core 474A-10 (250 m sub-bottom), the cores had to be split with a saw. Furthermore, in the sequence below 260 to 270 meters, scarcely any biogenic silica could be detected in the smear slides, and the nannofossils decrease to very small percentages. At about the same depth, the concentration of dissolved silica in the pore fluid is very low compared with the higher sections, where opal is still present. This signifies that the formation of chalcedony and authigenic clay minerals may have begun and contributed to the lithification of the sediment.

In the lower part of the sediment sequence, between 360 and 540 meters, the data for water content, bulk density, and porosity are relatively consistent and show only a small scattering (Fig. 27). Lithification, however, also proceeds in this interval. The vane shear strength increases considerably with depth. From about 400 meters downward, only small, high-capacity, hand-operated vanes could be used. Though the vane was pressed only

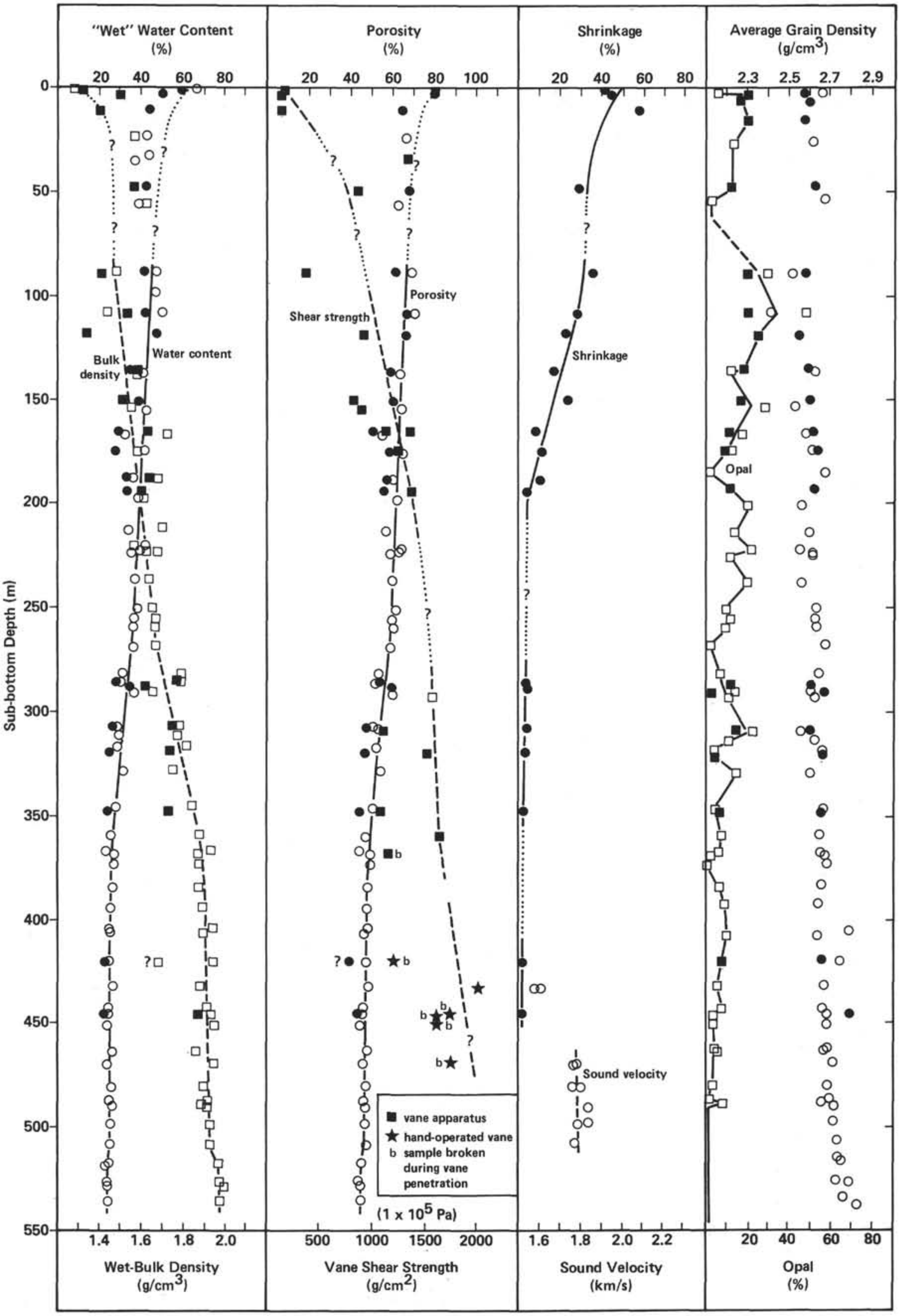

Figure 27. Mass physical properties, shrinkage, and proportion of opaline silica sediments, Holes 474 and 474A. (Closed symbols are cylinder samples. Open symbols are chunk samples.)

5 mm into the split core, the material broke during penetration. Highest values for vane shear strength or cohesion measured by this method are near 2×10^5 Pa (~ 2 kg/cm^2). In the sequence below 470 meters, no further vane measurements were possible, and small cylinders could no longer be used for sampling.

The trend line of the vane shear strength (Fig. 27) for 0 to 480 meters is very uncertain because of the wide scatter of data. One of the reasons for this scatter is differential lithification, which does not affect all sediment layers the same way. For example, vane shear strength at about 34 meters is very high. Nevertheless, some vane tests are affected by partially saturated conditions caused by expanding gas after the high *in situ* pressure on the sediment had been released.

On some selected chunks from the lower part of the sediment sequence, the sound-velocity data were measured perpendicular to the bedding (Fig. 27). From about 430 to 500 meters, the sound velocity increases from 1.6 to about 1.8 km/s. Similarly, acoustic impedance varies between 3.05 and 3.52×10^5 g/cm^2 *s*. Additional sound velocity measurements, not represented in Figure 27, are listed in Table 5. The acoustic impedance of the dolerites (Cores 474A-40 through 474A-42) varies between 17.66 and 18.51×10^5 g/cm^2 *s*. (See also section on Correlation of Drilling Results and Seismic Data, this chapter).

Bulk density curves obtained gravimetrically were compared with the GRAPE data from unsplit cores. Because the thickness of the cores varied, only the highest values in the hard copy of the GRAPE data were used for comparison. Though the GRAPE measurements appear to be not very accurate, they generally agree fairly well with the gravimetric determinations of bulk density.

As already mentioned, the physical properties are also somewhat related to short, vertical changes in the texture and composition of silty and clayey sediments. In Hole 474, some values for bulk density appear to be as much as 0.05 to 0.1 g/cm^3 lower than the average values at the corresponding depth, although water content and porosity are about normal. All samples contain large portions of siliceous, mostly diatomaceous, ooze. The relatively low bulk density is probably caused by the high content of biogenic opal with specific gravity values between 2.0 and 2.20 g/cm^3; this contrasts with the much higher values of quartz, feldspar, and clay minerals. For that reason, the average grain density also decreases with increasing opaline silica. If we assume an average specific gravity of 2.70 g/cm^3 for "normal" grains such as quartz, feldspar, carbonate, and clay minerals and 2.10 g/cm^3 for opaline silica, the percentage (per volume of solid particles) of opaline silica can be taken from Figure 28. The results of this procedure, and the corresponding data of grain density determinations aboard *Glomar Challenger* and in a shore-based laboratory (see Einsele on physical properties, this volume, Pt. 2), are plotted in Figure 27. The possible error in determining the percentage of biogenic silica—an error caused by specific gravities deviating from the values of the two principal "pure" constituents—can also be seen in Figure 28. A further source of error is organic matter, but since its percentage usually is low, it is not considered here. Generally, the curve for the biogenic silica versus depth (Fig. 28) confirms visual estimations from smear slides used for the core descriptions. Below about 260 meters, the content of opaline silica approaches zero, because this constituent is transformed to chalcedony (specific gravity = ~ 2.60 g/cm^2).

Nevertheless, clayey silts or clayey siltstones poor in, or devoid of, opaline silica may have, in relation to their sub-bottom depth, lower water contents and porosities but higher bulk densities than the average samples at the corresponding depth. Most of these samples are from the lower part of mud turbidites, whereas the samples from the upper part of these beds contain more water, have higher porosities, and have lower bulk densities

Table 5. Sound velocity (v_S), wet-bulk density (BD), and acoustic impedance (AI) of some hard rock samples from Hole 474A.

Sample (level in cm)	Rock Type	Orientation	v_S (km/s)	BD (g/cm^3)	AI ($\times 10^5$ g/cm^2 s)
474A-38-1, 37	arkosic sandstone, cemented		4.29		
			5.04		
			4.33		
474A-40-1, 70	dolerite	parallel	6.09	2.97	18.09
		parallel	6.12		17.88
			6.12		18.18
474A-42-1, 32	dolerite	parallel	6.67	2.87	19.14
		parallel	6.42		18.43
474A-42-3, 66	dolerite	parallel	6.07	2.91	17.66
			6.09		17.71
474A-42-5, 98	dolerite	parallel	6.30	2.92	18.40
		parallel	6.29		18.37
			6.34		18.51
474A-43-3, 19	dolerite	parallel	5.82		
		parallel	6.04		
			5.92		
			5.70		
474A-44-3, 39	basalt	parallel	4.80		
		parallel	4.97		
			4.95		
474A-45-3, 60	basalt		5.56		
474A-46-1, 124	fine-grained basalt	parallel	6.09		
			5.99		
474A-47-3, 48	plagioclase-phyric basalt	parallel	6.24		
			6.27		
474A-49-2, 68	plagioclase-phyric pillow basalt	parallel	5.77		
		parallel	5.79		
			5.95		
			5.88		

Note: All samples from Cores 474A-40 through 474A-49 were soaked in water before sound velocity measurement.

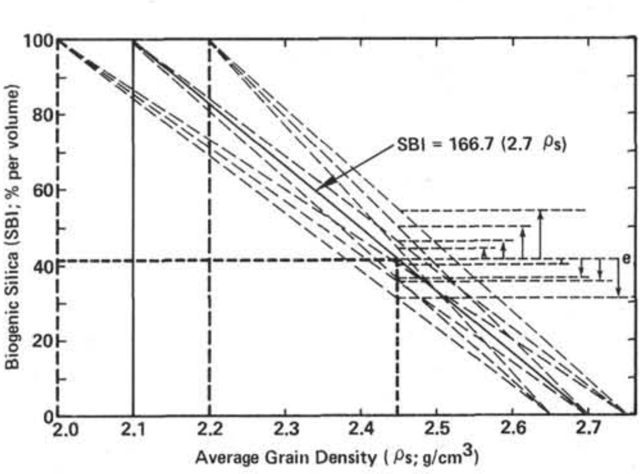

Figure 28. Graph to determine opaline silica content from average grain density (ϱ_s), Holes 474 and 474A. (The solid line and the SBI formula are valid for mixtures of "normal" grains [$\varrho_s = 2.70$ g/cm^3 and opal of $\varrho_s = 2.10$ g/cm^3; e = possible errors if grain densities of end members deviate from values assumed above].)

than the average samples. (For special information on physical properties of mud turbidites see Einsele and Kelts, this volume.) The differences between samples of changing texture and composition decrease downhole.

Therefore, in the lower part of the sediment sequence, the physical property data are surprisingly constant. Slight deviations of single data points from the general trend line are, however, still caused by sampling from different positions within single mud turbidites. The trend lines of Figure 27 correspond more or less with the middle part of mud turbidites.

HEAT FLOW AND THERMAL CONDUCTIVITY

Logging in Hole 474A provided one usable bottom temperature during the second temperature-logging run, 28 hr. after circulation was stopped in the hole. A temperature of 58.5°C was reached after the logging tool sat 15 min. at 509 meters sub-bottom. The temperature was still slowly rising when the tool was pulled up, suggesting an equilibrium temperature of about 60°C.

No thermal conductivity measurements were made in this hole. Above 509 meters, where the sub-bottom temperature was taken, the lithology can be approximated by two lithologic units—the claystone below 239 meters and the silty clay above this depth. We assume a thermal conductivity of about 3 mcal/cm s °C for the claystone and 2.5 mcal/cm s °C for the silty clay.

Heat flow can be estimated by the equation

$$T_z = T_0 + q \sum_i D_i/K_i,$$

where T_z = temperature at depth $z = \sum_i D_i$, K_i is the thermal conductivity of the ith homogeneous section of thickness D_i, T_0 = a constant bottom-water temperature, and q = heat flow (Beck, 1965). The calculation for Site 474 yields a heat flow of 3.1 μcal/cm^2 s, slightly low for oceanic crust around 4 m.y. old.

CORRELATION OF DRILLING RESULTS AND SEISMIC DATA

Extensive seismic reflection profiling has been done in the vicinity of Site 474. The site was selected at the crossing of two lines run on *Thomas Washington* in February 1978 on the Guaymas site-survey expedition (Moore et al., 1978) and a dense network of other lines, including some run by the University of Washington group in a 1975 site survey (Lewis et al., 1975). In addition, reflection records with 2- and 10-s sweeps and different bandpasses (40–160 Hz and 10–40 Hz, respectively) were collected on approaching the site. A sonobuoy wide-angle and refraction run was made while on the site, and a cross line with 5-s and 10–80-Hz bandpass was run after leaving the site. This section correlates drilling results with these various seismic records and information from the downhole logging.

The key to correlating this information is an estimation of seismic velocities to calculate depths. Because of the high gas content, laboratory measurements of velocity could not be made for most of the sediment section. We thus used the sonic log to estimate interval velocities, and the correlation between the sonic and the drilling lithologies is shown in Figure 29. The upper 135 meters of the hole could not be run with the sonic log, because the drill pipe was pulled out of the hole only to this depth, and the sonic log of the section down to about 200 meters was unusable because of poor correlation between the emitted and received pulses. Using these velocities, and assuming velocities of 1.60 and 1.70 km/s for the upper 0–60 and 60–200 meters of section, the lithologic section correlates well with seismic reflection records run through this site (Figs. 30, 31, 32).

Some details of lithology correlate with specific reflectors or groups of reflectors (Fig. 30). The most prominent reflecting horizons that appear to correlate are contact between Units I and II, the top and bottom of the sand and gravel debris-flow unit at 58 to 87 meters, changes in lithology at about 125 and 180 meters, a sand layer at 275 meters, and the tops of igneous units at 521 and 543 meters. Some of these same reflectors can be seen in the processed 24-channel reflection record from the Scripps Institution of Oceanography Guaymas Expedition run about 1.8 km from this site (Fig. 31) and in a 2-s sweep cross line from the Guaymas Expedition (Fig. 32). The debris flow from 58 to 87 meters shows up especially well, as do the sill and basement.

A sonobuoy run was made while drilling Hole 474A. Two airguns, 120 and 20 in.^{3}, were buoyed off the stern of *Glomar Challenger* and fired at 10-s intervals, while a Fairfield sonobuoy, with a large plastic box acting as a sail, drifted away on a heading of 105°. Two sweeps were recorded, 5 and 10 s, with bandpass set at 5 to 40 H_3 (Figs. 33, 34). The wide-angle reflection part of the records was analyzed ashore by R. T. Bachman of NOSC, San Diego. He obtained a solution for a single-layer-to-sub-bottom depth of 460 meters with a mean velocity of 1.69 km/s. This compares with about 1.75 km/s obtained from the velocities in Figure 29. A sonobuoy run during the multichannel survey of Guaymas Expedition—abeam of and about 1.8 km away from the site—gave a wide-angle velocity of 1.98 km/s for the sediments (and the one sill) above the reflector we interpret to be the dolerite at 543 meters depth. This compares with a mean velocity of 1.77 km/s obtained from the sonic log and the correlations already described.

Both sonobuoys run from *Glomar Challenger* and the Guaymas Expedition had strong refracted arrivals that gave apparent velocities of about 6.0 and 6.6 km/s, respectively. Simple layer solutions put this refracting horizon well below the dolerites drilled in Hole 474A. Both sonobuoy runs were at a heading of about 105°, and the shoaling of the "basement" in this direction would cause the apparent velocity to be greater than the true velocity and the apparent depth to be too great. Thus the refracted arrivals undoubtedly represent either the upper sill at 521 meters or the sequence of sills and flows starting at 543 meters. In retrospect, we now believe there is a good possibility that older sediments may exist in this stratified-layer-2 complex to depths as great

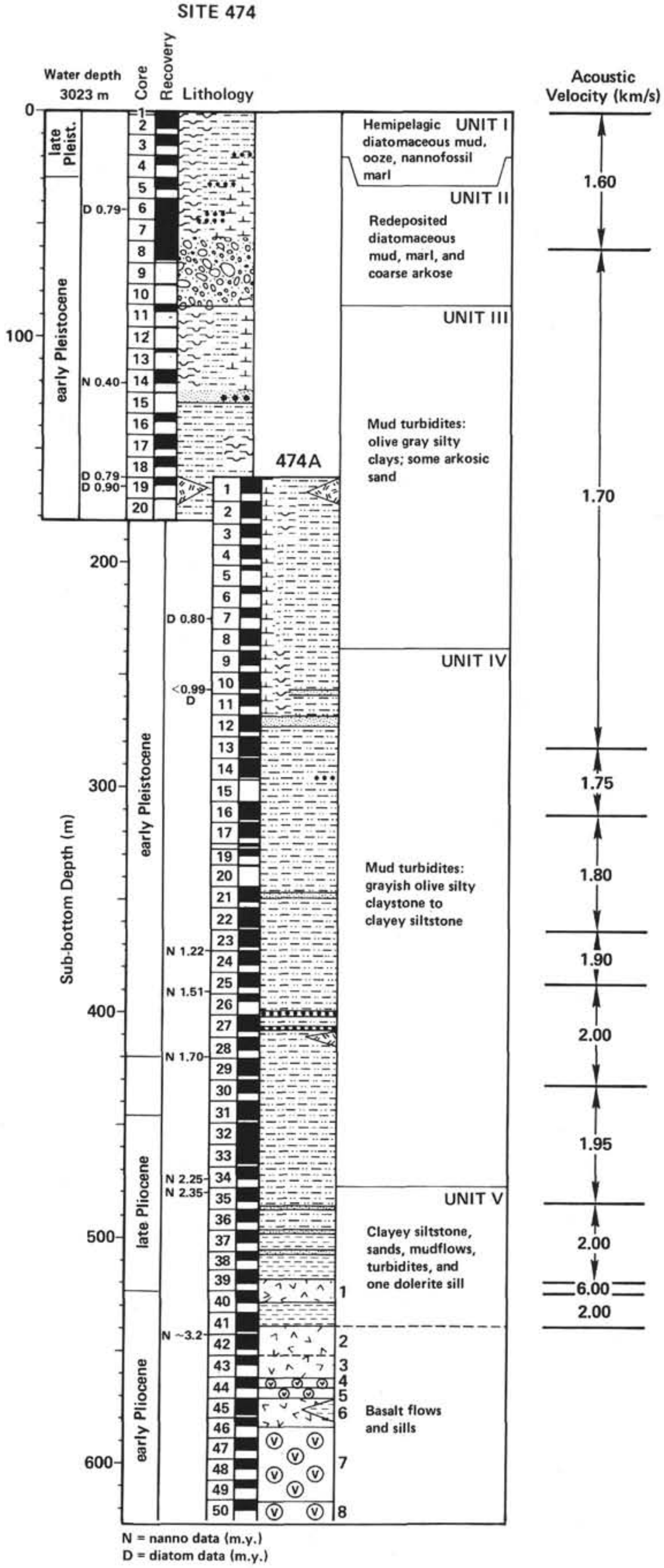

Figure 29. Correlation between lithology and acoustic velocities, Site 474.

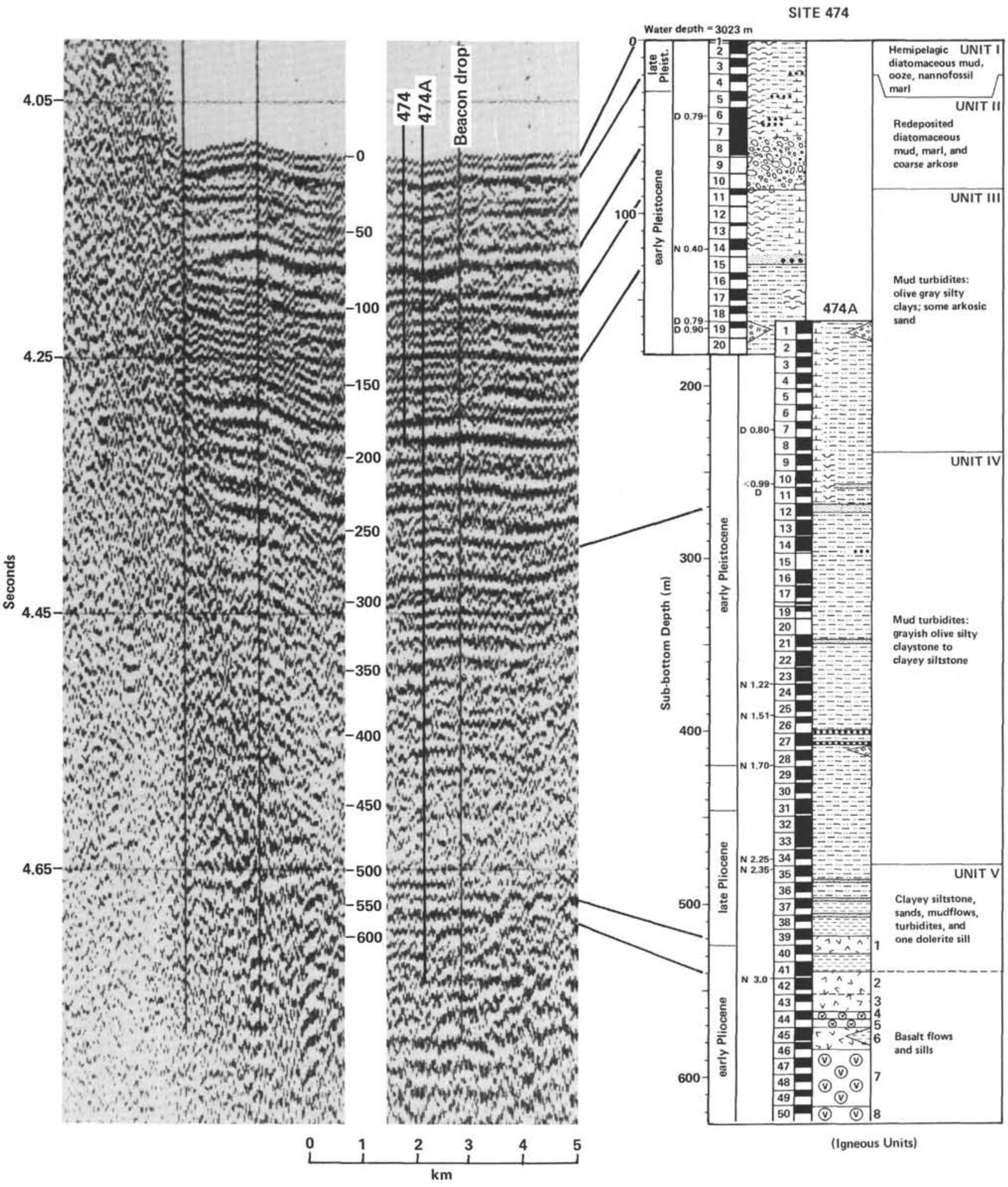

Figure 30. Correlation of drilling results with seismic reflection record from *Glomar Challenger*, Site 474.

as about 0.8 s below the sea floor or a total depth of about 1200 meters below the sea floor.

DOWNHOLE LOGGING FOR SITE 474

Results of downhole logging, compared to lithology, calcium carbonate, and physical properties, are shown in Figure 35. Original tapes are available from storage at the DSDP Information Handling Group. These provide significant information on the depth relationships of sills and their sub-unit boundaries, the position and thickness of various mass flow beds, the onset of diagenesis, the width of contact zones around sills, and clues to hard and soft lithologies that were disturbed during drilling or were not recovered.

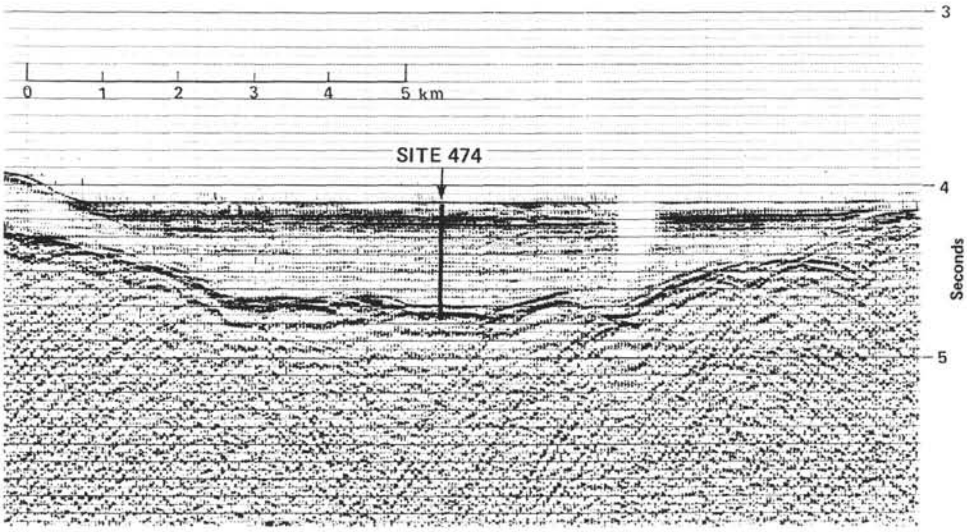

Figure 31. Correlation of Site 474 drilling with processed 24-channel reflection record from SIO Guaymas Expedition.

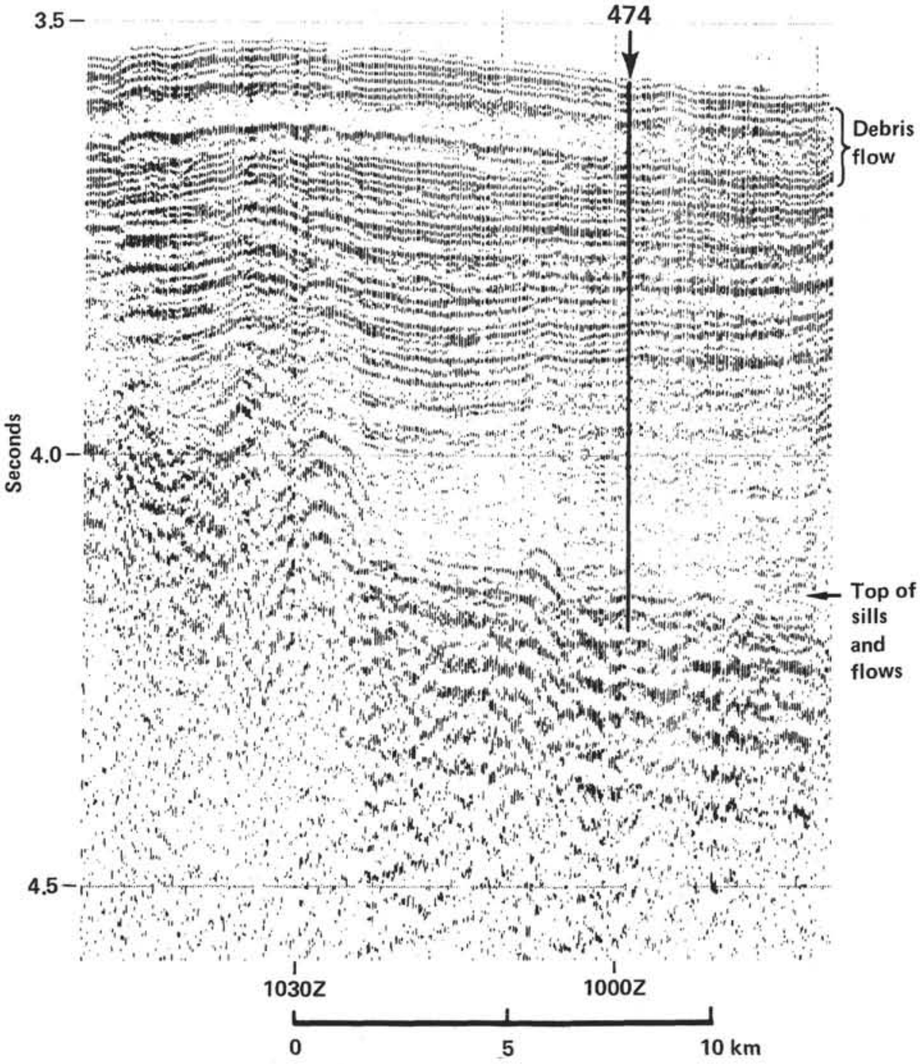

Figure 32. Correlation of Site 474 drilling with single-channel analog seismic reflection record from SIO Guaymas Expedition.

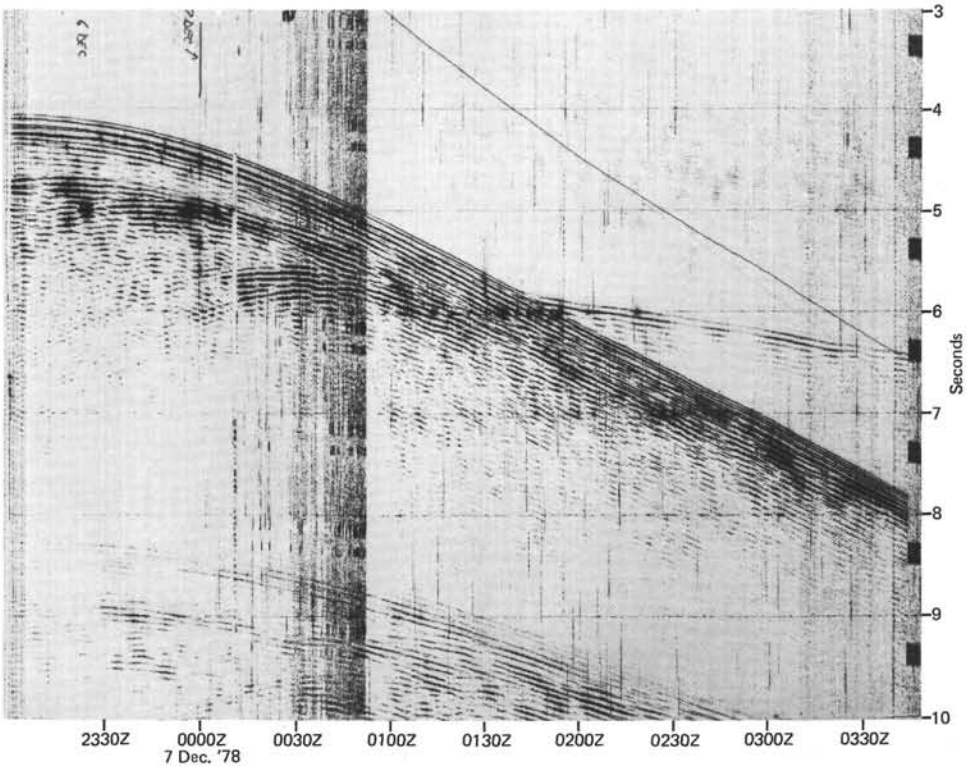

Figure 33. Airgun sonobuoy wide-angle reflection and refraction record from *Glomar Challenger*, Site 474 (10-s sweep).

SUMMARY AND CONCLUSIONS

Drilling Summary and Objectives

Site 474, in a basin at the base of the continental slope and 55 km southeast of the tip of Baja California, is the first of a three-site transect to study the evolution of a young, passive continental margin.

Specific objectives at Site 474 were as follows: to confirm that the site lies seaward of the continent/ocean-crust transition and to determine characteristics of the basement rocks; to determine the lithologic and biostratigraphic facies distribution; to look for evidence of Pleistocene sea-level fluctuations, and the subsidence history of the area; to study the nature and age of the oldest sediments on the oceanic basement and the extent of diagenesis of mineral and organic matter; and to seek evidence for changes in the paleoenvironment.

Two holes were drilled at Site 474. The first, in a water depth of 3023 meters, was continuously cored to 182.5 meters. Drilling terminated at that depth because of a bent heat-probe/pore-water sampler; this necessitated pulling the drill string. Hole 474A was offset 300 meters to the southeast and washed to 161 meters before being continuously cored to a total depth of 626 meters. Two dolerite sills were encountered between 521 meters and the first pillow basalt "basement" at 562.5 meters. Sediments were recovered from between these sills, and the oldest sediment was a small fragment of late Pliocene (NN16; 2.3-3.0 m.y.) claystone beneath the first pillow basalt flow at 572 meters. We penetrated 105 meters after encountering the first dolerite sill and 63.5 meters into the oceanic basement. The possibility remains, however, that older, intercalated sediment lies still deeper within the pillowed flows and that we did not penetrated to oldest sediment.

The Sedimentary Section

Five depositional units are recognized within the 562-meter sedimentary section. The units are based on lithologic, faunal, genetic, and age considerations and were not specifically selected to correlate with seismic or logging data. The sediment section at this site is mostly hemipelagic mud and a thick sequence of mud turbidites, indicating its position on the lower part of a submarine fan, fed primarily by the well-developed submarine canyon system of the southeastern tip of Baja California. A feature of the upper section is the redeposited slump-debris-flow-turbidite units from 21 to 87.3 meters (see Moore et al., this volume, Pt. 2). The base of this flow is coarse sand and conglomerates, and the upper nannofossil-diatomaceous mud contains evidence of warmer, shallower-water fauna than occurs in the sediments either above or below the slide deposit. The rate of accumulation from the oldest sediment to the top of the Pliocene is about 86 m/m.y. In the thick turbidites above the Pliocene/Quaternary contact, the rate dramatically increases to 395 m/m.y. Above the slide mass, the rate again decreases to about 47 m/m.y.

Biostratigraphy was determined primarily by the presence of nannofossils, which persist to the basement, whereas siliceous radiolarians and planktonic foraminifers are preserved only to 275 meters in the Quaternary

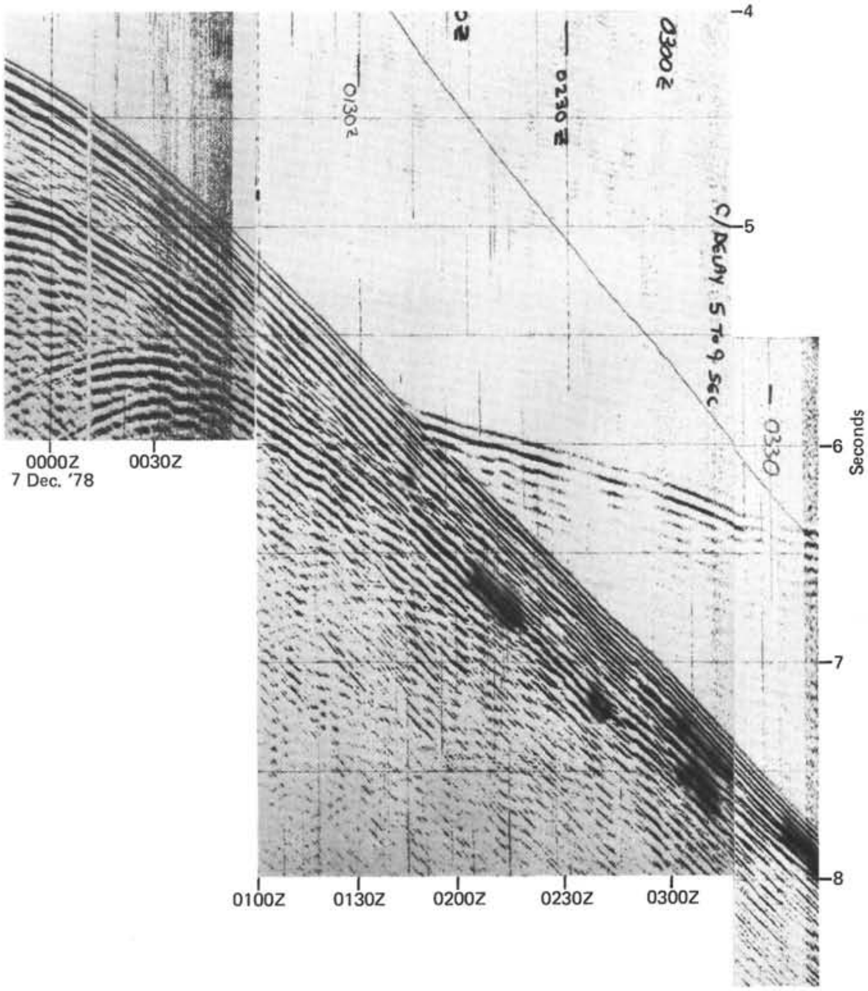

Figure 34. Airgun sonobuoy wide-angle reflection and refraction record from *Glomar Challenger*, Site 474 (5-s sweep).

section. Values for dissolved silica clearly indicate the abundance of siliceous materials in the upper 275 meters (Fig. 21). The drop to lower values at 300 meters may be related to the recrystallization of silica associated with the weathering of plagioclase feldspars (source for calcium) and the formation of smectites (sink for magnesium). Values of dissolved calcium increase and dissolved magnesium decrease in this same section.

Ratios of ethane to methane follow a similar pattern: There is a normal linear increase (semilog scale) to about 300 meters and then a decrease from the maximum of 8.5×10^{-4} to about 11.5×10^{-5} in the lower part of the section. Methane is an essentially constant component of interstitial gas, whereas ethane increases to a maximum and then decreases, reflecting the slower diffusion of ethane from the more indurated sediments below 300 meters. The organic matter of this sediment sequence is of biogenic origin. No typical petrogenic hydrocarbons occur, despite the high thermal gradient. The observed increase in the C_2-C_4 hydrocarbons (methane, ethane, propane, and isobutane) with depth may result from low-temperature decomposition of biogenic organic matter near the intruded dolerite in the lower sedimentary section. This phenomenon has been observed under similar circumstances on Leg 41.

Physical properties of the sediments also indicate a similar history of compaction and lithification. Strong gradients of increasing bulk density and shear strength and decreasing porosity in the upper 20 meters are normal but possibly amplified by the abundant biogenic silica in the sediment. From 20 to 100 meters, all data remain relatively constant, and between 100 and 250 meters water content, bulk density, and porosity change slowly with increasing overburden pressure. Recrystallization appears insignificant in this interval, because biogenic silica and calcareous nannofossils still occur in considerable quantities. From about 200 to 275 meters to about 360 meters, water content and porosity decrease rapidly, and bulk density increases from 1.67 to nearly 1.80 g/cm^3. In about this same interval, the

Igneous Rocks

We identified eight igneous lithologies at Site 474 and placed them in five petrologic units. These include several intrusive units, probably sills, and a pillow-lava sequence. Units 1 and 2 are intrusive, olivine dolerite sills concentration of dissolved silica is relatively very low, signifying that formation of chalcedony and authigenic clay minerals may have contributed to lithification of the sediments.

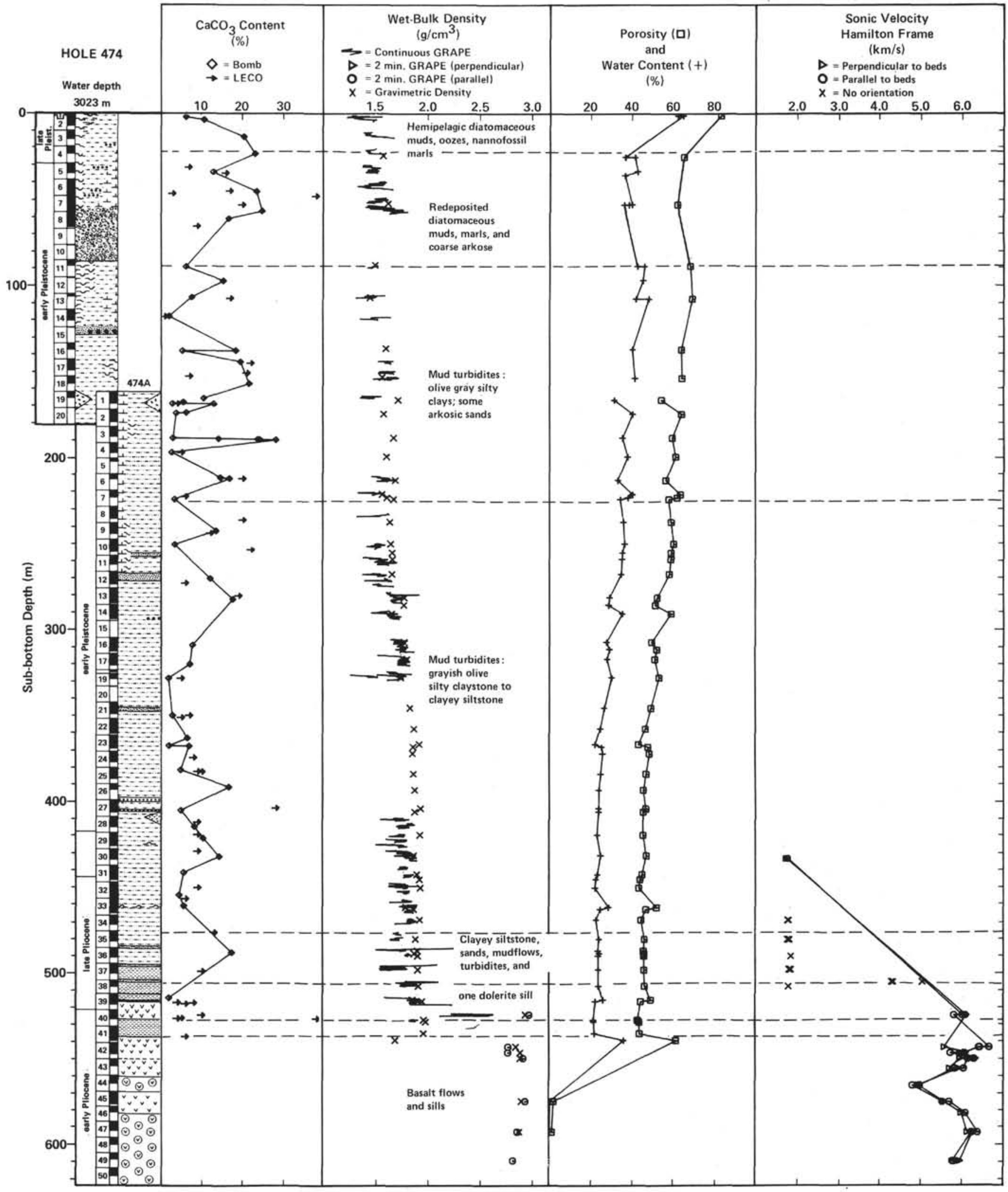

Figure 35. Results of downhole logging compared to lithology, calcium carbonate, and physical properties, Site 474.

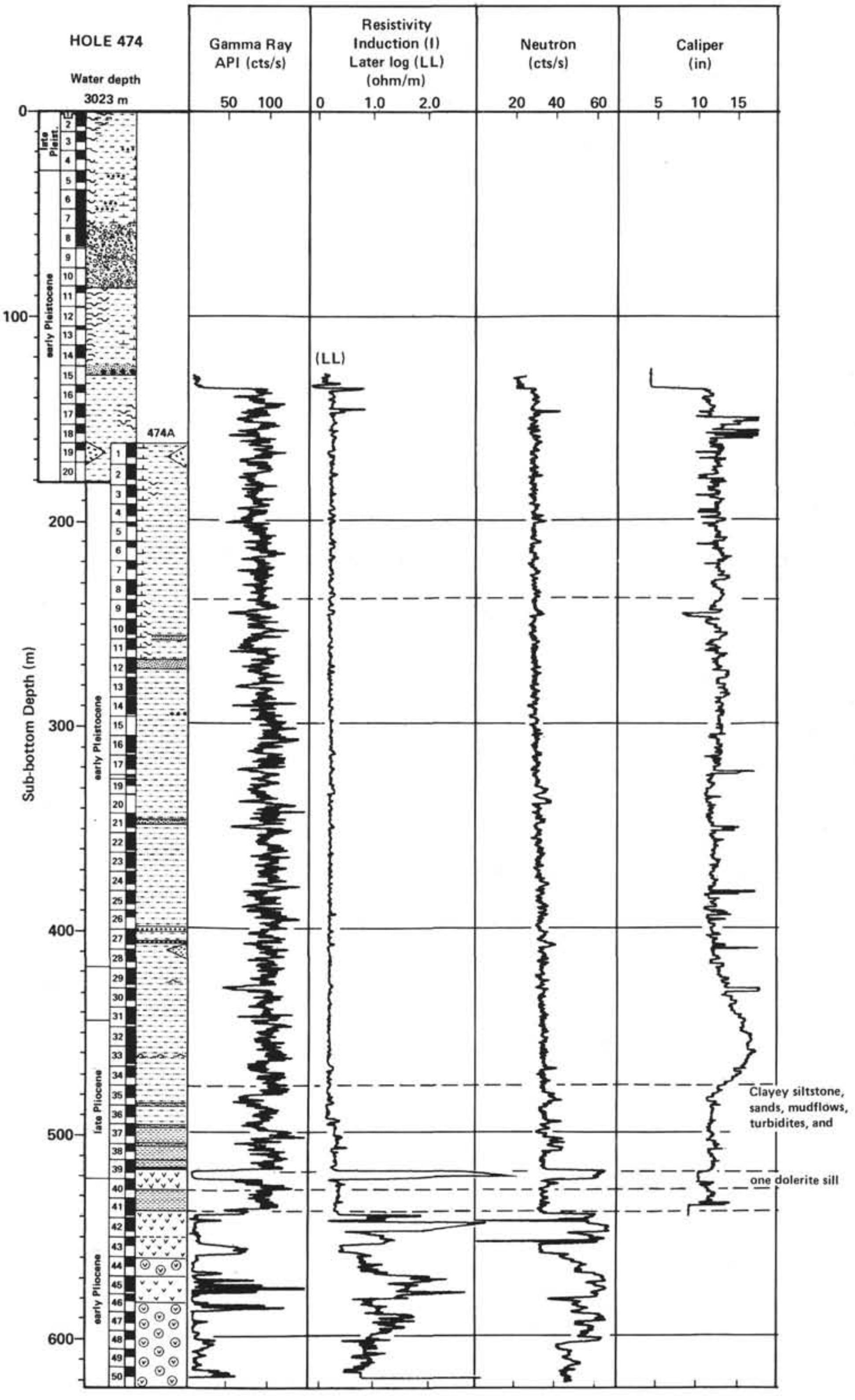

Figure 35. (Continued).

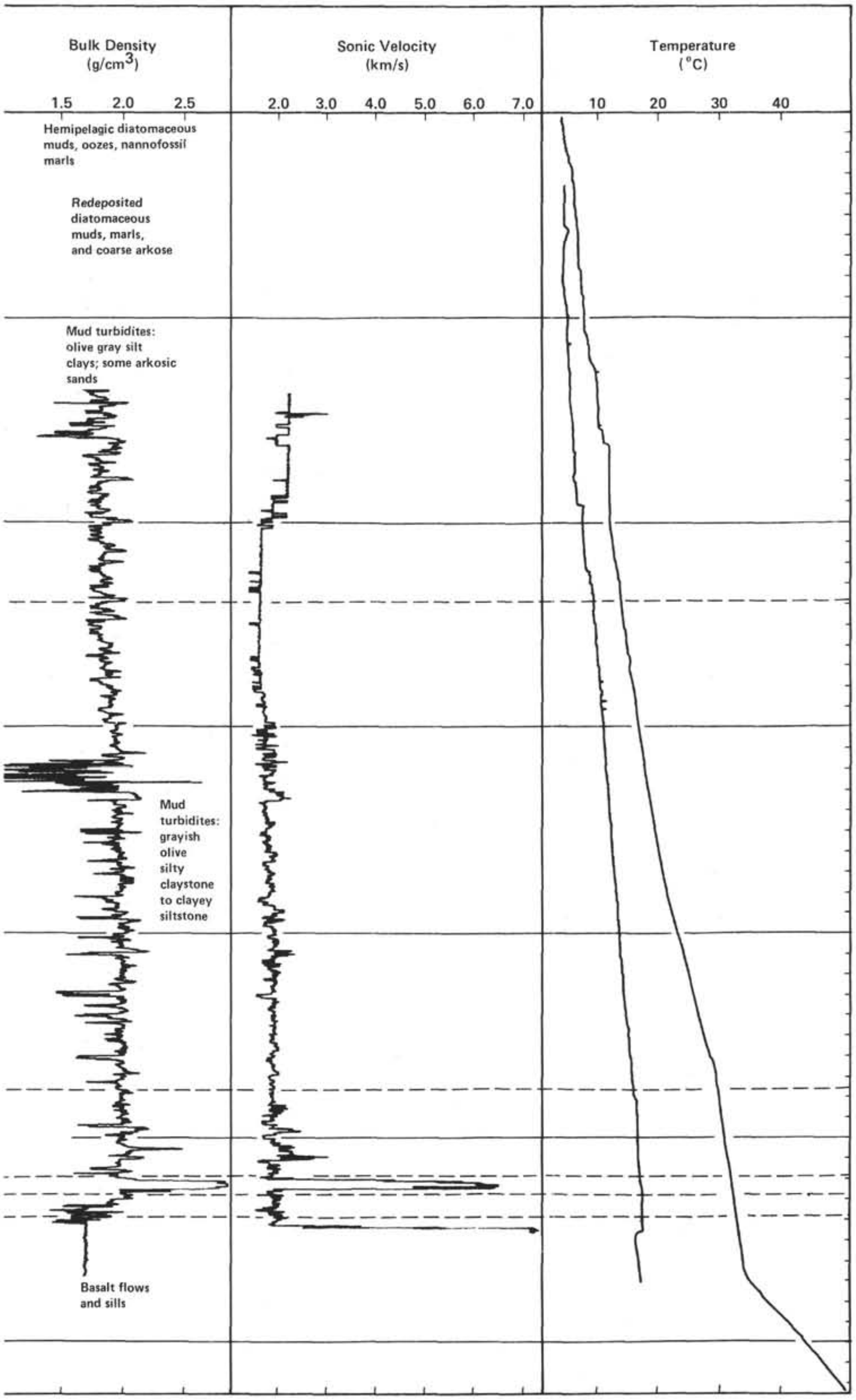

Figure 35. (Continued).

within the lower 43 meters of the sedimentary section. Unit 3 comprises two distinct pillow basalt flows. Unit 4 is a dolerite sill within the pillow-lava sequence, and Unit 5 comprises pillow basalt and coarse basalt or dolerite that may be a sill. The pillow-basalt sequences are predominantly plagioclase-phyric with minor olivine phenocrysts; clinopyroxene is not a phenocryst phase in any of the basalts. The pillow basalts are therefore similar to abyssal basalts from other ocean ridges and basins.

Correlation of Drilling Results with Seismic and Logging Data

This site lies in a network of previous underway geophysical surveys, and additional seismic reflection and sonobuoy wide-angle refraction lines were run before and after drilling. The downhole logging program included temperature, sonic, density, and porosity, caliper, natural gamma radiation, and guard (electric) measurements. On shipboard, the sonic log derived acoustic velocities for correlation with the seismic reflection records over the site. Correlations are generally good, and some major lithologic changes and depositional events can be observed in the records, principally the redeposited slump-debris-flow-turbidite unit. Reflection records suggest the possibility of an additional half kilometer of stratified material below the basement rock sampled. Intercalated sediments may be incorporated in these stratified units.

Geological History and Paleoenvironment

The petrologic and biostratigraphic evidence indicates that this site is floored by oceanic crust generated by rifting approximately 3.2 Ma with the initiation of the present phase of opening of the Gulf of California. These observations agree well with the magnetic chronology of the current spreading at the Gulf mouth (Larson et al., 1968; Lewis et al., 1975). At this initial rifting, the sea floor at this site was already at abyssal depths. No coarse volcaniclastic or continental conglomerates were recovered, and late Pliocene sediments overlying the basement already indicate a distal fan to hemipelagic character. During the late Pliocene (NN17/18; 2.2-1.8 m.y.), a sedimentation pattern of turbidites, hemipelagic mud, and sporadic mud flows was established and continues through the present.

Planktonic foraminifers in the Quaternary sections of this site record geographical shifting of water masses. Most of this section contains a "subtropical" population, but in certain intervals we observed an apparent increase in the population of species that recently dwelled in the California Current.

SITE 475 (HOLE 475)

Date occupied: 10 December 1978

Date departed: 12 December 1978

Time on hole (hr.): 33.83

Position: 23°03.03′N; 109°03.19′W

Water depth (sea level; corrected m, echo sounding): 2631

Water depth (rig floor; corrected m, echo sounding): 2641

Bottom felt (m, drill pipe): 2650

Penetration (m): 196

Number of cores: 21

Total length of cored section (m): 196.0

Total core recovered (m): 127.9

Core recovery (%): 65

Oldest sediment cored:
Depth sub-bottom (m): 196
Nature: Polymictic conglomerate
Age: Pliocene (NN15 or older)

Basement: Not reached

Principal results: Hole 475 is in a slope basin 21 km southeast of the tip of Baja California; it was continuously cored to a depth of 196 meters. A cobble conglomerate at 158 meters eventually stopped the drilling. Recovery was nearly 80% in the sediment column but only 5% in the conglomerate. Five lithologic units are recognized: Unit I, from the mudline to 34 meters, is late Quaternary nannofossil diatomaceous mud; Unit II, 34-130 meters, is late Pliocene to early Pleistocene clayey silt to silty clay; Unit III, 130-153 meters, is early Pliocene diatomaceous mud. These units accumulated at a rate of about 40 m/m.y. Unit IV, 153-158 meters, is early Pliocene zeolite-bearing and dolomite mudstone of unknown but slow depositional rate; and Unit V, 158-196 meters, is an early Pliocene(?) conglomerate of metavolcanics, and metasedimentary, rhyolite, and ignimbrite cobbles.

Heat flow and thermal conductivity measurements give a heat flow value of 3.9 heat flow units. No *in situ* basement was recovered, but the conglomerates are interpreted as a subaerial deposit that rapidly subsided as the first opening of the Gulf of California began.

SITE 475 (HOLE 475A)

Date occupied: 12 December 1978

Date departed: 12 December 1978

Time on hole (hr.): 5.33

Position: 23°03.44′N; 109°03.83′W

Water depth (sea level; corrected m, echo sounding): 2545

Water depth (rig floor; corrected m, echo sounding): 2555

Bottom felt (m, drill pipe): 2591.5

Penetration (m): 16

Number of cores: 1

Total length of cored section (m): 9.5

Total core recovered (m): 0.15

Core recovery (%): 1.6

Oldest sediment cored:
Depth sub-bottom (m): 16
Nature: Hard dolomitic mudstone
Age: Older than late Pliocene (NN15/16)

Basement: Not reached

Principal results: To avoid drilling conglomerate and to reach the assumed granitic basement, Hole 475A was drilled upslope of (1.34 km NW), and adjacent to, Hole 475. At 16 meters submudline, the bit hit a hard layer and only a small piece of hard mudstone was recovered.

SITE 475 (HOLE 475B)

Date occupied: 12 December 1978

Date departed: 13 December 1978

Time on hole (hr.): 12.08

Position: 23°03.36′N; 109°03.57′W

Water depth (sea level; corrected m, echo sounding): 2593

Bottom felt (m, drill pipe): 2629.5

Penetration (m): 96

Number of cores: 4

Total length of cored section (m): 38

Total core recovered (m): 10.4

Core recovery (%): 27

Oldest sediment cored:
  Depth sub-bottom (m): 9.5
  Nature: Diatomaceous mud/basalt
  Age: Late Pleistocene (NN21/?)

Basement: Not reached

Principal results: Drilling in Hole 475B recovered a mudline core of Quaternary nannofossil diatomaceous silty clay. The hole was washed to 76 meters before basalt cobbles were encountered; we cored 20 meters in cobbles and recovered a few percent. Basalts are of subaqueous extrusion and petrographically similar to mid-ocean ridge basalts but are not part of an *in situ* flow.

SITE 475: BACKGROUND AND OBJECTIVES

Site 475 (Planning Site GCA-6) was the second site in the passive continental margin transect off Baja California. The general objectives of drilling this transect are outlined elsewhere in the volume. More specific objectives are listed here.

This site lies on the lowermost continental slope, southeast of the tip of Baja California (Figs. 2, 7); it was selected as one of the sites to bracket the continent/ocean crust transition. From geophysical surveying and rock dredging we presumed that the transition was between Site 474 and this site, which lies on a ridge in line with the northeasterly trend of Cabrillo Seamount (Fig. 2). Granodiorites and quartz diorites have been dredged from the Cabrillo Seamount (Shepard, 1964; Moore et al., 1978), but Lewis et al. (1975) dredged basalt from another location (DH-8 in Fig. 2).

Our plan was to drill at this site if oceanic crust had been reached at Site 474; if continental crust were recovered at Site 474, we would move farther seaward.

The specific objectives of this site included, but were not limited to, the following:

1) Basement rocks
    a) Determining whether this site lies seaward or landward of the continent/ocean transition
    b) Determining the composition, character, and—if possible—the age of the basement rocks, which were presumed to be either the oldest oceanic basement or the most seaward continental rocks near the transition
2) Nature of the sedimentary section
    a) Determining general lithologic and biostratigraphic facies distributions
    b) Determining water depth indicator changes downward in the section as a record of subsidence history and age of the oldest marine sediments
    c) Determining the nature and age of the oldest sediments on basement
    d) Obtaining a record of Pleistocene sea-level fluctuations
    e) Determining the diagenesis of organic and inorganic matter
3) Evidence of climatic or oceanic circulation changes
4) Evidence relating to the proto-Gulf of California history.

OPERATIONS

From Site 474, we made a seismic survey for Site 475 (Figs. 7, 36). We passed over our Site 474 beacon on 10 December 1978 at 0000Z. Our course was 010°T, and at 0022Z we changed to 298°T, profiling up the slope approximately parallel to the track of the *Thomas Washington* Guaymas 01 record of 19 February 1978. At 0114Z we dropped a 13-kHz beacon on Site 475 and continued on course until 0134Z, when we retrieved equipment to return to the beacon. No signal strong enough to verify was found, however, and we had to wait for a satellite fix at 0420Z before returning to the DR position of the beacon. We were able to position directly over the weak 13-kHz beacon and drop a new 16-kHz beacon; at 0640Z we were in automatic positioning over Site 475. At 1412Z on 10 December, we spudded in the hole. The mud line was found on the second core at 2650 meters, corresponding to a PDR depth of 2641 meters (Table 6).

We cored continuously to a depth of 196 meters. Recovery was unusually good, averaging 79% for the first 158 meters. At that depth, we encountered a thin, lithified dolomitic mudstone overlying cobbles of various metamorphic rock types that reduced recovery to a few

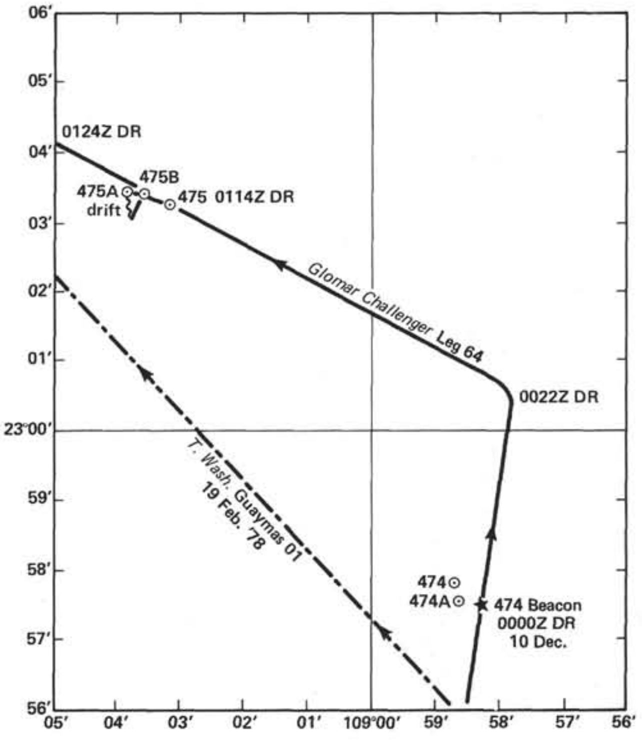

Figure 36. Track of *Glomar Challenger:* Site 474 to Site 475.

Table 6. Coring summary, Site 475.

Core	Date (December, 1978)	Time (Z)	Depth from Drill Floor (m; top-bottom)	Depth below Sea Floor (m; top-bottom)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 475							
1	11	0831	2650.0-2656.0	0.0-6.0	6.0	2.91	49
2	11	0921	2656.0-2665.5	6.0-15.5	9.5	9.40	99
3	11	1012	2665.5-2675.0	15.5-25.0	9.5	9.80	103
4	11	1102	2675.0-2684.5	25.0-34.5	9.5	8.20	86
5	11	1153	2684.5-2694.0	34.5-44.0	9.5	8.45	89
6	11	1243	2694.0-2703.5	44.0-53.5	9.5	9.39	99
7	11	1329	2703.5-2713.0	53.5-63.0	9.5	8.10	85
8	11	1450	2713.0-2722.5	63.0-72.5	9.5	7.89	83
9	11	1545	2722.5-2732.0	72.5-82.0	9.5	5.99	63
10	11	1635	2732.0-2741.5	82.0-91.5	9.5	1.10	12
11	11	1735	2741.5-2751.0	91.5-101.0	9.5	9.02	95
12	11	1825	2751.0-2760.5	101.0-110.5	9.5	7.32	77
13	11	2051	2760.5-2770.0	110.5-120.0	9.5	5.89	62
14	11	2147	2770.0-2779.5	120.0-129.5	9.5	9.57	101
15	11	2245	2779.5-2789.0	129.5-139.0	9.5	9.34	98
16	11	2333	2789.0-2798.5	139.0-148.5	9.5	7.04	74
17	12	0240	2798.5-2808.0	148.5-158.0	9.5	6.41	67
18	12	0435	2808.0-2817.5	158.0-167.5	9.5	0.72	8
19	12	0607	2817.5-2827.0	167.5-177.0	9.5	0.25	3
20	12	0730	2827.0-2736.5	177.0-186.5	9.5	0.57	6
21	12	0903	2736.5-2746.0	186.5-196.0	9.5	0.50	5
Hole 475A							
1	12	2040	2598.0-2607.5	6.5-16.0	9.5	0.15	1.6
Hole 475B							
1	12	2333	2629.5-2639.0	0.0-9.5	9.5	9.84	103
2	13	0326	2705.5-2715.0	76.0-85.5	9.5	0.35	4
3	13	0656	2715.0-2724.5	85.5-95.0	9.5	0.15	2
4	13	0920	2724.5-2725.5	95.0-96.0	1.0	0.05	5

percent and eventually resulted in loss of the hole. The heat probe was deployed successfully in stiff mud at 110.5 meters and again at 148.5 meters.

As we penetrated the cobble zone, drilling times increased sharply from 6 to 8 to 22 to 60 min. per core. After Core 475-21 was retrieved from 196 meters at 1603Z on 12 December, the drill string became stuck as we attempted to resume drilling. The drill string was worked free with difficulty and pulled above the cobble zone. At 1900Z we decided to abandon the hole and move to a position presumably beyond the cobble zone. The bit was not released and no logging was attempted; we believed that the new position would allow basement penetration and result in more useful logging. The drill string was therefore pulled above the mud line and trailed 914 meters upslope (bearing 298°T). The depth at this position did not correspond to that of the seismic line made on our original, dead reckoning approach to Site 475. An attempt to collect in-place seismic data—to check the section against the approach line—was precluded by thruster noise.

By 2230Z on 12 December, the ship was in automatic positioning over the proposed Hole 475A. We found the mud line at 2591.5 meters, and it corresponded to the corrected PDR depth of 2554 meters. We began washing to reach the equivalent Hole 475 depth. At 16 meters, however, we encountered hard drilling. At 0340Z on 13 December, we recovered the barrel and found a short section of the same stiff mud overlying the cobble zone of Hole 475.

Having drifted to the south-southeast, we moved to a new locality midway between Holes 475 and 475A with the drill string pulled above the mudline and the seismic gear deployed. We profiled in this way across the proposed site to a more desirable position somewhat north of a line between the two previous holes; at 0440Z, we were in position above the proposed Hole 475B. At 0545Z, we spudded and found the mudline at 2629.5 meters. We then washed to 76 meters and again encountered a very hard basalt formation. Subsequently, we cored continuously to 96 meters, recovering only 3% of the 20 meters eventually cored in basalt rubble. The hole was caving badly, and we abandoned the site, without attempting a downhole logging program, to avoid possible loss of the bottom hole assembly. Orientation of the three holes at this site is shown in Figure 36. At 2245Z on 13 December, we departed for Site 476.

SEDIMENTARY LITHOLOGY

Site 475 includes Holes 475, 475A, and 475B, but the following description is based only on the complete section from 475. Five lithologic units (Fig. 37; Table 7) were selected on the basis of microfossil abundance, primary sedimentary structures, and mineralogy.

Unit I: Nannofossil diatomaceous hemipelagic mud (Cores 475-1–475-4, 0–34.5 m). Unit I consists of a rather uniform, drab grayish olive to moderate olive brown nannofossil diatomaceous mud. Drilling disturbance is intense, obliterating most sedimentary structures; bedding is indistinct and color boundaries are gradational. Carbonate content—as high as 15%—is from nannofossils. Coccoliths are abundant in Cores 475-1 through 475-4, as are discoasters in Cores 475-5 through 475-11. Diatoms average as high as 25% of the total sediment. Foraminifers, silicoflagellates, radiolarians, and sponge spicules are rare. Sponge spiculites occur sporadically throughout the unit as thin, white laminae or lenses (1–2 mm thick). Dusky yellow green mottling and black reduction spots are common. These lighter zones are characterized by more nannofossils and fewer diatoms.

Minor, angular, silt-size quartz and feldspar range from 5–30% and 2–10%, respectively. Clays range from

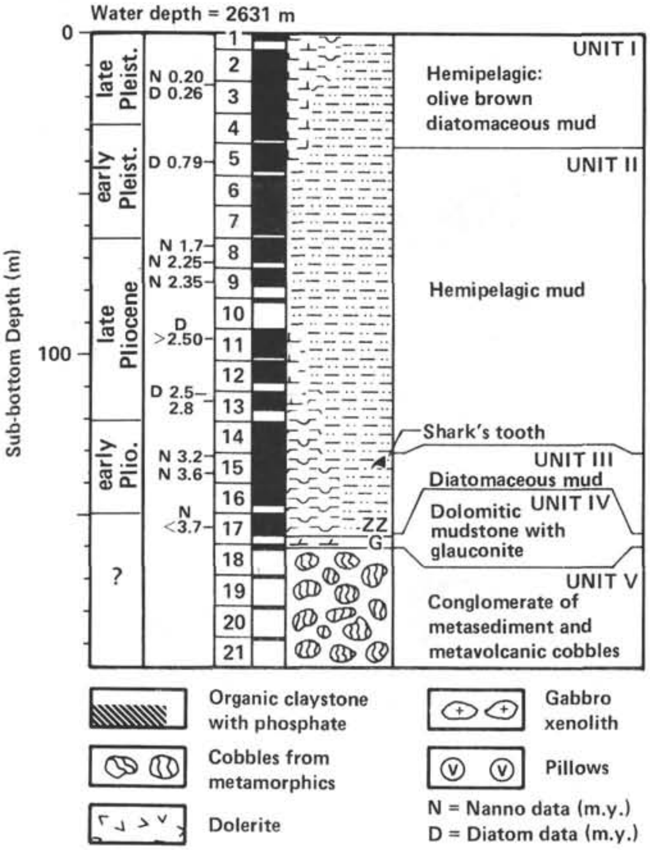

Figure 37. Lithology, lithologic units, and core recovery (shown in black), Site 475.

15-60%. Pyrite is rare but occurs as black, opaque framboids, commonly as a filling in diatom frustules or, rarely, in foraminifer tests. Rare, scattered glauconite occurs as 1-2-mm-thin, bright green lenses set against the grayish olive of the host sediment. Glauconite is commonly associated with the spiculites.

Sporadic undisturbed sections show evidence of decimeter-scale mud turbidites with thin basal sands grading subtly up into grayish olive silty clay.

Unit II: hemipelagic mud (Cores 475-5–475-14, 34.5–130.2 m). Unit II is a firm, grayish olive green to grayish olive clayey silt to silty clay. The contact to Unit I is gradational and best defined by the disappearance of the biogenic components. Biogenic components mostly compose less than 5% of the total sediment but increase again below Core 475-12.

Quartz and feldspar percentages are similar to Unit I. Clay percentages are higher, ranging from 55 to 70% of the total sediment. Black reduction streaks and spots are common.

Drilling disturbance is intense, with brecciation of Cores 475-6, 475-7, and 475-14. Where disturbance is less severe (Cores 475-8 and 475-11), we observed a distinct layering delineated by alternating sediment colors. The color changes are subtle but contacts are sharp. The colors alternate between a dark grayish olive and a lighter color, either moderate olive brown, dusky yellow green, or grayish green. We infer that the mottling observed in Unit I is a more disturbed equivalent to these layers in Unit II—with one exception: The lighter, mottled sediments in Unit I are overshadowed by a nannofossil-rich biogenic component, whereas the lighter layers in Unit II are mostly barren. The darker layers in Unit II contain more silt-size grains and a greater abundance of pyrite (as high as 8%). Some pyrite concretions appear to be cemented burrows. A large nodule from Section 475-13-1 is shaped like *Planolites*. Small discontinuous lenses of sandy silt occur in Sections 475-5-2, 475-6-2, and 475-7-1, possibly as remnants of basal sands from mud turbidites. Above these silty pockets, there is little evidence of grading. A small fragment of

Table 7. Lithological units, Site 475.

Unit	Interval	Depth (m)	Thickness (m)	Lithology	Paleo-environment	Age (m.y.)	Approximate Accumulation Rate (m/m.y.)
I	Cores 475-1–475-5	0.0–34.5	34.5	grayish olive (10Y 4/2) to moderate olive brown (5Y 4/2) nannofossil diatomaceous mud; gradational contacts	hemipelagic with minor mud turbidites	late Pleistocene (~0–0.7)	40
II	Cores 475-6–475-14	34.5–130.2	95.7	grayish olive to drab grayish olive green clayey silts to silty clays; firm; sparse biogenic components (<5%) increasing below Core 475-11	hemipelagic with mud turbidites	late Pliocene to early Pleistocene (~0.7–2.8) (~0.7–2.8)	40
III	Sections 475-15-1–475-17-4	130.2–154.2	23.0	bioturbated to homogeneous diatomaceous moderate olive brown (5Y 5/4) to dusky yellow (5Y 6/4) muds with graded cycles	diatomaceous mud turbidites	early Pliocene	~40+
IV	Sections 475-17-5–475-17,CC	154.2–158.0	4.8	brown gray (5YR 4/1) zeolite-bearing clay, overlying a dusky yellow (5Y 6/4) dolomitic mudstone with glauconite grains	isolated offshore bank within the O_2-minimum zone	early Pliocene(?)	slow(?)
V	Section 475-18-1–Core 475-21	158.0–196.0	38.0	polymictic conglomerate, consisting of metavolcanics, metasedimentary rocks, rhyolite, and ignimbrites and some fresh basalts (Hole 475B)	subaerial alluvial plain; later rifted	?	rapid

wood is embedded in the homogeneous silty clay of Section 475-9-4. Unit II appears to be a series of distal-fan, fine-grained, graded beds in the undisturbed section differing from Unit I only by the lack of biogenic components and turbidites.

Single, well-rounded andesite tuff (pumice) pebbles occur in the hemipelagic sediment of Sections 475-11-5, 475-12-1, and 475-14-1, but drill disturbance leaves their stratigraphic context unclear.

Unit III: mud turbidites (Cores 475-15–475-17, 130.2–154.2). The sharp contact between Unit II and Unit III is defined by a layer of fine, gray white sand, 1-2 cm thick. Drilling disturbance in Unit III is slight, revealing sedimentary structures only inferred in Units I and II.

Unit III is characterized by bioturbated diatom-bearing, moderate, olive brown to dusky yellow silt-clay and homogeneous, moderate olive brown, light olive gray to olive-gray-brown diatomaceous mud. Evidence of subtle grading is common. Most graded beds have a thin basal sand (30–60% quartz; 15–25% feldspar; 6–8% pyrite; 5–20% biogenic material), grading upward to a muddy ooze (20–70% clay; 20–45% diatoms). The top of each graded bed has a "waxy" appearance and is commonly and extensively bioturbated. Bioturbation is often so intense in a graded bed that basal sands deposited in the next graded bed above have been drawn down into the bed below, causing an apparent reverse grading. Some of the basal sands appear winnowed, although this may result from drilling disturbance. This sequence of graded beds, ranging in thickness from 10 to 200 cm and averaging 30 cm, is probably a sequence of distal mud turbidites. A shark's tooth is imbedded in one of these mud turbidites at Section 475-15-3 (36 cm).

Diatoms show a steady increase from ~20% at the top of the unit to 45% in Section 475-17-2 (151.5 m). Diatoms then rapidly decrease, and the sediment is barren by Section 475-17-4 (153.7 m). The basal part of Unit III contains a glauconite- and pyrite-bearing silty clay, underlain by a zeolitic clay and basal sand. The presence of 10% glauconite and pyrite and 30% zeolite suggests a rapid change in sedimentary environment.

Unit IV: dolomitic mudstone with glauconite (Cores 475-17–475-18, 154.2–158.0). This basal sedimentary stratigraphic unit is in sharp contact with the overlying Unit III. A hard zeolite-bearing (clinoptilolite) brown gray clay with glauconite grains characterizes the upper part of this unit and is underlain by a hard, dusky yellow dolomitic mudstone (Fig. 38). The dolomitic mudstone contains quartz clasts and glauconite grains within an equigranular, limpid dolomite rhomb matrix constituting 40% of the total sediment (see Kelts and Lyle, this volume, Pt. 2).

Zeolitic clay and dolomite mudstone are firm but friable, show faint evidence of bioturbation, and are unfossiliferous.

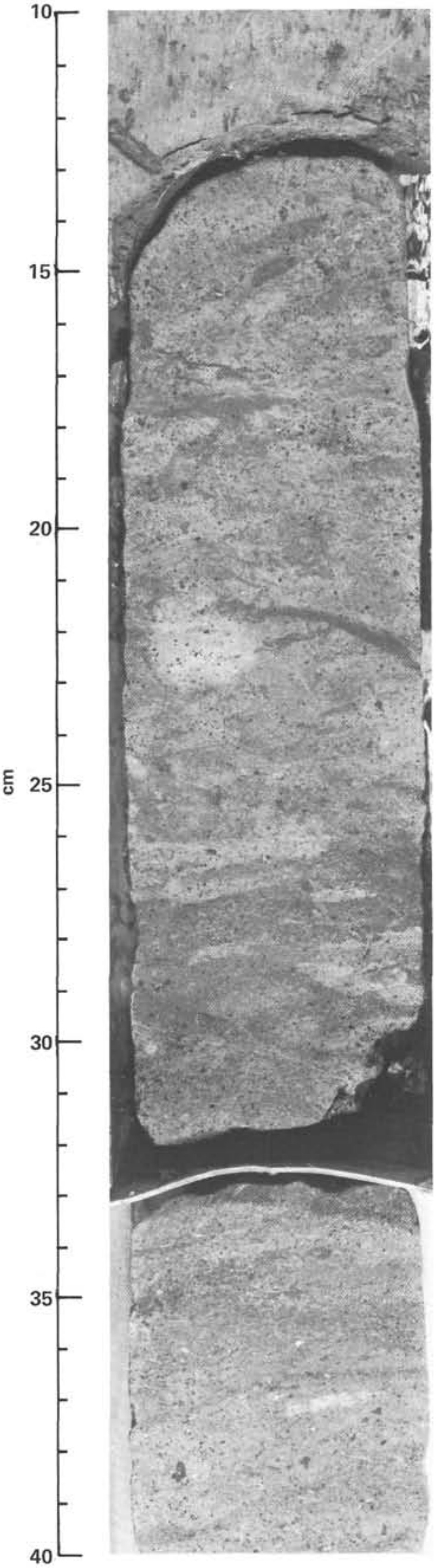

Figure 38. Sample 475-17-5, 10–40 cm, Unit IV: dolomitic mudstone with glauconite pellets and evidence of bioturbation.

Unit V (Cores 475-18–475-21; 158.0–196.0 meters)

Unit V is characterized by a poorly recovered sequence of polymictic pebbles to cobbles. Most are rounded and partially weathered, but any rinds have been removed by drilling abrasion. Component clasts include ignimbrites, fine-grained volcanics, graywacke, low-grade metasediments, perlitic rhyolite, quartzite, shale, schist, and a quartzose metaconglomerate.

Thin sections indicate that some of the metavolcanics include basalts with abundant opaque minerals, altered clinopyroxenes and olivine phenocrysts, small white calcite veins, and no foliations. Metagraywackes are medium grained and poorly sorted.

None of the matrix was recovered, but it is assumed that the conglomerate is clast supported, with a sandy matrix.

In Hole 475B, cobbles were also cored, but these are composed of basalt (see section on igneous petrology, this volume). The basalt cobbles have brown-stained rinds, indicating weathering; this suggests that they are not in place basement rocks.

ORGANIC GEOCHEMISTRY

The monitoring program was carried out aboard ship. No hydrocarbon gases were detected in this sediment sequence (i.e., no gas pockets in the core liners; no pressure buildup in the core caps). Hydrogen sulfide (detected only by odor) occurs from about 11 to 35 meters in significantly lower amounts than in Hole 474.

Fluorescence

Fluorescence data were measured on raw sediment samples, trichloroethane extract solutions of raw samples, and pyrolized samples. Most raw samples and trichloroethane solutions exhibited no fluorescence; some pyrolized sample extracts exhibited yellow fluorescence, indicating the absence of petroleum.

Organic Carbon and Nitrogen

The results from the CHN analyzer are summarized in Appendix I, this volume, Pt. 2. The organic carbon and nitrogen values and their ratios are plotted versus depth in Figure 39. The organic carbon ranges from about 1 to 3% with considerable scatter throughout the core; the organic nitrogen parallels the distribution of organic carbon and ranges from about 0.1 to 0.26%. The C/N ratio does exhibit a slight trend to higher values with depth. The upper section exhibits C/N values of 10 to 15, typical of Recent, unaltered, and immature sediments. The onset of diagenetic alteration of the organic matter is reflected by this C/N increase with depth.

INORGANIC GEOCHEMISTRY

Interstitial Water Chemistry (Fig. 40)

This site shows only relatively small increases in alkalinity, ammonia, and phosphate, indicating that only sulfate reduction is an important process for organic matter decomposition. Dissolved calcium shows a typical minimum—a result of calcium carbonate precipitation. Decreases in dissolved magnesium are caused by an uptake in the solid phases of the sediment. Gradual increases in dissolved silica reflect higher solubilities of opaline silica—a result of increased temperatures with depth.

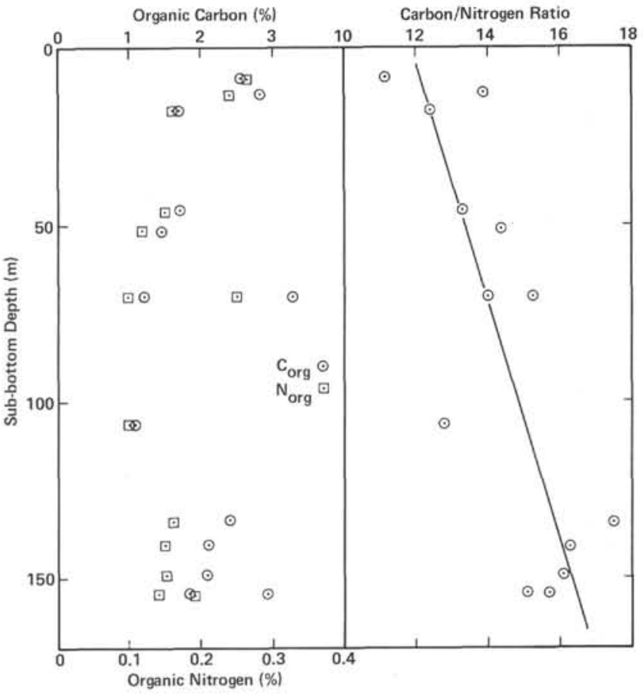

Figure 39. Organic carbon and nitrogen: content and ratios versus depth, Site 475.

BIOSTRATIGRAPHY

Hole 475 has a complete sequence of sediments from late Pleistocene through early Pliocene (Fig. 41). No fossils occur in either the dolomitic mudstone of Unit IV or in the conglomerates of Unit V.

Coccoliths

Sediments from Hole 475 yielded common calcareous nannofossils in various states of preservation and of moderate to high diversity. A complete sequence was recognized from the upper Pleistocene to the lower Pliocene. Because of reworking, however, a biostratigraphic assignment was often difficult. Mixtures of well- and poorly-preserved coccoliths, discontinuous occurrences of marker species, and occurrences of extinct species are evidence of reworking. Sediment from Core 475-1 to Section 475-3-1 is late Pleistocene; Section 475-3-2 to Core 475-4 is early Pleistocene. The Pleistocene/Pliocene boundary occurs between Cores 475-7 and 475-8. Cores 475-8 to 475-14 are late Pliocene, and Cores 475-15 through 475-17 are early Pliocene. *Pseudoemiliania lacunosa* first occurs in Sample 475-3-2, 92–93. *Discoaster brouweri* occurs with a sudden abundance in Sample 475-8-1, 19–20. *D. pentaradiatus* first occurs in Sample 475-8-6, 4–5, and *D. surculus* first occurs in Sample 475-9-4, 34–35. Typical *Reticulofenestra pseudoumbilica* first occurs at the top of Core 475-15, and *Amaurolithus tricorniculatus* appears first in Sample 475-15-5, 26–27; the last occurrence of *D. asymmetricus* is in Sample 475-17-2, 76–77. In the Pleistocene sequence, a sphenolith with close affinities to *Sphenolithus abies* occurs abundantly.

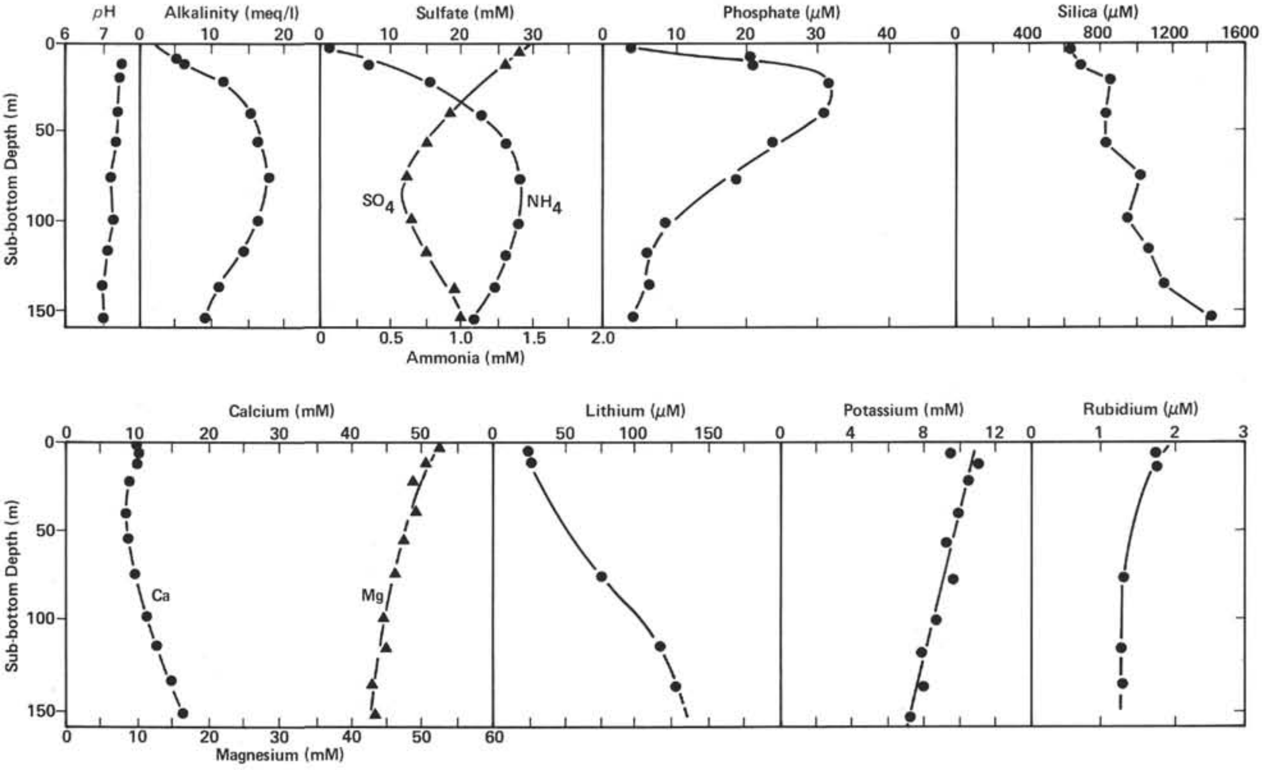

Figure 40. Interstitial water chemistry, Site 475.

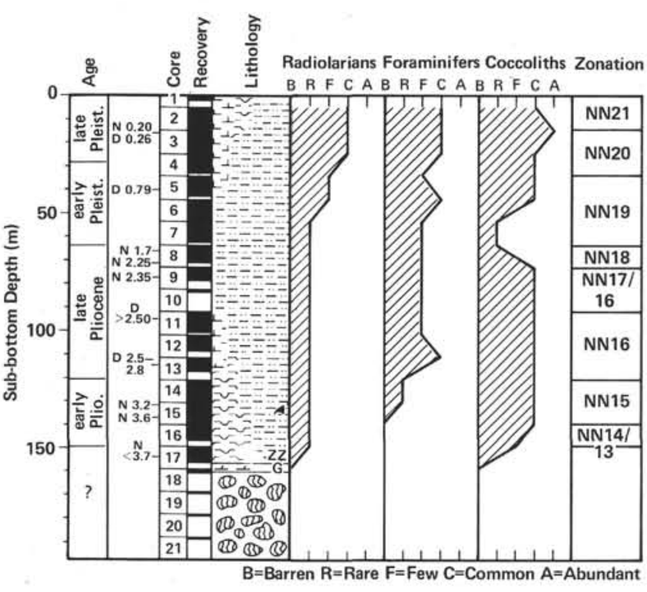

Figure 41. Biostratigraphy, Site 475.

Helicosphaera sellii and *Cyclococcolithus macintyrei* occur sporadically and thus are not used to provide biostratigraphic data.

Diatoms

Open marine tropical to subtropical planktonic diatoms are abundant and well preserved to rare and poorly preserved in the hemipelagic sediments at Site 475 (Core 475-1–Core 475-17; lowest available sample). The mixture of marine benthic species is generally very small—less than 1% of the total assemblage. Important biostratigraphic marker species include *Nitzschia reinholdii*, 475-3-1, 70–72 cm; *Rhizosolenia curvirostris*, 475-3-3, 116–118 cm; *Mesocena quadrangula*, 475-5-2, 37–39 cm; *Cussia tatsunokuchiensis*, 475-11-6, 45–47 cm, *Thalassiosira convexa*, 475-13-2, 75–77 cm (or 475-15-1, 93–95 cm); and *N. jouseae*, 475-16-2, 60–62 cm.

Radiolarians

Radiolarian remains consistently occur downhole. Nevertheless, their unusual abundance in the Pliocene and the absence of a recognized index species (worldwide or regional) precludes establishing a radiolarian biozonation for Hole 475. But the scarce index species, which do occur downhole, apparently coincide with the nannoplankton zonation. In the Quaternary sequence, *Axoprunum angelinum* occurs from Sections 475-3,CC to 475-6,CC and *Stichocorys peregrina* from Nannoplankton Zones 13 to 16 (Sections 475-11,CC, 475-12,CC, 475-16,CC), thus providing further evidence for the early Pliocene age of the sedimentary sequence at the bottom of Hole 475.

The species occurring more abundantly downhole are typical of subtropical continental margin zones; among others: *Tetraphyle octacantha*, the *Botryostrobus auritus-australis* group, *Duppatractus* cf. *pyriformis, Lithelius minor, Ommatodiscus* sp., *D. irregularis, Teocalyptra davisiana*, and *Echinomma delicatulum*.

Planktonic Foraminifers

Planktonic foraminifers consistently occur nearly to the bottom of Hole 475. Insufficient diagnostic species for biostratigraphy and the lack of a shipboard planktonic foraminifer specialist precluded establishing a zonation for Hole 475—thus far. Nevertheless, the Quaternary (defined by the nannoplankton zonation) is characterized by abundant *Neogloboquadrina dutertrei*, whereas the Pliocene is characterized by *Globigerinoides obliquus extremus*(?).

Like the radiolarian population, the planktonic foraminifer population also suggests that a subtropical environment with occasional incursions of the California Current prevailed at Site 475 during the Pliocene and Quaternary.

The species that commonly do occur downcore are *N. dutertrei, G. ruber, Globoquadrina pachyderma, Globigerina bulloides, Pulleniatina obliquiloculata, Orbulina universa*, and *Globigerinoides obliquus extremus*(?).

SEDIMENT ACCUMULATION RATES

The sediments from Hole 475 seem to have been continuously deposited during the late Pliocene and Pleistocene. Nannofossil and diatom datum planes (Fig. 42) indicate that the average rate of accumulation is about 40 m/m.y.

The rate of accumulation of the lower Pliocene dolomitic mudstone, zeolitic claystone, and Unit V conglomerates can be estimated only on sedimentologic grounds. Unit IV must have been deposited very slowly (perhaps less than 5 m/m.y.), whereas Unit V must have been deposited very rapidly.

IGNEOUS ROCKS

Drilling in Hole 475B encountered basalt at 76 meters sub-bottom; and coring continued for an additional 20 meters until the hole was finally abandoned. The basalt is extensively fragmented, and the brown-stained, weathered rims that follow the outline of individual fragments suggest that the basalt was in the form of cobbles prior to drilling. All of the basalt recovered at Hole 475B is mineralogically similar and may be considered as a single type. It comprises approximately 10% euhedral-to-anhedral phenocrysts of olivine (0.2–2.0 mm), dispersed throughout a variolitic-to-intersertal groundmass of plagioclase microlites, skeletal olivine, and clinopyroxene, and an iron-rich mesostasis. In addition to olivine, a pale red chrome spinel appears to be a phenocryst phase. No vesicles are present, and alteration is very slight. Fresh, black sideromelane selvages on Samples 475B-2-1 (Piece 3, 20–25 cm), 475B-2-1 (Piece 5, 30–40 cm), 475B-3-1 (Piece 1, 0–8 cm), and 475B-3-1 (Piece 3, 15–21 cm) provide strong evidence of subaqueous extrusion and concomitant rapid quenching.

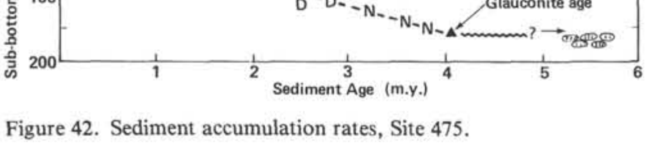

Figure 42. Sediment accumulation rates, Site 475.

PHYSICAL PROPERTIES[4]

The relationship of physical properties to depth in the range of 0 to 155 meters sub-bottom is better established at Site 475 than at Site 474. The Site 475 data show less scatter, and the clayey sequence is not interrupted by thick sand or gravel deposits. Cores 475-1 through 475-5, however, also were rather disturbed. Because the less-disturbed sections were always measured, wet-water content, wet-bulk density, and porosity probably were not seriously affected. Nevertheless, the shear-strength and sound-velocity values may be too low for this depth range (0–50 m) (Figs. 43, 44).

Water content, bulk density, and porosity begin near the surface and have the same values (ca. 60%, ca. 1.3 g/cm^3, ca. 80%, respectively) as those at Site 474, but they decrease more slowly downhole. Thus, between 110 and 120 meters, water content is still 50% or higher, bulk density is 1.5 g/cm^3 or less, and porosity is at least 70%. Shrinkage of the dried cylinder samples also remains high (40% and more) to this depth, and sound velocity barely exceeds 1.5 km/s.

From 110 to 120 meters down, all physical-property values show the same remarkable change as at Site 474 (there from about 260 m). At 130 meters the sediment appears to be distinctly firmer than in the higher sections. The highest shear strength measured is about 1.4×10^5 Pa (1.4 kg/cm^2). Within the same interval, sound velocity and acoustic impedance increase to 1.54 km/s and 2.42×10^5 g/cm^2 s, respectively. A hard dolomitic mudstone (155 m) directly on top of the cobble bed had a sound velocity of 2.78 km/s.

Unlike Site 474, at Site 475 the comparatively strong gradients of the physical properties below 110 meters are apparently not related to changes in the composition of sediment or interstitial water. In Hole 475, from 110 to 150 meters, the sediments again become rich in opaline microfossils, and the concentration of dissolved silica is very high. Nevertheless, lithification by solution and recrystallization of silica may also have begun here. This is also indicated by relatively high values of average grain density (about 2.55 g/cm^3), incompatible with a large proportion of opaline silica (as assumed from smear slide descriptions).

At Site 475, two thick (1 m and 1.4 m) mud turbidite samples with fining-upward grain-size distribution were measured for physical properties (Fig. 43). The results and those from similar studies at other sites are summarized in the chapter on turbidite sedimentation and physical properties (Einsele and Kelts, this volume, Pt. 2). To evaluate the trend curves in Figure 43, it is important to realize that part of the mud turbidites show strong gradients of physical properties from bottom to top; but others do not and do not differ very much from the "background" sedimentation. Thus, host sediments and mud turbidites are often difficult to distinguish during sampling, and in the visual description of wet cores. Therefore, at least some of the scattering of the physi-

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[4] For general remarks on physical properties, see site description for Site 474, earlier, or Einsele (this volume, Pt. 2).

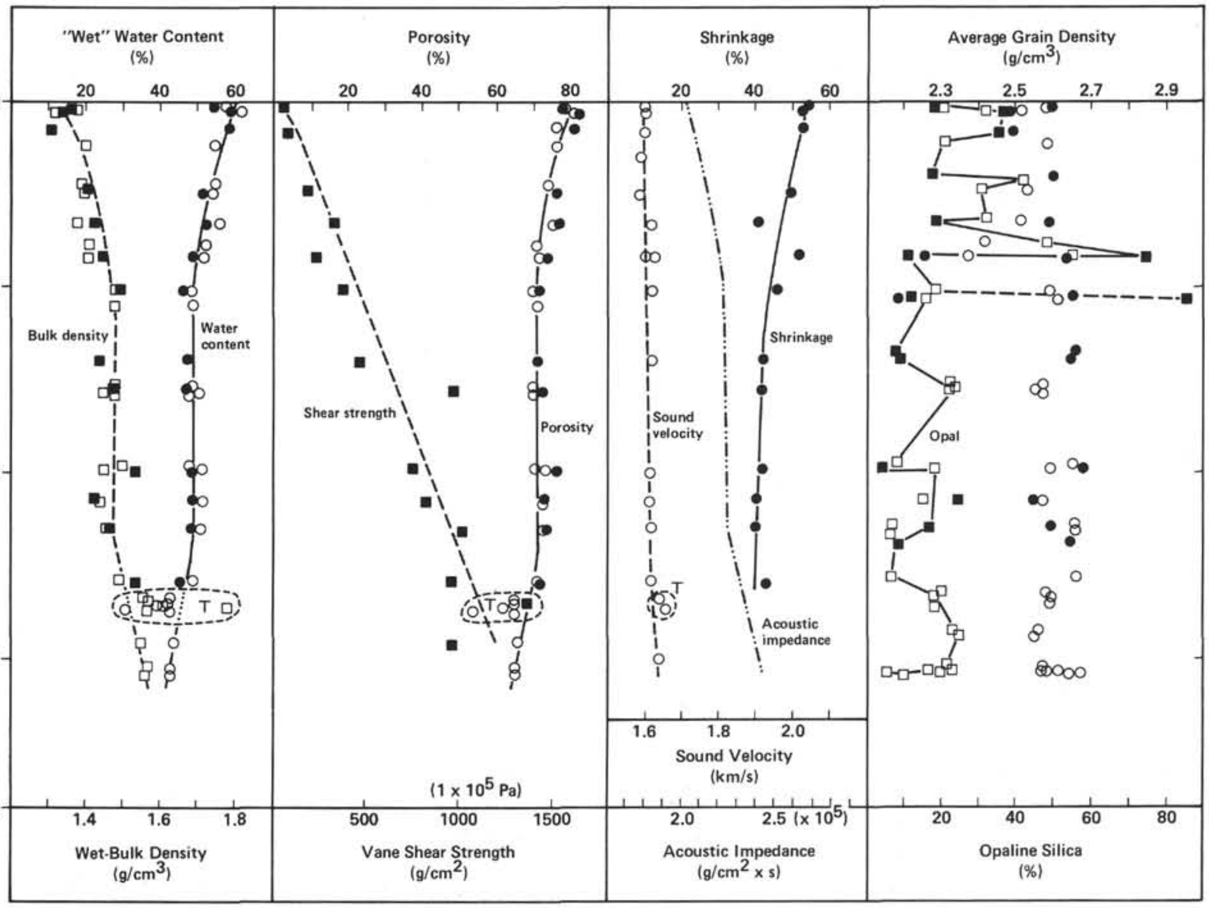

Figure 43. Mass physical properties, shrinkage, and proportion of opaline silica of Site 475 sediments (T = samples from mud turbidites. Closed symbols are cylinder samples. Open symbols are chunk samples.)

cal-property data is caused by the intermixing of layers of somewhat differing composition. Similarly, layers of different color may be caused by changes in their composition and, therefore, have somewhat differing physical properties. A light olive gray silty clay from Section 475-9-4 contained about 2% less water and had a lower porosity by 1.5% but a somewhat higher (0.03 g/cm³) bulk density than an adjacent dark brown silty clay containing more siliceous microfossils and organic matter. If the cores are little disturbed, thick mud turbidites with marked changes in bulk densities can be identified in the GRAPE logs. Hence, the corresponding deductions from the Site 474 data are confirmed.

HEAT FLOW AND THERMAL CONDUCTIVITY

Thermal conductivity was measured at 12 intervals downcore using a procedure similar to the needle-probe method described by von Herzen and Maxwell (1959); the instrument employed was designed by V. Vacquier. The thermal conductivities were calibrated using a variety of standards. Remeasurement of standards during the actual sample measurements suggests that the conductivities reported in Table 8 may be about 0.15 × mcal/cm s °C high. The measurements have a precision of better than 10%. Thermal conductivities are shown in Table 8 and Figure 45. Low thermal conductivity (~2.45 mcal/cm s °C) in the upper sediment column correlates with the column's higher water content (see Bullard, 1963 for discussion of this phenomenon). Sediments from below 30 meters have a relatively constant thermal conductivity of about 2.6 mcal/cm s °C.

Heat flow was measured by the Uyeda/Kinoshita downhole temperature probe. This instrument takes an *in situ* temperature reading one meter deeper than the drill bit. The two measurements roughly describe a linear temperature gradient to a bottom-water temperature of 3.5°C; measured temperatures were approximately 14.0°C at 110.5 meters and 25.5°C at 148.5 meters. The temperature probe did not equilibrate completely in either measurement, so the temperature values are slightly extrapolated.

Three different temperature gradients can be calculated for Hole 475 using: (1) temperature at 110.5 meters and bottom-water temperature; (2) temperature at 148.5 meters and bottom-water temperature: or (3) temperature at 148.5 and 110.5 meters. Heat-flow calculations based on these three gradients and measured thermal conductivities yielded 2.5, 3.9, and 7.9 HFU, respectively. The high heat flow calculated from the two *in situ* measurements (7.9 HFU) suggests that the 110.5-meter temperature may be low. We therefore believe that heat flow at Site 475 should be about 4 HFU.

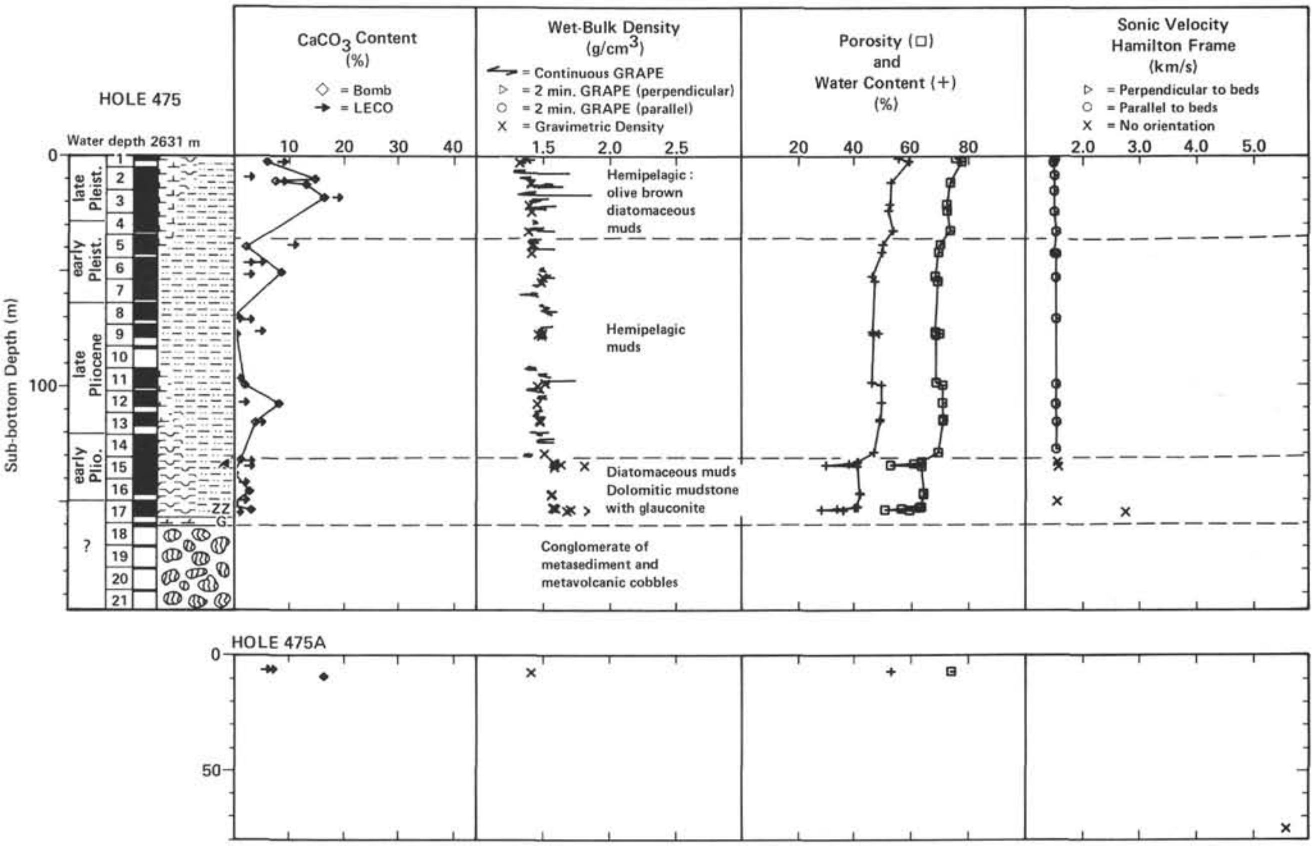

Figure 44. Calcium carbonate and physical properties, Site 475. Analyzed ashore at Scripps Institution.

Table 8. Thermal conductivity, Hole 475.

Sample (interval in cm)	K (mcal/cm s °C)
475-2-4, 33–35	2.47
475-3-1, 95–97	2.40
475-4-6, 3–5	2.59
475-5-6, 53–55	2.53
475-6-6, 57–59	2.71
475-7-1, 74–76	2.69
475-8-5, 139–141	2.66
475-9-4, 86–88	2.62
475-11-6, 90–92	2.72
475-12-5, 49–51	2.52
475-13-4, 12–14	2.61
475-16-4, 72–74	2.61
fused quartz standard	3.46

CORRELATION OF DRILLING RESULTS AND SEISMIC DATA

Our velocity control for Site 475 is very poor. Because of the sloping sea floor and limited extent of the basin, we have no sonobuoy records on which to base velocity estimates—and neither did we run downhole logs. We have only laboratory velocity measurements on a limited number of samples; these samples give very low velocities, apparently because the sediments are not well consolidated, have high water content, and generally contain high proportions of siliceous microfossils. Using the measured velocities as guides, the following acoustic velocities were developed for the correlations: 0–100 meters—1.50 km/s; 100–150 meters—1.52 km/s; and >150 meters—1.55 km/s.

The seismic reflection record of our approach to the site is shown in Figure 46. Because of the failure of the first beacon and because Hole 475 was about 366 meters approximately southeast of the beacon, positioning the site in this survey line may not be precise. Holes 475A and 475B do not lie in this section.

Correlation with drilling results is shown in Figure 46. The boundaries between the lithologic units appear to correlate with the indicated reflectors. The dolomite (Unit IV) and the top of the conglomerates (Unit V) appear as a meniscus-like fill in the bottom of this slope basin. The base of Unit II shows a downlap relation. There is a prominent reflector within Unit II, although we cannot determine what horizon in the section correlates with it.

The relation between Hole 475 and the sections drilled in Holes 475A and 475B was especially confusing during the occupation of this site. The 3.5-kHz record (Fig. 47) run to relate these holes after leaving Site 475 and before occupying Site 476 helps to show the relationship. (See operations section, Site 476).

The total depths of Holes 475, 475A, and 475B are plotted in Figure 48. The hard rock at 16 meters in Hole 475A may coincide with the reflecting horizon that appears at that depth in Figures 47 and 48. The top of the

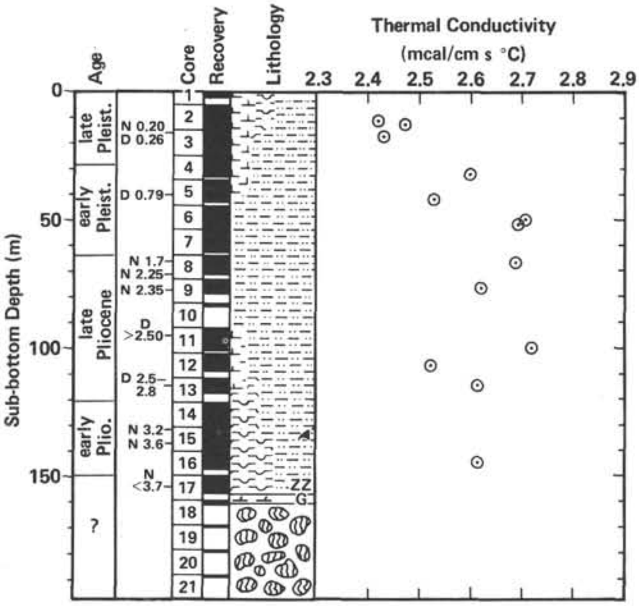

Figure 45. Thermal conductivity of sediment, Site 475.

basalt rubble at 76 meters in Hole 475B also appears to be a reflector, especially as it is shown in the 3.5-kHz record of Figure 47. The 2-s-sweep seismic record may be interpreted to fit the drilling results as indicated in Figure 46.

The reflection line in Figure 49 was made while in transit from Hole 475A to Hole 475B. Survey speed was very slow because more than 2500 meters of drill string were hanging beneath the ship. Drilling in Hole 475B encountered the top of the basalt rubble at the level that is indicated on the figure.

SUMMARY AND CONCLUSIONS

Drilling Summary and Objectives

Site 475, the second in the passive margin transect, is in a slope basin 21 km southeast of the tip of Baja California. Drilling objectives were the same as those of Site 474. By studying the composition, character, and age of the basement, we wanted to determine whether the site is seaward or landward of the ocean/continental-crust transition. In the sedimentary section, our goals were to determine the general lithologic and biostratigraphic facies distribution, to obtain the record of Pleistocene sea-level fluctuations and subsidence history, to learn the nature and age of oldest sediments on basement, and to study diagenesis of organic and inorganic matter. Three holes were drilled. Hole 475 was drilled in a water depth of 2631 meters and continuously cored to a depth of 196 meters below the mudline. A cobble conglomerate at 148 meters eventually stopped the drilling. Above the conglomerate, the drilling operations were routine, and an unusually good recovery (79.6%) was obtained. The heat probe was successfully deployed in stiff mud at 110.5 meters and again at 148.5 meters. Drilling times increase sharply (from 6–8 to 22–60 min. per core) as we penetrated the conglomerate zone; and our average recovery decreased to only 5.3%. The two other holes at this site were selected upslope of Hole 475 to avoid the conglomerate and to attempt to sample the presumed granite basement. Both holes were washed to the equivalent depth reached in Hole 475. Drilling in Hole 475A, in 2545 meters of water, hit a hard layer at 16 meters below mudline. Drilling in Hole 475B, in 2593 meters of water, washed to 76 meters before encountering basalt cobbles. These were cored to 96 meters total depth (TD) with only 3% recovery, before caving of the hole forced us to abandon the site.

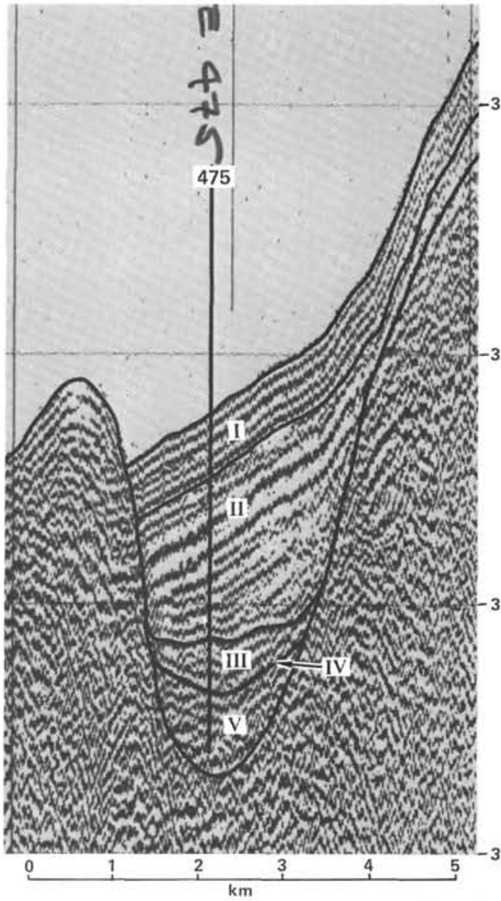

Figure 46. Correlation of lithological units with seismic reflection record from *Glomar Challenger*, Site 475.

Lithology and Sediment Properties

Microfossil abundances, sedimentary structures, and mineralogical components indicate five lithological units in Hole 475.

Unit I (0–34.5 m)—hemipelagic pelagic diatomaceous muds

Unit II (130.2 m)—hemipelagic mud

Unit III (154.2 m)—mud turbidites

Unit IV (a thin basal stratigraphic element to 158 m)—dolomitic mudstone

Unit V (196 m TD)—a conglomerate of metasediment and metavolcanic cobbles

Organic geochemistry showed hydrogen sulfide present from 11 to 35 meters but in much lower amounts

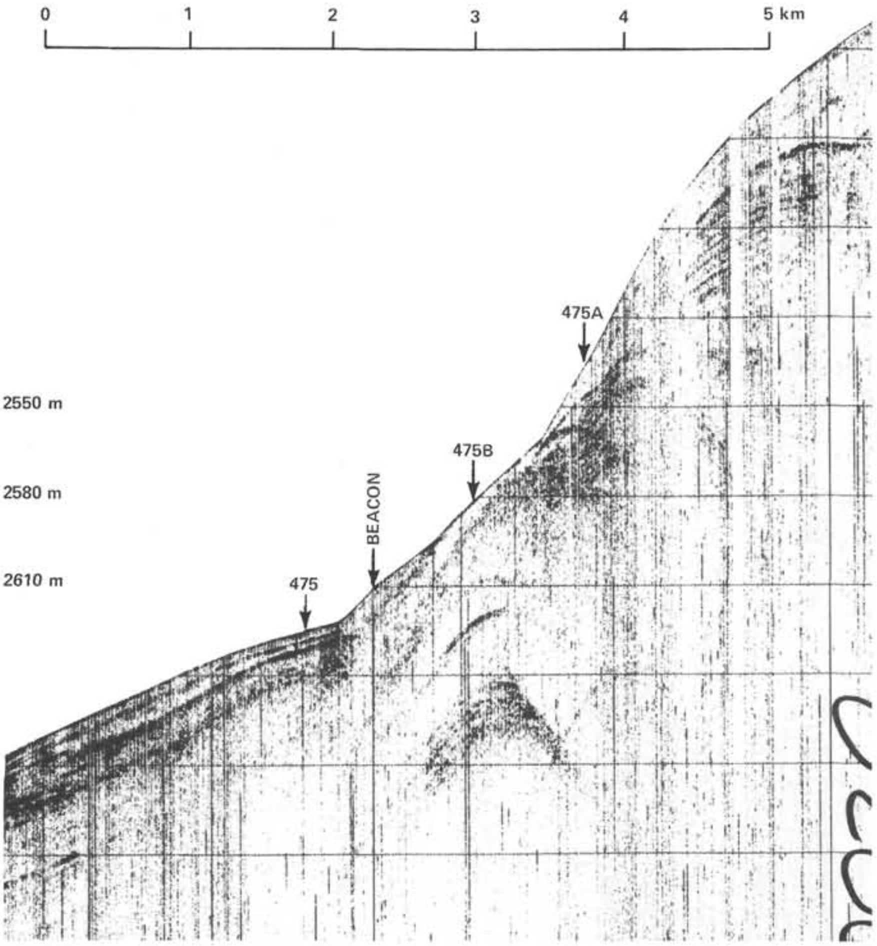

Figure 47. Correlation of drilling results with 3.5-kHz record, Site 475.

than at Site 474. No hydrocarbon gases were detected. Dissolved calcium passes through a typical minimum in the upper section, indicating precipitation of calcium carbonate. Dissolved silica values are high at this site and increase progressively downhole; this may be associated with a progressive increase in biogenic silica. Calcium carbonate content is moderate in the upper diatomaceous ooze but relatively low throughout the rest of the hole. No increase occurred in the lower diatomaceous section, suggesting a lack of calcite microfossil deposition. Comparatively strong gradients in the water content, bulk density, and porosity from 110 meters to the base of the sediments above the conglomerate are apparently not related to sediment composition or interstitial water. The concentration of dissolved silica is high, and the sediments become richer in opaline microfossils. This contrasts with the sediment characteristics at Site 474, where a correlation between sediment chemistry and physical properties is apparent. Only a very small piece of the dolomitic mudstone cored at Hole 475 was recovered from Hole 475A, just above the metamorphic cobble conglomerate. Olivine basalt occurs in Hole 475B at 76 meters sub-bottom. Drilling continued 20 meters into the basalt and recovered 0.55 meters of basalt cobbles. The basalt has quenched textures and glassy selvages, indicating subaqueous extrusion; but concentric weathering auras on the cobbles indicate that *in situ* flows were probably not sampled. The basalts are petrographically similar to mid-ocean ridge basalts.

Correlation of Drilling Results with Seismic Reflection

No sonobuoy record or downhole acoustic logging was available for this site. Thus, to calibrate the seismic reflection records with drilling results, we were forced to rely on sound velocities measured in the laboratory. The velocities were quite low, and we need them to develop the following velocities for correlating the section: 1.50 km/s to 100 meters, 1.52 km/s from 100 to 150 meters, and 1.55 km/s beyond 150 meters to the base of the sediments above the lithified dolomitic unit at the top of the conglomerate. With these velocities, the sedimentary units correlate well with the reflection record. The relations among Holes 475, 475A, and 475B—as seen in the seismic record collected during a short survey on leaving Site 475—show that the sedimentary units of Site 475 can be well correlated within the section, and that the metamorphic rock cobbles of Hole 475B and the basalt rubble of Hole 475A are indeed related to the apparent basement reflector recorded. The occurrence of planktonic foraminifers throughout the section in Site 475 and above the hard claystone/cobble contact suggests that a subtropical environment, with periodic incursions

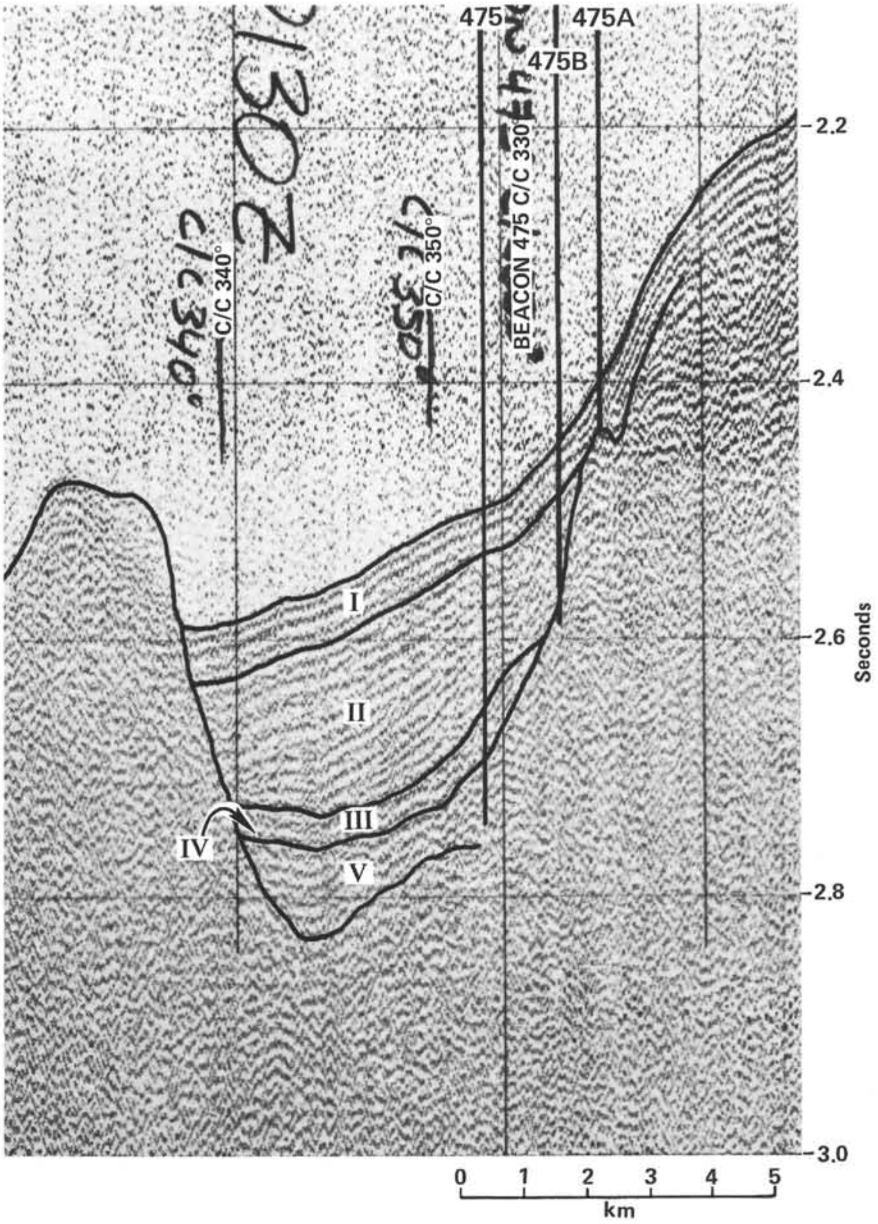

Figure 48. Correlation of seismic reflection record from *Glomar Challenger* with Holes 475, 475A, and 475B. (C/C = course change.)

of the California Current, prevailed during the Pliocene and Quaternary.

Geological history and paleoenvironment for Sites 475 and 476 will be discussed in the Site 476 summary and in the chapter on the geological history of this transect region (Curray et al., this volume, Pt. 2).

SITE 476

Date occupied: 14 December 1978

Date departed: 16 December 1978

Time on hole (hr.): 36.07

Position: 23°02.43′N; 109°05.35′W

Water depth (sea level; corrected m, echo-sounding): 2403

Water depth (rig floor; corrected m, echo-sounding): 2413

Bottom felt (m, drill pipe): 2429

Penetration (m): 294.5

Number of cores: 32

Total length of cored section (m): 294.50

Total core recovered (m): 164.78

Core recovery (%): 81.7; total 56.0

Oldest sediment cored:
Depth sub-bottom (m): 256
Nature: Gray quartzose sandy clay
Age: Pliocene/late Miocene (NN14) or older

Basement:
Depth sub-bottom (m): 256.5
Nature: Weathered granite
Measured velocity (km/s): 4.53

Principal results: Site 476, the landward end of a three-site transect across the ocean/continent transition, was spudded-in on a small

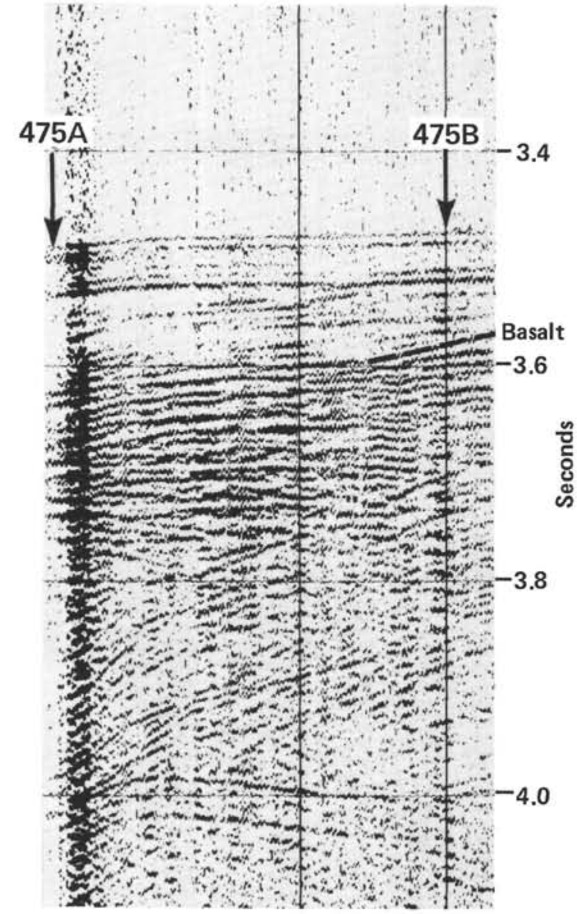

Figure 49. Seismic reflection record made while in transit from Hole 475A to Hole 475B at extremely slow ship speed (2500 m of drill string beneath the ship).

terrace on the lower continental slope, southeast of the tip of Baja California. Our objectives were to establish basement type, subsidence history, and sedimentary record. The hole was continuously cored to a depth of 294.5 meters. Six lithological units provide evidence for deposition on a subsiding continental margin. The last four cores (256.5-294.5 m) contain weathered granite. The basement is overlain by cobbles (199.0-256.5 m) from a subaerial conglomerate, containing metamorphic clasts and gray sandy clay. Deposited above the conglomerate were shallow (183.0-199.0 m) early Pliocene to Miocene marine claystones, glauconite sands, and barren zeolitic clays. Subsequently, early Pliocene diatom oozes with turbidites (145.0-183.0 m) to late Pliocene hemipelagic silty clays (66.0-145.0 m) and then fluctuating amounts of Pleistocene muds and nannofossil and diatom oozes (0.0-66.0 m) were deposited at a rate of 42 m/m.y. Recovery was excellent (82%) in the marine sediment section to 199 meters but less than 4% in the coarse rubble below.

SITE 476: BACKGROUND AND OBJECTIVES

Site 476 (Planning Site GCA-7A) is the third site of the continental margin transect at the mouth of the Gulf of California. It lies on the continental slope (Figs. 2, 7) about 40 km southeast of the tip of Baja California and about 3.6 km west-southwest of Site 475. It is on the same northeast-southwest-trending ridge as Site 475 and about 30 km northeast of the crest of the Cabrillo Seamount (Fig. 2). Granodiorite, quartz diorite, and basalts have been dredged from the Cabrillo Seamount (Shepard, 1964; Moore et al., 1978), and basalt was dredged from DH-8 (Fig. 2; Lewis et al., 1976). Site 474 bottomed in oceanic basalt basement, and one Site 475 hole bottomed in basalt rubble.

Our primary objective at this site was to establish the basement type and thus delineate the ocean/continental crust transition.[5] If oceanic rather than granitic continental basement had been recovered here, another site would have been chosen farther up on the continental slope, thus continuing our attempt to delineate the ocean/continent transition.

OPERATIONS

On leaving Hole 475B at 2245Z on 13 December, we began a seismic reflection survey to link all of our sites and an earlier dredge-haul site on this transect. Five-and two-second sweep records were recorded. We began the survey from Hole 474A, using the beacon at that site for navigation. We passed the beacon at 2346Z and made our turn at 2357Z to begin the survey (Fig. 50). On 14 December, we passed Hole 474A at 0025Z, were over the beacon of Site 475 at 0147Z, and crossed the dredge site at 0310Z. After a short loop to the NW, we returned to our desired position for Site 476, dropped the beacon at 0551Z, and selected on an open-slope locality in 2413 meters of water with a 0.30-s section of sediment overlying the basement.

After positioning over the site we lowered drill pipe, and at 1552Z on 14 December we spudded-in, finding the mudline in the second core at 2429 meters, corrected PDR depth. Our first core from Hole 476 was on deck

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[5] Other objectives are the same as those for Site 475.

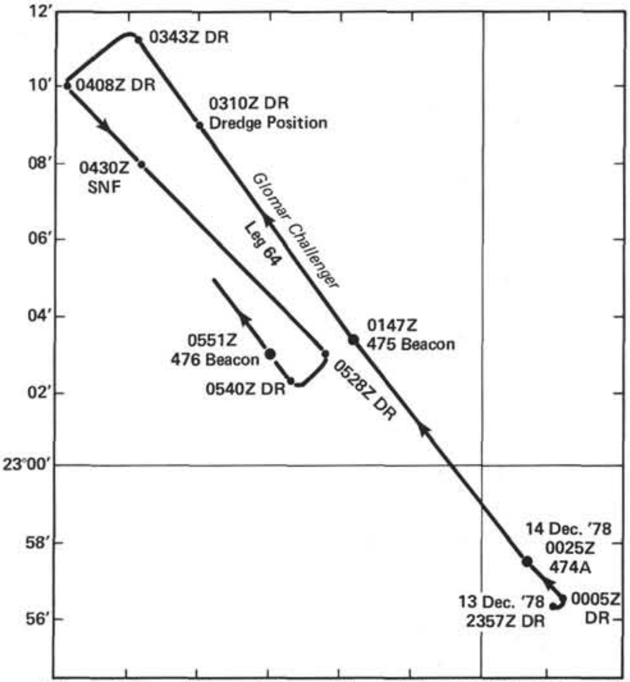


Figure 50. Track of *Glomar Challenger* from Sites 474 and 475 to Site 476.

at 0921Z. Thereafter, we continuously cored to a total depth of 294.5 meters. Within the section and to a depth of 199.0 meters, six lithological units were recognized. With an average of 81.7%, our recovery was excellent. Two successful heat-flow measurements were made in this interval: one at 47 meters and another at 132.5 meters. At 199 meters we apparently encountered a sand zone and recovered only a trace of sand and a pebble of sandstone. Thereafter, recovery was very poor and drilling difficult as we cored through metamorphic rock cobbles until reaching deeply weathered granite below 256 meters. We drilled into this granite wash to 294.5 meters before decomposed granite caused sticking problems, loss of circulation, and finally required that we discontinue drilling.

Between 0500 and 0745Z, the hole was washed and flushed with 100 barrels of mud to prepare for logging, and the go-devil was pumped down to release the bit. Unfortunately, even with as much pressure as 2500 psi the bit would not release. We could not retrieve the go-devil; it too was stuck fast, and two pins were sheared on the sand-line coupling in the attempted recovery. Thereafter, until 0845Z, four stands of pipe were pulled and the bit release again attempted to no avail. We were now forced to abandon the site with no logging. Pipe was pulled out of the hole, the hole was filled with mud, and at 1330Z the bit was on deck. The hydraulic bit release did not shift because it was jammed with sand. At 1344Z on 16 December we abandoned Site 476 and were underway for Site 477 (Table 9).

SEDIMENTARY LITHOLOGY

Site 476 is on a small slope terrace a few kilometers northwest of, and 191 meters shallower than, the outer slope basin of Site 475. The last four cores contained weathered granite and granite wash.

The sediments at Site 476 provide evidence for deposition on a subsiding, granitic, continental margin. Subaerial conglomerates are overlain with laminated, organic, shallow-marine claystones with phosphorite, pyrite, and abundant glauconite. These are followed by barren zeolitic clays, diatom oozes with turbidites, hemipelagic clay, and then fluctuating amounts of terrigenous mud, nannofossil ooze, and diatom ooze to mud in the upper Pleistocene.

The sediment section has been subdivided into six units summarized in Table 10 and the stratigraphic section (Fig. 51). The subdivision is based on compositional differences, which group the sediments into units with similar paleoenvironmental settings. Hemipelagic muds from Units I, II, and III are separated by the relative abundance of diatoms, nannofossils, and graded sandy silts. Unit IV is a barren but distinguished by a sudden drop in siliceous fossils in Core 476-20 and then a change to fine zeolitic claystone. At the base of Core 476-21, organic claystones mark the change to the poorly recovered metamorphic cobbles of Unit V and the weathered granite of Unit VI. There is good correlation with the units at Site 475.

Unit I: nannofossil-diatom ooze, (Cores 476-1-476-7, 0-66 m, Pleistocene). Below the first two cores, the sediments are highly disturbed, but remnants of diffuse, lighter-and-darker beds on a centimeter to decimeter scale are recognizable. Unit I comprises mostly nannofossil ooze, nannofossil-diatom ooze, and diatomaceous ooze to nannofossil-diatom-bearing mud. Subtle variations in color seem to reflect fluctuations in biogenic components. Some, but not all, of the lighter beds are richer in nannofossils. Colors vary among grayish olive green (5GY 3/2), light olive (10Y 5/4), grayish olive (10Y 4/2), and dusky yellow green (5GY 5/2) or moderate olive brown (5Y 4/4). Brownish layers tend to be richer in diatoms. Nannofossils range from 10 to 60%; diatoms range from 15 to 40% and are accompanied by minor amounts of radiolarians, sponge spicules, or silicoflagellates. Foraminifers are concentrated in some scattered, well-sorted sand layers. These ungraded (2-3 cm-thick) sandy beds are common in Cores 476-5 to 476-7 near the base of the unit and consist of about 50% foraminifers and 50% angular quartzose-feldspathic sand. Benthic and planktonic foraminifers are abundant; some are filled with pyrite or glauconite.

The carbonate content varies from about 10 to 50%, and the terrigenous suite, with clear, angular quartzose, partly weathered feldspars, and biotite with apatite, zircon, and some epidote, is similar to that at Sites 474 and 475. Pyrite is a ubiquitous accessory because the sediments are reducing. Dark gray spots are common, as is a slight H_2S odor from Section 476-1-2 through Core 476-7—consistent with a relatively high sedimentation rate.

Near the boundary with Unit II, the color lightens to grayish yellow (5GY 6/2). Carbonate content and both the quantity and quality of microfossil preservation decrease.

Unit II: silty clay (Core 476-8-Section 476-16-3, 66.0-145.0 m; late Pliocene). Unit II sediments form a homogeneous layer and have a uniform color scale indicating reducing conditions—grayish olive green (5GY 3/2) to dusky yellow green (5GY 5/2) to grayish green (10GY 5/2) slightly siliceous silty clays. Bedding has been nearly obliterated by drill disturbance, although the sediments tend to be firm toward the base of the unit. Nannofossils are rare, and siliceous fossils occur as thin, poorly preserved fragments. There are minor mottles and reduction spots. Carbonate content is less than 5%, clay ranges from 60 to 75%; the remainder is fine quartz-feldspar (20-30%) or siliceous debris (~5%) and pyrite (1-5%). Other sandy patches in this unit (Core 476-10) are very poorly sorted, faintly graded, and, because they are also associated with micaceous, silty zones, may be parts of mud turbidites.

Minor lithologies in this unit include a thin, vitric, rhyolitic ash bleb and pyritized burrow fillings (Core 476-12) and some scattered pumice and tuff pebbles (Cores 476-13, 476-14).

Unit III: muddy diatomaceous ooze (Sections 476-16-3-476-20-3, 145-183 m, early Pliocene). In Section 476-16-3, the lithology changes rather abruptly to muddy diatomaceous ooze with sand interlayers. Colors become predominantly dusky yellow green (5GY 5/2), dusky yellow (5Y 6/4), or moderate olive brown (5Y

Table 9. Coring summary, Hole 476.

Core	Date (December, 1978)	Time (Z)	Depth from Drill Floor (m; top-bottom)	Depth below Sea Floor (m; top-bottom)	Length Cored (m)	Length Recovered (m)	Recovery (%)
1	14	0921	2428.5-2438.0	0.0-9.0	9.0	9.03	100
2	14	1003	2438.0-2447.5	9.0-18.5	9.5	6.05	64
3	14	1044	2447.5-2457.0	18.5-28.0	9.5	8.95	94
4	14	1132	2457.0-2466.5	28.0-37.5	9.5	7.15	75
5	14	1216	2466.5-2476.0	37.5-47.0	9.5	8.44	89
6	14	1412	2476.0-2485.5	47.0-56.5	9.5	6.10	64
7	14	1500	2485.5-2495.0	56.5-66.0	9.5	9.83	103
8	14	1547	2495.0-2504.5	66.0-75.5	9.5	4.32	45
9	14	1635	2504.5-2514.0	75.5-85.0	9.5	8.89	94
10	14	1733	2514.0-2523.5	85.0-94.5	9.5	9.87	104
11	14	1819	2523.5-2533.0	94.5-104.0	9.5	9.82	104
12	14	1915	2533.0-2542.5	104.0-113.5	9.5	8.82	93
13	14	2015	2542.5-2552.0	113.5-123.0	9.5	9.85	104
14	14	2124	2552.0-2561.5	123.0-132.5	9.5	7.55	79
15	14	2340	2561.5-2571.0	132.5-142.0	9.5	4.93	52
16	15	0030	2571.0-2580.5	142.0-151.5	9.5	5.51	58
17	15	0128	2580.5-2590.0	151.5-161.0	9.5	3.95	42
18	15	0225	2590.0-2599.5	161.0-170.5	9.5	8.76	92
19	15	0330	2599.5-2609.0	170.5-180.0	9.5	9.94	105
20	15	0453	2609.0-2618.5	180.0-189.5	9.5	9.61	101
21	15	0633	2618.5-2628.0	189.5-199.0	9.5	5.20	55
22	15	0811	2628.0-2637.5	199.0-208.5	9.5	tr	>0
23	15	1005	2637.5-2647.0	208.5-218.0	9.5	0.10	1
24	15	1245	2647.0-2656.5	218.0-227.5	9.5	0.03	>1
25	15	1617	2656.5-2666.0	227.5-237.0	9.5	0.25	3
26	15	1804	2666.0-2675.5	237.0-246.5	9.5	0.70	7
27	15	1930	2675.5-2685.0	246.5-256.0	9.5	0.015	>1
28	15	2050	2685.0-2694.5	256.0-265.5	9.5	0.06	>1
29	15	2231	2694.5-2704.0	265.5-275.0	9.5	0.65	7
30	15	2354	2704.0-2713.5	275.0-284.5	9.5	0.06	1
31	16	0135	2713.5-2723.0	284.5-294.0	9.5	0.09	1
32	16	0300	2723.0-2723.5	294.0-294.5	0.5	0.25	25
33	16	0523	2685.0-2723.5	256.0-294.5	NA	—	NA

Note: The last "core" is washings and cavings—a sample of the "matrix" from the "granite wash."

Table 10. Lithological units, Site 476.

Unit	Interval	Sub-bottom Depth (m)	Thickness (m)	Lithology	Paleoenvironment	Age (m.y.)	Estimated Sedimentation Rate (m/m.y.)
I	Cores 476-1-476-7	0.0-66.0	66.0	nannofossil and diatomaceous oozes to muds	hemipelagic	NN21-NN19; Pleistocene; ~0-1.0	42
II	Core 476-8-Section 476-16-3	66.0-145.0	79.0	silty clay	outer-slope hemipelagic	early Pleistocene-late Pliocene; ~1.0-2.6	42
III	Sections 476-16-3-476-20-2	145.0-183.0	—	muddy diatomaceous ooze with numerous turbidite layers, some vitric ash, and glauconite sands	mud turbidites, slope basin	early Pliocene ~2.6-4.5	42
IV	Sections 476-20-3-476-21,CC	183.0-199.0	16.0	glauconite sands, zeolitic silty clay, phosphorite, and pyrite organic claystone	protected offshore bank in low-oxygen zone	Pliocene/ Miocene(?); >4.5	very slow
V	Core 476-22- Section 476-27,CC	199.0-256.5	57.5	cobbles from metamorphic rocks and a gray quartzose sandy clay	fluvial outwash plain.	?	rapid
VI	Core 476-28- Section 476-33,CC	256.5-294.0	37.5	light gray deeply weathered granite ("granite wash")	subaerially weathered surface	?	—

5/4) with shades and faint mottles of pale olive (10Y 6/2) to light olive gray (5Y 5/2). The fine-grained sediments are structureless but have a color banding with diffuse boundaries. Scattered white specks and sandy patches suggest extensive bioturbation. Darker shades appear slightly siltier and subtly "fine upward." Diatom frustules (40-70%) again are a main component, but silicoflagellates and some radiolarians are also conspicuous. Except in sand layers, carbonate content is minimal, but nannofossils persist. The siliceous fossils show excellent preservation, which may indicate rather rapid deposition. The evidence for multiple mud tur-

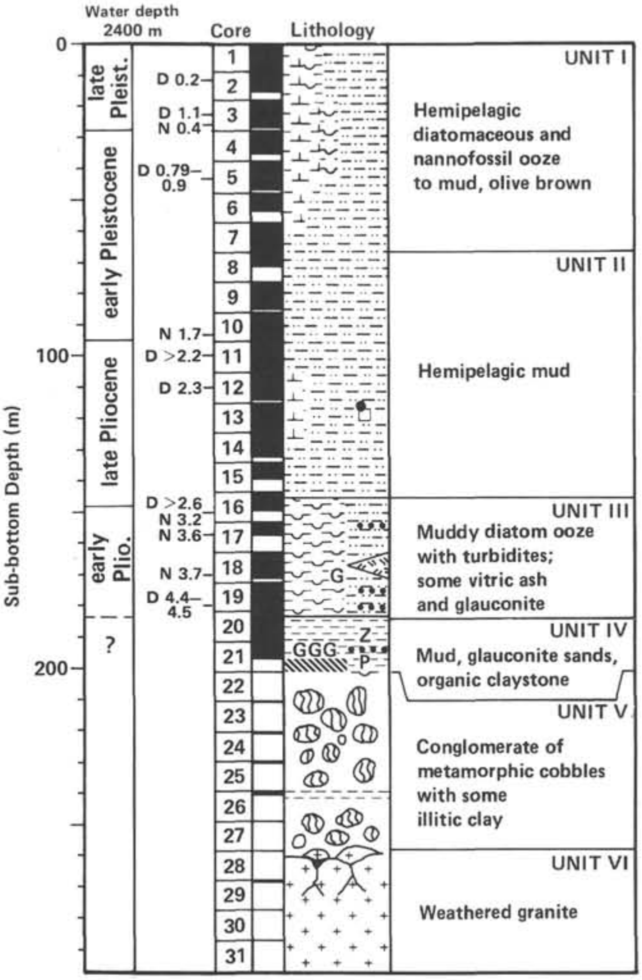


Figure 51. Simplified stratigraphic column, Site 476.

bidites is obscure, because bioturbation has erased contacts. Still, there are numerous traces of possible grading of components and color (e.g., Sections 476-18-6, 476-33-96). Unfortunately, core disturbance is intense in key places. Interspersed within Unit III are unconsolidated dark gray (N2) sand layers, mostly 1 to 2 cm but as thick as 25 cm. Typically, they are well-sorted, grain-supported, discrete beds with very sharp basal contacts, although drilling may have winnowed out some of the fines. The components in coarse fractions are diverse. At the top of the section they comprise mainly angular quartz-feldspar-biotite grains with accessory foraminifers; others are mostly benthic and planktonic foraminifers (20–50%) and rounded glauconite grains (30–40%) within coincidental pyrite, radiolarians, and other miscellanea. Pelagic foraminifers are commonly filled with glauconite or pyrite. The condition of the glauconite grains suggests that they are not transported very far but may have been winnowed and redeposited from local submarine highs.

The most compelling evidence for regional early Pliocene subaerial rhyolitic volcanism is a 45-cm-thick dark gray (N4) vitric ash layer from Sections 476-18-3 (130 cm) to 476-18-4 (15 cm). Shards are lacy, well-sorted glass (100–200 μm); they are fresh, clear, have a refractive index (RI) of 1.50 to 1.51, and have no feldspar fragments. The uniform character suggests a windborne sediment (see Fig. 52). Similar vitric ash layers also occur in lower Pliocene sediments from DSDP Site 473, which at that time may have been quite near. A 45-cm-thick ash fall suggests a not-too-distant source.

Unit IV: organic claystones, glauconite sands, and zeolitic silty clay (Sections 476-20-3 [10 cm]–476-21,CC; 183–199.0 m, late Miocene–early Pliocene[?]). Unit IV is only 16.0 meters thick but contains a varied and complex group of sediments that possibly indicate a shallow shoal environment. As diatom debris dwindles, there is a gradational but rapid transition downward from the overlying sediments. The lithology changes to hard, light olive gray (5Y 5/2) silty clay with a brownish cast.

Smear slides show abundant, very fine-grained (~4 μm), low RI, low-birefringent, elongated, ragged minerals identified as clinoptilolite, possibly an alteration product of disseminated, vitric ash. Bedding is disturbed to vertical, and some sandier zones contain glauconite sands, which are also more calcareous. Three well-preserved, rhythmic units (Section 476-20-6) show grading color shades but lack clear evidence of size grading. Some hard, silty lumps seem to have a carbonate cement. Below Section 476-21-2, these zeolitic clays are mixed (as a drilling breccia) with massive, coarse glauconite sands. The sands form a loose fill around claystone chunks. There are abundant quartz grains with the glauconite pelloids, but benthic foraminifers are rare. In Section 476-21-3, the glauconite sand fills the section, and two rhythmic beds at the base grade from clay to glauconite sand. The sands are grain-supported and apparently winnowed of fines. An or-

Figure 52. Photomicrograph of rhyolitic vitric ash, Section 476-18-3, 130 cm.

ganic claystone with a petroliferous odor marks the bottom 70 cm of this unit, but there is a thin (2 mm), hard, brown phosphorite layer at Section 476-21-4 (2 cm), pyrite-cemented sand concretions, green-cemented siltstone, and three rhythms of thin sandy clays with large quartz grains, some possibly analcime, and glauconite, just above 20 cm of olive black (5Y 2/1) claystone.

The organic claystone is centimeter-banded to thinly laminated and contains 7.5% total carbon, along with quartz silt, sparse glauconite, and many blue-green algal threads. Pollen grains and fungi spores are rare, which also suggests a marine origin.

Unit V: cobble conglomerate with metamorphic clasts (Core 476-22–Section 476-22,CC; 199.0–256.5 m, age unknown). Less than two meters were recovered from this 57-meter thick unit, which contains a diverse suite of lower greenschist-facies metamorphic clasts. These are probably part of a thick, coarse conglomerate unit with an inferred fine-sand matrix. Most are very quartz-rich and show various levels of weathering. They include a green metagranite, metavolcanics, rhyolite, welded tuffs, metabreccia, metasedimentary siltstones, a graywacke, metasandstone, a metaconglomerate, and quartzite. Some were cored, which means some original cobbles may have been 30 cm or greater, indicating relatively short transport distance. None of the clasts consisted of batholith-type granite or granodiorite.

Sandwiched between two cobbles in Section 476-26-1, are 45 cm of a dark gray (N4), disturbed sandy clay. The origin of this clay is conjectural, but it resembles the granite below; it comprises very angular chips of quartz, highly weathered feldspars, and a moderately high birefringent, coarse clay with a ragged splinter appearance. With minor dessication, the sandy clay hardens to a solid rock. This clay is tentatively identified as hydromuscovite (illite), and its presence supports a waterlain continental setting for this bed. An alternative interpretation is that the clay represents a fault gauge from the granite. A single, well-preserved fungus spore in a smear side is further evidence of a continental sediment.

Unit VI: weathered, gray granite and rubble ("granite wash") (Cores 476-28–476-33, 256.5–294.0 m, Upper Cretaceous[?]). This unit is not strictly a sediment, but it appears to partially comprise weathered granitic boulders on a deeply weathered granitic basement. Many feldspars have been pervasively sericitized, and biotites and hornblendes are chloritized. Two harder pieces are described in the igneous rocks section. In most pieces there is flow structure, and quartz grains are highly fractured, suggesting proximity to a fault. The characteristics and type of weathering indicate an *in situ* subaerial weathering in an arid environment.

Paleoenvironment

Unit I sediments are considered to be typically hemipelagic, open-ocean, outer-slope sediments, with climatically induced pulses of diatom and nannofossil productivity or fluctuating terrigenous contributions. The sands are mostly winnowed lag deposits from periods of increased bottom currents, including times of lowered sea level.

Unit II is probably an outer-slope hemipelagic sequence. Sediments accumulated relatively slowly (40–50 m/m.y.) with episodic winnowing and redeposition.

The exact paleoenvironmental setting is not clear, but sediments from Unit III suggest an upper-slope fringe or plateau, perhaps protected from continuous terrigenous contributions and periodically winnowed by current. Intense upwelling may also have generated high diatom productivity. Local highs could have provided episodic influxes of spill-over lag deposits of benthic foraminifers, glauconite, angular quartz, and diatoms. Sporadically, muddy turbidites from other sources might have reached this area.

The environment of deposition for Unit IV is unclear, but it must represent moderately shallow water (initially in the photic zone) in a restricted, protective setting. Intertidal algal mats are unlikely settings because of the presence of glauconite grains and the lack of shallow-water carbonate. We envisage an offshore bank, subsiding in a restricted setting or O_2-minimum zone and isolated from the mainland. It is, however, difficult to explain the source of coarse quartz silt in the interlayered muds, unless they are storm deposits or the product of winnowing. The association of phosphorite, pyrite, and glauconite also points to an isolated, offshore bank, about 200 meters or deeper, near the zone of upwelling bottom waters. From the thickness of this facies, we suggest that Site 476 moved fairly rapidly through this sediment regime.

One interpretation for the Unit V metamorphic cobble beds and quartz-illite clay invokes large arroyos draining from the "Paleozoic," metamorphic cover on the Baja batholith, dumping the rocks at the mouth of an outwash, braided river plain. Similar rock assemblages outcrop along the tip of Baja California—for example, near San José del Cabo. After only a short transport distance, the present rivers have few granite cobbles—most of them crumble quickly from semiarid weathering.

In general, recent examples of almost all the sediment facies cored at Site 476 can be found in regions on, or offshore from, present-day Baja California. The lithological units also correlate closely with the drilled sequence at Site 475.

ORGANIC GEOCHEMISTRY

The monitoring program was conducted aboard ship. Hydrocarbon gases were not detected in this sediment sequence, since no gas pockets formed in any core liner. In some sections, however, slow gas diffusion built up a pressure under the caps, and these were sampled and analyzed. The results are plotted in Fig. 53. This increase in gas pressure was caused by outgassing of CO_2, and the data are very scattered; there is a possible decreasing trend in concentration with depth. The odor of H_2S was evident in the sediments from about 3 to 66 meters sub-bottom, and it was strongest in the shallower cores. The concentration was below the GC-detection limit, and the qualitative odor strength was Hole 474 > Hole 476 > Hole 475.

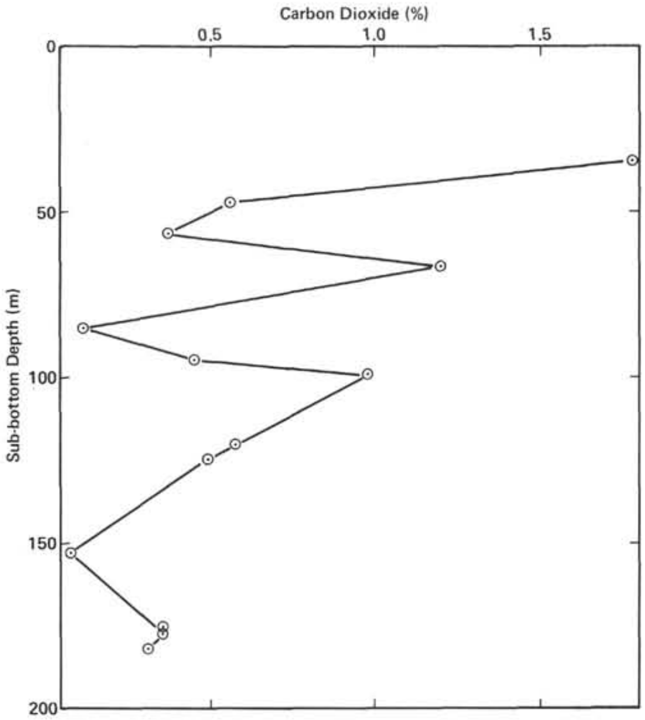


Figure 53. Carbon dioxide concentration versus depth, Site 476.

Organic Carbon and Nitrogen

The samples were analyzed as before and the results from the CHN analyzer are summarized in Appendix I, this volume, Pt. 2. The organic carbon and nitrogen values and ratios are plotted versus depth in Fig. 54. The organic carbon content ranges from about 0.7 to 7%, with three maxima downhole. In Units I (a nannoplankton ooze) and II (a silty clay), the values range to a maximum of about 3%, and in the base of Unit IV (pyritic claystone) the values range to about 7%. The organic nitrogen content parallels the organic carbon distribution and ranges from about 0.03 to 0.23% with the same maxima. The C/N ratio exhibits a trend to higher values with depth, and the values of the upper section are within the range (about 12) typical for Recent, unaltered, and immature sediments (Ryther, 1956). The onset of diagenetic alteration of the organic matter is indicated by the trend of the C/N increase with depth.

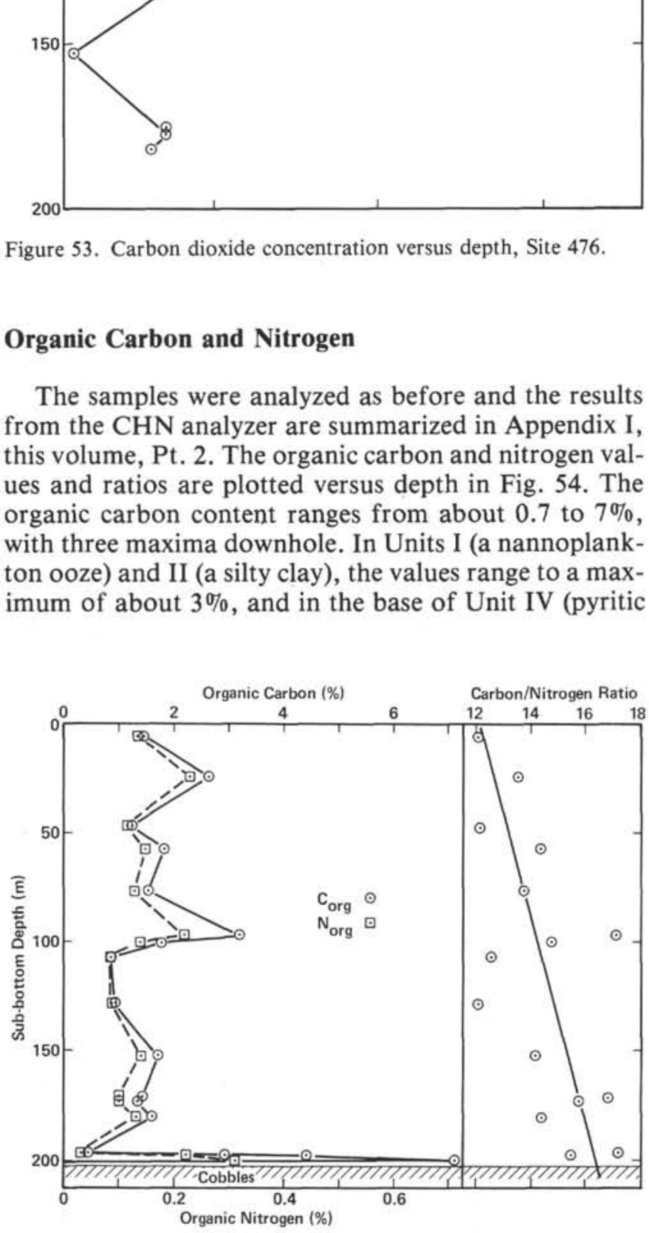


Figure 54. Organic carbon and nitrogen: content and ratios versus depth, Site 476.

Fluorescence

Fluorescence data were obtained from dried sediment samples, trichloroethane extract solutions of dried sediment, and pyrolized samples. Most of the samples exhibited no fluorescence for the extract and raw sediment, and most exhibited yellow fluorescence for the pyrolized sample extracts. The pyritic organic claystones (Sections 476-21-4 and 476-21,CC) exhibited very strong, yellow blue fluorescence for the pyrolysis extract. With the exception of the organic claystone section, the samples contain no petroleum; under the present *in situ* environmental conditions they lack a high potential as source material for petrogenesis.

Bromide Determination

The organic claystones (Sections 476-21-4 and 476-21,CC) may contain algal detritus as found in sapropels (indicated by color and visual and microscopic examination), and therefore a test for bromide was carried out. This is a qualitative spot test based on the reaction:

$$2MnO_4^- + 10Br^- + 16H^+ \rightarrow 2Mn^{++} + 5Br_2 + 8H_2O.$$

The samples were first leached with water and then digested with nitric acid (conc.). Clear supernatant was taken from each treatment and acidified or diluted to yield about a 0.5-M HNO_3 solution. Potassium permanganate (0.02 M) was added dropwise until no further oxidation took place (loss of MnO_4^- purple color). Tetrachloroethane was added to extract any resulting Br_2.

Both samples, as well as seawater, showed no Br_2 formation. This negative result may have been caused by the poor sensitivity of the test, or it may be that the organobromides accumulated by living algae have undergone diagenesis or decomposition with loss of Br^-.

The sedimentation rate at Site 476 was relatively slow, thus the potential for endogenous biogenic gas is low. Only H_2S and CO_2 were detected. The organic carbon and nitrogen contents were typical for biogenic ooze and silty clay. At the base of the sequence (in Unit IV) the C and N values increased in the pyritic organic claystone. The petrogenic potential of the organic matter is immature.

INORGANIC GEOCHEMISTRY

Interstitial Water Chemistry (Fig. 55)

Alkalinity values and ammonia and phosphate concentrations show maxima in the upper 100 meters of the sediment column and are a result of biochemical degradation of organic matter. Dissolved calcium shows a

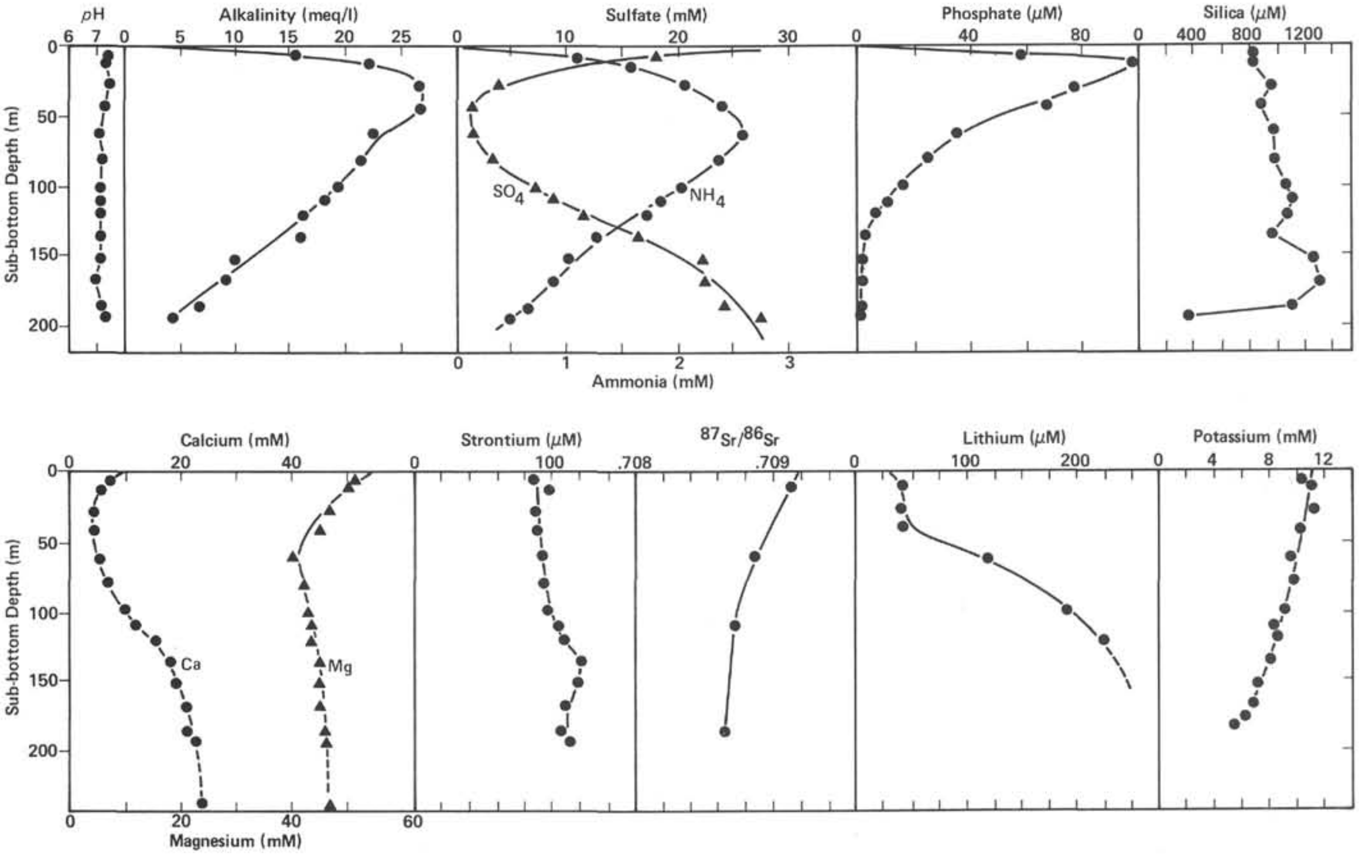


Figure 55. Interstitial water chemistry, Site 476.

minimum—from calcium carbonate precipitation—at about 40 meters. Below this, calcium concentrations increase rapidly and are probably related to weathering involving underlying continental basement rocks. Of special interest is the reversal in the magnesium concentrations, a phenomenon rarely observed at DSDP sites. This can best be explained by the weathering of underlying granitic rocks. Dissolved silica concentrations indicate the presence of biogenic silica, and the overall increase in concentrations with depth is the result of higher opaline silica solubilities caused by increased temperatures.

BIOSTRATIGRAPHY

The sedimentary sequence at Site 476 (Fig. 56) contains calcareous nannofossil assemblages similar to those at Site 475. Abundance, preservation, and composition of these assemblages are also very similar at both sites.

Coccoliths

Cores 476-1, 476-2, and 476-3 are late Pleistocene. Core 476-4 through Section 476-10-5 is early Pleistocene. The Pleistocene/Pliocene boundary, less sharply marked than at Site 475, occurs between Sample 476-10-5, 82–83 cm and 476-11-1, 70–71 cm. Sample 476-11-1, 70–71 cm through Section 476-16-2 is late Pliocene, and Section 476-16-3 through Core 476-21 is early Pliocene.

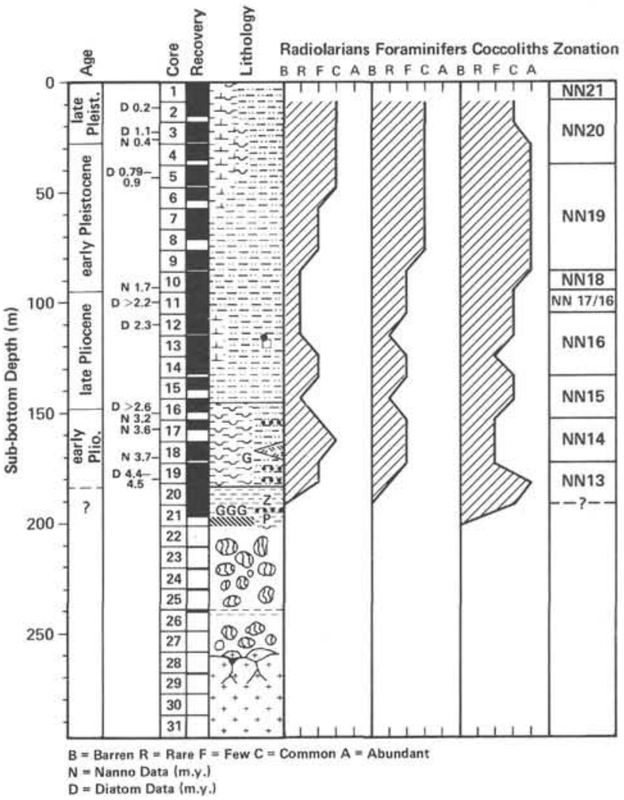


Figure 56. Biostratigraphy, Site 476.

Pseudoemiliania lacunosa first occurs in Sample 476-4-5, 37–38 cm. Because of reworking the occurrences of *Helicosphaera sellii* and *Cyclococcolithus macintyrei* are sporadic and therefore do not provide biostratigraphic data. *Discoaster brouweri* increases in abundance in Sections 476-10-5, 476-10-6, and 476-10-7. *Discoaster pentaradiatus* occurs in Sample 476-11-3, 74–75 cm, where it may be reworked; it occurs again in Core 476-12 with *D. surculus*. Typical *Reticulofenestra pseudoumbilica* first occurs in Sample 476-16-3, 58–59 cm, *Amaurolithus tricorniculatus* in Sample 476-17-3, 51–52 cm.

Diatoms

Open-marine-tropical-to-subtropical planktonic diatoms are abundant and well preserved to rare and poorly preserved in the hemipelagic sediment sequence in Cores 476-1 through 476-20; samples below Section 476-20-5, are barren of diatoms. The following key biostratigraphic species were found: *Nitzschia reinholdii*, 476-2-1, 95–97 cm; *Mesocena quadrangula*, 476-5-5, 36–38 cm; *Rhizosolenia barboi/curvirostris*, 475-8-1, 72–74 cm; *Thalassiosira convexa*, 476-11-5, 93–95 cm; *Cussia tatsunokuchiensis* and *N. jouseae*, 476-16-4, 34– 36 cm; *Cosmiodiscus insignis*, 476-19-3, 84–86 cm; *N. cylindrica*, 476-19-6, 84–86 cm. Distinct colder intervals, determined by the presence of *R. barboi/curvirostris* occur at the following levels: 476-3-4, 49–51 cm and 476-8-1, 72–74 cm. The assemblage correlates with that of Site 475.

Radiolarians

Hole 476 has index species for biostratigraphical control only in the lowermost part of the fine-grained sedimentary sequence (Sections 476-16–476-20). The species are *Stichocorys peregrina, Ommatartus avitus*, and *O. penultimus* and are dated late Miocene to early Pliocene. Such an age agrees with the nannoplankton zonation (NN15–13).

The fine-grained lowermost sedimentary sequence in Hole 476 is a diatomaceous ooze. Within this sequence, we observed a bloom of *Euchitonia* spp. and *Spongodiscus biconcavus*.

The composition of species in the radiolarian population in the Quaternary is typical of subtropical continental margins; among others: *Tetrapyle octacantha, Botryostrobus auritus-australis* group, *Euchitonia furcata, O. tetrathalamus, Stylochlamydium asteriscus*, and *Lithelius minor*. This radiolarian population shows some effect of coastal upwelling, as is suggested by the relative abundance of *Duppatractus* cf. *pyriformis, D. irregularis*, and *Polysolenia murrayana*.

The relative abundance of radiolarians in the upper two-thirds of Hole 476 has a trend similar to the record in Hole 475.

Planktonic Foraminifers

A planktonic foraminiferal zonation for Hole 476 has not been established, because "typical" index species for biostratigraphic control have not been found. Nevertheless, the Pliocene portion of the hole is characterized by the presence of *Globigerinoides obliquus extremus*(?). In the Quaternary, a subtropical planktonic foraminiferal population is common, probably affected by the California Current and coastal upwelling. This population is dominated by *Neogloboquadrina dutertrei, G. ruber, Globigerina bulloides*, and *Globoquadrina pachyderma* right coiling.

The composition of the foraminiferal population in Hole 476 is similar to that in Hole 475. Also, the relative abundance of planktonic foraminifers in the upper two-thirds of Hole 476 resembles the record in Hole 475.

SEDIMENT ACCUMULATION RATES

The sediment accumulation rates (Fig. 57) are slightly higher at Site 476 than at Site 475. This may reflect its location nearer to an outer slope basin axis. Despite varying abundances of plankton, the overall rate for Units I, II, and III is fairly uniform (42 m/m.y.).

Glauconitic–phosphoritic claystones in Unit IV probably had a much lower rate of accumulation, but if the hemipelagic rates are projected further, deposition of the conglomerates could have occurred before the latest Miocene and they were probably rapidly emplaced.

IGNEOUS PETROLOGY

Weathered granite was encountered in the core catcher of Core 476-28 (256.0–265.0 m sub-bottom), although drilling an additional 29.0 meters recovered only 1.14 meters of rock. The samples (Fig. 58) in Cores 476-28 through 476-31 are a biotite- and hornblende-bearing granite that is medium-grained, inequigranular, and light gray (5B 7/1). In the fresher samples, the major mineralogical components are anhedral-to-subhedral feldspar, comprising albite (15%) and perthitic orthoclase (40%), although no microcline was observed; anhedral, rounded, fractured, and strained quartz (35%); equant and acicular grains of hornblende (<5%), now variably replaced by chlorite; and biotite and muscovite (<5%) also now replaced by chlorite and containing zircon. Minor amounts of euhedral pyrite crystals occur in veins and clusters; apple green epidote fills a few small cavities. Drusy quartz commonly lines small microlitic cavities (as large as 5 × 2 mm).

Within the granite, texture varies considerably. Pieces 5 and 12 of Section 476-29-1 are the freshest samples, exhibiting hypidiomorphic textures and slight alteration of the biotite and hornblende. Most pieces, however, show replacement of the mafic minerals by chlorite, sericitization of the albite, and cataclastic textures indicating intense deformation. In the most deformed samples, the minerals form isolated fragments within a streaky, aphanitic, mylonitized matrix.

Many of the samples are cobbles that lack drilling surfaces and therefore have no orientation. This is par-

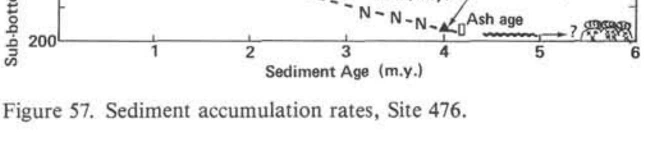


Figure 57. Sediment accumulation rates, Site 476.

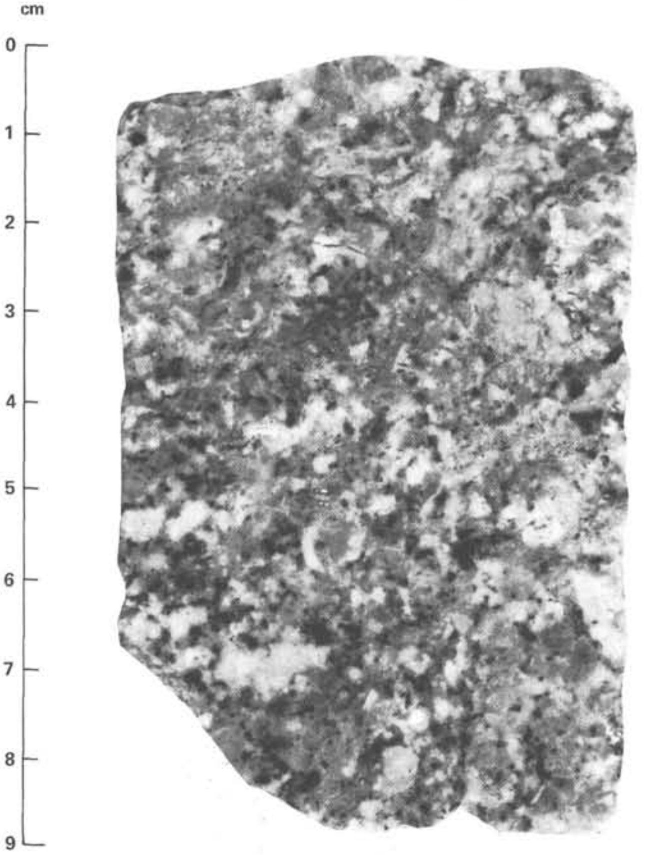


Figure 58. Hornblende, biotite granite from Section 476-29-1, Piece 6.

tially explained by the drilling record which indicates that the bit encountered mostly unconsolidated material, thereby allowing each 9.5-meter core to be drilled quickly (20–28 min.). Perhaps we drilled through a sequence of granite blocks interspersed with weathered granite or granitic detritus—an association common in subaerially exposed terrains. Because granite is easily weathered by subaerial (or subaqueous) processes, the samples from Hole 476 probably were not transported very far, if at all, from their site of exposure.

PHYSICAL PROPERTIES

As at the previous sites, the uppermost and some deeper cores (e.g., Cores 476-6, 476-8, 476-9, 476-21) are strongly and rather continuously disturbed. Therefore, in general, only samples for determining water content were taken from these cores. The lowermost part of the hole (from 200 m down), where cobbles, some highly disturbed clayey silt, and quartz silt were encountered, is not represented in Figure 59.

In the upper 130 to 140 meters of the Pliocene to Quaternary sediments, the trend curves for the different physical properties are very similar to those of Site 475 (Figs. 59, 60). At the transition from Sedimentary Unit I (diatomaceous nannofossil-bearing silty clay) to Unit II (a rather pure silty clay at about 70 m), water content and porosity distinctly decrease, whereas bulk density increases. Farther downhole, to about 140 meters, these physical properties remain more or less constant.

Unlike Sites 474 and 475, in a section from 150 to 180 meters, water content and porosity again increase from 45 to 55% and 70 to 75%, respectively. Bulk density drops from 1.53 to 1.40 g/cm^3, and vane shear strength and sound velocity are also somewhat reduced. This unusual change of physical properties is caused by the high content of diatoms (diatomaceous ooze of Unit III), which are not strongly affected by diagenesis. The proportion of opaline silica—as determined from the average grain density of the total samples—is plotted in Figure 59 (for further details, see Site 474 remarks, earlier). The shrinkage of dried (110°C) cylinder samples, which ranges from about 35 to 40% in upper Sedimentary Units I and II, is now, however, limited to 10%, indicating that the grain packing must have been somewhat stabilized. Yet sediments very rich in biogenic silica appear to shrink less than samples with higher clay content, provided that the initial water content or porosity was about the same. Unfortunately, the transition to the deeper Unit IV, consisting of firm zeolite-bearing clay, could not be tested because of strong core disturbances. Several samples within this unit now show very low water contents (about 30%), porosities of 55% and less, high bulk densities of 1.8 g/cm^3, and an increase in shear strength (more than 1.3×10^5 Pa = ~1300 g/cm^2) and sound velocity (1.63 km/s). At 200 meters, acoustic impedance is nearly 3.0×10^5 g/cm^2 s. The marked change of all physical properties in Unit IV is confirmed by the observation that in some silty layers cementation by calcite has already begun (Sample 476-20-4, 25–30 cm). Whether this is caused solely by the presumably higher age of this material (NN11–NN13) or whether a former sediment column on top of Unit IV has been removed by erosion before the present Units III to I were accumulated cannot be resolved.

As at Site 476, a light olive gray, nannofossil-rich layer and a dark brownish layer rich in diatoms from the same depth were compared (Samples 476-1-3, 23–25 cm and 476-1-3, 44–46 cm). The results are as follows:

	Water Content (%)	Porosity (%)	Bulk Density (g/cm^3)
Dark layer, high in diatoms	65.5	82.1	1.28
Light layer	56.1	76.7	1.40

Although the sediments were disturbed, the difference in physical properties between these very common "subunits" of the Pliocene–Quaternary sediment sequence appears to be well established (e.g., see Tucholke et al., 1976).

From selected samples from the lowermost part of the hole (but not represented in Fig. 59), we determined sonic velocity (by the Hamilton Frame), wet-bulk density, and acoustic impedance (Table 11).

HEAT FLOW AND THERMAL CONDUCTIVITY

Thermal conductivities at Site 476 are low (~2.2 mcal/cm s °C) in the surface 30 meters of diatomaceous ooze, are higher (2.4–2.5 mcal) in the silty claystone ex-

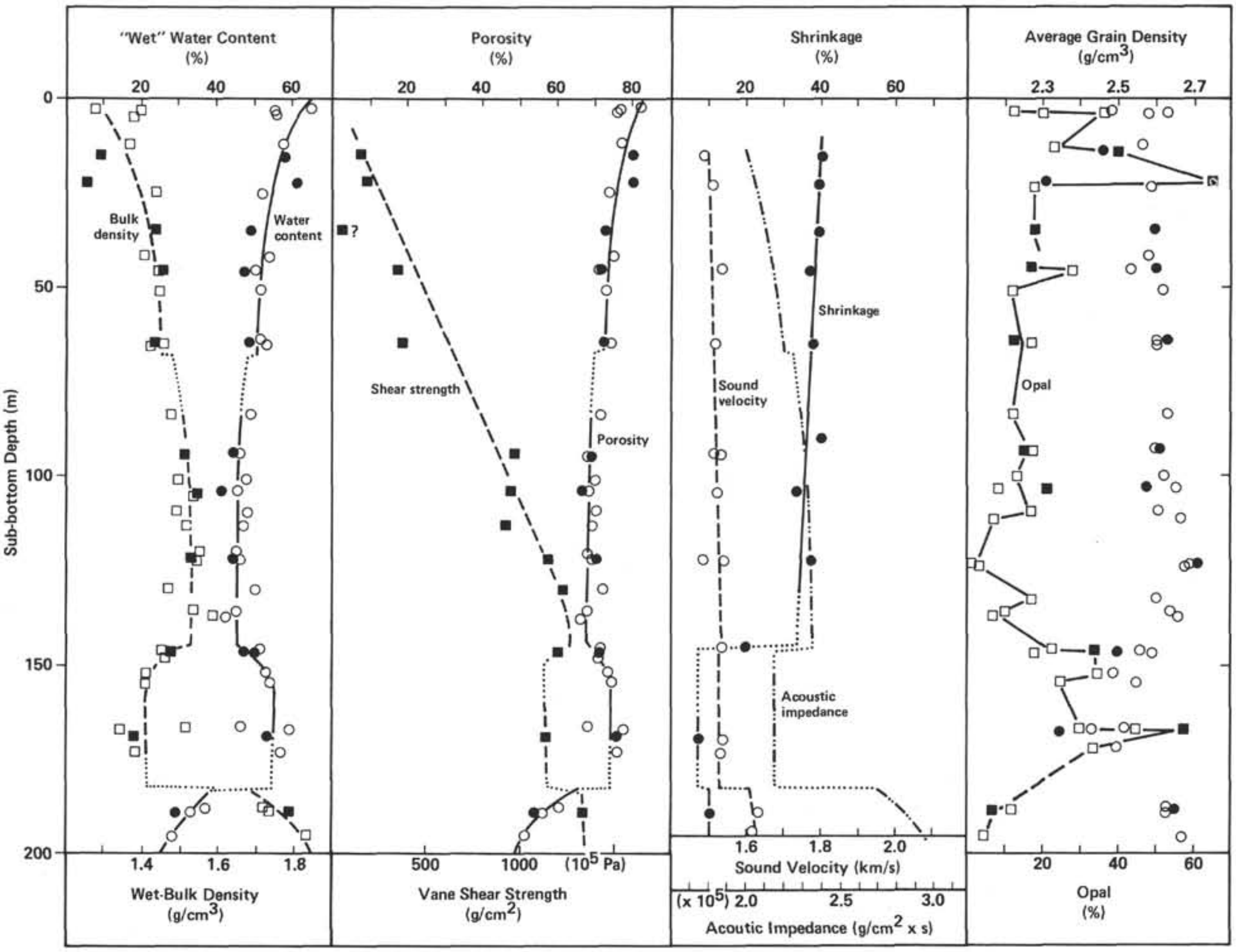


Figure 59. Mass physical properties, shrinkage, and proportion of opaline silica, Site 476 sediments. (Note the pronounced changes [140–180 m] caused by high content of opaline silica; note also the unusual increase of compaction in the section from 180–200 m. Closed symbols are cylinder samples. Open symbols are chunk samples.)

tending to 145 meters, and are again low (2.1–2.2 mcal) in the lower diatomaceous ooze (see Fig. 61A). The highest thermal conductivity is in the lowest clay (Core 476-21; 2.94 mcal/cm s °C). Thermal conductivities are again inversely correlated with the water content of the units.

In situ temperatures were measured in Hole 476 at depths of 47.0 and 123.0 meters and plotted versus depth (Fig. 61B).

Three distinct temperature gradients can be calculated using the temperature at 47.0 meters and the bottom-water temperature, the temperature at 123.0 meters and the bottom water temperature, and the temperatures at 123.0 and 47.0 meters. Heat flow calculations, taking thermal conductivity changes into account, yield heat flows of 4.0, 2.4, and 1.4 HFU, respectively.

The low heat flow calculated using the two *in situ* temperatures (1.4 HFU) suggests that the temperature measured at 47.0 meters may be high and that heat flow at this site is approximately 2.4 HFU. If this is true, the transect from oceanic to continental crust is marked by moderate-to-low heat flows for the young oceanic crust (3.1 HFU at Site 474), high heat flow in the transition zone (4.0 HFU at Site 475), and lower heat flow on the continental site (2.4 HFU at Site 476).

CORRELATION OF DRILLING RESULTS AND SEISMIC DATA

Site 476 is in an area with extensive seismic-reflection coverage from the Scripps Institution of Oceanography, the University of Washington International Program on Oceanic Drilling (IPOD) Site-Survey cruises, and other studies. We will attempt later (Curray et al., this volume, Pt. 2) to relate results of drilling at this and the previous two sites, 474 and 475, to regional structure and tectonics. We intend now only to relate the lithological column to the reflection record obtained when the beacon was dropped.

No multichannel moveout velocities and no sonobuoy wide-angle reflection velocity information is available; neither were downhole logs run. The only velocity information is the laboratory measurements reported in this chapter. Accepting these values and assuming velocities for the other units, we assign velocities to the lithological units as follows:

Unit I: 0–66 meters; Pleistocene nannofossil and diatom ooze; 1.51 km/s

Unit II: 66–145 meters; late Pliocene silty clay; 1.53 km/s

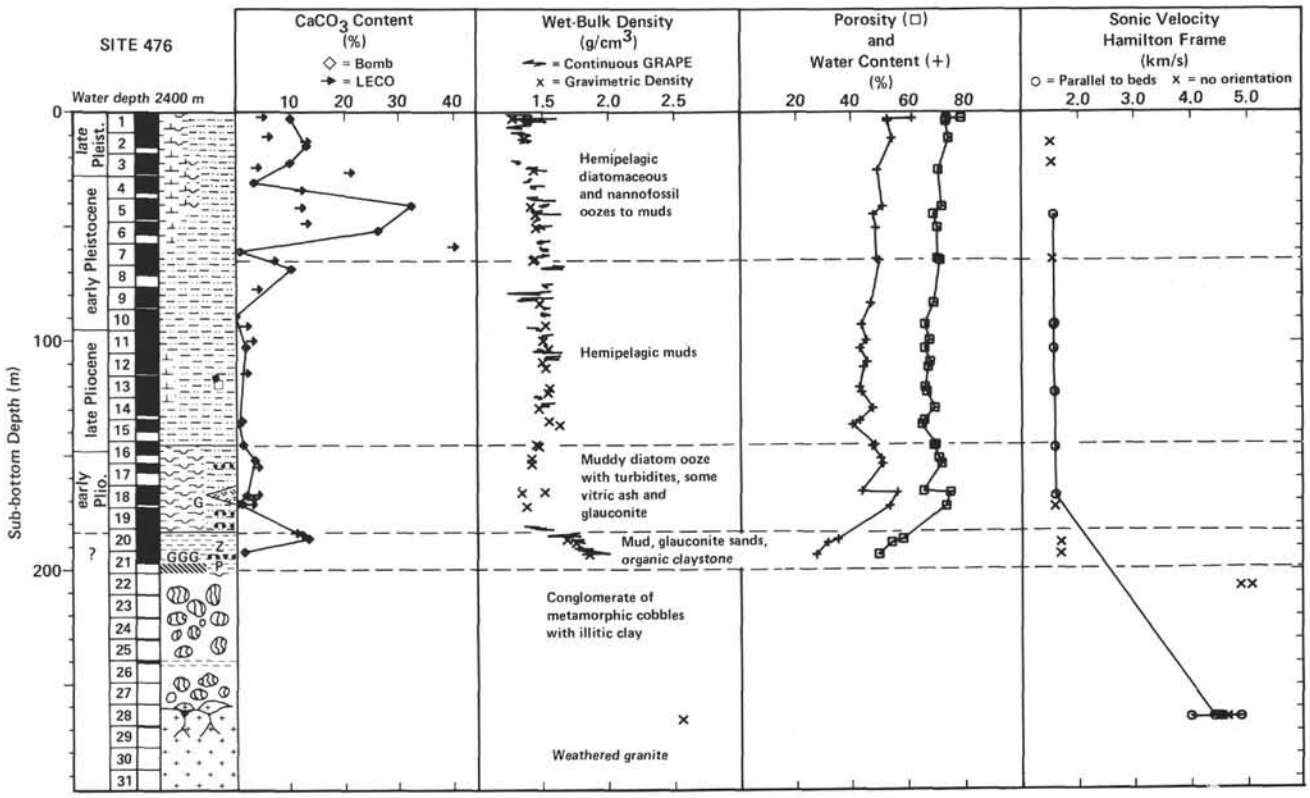


Figure 60. Calcium carbonate and physical properties, Site 476. Analyzed ashore at Scripps Institution.

Table 11. Sonic velocity (v_S), wet-bulk density (BD), and acoustic impedance (AI) of some samples from Unit V, Site 476.

Sample (level in cm)	Description	v_S (km/s)	BD (g/cm^3)	AI ($\times 10^5$g/cm^2 s)
476-23,CC	metamorphic sandy siltstone	5.13	—	—
476-23,CC	metamorphic sandy siltstone	4.92	—	—
476-29-1, 20	fresher granite	4.42	—	—
476-29-1, 20	fresher granite	4.53	—	—
476-29-1, 37	cataclastic granite, weathered	4.91	2.51	11.4
476-29-1, 37	cataclastic granite, weathered	3.99	2.51	11.4
476-29-1, 37	cataclastic granite, weathered	4.66	2.51	11.4
476-29-1, 37	cataclastic granite, weathered	4.57	2.51	11.4

Unit III: 145–183 meters; early Pliocene diatom ooze; 1.54 km/s

Unit IV: 183–199 meters; Pliocene–Miocene glauconitic sand, phosphorite, and the like; 1.61 km/s

Unit V: 199–256 meters; cobble conglomerate; 1.61 km/s

Unit VI: 256–294 meters; weathered granite: 1.61 km/s.

The two-second sweep record across this site, without interpretation or correlation, is shown in Figure 62A. Figure 62B shows the same record with an interpretation of structure and a correlation with the units as defined. The overall structure is a series of low-angle normal

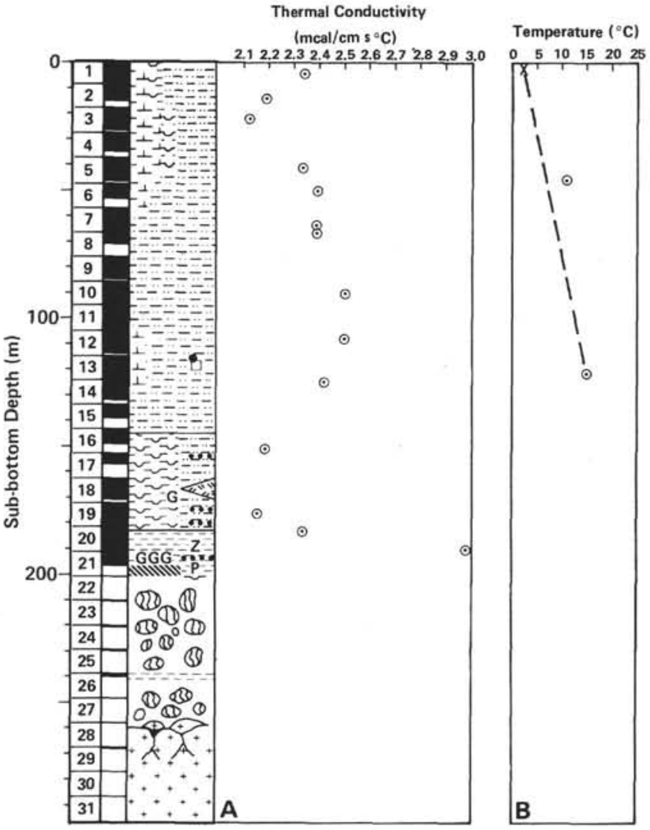


Figure 61. Thermal conductivities (A) and *in situ* temperatures (B), Site 476.

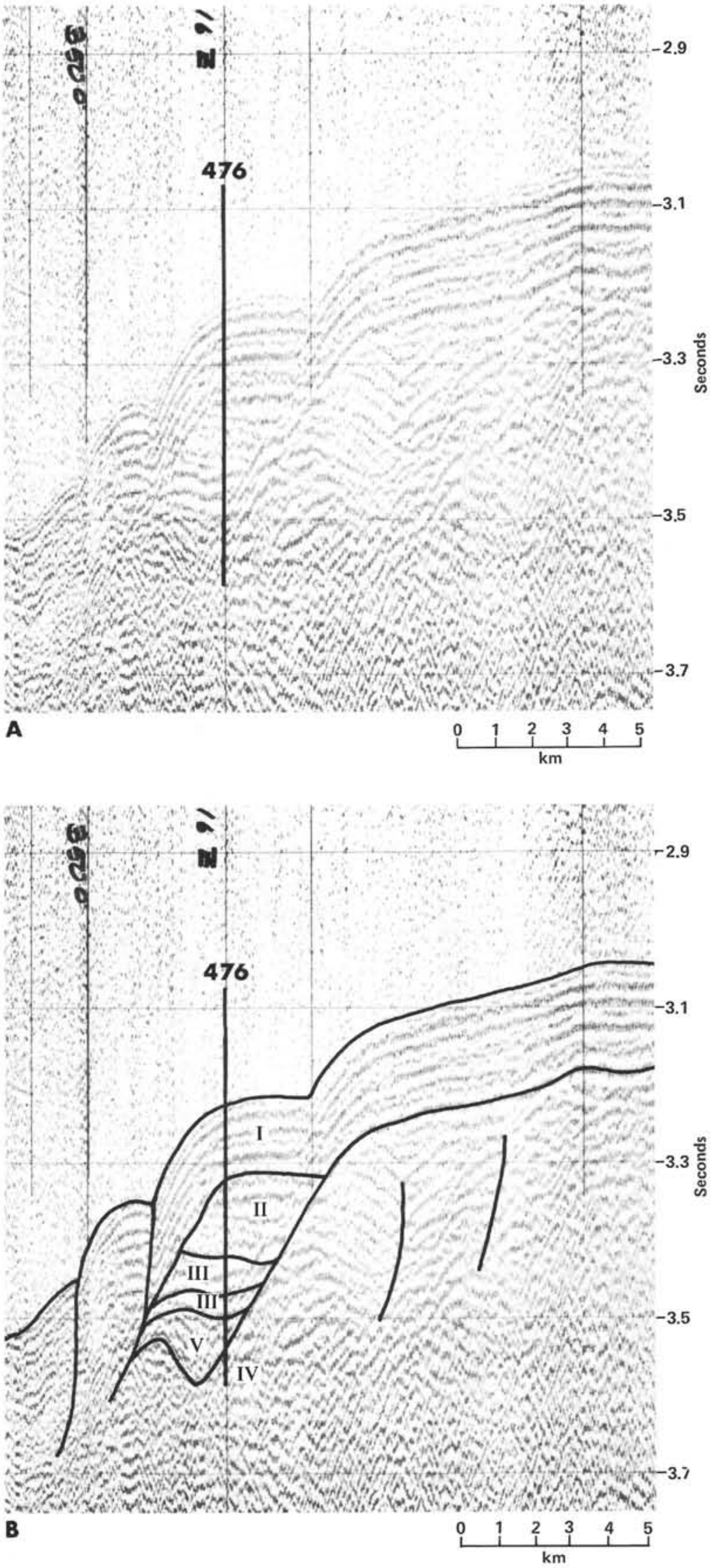


Figure 62. A. Single-channel analog seismic reflection record across Site 476 (from *Glomar Challenger*). B. Same record, showing interpreted correlations of drilling results with structure and stratigraphy.

faults separating rotational fault blocks and covered with a drape of younger hemipelagic sediments. Some of the normal faults may surface and demonstrate recent or continuing movement of the underlying slump blocks.

Possible unconformable relations may exist between Units I and II and between Units II and III. Unit V, the cobble conglomerate, appears to rest at the foot of a fault scarp as a talus accumulation. The sharp contact between the conglomerate may have been caused by the penetration of the fault that formed the scarp.

SUMMARY AND CONCLUSIONS

Site 476 is the third and most landward site of the three-site transect across the youthful passive continental margin of the tip of Baja California. The site is on a terrace, low on the continental slope, and about 42 km southeast of the peninsula in 2400 meters of water. The seismic record indicates that this terrace overlies one of a series of small rotational slump blocks. Specific objectives at this site were to confirm the existence of continental crust, to learn the nature of the sediments, and to obtain evidence for subsidence and changes in environmental factors. All were realized. We drilled to a depth of 294.5 meters and bottomed in a basement of deeply weathered granite. The failure of the newly developed hydraulic bit-dropping mechanism precluded any logging.

The lithological section is divided into six units, including the sedimentary and igneous material.

Unit I (0–66 m) is hemipelagic Pleistocene nannofossil and diatomaceous ooze to mud;

Unit II (66–145 m) is late Pliocene hemipelagic mud;

Unit III (145–183 m) is early Pliocene, upper-continental-slope, muddy diatomaceous ooze with turbidite layers, vitric ash, and glauconite sands;

Unit IV (183–199 m) is late Miocene–early Pliocene(?) organic claystone, glauconitic sands, and silty clay. This thin unit suggests the existence of an isolated shallow bank environment in the oxygen minimum.

Unit V (199–256 m) comprises a metamorphic cobble conglomerate of unknown age. It was probably deposited in a continental arroyo, outwash, or alluvial fan environment;

Unit VI (256–294 m) is a deeply weathered granite.

Physical properties are difficult to determine because of severe coring deformation, but water content and porosity trends reverse their normal downhole decrease with higher values in the diatomaceous ooze of Unit III; bulk density and sound velocity decrease in the same unit. Sonic velocity is generally low in Units I through III at just above water velocity, with values of about 1.51 to 1.54 km/s. It increases in Unit IV to over 1.60 km/s. Granite cobble velocities are 4.0 to 4.9 km/s, but the *in situ* velocity of this weathered zone must be much lower.

The amount of organic material is generally low, and this sedimentary section would not constitute a good hydrocarbon source rock. The interesting increase in Mg content with depth below about 60 meters is probably an upward flux from the weathering of the continental basement and the terrigenous constituents of the basal conglomerates. Most oceanic DSDP sites show a continuing decrease in Mg with depth.

Measurements of heat flow suggest higher than average heat flow—about 2.4 HFU.

The only velocity information available is the shipboard laboratory measurements. To correlate the drilling results with our seismic data, we utilized the measured velocities and assumed others for units not covered; we derived the following velocity structure: Unit I = 1.51 km/s; Unit II = 1.53 km/s; Unit III = 1.54 km/s; Unit IV = 1.61 km/s, Unit V = 1.61 km/s, and Unit VI = 1.61 km/s. With these velocities the lithology can be correlated with the seismic data. To link the three holes, we conducted a seismic survey while departing Site 475. It shows that our drilled sections are within one block of a series of fault blocks draped with younger hemipelagic sediments. Units I, II, and III appear to have possible unconformable relations. Unit V, the cobble conglomerate, rests at the foot of a fault scarp probably as a talus accumulation.

Our drilling at Sites 475 and 476 provides evidence for depositions on a subsiding, granitic continental margin. Subaerial conglomerates of possible middle to late Miocene are overlain by shallow-marine mudstones and claystones with abundant glauconite. This is followed by diatom ooze or mud, hemipelagic clay, and fluctuating amounts of terrigenous mud, nannofossil, and diatom ooze in the upper Pleistocene.

A comprehensive discussion of the geological history of the young passive margin off the tip of Baja California is presented elsewhere in the volume.

REFERENCES

Beck, A. E., 1965. Techniques of measuring heat flow on land. *In* Lee, W. H. K. (Ed.), *Terrestrial Heat Flow: Geophysical Monograph 8:* Washington (American Geophysical Union), pp. 24–51.

Doose, P. R., Sandstrom, M. W., Jodele, R. Z., et al., 1978. Interstitial gas analysis of sediment samples from Site 368 and Hole 369A. *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP,* 41: Washington (U.S. Govt. Printing Office), 861–863.

Gastil, G., et al., 1976. La zona batolitica del Sur de California y el Occidente de México. *Bol. Soc. Geol. Mex.*, 37:84–90.

Hays, J. D., 1970. Stratigraphy and evolutionary trends of radiolaria in North Pacific deep sea sediments. *In* Hays, J. D. (Ed.), *Geological Investigations of North Pacific. Geol. Soc. Am. Mem.*, 126:185–218.

Hays, J. D., et al., 1972. *Init. Repts. DSDP,* 9: Washington (U.S. Govt. Printing Office).

Kling, S. A., 1973. Radiolaria from the eastern North Pacific. Deep Sea Drilling Project, Leg 18. *In* Kulm, L. D., von Huene, R., et al., *Init. Repts. DSDP,* 18: Washington (U.S. Govt. Printing Office), 617–671.

Kulm, L. D., von Huene, et al., 1973. *Init. Repts. DSDP,* 18: Washington (U.S. Govt. Printing Office).

Larson, R. L., 1972. Bathymetry, magnetic anomalies, and plate tectonic anomalies, and plate tectonic history of the mouth of the Gulf of California. *Geol. Soc. Am. Bull.*, 83:3345–3360.

Larson, R. L., Menard, H. W., and Smith, S. M.,1968. Gulf of California: A result of ocean-floor spreading and transform faulting. *Science*, 161:781–784.

Lewis, B. T. R., McClain, J., Snydsman, W. E., et al., 1975. Gulf of California IPOD site survey, final report. (Unpublished)

Lopéz Ramos, E., 1976. *Carta Geologica de la Republica de México* (4th ed.). Comite de la Carta Geologica de Mexico.

Molina-Cruz, A., 1978. Late Quaternary circulations along the Pacific coast of South America [Ph.D. dissert]. Oregon State University.

Moore, D. G., 1973. Plate-edge deformation and crustal growth, Gulf of California structural province. *Geol. Soc. Am. Bull.*, 84: 1883–1906.

Moore, D. G., and Buffington, E. C., 1968. Transform faulting and growth of the Gulf of California since the late Pliocene. *Science*, 161:1238–1242.

Moore, G. F., Becker, K., Bibee, L. D., et al., 1978. Gulf of California IPOD site summary, final report. (Unpublished)

Nigrini, C. A., 1971. Radiolarian zones in the Quaternary of the equatorial Pacific Ocean. *In* Funnell, B. M., and Riedel, W. R. (Eds.), *The Micropaleontology of Oceans:* Cambridge (Cambridge University Press), pp. 443–461.

Normark, W. R., and Curray, J. R., 1968. Geology and structure of the tip of Baja California, Mexico. *Geol. Soc. Am. Bull.*, 69: 1589–1600.

Phillips, R. P., 1964. Seismic refraction studies in Gulf of California. *In* van Andel, Tj. H., and Shor, G. G. (Eds.), *Marine Geology of the Gulf of California: A Symposium:* Tulsa (American Association of Petroleum Geologists), pp. 90–121.

Piper, D. J. W., 1978. Turbidite muds and silts on deep sea fans and abyssal plains. *In* Stanley, D. J., and Kelling, G. (Eds.), *Sedimentation in Submarine Canyons, Fans, and Trenches:* (Dowden, Hutchinson, and Ross), pp. 163–176.

Ryther, J. H., 1956. Photosynthesis in the ocean as a function of light intensity. *Limnol. Oceanogr.*, 1:6–70.

Shepard, F. P., 1964. Sea floor valleys of Gulf of California. *In* van Andel, Tj. H., and Shor, G. G. (Eds.), *Marine Geology of the Gulf of California: A Symposium:* Tulsa (American Association of Petroleum Geologists), pp. 157–193.

Srinivasan, M. S., and Kennett, J. P., 1976. Evolution and phenotypic *Neogloboquadrina dutertrei plexus. In* Takayanasi, Y., and Saito, T. (Eds.), *Progress in Micropaleontology:* New York (American Museum of Natural History), pp. 329–355.

Tucholke, B. D., Edgar, N. T., and Boyce, R. E., 1976. Physical properties of sediments and correlations with acoustic stratigraphy: Leg 35, Deep Sea Drilling Project. *In* Hollister, C. D., Craddock, C., et al., *Init. Repts. DSDP*, 35: Washington (U.S. Govt. Printing Office), 229–249.

van Andel, Tj. H., 1964. Recent marine sediments of Gulf of California. *In* van Andel, Tj. H., and Shor, G. G. (Eds.), *Marine Geology of the Gulf of California: A Symposium:* Tulsa (American Association of Petroleum Geologists), pp. 216–311.

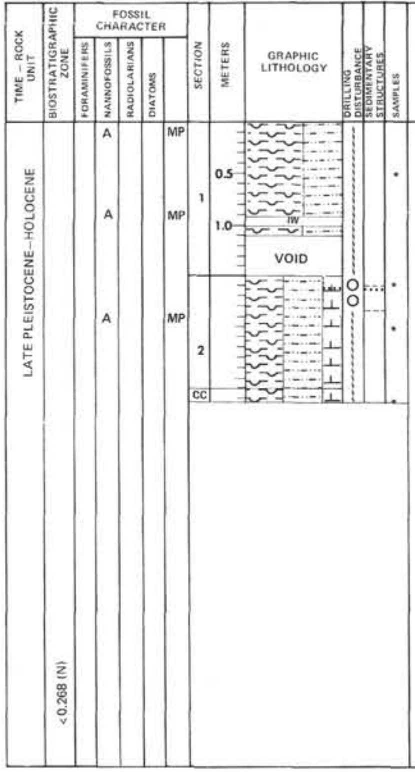
Von Herzen, R., and Maxwell, A. E., 1959. The measurement of thermal conductivity of deep-sea sediments by a needle probe method. *J. Geophys. Res.*, 64:1557–1563.

von Rad, U., Ryan, W. B. F., et al., 1977. *Init. Repts. DSDP*, 47, Pt. 1: Washington (U.S. Govt. Printing Office).

Whelan, J. K., 1979. C_1 to C_7 hydrocarbons from IPOD Holes 397 and 397A. *In* von Rad, U., Ryan, W. B. F., et al., *Init. Repts. DSDP*, 47, Pt. 1: Washington (U.S. Govt. Printing Office), 531–539.

Wyman, R. E., and Castaño, J. R., 1974. Show descriptions from core, sidewall and ditch samples. *SPWLA 15th Ann. Logging Symp.*, pp. 1–21.

SITE 474 HOLE CORE 1 CORED INTERVAL 0.0–2.0 m



LITHOLOGIC DESCRIPTION

5GY 3/2

Highly disturbed, homogenous grayish olive green (5GY 3/2) **MUDDY DIATOMACEOUS OOZE to CLAYEY SILT.** Some very dark streaks occur at Section 1, 35 to 45 cm and 53 to 55 cm suggesting former decimeter bedding. Surface sprinkled with detrital grains, including mica. Dark greenish gray (5G 4/1) **SAND** at Section 2, 9 to 12 cm includes quartz (~250μm) and some shell fragments. Gradational contacts.

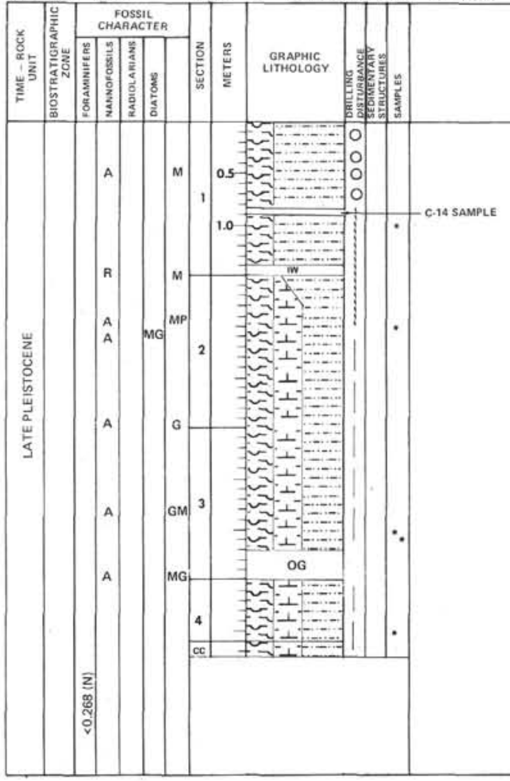
SMEAR SLIDE SUMMARY

	1-50 (D)	2-10 (CF)	2-50 (D)	CC (M)	CC (D)
TEXTURE:					
Sand	5	–	10	15	10
Silt	60	–	60	45	60
Clay	35	–	30	40	30
COMPOSITION:					
Quartz	10	50	10	5	15
Feldspar	5	10	2	–	2
Mica	2	5	2	1	TR
Heavy minerals	TR	2 (AP)	–	1	TR
Clay	30	–	5	30	20
Volcanic glass	–	–	–	2	TR
Pyrite	2-3	–	1	3	5
Foraminifers	–	–	2	TR	5
Calc. nannofossils	20	–	30	–	5
Diatoms	15	–	40	40	30
Radiolarians	–	–	3	2	10
Sponge spicules	2	–	5	3	5
Silicoflagellates	–	–	–	TR	2
Plant debris	4	–	4	0	TR

COARSE FRACTION: CC (Radiolarian-bearing muddy diatomaceous ooze)

Radiolarians	10- 5
Fecal pellets	60
Chlorite	5
Biotite	5
Fish debris	TR
Foraminifers	10

SITE 474 HOLE CORE 2 CORED INTERVAL 2.0–11.5 m



LITHOLOGIC DESCRIPTION

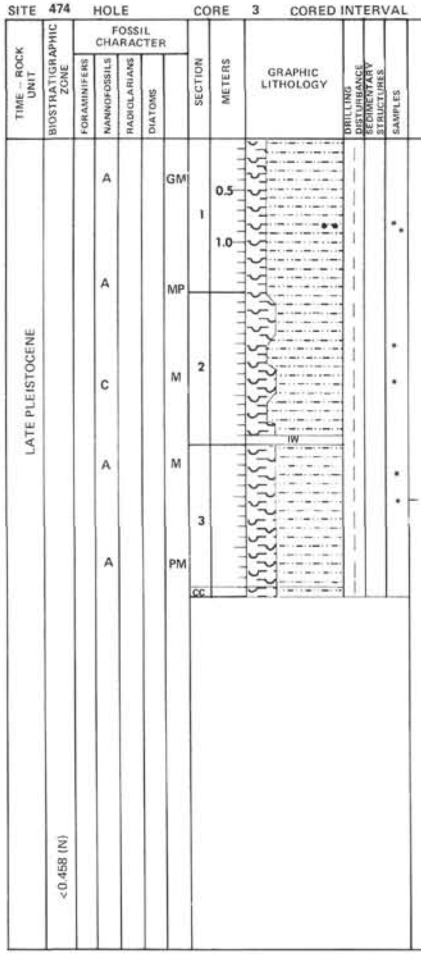
Grayish olive green (5GY 3/2) **MUDDY DIATOMACEOUS OOZE to CLAYEY SILT** in Section 1 grades into dusky yellow green (5GY 5/2) **DIATOMACEOUS NANNOFOSSIL OOZE** to bottom of core. Some streaks of black matter (organics?) present with strong H_2S smell. Moderately disturbed laminae in Section 2, 58 cm through bottom of core are sharp contacts alternating between grayish olive green (5GY 3/2) and dusky yellow green (5GY 5/2) hemipelagic muds. Mica flakes visible throughout the core. Sponge spiculites seen locally as small white spots. Sand fraction enriched in quartz, feldspar and heavy minerals. Scattered shell fragments.

SMEAR SLIDE SUMMARY

	Muddy diatomaceous ooze 1-100 (M)	Muddy diatomaceous-nannofossil ooze 2-50 (D)	Spiculite 3-102 (M)	Muddy diatomaceous-nannofossil ooze 3-111 (D)	Muddy diatomaceous ooze 4-50 (D)
TEXTURE:					
Sand	10	–	–	–	5
Silt	50	70	90	40	45
Clay	40	30	–	50	50
COMPOSITION:					
Quartz	5	15	40	10	7
Feldspar	2	23	5	2	3
Mica	2	–	–	–	2
Heavy minerals	–	5	–	–	–
Clay	40	25	–	30	40
Pyrite	3	2	–	1	2-3
Carbonate unspec.	1	3	2	–	2
Foraminifers	–	3	5	2	5
Calc. nannofossils	1-2	30	5	25	20
Diatoms	30	30	–	30	20
Radiolarians	10	TR	–	TR	TR
Sponge spicules	10	TR	50	2	35
Silicoflagellates	–	5	–	5	–
Fish remains	2	–	–	TR	–
Plant debris	–	–	–	2	–

Information on core description sheets, for ALL sites, represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.

SITE 474 HOLE CORE 3 CORED INTERVAL 11.5–21.0 m



LITHOLOGIC DESCRIPTION

Gray orange streak

Disturbed dusky yellow green (5GY 3/2) to moderate olive brown (5Y 4/4) **NANNOFOSSIL-BEARING DIATOMACEOUS CLAYEY SILTS** alternate with olive gray (5Y 5/3) **CLAYEY SILTS.** Olive gray (5Y 5/3) **CLAYEY SILT LAYERS** (4 to 11 cm thick at top of core) thicken with depth to 30 to 40 cm thick at bottom of core and suggest sediment cycles (turbidites?). Strong H_2S smell throughout the core. Mica flakes visible throughout. Sponge spiculites locally present as small white spots. Three mm–thick, very disturbed sand (arkosic) (terrigenous components) layer found at Section 3, 40 to 55 cm.

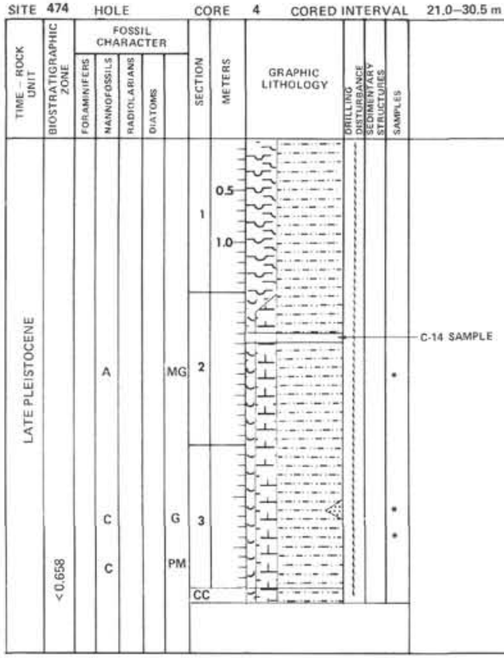
SMEAR SLIDE SUMMARY

	1-85 (M)	1-90 (M)	2-53 (D)	2-90 (D)	3-30 (D)	3-55 (M)
TEXTURE:						
Sand	17	–	5	5	10	–
Silt	60	60	65	50-60	70	30
Clay	25	40	30	35	20	70
COMPOSITION:						
Quartz	15	20	10	10	10	30
Feldspar	5	5	10	10	5	10
Mica	–	2	5	–	3	–
Heavy minerals	–	–	5	2-3	2	–
Clay	50	40	15	35	20	60
Pyrite	–	2	2	1-2	2	2
Carbonate unspec.	2 (large)	–	10	–	3	1
Foraminifers	–	–	3-5	–	5	2
Calc. nannofossils	1	2	–	<1	30	20
Diatoms	25-30	20	20	35	45	2
Radiolarians	–	2	3	5	–	2
Sponge spicules	–	–	3	5	2	1
Silicoflagellates	1-2	5	5	–	2	–
Plant Debris	–	1-2	–	–	–	TR
Organics	–	2	–	–	–	–
Apatite	–	1	5	–	–	–
Pyroxene	–	1	–	–	–	–

COARSE FRACTIONS: CC

	>140 µm	<140 to 63 µm
Quartz	5	20
Mica	10	10
Chlorite	10	20
Foraminifers	50	30
Fecal pellets	20	–
Pyrite	2	–
Heavy minerals	2	–
Radiolarians	–	5
Sponge spicules	–	5
Plant debris	–	1

SITE 474 HOLE CORE 4 CORED INTERVAL 21.0–30.5 m



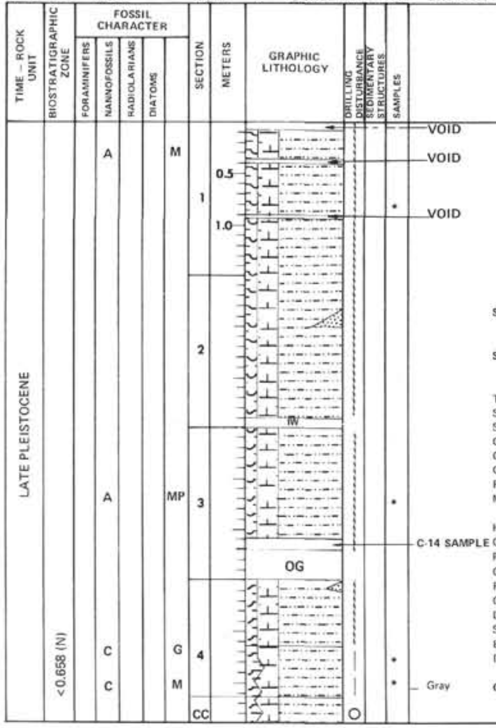
LITHOLOGIC DESCRIPTION

Intensely disturbed dusky yellow green (5GY 5/2) to moderate olive brown (5Y 4/4) **MUDDY NANNOFOSSIL-DIATOMACEOUS OOZE.** Layering, if any, was obliterated. Mica flakes visible throughout. Moderate H_2S smell. Occurrence of wood chip at Section 1, 89 cm, arkosic sand blebs (terrigenous components) at Section 3, 60 cm and 135 cm, and macrofossil shells at Section 3, 65 cm; Sediment appears to be gas rich with small pimples on clay-rich surfaces. Section 3 has streaks of lighter gray nannofossil mudstone.

SMEAR SLIDE SUMMARY

	2-80 (D)	3-60 (D)	3-90 (M)
TEXTURE:			
Sand	10	25	10
Silt	60	60	50
Clay	30	15	40
COMPOSITION:			
Quartz	10	3	20
Feldspar	5	–	5
Mica	2	2	5
Heavy minerals	1	–	1
Clay	10	20	25
Volcanic glass	2	–	–
Pyrite	1	1	3
Carbonate unspec.	2	–	–
Foraminifers	2	1	2
Calc. nannofossils	50	15	20
Diatoms	20	40	4
Radiolarians	2	–	5
Sponge spicules	2	10	1
Silicoflagellates	1	2	2
Plant debris	2	–	4

SITE 474 HOLE CORE 5 CORED INTERVAL 30.5–40.0 m



LITHOLOGIC DESCRIPTION

Intensely disturbed moderate olive brown (5Y 4/4) to grayish olive (10Y 4/2) **NANNOFOSSIL-DIATOMACEOUS CLAYEY SILT.** Sand blebs present (terrigenous arkosic components) and 1 small pebble at Section 2, 87 cm. Intense H_2S smell throughout *the core. Sponge spiculites present as white spots locally.* Olive gray (5Y 3/2) diatom-bearing nannofossil clayey silt layer (15 cm thick) at Section 4, 85-100 cm with small sand blebs underlying suggests another turbidite cycle although evidence of graded bedding is absent.

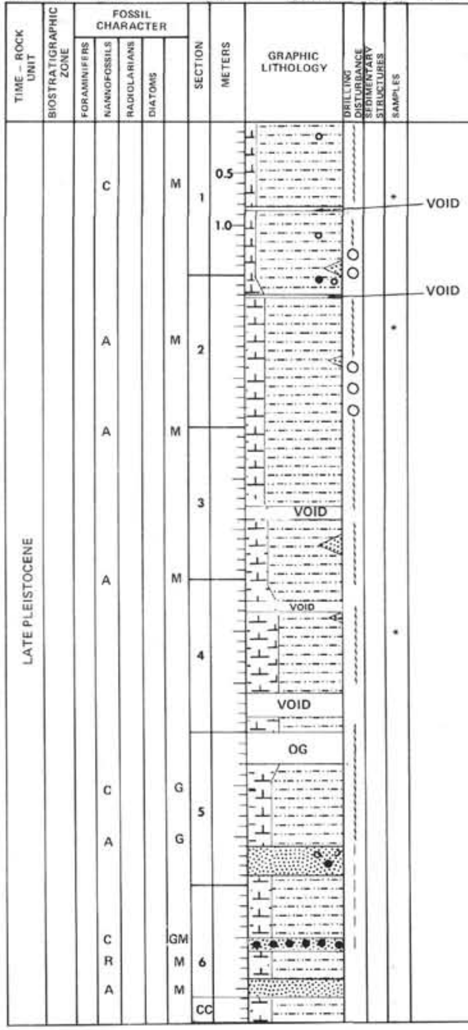
SMEAR SLIDE SUMMARY
1-80 2-75 4-75 4-100 CC

SMEAR SLIDE SUMMARY

	1-80 (D)	3-75 (D)	4-75 (CF)	4-100 (D)	CC (CF)
TEXTURE:					
Sand	10	10	–	10	–
Silt	60	70	–	50	–
Clay	30	20	–	40	–
COMPOSITION:					
Quartz	15	10	90	15	50
Feldspar	3	3	–	5	30
Mica	1	3	–	3	5 (muscovite) 5 (biotite)
Heavy minerals	1	1	–	2	3
Clay	35	20	–	–	–
Pyrite	–	–	–	5	–
Carbonate unspec.	5	1	10	TR	10 (+ shell frag.)
Foraminifers	3	2	–	–	–
Calc. nannofossils	20	30	–	20	–
Diatoms	30	20	–	12	–
Sponge spicules	–	–	–	2	3
Brown specks	–	3	–	–	–
Dolomite	–	–	–	1	–

CARBONATE BOMB: 1-55 = 7%
3-105 = 15.5%

SITE 474 HOLE CORE 6 CORED INTERVAL 40.0–49.5 m



LITHOLOGIC DESCRIPTION

Intensely disturbed firm moderate olive brown (5Y 4/4) to grayish olive (10Y 4/2) **NANNOFOSSIL-BEARING CLAYEY SILT** with sand intercalations. Moderate H_2S smell. Mica flakes visible throughout. Reworked bryozoan pieces and quartz-feldspar porphyry and basalt pebbles in Sections 1 and feldspar porphyry and basalt pebbles in Sections 1 and 2. Possibly these pebbles are from the same layer. Sand blebs and contorted layers of arkosic terrigenous material associated with pebbles in Sections 3 and 4.

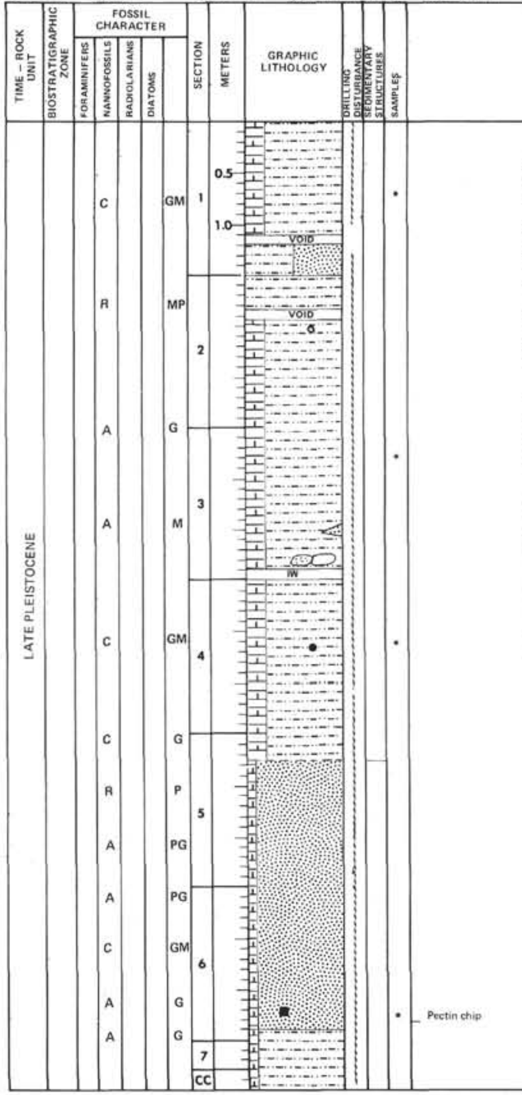
Alternating grayish olive (10Y 4/2) and well-washed, loose yellow gray (5Y 7/2) **"BEACH" SAND with VOLCANIC PEBBLES** in Section 5 to bottom of core. Sharp contacts. Many shallow water clasts suggests resedimentation.

SMEAR SLIDE SUMMARY

	1-75 (D)	2-50 (D)	4-50 (D)
TEXTURE:			
Sand	20	15	10
Silt	40	50	35
Clay	40	35	55
COMPOSITION:			
Quartz	40	15	15
Feldspar	10	1	5
Mica	15	5	10
Heavy minerals	–	–	2
Clay	10	20	20
Pyrite	2	2	2
Foraminifers	~ 3?	–	5
Calc. nannofossils	10	25	35
Diatoms	2	3	2
Radiolarians	–	2	5
Sponge spicules	2	3	–
Silicoflagellates	–	2	–
Plant debris	3	2	2

CARBONATE BOMB: 4-41 = 17%
5-32 = 3%
6-50 = 38% (sand)

SITE 474 HOLE CORE 7 CORED INTERVAL 49.5–59.0 m



LITHOLOGIC DESCRIPTION

Intensely disturbed, grayish olive (10Y 4/4) firm **SILTY TO SANDY MUD** with patches of discreet light gray **SAND.** Sands appear to be very calcareous, muds do not. No evidence of graded bedding.

Section 3 – Sediment color lightens to light olive gray (5Y 5/2) **NANNOFOSSIL SANDY MUD.** Large sandstone pebble (quartz-feldspar, silica cement at Section 3, 130-140 cm.

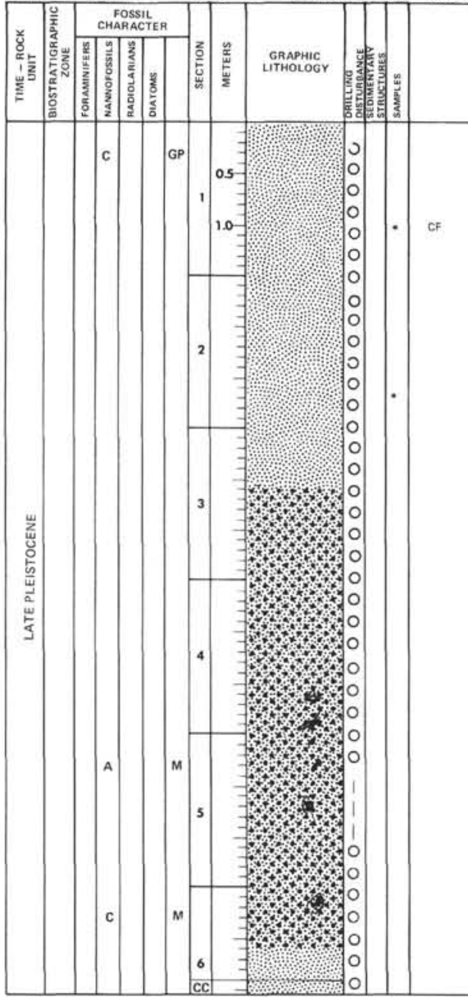
Section 5 – Moderate olive brown (5Y 4/4) **SILTY NANNOFOSSIL MUD to SANDY SILT** in Section 4 grades into greenish gray (5GY 6/4) unconsolidated **GRANITIC SAND** with calcareous components; benthics, bryozoan and shallow water carbonates.

SMEAR SLIDE SUMMARY

	1-73 (D)	3-30 (D)	4-62 (D)	CC (CF)
TEXTURE:				
Sand	15	5	5	–
Silt	40	10	15	–
Clay	45	85	80	–
COMPOSITION:				
Quartz	20	15	15	45
Feldspar	–	1	–	–
Mica	1	3	2	2
Heavy minerals	1	–	–	–
Clay	15	15	40	–
Pyrite	2	2	–	–
Opaque	2	–	–	–
Foraminifers	1	3	5	50
Calc. nannofossils	30	40	30	–
Diatoms	15	5	2	–
Radiolarians	3	5	2	–
Sponge spicules	2	–	1	5
Silicoflagellates	2	–	1	–
Plant debris	2	–	2	5

CARBONATE BOMB: 3-51 = 20%

SITE 474 HOLE CORE 8 CORED INTERVAL 59.0–68.5 m



LITHOLOGIC DESCRIPTION

Drilling breccia of grayish green (5GY 6/4) to greenish gray (5G 6/1) coarse **ARKOSIC SAND** (quartz, feldspar, biotite, calcareous chips of mollusks, bryozoan nd foraminifers [orbulina?]). Clasts are rounded and polished and sorted, **GRANITIC SAND.** Some nannofossil muds remain in what has been washed in drilling. No H_2S smell.

Section 4, 106 cm – 3 cm cobble of granodiorite, mollusk shell (venus) at Section 5, 9 cm, and snail shell at Section 6, 30 cm.

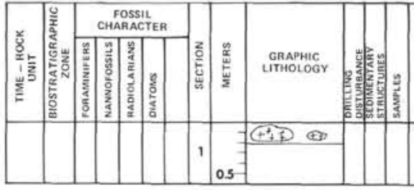
SMEAR SLIDE SUMMARY

	1-100 (CF)	2-118 (D)
TEXTURE:		
Sand	100	–
Silt	–	–
Clay	–	–
COMPOSITION:		
Quartz Feldspar	80	5
Mica	TR	1
Heavy minerals	3	–
Clay	–	50
Carbonate unspec.	15 (molluscs, pelycepods)	2
Foraminifers	1	–
Calc. nannofossils	–	40
Diatoms	–	1
Sponge spicules	–	1
Plant debris	–	1

CARBONATE BOMB: 5-38 = 9%

NOTE: Site 474, Core 9, 68.5–78.0 m: NO RECOVERY.

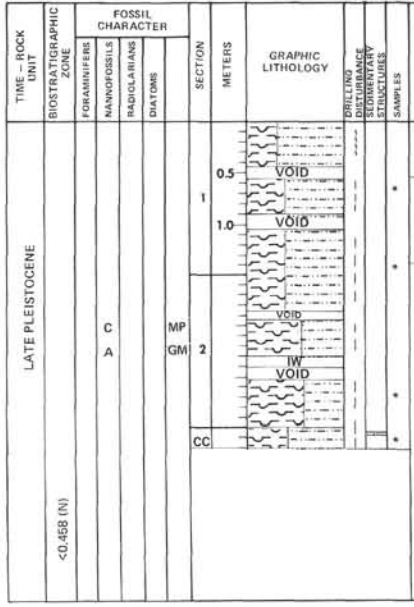
SITE 474 HOLE CORE 10 CORED INTERVAL 87.5–97.0 m



LITHOLOGIC DESCRIPTION

Two pieces of medium gray plutonic rock pebbles (granodiorite).

SITE 474 HOLE CORE 11 CORED INTERVAL 87.5–97.0 m



LITHOLOGIC DESCRIPTION

Spiculite

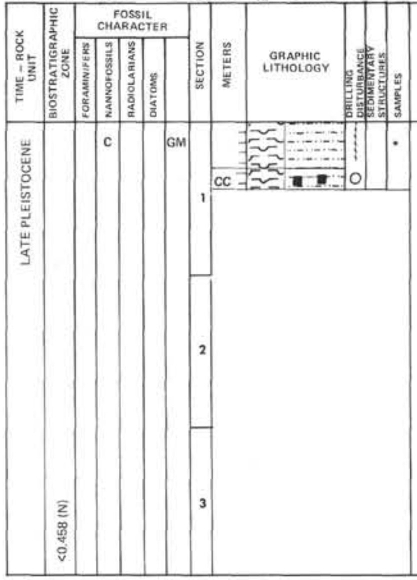
Olive

Firm to hard, homogeneous hemipelagic mud mainly consisting of: grayish olive green (5GY 3/2) nannofossil-bearing **SILICEOUS CLAYEY SILT TO HARD SILTY CLAY**. Contacts appear gradational. Section 1, 30 to 80 cm is more silty where as Section 1, 100 to 145 cm is more clayey. The surface shows a mica glint. Scattered tiny snowy white specks are pure sponge spicule blebs. A thin sand layer (5 cm) occurs in Section 3, 9 to 14 cm. Other small sandy patches may derive from bioturbation.

SMEAR SLIDE SUMMARY

	1-68 (M)	1-141 (D)	2-121 (D)	CC (D)
TEXTURE:				
Sand	–	5	10	–
Silt	60	20	70	
Clay	35	70	30	
COMPOSITION:				
Quartz	5	15	15	5
Feldspar	10	7	2	1
Mica	–	TR	2	1
Heavy minerals	2	TR	TR	–
Clay	30	30	30	40
Pyrite/opaques	–	2	5	5
Carbonate unspec.	–	2	3	–
Foraminifers	1	1	TR	–
Calc. nannofossils	–	5	10	5
Diatoms	–	25	35	40
Radiolarians	–	2	–	–
Sponge spicules	50	1	3	3
Silicoflagellates	–	1	TR	–
Apatite	2	–	–	–

SITE 474 HOLE CORE 12 CORED INTERVAL 97.0–106.5 m



LITHOLOGIC DESCRIPTION

Muddy

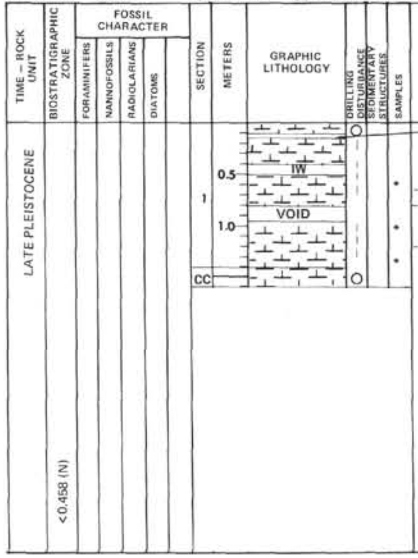
Highly disturbed hemipelagic sediment, firm, grayish olive green (5GY 4/2) **MUDDY NANNOFOSSIL-BEARING DIATOMACEOUS OOZE**. Homogeneous but lower part slightly paler (30 to 47 cm). Mica flakes visible on the surface.

Several flat, well-rounded **PEBBLES** were recovered in the Core-Catcher including: 1) fine-grained basalt(?) volcanic; 2) granite 2 to 3 cm; and 3) a more angular piece of granite.

SMEAR SLIDE SUMMARY

	1-20 (D)
TEXTURE:	
Sand	10
Silt	60
Clay	30
COMPOSITION:	
Quartz	20
Feldspar	1- 2
Mica	15
Clay	10
Pyrite/opaques	2
Carbonate unspec.	1- 2
Foraminifers	TR
Calc. nannofossils	15
Diatoms	40
Radiolarians	5
Sponge spicules	1- 2
Silicoflagellates	1- 2

SITE 474 HOLE CORE 13 CORED INTERVAL 106.5–116.0 m



LITHOLOGIC DESCRIPTION

VOID
10GY 3/2

CF Sand
10GY 5/2

10GY 3/2

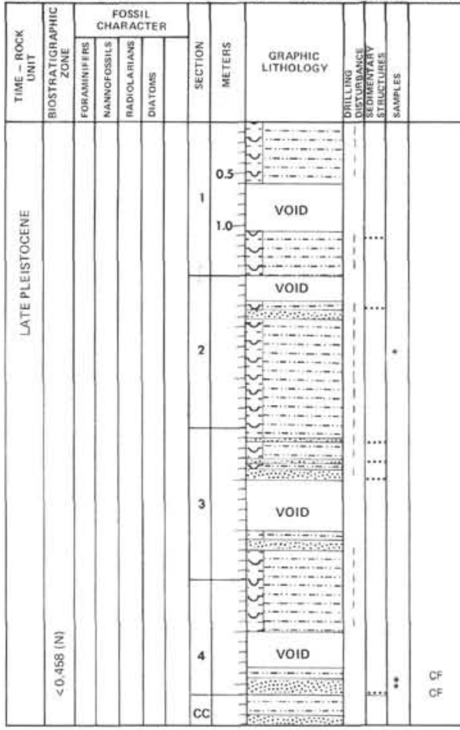
Dusky yellow green (10GY 3/2) **DIATOM-BEARING CLAYEY NANNOFOSSIL OOZE** (0 to 68 cm, 125 to 150 cm and CC). Changes to grayish green (10GY 5/2) **CLAYEY NANNOFOSSIL OOZE** (68 to 125 cm). Small **ARKOSIC, SANDY-SILT** layer at 52 to 54 cm with gradational contacts.

SMEAR SLIDE SUMMARY

	1-60 (CF)	1-100 (D)
TEXTURE:		
Sand	–	–
Silt	–	30
Clay	–	70
COMPOSITION:		
Quartz	65	2
Feldspar	35	–
Mica	–	1-
Clay	–	30
Pyrite	–	2
Carbonate unspec.	–	5
Foraminifers	TR	–
Calc. nannofossils	–	50
Diatoms	–	10
Radiolarians	–	1- 2
Silicoflagellates	–	1- 2

CARBONATE BOMB: 1-104 = 17%

SITE 474 HOLE CORE 14 CORED INTERVAL 116.0–125.5 m



LITHOLOGIC DESCRIPTION

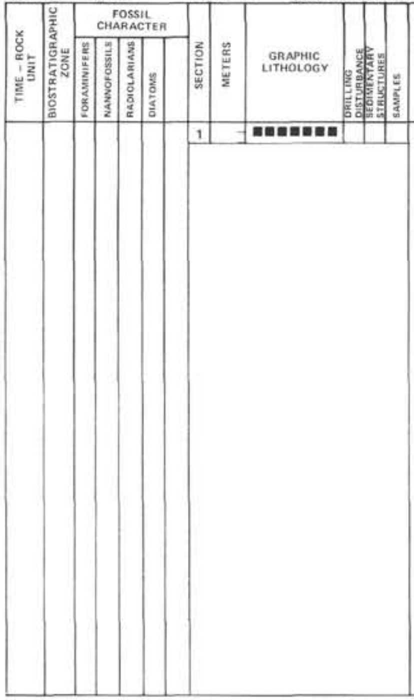
Moderately disturbed, firm hemipelagic sediment; grayish olive green (5GY 4/2) **DIATOMACEOUS CLAYEY SILT** with some nannofossils. Mica flakes glisten on the surface. Bedding is diffuse as most contacts are gradational. Variations include zones containing more and less sand fraction or clay. Some discrete beds of clean **ARKOSIC SAND** occur; at Section 2, 44 cm, Section 3, 10 to 15 cm, 29 to 33 cm, and 47 to 49 cm. These are without grading but well-sorted. Some scattered spiculite specks at Section 1, 9, 15, and 42 cm. Cores were under gas pressure, leaving some gas holes. A silty sand at Section 3, 96 to 108 cm shows a fining upward texture.

SMEAR SLIDE SUMMARY

	2-75 (D)	4-97 (CF)	4-102 (CF)
TEXTURE:			
Sand	10	–	–
Silt	35	–	–
Clay	55	–	–
COMPOSITION:			
Quartz	10	50	45
Feldspar	–	30	45
Mica	5	15	5
Heavy minerals	–	5	1- 2
Clay	40	–	–
Pyrite	2	–	–
Carbonate unspec.	1- 2	–	–
Foraminifers	–	–	TR
Calc. nannofossils	10	–	–
Diatoms	20	–	–
Radiolarians	2	–	–
Sponge spicules	2	–	–
Silicoflagellates	2	–	–
Plant debris	TR	–	–

CARBONATE BOMB: 2-56 - 1%

SITE 474 HOLE CORE 15 CORED INTERVAL 125.5–135.0 m



LITHOLOGIC DESCRIPTION

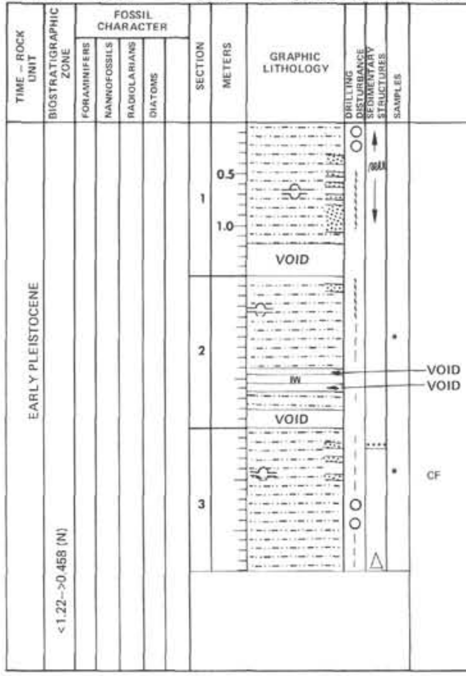
Well-rounded (transported) **PEBBLES OF BASALT** and **OTHER IGNEOUS** or **META-IGNEOUS ROCKS**. Pebbles approximately 4 cm in diameter. Basalt fine-grained. Others; fine groundmass with 1 to 2 mm diameter phenocrysts (feldspar?).

TS No. 1: Light cream-colored, **PORPHYRITE**. Quartz (1 mm) and feldspar (1–2 mm). Feldspars tabular, no alignment. Slight alteration of groundmass; texture not visible. Inequigranular, medium-grained, igneous rock. **PHENOCRYSTS:** Feldspar, 15%, multipletwinned, slightly sercitized, tabular strongly zoned. Up to 2 mm across, frequently fractured. Hornblende, 3% seriate texture, up to 2 mm across ocasionally deformed, tabular to irregular. **GROUNDMASS** hypidiomorph granular feldspar 70%, quartz 10%, hornblende 15%, biotite 4%, opaques 1%, 0.1–0.2 mm. Feldspars all show strong zoning, especially along rims, with sodic overgrowths. Interstitial K-feldspar may comprise up to 15% of groundmass. Deformation slightly recorded by biotite.

TS No. 2: **FELDSPAR ACID-TUFF.** Strongly porphyritic; **PHENOCRYSTS:** Feldspar, 20%, up to 3 mm, dominantly untwinned K-feldspar but also albite?; quartz, 10% of rock, rounded, emboyed, 0.2 mm. Phenocrysts show fabric. **GROUNDMASS:** Dominantly very fine-grained, cryptically banded, quartz-o-feldspath, amorphous, dendritic opaques surround some phenocrysts. Secondary: narrow clinozoisite veins, sericitization of plagioclase. Groundmass, quartz-feldspar, may be primary.

TS No. 3: **METAVOLCANIC.** Probable basic volcaniclastic or tuff. Low grade meatmorphic; affected by later weathering. **GROUNDMASS:** Quartzo-feldspathic with undulating extinction from deformation strain. **COMPONENTS:** mainly altered feldspars, altered mafics, partially sericitized or replaced by epidote and clinozoisite. Feldspars, 30%; plagioclase twins and K-feldspar, 5%, altered biotite, hornblende. Some large rounded quartz and large relict (<100 μm) plagioclase laths with occluded clay and calcite.

SITE 474 HOLE CORE 16 CORED INTERVAL 135.0–144.5 m



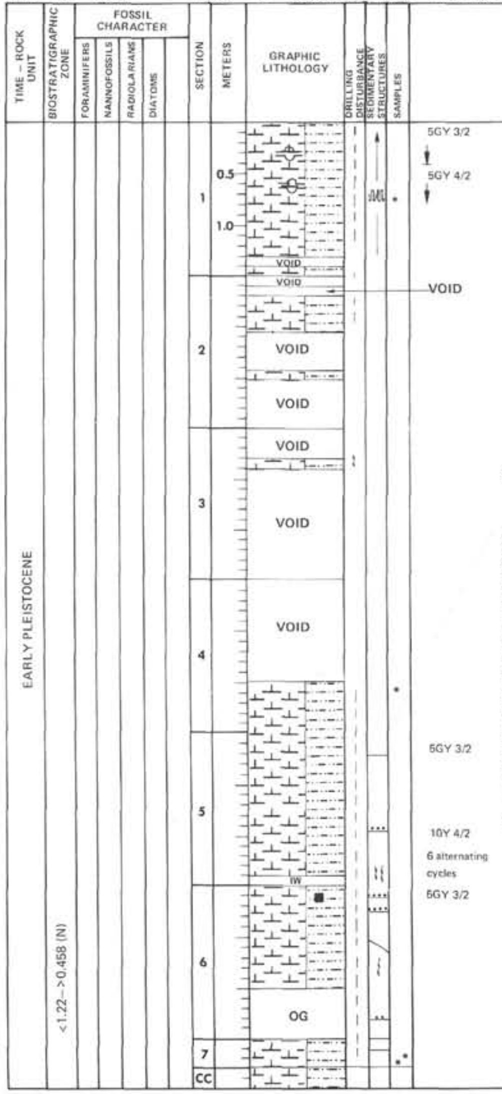
LITHOLOGIC DESCRIPTION

Highly to slightly disturbed hemipelagic sediment, firm. Mainly grayish olive green (5GY 4/2) **CLAYEY SILT to SANDY SILT**. Decimeter zones with slightly finer and coarser muds. Some sandier muds have matrix supported coarse terrigenous pebbles and sand. Contacts distorted. A graded turbidite bed occurs in Section 3, 5 to 14 cm with grayish-green (10GY 5/2) arkosic sand and grain sizes in excess of 2 mm. All beds contain varying amounts of nannofossils and very poorly preserved remnants of siliceous fossils mainly diatoms. Eight sandy layers with fine upwards were recovered.

SMEAR SLIDE SUMMARY

	2-60 (D)		3-43 (CF)
TEXTURE:			
Sand	–		–
Silt	30		–
Clay	70		–
COMPOSITION:			
Quartz	15		90
Feldspar	5		2
Mica	2		–
Heavy minerals	1	(apatite)	–
Clay	60		–
Volcanic glass	1		–
Rock fragments	2		2
Pyrite	3		–
Carbonate unspec.	–		5
Calc. nannfossils	3	(poorly preserved)	–
Diatoms	5		–
Radiolarians	5		–
Sponge spicules	1		–
Silicoflagellates	TR		–
Mollusc fragments	2		

SITE 474 HOLE CORE 17 CORED INTERVAL 144.5–154.0 m



LITHOLOGIC DESCRIPTION

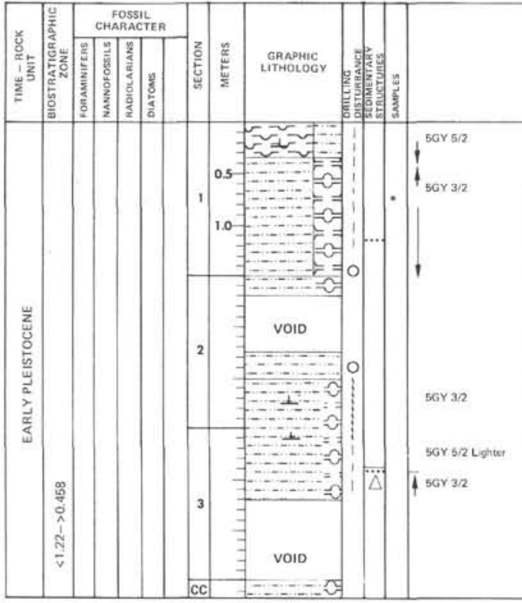
Interlayrering of several varieties of firm hemipelagic sediment. Lighter shades are richer in nannofossils. The main lithology is a dusky yellow green (5GY 4/2) **DIATOMACEOUS NANNOFOSSIL SILT to MARL to OOZE**. Grayish olive green (5GY 3/2) **SILICEOUS NANNOFOSSIL SANDY SILTS** occur as mottles and beds (Section 1, 3 to 30 cm; Section 4, 98 to 150 cm; Section 5, 0 to 3 cm; and Section 7, 0 to 29 cm, 29 to 35 cm, and 41 to 56 cm). Some appear no fine upwards with a clayey silt top and commonly have a thin, well-sorted sand at the base. The graded bed at Section 5, 24 to 94 cm is the thickest of these **MUD TURBIDITES**. At Section 5, 94 to 140 cm there is evidence of bioturbation in mottled grayish olive (10Y 4/2) nannofossil marl–mud with small sand pockets. Section 6 has 3 graded cycles 0 to 10 cm, 10 to 25 cm, and 25 to 85 cm. At the top of Section 3 several redeposited clasts are mud-supported including: basaltic glass, bryozoan fragments and granite pieces. Some scattered benthic foraminifers occur. At Section 4, 106 cm there is a dark organic lamination. Spiculite blebs were observed at Section 2, 49 cm, and Section 4, 133 cm. A brown silt at Section 5, 4 to 22 cm is mainly terrigenous. Pebbles (Section 6, 9 to 26 cm) of basalt, glass, granite, foraminifers, and bryozoan debris.

SMEAR SLIDE SUMMARY

	1-75 (D)	4-107 (D)	5-50 (D)	5-110 (D)	7-60 (M) (light)	7-67 (M) (white)
TEXTURE:						
Sand	1	20	5	15	5	10
Silt	40	50	50	75	25	50
Clay	59	30	45	10	70	40
COMPOSITION:						
Quartz	5	30	3	30	15	50
Feldspar	1	5	1	–	1	2
Mica	2	–	1	2	1	1
Heavy minerals	–	–	–	1	–	–
Clay	10	20	10	20	35	5
Pyrite	5	5	5	2	2	–
Carbonate unspec.	15	3	2	–	8	–
Foraminifers	5	1	3	–	2	1
Calc. nannofossils	45	10	40	35	40	35
Diatoms	15	10	30		4	2
Radiolarians	2	2	–	25	3	–
Sponge spicules	–	–	5		2	1
Silicoflagellates	–	–	1	–	1	–
Plant debris	–	–	3	1	2	2

CARBONATE BOMB: 1-75 = 22%
5-49 = 20.5%
6-93 = 7%

SITE 474 HOLE CORE 18 CORED INTERVAL 154.0–163.5 m



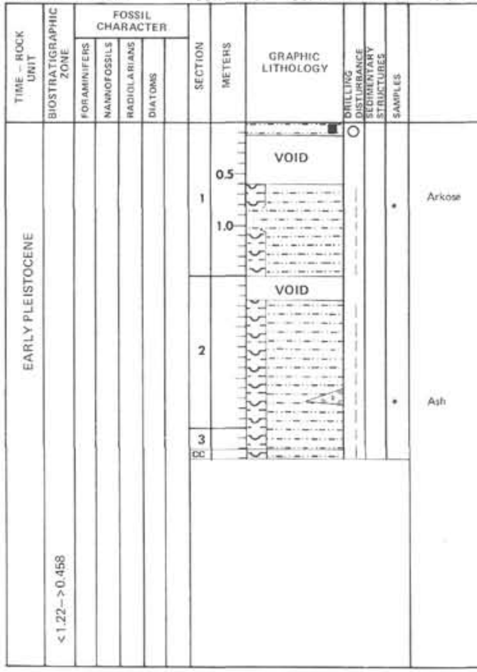
LITHOLOGIC DESCRIPTION

Firm, hemipelagic sediment which has a darker dominant grayish olive green (5GY 3/2) **NANNOFOSSIL-BEARING SILICEOUS CLAYEY SILT** and a less abundant dusky-yellow green (5GY 5/2) **NANNOFOSSIL MUD to MARL.** Beds are fairly uniform and contacts appear partly gradational, scattered sand blebs. Micas are visible on darker lithologies which are also coarser silt.

SMEAR SLIDE SUMMARY

	1-75 (D) (lighter)	3-30 (D) (darker)
TEXTURE:		
Sand	5	10
Silt	75	80
Clay	20	10
COMPOSITION:		
Quartz	10	20
Feldspar	3	5
Mica	3	2
Heavy minerals	1	2
Clay	26	10
Pyrite	2	TR
Carbonate unspec.	2	5
Foraminifers	2	1
Calc. nannofossils	1	40
Diatoms	15	<10 fragments
Radiolarians	2	
Sponge spicules	5	
Silicoflagellates	2	
Plant debris	2	2

SITE 474 HOLE CORE 19 CORED INTERVAL 163.5–173.0 m



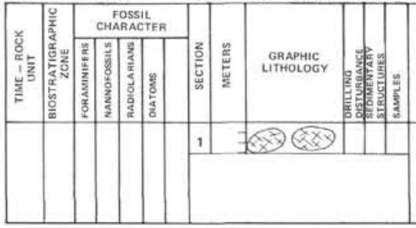
LITHOLOGIC DESCRIPTION

Firm hemipelagic sediment, moderately disturbed **NANNOFOSSIL-BEARING CLAYEY SILT** in diffuse layering and varying texture. Most grayish olive green, individual sedimentary units are typically uniform silts, without grading, others show upward fining. Scattered pebbles, including quartzite sandstone. Color hues change gradationally e.g. at Section 2, 35 cm to dark green gray (5G 4/1) 3 such cycles in Section 2, and one in Section 3. A more brownish hue sandy silt at Section 1, 75 to 84 cm contains little biogenic but rather deeply weathered feldspars having an iron oxide coating suggestive of oxidizing environments. At Section 2, 123 cm there is a thin grayish white vitric rhyolitic ash layer, 2 to 3 mm thick (RI = 1.50).

SMEAR SLIDE SUMMARY

	1-80 (M) (brown)	2-123 (M) (white ash layer)
TEXTURE:		
Sand	10	–
Silt	40	100
Clay	40	–
COMPOSITION:		
Quartz	15	–
Feldspar	20 (altered K-Fe)	–
Mica	2	–
Heavy minerals	2 (py, amp)	–
Clay	40	–
Volcanic glass	–	95 (RI = 1.50)
Pyrite	3 (opaques)	–
Ferruginous	5	–
Carbonate unspec.	5	–
Foraminifers	2	TR
Calc. nannofossils	5	–
Diatoms	–	5

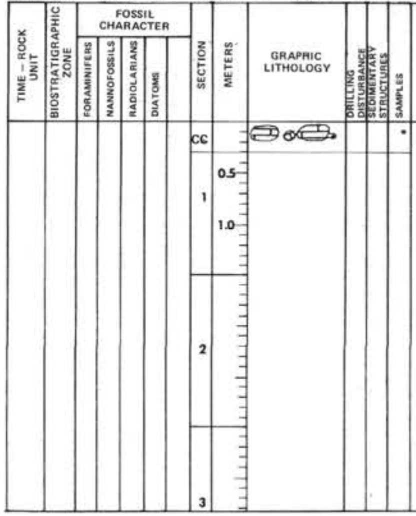
SITE 474 HOLE CORE 20 CORED INTERVAL 173.0–182.5 m



LITHOLOGIC DESCRIPTION

PEBBLES: Only recovery consists of two pebbles; about 2 cm each. No. 1: subangular, dark gray-black with light phenocrysts? No. 2: Lighter gray, fine-grained tuff(?) with a low specific gravity.

SITE 474 HOLE A CORE H1 CORED INTERVAL 0.0–163.5 m (Wash)



LITHOLOGIC DESCRIPTION

Three fragments of a hard silty quartzose **LIMESTONE** pebble. Buff tan, faintly layered. Recovered from 147 meters sub-surface, according to drilling records.

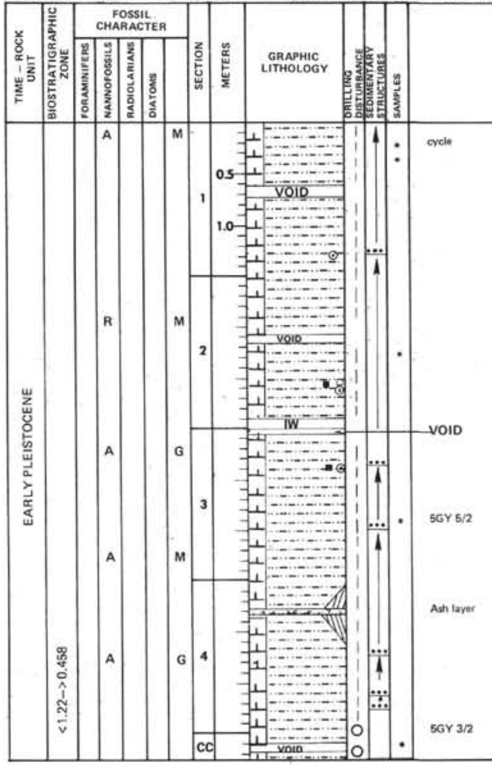
TS – CC:

60%	unspecified carbonate; micro-crystalline calcite, anhedral, may be dolomitic
10%	relict opaline diatom and siliceous tests and fragments
15%	angular quartzo-feldspathic grains, silt-size
1%	rounded and shard-like fragment of anamorphous silica
2%	large pyrite framboids
2%	benthic foraminifers
2%	recrystalized CC-microfossils

SMEAR SLIDE SUMMARY

	CC (white specks)
TEXTURE:	
Sand	–
Silt	–
Clay	–
COMPOSITION:	
Sponge spicules	85
Silicoflagellates	15

SITE 474 HOLE A CORE 1 CORED INTERVAL 163.5–173.0 m



LITHOLOGIC DESCRIPTION

Moderate olive brown (5Y 4/4) firm **CLAYEY SILT to SILTY CLAY.** Nannofossils common, particularly in siltier beds, partly calcareous. Several thick, muddy turbidite or debris flow cycles are present. Large (1-3 cm) matrix supported clasts and shell fragments (pecten) in Sections 1 and 2 and a few scattered sand pockets. Mica flakes glint on the surfaces. Approximately 9 cycles present from 15 to 20 cm thick, show a shift to lighter color hue toward silitier base. Basal contacts sharp, upper transitional. Pebbles include quartz, bryozoan chunks and a fine-grained limestone. In Section 4, 28 cm a vitric white ash occurs which correlates with Site 474, Core 19, Section 2, 121 to 124 cm. Foraminifera fragments appear partly recrystallized. At the base of first cycle (Section 1, 32 cm) find concentration of authigenic calcite crystals; equidimensional, subhedral, ~10 microns large.

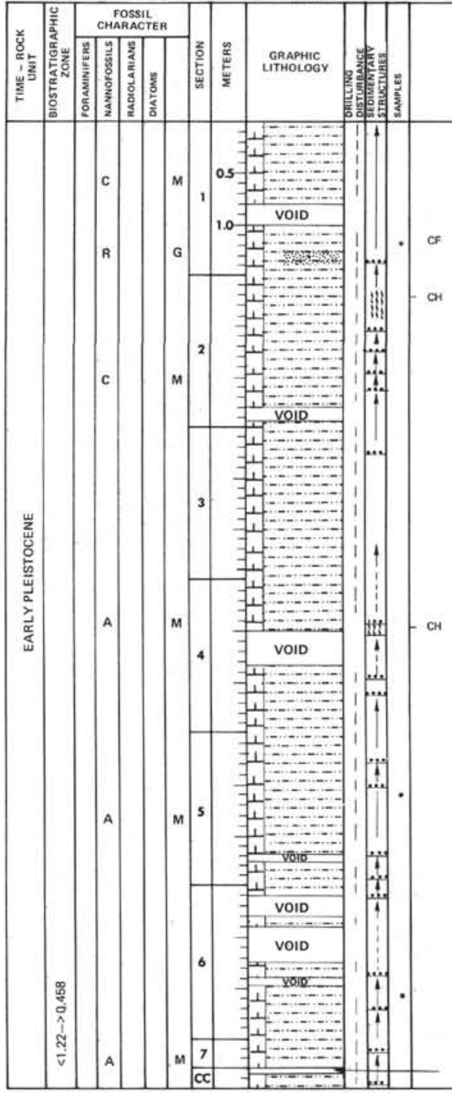
SMEAR SLIDE SUMMARY

	1-27 (D)	1-32 (M)	2-80 (M)	3-93 (M)	CC (D)
TEXTURE:					
Sand	10	–	–	–	–
Silt	20	70	20	40	60
Clay	60	30	80	60	40
COMPOSITION:					
Quartz	}20	–	5	2	5
Feldspar		–	5	–	–
Mica	2	–	2	5	–
Heavy minerals	–	–	–	2	TR
Clay	40	10	50	60	5
Volcanic glass	2	2	1	–	–
Pyrite/Opaques	–	2	4	2	3
Carbonate unspec.	15	80	5	2	85
Foraminifers	TR	–	4	–	–
Calc. nannofossils	7	TR	15	10	–
Diatoms	5	–	5	5	TR
Radiolarians	2	–	2	1	–
Sponge spicules	1	–	3	10	–
Silicoflagellates	–	TR	–	–	–
Dolomite	?TR	–	–	–	–

CARBONATE BOMB: 4-78 = 4%
4-99 = 9% (sand)

	4, 68–70	4, 85–87	4, 101–103
Lithology	Silty clay	Clayed-silt	Silty sand
Sand	3.75	0.62	71.28
Silt	40,45	54.50	23.12
Clay	55.80	44.80	5.60

SITE 474 HOLE A CORE 2 CORED INTERVAL 173.0–182.5 m



LITHOLOGIC DESCRIPTION

Several muddy turbidite cycles of firm grayish olive-green (5GY 3/2) **SILTY CLAY** grading to **SAND-SILT-CLAY (MUD).** Some (Section 6, 110 cm) have thin layer of coarse quartz-feldspar-mica concentrated at the basal contact. Upper contacts burrowed, 12 cycles visible. Siltier portions have more mud, olive brown (5Y 4/4) hues. Unspecified carbonate grains and nannofossils. Contents vary with grain size but siltier zones are more calcareous. Siliceous components, poorly preserved, broken fragments. In sands, quartz grains are rounded and heavy minerals include many mafics including hornblende and apatite. CH = symbol for evidence of Chondrites.

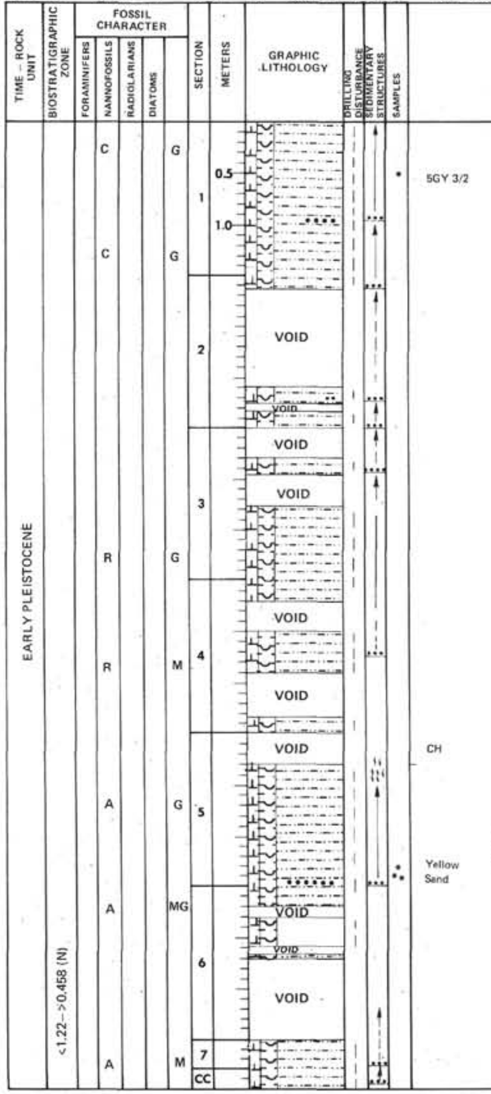
SMEAR SLIDE SUMMARY

	1-120 (CF)	5-60 (D)	6-105 (M) (Arkose)
TEXTURE:			
Sand	50	–	100
Silt	40	55	–
Clay	10	45	–
COMPOSITION:			
Quartz	30	20	30
Feldspar	15	10	30
Mica	20	2	5
Heavy minerals	6	3	10
Clay	10	30	–
Glauconite	2	–	–
Pyrite	–	1	–
Carbonate unspec.	5	2	5
Foraminifers	5	–	–
Calc. nannofossils	3	20	–
Diatoms	–		
Radiolarians	–		
Sponge spicules	5	10 fragments	
Silicoflagellates	–		
Plant debris	3	2	–
Opaques	3	2	–
Rock fragments	–	–	10

CARBONATE BOMB: 1-111 = 9%

	1, 103–105	1, 137–139
Lithology	Sandy silt	Silty sand
Sand	21.43	53.37
Silt	69.16	31.08
Clay	9.41	15.55

SITE 474 HOLE A CORE 3 CORED INTERVAL 182.5–192.0 m



LITHOLOGIC DESCRIPTION

Moderately disturbed, **MUDDY TURBIDITES** comprising of hard grayish olive-green (5GY 3/2) **CLAYEY SILT** marked by a thin basal sand. Contain nannofossils and poorly preserved siliceous fragments. Approximately 8 to 9 cycles preserved.

SANDS (yellow brown) e.g. Section 5, 119 cm to dark gray (N2), Section 2, 110 cm with shallow water carbonates and heavy minerals; continental-derived organic matter. Section 3, 40 cm; calcareous-sand. Includes benthick foraminifers, echinoderm spines, bryozoan stocks and granitic rock fragments. Heavy minerals are hornblende, mica, calcareous and siliceous components diminishing downhole.

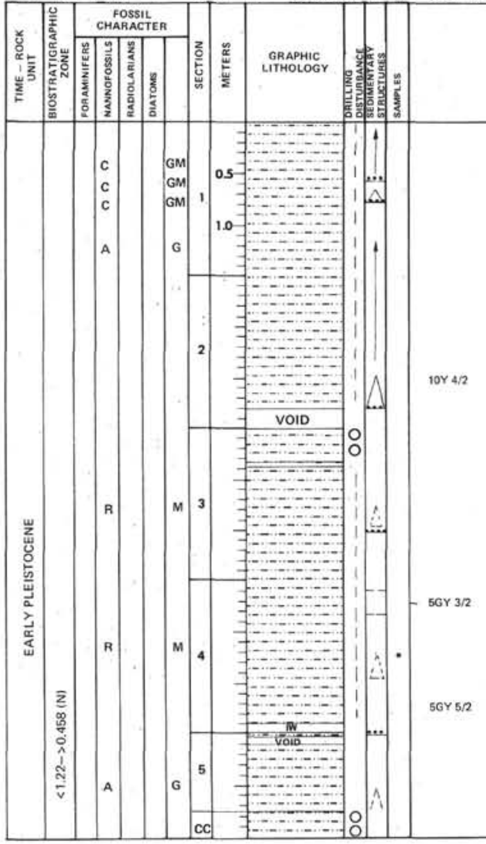
SMEAR SLIDE SUMMARY

	1-50 (D)	5-139 (M)	5-142 (D)	5-143 (M)
TEXTURE:				
Sand	–	85	5	5
Silt	60	10	25	30
Clay	40	5	70	65
COMPOSITION:				
Quartz	10	30	15	15
Feldspar	15	15	5	5
Mica	3	2	5	5
Heavy minerals	–	2	TR	1
Clay	3	–	40	45
Rock fragments	–	5	–	–
Pyrite	3	–	3	2
Opaque minerals	2	–	3	2
Zeolites	–	–	TR	–
Carbonate unspec.	5	10	1	1
Foraminifers	TR	5	3	3
Calc. nannofossils	15	–	10	10
Diatoms	20	–	10	3
Radiolarians			–	–
Sponge spicules	5	fragments	5	2
Silicoflagellates			1	1
Plant debris	4		5	5
Carbonate clasts	–	30	–	–

CARBONATE BOMB: 5-114 = 24% (low; increases in sands)

	5, 35–37	5, 78–80	5, 109–111	5, 137–139
Lithology	Clayed silt	Clayed silt	Silty sand	Sand
Sand	0.61	1.41	50.12	75.90
Silt	61.33	61.10	42.59	20.44
Clay	38.06	37.49	7.29	3.68

SITE 474 HOLE A CORE 4 CORED INTERVAL 192.0–201.5 m



LITHOLOGIC DESCRIPTION

Moderately disturbed, firm, grayish olive **(10Y 4/2) SILTY CLAY (MUD)** with some slightly lighter (5GY 3/2) **SILTY MUD TURBIDITES. These** (e.g. Section 1, 110 cm to Section 2, 128 cm) have a thin sandy base and subtly grade up to a burrowed top. Sorting is poor and most parts are clayey silt with a massive texture and a few sand blebs. In Sections 3 and 4 mud turbidite cycles are very subtle, marked by a small sand layer and upward darkening of color. Basal portions contain smattering of wood debris.

SMEAR SLIDE SUMMARY

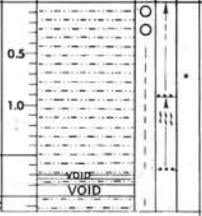
	4-75 (D)
TEXTURE:	
Sand	2
Silt	38
Clay	60
COMPOSITION:	
Quartz	25
Clay	58
Pyrite	1
Micronodules	1
Calc. nannofossils	2
Diatoms	2
Radiolarians	1
Sponge spicules	2
Plant debris	6

CARBONATE BOMB: 4-71 = 5%

	4, 76–78
Lithology	Silty clay
Sand	0.93
Silt	36.33
Clay	62.74

SITE 474 HOLE A CORE 5 CORED INTERVAL 201.5–211.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER FORAMINIFERS	FOSSIL CHARACTER NANNOFOSSILS	FOSSIL CHARACTER RADIOLARIANS	FOSSIL CHARACTER DIATOMS		SECTION
EARLY PLEISTOCENE	<1.22–>0.458 (N)		C			GM	1
			C			M	
			C			M	2
							CC



LITHOLOGIC DESCRIPTION

10Y 4/2

CH, P

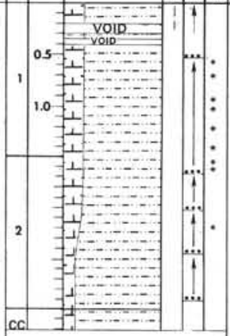
Three mud turbidites of hard, grayish olive (10Y 4/2) **SILTY CLAY**; slightly calcareous. Slight grayish green (10GY 4/2) mottling in the tops of some graded cycles, base marked by thin sands.

SMEAR SLIDE SUMMARY

	1-75 (D)
TEXTURE:	
Sand	10
Silt	40
Clay	50
COMPOSITION:	
Quartz	25
Feldspar	2
Mica	10
Heavy minerals	3
Clay	25
Pyrite	2
Opaques	3
Carbonate unspec.	10
Foraminifers	2
Calc. nannofossils	5
Diatoms	1
Sponge spicules	3
Plant debris	6

SITE 474 HOLE A CORE 6 CORED INTERVAL 211.0–220.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER FORAMINIFERS	FOSSIL CHARACTER NANNOFOSSILS	FOSSIL CHARACTER RADIOLARIANS	FOSSIL CHARACTER DIATOMS		SECTION
EARLY PLEISTOCENE	<1.22–>0.458 (N)		A			G	1
			A			M	
			C			G	
			C			G	
			C			G	
			C			G	
			C			M	2
			C			M	
							CC



	1, 99–101	1, 148–150	2, 11–13
Lithology	Clayed silt	Sandy silt	Silt-sand-clay
Sand	1.26	40.90	21.13
Silt	60.53	42.98	37.40
Clay	38.21	16.12	30.47

LITHOLOGIC DESCRIPTION

5GY 3/2

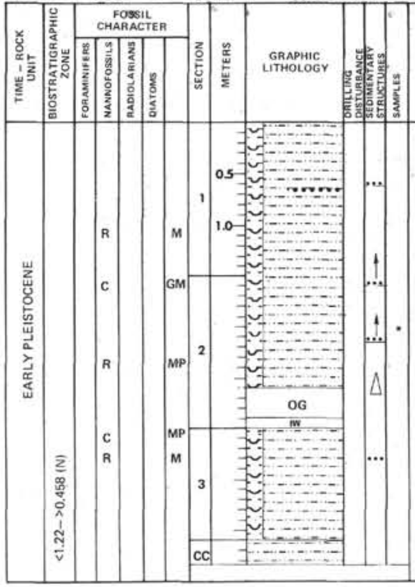
Parts of 6 mud turbidites; grayish olive-green (5GY 3/2) **NANNOFOSSIL-BEARING SILTY CLAY TO CLAYEY SILTS** and muddy sand layer with grains over mm-scale. Slightly calcareous (~5%) in finer fraction. More (~8 to 15%) in coarser parts. Main body of a graded unit is massive, clayey silt without sediment structures. Burrowing common near tops of chondrites type. Set of smear slides taken over one thick turbidite (109 cm) shows continuous, subtle grading present in thick, muddy mid-section, average thickness of 5 beds is 55 cm. Woody fragments common in sands along with foraminiferas and mica flakes. Base of coarse sand turbidite (Section 2, 13 cm) with subangular, broke subhedral quartz and felspar (40%) with micrite grains (25%) heavy minerals (apatite, zircon, sphene, chlorite) (10%) and scattered foraminifers, micas, and opaques, with iron stains. Numerous granitic rock fragments.

SMEAR SLIDE SUMMARY

	1-55 (D)	1-75 (D)	1-95 (D)	1-105 (D)	1-125 (D)	1-145 (D)	2-5 (D)	2-12 (CF)	2-77 (M)
TEXTURE:									
Sand	1	2	5	–	10	20	60	100	2
Silt	19	28	30	60	45	50	20	–	33
Clay	80	70	65	40	45	30	20	–	65
COMPOSITION:									
Quartz	5	10	15	10	40	50	40	50	10
Feldspar	1	5	5	5	3		10	20	2
Mica	2	2	2	5	6	2	10	3	5
Heavy minerals	1	–	–	–	1	2	10	5	1
Clay	65	40	40	40	16	20	10	–	25
Volcanic glass	–	–	–	5	–	–	–	–	
Pyrite	1	–	1	5	1	–	2	–	2
Micronodules	2	3	2	–	4	–	–	–	2
Zeolite	–	–	–	2?	–	–	–	–	–
Carbonate unspec.	3	5	5	10	–	–	–	20	10
Foraminifers	2	3	2	–	3	10	10	–	2
Calc. nannofossils	5	15	15	10	15	10	5	–	15
Diatoms	1	1	1	1	1	2	1	–	2
Radiolarians	–	–	–	1	1	2	1	–	1
Sponge spicules	3	3	2	2	3	1	1	–	4
Silicoflagellates	–	–	–	–	1	–	–	–	–
Plant debris	3	3	4	–	3	–	–	–	18
Euhedral calcite	–	–	–	2	–	2	–	–	–

CARBONATE BOMB: 1-148 = 20% (D)

SITE 474 HOLE A CORE 7 CORED INTERVAL 220.5–230.0 m



LITHOLOGIC DESCRIPTION

5GY 3/2

Firm grayish olive-green (5GY 3/2) **SILTY CLAY to CLAYEY SILT,** nannofossil-bearing. Color hues darker towards the base of units of possible mud turbidites. Scattered sand layers (1-2 cm); grayish are non-calcareous others, yellowish carbonate-rich. Most of section is bioturbated. Siliceous fragments reappear, many complete frustules.

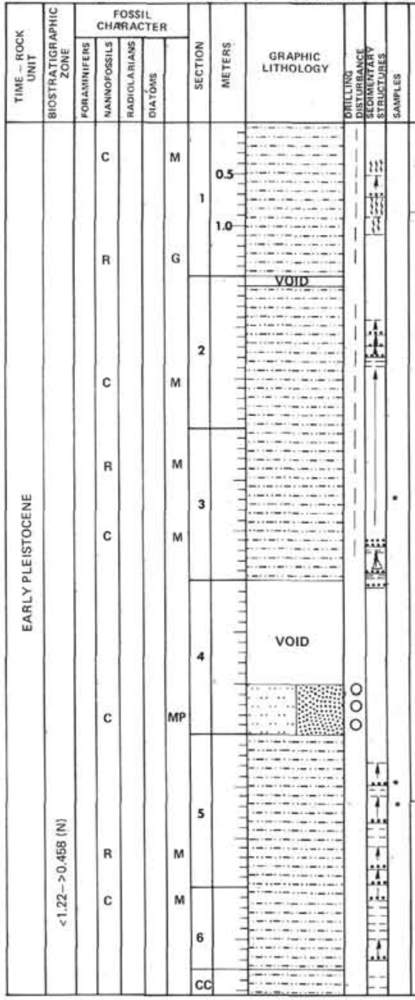
SMEAR SLIDE SUMMARY

	2-50 (D)
TEXTURE:	
Sand	1
Silt	49
Clay	50
COMPOSITION:	
Quartz	20
Feldspar	10
Mica	2
Heavy minerals	1
Clay	25
Pyrite	2
Opaques	8
Carbonate unspec.	5
Calc. nannofossils	5
Diatoms	15
Sponge spicules	5
Plant debris	5

	2, 49–51
Lithology	Clayed silt
Sand	6.32
Silt	48.38
Clay	45.30

CARBONATE BOMB: 2-107 = 6%

SITE 474 HOLE A CORE 8 CORED INTERVAL 230.0–239.5 m



LITHOLOGIC DESCRIPTION

CH

5Y 4/4

10Y 4/2

Clayey silt

Gray (N2) sand

5Y 4/4

Silty clay

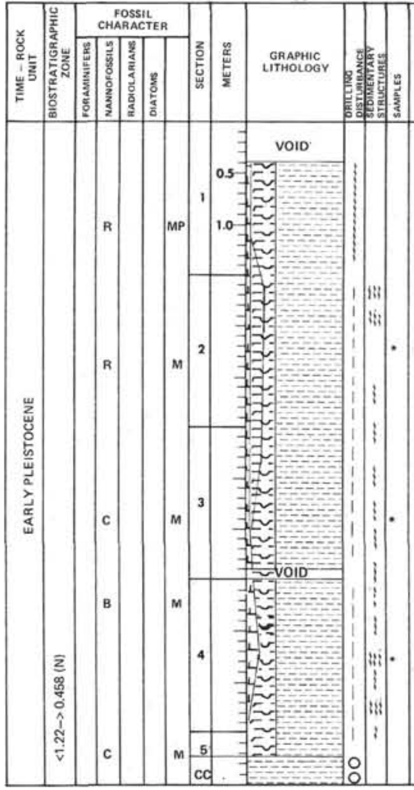
Very hard, grayish-olive (10Y 4/2) silty clay to clayey silt and, **MUD TURBIDITES.** Clays low in carbonate (< 5%), silts about 10%. Some graded silts show color change to moderate olive brown (5Y 4/4) near base. Main body of turbidites structureless, poor grading top bioturbated-waxy. One over 185 cm thick; average of 31 cm for 14 turbidites and about 55% of core in mud turbidite facies. Drill breccia in Section 3 may contain coarse basal sand from a large turbidite.

SMEAR SLIDE SUMMARY

		3-70 (D)	5-43 (CF)	5-68 (D)
TEXTURE:				
Sand		10	85	1
Silt		70	–	39
Clay		20	–	60
COMPOSITION:				
Quartz		50	40	15
Feldspar			20	5
Mica		1	15	4
Heavy minerals		TR	–	–
Clay		20	–	25
Volcanic glass		TR	–	–
Rock fragments		–	5	–
Pyrite/Opaques		10	–	6
Carbonate unspec.		3	–	10
Foraminifers		–	2	2
Calc. nannofossils	fragments	4	–	10
Diatoms		2	–	4
Radiolarians		1	–	–
Sponge spicules		5	–	5
Plant debris		–	2	~5
Dolomite		–	–	TR

CARBONATE BOMB: 5-67 = 20% (D)

SITE 474 HOLE A CORE 9 CORED INTERVAL 239.5–249.0 m



LITHOLOGIC DESCRIPTION

10Y 4/2

Planolites

CH

Change to hemipelagic claystone with a low carbonate content and increased diatomaceous fragments. Grayish olive (10Y 4/2) **SILTY CLAYSTONE**, slightly calcareous; poorly-preserved fragments of diatomaceous siliceous fossils. The claystone is fissile, parting readily along bedding. Variations in burrow intensity. Carbonate content increases and diatoms decrease in lighter (silter) hues. There is a fluctuation in siliceous and nannofossil components. Scattered discoasters are observed.

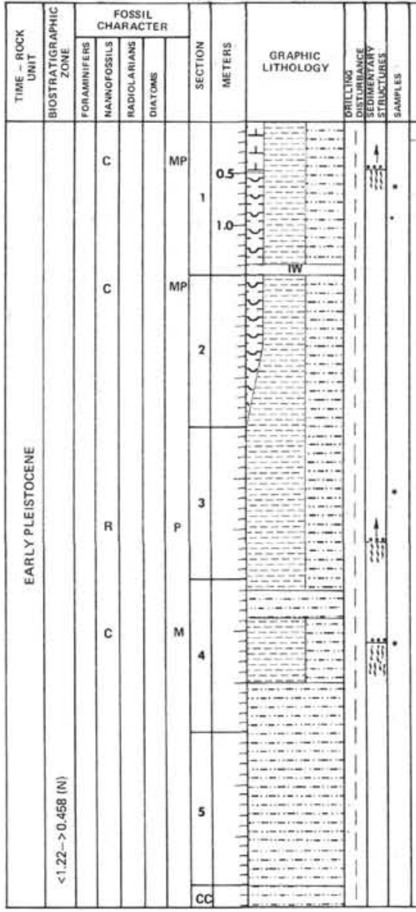
SMEAR SLIDE SUMMARY

	2-81 (D)	3-90 (D)	4-77 (M) (siltier)	4-77 (M)
TEXTURE:				
Sand	3	5	2	
Silt	12	40	43	
Clay	85	55	55	
COMPOSITION:				
Quartz	10	10	10	10
Feldspar	5	3	5	5
Mica	4	2	1	–
Heavy minerals	1	–	–	–
Clay	45	45	45	60
Pyrite	1	2	1	5
Opaques	5	4	3	–
Carbonate unspec.	5	5	10	5
Foraminifers	3	–	–	1
Calc. nannofossils	10	–	10	3
Diatoms	10	25	1	10
Radiolarians	1	2	1	–
Sponge spicules	2	5	1	–
Silicoflagellates	1	2	–	–
Plant debris	4	5	5	4

CARBONATE BOMB: 4-55 = 12% (D)

	3, 59–60
Lithology	Clayed silt
Sand	2.40
Silt	49.08
Clay	48.52

SITE 474 HOLE A CORE 10 CORED INTERVAL 249.0–258.5 m



LITHOLOGIC DESCRIPTION

5Y 4/4

10Y 4/2

Grayish olive (10Y 4/2) **CLAYSTONE** with some more moderate olive brown (5Y 4/4) **SILTY CLAYSTONES** (Section 1, 0 to 52 cm). Burrowed in darker hues. Some minor scattered spiculite specks. Slightly calcareous, with some diatom fragments poorly preserved. Graded beds marked by burrowed lutite tops. Claystone to silty claystone may be turbidite cycles.

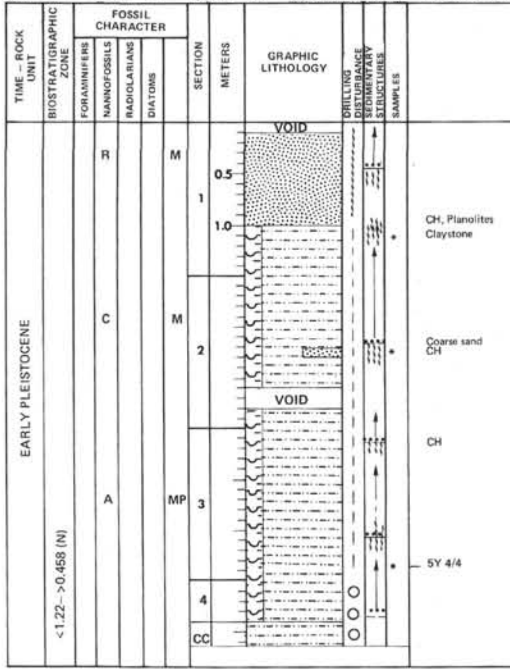
SMEAR SLIDE SUMMARY

	1-60 (D)	3-60 (D)	4-60 (D)
TEXTURE:			
Sand	10	10	20
Silt	60	30	20
Clay	30	60	50
COMPOSITION:			
Quartz	10	20	25
Feldspar	5	5	1
Mica	2	5	3
Heavy minerals	TR	1	TR
Clay	40	40	36
Pyrite	1	TR	1
Opaques	5	3	2
Carbonate unspec.	5	15	20
Foraminifers	–	2	1
Calc. nannofossils	5	2	5
Diatoms	25	15	1
Radiolarians	5	1	–
Sponge spicules	–	2	2
Silicoflagellates	–	1	–
Plant debris	4	5	5

CARBONATE BOMB: 4-58 = 22%

	2, 60–62
Lithology	Clayed silt
Sand	2.10
Silt	66.06
Clay	31.84

SITE 474 HOLE A CORE 11 CORED INTERVAL 258.5–268.0 m



LITHOLOGIC DESCRIPTION

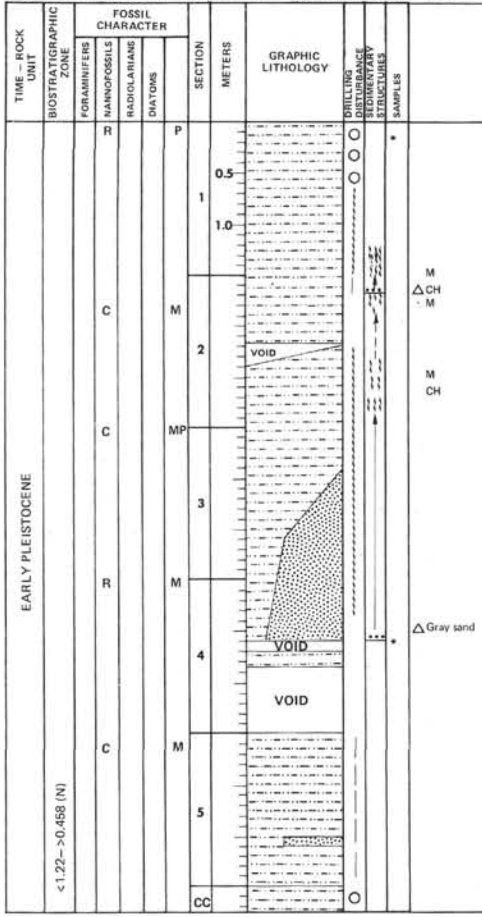
Section 1, 0 to 40 cm: dark olive gray (10Y 3/4) **MICACEOUS SAND**, drilling disturbed.

Below Section 1, 90 cm: Reappearance of mud turbidites in hemipelagic clay. Subtle variations of grayish olive (10G 4/2) **SILTY CLAYSTONE to SAND-CLAY-SILT**. Graded mud units marked by a burrowed top with chondrites (CH). Basal contact sharp. Carbonate (up to 20%) more prevalent in siltier portions of turbidites, contain shallow water debris, much organic matter. Silty claystones are carbonate poor but contain some diatom fragments. Heavy minerals in sand include apitite, aircon, augite, pyroxene, and epidote.

SMEAR SLIDE SUMMARY

	1-110 (D)	2-71 (CF)	3-139 (D)	3-139 (D)
TEXTURE:				
Sand	–	85	5	15
Silt	30	15	35	60
Clay	70	–	55	20
COMPOSITION:				
Quartz	25	30	20	} 40
Feldspar	20	15	3	
Mica	2	6	3	–
Heavy minerals	TR	6	1	–
Clay	25	–	40	10
Pyrtie/Opaques	3	10	4	5
Carbonate unspec.	15	–	20	40 (clastic)
Foraminifers	–	2	2	1
Calc. nannofossils	< 5	–	2	2
Diatoms	10	–	–	–
Radiolarians	2	2	–	1
Sponge spicules	–	1	–	2
Plant debris	3	4	–	–
Rock fragments	–	20	–	–
Molluscs fragments	–	–	4	–

SITE 474 HOLE A CORE 12 CORED INTERVAL 268.0–277.5 m



LITHOLOGIC DESCRIPTION

Disturbed, grayish olive (10Y 4/2) **CLAYEY SILT to SILTY CLAYSTONE** and two major mud turbidites (Section 2, 23 to 80 cm and 80 cm; Section 4, 61 cm). Thick clayey silt portion of poorly graded bed, massive, structureless. Carbonate increasing towards base. Upper part burrowed with chondrites (CH), and meniscate forms (M). Scattered wood bits in coarse sandy base Section 4, 0 to 20 cm. Heavy mineral concentrate with apatite, zircon, hornblende. Angular quartz-feldspathic grains 200 to 400 microns large.

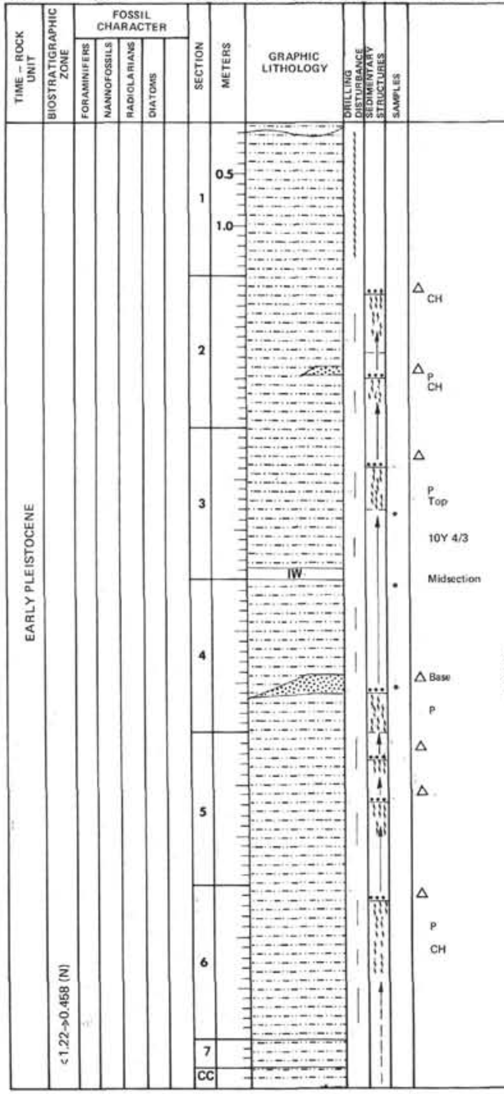
SMEAR SLIDE SUMMARY

	2-15 (D)	4-60 (M)
TEXTURE:		
Sand	5	50
Silt	50	20
Clay	45	30
COMPOSITION:		
Quartz	} 50	40
Feldspar		20
Heavy minerals	5	5 (Ap, Zr)
Clay	30	5
Volcanic glass	–	10
Pyrite	5	2
Carbonate unspec.	10	20
Calc. nannofossils	2	1
Diatoms	1	1
Sponge spicules	1	1

CARBONATE BOMB: 4-121 = 6%
CC = 10% (in silty clay)

	3, 62–64
Lithology	Clayed silt
Sand	4.44
Silt	60.24
Clay	36.32

SITE 474 HOLE A CORE 13 CORED INTERVAL 277.5–287.0 m



LITHOLOGIC DESCRIPTION

Grayish olive (10Y 4/2) **MUD TURBIDITES** mainly **CLAYEY SILTSTONE to SILTY CLAYSTONES;** quartzose. Seven well-defined, upward fining units, one (Section 3, 70 cm to Section 4, 110 cm) 180 cm thick, mostly siltstone, massive, with faint grading. Tops burrowed by **CHONDRITES** (CH) below and **PLANOLITES** (P) in the lutite portion: Euhedral calcite crystals and heavy minerals common in sands.

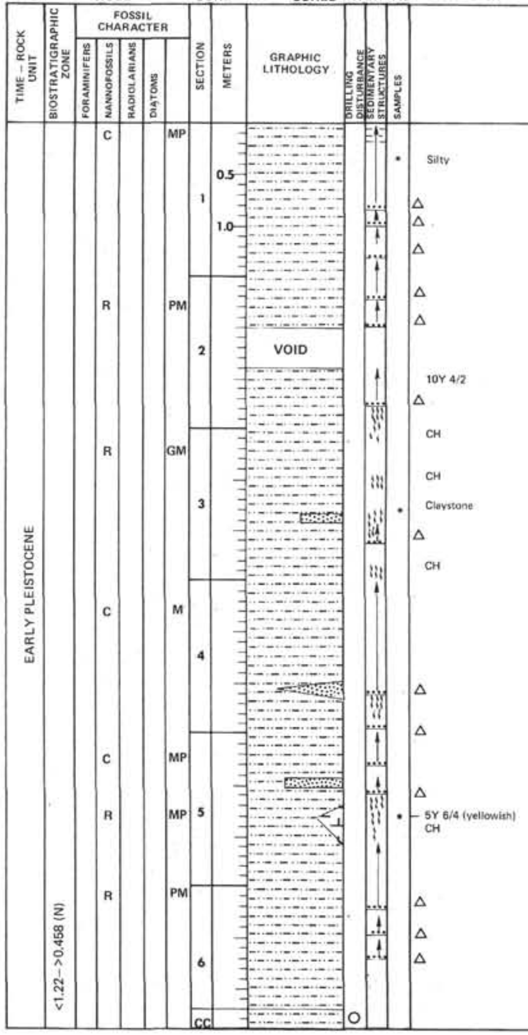
SMEAR SLIDE SUMMARY

	3-83 (D)	4-6 (D)	4-106 (D)
TEXTURE:			
Sand	0	–	60
Silt	80	40	40
Clay	20	60	–
COMPOSITION:			
Quartz	30	10	30
Feldspar	20	2	40
Mica	2	2	5
Heavy minerals	5	15	5
Clay	10	40	–
Pyrite	10	5	3
Carbonate unspec.	10	20	10
Foraminifers	–	–	1
Calc. nannofossils	5	7	5
Sponge spicules	–	–	1
Plant debris	TR	–	TR (wood)

CARBONATE BOMB: 3-58 = 19%

	3, 81–83	4, 7–9	4, 108–110	4, 116–118
Lithology	Clayed silt	Clayed silt	Sandy silt	Clayed silt
Sand	0.67	3.53	22.48	15.24
Silt	62.87	67.04	60.99	57.24
Clay	36.46	29.43	16.53	27.52

SITE 474 HOLE A CORE 14 CORED INTERVAL 287.0–296.5 m



LITHOLOGIC DESCRIPTION

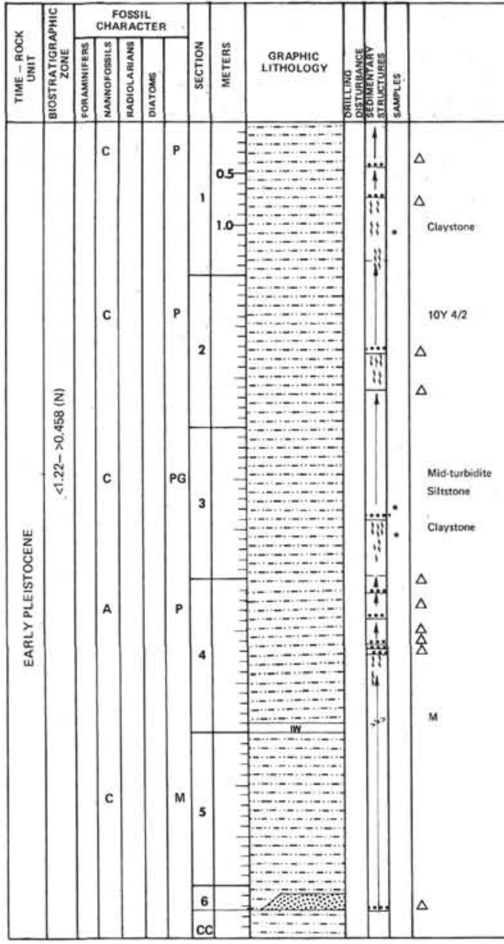
Grayish olive (10Y 4/2) **MUDDY TURBIDITES** and **BURROWED SILTY CLAY.** Only traces of carbonate including rare shallow water debris in coarser layers. Mostly clayey siltstone with one massive bed Sections 3 to 4. Fourteen turbidites form 55% of core with an average thickness of 33 cm. One nannofossil-rich marl, heavily burrowed occurs at Section 5, 80 to 85 cm, dusky yellow (5Y 6/4).

SMEAR SLIDE SUMMARY

	1-39 (D)	3-79 (M)	5-80 (M)
TEXTURE:			
Sand	10	30	10
Silt	80	50	20
Clay	10	20	70
COMPOSITION:			
Quartz Feldspar	70	25	30
Mica	–	15	–
Heavy minerals	2	1- 2 (Ap,Zr)	TR (Zr)
Clay	5	25	10
Pyrite	3	10	5
Carbonate unspec.	12	5	5
Foraminifers	TR	2	–
Calc. nannofossils	5	5	50
Sponge spicules Silicoflagellates	–	1- 2 1	TR
Plant debris	–	10	5

Site 474A, Core 15, 296.5–306.0 m: NO RECOVERY.

SITE 474 HOLE A CORE 16 CORED INTERVAL 306.0–315.5 m



LITHOLOGIC DESCRIPTION

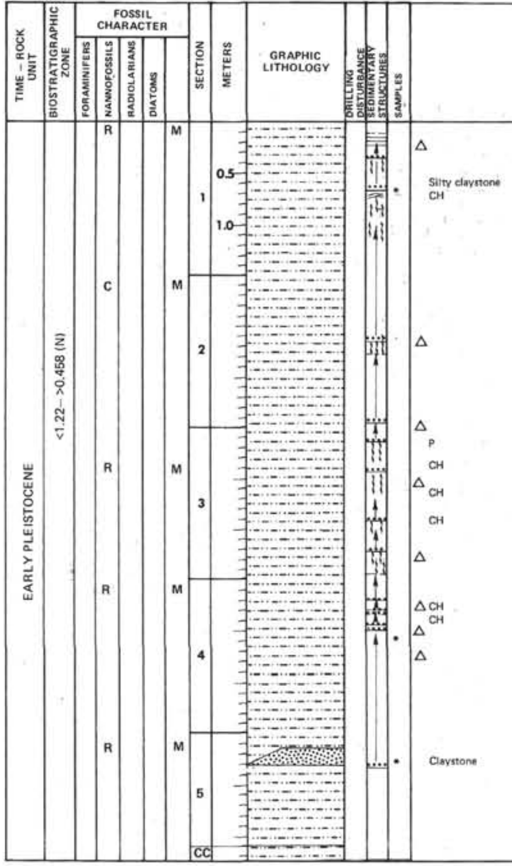
Hemipelagic mudstone and thick mud turbidites of grayish olive (10Y 4/2) **CLAYEY-SILTSTONE to SILTY CLAYSTONE.** Extensively bioturbated in claystones. Fucoid type in Section 2, 80 to 100 cm, and Section 3, 90 to 130 cm. Ten turbidite cycles; muddy, structureless, faintly graded at the base and burrowed tops (chondrites). One over 240 cm (Sections 4, 5, and 6). Sediments slightly calcareous, more in coarse silts. Seventy-three percent of the section comprises turbidites of average 50 cm thickness.

SMEAR SLIDE SUMMARY

	1-103 (D)	3-77 (D)	3-101 (D)
TEXTURE:			
Sand	–	15	–
Silt	40	50	20
Clay	60	35	80
COMPOSITION:			
Quartz	18	15	15
Feldspar	5	8	5
Mica	5	15	–
Heavy minerals	4	2	1
Clay	30	40	60
Pyrite/Opaques	5	5	2
Carbonate unspec.	10	2	3
Foraminifers	–	1	–
Calc. nannofossils	10	15	–
Radiolarians	–	2	–
Sponge spicules	–	1	–
Plant debris	2	1	2

	3, 67–69
Lithology	Clayed silt
Sand	4.90
Silt	57.95
Clay	37.15

SITE 474 HOLE A CORE 17 CORED INTERVAL 315.5–325.0 m



LITHOLOGIC DESCRIPTION

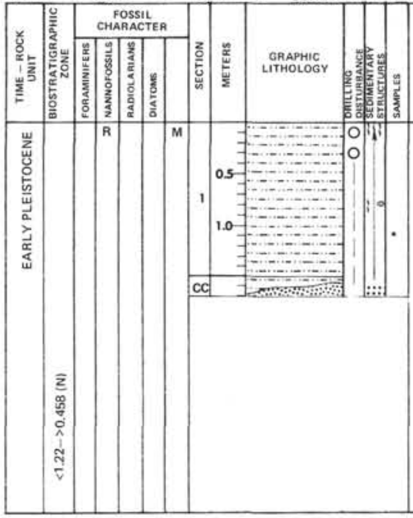
Olive gray (5Y 3/2) **SILTY CLAYSTONE to CLAYEY SILTSTONE** with thick mud turbidites. Marked by chondrites. Hemipelagic mudstones strongly burrowed with planolite types. Claystones only slightly calcareous, more in faintly graded basal parts. Wood fragments also common. Basal sand of coarse layer approaches arkose. Heavy minerals; apatite.

SMEAR SLIDE SUMMARY

	1-65 (M)	4-60 (M)	5-26 (M)
TEXTURE:			
Sand	2	2	–
Silt	38	40	55
Clay	70	58	45
COMPOSITION:			
Quartz Feldspar	20	30	30
Mica	5	–	20
Heavy minerals	2	–	–
Clay	65	50	40
Volcanic glass	–	4	2
Pyrite	2	2	10
Carbonate unspec.	2	10	–
Calc. nannofossils	5	5	2
Diatoms Radiolarians Sponge spicules Silicoflagellates	– – – –	TR	TR
Plant debris	–	–	TR

	4, 82–84
Lithology	Clayed silt
Sand	0.75
Silt	66.98
Clay	32.27

SITE 474 HOLE A CORE 18 CORED INTERVAL 325.0–327.0 m



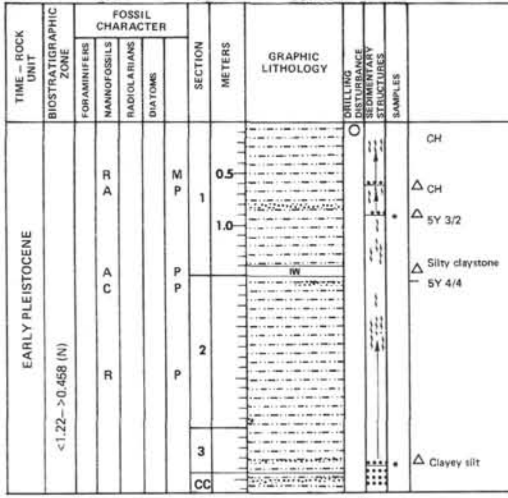
LITHOLOGIC DESCRIPTION

Disturbed olive gray (5Y 3/2) quartzose **SILTY CLAYSTONE** grading to **SANDY MUD** at base. Mud turbidite with structureless mid-portion and scattered burrows.

SMEAR SLIDE SUMMARY

	1-110 (D)
TEXTURE:	
Sand	–
Silt	35
Clay	65
COMPOSITION:	
Quartz Feldspar	35
Mica	10
Heavy minerals	TR
Clay	5
Volcanic glass	2
Pyrite	1
Carbonate unspec.	5
Foraminifers	2
Calc. nannofossils	5
Radiolarians	TR

SITE 474 HOLE A CORE 19 CORED INTERVAL 327.0–334.5 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 3/2) **SILTY CLAYSTONE**; mud turbidites. Lighter olive-brown (5Y 4/4) silty claystone layer (Section 1, 145 cm) contains more carbonate.

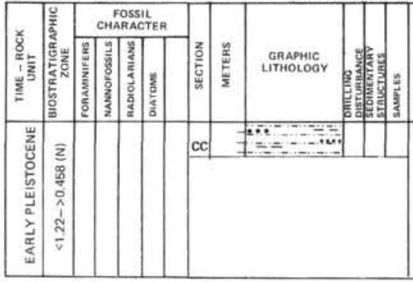
SMEAR SLIDE SUMMARY

	1-90 (D)	3-35 (D)
TEXTURE:		
Sand	–	–
Silt	40	–
Clay	60	–
COMPOSITION:		
Quartz Feldspar	30	55
Mica	10	
Clay	60	45
Volcanic glass	–	1
Pyrite	1- 2	TR
Carbonate unspec.	–	1- 2
Foraminifers	TR	–
Calc. nannofossils	TR	–

	2, 52–54
Lithology	Clayed silt
Sand	0.27
Silt	53.53
Clay	46.20

CARBONATE BOMB: 2-55 = 5%

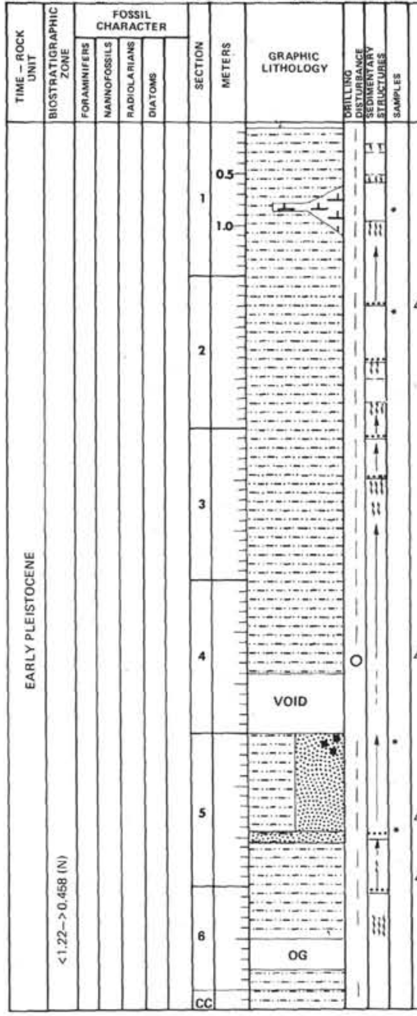
SITE 474 HOLE A CORE 20 CORED INTERVAL 334.5–344.0 m



LITHOLOGIC DESCRIPTION

Core-Catcher only – highly disturbed, a few sandy blebs of olive-gray (5Y 3/2) **SILTY CLAYSTONE.**

SITE 474 HOLE A CORE 21 CORED INTERVAL 344.0–353.5 m



LITHOLOGIC DESCRIPTION

VOID
CH
CH
5Y 4/4
Marlstone

Olive-gray (5Y 3/2) **SILTY CLAYSTONE TO CLAYEY SILTSTONE**: Mud turbidites indicated by the presence of episodic chondrites burrows (CH) but grading only faint. Main part is structureless mud. Pebbles occur in Section 5; possibly oxidized sediment transported as debris flows. Other rounded quartz, mud pebble, coarse gray sandy silt light olive brown (5Y 5/6) arkosic sand pockets. Section 1, 80 to 85 cm, thin yellowish olive brown (5Y 4/4) nannofossil marlstone. Nannofossil-debris poorly preserved.

△

M
CH
CH
CH
CH

SMEAR SLIDE SUMMARY

	1-83 (M)	2-34 (D)	5-6 (CF)	5-90 (CF)
TEXTURE:				
Sand	1	5	70	80
Silt	14	30	20	15
Clay	85	65	10	5
COMPOSITION:				
Quartz	4	6	40	40
Feldspar	1	4	10	10
Mica	2	2	15	10
Heavy minerals	–	1	–	3
Clay	40	60	5	5
Pyrite	–	2	5	5
Opaques	2	1		
Carbonate unspec.	50	20	7	5
Foraminifers	1	1	1	1
Calc. nannofossils	TR	TR	–	–
Plant debris (wood)	3	5	10	20

(nannofossil debris)

CARBONATE BOMB: 5-76 = 7%
6-46 = 5%

△

Pebbles

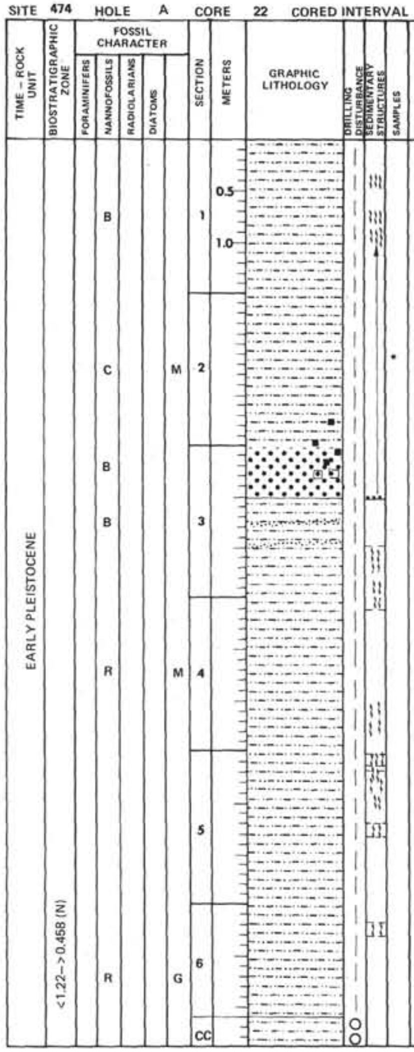
	5, 79–81
Lithology	Clayed silt
Sand	2.01
Silt	52.85
Clay	45.14

△
Sand arkose

△

CH
Sandy

SITE 474 HOLE A CORE 22 CORED INTERVAL 353.5–363.0 m



LITHOLOGIC DESCRIPTION

CH
CH
CH

Olive gray (5Y 3/2) **SILTY CLAYSTONE TO SILTSTONE** with alternating zones bioturbated and homogeneous. Very chaotic bed in Section 3, 0 to 50 cm with oxidized pebbles (■) of mudstones with some wood (□). Grading in this 240 cm unit unclear but general fining upwards. Below in Sections 4 to 6 uniform silty claystone.

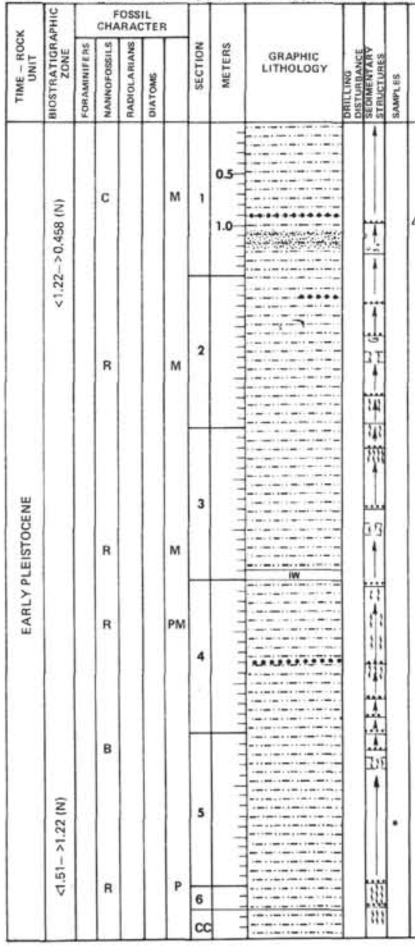
5Y 3/2

SMEAR SLIDE SUMMARY

	2-60 (M)
TEXTURE:	
Sand	2
Silt	38
Clay	60
COMPOSITION:	
Quartz	30
Feldspar	1
Mica	2
Clay	55
Pyrite Micronodules	3
Carbonate unspec.	5
Foraminifers	1
Calc. nannofossils	1
Plant debris	3

5Y 3/2

SITE 474 HOLE A CORE 23 CORED INTERVAL 363.0–372.5 m



LITHOLOGIC DESCRIPTION

5Y 3/2

△

Debris flow

CH

CH

P

P

CH

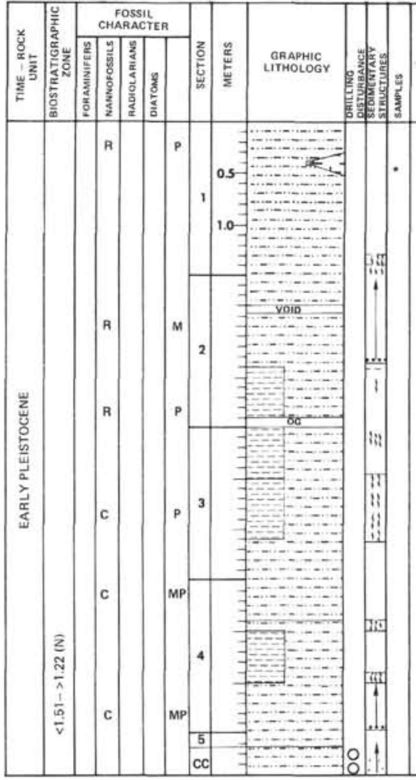
Olive-gray (5Y 3/2) **SILTY CLAYSTONE TO CLAYEY SILTSTONE** as mud turbidites wih burrowed tops and interlayers. Section 1, 100 to 120 cm a chaotic sandy mud. May be a debris flow base. Other fining upward beds show light to darker color change upwards but just beneath the overlying sandy mud contact is commonly oxidized. Pelecypod shell, open upwards in *fine claystone at Section 2, 53 cm.*

SMEAR SLIDE SUMMARY

	5-85 (D)
TEXTURE:	
Sand	5
Silt	35
Clay	60
COMPOSITION:	
Quartz	15
Feldspar	15
Mica	1
Clay	45
Volcanic glass	2
Pyrite	3
Carbonate unspec.	15
Foraminifers	1 (pyrite)
Calc. nannofossils	2
Diatoms	5 (debris)
Radiolarians	
Sponge spicules	
Silicoflagellates	
Plant debris	4

	1, 88–90	4, 87–89	4, 113–115
Lithology	Silt-sand-clay	Clayed silt	Clayed silt
Sand	33.23	1.41	3.98
Silt	45.42	58.45	67.47
Clay	21.35	39.64	28.55

SITE 474 HOLE A CORE 24 CORED INTERVAL 372.5–382.0 m



LITHOLOGIC DESCRIPTION

Nannofossil marlstone

5Y 3/2

CH

CH

M

P large

P

P

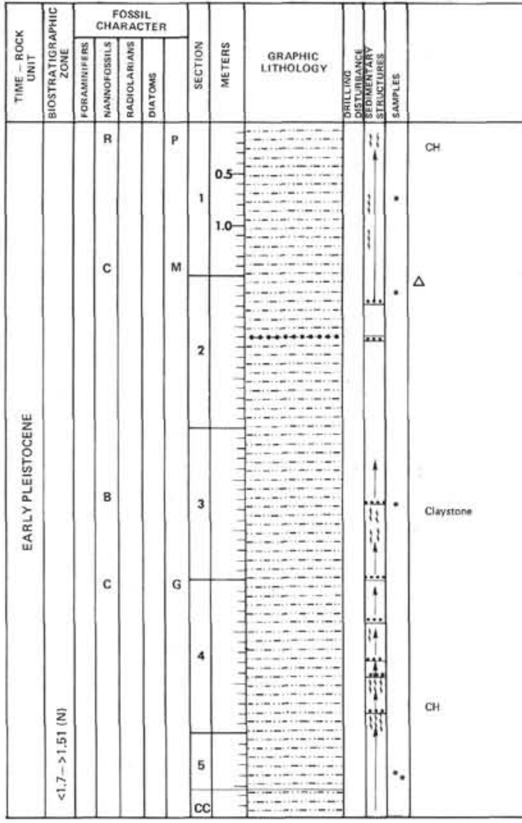
Olive gray (5Y 3/2), hard, **SILTY CLAYSTONE**. Color hues lighter (e.g. Section 1, 40 cm) in some zones with over 20% carbonate. A lightening of color hues suggests a size gradient in alternating beds. On mud turbidites not as prominant; chondrites may mark tops but without obvious basalt sand.

SMEAR SLIDE SUMMARY

	1-43 (M)
TEXTURE:	
Sand	–
Silt	30
Clay	70
COMPOSITION:	
Clay	40
Volcanic glass	TR
Pyrite	1- 2
Carbonate unspec.	5
Calc. nannofossils	55

CARBONATE BOMB: 2-137 = 8%

SITE 474 HOLE A CORE 25 CORED INTERVAL 382.0–391.5 m



LITHOLOGIC DESCRIPTION

Grayish-olive (10Y 4/2) **CLAYSTONE TO SILTY CLAYSTONE** from thick mud turbidites. Section 1, homogeneous mud with scattered burrows. May be silty clay part of a thick turbidite. Some faint burrow streaking causes a speckled surface. Much of core is a homogeneous silty claystone which shows partings along bedding. Recovered about 9 turbidite cycles thicker than 5 cm.

Coarse fractions dominated by micas, quartz, feldspars. Accessories include apatite, hornblende and calcareous grains.

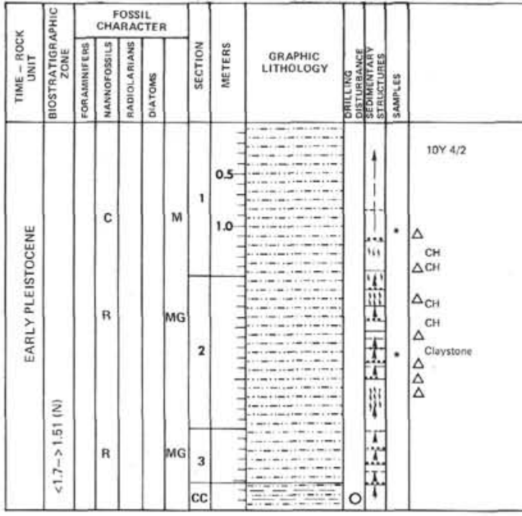
SMEAR SLIDE SUMMARY

	1-77 (D)	2-18 (M)	3-77 (M)	5-40 (CF)	5-41 (M)
TEXTURE:					
Sand	2	5	–	100	3
Silt	28	75	40	–	30
Clay	70	20	60	–	65
COMPOSITION:					
Quartz	20	30	} 15	20	} 30
Feldspar	10	5	}	20	}
Mica	2	1	2	40	5
Heavy minerals	1	2	2	5	1
Clay	35	20	60	–	20
Pyrite	} 5	5	5	–	6
Micronodules	}				
Carbonate unspec.	15	25	10	5	10
Foraminifers	1	–	–	–	1
Calc. nannofossils	1	5	TR	–	5
Plant debris	5	–	–	–	10

CARBONATE BOMB: 1-140 = 9%
2-15 = 10%

	1, 62–64
Lithology	Clayed silt
Sand	3.60
Silt	65.20
Clay	31.20

SITE 474 HOLE A CORE 26 CORED INTERVAL 391.5–401.0 m



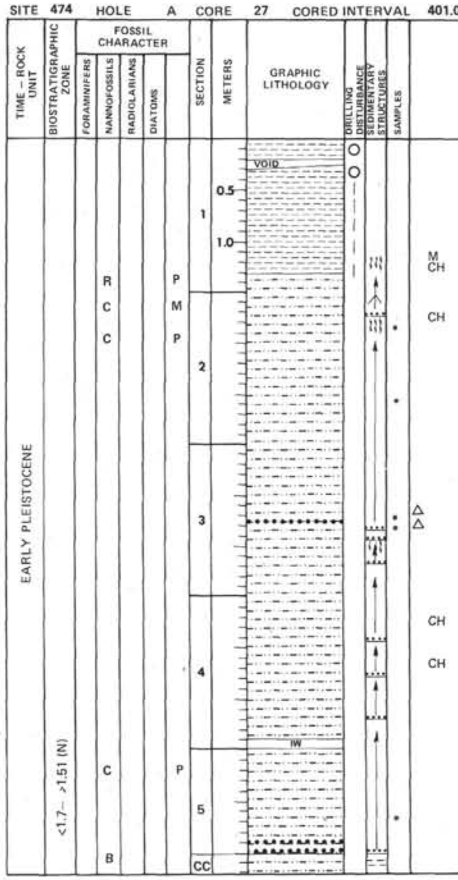
LITHOLOGIC DESCRIPTION

Grayish-olive (10Y 4/2) **SILTY CLAYSTONE** with some beds of olive brown (5Y 4/4) siltier claystone. Mud turbidite facies, but difficult to distinguish top. Usually shows chondrites (CH) burrows, and thin sand at base.

SMEAR SLIDE SUMMARY

	1-105 (M)	2-78 (D)
TEXTURE:		
Sand	5	–
Silt	35	70
Clay	60	30
COMPOSITION:		
Quartz	40	} 60
Feldspar	2	}
Mica	3	3
Heavy minerals	1	–
Clay	25	25
Pyrite	} 2	5
Micronodules	}	
Carbonate unspec.	10	5
Foraminifers	1	1
Calc. nannofossils	2	1
Plant debris	10	5

SITE 474 HOLE A CORE 27 CORED INTERVAL 401.0–410.5 m



LITHOLOGIC DESCRIPTION

Grayish-olive (10Y 4/2) **CLAYSTONE TO SILTY CLAYSTONE**, with 7 thick mud turbidite cycles. Slightly calcareous, one over 206 cm thick. Mostly massive siltstone without structures, containing abudant contonental plant detritus. Meniscate (M) burrows common but chondrites burrows (CH) at top of all turbidites. Carbonate mainly -redeposited, much is silt-sand size.

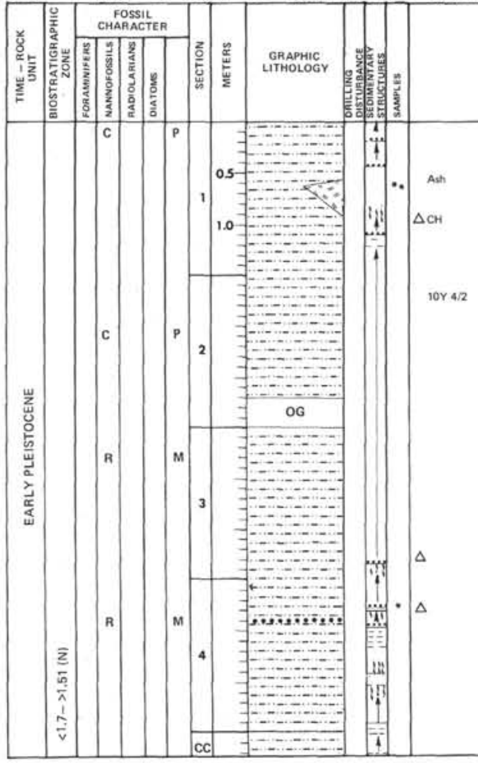
SMEAR SLIDE SUMMARY

	2-36 (D)	2-104 (D)	3-72 (D)	3-80 (D)	5-66 (D)
TEXTURE:					
Sand	–	5	50	–	10
Silt	40	50	20	10	30
Clay	60	45	30	90	60
COMPOSITION:					
Quartz	35	40	40	5	} 20
Feldspar	3	4	10	1	
Mica	4	3	2	1	1
Heavy minerals	1	3	–	–	–
Clay	35	28	20	75	60
Pyrite Micronodules	} 5	5	8	1	3
Carbonate unspec.	15	10	20	10	10
Foraminifers	1	1	1	+	1
Calc. nannofossils	1	1	–	1	2
Diatoms	–	1	–	–	–
Plant debris	5	5	5	5	–
Plant debris (wood)	1	–	–	–	–

CARBONATE BOMB: 3-78 = 28% (sand)

	4, 69–71
Lithology	Silty clay
Sand	0.84
Silt	48.22
Clay	50.94

SITE 474 HOLE A CORE 28 CORED INTERVAL 410.5–420.0 m



LITHOLOGIC DESCRIPTION

Mainly grayish-olive (10Y 4/2) **CLAYEY-SILTSTONE TO SILTY CLAYSTONE** as mud turbidites and hemipelagic mud. Slightly calcareous.

Section 1, 110 cm through Section 3, 140 cm is a 325 cm thick, upward fining unit interpreted as a single mud turbidite cycle. Dominantly structurless silty-mud with a few scattered burrows. Grades gradually from sand-silt-clay to a clayey silt.

In Section 1, 64 cm: white streaks of pure montmorillonite clay and sanidine from former ash.

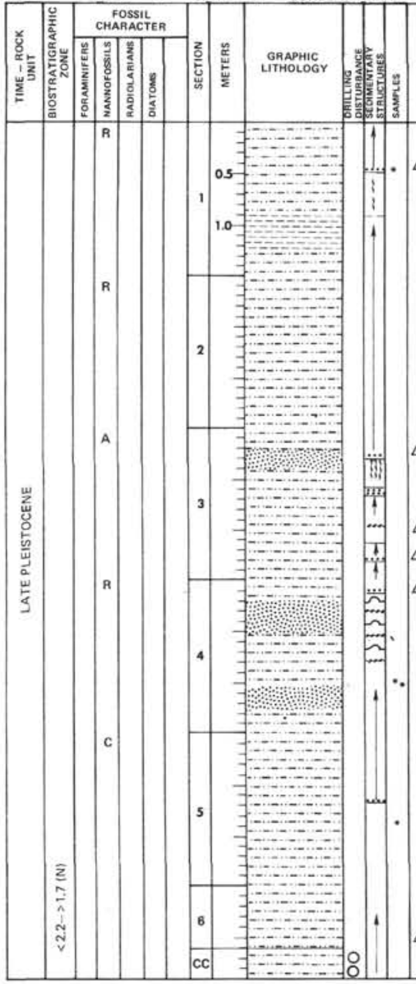
SMEAR SLIDE SUMMARY

	1-64 (D)	1-66 (M) (ash)	4-28 (D)
TEXTURE:			
Sand	2	10	5
Silt	30	–	40
Clay	68	90	55
COMPOSITION:			
Quartz	30	3	25
Feldspar	1	5 (sanidine)	2
Mica	2	1	2
Heavy minerals	1	–	1
Clay	35	90	45
Pyrite Micronodules	} 5	–	3
Carbonate unspec.	10	–	20
Foraminifers	1	–	4
Calc. nannofossils	TR	–	1
Plant debris (marine)	10	–	5
Plant debris (wood)	3	–	–

CARBONATE BOMB: 2-119 = 9%

	4, 69–71
Lithology	Silty clay
Sand	0.84
Silt	48.22
Clay	50.94

SITE 474 HOLE A CORE 29 CORED INTERVAL 420.0–429.5 m



LITHOLOGIC DESCRIPTION

5Y 4/4

△ Base sand

△

△

△

△

5Y 4/4

△

Grayish olive (10Y 4/2) **SILTY CLAYSTONE TO CLAYEY SILTSTONE,** mainly as part of thick mud turbidites. These are faintly graded at the base, with a sharp contact marked by a thin sorted, sandy-silt and burrowed at the top by chondrites. The thick mid-section is structureless, uniform, clayey silststone with rare burrows. At Section 4, 10 to 90 cm, several contorted unsorted sand-silt layers may be a debris flow deposit. Includes reddish wood fragments and shallow-water carbonate debris. Feldspathic sand grains have iron-oxide coatings, show weathering.

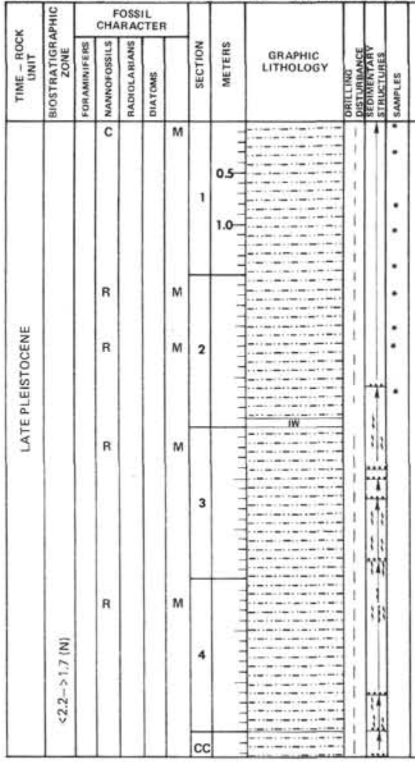
SMEAR SLIDE SUMMARY

	1-45 (M)	4-106 (CF)	4-107 (M)	5-86 (M)
TEXTURE:				
Sand	–	–	20	–
Silt	30	–	30	80
Clay	70	–	50	20
COMPOSITION:				
Quartz Feldspar	} 30	30	} 10	60
Mica	–	10	5	–
Heavy minerals	3	–	5	–
Clay	60	–	40	15
Pyrite/Opaques	2	–	4	5
Carbonate unspec.	5	2	25	5
Foraminifers	–	2	–	–
Calc. nannofossils	5	–	5	5
Plant debris	1	–	–	1
Plant debris (wood)	–	10	–	–
Rock fragments	–	10	–	–

CARBONATE BOMB: 1-44 = 9%

	2, 112–114
Lithology	Silt
Sand	1.29
Silt	77.52
Clay	21.19

SITE 474 HOLE A CORE 30 CORED INTERVAL 429.5–439.0 m



LITHOLOGIC DESCRIPTION

5G 4/1

10Y 4/2

CH

Grayish olive (10Y 4/2) to olive gray (5G 4/1) **SILTY CLAYSTONE TO CLAYEY SILTSTONE;** mud turbidites (Section 1, 0 cm to Section 2, 114 cm, type section). Bioturbation increases with depth. Series of smear slide samples taken in homogenous mud section.

SMEAR SLIDE SUMMARY

	1-140 (D)
TEXTURE:	
Sand	15
Silt	25
Clay	60
COMPOSITION:	
Quartz Feldspar	} 30
Mica	1
Heavy minerals	2
Clay	50
Volcanic glass	2
Pyrite/Opaques	6
Zeolite	2
Carbonate unspec.	5
Calc. nannofossils	2
Plant debris	1
Euhedral calcite	10

CARBONATE BOMB: 1-69 = 9%

7

	1, 121–123	2, 3–5	2, 43–45	2, 113–115	3, 68–70
Lithology	Silt	Clayed silt	Sandy silt	Silty sand	Silty clay
Sand	2.49	13.77	27.06	70.24	1.01
Silt	76.87	64.29	55.15	21.26	45.41
Clay	20.64	21.94	17.79	8.73	53.58

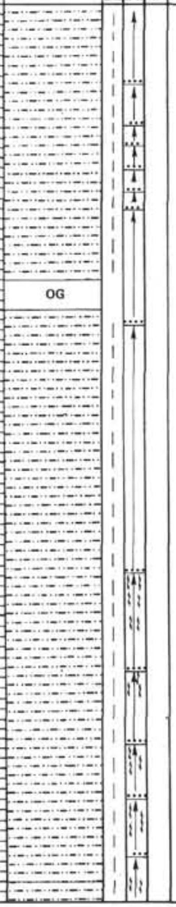
SITE 474 **HOLE** A **CORE** 31 **CORED INTERVAL** 439.0–448.5 m

TIME – ROCK UNIT: LATE PLEISTOCENE

BIOSTRATIGRAPHIC ZONE: <2.2–>1.7 (N)

SECTION	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	
1		R			M
2		C			MG
3		R			P
4		R			M
5		R			MP
6		R			MP
CC					

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

10Y 4/2

P, M

CH

CH

CH

CH

Gray olive (10Y 4/2) **SILTY CLAYSTONE**; turbidites. Chondrites, planolites and meniscate type bioturbation.

SMEAR SLIDE SUMMARY

	2-129 (D)	3-54 (D)
TEXTURE:		
Sand	2	–
Silt	10	40
Clay	78	60
COMPOSITION:		
Quartz Feldspar	10	25
Mica	1	3
Clay	75	55
Volcanic glass	1	–
Pyrite/Opaques	–	2
Zeolite	–	2
Carbonate unspec.	5	10
Calc. nannofossils	2	2
Euhedral calcite	10	–
Discoasters	TR	–

	3, 54–56
Lithology	Silt
Sand	0.24
Silt	75.37
Clay	24.39

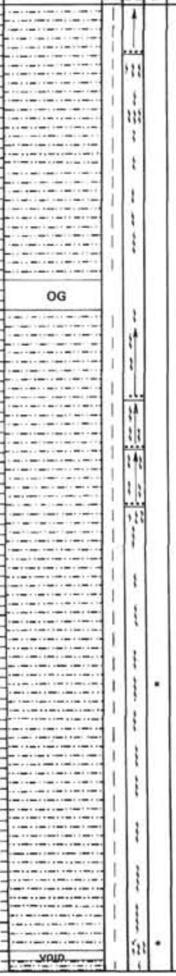
SITE 474 **HOLE** A **CORE** 32 **CORED INTERVAL** 448.5–457.0 m

TIME – ROCK UNIT: LATE PLEISTOCENE

BIOSTRATIGRAPHIC ZONE: <2.2–>1.7 (N)

SECTION	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	
1		R			M
2		R			P
3		R			P
4					
5		R			P
6					
7		R			P
CC					

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

CH

P

P

5Y 3/2

CH

CH

P, CH

CH

P

P

P

Olive gray (5Y 3/2) **SILTY CLAYSTONE**, very uniform with little bioturbation except where indicated. Few mud turbidites. Some scattered moderate olive brown (5Y 4/4) clayey siltstones (possible oxidation layers or higher content of nannofossils).

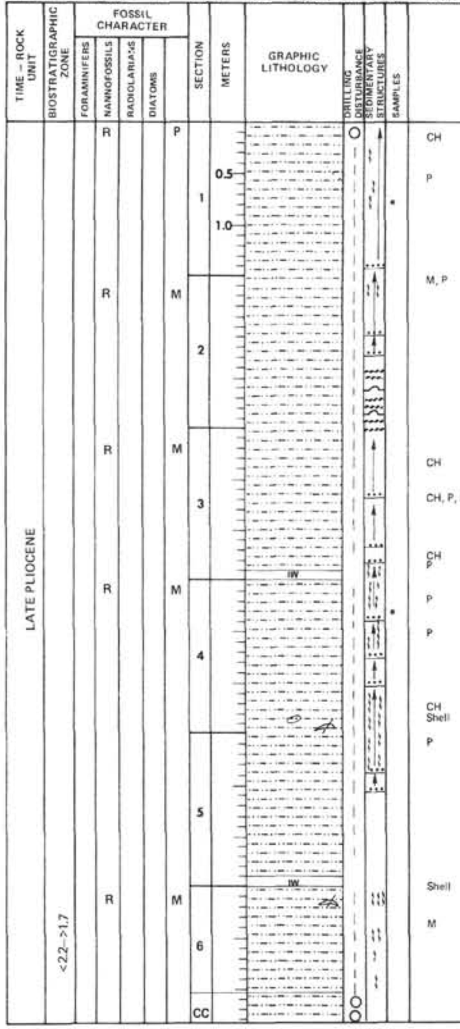
SMEAR SLIDE SUMMARY

	5-70 (D)	7-20 (D)
TEXTURE:		
Sand	5	–
Silt	35	50
Clay	60	50
COMPOSITION:		
Quartz	10	15
Feldspar	20	15
Mica	2	–
Heavy minerals	–	1
Clay	60	50
Pyrite/Opaques	3	5
Carbonate unspec.	3	3
Calc. nannofossils	3	3
Plant debris	8	7
Dolomite	1	–
Discoasters	–	1

CARBONATE BOMB: 2-120 = 9%
7-20 = 6%

	5, 108–110
Lithology	Silt
Sand	1.49
Silt	79.66
Clay	18.85

SITE 474 HOLE A CORE 33 CORED INTERVAL 457.0–466.5 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 3/2) **CLAYSTONE TO SILTY CLAYSTONE,** moderate bioturbation. CH = chondrites, P = planolites, and M = meniscate types. Small mud turbidites. Sandy fraction contains many weathered grains.

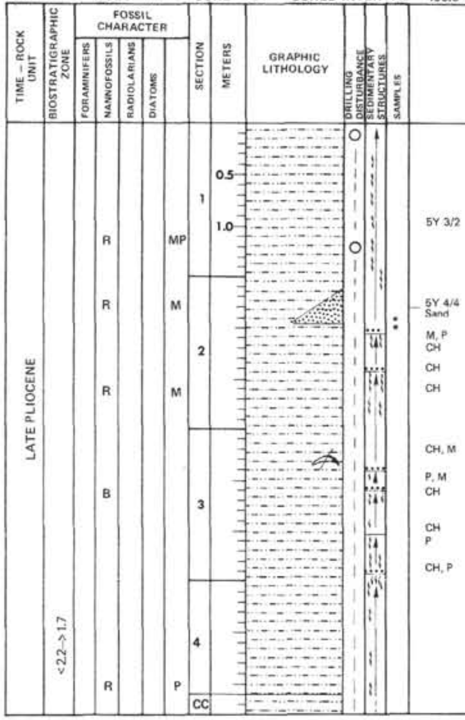
Section 2, 75 cm to Section 3, 10 cm: contorted sand and claystone layers, possibly related to debris flow.

SMEAR SLIDE SUMMARY

	1-73 (D)	4-30 (D)
TEXTURE:		
Sand	–	5
Silt	35	40
Clay	65	55
COMPOSITION:		
Quartz	35	30
Feldspar		15
Mica	5	5
Heavy minerals	1- 2	3
Clay	40	35
Volcanic glass	1- 2	1- 2
Pyrite/Opaques	10	1- 2
Carbonate unspec.	2	2
Foraminifers	TR	–
Calc. nannofossils	5	10
Plant debris	5	5
Discoasters	TR	–

	3, 83–85
Lithology	Clayed silt
Sand	6.07
Silt	63.10
Clay	30.83

SITE 474 HOLE A CORE 34 CORED INTERVAL 466.5–476.0 m



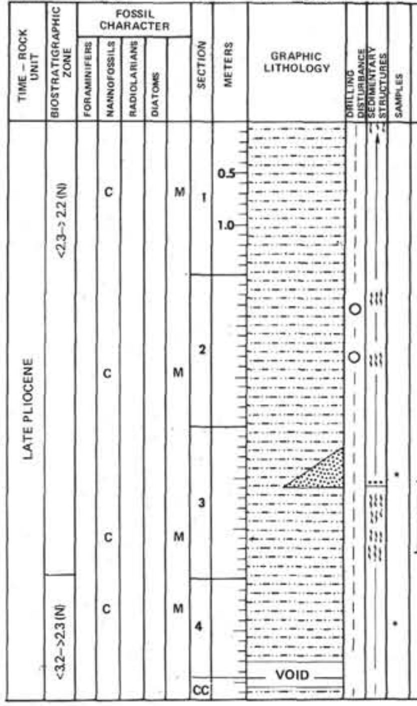
LITHOLOGIC DESCRIPTION

Olive gray (5Y 3/2) **CLAYEY SILTSTONE TO SILTY CLAYSTONE.** Moderate to extensive bioturbation with chondrites (CH), planolites (P) and some large mud turbidite sequences. Sandy layers show lighter medium olive brown (5Y 4/4) hues. These tend to be very feldspathic, with weathered angular grains. Foraminifera tests commonly pyrite filled, recrystallized. Micas include much chlorite.

SMEAR SLIDE SUMMARY

	2-40 (M)	2-50 (D)
TEXTURE:		
Sand	60	–
Silt	30	25
Clay	10	75
COMPOSITION:		
Quartz	30	40
Feldspar	30	
Mica	10	3
Heavy minerals	1- 2	2
Clay	15	40
Pyrite	–	5
Carbonate unspec.	5	5
Foraminifers	2	–
Calc. nannofossils	5	TR
Diatoms	3	–
Plant debris	–	5
Euhedral calcite	1	–
Discoasters	2	–

SITE 474 HOLE A CORE 35 CORED INTERVAL 477.0–486.5 m



LITHOLOGIC DESCRIPTION

Chondrites

5Y 3/2

CH (rare)
Planolites
Meniscates

No basal sand

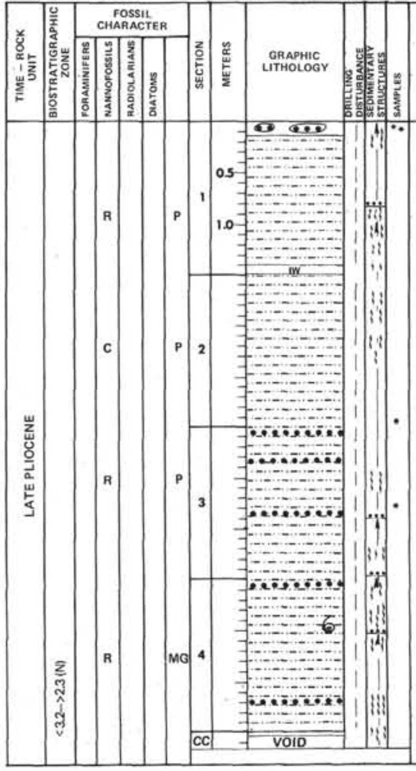
Slightly disturbed, olive gray (5Y 3/2) hard, **SILTY CLAYSTONE TO CLAYEY SILTSTONE** (very uniform). Appears to mainly consist of one large mud turbidite unit (~2.5 m thick). Basal sandy layer, *more fine-grained.* Bioturbation present and identifiable in Sections 3, 50 to 110 cm, but in other sections is very faint. Below Section 3, 48 cm nannofossils more abundant, bioturbation present.

SMEAR SLIDE SUMMARY

	3-48 (M)	4-40 (D)
TEXTURE:		
Sand	2	–
Silt	50	40
Clay	48	60
COMPOSITION:		
Quartz	35	10
Feldspar	3	5
Mica	4	2
Heavy minerals	2	3
Clay	25	30
Pyrite	5	5
Carbonate unspec.	10	15
Foraminifers	1	–
Calc. nannofossils	3	10
Plant debris (marine)	10	5

CARBONATE BOMB: 1-22 = 13%

SITE 474 HOLE A CORE 36 CORED INTERVAL 486.5–496.0 m



LITHOLOGIC DESCRIPTION

P

CH

?
CH
CH
CH
P
CH, P
M
No basal sand

Slightly disturbed olive-gray (5Y 3/2) hard, **SILTY CLAYSTONE TO CLAYEY SILTSTONE.** Homogeneous with faint bioturbation thought to separate mud turbidites. An indurated **ARKOSIC SANDSTONE** occurs at the top. Possibilities of origin include 1) coarse fractions from the base of large turbidite layer and 2) redeposited as debris flow boulder or cobble. Not considered a cemented basal turbidite bed as no other evidence of lithification. Shell fragments prevalent in mud turbidites (some large in thickness, some small) from Sections 3 and 4.

TS 1, 4 to 8 cm: moderately well-sorted (100 to 250μm), grains supported carbonate-cemented quartz-feldspar sandstone.

40%	matrix calcite-cement as 0.05 mm mosaic
30%	angular quartz
20%	feldspars (plagioclase and K-feldspars) broken, fresh
5%	benthic foraminifers
2%	opaques
10%	porosity
2%	chalcedony rock fragments
2%	calcareous fragments
2%	heavy minerals, *pyroxene, hornblende,* biotite, chlorite

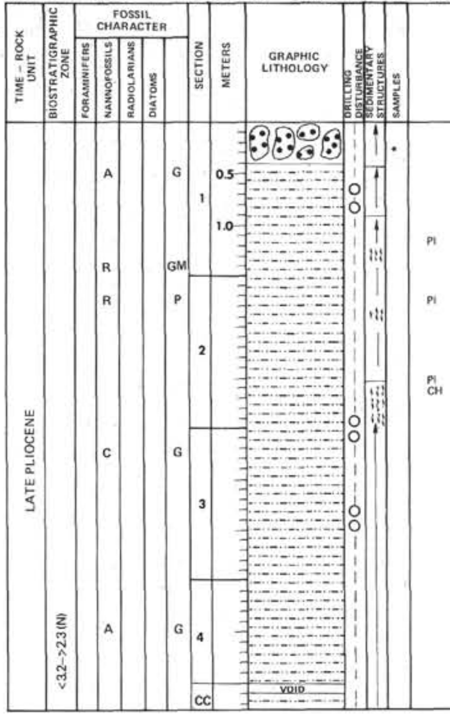
TS 1, 6 to 7 cm: as above.

SMEAR SLIDE SUMMARY

	2-147 (D)	3-78 (M)
TEXTURE:		
Sand	1	50
Silt	29	25
Clay	70	25
COMPOSITION:		
Quartz	20	30
Feldspar	1	30
Mica	2	2
Heavy minerals	1	1
Clay	50	25
Pyrite	–	3
Micronodules	5	–
Carbonate unspec.	3	10
Calc. nannofossils	5	1
Plant debris	3	1

	2, 104–106
Lithology	Clayed silt
Sand	1.50
Silt	50.60
Clay	47.90

SITE 474 HOLE A CORE 37 CORED INTERVAL 496.0–505.5 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 3/2), hard, **SILTY CLAYSTONE,** very uniform with little discernible bioturbation. Section 1, 0 to 40 cm: **AR̃KOSIC SANDSTONE** (40 cm) cobbles at top of core may derive from 1) the base of a very sandy turbidite bed or 2) may be an exotic block from some other source. Again mud turbidites below do not have indurated basal sandstones. Sandstone components show a general grading upward.

TS 1-34 to 36- cm: grain-supported, moderately well-sorted quartzo-feldspathic sandstone (100 to 250 microns).

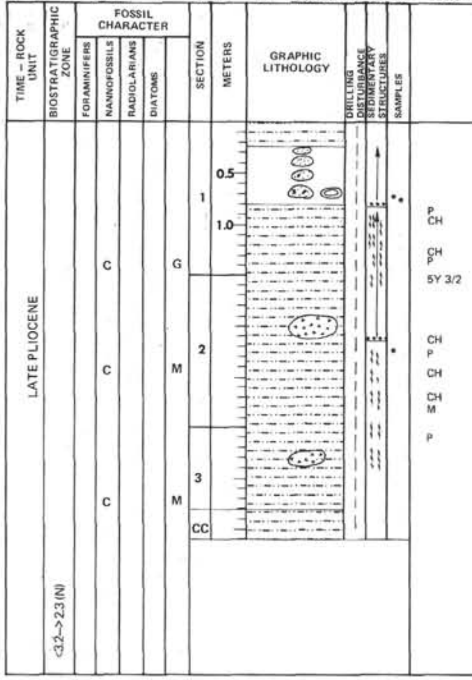
40%	cemented by calcareous mosaic, some acicular
3%	benthic foraminifers including miliolids
30%	quartz, angular fragments
20%	K-feldspar and plagioclase
1%	basaltic rock fragments
1%	pyroxenes, hornblende, mica

SMEAR SLIDE SUMMARY

	2-45 (D)
TEXTURE:	
Sand	2
Silt	30
Clay	68
COMPOSITION:	
Quartz	10
Feldspar	10
Mica	2
Clay	70
Pyrite	3
Carbonate unspec.	5
Calc. nannofossils	1
Plant debris	1

CARBONATE BOMB: 3-100 = 10%

SITE 474 HOLE A CORE 38 CORED INTERVAL 505.5–515.0 m



LITHOLOGIC DESCRIPTION

Section 1, 80 cm to Core-Catcher: moderately disturbed uniform olive gray (5Y 3/2), hard, **SILTY CLAYSTONE**. Section 1, 25 to 80 cm: basal **ARKOSIC SANDSTONE** which appears graded contains angular basalt clasts and shell fragments. Pebble at bottom of mud turbidite at Section 1, 80 cm, has either an alteration rim or chemical coating (phosphorite?). Turbidites with bioturbation continues. Occasionally large diabase pebbles (Section 2, 50 cm) are seen at the bottom of a turbidite to debris flow.

TS 38-1, 70 to 72 cm: Coarse polygenetic sandstone, quartzo-feldspathic, rock fragments (30%) include quartz, siltstone, basalt, metamorphics.

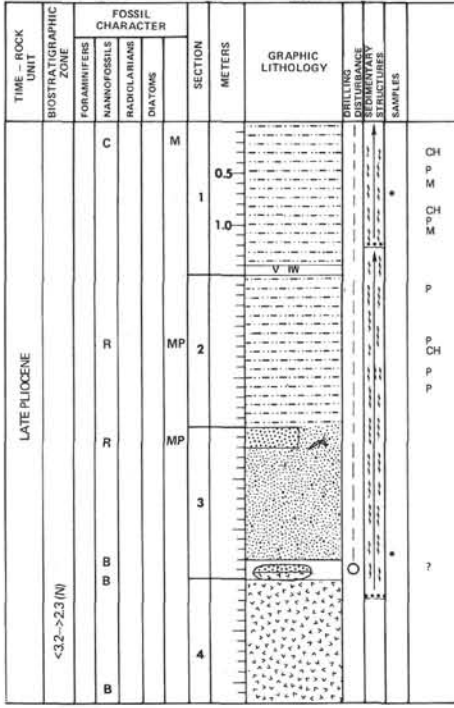
20%	quartz grains
30%	feldspar grains
30%	calcium carbonate cement

Some scattered benthic foraminifers and possibly opaline silica cement. Most grains 1 to 3 mm.

SMEAR SLIDE SUMMARY

	2-75 (D)
TEXTURE:	
Sand	–
Silt	40
Clay	60
COMPOSITION:	
Quartz	20
Feldspar	5
Mica	5
Heavy minerals	3 (Zr, Ap)
Clay	55
Opaques	10
Carbonate unspec.	2
Calc. nannofossils	1
Plant debris	8
Discoasters	1

SITE 474 HOLE A CORE 39 CORED INTERVAL 515.0–524.5 m



LITHOLOGIC DESCRIPTION

Sections 1 to 3, 130 cm: olive gray (5Y 3/2) hard, **UNIFORM CLAYSTONE.** Extensively burrowed with chondrites, planolites; meniscate types. Large turbidite sequence (3.3 m thick) at Section 1, 110 cm to base with shell fragments. Thin contact zone (Section 3, 80 cm) with an **ARKOSE SANDSTONE** in contact with **BASALT** occurring in one pebble from a drilling rubble.

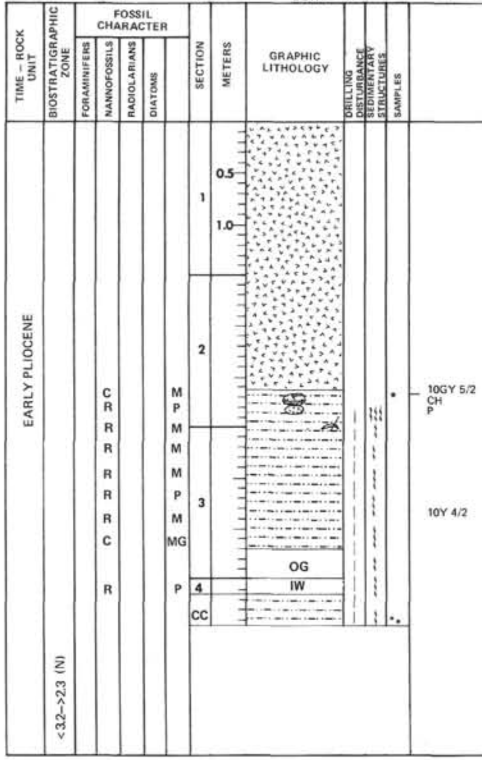
Section 3, 140 cm to Section 4: **APHYRIC BASALT** in contact with calcite-cemented sandstone grades to medium-grained dolerite.

SMEAR SLIDE SUMMARY

	1-70	3-121
	(D)	(D)
TEXTURE:		
Sand	3	–
Silt	40	55
Clay	55	45
COMPOSITION:		
Quartz	25	15
Feldspar	2	10
Mica	5	1
Heavy minerals	1	–
Clay	45	45
Opaques	4	2
Carbonate unspec.	10	30
Calc. nannofossils	1	1
Radiolarians	–	2
Plant debris	5	3
Discoasters	–	1

CARBONATE BOMB: 3-29 = 4%
3-51 = 8%
3-111 = 6%

SITE 474 HOLE A CORE 40 CORED INTERVAL 524.5–534.0 m



LITHOLOGIC DESCRIPTION

Section 1–Section 2, 115 cm: **DOLERITE SILL.**
Section 2, 115–140 cm: peppered gray and light gray-green (10GY 5/2) **SANDSTONE,** well indurated, calcite-cemented, laminated, micaceous, poorly sorted, no grading, in contact (chill margin?) with diabase sill.

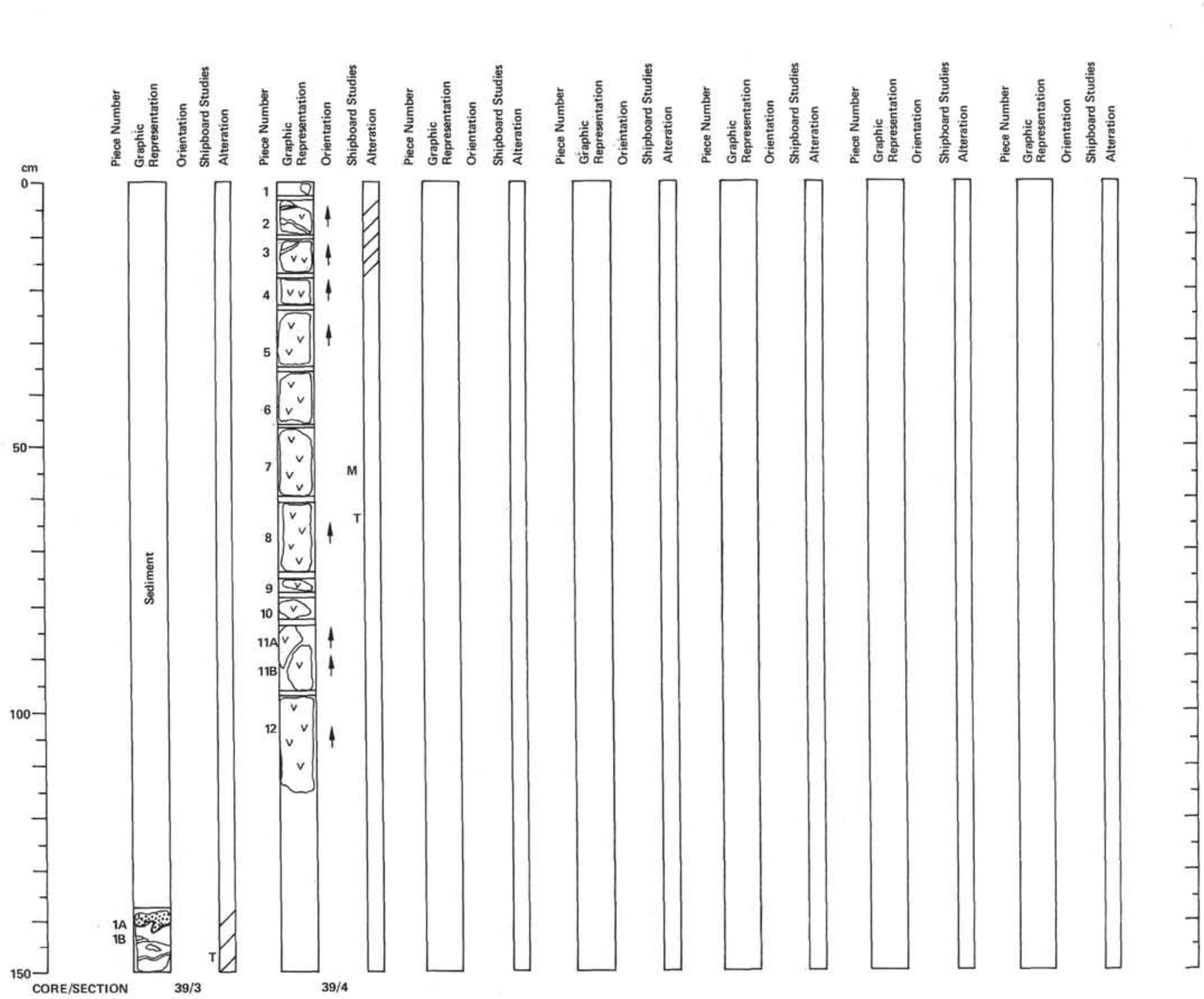
Section 3 and 4: olive gray (10Y 4/2) **SILTY CLAYSTONE,** hard, uniform bioturbated slightly calcareous. Locally white specks, no clear grading. Some scattered shell fragments.

TS 40-2, 123 cm: very coarse quartz (30%) sandstone (0.2 to 0.3 mm), very angular components, calcite-cemented.
10% plagioclase and K-feldspars, micaceous lineation, rare hornblende (2)
2% scattered carbonate clasts and relict recrystallized foraminifers (miliolids?), some scattered eutectic quartz grains from plutonic rocks

SMEAR SLIDE SUMMARY

	4-40	4-42
	(D)	(D)
TEXTURE:		
Sand	10	2
Silt	40	70
Clay	50	28
CMP		
Quartz	20	60
Feldspar	15	2
Mica	5	3
Heavy minerals	2 (Ap,Zr,Sph.)	3
Clay	40	28
Volcanic glass	3	–
Opaques	8	–
Micronodules	–	1
Carbonate unspec.	2	1
Calc. nannofossils	1	TR
Plant debris (pyritized	5 (pyritized)	2

CARBONATE BOMB: 1-120 = 10%
2-136 = 5%
3-5 = 4%



64-474A-39 Depth 515.0 to 524.5 m

SECTION 3: DOMINANT LITHOLOGY: APHYRIC BASALT CONTACT with sandstone.

Macroscopic Description

Aphyric basalt with 1 mm calcite vein and 5 mm calcite vug. Distinct glassy chill against sandstone. Sandstone not baked, but claystone above sandstone extensively brecciated, and fossils in sediment have been atlered in areas adjacent to basalt.

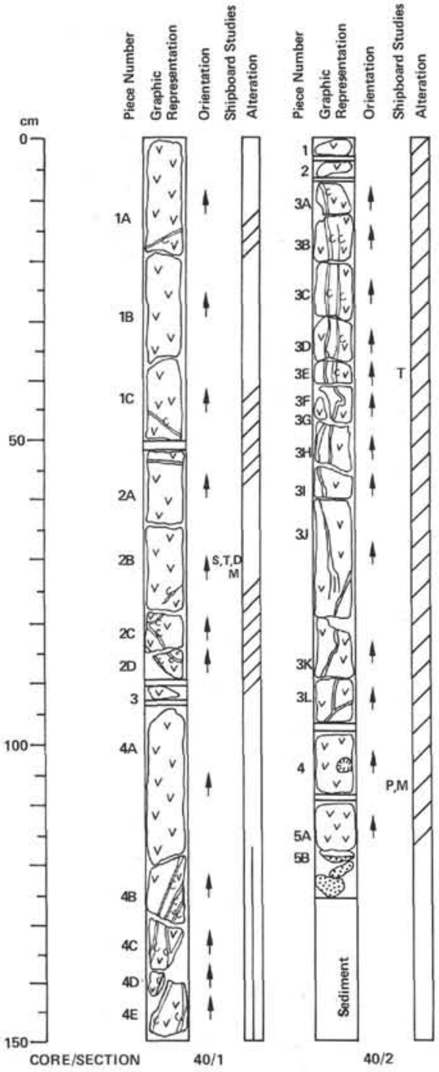
TS 149 cm (Piece 1B): Porphyritic BASALT, sampled adjacent to chilled margin. Phenocrysts: plagioclase approximately 15%, up to 2 mm across, subhedral tabulate and lath-shaped crystals; spinel approximately 2%, 0.1–0.2 mm, euhedral red chromespinel. Groundmass: fine-grained variolitic/sub-spherulitic groundmass comprising plagioclase microlites, pyroxene, disseminated opaques and mesostasis. Vesicles: none. Alteration: about 20% of the rock contains pseudomorphs of an unidentified mineral, probably replacing olivine.

SECTION 4: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Fine- to medium-grained equigranular dolerite; fresh appearance, 1–2 mm wide veins of $CaCO_3$ (rock with HCl) in Pieces 2 and 3.

TS 65 cm (Piece 8): DOLERITE. Texture: subophitic, with seriate gradation of groundmass to phenocryst phases (olivine). Phenocrysts: olivine, ranging in size up to 2 mm; subhedral, fractured, slightly altered to bowlingite (a green clay mineraloid) 5%. Groundmass: comprises olivine, 10%; plagioclase, 40%, An_{50}, and pale brown augite, frequently enclosing plagioclase laths, 35%; magnetite, 0.1–0.2 mm, occurs interstitially. Grain-size varies from 0.1–1.0 mm. No vesicles are seen. Alteration restricted to rims and cracks of olivine.



64-474A-40 **Depth 524.5 to 534.0 m**

SECTION 1: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Dominantly equigranular dolerite. More plagioclase crystals occur in lower portion of section (140–150 cm) (phenocrysts up to 1 mm). No vesicles.

Alteration of main body of dolerite slight, but severly veined by calcite at 120–150 cm. Minor calcite veins occur throughout.

TS 70 cm (Piece 2B): OLIVINE DOLERITE. Texture: porphyritic subdoleritic, small (<1 mm) interlocking plagioclase laths surrounded by 1.0–1.3 mm olivine, partially altered to bowlingite and clinopyroxene. Groundmass: plagioclase laths, 40%, up to 1 mm, An_{52}, unzoned. Olivine, 10%, 0.2–0.5 mm, subhedral, microphenocrysts; clinopyroxene, 25%, 0.2–0.8 mm, augite, anhedral, brown, may be TiO_2-rich; opaques mainly magnetite, dispersed.

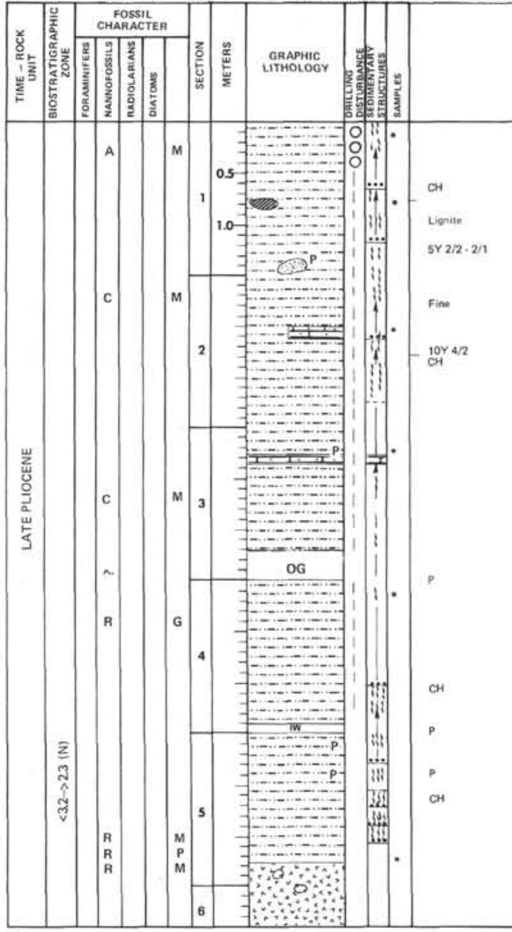
SECTION 2: DOMINANT LITHOLOGY: DOLERITE and contact to SANDSTONE.

Macroscopic Description

Medium-grained, dark gray dolerite. Mainly equigranular but altered olivine(?) phenocrysts (up to 2 mm) occur in random concentrations throughout intervals 16–98, 104–107, and 113–116 cm. Veining intense (mainly $CaCO_3$), with 1–5 mm wide veins. Vertical trending veins most common. Lower contact preserved in Piece 5B as a wide chilled(?) (not glassy) margin, containing rock SANDSTONE similar to that at upper contact except that sandstone is baked at lower contact at approximately 121 cm.

TS 38 cm (Piece 3E): Sampled adjacent to veining material and within phenocryst-rich zone. OLIVINE-RICH DOLERITE/COARSE BASALT. Phenocrysts: no primary phenocrysts have been preserved, but up to 30% of the sample comprises euhedral to subhedral pseudomorphs of green bowlinglite, presumably after olivine. Size from 0.3–3.0 mm. Groundmass: bowlingite, after olivine (0.3–0.6 mm), 10%; plagioclase (An_{50}, 0.3–0.8 mm), 30%; medium brown anhedral augite, generally interstitial to feldspar, 0.3–0.8 mm, 30%; magnetite, 5%. Texture: sub-doleritic to intergranular. Alteration: olivine completely replaced by bowlingsite.

SITE 474 HOLE A CORE 41 CORED INTERVAL 534.0–543.5 m



LITHOLOGIC DESCRIPTION

Dominantly, grayish-olive black (5Y 2/2) **SILTY CLAYSTONE,** very indurated, slightly calcareous. Bioturbation extensive and lithified, with pyrite. Some zones more silty. Section 2, 32 cm: white radial specks barite or apatite concretions. Section 1, 145 cm: calcite-cemented sandstone and pyritized burrow. Section 2, 54 cm and Section 3, 22 cm: calcareous, hard siltstones at the base of what look like mud turbidites. Just above the contact to **A DOLERITE** (below Section 5, 125 cm) are 7 or more thin (10 cm) turbidites (silty to clay cycles). Calcite veins, and pyrite, in black siltstone at contact.

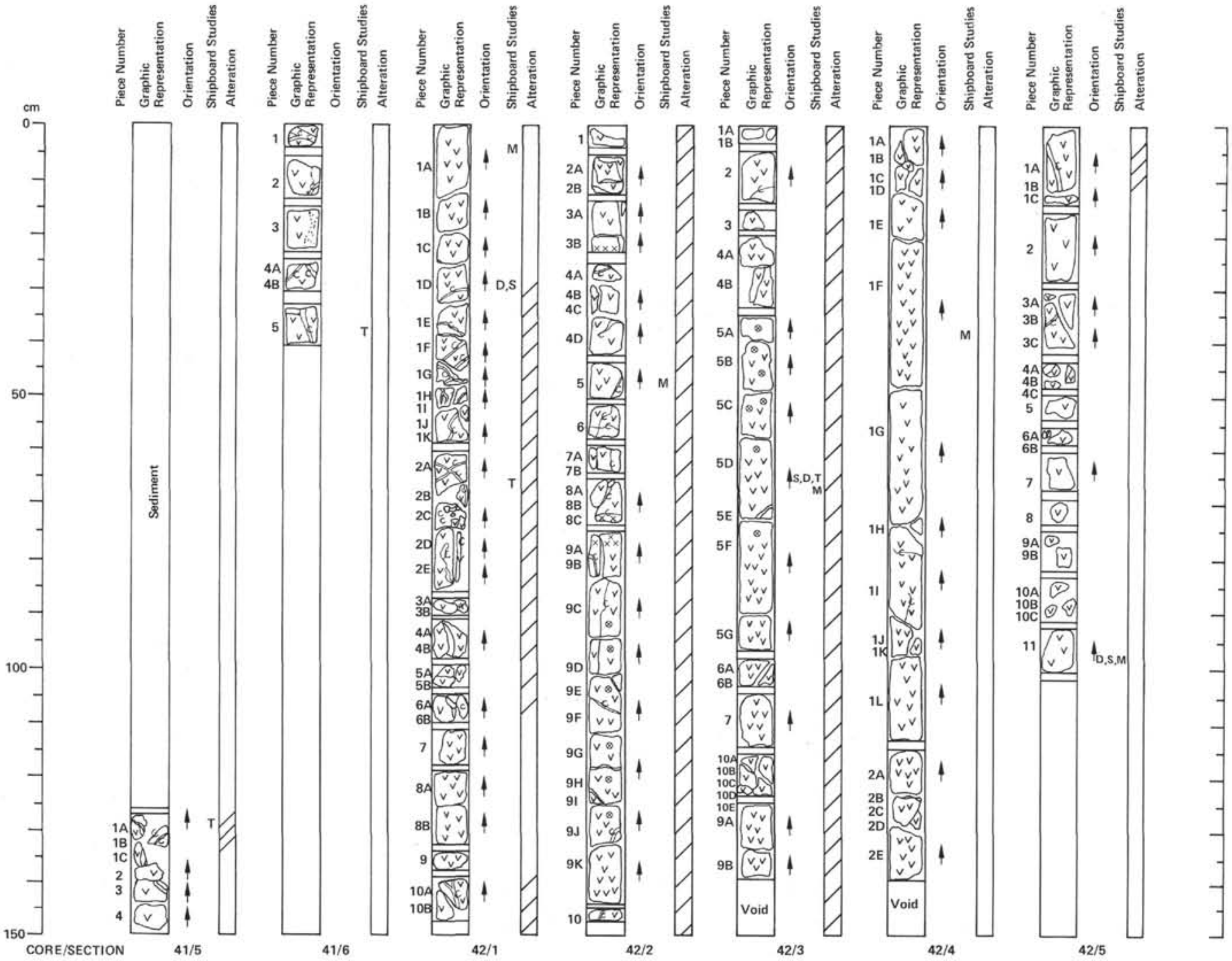
TS 41-3, 110 cm: laminated, calcareous siltstone, very angular, clastic fragments

30%	calcite cement
10%	porosity
5%	calcareous fossils (benthic foraminifers) filled or recrystallized
29%	quartz
25%	feldspars (mostly K-feldspar)

SMEAR SLIDE SUMMARY

	1-17 (M)	1-80 (M)	2-54 (M)	4-17 (M)	5-128 (D)
TEXTURE:					
Sand	5	–	2	–	5
Silt	50	–	60	–	25
Clay	45	–	38	–	70
COMPOSITION:					
Quartz	–	–	5	–	10
Feldspar	–	–	5	–	5
Mica	–	–	1	–	2
Heavy minerals	–	–	1	–	2
Clay	10	–	35	20	65
Volcanic glass	–	–	–	–	2
Opaqyes/Pyrite	–	–	–	80	2
Carbonate unspec.	–	–	60	–	10
Calc. nannofossils	TR	–	–	–	–
Plant debris	20	–	1	–	–
Lignite	–	100	–	–	–
Apatite? Barite?	70	–	–	–	–

CARBONATE BOMB: 3-19 = 38% (siltstone cement)
3-119 = 6%


cm
0
50
100
150
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
Sediment
Void
M
D,S
T
S,D,T
D,S,M
1A 1B 1C 2 3 4
1 2 3 4A 4B 5
1A 1B 1C 1D 1E 1F 1G 1H 1I 1J 1K 2A 2B 2C 2D 2E 3A 3B 4A 4B 5A 5B 6A 6B 7 8A 8B 9 10A 10B
1 2A 2B 3A 3B 4A 4B 4C 4D 5 6 7A 7B 8A 8B 8C 9A 9B 9C 9D 9E 9F 9G 9H 9I 9J 9K 10
1A 1B 2 3 4A 4B 5A 5B 5C 5D 5E 5F 5G 6A 6B 7 10A 10B 10C 10D 10E 9A 9B
1A 1B 1C 1D 1E 1F 1G 1H 1I 1J 1K 1L 2A 2B 2C 2D 2E
1A 1B 1C 2 3A 3B 3C 4A 4B 4C 5 6A 6B 7 8 9A 9B 10A 10B 10C 11
CORE/SECTION
41/5
41/6
42/1
42/2
42/3
42/4
42/5

64-474A-41 Depth 534.0 to 543.5 m

SECTION 5: DOMINANT LITHOLOGY: DOLERITE AND BAKED SEDIMENT

Macroscopic Description

128–129 cm: baked contact between overlying sediment and top of dolerite sill contact is chilled (~ 2 mm) and grain-size decreases from contact where it is olivine(?) phyric (1 mm grains) to more fine-grained at about 145 cm. Large (8 mm) calcite vein occurs between 131–132 cm. Below approximately 145 cm dolerite is equigranular to aphyric.

TS 129 cm (Piece 1A): section taken in chilled margin. Variolitic to HYALOPILITIC BASALT. Phenocrysts of euhedral olivine (15%, 0.5–1.2 mm, now altered to green clay minerals; plagioclase, 5%, 0.1–0.2 mm ; microphenocrysts (chrome?) spinel, 2%, 0.1 mm. Groundmass, 70%, very fine-grained (0.2 mm), comprising minute feldspar microlites in a dark, iron-rich mesostasis. Glassy. Minor clay. Narrow veins (~ 0.5 mm wide) cross-cut glassy margin and sediment. Composed almost entirely of calcite.

SECTION 6: DOMINANT LITHOLOGY: DOLERITE veins with calcite.

Macroscopic Description

Large, 1.2 cm thick calcite vein cuts across Piece 1 – equigranular dolerite showing some tendency towards altered olivine phyric basalt near calcite veins. Other pieces 2–5; dolerite.

TS 38–40 cm (Piece 5): OLIVINE DOLERITE/COARSE BASALT. Crosses vein. Texture is porphyritic, doleritic. Phenocrysts: 15% olivine, up to 1 mm size, completly altered to green clay minerals (bowlingite). Groundmass: olivine, 5%, now completely altered; plagioclase, 45%, 0.10–0.5 mm, An_{50}; clinopyroxene, ~ 30%, 0.1–0.5 mm, augite (possibly titaniferous) and magnetite, ~2%. Veins consist of 5% $CaCO_3$ and 95% zeolite (trigonal? chabazite).

64-474A-42 Depth 543.5 to 553.0 m

SECTION 1: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Fine-grained equigranular gray-dolerite for most of the section. Dark green olivine phenocrysts occurring in random orientation from interval 40–118 cm, in the vicinity of calcite-green clay(?) veins. These veins cut across in a subvertical direction, with a maximum width of 1 cm. Some phenocrysts are up to 3 mm long. At intervals 0–30 and 113––140 cm dolerite is fairly fresh. The rest of the section is moderately altered veining occurs at intervals 31–110 cm and 139–146 cm.

TS 68 cm (Piece 2A): fine-grained olivine-rich dolerite. Texture: subophitic-porphyritic. Phenocrysts: olivine 25%, 0.5–2.0 mm, mostly altered to green clay minerals; plagioclase, 2%, 0.5 mm, tabulate; spinel, 2%, 0.05–0.1 mm, red chromite. Groundmass: olivine, 10% (< 0.5 mm), altered to green clay minerals; plagioclase 40% (0.2–1.0 mm), An_{56}; clinopyroxene, 20% (0.2–1.0 mm), pale brown augite; and magnetite, 4% (0.05–0.1 mm).

SECTION 2: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Fine-grained dark gray equigranular dolerite, with some phenocrysts of altered olivine occurring at intervals 21–23 and 73–82 cm. Calcite veins cut in vertical trends. At interval 92–134 cm variolitic cavities are filled with radial fibrous zeolitic(?) material. Moderate alteration throughout the section. Some quartz visible in Piece 1(?).

SECTION 3: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Fine-grained dark gray equigranular dolerite. Almost no calcite veining is present. The whole section looks very homogeneous. At interval 35–75 cm some vesicles are filled with calcite-zeolite(?). Alteration is moderated.

TS 66 cm (Piece 5D): dolerite with subophitic texture. No phenocryst phases. Groundmass: olivine, 10%, 0.1–0.2 mm, 50% of which is replaced by bowlingite, green clay minerals; plagioclase, 40%, 0.5–1.0 mm; augite, 40%, 0.1–0.2 mm, pale brown; and magnetite, 3%, 0.1–0.2 mm. Alteration restricted to green clay minerals around olivine grains. Pyroxenes very fresh.

SECTION 4: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

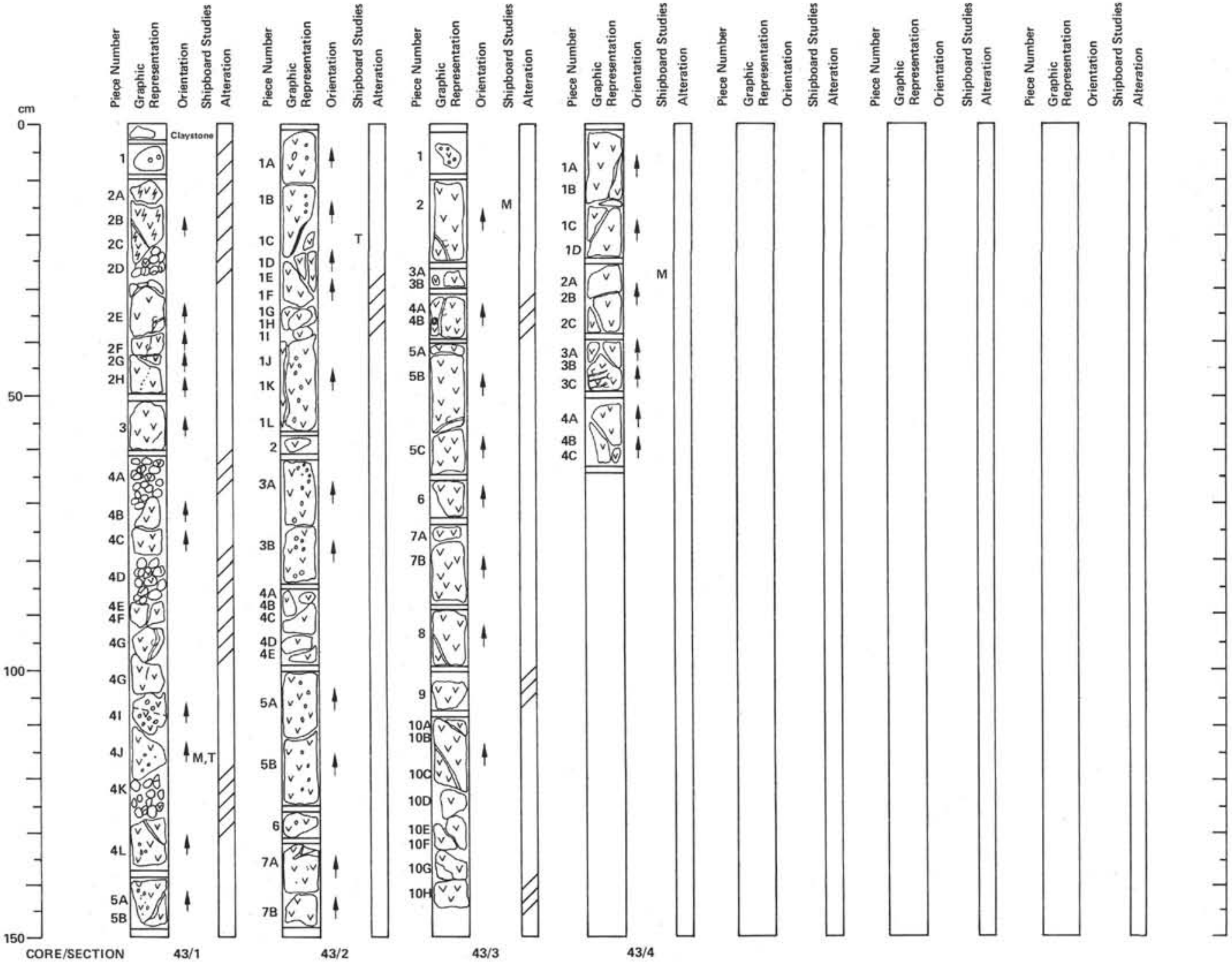
Fine-grained dark gray equigranular fresh dolerite, aphyric, very massive and homogeneous. Some minor calcite veins. No vugs are visible.

64-474A-42 Depth: 543.5 to 553.0 m

SECTION 5: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Fine-grained, equigranular, dark gray dolerite, massive, homogeneous. Some calcite veining; largest ones <1 mm thick. Similar to Section 4.



64-474A-43 **Depth 553.0 to 562.5 m**

SECTION 1: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

0–2 cm: top of section comprises 2 cm of greenish-gray CLAYSTONE. No chilled contact seen.

Entire section comprises gray-dolerite, similar to Core 42.

Essentially equigranular, although from 32–78 and 105–150 cm about 10% green phenocrysts(?) of altered olivine (< 1 mm) occur. Rare calcite-filled vesicles (< 1 mm) from 105–150 cm. Calcite veining has caused considerable break-up of the dolerite in regions 93–97 cm. Fracturing common, resulting in many small fragments in intervals 24–29, 64–70, 81–87 cm. Slickensides in fractures around 10–28 cm.

TS 118 cm (Piece 4J): dolerite/coarse basalt. Phenocrysts: olivine, 5%, 0.5 mm, microphenocrysts; plagioclase, 5%, <2 mm, elongate and tabulate. Groundmass: olivine, 20%, 0.1–0.5 mm, interstitial, subhedral, probably growing in situ; plagioclase, 40%, 0.2–1.0 mm, laths, radial cluster (varioles); clinopyroxene in mesostasis; and altered groundmass, mainly altered to yellow clay mineraloids. Texture is fine-grained almost basaltic with occasional vesicles.

SECTION 2: DOMINANT LITHOLOGY: dolerite.

Macroscopic Description

Dark gray equigranular dolerite. Green crystals noted in previous sections are more rounded and may be olivine replaced by clay pseudomorphs. Occasional 1 mm calcite- and smectite-filled vesicles.

Pieces 1B and 1C at 12–25 cm, and 1J, 1K and 1L at 40–55 cm have a 1–3 mm wide vein subparallel to the core liner, comprising dark, cryptocrystalline material, possibly altered glass, probably to clay minerals with accessory pyrites.

TS 20 cm (Piece 1B): coarse basalt or dolerite. Texture is sub-doleritic. Groundmass: plagioclase, 40%, up to 1.5 mm laths; clinopyroxene: up to 1.0 mm, elongate anhedral cyrstals of pale-brown augite; magnetite, 5%, granular; and ilmenite, 2%, elongate, skeletal, dendritic. Vesicles, 5%, up to 3 mm across, spherical, and with green clay mineral infilling. Alteration: clays, 10%, in groundmass mesostasis (olivine?) and zeolite, 20%, in vein.

SECTION 3: DOMINANT LITHOLOGY: DOLERITE.

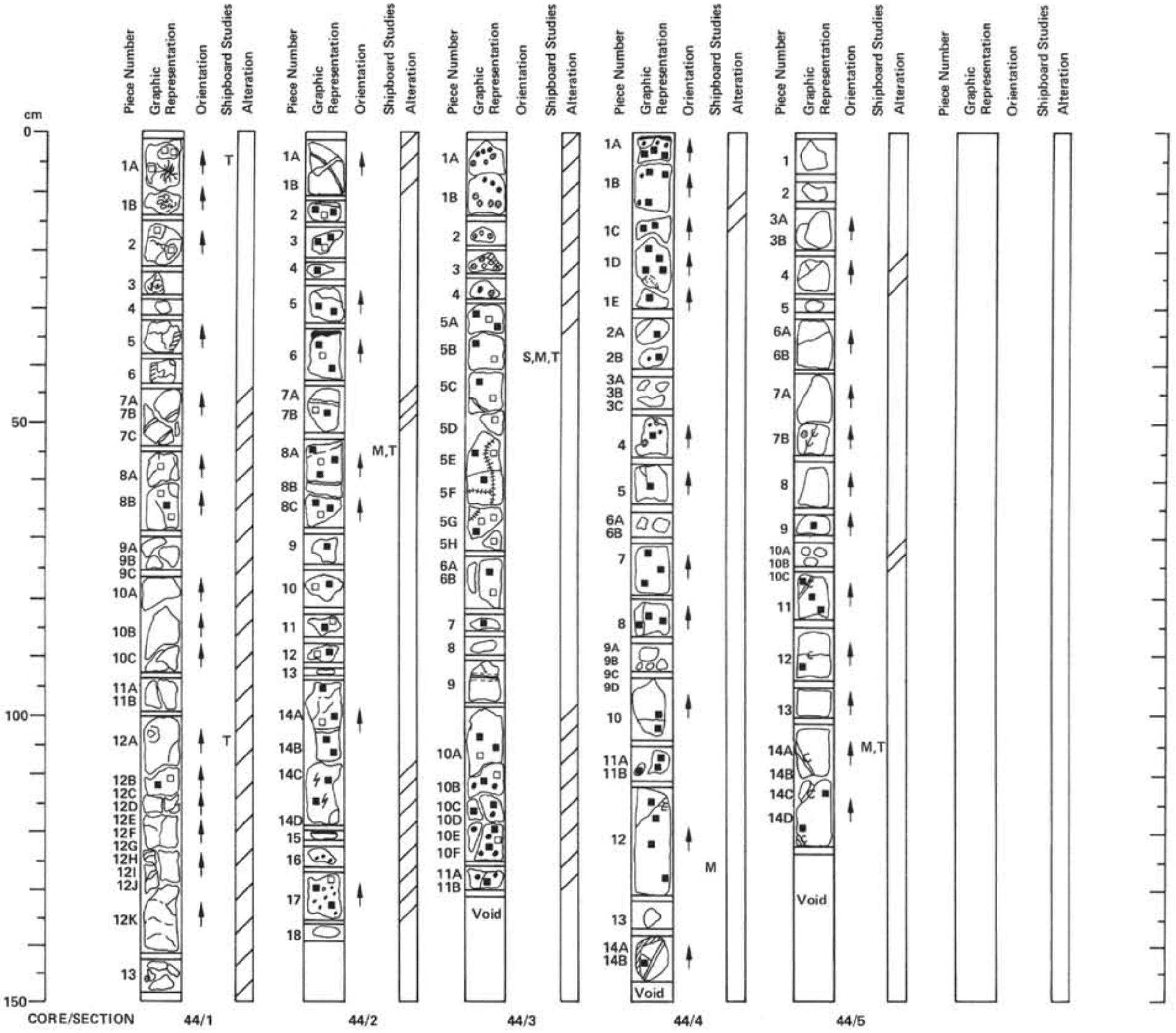
Macroscopic Description

Dark gray equigranular dolerite, medium-grained, with sporadic green ?phenocrysts of altered olivine. Calcite veins rare (Pieces 2, 4, and 8). Composite veins in Pieces 10A,B,C, and D comprise calcite and dark material (as in Core 43, Section 2, 12–25 cm and 40–55 cm) with pyrite.

SECTION 4: DOMINANT LITHOLOGY: DOLERITE.

Macroscopic Description

Medium-grained equigranular dark gray generally fresh dolerite. Occasional green clay patches(?) after olivine. Fresh tabloid olivine crystals (up to 3 mm long) clearly visible.



64-474A-44 **Depth 562.5 to 572.0 m**

SECTION 1: DOMINANT LITHOLOGY: BASALT with baked mudstone selvage.

Macroscopic Description

0–43 cm: medium gray aphanitic basalt in a brecciated mixture of coarse basalt contains 2 mm wide glomerocrysts of plagioclase and olivine. This section much fractured and calcite (1 mm wide) veined. This section grades downward into fresher, fine-grained gray basalt with occasional plagioclase phenocrysts (~2%, up to 2 mm long). 105–115 cm interval contains occasional plagioclase/olivine glomerocrysts.

TS 7 cm (Piece 1A): hyalo-crystalline basalt. Chilled margin. Phenocrysts: plagioclase, 5%, 0.5–1.0 mm. Groundmass: plagioclase: ~40%, 0.05–0.1 mm microlites; magnetite; altered groundmass, 30%. Vesicles: ~ 20%, spherical, 0.5–4.0 mm, found in chill zone. Zeolites, 5%, in vesicles.

TS 105 cm (Piece 12A): aphyric basalt. Groundmass: plagioclase,<0.5 mm, 50%, skeletal; clinopyroxene, <0.1 mm, quench,~20%; magnetite, 3%, disseminated. Variolitic texture, 15% vesicles, and ~10% minerals.

SECTION 2: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

0–11 cm: dark gray aphanitic basalt with occasional plagioclase microphenocrysts. A continuation of the basalt in Core 44 Section 1. Baked mudstone selvages at 0–10 cm and Piece 7A.

11–116 cm: light to medium gray aphanitic basalt with numerous (~5%) large plagioclase phenocrysts (up to 5 mm diameter) as well as phenocrysts as indicated. Glassy selvage at 34 cm (Core 44, Section 2, Piece 6).

116–140 cm: dark gray basalt, fine-grained, with abundant (~20%) green clay-filled amygdales (< 1 mm diameter). Xenocrysts still present. Glassy selvage at 119 cm (Core 44, Section 2, Piece 15).

Alteration: green clay-filled veins in Pieces 1, 7, and 14 (vesicles filled with clay).

TS 56 cm (Piece 8A): Intersertal to hyalopilitic pillow basalt – slightly vesicular with clay- and calcite-filled 0.1–1.0 mm vesicles; 20%, 0.5–2.0 mm plagioclase laths (An_{50-60}), many have small fractures. Abundant plagioclase microlites ~1 mm (15%) in diameter indicate rapid chilling of pillow margin up to 20 cm from the glassy pillow selvage. Plagioclase laths and microlites, along with altered augite occurs on subhedral, 2.5–1.0 mm phenocrysts, are surrounded by a mesostasis of slightly altered basaltic glass and plagioclase and clinopyroxene groundmass crystals. Ilmenite laths, 0.1–0.3 mm long, are very abundant and evenly dispersed throughout the rock.

SECTION 3: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

0–28 cm: dark gray fine-grained plagioclase basalt: phenocrysts of plagioclase frequent (~10%) as in Section 2. Over 20% clay minerals and calcite-filled vesicles. Baked clay selvage at ~22 cm.

29–98 cm: xenocrystic, gray, fine-grained basalt, with a zone of amygdale free, aphanitic basalt (but still containing glomerocrysts as in remainder of section) between 53–98 cm.

99–132 cm: dark gray fine- to medium-grained xenocrystic basalt. Xenocrysts as in remainder of section, up to 6 mm in diameter, and composed of olivine? and plagioclase. Green clay-filled vesicles again abundant as in 0–28 cm interval.

Alteration slight, restricted to areas where filled vesicles are present.

TS 38 cm (Piece 5B): basalt. Phenocrysts: plagioclase, 5%, large (1–4 mm) tabulate crystals, commonly in aggregates, the crystals having resorbed edges and frequently zoned; plagioclase, 30%, elongate microphenocrysts; spinel, 2–4%, ?chrome spinel, in groundmass and in plagioclase phenocrysts. Groundmass (quenched textures): olivine 5%, plagioclase 20%, clinopyroxene 15%, magnetites 5%; 10% altered mesostasis; 10% vesicles, containing some clay and calcite.

SECTION 4: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

0–4 cm: 2 mm vesicles filled with green clay minerals, many 1–2 mm phenocrysts of plagioclase in a roughly equigranular textured medium gray basalt at 14–15 cm, phenocrysts are ~4 mm in diameter. Small alteration zone (inches) at 15 cm. Texture is fairly uniform throughout section. Rocks are slightly fractured but only small calcite veins are present. Few vesicles <1 mm are filled with calcite.

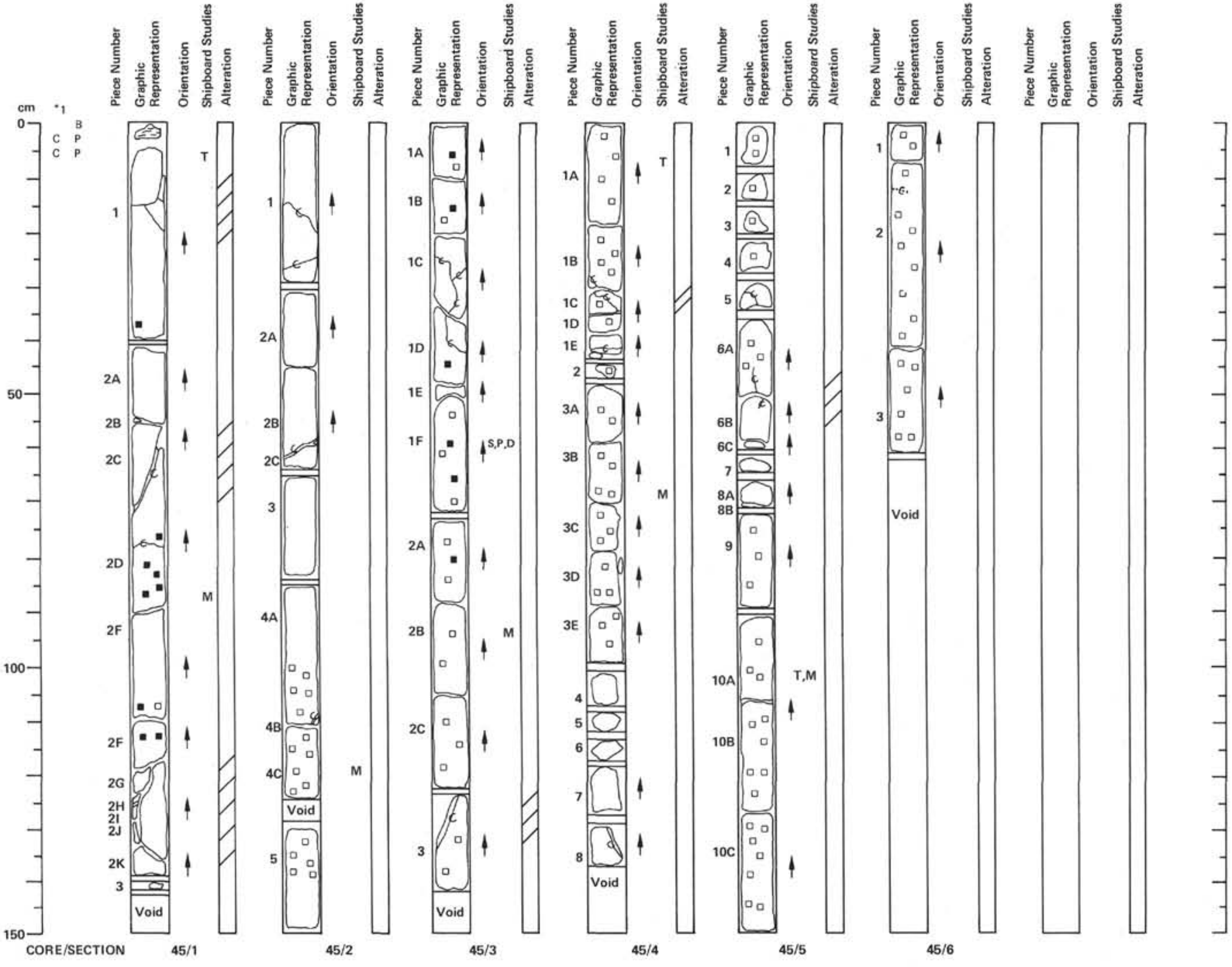
Baked sediment contact occurs in Piece 14A on top and side of piece – fractures and feel characterize baked sediment.

SECTION 5: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Aphanitic to slightly coarser-grained medium gray basalt. Texture is fine equigranular up to 70 cm then becomes coarser-grained with phenocrysts of plagioclase. Entire section is fresh with only slight alteration near small calcite veins. Larger calcite veins occur in Pieces 11 and 14.

TS 105 cm (Piece 14A): subophitic basalt, slightly altered, up to 2 mm laths of plagioclase – some showing slight alteration to clays at their edges – surrounding small olivine and clinopyroxene microphenocrysts, 0.1–0.3 mm in size in a matrix of plagioclase, clinopyroxene, olivine and ilmenite and basalt glass. Many of the olivine and clinopyroxene are moderately to completely replaced by alteration products. Non-vesicular.



*1
Claystone age
(N)
C B 2.3–3.0 m.y.
C P late Pliocene
P

64-474A-45 **Depth 572.0 to 581.0 m**

SECTION 1: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Top 3 cm is an olive gray fine-grained claystone (NN 16). Interval 3–138 cm is a fine-grained dark gray equigranular basalt with some plagioclase glomerocrysts mainly from the 75–120 cm interval. Calcite green clay(?) veining occurs in Pieces 1, 2C, 2D, and 2G to 2K. Veins are up to 5 mm thick. No chlorite-calcite vesicles are present in this section. Except for the veining restricted to some areas, the basalt looks very fresh.

SECTION 2: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Medium- to fine-grained basalt grains become coarser toward the base of the section with some glomerocrysts throughout it. Calcite green clay(?) veins occur in Piece 1 at 15–27 cm and in Pieces 2B to 2C and 4A to 4B. Veins are about 2 mm wide.

Microphenocrysts of plagioclase in an equigranular texture from 100 to 140 cm interval. Basalt is fresh. Alteration only in veins.

SECTION 3: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Medium- to fine-grained aphyric dark gray basalt, plagioclase laths up to 3 mm. Some glomerocrysts throughout the section. Alteration seems to be restricted to some cracks in Pieces 1C and 1D, otherwise basalt is very fresh. Piece 3 shows a green-clay chlorite(?) vein.

SECTION 4: DOMINANT LITHOLOGY: PLAGIOCLASE-PHYRIC DOLERITE.

Macroscopic Description

Medium- to fine-grained dark gray aphyric basalt. Plagioclase laths up to 3 mm. Glomerocrysts throughout the section. Calcite-chlorite(?) veins restricted to 30–40 cm and 120–138 cm intervals. No vesicles are present. No alteration except for veins.

TS 10 cm (Piece 1A): Subophitic to hyalopilitic dolerite – 0.5 to 20 mm laths of plagioclase, some interlocking; surrounding altered olivine phenocrysts (to bowlingite) and fresh clinopyroxene (augite) phenocrysts (0.25–1 mm in size) in a matrix of plagioclase, clinopyroxene and glass with abundant opaques. Some glass and all olivines are altered. Clinopyroxene is anhedral and is present in lath shapes that have parted along cleavage planes.

SECTION 5: DOMINANT LITHOLOGY: BASALT.

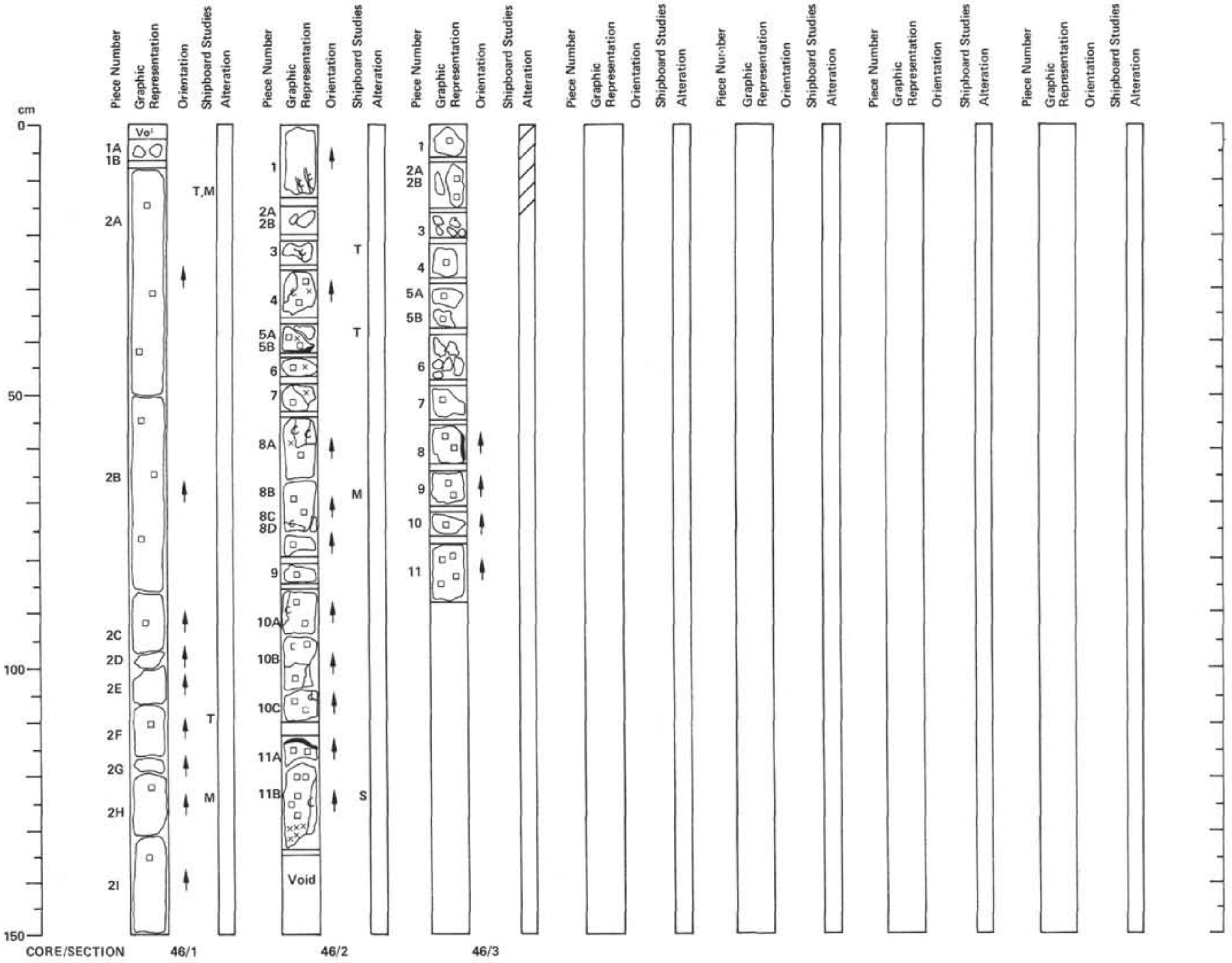
Macroscopic Description

Same as Section 4. Medium- to fine-grained aphyric, dark gray, basalt. Plagioclase laths up to 4 mm visible. Some calcite veins in Pieces 6A–6B. No alteration observed and no vugs.

SECTION 6: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Similar to Section 5, medium- to fine-grained dark gray aphyric basalt, with plagioclase phenocrysts up to 3 mm. Small chlorite (green clay?)-calcite vein at 12 cm. Rock very fresh, and homogeneous. Glomerocrysts become less abundant than in previous sections.



64-474A-46 Depth 581.0 to 590.0 m

SECTION 1: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Dark gray aphanitic basalt with some plagioclase laths up to 3 mm. Very massive and homogeneous, it is essentially the continuation of Core 45, Section 6, becoming finer to the bottom. No veins, vesicles, or any alteration is visible in this section.

TS 10 cm (Piece 2A): Dolerite. Subophitic texture. Phenocrysts: plagioclase, 5%, 2 mm diameter. Tabulate form, often forming multicrystal aggregates. The margins are resorbed and the crystals are zoned. Groundmass: olivine, 5%, 0.3–0.5 mm; plagioclase, 40%, 0.3–0.1 mm, An_{45-55}, generally lath-shaped and ophitically enclosed in clinopyroxene; augite, 40%, up to 2 mm across; opaques. Alteration restricted to replacement of olivines by clay minerals.

TS 110 cm (Piece 2F): Same as above, dolerite.

SECTION 2: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

From 0–19 cm, fine-grained dark gray aphanitic basalt with scarce plagioclase phenocrysts (2 mm). This Piece 1 is the continuation of the previous Section 1. Two calcite-filled veins at the base of Piece 1. This and the two Pieces 2 seem to be the bottom of a cooling unit, as contrasted with the rest of the section below. The contact was not recovered.

Interval 20–110 cm shows a different texture, with a much larger amount of plagioclase megacrysts up to 1 cm long and also a larger amount of clinopyroxenes. Some calcite veins appear in this sill.

Interval 113–134 cm is possibly another unit whose upper part (Piece 11A) shows glass near the top. Some megacrysts of plagioclase and clinopyroxene are observed. Minor alteration.

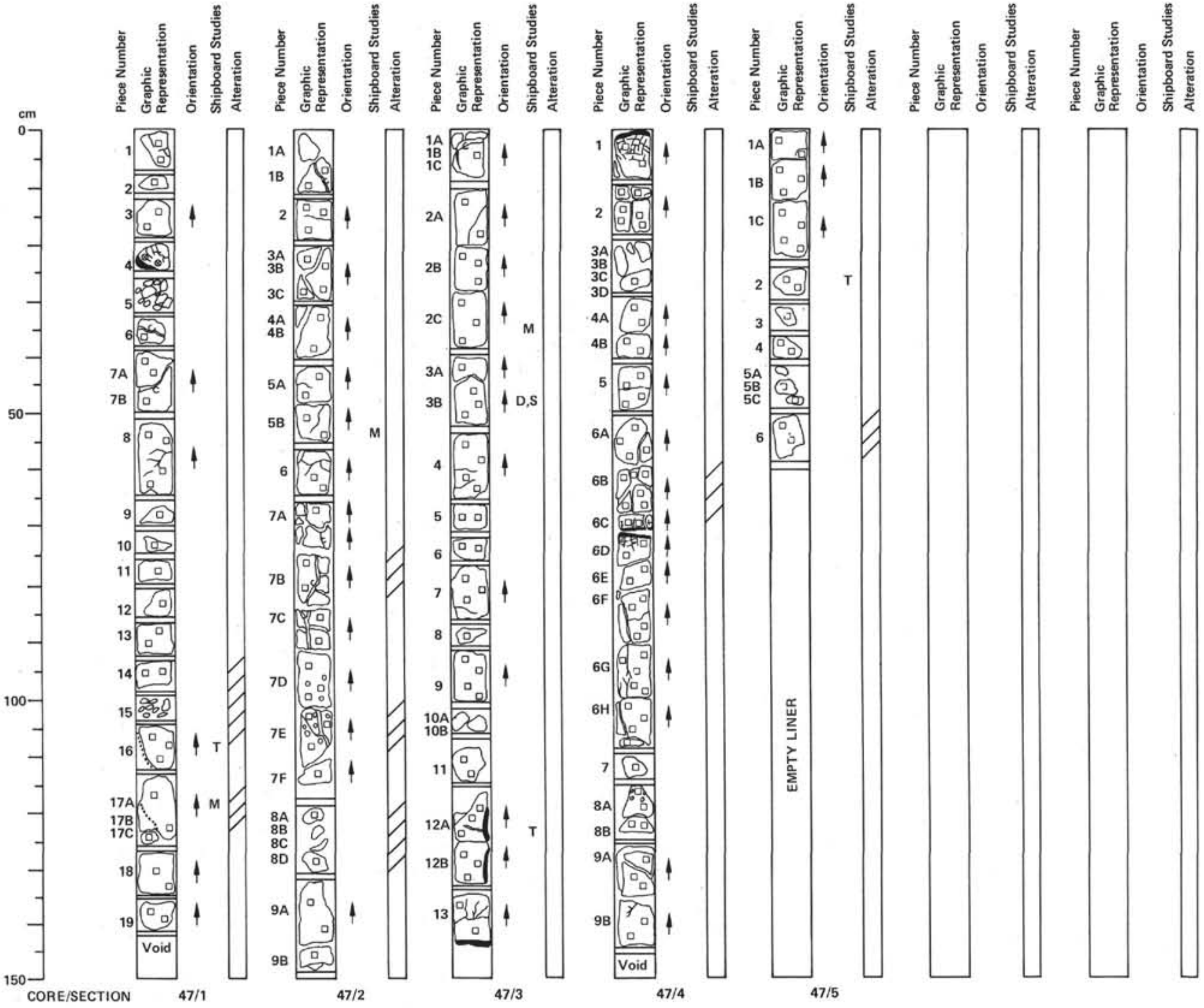
TS 21 cm (Piece 3): porphyritic basalt. Texture: porphyritic; pilotaxitic quenched groundmass. Phenocrysts: plagioclase A ($\sim An_{70}$) (1–6 mm, 5% of rock). Subhedral, tabulate, many inclusions, resorbed margins, zoned. These have been termed megacrysts. Plagioclase B ($\sim An_{60-70}$) subhedral, lath-like or tabulate phenocrysts (10% of rock). Groundmass: 20% plagioclase microlites, 20% clinopyroxene and 10% disseminated magnetite, 30% amorphous groundmass mesostasis. Alteration: small degree of alteration of mesostasis to clay. Pseudomorphs of bowlinite, 0.5–1.0 mm across, are probably after olivine phenocrysts.

TS 35 cm (Piece 5): very similar to 21 cm description. Megacrysts of plagioclase up to 5 mm, and 5% of rock consists of 1 mm-diameter, clay-lined vesicles. Pilotaxitic textures again.

SECTION 3: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Dark gray aphyric basalt, large plagioclase megacrysts up to 1 cm long, altered olivine, clinopyroxene crystals 1 mm long. Some veining with calcite-green-clay?.



64-474A-47 **Depth 590.0 to 599.0 m**

SECTION 1: DOMINANT LITHOLOGY: megacryst-rich BASALT.

Macroscopic Description

Dark gray basalt with fine-grained to aphanitic groundmass, containing approximately 10–15% anhedral to subhedral plagioclase megacrysts (up to 1.5 cm across, usually ~0.5 cm). Alteration very slight, restricted to minor calcite and green clay veining (Pieces 6, 7, 8, 15, 16, and 17) and of green clay in small amygdales (< 0.5 mm) in groundmass. Glass selvage in Piece 4.

TS 110 cm (Piece 16): porphyritic basalt, porphyritic/variolitic. Phenocrysts: olivine, ~4%, ~0.3 mm, subhedral microphenocrysts; plagioclase, ~10%, 1–5 mm, megacrysts and phenocrysts; and spinel, <2%, 0.1–0.2 mm, chrome-spinel (red). Groundmass: 5% olivine – may be microphenocrysts; 40% plagioclase, 0.2–1.0 mm, microlites and laths; 20% brown augite up to 1.0 mm laths; 5% magnetite – disseminated and granular; 2% ilmenite; and 20% mesostasis. Vesicles: 4%, 0.8–1.2 mm random, spherical vesicles filled with clay minerals. Alteration: 5% clay minerals throughout groundmass.

SECTION 2: DOMINANT LITHOLOGY: megacryst-rich BASALT.

Macroscopic Description

Dark gray basalt with fine-grained to aphanitic groundmass containing approximately 10 to 15% anhedral to subhedral plagioclase megacrysts (0.5–1.0 cm width). Alteration slight, restricted to calcite and chlorite veining (1–2 mm wide vein runs through Pieces 7A–F). Small, calcite-filled vesicles occur sporadically in Pieces 7E and F.

SECTION 3: DOMINANT LITHOLOGY: megacryst-rich BASALT.

Macroscopic Description

Dark gray basalt with a fine-grained aphanitic groundmass, containing approximately 10–15% anhedral to subhedral plagioclase megacrysts (0.5–1.5 cm). Alteration very slight. Calcite veins in Pieces 1, 2A, 11 and 12. Glassy selvages at base of Piece 13, and along edge of Piece 12.

TS 122 cm (Piece 12): plagioclase-phyric basalt, sampled adjacent to glassy margin. Texture is quenched; pilotaxitic. Phenocrysts: olivine, 5–8%, 0.3-2 mm euhedral, mostly replaced by bowlingite; plagioclase, 15%, 5%, 0.5–8.0 mm, megacrysts and 10%, 0.5–2 mm, phenocrysts; spinel: 1% < 0.2 mm, red chrome-spinel. Groundmass: very fine-grained quenched texture. Alteration: < 5% clays in groundmass, and replacement of olivine by bowlingite.

SECTION 4: DOMINANT LITHOLOGY: megacryst-rich BASALT.

Macroscopic Description

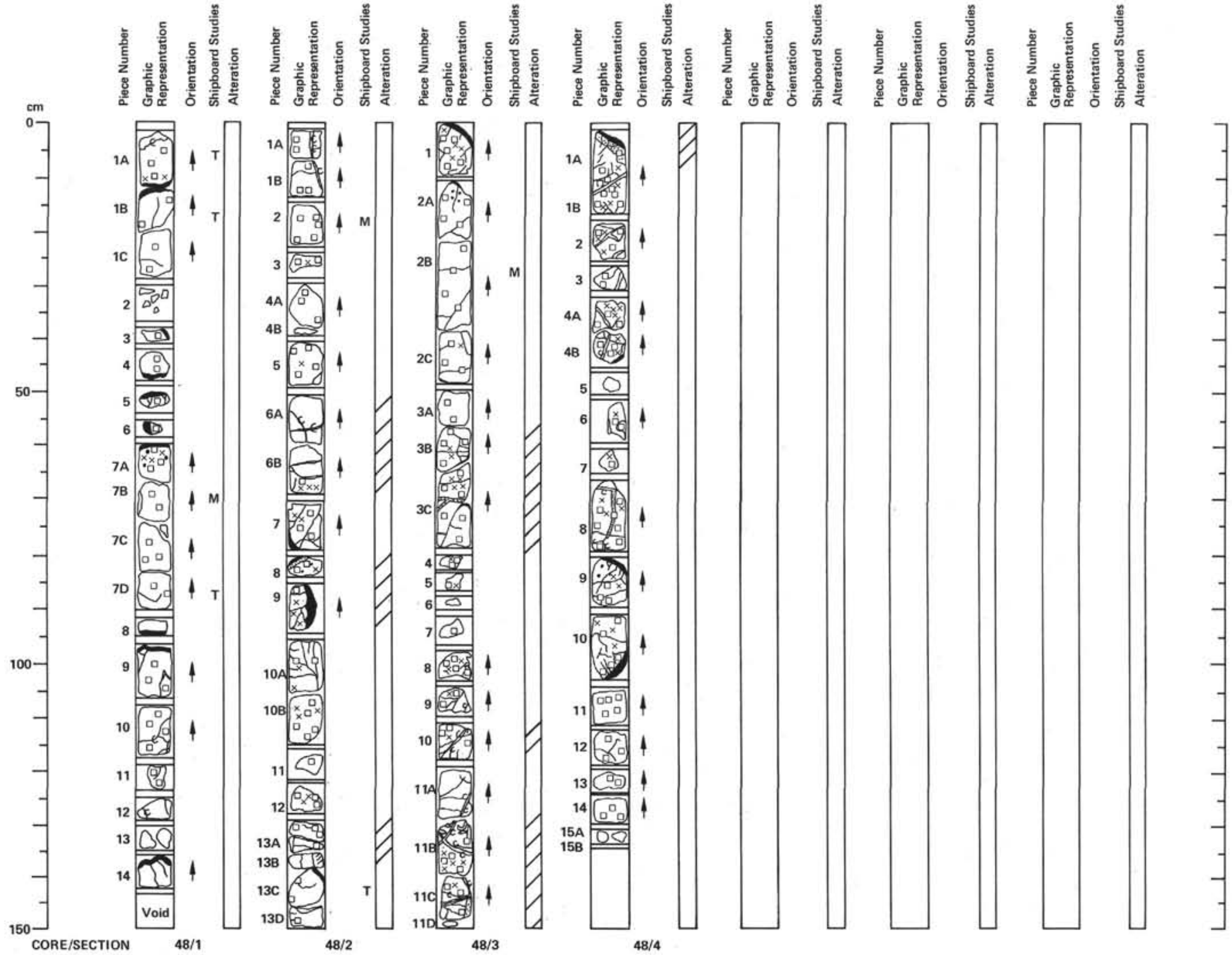
Gray basalt with a fine-grained aphanitic matrix, containing approximately 10–15% anhedral to subhedral plagioclase megacrysts (0.5–1.5 cm). Alteration slight, restricted to calcite and green-clay chlorite-filled veins (1 mm width). Glassy selvages in Pieces 1, 5C and D.

SECTION 5: DOMINANT LITHOLOGY: megacryst-rich BASALT.

Macroscopic Description

Gray basalt with a fine-grained to aphanitic matrix, containing approximately 10–15% anhedral to subhedral plagioclase megacrysts (0.5–1.5 cm). Alteration slight; restricted to calcite/chlorite veins on Piece 6.

TS 35 cm (Piece 3): PLAGIOCLASE-PHYRIC BASALT. Texture is porphyritic or pilotaxitic. Phenocrysts: pseudomorphs of bowlingite, 0.5–1.0 mm across, replacing olivine (5%); plagioclase, 5% large, tabulate aggregate megacrysts, 1–5 mm, > An_{70}; plagioclase ~10%, 0.5–1 mm lath shaped phenocrysts, ?An_{60}–An_{75}; red spinel, ~3%, 0.1–0.2 mm cubes and octahedra, probably chrome-spinel. Groundmass: plagioclase, 15%, 0.2–0.4 mm, microlites and quench overgrowths on plagioclase phenocrysts; clinopyroxene, 40%?, < 0.1 mm dendrites, wheat sheaves; and magnetite, 5%, disseminated. Vesicles: 5%, 1 mm diameter spherical filled with green clay. Alteration: clays in veins and replacing olivine (no more than 10%).



64-474A-48 **Depth: 599.0 to 608.0 m**

SECTION 1: DOMINANT LITHOLOGY: plagioclase megacryst-rich pillow BASALT.

Macroscopic Description

Dark gray porphyritic basalt with plagioclase megacrysts up to 1.5 cm (~15%). Plagioclase is subhedral. Matrix is aphanitic. Calcite veins restricted to Pieces 1A, 1B, 10, and 11. Glass selvage on Pieces 1A, 1B, 4, 5, 6, 7A, 8, 9, and 14. Slight alteration restricted to veins. Many small veinlets are zeolite and clays. Glass selvages are mostly very fresh and only at times slightly palagonitized. Small hair-like fractures (vertical to subvertical) occur in the pillow selvages and extend about 2–4 cm into a pillow (down-core). Larger megacrysts of plagioclase do not occur near top of pillows, but are usually found 5–7 cm down-core from the selvage.

TS 5 cm (Piece 1A): porphyritic basalt with pilotaxitic texture. Similar to TS 88 cm (Piece 7D), but with 5% vesicles filled with iron-rich mesostasis, and with 10% bowlingite replacing olivine phenocrysts

TS 19 cm (Piece 1C): porphyritic basalt with quenched spherulitic texture, 15% plagioclase phenocrysts up to 3 mm. Very fine-grained quenched groundmass. Sampled adjacent to glassy margin. Spherulites present. Clays in groundmass (5%).

TS 88 cm (Piece 7D): plagioclase-phyric basalt. Phenocrysts: olivine, 5%, 0.1–1.0 mm across, very fresh; plagioclase A, 5%, 2–10 mm, $>An_{70}$, subhedral, tabulate, aggregate megacrysts; plagioclase B, 10%, 0.5–1.0 mm, ~ An_{70}, lath-shaped; and spinel, 3%, 0.1–0.2 mm, chrome-spinel. Groundmass: plagioclase, 15%, 0.1–0.5 mm, microlites; clinopyroxene not distinuishable from mesostasis; opaques, 5%, disseminated; mesostasis, 60%, very slightly altered. No vesicles. Texture: porphyritic; pilotaxitic to variolitic. Alteration: very slight, restricted to ~5% clays in mesostasis.

SECTION 2: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

Macroscopic Description

Several pillow basalt flows – medium gray unaltered basalt with abundant plagioclase megacrysts, most are subhedral to anhedral although some euhedral. Plagioclase megacrysts are from 2 mm to 1 cm large. Fresh basaltic glass, occurs in Pieces 7 and 8 – slightly altered glass is found in Piece 9 – glassy pillow selvages are from 2 mm to <1 cm thick, however it appears that parts of the glassy selvages were destroyed by the drilling. Numerous fractures are present <1 mm thick. Those from the pillow selvages are vertical and roughly radial from an imaginary center point of the pillow. Small calcite veinlets at times fill the fractures. Clay minerals are also present in some of the fractures.

TS 141 cm (Piece 13C): plagioclase phyric basalt. Texture is porphyritic, sub-spherulitic. Phenocrysts: 10%, lath-like, with quench overgrowths developing (0.2–1.5 mm); groundmass: too fine to be distinguished; vesicles: <1%, spherical, filled with zeolite; alteration: zeolites, 10% in veins and vesicles.

SECTION 3: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

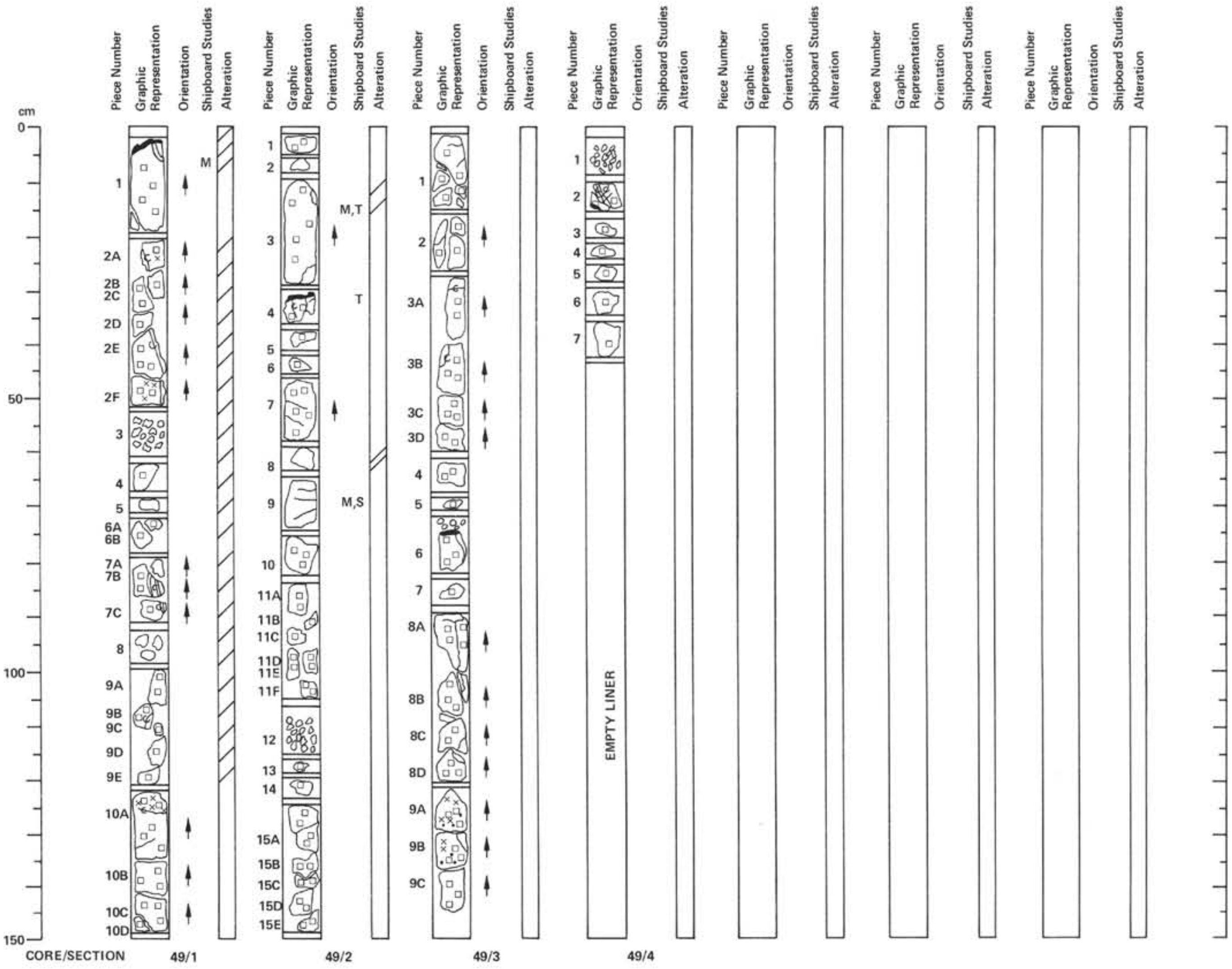
Macroscopic Description

Medium gray plagioclase phyric pillow basalt with abundant 0.5–1 cm plagioclase megacrysts and some clinopyroxene and olivine phenocrysts. A ~0.5 cm glass selvage occurs in Section 1. Thin fractures common. Some calcite and clay veins occur within fractures. Larger 1–2 mm thick, calcite-zeolite veins occur in Pieces 10 and 11. Alteration is slight to moderate in areas with veins. Otherwise section is similar to top 2 sections in this core.

SECTION 4: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

Macroscopic Description

Fairly fresh medium gray basalt, with some calcite and clay veins filling fractures. Fractures common. Abundant plagioclase megacrysts evenly distributed. Some clinopyroxene and olivine phenocrysts. Fresh glassy selvages occur in Pieces 9 and 10. Palagonitized selvage occurs in Piece 1, interestingly one plagioclase megacryst is included in the glassy selvage indicating that megacrysts are pre-eruptive. Section is similar in texture and appearance to the other sections of this core.



64-474A-49 **Depth: 608.0 to 617.0 m**

SECTION 1: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

Macroscopic Description

Dark gray plagioclase megacryst-rich pillow basalt. Plagioclase megacrysts evenly distributed throughout the section in an aphanitic matrix. They range in size from 1 mm up to 1.5 cm, making up about 15% of the rock. Some clinopyroxenes visible in Pieces 2A, 2F, and 10A. Fractures up to 1 cm wide (Piece 2E) filled with calcite and clay minerals in a subvertical trend. Thinner fractures run horizontally. Glassy selvage at top of Piece 1 (palagonite) including some plagioclase phenocrysts. Section very fractured and moderately altered at interval 20–120 cm, where veins occur.

SECTION 2: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASAT.

Macroscopic Description

Dark gray plagioclase megacryst-rich pillow basalt. Plagioclase megacrysts (~10%) distributed in an aphanitic matrix throughout the section, size from 2 mm to 1.5 cm. A few calcite-clay(?)-filled veins show a subvertical trend. Horizontal cracks in several pieces. Glassy selvage in Piece 4. Section highly fractured but moderate alteration restricted to some veins (Pieces 3 and 4). Mostly fresh.

TS 14 cm (Piece 3): hyalopilitic, plagioclase-megacryst-rich pillow basalt. Large plagioclase megacrysts (2–4 mm) some rectangular inclusions of glass(?) along cleavage. Some phenocrysts of clinopyroxene and olivine, which is commonly altered. Surrounded by a mesostasis of basaltic glass, tiny plagioclase laths and opaques. Plagioclase megacrysts are commonly composed of several large interlocking plagioclase laths. Normal feldspar zoning is common. Glass in mesostasis is fairly fresh. Some small 0.5–0.75 mm round vesicles are present and are filled with clays and zeolites and/or calcite.

TS 30 cm (Piece 4): Glassy margin of pillow basalt (selvage) somewhat altered basaltic glass in some megacrysts of plagioclase up to 4 mm long. Pilotaxitic texture with plagioclase surrounded by glass pilotaxitic and plagioclase microlites and tiny laths. Minor opaques.

SECTION 3: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

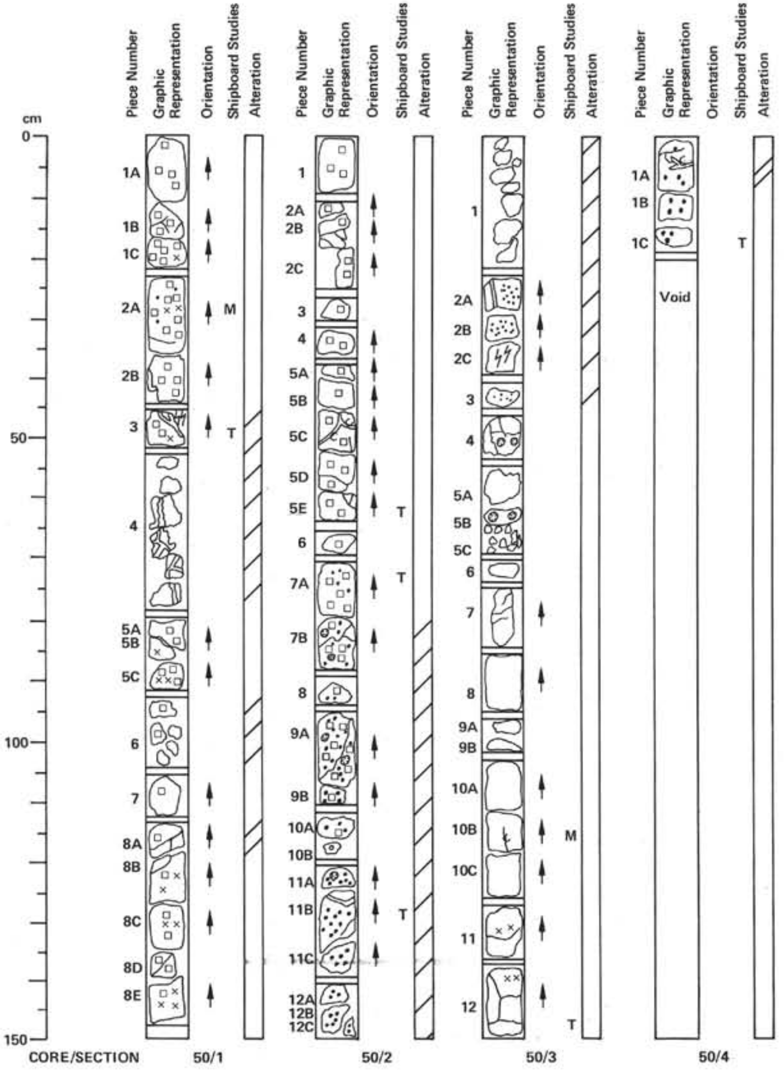
Macroscopic Description

Dark gray plagioclase megacryst-rich basalt. Plagioclase megacrysts up to 1.5 cm distributed evenly along the section in an aphanitic matrix. Section highly fractured with some calcite-clay mineral veins in Pieces 6 and 8D. Clinopyroxenes visible in Piece 9, with some green clay-filled vesicles. Minor alteration of the section except for the veins. Glassy selvage on Piece 6.

SECTION 4: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC PILLOW BASALT.

Macroscopic Description

Dark gray plagioclase megacryst-rich basalt. Plagioclase megacrysts up to 1 cm and less abundant than in the upper sections of this core. Calcite-filled veins and fractures with clay minerals in Piece 2. Matrix is aphanitic. Glassy selvage in Piece 2.



64-474A-50 **Depth 617.0 to 626.0 m**

SECTION 1: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC BASALT.

Macroscopic Description

Dark gray porphyritic basalt, 1 cm make up ~10% of the section. Matrix is aphanitic. Altered olivines visible in some pieces (2A, 5B, 5C, 8B, 8C, and 8E) ~1–2 mm size. Green clay-filled vesicles also present in 2A. Small pyrite crystals occur at 78 cm and at 144 cm. Slickenside structure developed in Piece 3 at 49 cm, along a green clay(?)-filled vein about 0.5 cm wide. This vein is continuous above on Piece 2B and below on Piece 4. In a subvertical fashion, thinner horizontal cracks are visible throughout the section. Alteration is restricted to pieces with chlorite(?) veins and to some vesicles filled with green clay chlorite, on Piece 2.

TS 47 cm (Piece 3): porphyritic basalt, sampled adjacent to veined and sheared area. Phenocrysts: plagioclase up to 10%, up to 5 mm in size, large, tabulate rounded megacrysts and smaller lath-shaped crystals. Groundmass: very fine-grained, quenched, comprising microlites, wheat sheave pyroxene and disseminated ore. No vesicles. Little alteration, restricted to staining of groundmass.

SECTION 2: DOMINANT LITHOLOGY: PLAGIOCLASE PHYRIC BASALT.

Macroscopic Description

Dark gray porphyritic basalt. Plagioclase megacrysts up to 1 cm wide distributed in the upper part of the section from 0 to 110 cm. Matrix is aphanitic. The size of the megacrysts diminishes downhole. At interval 60 to 150 cm there are abundant green clay(?)-filled vesicles and some calcite-filled ones. Calcite veins appear in Piece 5C (2 mm), while some green clay-filled veins appear in Pieces 5E, 9A, and 11B up to 3 mm wide. Pyrite crystals appear in Piece 5E, about 4 mm long. Alteration is restricted to veins and to the lower part of the section (70–150 cm).

TS 62 cm (Piece 5E): PORPHYRITIC BASALT. Sampled adjacent to vein. Variolitic. Phenocrysts: plagioclase A, 1–2 mm tabulate, rounded, partially resorbed phenocrysts, 10% and plagioclase B, 0.5–2 mm long lath-shaped phenocrysts; olivine, <0.5 mm (5 %), anhedral microphenocrysts which may be groundmass phases in part. Groundmass: possibly some olivine; plagioclase about 30% microlites, 0.1–0.5 mm long. Rest of groundmass is very fine-grained, quench textured clinopryoxene, opaques and mesostasis. Vesicles: 5%, ~1 mm diameter spherical with clay and calcite filling. Vein: containing zeolite, about 2 mm wide. Alteration: about 5% clay minerals in groundmass. Olivines fresh.

TS 72 cm (Piece 7A): sparsely phyric VARIOLITIC BASALT. Phenocrysts: plagioclase about 8%, 0.5–1.3 mm, heavily resorbed equant crystals. Groundmass: olivine, 5%, <0.5%, anhedral, skeletal, may be microphenocrysts. Plagioclase, 50%, < 1.0 mm lath-shaped. Rest of groundmass very fine-grained. Vesicles: 10%, spherical, 0.3–1 mm, filled with clay. Alteration: clay in mesostasis.

TS 126 cm (Piece 11B): Aphyric basalt. Similar to TS 72 cm (Piece 7A) but with ~1% plagioclase and 15% vesicles.

SECTION 3: DOMINANT LITHOLOGY: dark gray BASALT.

Macroscopic Description

Interval 0 to 45 cm is an equigranular aphanitic to very fine-grained basalt badly fractured and cut by green clay-filled veins. Piece 2C shows some slickensides along the vein plane.

The next interval from 45 to 150 cm is a dark gray aphanitic equigranular basalt, which shows no megacrysts as in the cores above. Probably this is a different unit whose contact has not been recovered. Only a very few olivine crystals can be seen (~1 mm) in the lower portions. Contrasting with interval above this basalt looks very fresh, massive, and homogeneous and shows no signs of alteration except for a few minute calcite-filled vesicles in Pieces 4 and 5A.

TS 146 cm (Piece 12): COARSE BASALT or dolerite, practically indistinguishable from Core 50, Section 4, 16 cm. Intergranular to subophitic texture. Phenocrysts: a few (5%) tabulate plagioclase (0.5–2 mm). Groundmass comprises plagioclase (40%), 0.1–1 mm and anhedral clinopyroxene (30%), 0.2–1.5 mm. Alteration: 20% pseudomorphs of clay (bowlingite replacing olivine).

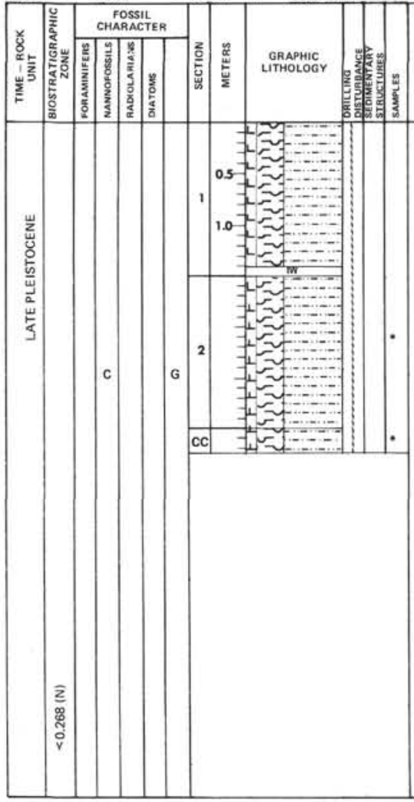
SECTION 4: DOMINANT LITHOLOGY: BASALT.

Macroscopic Description

Mostly aphyric medium gray (N5) basalt with some calcite veins (1 mm wide) and some small fractures. Some vesicles 1–2 mm in size and filled with green clay minerals. Some small phenocrysts of plagioclase is evenly distributed in an otherwise fine matrix.

TS 16 cm (Piece 1C): DOLERITE OR COARSE BASALT. Phenocrysts: plagioclase, 5%, 0.5–2 mm tabulate and lath-shaped, completely altered olivine: 10% bowlingite pseudomorphs after olivine. Groundmass: 10% bowlingite probably after olivine; 40% plagioclase, 0.2–1.0 mm lath-shaped partially enclosed in clinopyroxene; 30% augite partially interstitial to plagioclase (0.2–1.5 mm); 5% magnetite, 0.1–0.5 mm cubic-anhedral grains; and 2% ilmenite. Texture: subophitic to intergranular. Alteration: replaced olivines as noted above.

SITE 475 HOLE CORE 1 CORED INTERVAL 0.0–6.0 m



LITHOLOGIC DESCRIPTION

Highly disturbed, homogeneous greenish grayish olive (10Y 4/2) nannofossil-bearing **DIATOMACEOUS SILTY CLAY.** Variable diatom abundances. Scattered calcium carbonate silt particles.

SMEAR SLIDE SUMMARY

	2-62 (D)	CC (D)
TEXTURE:		
Sand	–	–
Silt	30	40
Clay	62	60
COMPOSITION:		
Quartz	15	7
Feldspar	5	2
Mica	2 (brn)	1 (Hbl, Ap)
Heavy minerals	1	1 (Hbl, Ap)
Clay	40	45
Glauconite	TR	?
Pyrite	1	2
Other opaque	1	3
Carbonate unspec.	3	3
Foraminifers	5	3
Calc. nannofossils	10	10
Diatoms	15	35
Radiolarians	3	4
Sponge spicules	2	2
Silicoflagellates	1	–
Plant debris	1	TR

	2, 62–64
Lithology	Silty clay
Sand	3.12
Silt	33.58
Clay	63.30

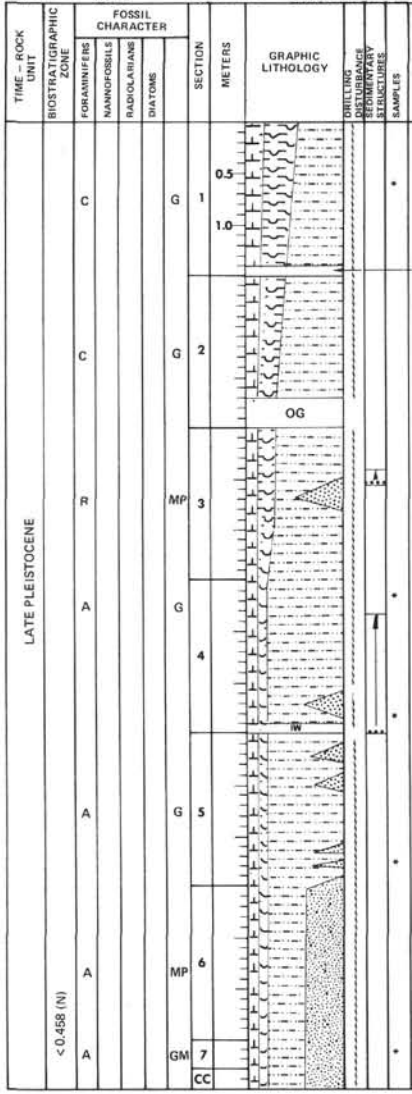
COARSE FRACTION:

	<140 µm	>140 µm
Foraminifers	20	40
Radiolarians	30	40
Plant debris	1	1
Sponge spicules	–	3
Fecal pellets	–	7
Diatoms	20	–
Glauconite filling	TR	–
Mica	3	–

(light green glauconite as foraminifer filling and fecal pellets)

CARBONATE BOMB: 2-62 = 9%

SITE 475 HOLE CORE 2 CORED INTERVAL 6.0–15.5 m



LITHOLOGIC DESCRIPTION

10Y 4/2

Bacteria

5GY 5/2

Lighter mottles

Sand

Dusky yellow green

5GY 5/2

Quartz-Biotite Sand

5GY 3/2

10Y 4/2

5GY 5/2

DIATOMACEOUS SILTY CLAY, with evidence for cm-thick bedding, varying nannofossil abundance with only a trace of carbonate in most sections. Some lighter mottles, trace of glauconite (Section 3, 132 cm). Locally, dusky yellow-green; lighter mottles (5GY 5/2) are less siliceous, more nannofossil-bearing and carbonate rich. Quartz-rich **SAND LAYERS** at Section 3, 45 to 65 cm; mud turbidites with thin basal sand, micaceous quartz-rich at Section 4, 42 to 150 cm with coarse sand at base, light olive gray (5Y 5/2) – poorly graded unit; darker brown towards the base. At Section 5, 4 pockets of well-washed-sorted gray (N4) sand, sharp contact, quartz- and biotite-rich.

SMEAR SLIDE SUMMARY

	1-60 (D)	4-17 (M)	4-132 (M)	5-124 (M)	CC (D)
TEXTURE:					
Sand	2	–	85	100	–
Silt	48	30	15	2	–
Clay	50	70	–	–	–
COMPOSITION:					
Quartz	10	10	70	65	5
Feldspar		5	20	20	2
Mica	2	6	5	2	2
Heavy minerals	TR	1	3(a)	5(b)	TR
Clay	35	55	–	–	40
Pyrite	2	–	–	–	10
Opaque	–	TR	–	–	–
Carbonate unspec.	5	–	–	10(c)	3
Foraminifers	1	5	5	–	3
Calc. nannofossils	15	10	–	–	15
Diatoms	30	5	–	–	8
Radiolarians	3			–	
Sponge spicules	–	3 (d)	2	–	5 (d)
Silicoflagellates	3			–	
Plant debris	–	1	–	–	–

(a) Hbl, Ap, Ep

(b) Zr, Hbl, Ap

(c) Foraminifer debris

(d) Fragments

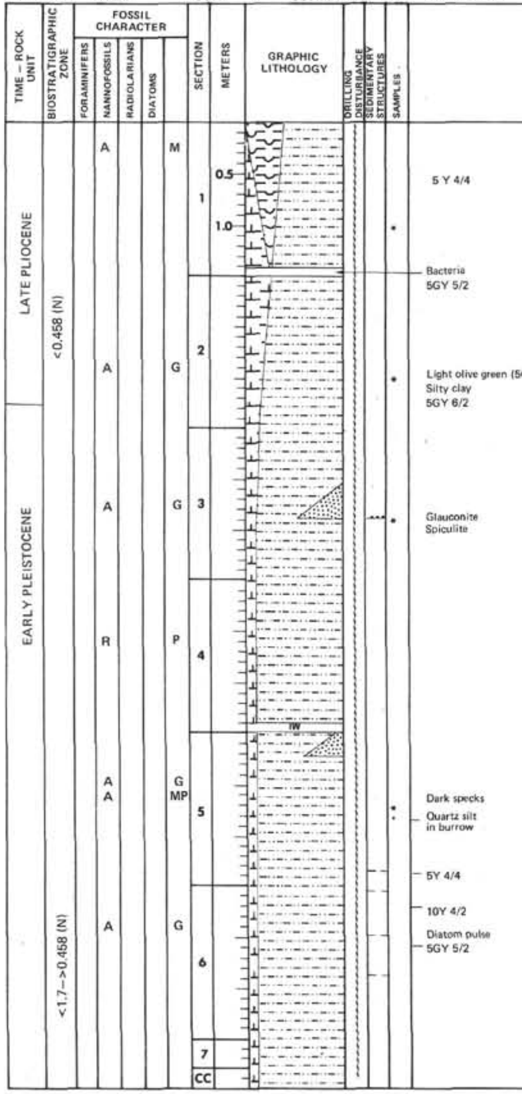
COARSE FRACTION:

	5-124
Quartz	65
Feldspar	15
Carbonate unspec.	1
Planktonic foraminifers	2
Sponge spicules	1
Biotite	10
Heavy minerals	5

CARBONATE BOMB: 2-127 = 2.5%
4-16 = 9%

	5, 121–123
Lithology	Clayed sand
Sand	54.40
Silt	18.87
Clay	26.73

SITE 475 HOLE CORE 3 CORED INTERVAL 15.5–25.0 m



LITHOLOGIC DESCRIPTION

Core very disturbed but stratigraphically in order. Section 1: moderate olive brown (5Y 4/4) to grayish olive (10Y 4/4) **DIATOMACEOUS CLAYEY-SILT**, with radiolarian-rich pulses. Sections 2 and 3: changes gradationally to dusky yellow-green (5GY 5/2) **NANNOFOSSIL-RICH SILTY CLAY.** Section 4 and below, alternating nannofossil-rich; diatom-rich dusky yellow-green (5GY 5/2) and moderate olive-brown (5Y 4/4) respectively **SILTY CLAYS.** May indicate **HEMIPELAGIC** gradational pulses, or mud turbidites but no sands present. Locally, sponge spiculite specks. Glauconite and black (organic-FeS) streaks.

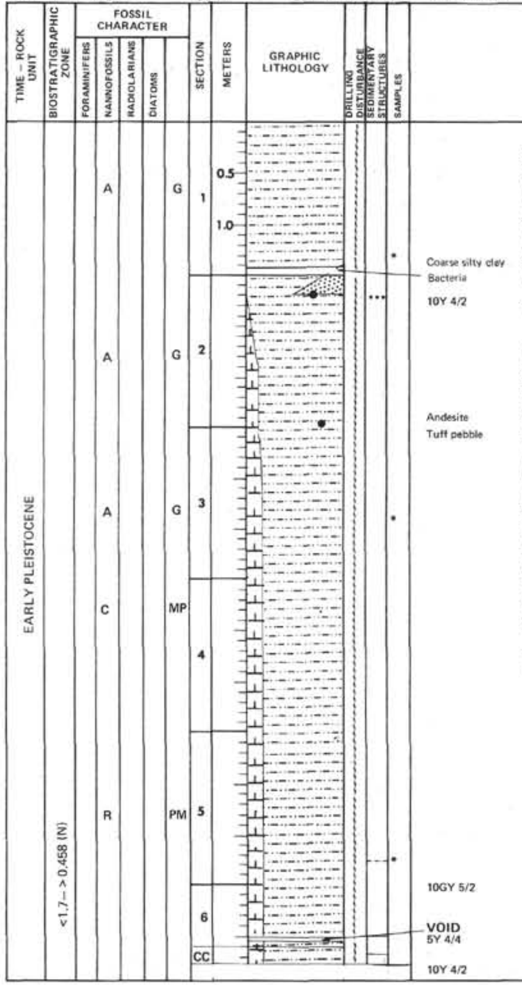
SMEAR SLIDE SUMMARY

	1-100 (D)	2-100 (D)	3-93 (M)	5-73 (M)
TEXTURE:				
Sand	–	–	–	–
Silt	40	40	–	70
Clay	60	60	–	30
COMPOSITION:				
Quartz	5	7	2	50
Feldspar		2	1	
Mica	2 (grn)	2	–	–
Heavy minerals	TR	1 (a)	–	–
Clay	30	50	–	30
Volcanic glass	2	3	3	–
Glauconite	–	–	30	–
Pyrite	1	TR	10	7
Carbonate unspec.	3	–	–	2
Foraminifers	2	TR	2	TR
Calc. nannofossils	5	30	–	1
Diatoms	30	10	–	
Radiolarians	3	2	–	3
Sponge spicules	2	1	50	
Silicoflagellates	3	–	–	–
Plant debris	4	1	TR	–

(a) Zr, Hbl

CARBONATE BOMB: 2-70 = 19%

SITE 474 HOLE CORE 4 CORED INTERVAL 25.0–34.5 m



LITHOLOGIC DESCRIPTION

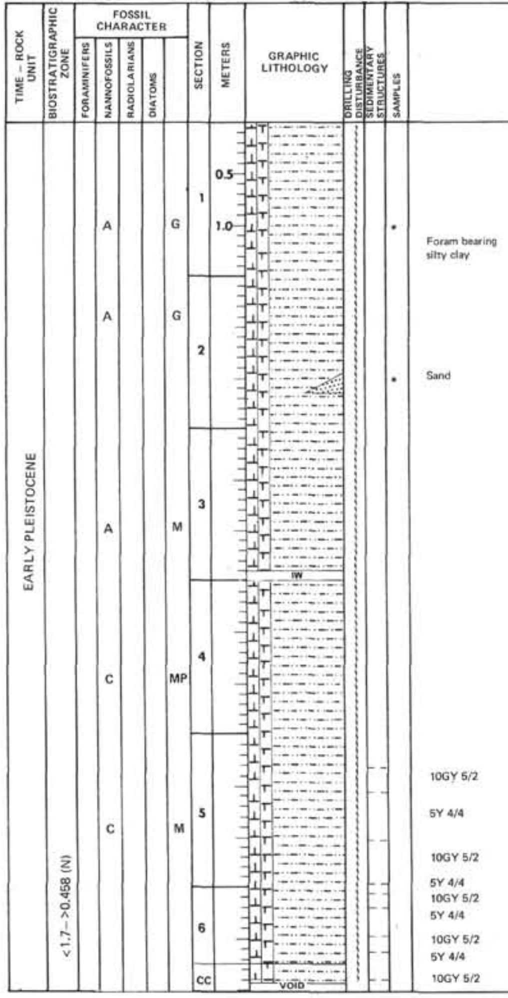
Highly disturbed grayish olive (10Y 4/2) nannofossil-bearing **SILTY CLAY TO CLAYEY SILT.** Minor vitric nannofossil muds, variable nannofossil content. Slight H_2S smell, rare, no sand layers. Little carbonate in Section 1 increasing to bottom. Black (organic) streaks prevalent throughoirt core. Mica flakes visible on surface and increase from Section 5, 127 cm to bottom. Alternating grayish olive (10Y 4/2) or grayish green (10GY 5/2) and moderate olive brown (5Y 4/4) with no grading texture from Section 5, 127 cm to core bottom (sharp contacts), suggest hemipelagic productivity phases.

SMEAR SLIDE SUMMARY

	1-130 (D)	3-90 (D)	5-123 (M)
TEXTURE:			
Sand	10	–	2
Silt	60	25	28
Clay	30	75	70
COMPOSITION:			
Quartz	25	6	10
Feldspar	10	3	
Mica	2	1	1
Heavy minerals	2	–	–
Clay	50	45	45
Volcanic glass	5	10	–
Glauconite	4	TR	1
Pyrite	–	3	–
Carbonate unspec.	2	5	4
Foraminifers	5	–	1
Calc. nannofossils	–	20	30
Diatoms	2	3	5
Radiolarians	1	2	3
Sponge spicules	2	TR	–
Silicoflagellates	2	–	–

Scattered dolomite traces. Volcanic glass shards are clear. Heavy minerals include apatite, sphene.

SITE 475 **HOLE** **CORE** 5 **CORED INTERVAL** 34.5–44.0 m



LITHOLOGIC DESCRIPTION

Highly disturbed mostly dusky yellow green (5GY 5/2) to grayish-green (10GY 5/2) to grayish-olive (10Y 4/2) **SILTY CLAY** some foraminifera-bearing. No **SAND LAYERS** except small sand bleb at Section 2, 101 cm. Sections 2 and 3: alternating sequence of grayish-green (10GY 5/2) and moderate olive brown (5Y 4/4) at Section 5, 30 cm to bottom, micaceous hemipelagic pulses. Black (organic) streaks prevalent.

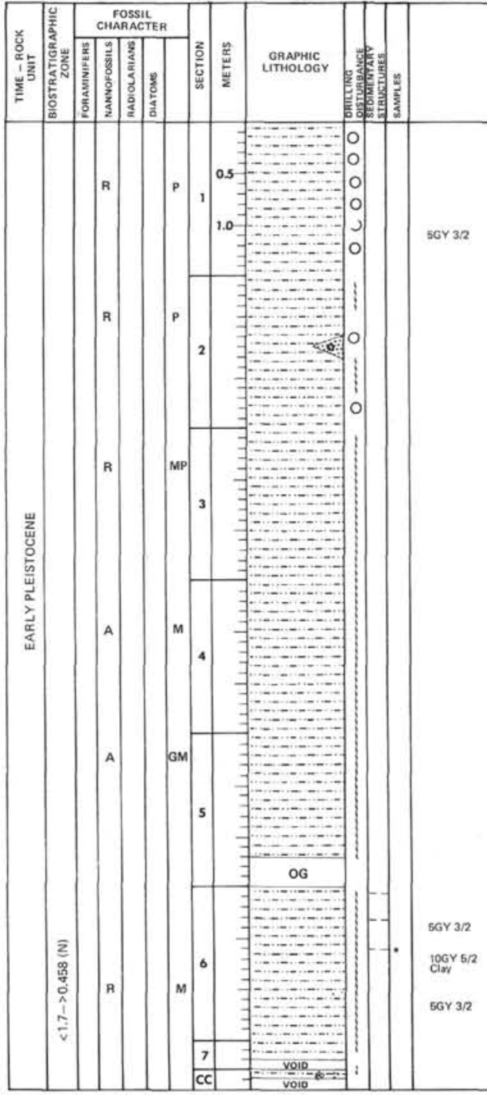
SMEAR SLIDE SUMMARY

	1-100 (D)	2-101 (M)
TEXTURE:		
Sand	–	25
Silt	30	60
Clay	70	15
COMPOSITION:		
Quartz	10	30
Feldspar	3	10
Mica	1	3
Heavy minerals	1	3 (Ap, Hbl)
Clay	60	20
Glauconite	3	–
Pyrite	TR	–
Carbonate unspec.	–	10 (debris)
Foraminifers	10	10 (pyritic)
Calc. nannofossils	5	5
Diatoms	2	–
Radiolarians	2	2
Sponge spicules	1	3
Silicoflagellates	1	–
Plant debris	1	–

CARBONATE BOMB: 3-70 = 11%

	4, 71–78
Lithology	Silty clay
Sand	8.66
Silt	37.94
Clay	53.40

SITE 475 **HOLE** **CORE** 6 **CORED INTERVAL** 44.0–53.5 m



LITHOLOGIC DESCRIPTION

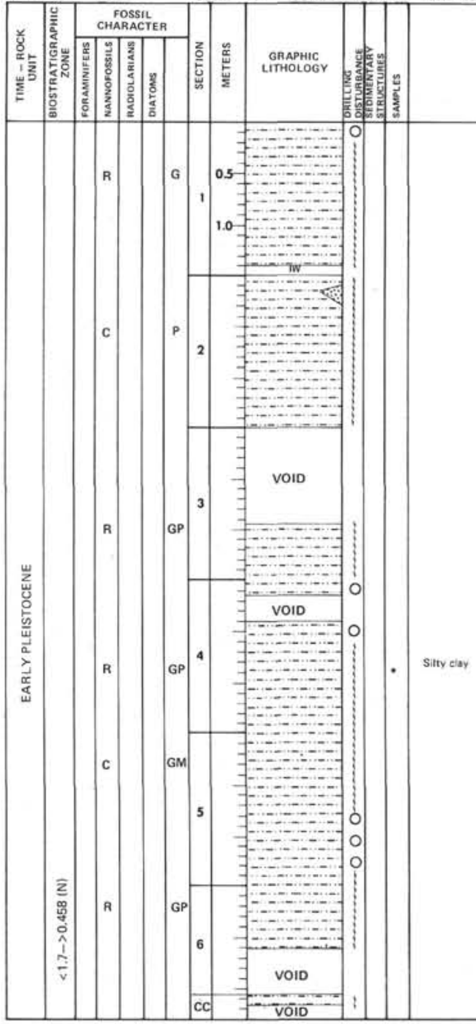
Highly disturbed grayish olive green (5GY 3/2) **SILTY CLAY.** Black (organic) streaks prevalent. Scattered mottling due mainly to drilling disturbance. Below Section 5 alternating colors (grayish olive green (5GY 3/2) to grayish-green (10GY 5/2) **SILTY CLAY.** Section 6 is considerately firmer and less disturbed than the rest of core. Color alternation may be present in the entire core but is effectively destroyed in the upper sections. More mica flakes are visible in Section 6 and below.

SMEAR SLIDE SUMMARY

	6-66 (D)
TEXTURE:	
Sand	–
Silt	18
Clay	82
COMPOSITION:	
Quartz	15
Feldspar	3
Mica	4
Heavy minerals	2
Clay	65
Glauconite	1
Pyrite	2
Zeolite	12?
Carbonate unspec.	2
Foraminifers	TR
Calc. nannofossils	2
Diatoms	1
Radiolarians	1
Sponge spicules	1
Silicoflagellates	1 (fragments)
Fish remains	1
Plant debris	1

CARBONATE BOMB: 2-50 = 2.5%
2-53 = 5%
5-115 = 2.5%

SITE 475 HOLE CORE 7 CORED INTERVAL 53.5–63.0 m



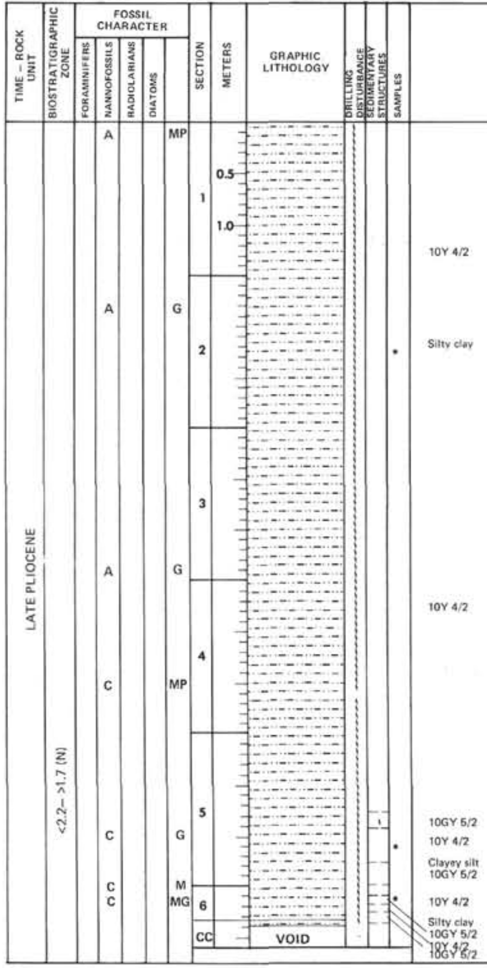
LITHOLOGIC DESCRIPTION

Highly deformed (drill breccia) grayish-olive green (5GY 3/2) **SILTY CLAY.** Uniform hemipelagic mud. Silt particles angular, quartz-rich. A few radiolarian and sponge spicules are found as fragments, but no foraminifers or nannofossils. Section 2, 20 cm: minor gray sand patch, organic-rich without carbonate.

SMEAR SLIDE SUMMARY

	4-90 (D)
TEXTURE:	
Sand	–
Silt	40
Clay	60
COMPOSITION:	
Quartz	10
Feldspar	3
Mica	5
Heavy minerals	2 (anatase, zircon)
Clay	65
Glauconite	1
Pyrite	5 (framboidal)
Opaques	5
Carbonate unspec.	1
Calc. nannofossils	1
Radiolarians	1
Sponge spicules	1 (fragments)

SITE 475 HOLE CORE 8 CORED INTERVAL 63.0–72.5 m



LITHOLOGIC DESCRIPTION

Highly disturbed grayish-olive (10Y 4/2) **SILTY CLAY TO CLAYEY SILT** (Section 1 to Section 5, 75 cm) uniform, hemipelagic mud. Below Section 5, 75 cm: alternating darker and lighter color layers. Darker layers – more silt, more pyrite than lighter layers. Siliceous components occur as tiny fragments. Conspicuous mica flakes. Pliocene–Pleistocene boundary occurs between top of core and middle of Section 2.

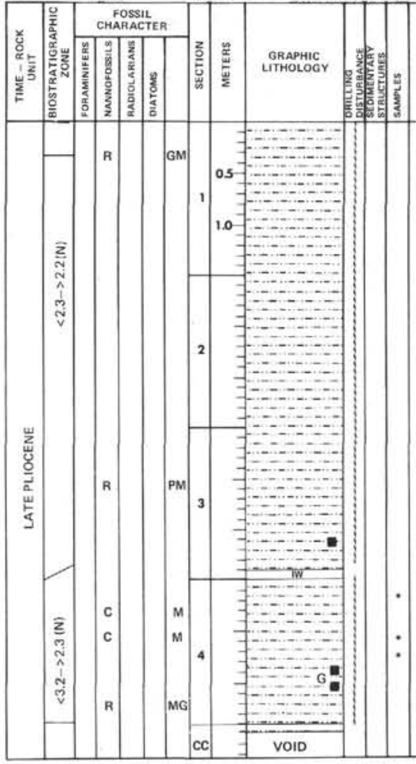
SMEAR SLIDE SUMMARY

	2-75 (D)	5-110 (D)	6-12 (M)
TEXTURE:			
Sand	2	–	5
Silt	28	40	40
Clay	70	60	55
COMPOSITION:			
Quartz	10	10	45
Feldspar	5	2	
Mica	2	8	3
Heavy minerals	2 [(a)]	–	1
Clay	70	55	60
Glauconite	1	TR	–
Pyrite	5	8	3
Opaques	2	–	–
Carbonate unspec.	1	3	5
Foraminifers	–	–	1
Calc. nannofossils	4	–	5
Diatoms	2	1	2
Radiolarians	–	1	2
Sponge spicules	1	1	–
Silicoflagellates	2	2	TR
Plant debris	–	TR	–
Discoasters	4	3	–

CARBONATE BOMB: 5-133 = 1%
6-22 = 3%

	5, 64–66
Lithology	Clayed silt
Sand	3.53
Silt	53.43
Clay	43.04

SITE 475 HOLE CORE 9 CORED INTERVAL 72.5–82.0 m



LITHOLOGIC DESCRIPTION

Coal

Coal
Glauconite

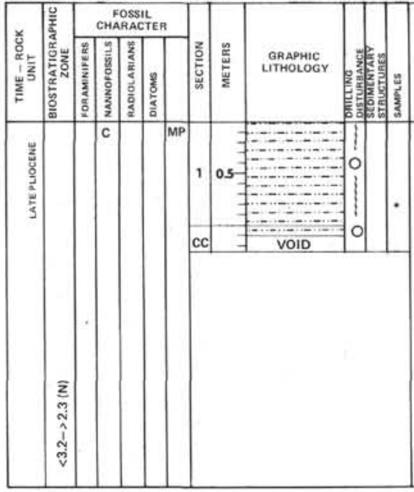
Highly disturbed, dominantly grayish olive (10Y 4/2) **SILTY CLAY,** uniform texture hemipelagic mud, but drilling disturbance has effectively homogenized the core. Compaction and mica flakes *increase toward bottom of core.* Locally sponge spiculites specks present (e.g. Section 3, 104 cm). Section 4, 38 cm: Gradual change to a much firmer, olive gray (5Y 3/2) **SILTY CLAY.** Appears to be bioturbated at top. Alternating hemipelagic pulses, 20 to 30 cm wide. Color change back to grayish-olive (10Y 4/2) at Section 4, 75 cm and less firm sediment. Glauconitic sand blebs present at Section 4, 83 cm, increased mica below Section 4, 75 cm. Small pieces of charcoal-like (lignite?) carbonaceous material (Section 3, 110 and Section 4, 80 cm).

SMEAR SLIDE SUMMARY

	4-19 (D)	4-60 (D)	4-78 (M)
TEXTURE:			
Sand	TR	–	–
Silt	25	30	–
Clay	75	70	–
COMPOSITION:			
Quartz Feldspar	10	10	–
Clay	70	65	–
Volcanic glass	1	5	–
Glauconite	1	–	–
Pyrite	2	5	–
Carbonate unspec.	5	2	–
Calc. nannofossils	3	4	–
Diatoms	2	2	–
Radiolarians	1	1	–
Sponge spicules	1	1	–
Silicoflagellates	1	–	–
Plant debris	1	1	–
Coal, lignite	–	–	100

CARBONATE BOMB: 3-29 = 5%

SITE 475 HOLE CORE 10 CORED INTERVAL 82.0–91.5 m



LITHOLOGIC DESCRIPTION

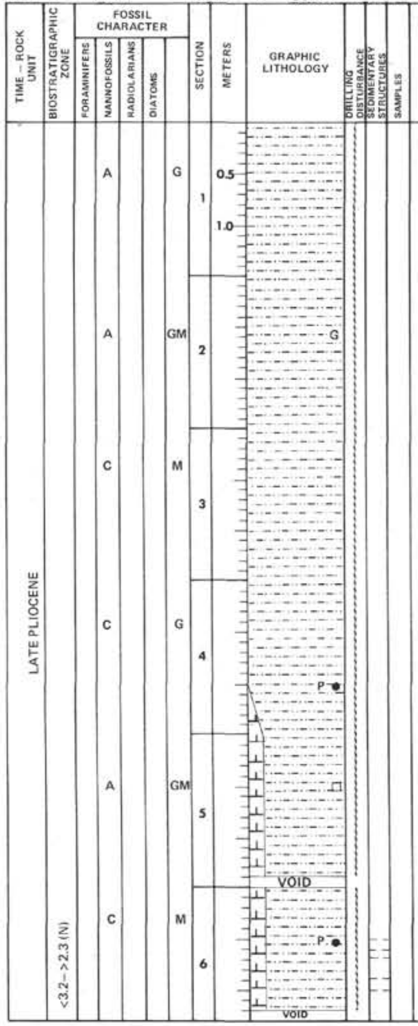
10Y 4/2

Highly disturbed, uniform grayish olive (10Y 4/2) **SILTY CLAY,** hemipelagic mud without sand or other minor lithologies or exotics.

SMEAR SLIDE SUMMARY

	1-80 (D)
TEXTURE:	
Sand	–
Silt	40
Clay	60
COMPOSITION:	
Quartz Feldspar	20
Mica	3
Clay	60
Pyrite	2
Carbonate unspec.	5
Foraminifers	1
Calc. nannofossils	3
Diatoms	2
Radiolarians	2

SITE 475 HOLE CORE 11 CORED INTERVAL 91.5–101.0 m



LITHOLOGIC DESCRIPTION

10Y 4/2

Glauconite

Nodule

Wood

10GY 5/2
10Y 4/2
10GY 5/2
10Y 4/2
10GY 5/2

Highly disturbed, grayish-olive (10Y 4/2) to grayish-green (10GY 5/2) **SILTY CLAY.** Homogenized to uniform texture by drilling. Some black (organic) streaks present. Section 2, 50 cm: glauconite blebs present. Section 5, 40 cm: woody fragments present. Pyrite concretion (Section 4, 100 cm); irregular shapes quite dense, appear to consist almost completely of pyrite with some sand. Probably pyritic burrow fillings. May be reworked previous to drilling or out of place due to drilling, as some seem quite large. Color alternates below Section 6, 55 to 123 cm (10G 4/2 and 10GY 5/2), as hemipelagic pulses(?) 10 to 20 cm thick.

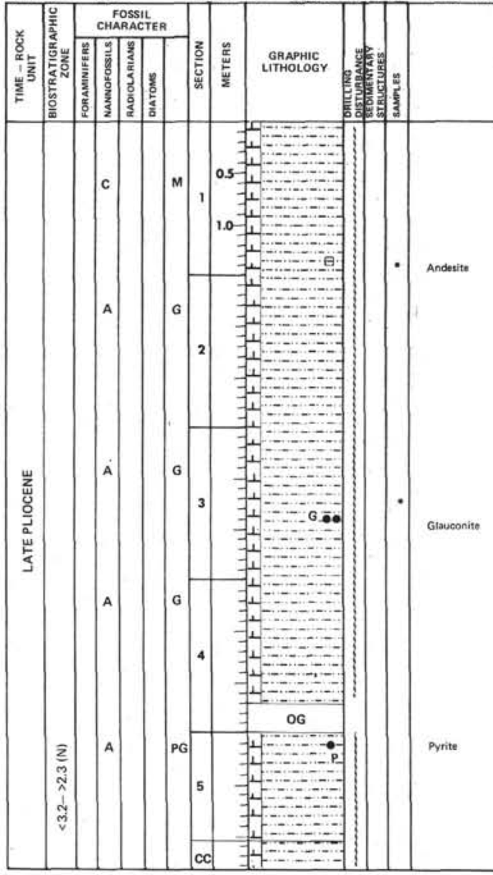
SMEAR SLIDE SUMMARY

	5-80 (D)
TEXTURE:	
Sand	TR
Silt	30
Clay	70
COMPOSITION:	
Quartz	10
Feldspar	2
Mica	2
Heavy minerals	TR
Clay	60
Volcanic glass	1
Glauconite	1
Pyrite	3
Opaques	3
Carbonate unspec.	2
Foraminifers	TR
Calc. nannofossils	15
Diatoms	1
Radiolarians	1
Sponge spicules	2
Silicoflagellates	1

CARBONATE BOMB: 4-29 = 1%

	6, 16–18
Lithology	Silty clay
Sand	4.30
Silt	37.70
Clay	58.00

SITE 475 HOLE CORE 12 CORED INTERVAL 101.0–110.5 m



LITHOLOGIC DESCRIPTION

Highly disturbed grayish-green (10GY 5/2) **SILTY CLAY** uniform texture throughout core, scattered black, organic-rich streaks. Section 1, 140 cm: andesite tuff rounded pebble. Section 3, 95 cm: glauconite occurs. Section 5, 10 cm: pyrite nodule (burrow filling concretion [cementation]).

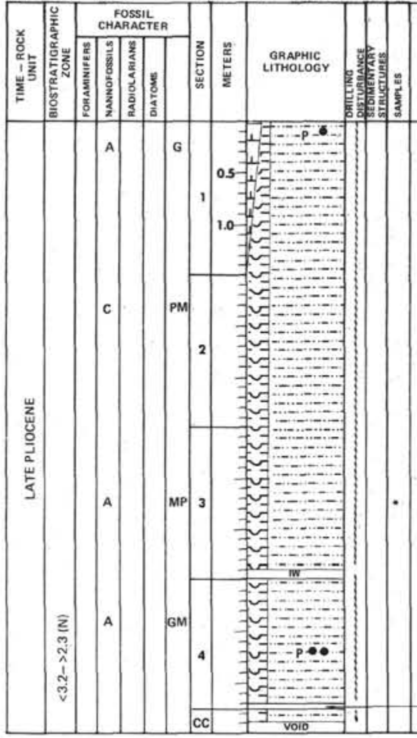
TS 12-1, 141 cm: rounded andesitic pebble. Scattered euhedral plagioclase laths 1 to 2 mm in a variolitic, vesicular, glassy fine-grained groundmass. Flow lineation, 25% opaques, and 5% feldspar.

SMEAR SLIDE SUMMARY

	3-75 (D)
TEXTURE:	
Sand	TR
Silt	40
Clay	60
COMPOSITION:	
Quartz	15
Feldspar	2
Clay	50
Volcanic glass	3
Pyrite	1
Carbonate unspec.	2
Calc. nannofossils	5
Diatoms	5
Radiolarians	TR
Sponge spicules	2
Silicoflagellates	1

CARBONATE BOMB: 4-117 = 2%

SITE 475 HOLE CORE 13 CORED INTERVAL 110.5–120.0 m



LITHOLOGIC DESCRIPTION

10Y 4/2

Highly disturbed, uniform texture, grayish-olive (10Y 4/2) **DIATOMACEOUS SILTY CLAY.** Grades in color only to grayish green (10GY 5/2) to dusky yellow green (5GY 5/2). Some light mottling or bioturbation?. Mica more visible down core, scattered black organic-rich streaks. At Section 1, 10 cm and Section 4, 70 cm: pyritized burrow filling (looks like a flattened planolites burrow).

10GY 5/2

SMEAR SLIDE SUMMARY

	3-75 (D)
TEXTURE:	
Sand	–
Silt	30
Clay	70
COMPOSITION:	
Quartz	5
Heavy minerals	3
Clay	60
Pyrite	3
Foraminifers	1
Calc. nannofossils	5
Diatoms	15
Radiolarians	2
Sponge spicules	1
Silicoflagellates	2
Plant debris	1

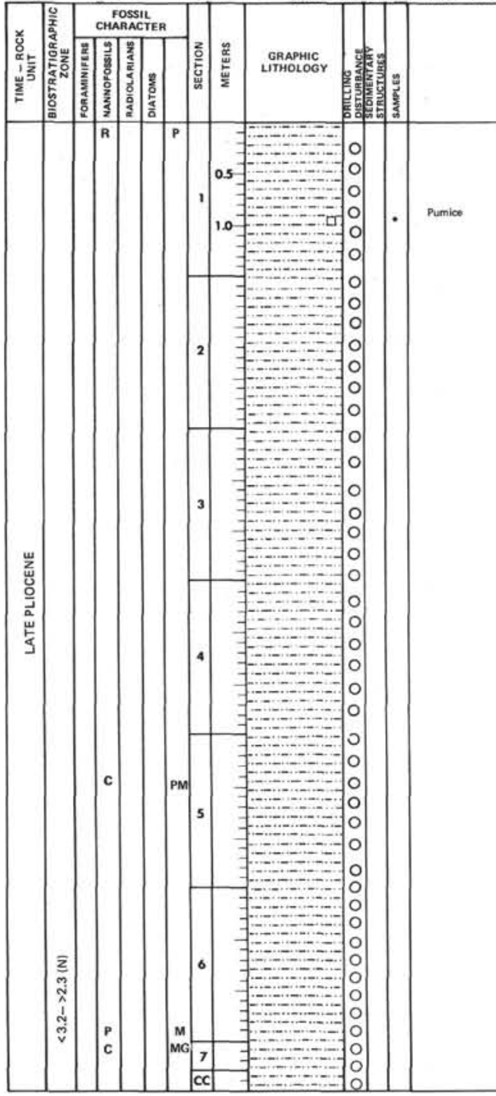
CARBONATE BOMB: 4-48 = 5%

5GY 5/2

	4, 51–53
Lithology	Clayed silt
Sand	1.33
Silt	51.34
Clay	47.33

VOID

SITE 475 HOLE CORE 14 CORED INTERVAL 120.0–129.5 m

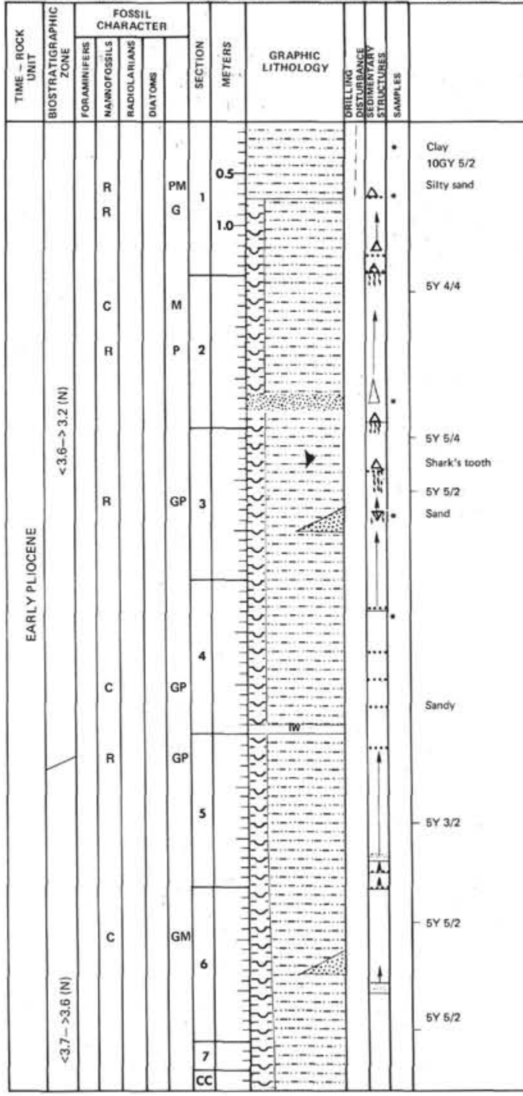


LITHOLOGIC DESCRIPTION

Severely disturbed, brecciated by drilling. Dusky yellow green (5GY 5/2) **SILTY CLAY**, *uniform scattered dark gray streaks and* small sand blebs indicate burrowing and suggest original alternation of color shades. Scattered mica flakes, prominent in Section 7. Section 1, 93 cm: **ANDESITE(?) TUFF PEBBLE**, mostly opaque, scattered glass fragments – pumice.

CARBONATE BOMB: No reaction to HCl drops

SITE 475 HOLE CORE 15 CORED INTERVAL 129.5–139.0 m



LITHOLOGIC DESCRIPTION

Section 1, 0 to 71 cm: grayish-green (10GY 5/2) **SILTY CLAY**, uniform, *rare black streaks*. Below Section 1, 71 *cm: Lithology* changes to turbidite sequence of more brownish hues of moderate olive brown (5Y 5/4) to dusky yellow (5Y 6/4) burrowed **SILTY CLAY**, with diatoms and homogeneous mud, olive brown, light olive gray to olive gray brown (5Y 3/2) **DIATOMACEOUS SILTY CLAY**. Scattered spiculite clusters. Some of these muds appear as light to darker fining upward cycles, possibly redeposited. Several units are marked at the base by thin sand laminae or a sandy mud. Most have a very thick section of homogeneous mud. In some larger cycles the top of a bed below the next thin sand has a fine-grained, waxy texture, interpreted as the top of a **MUD TURBIDITE**. Section 3, 87 cm: a reversely graded and burrowed sand.

SMEAR SLIDE SUMMARY

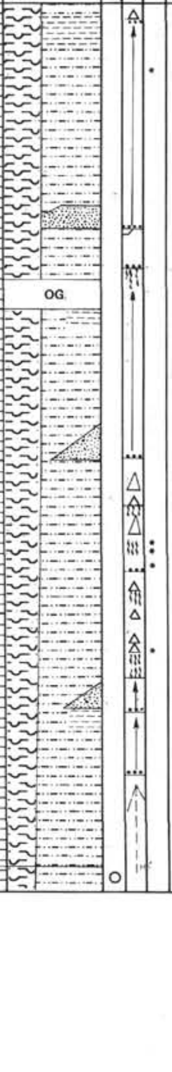
	1-25 (D)	1-72 (M)	2-122 (D)	3-87 (D)	4-34 (D)
TEXTURE:					
Sand	–	60	20	80	–
Silt	15	30	55	15	45
Clay	85	10	25	5	55
COMPOSITION:					
Quartz	15	35	30	60	10
Feldspar		25	15	20	10
Mica	1	5	2	2	2
Heavy minerals	1	2	2	2	2
Clay	75	10	25	–	50
Pyrite	–	–	8	6	5
Micronodules	–	–	–	–	TR
Carbonate unspec.	TR	3	2	–	–
Foraminifers	–	1	2	2	1
Calc. nannofossils	2	1	TR	–	–
Diatoms	1	15	10	5	20
Radiolarians	2	3	2	–	1
Sponge spicules	–	1	1	–	1
Silicoflagellates	2	2	1	–	2
Dinoflagellates	–	2	–	–	–
Limpid dolomite rhombs	–	–	–	–	13

CARBONATE BOMB: 2-122 = 2.5%
4-55 = 3%

SITE 475 **HOLE** **CORE** 16 **CORED INTERVAL** 139.0–148.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
EARLY PLIOCENE			A		GM	1	0.5 1.0
			C		GM	2	
			C		GM	3	
			C		MP	4	
			R		GM	5	
			R		P	6	
						CC	

GRAPHIC LITHOLOGY · DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES



LITHOLOGIC DESCRIPTION

Clayey silt

5Y 4/4

Uniformly colored moderate olive brown (5Y 4/4), **MUDDY DIATOMACEOUS OOZE TO MUD.** Texture varies from slightly silty clay to clayey silt with some thin muddy sands, very hard. Considered thick mud turbidite-beds with subtle upward finings, marked by discrete, commonly winnowed thin gray sand laminae. Some scattered gray specks. Some sandy layers are laminated. Multiple upward-fining cycles. The tops of cycles in Sections 4 to 5 are slightly burrow mottled by dusky-yellow (5Y 6/4). Two large and 9 small graded cycles recognized.

SMEAR SLIDE SUMMARY

	1-65 (D)	4-80 (M)	4-91 (M)	4-103 (M)	5-36 (D)
TEXTURE:					
Sand	2	1	1	20	10
Silt	50	80	60	50	60
Clay	48	19	39	30	30
COMPOSITION:					
Quartz Feldspar	30	15	15 5	35	30
Mica	TR	1	2	2	1
Heavy minerals	–	–	1	1	1
Clay	20	50	30	20	–
Pyrite Micronodules	2	2	2	2	2
Carbonate unspec.	5	1	3	3	–
Foraminifers	1	–	–	2	3
Calc. nannofossils	5	–	2	2	–
Diatoms	25	45	30	30	20
Radiolarians	TR	TR	–	–	–
Sponge spicules	1	1	–	–	–
Silicoflagellates	2	1	2	2	2
Plant debris	3	1	2	2	2

CARBONATE BOMB: 2-104 = 2%

5Y 6/4

Top

Middle

Base

	5, 33–35
Lithology	Clayed silt
Sand	1.62
Silt	70.92
Clay	27.46

5Y 6/4

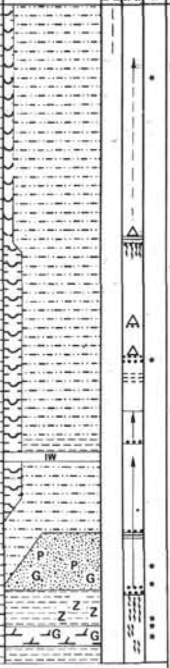
Yellow diatom

5Y 4/4

SITE 475 **HOLE** **CORE** 17 **CORED INTERVAL** 148.5–158.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	NN 15		R		GM	1	0.5 1.0
			R		G	2	
			B			3	
	?		B B B			4	
						5	
						CC	

GRAPHIC LITHOLOGY · DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES



	2, 44–46	4, 42–44
Lithology	Clayed silt	Clayed silt
Sand	14.31	1.33
Silt	57.33	68.40
Clay	28.36	30.27

LITHOLOGIC DESCRIPTION

Section 1 to 3, 130 cm mainly uniform, moderate olive brown (5Y 4/4) **DIATOMACEOUS SILTY CLAY** with some rare dusky yellow (5Y 6/4) mottled bands and sand laminae or muddy sand. These may be mud-turbidite units as textures show fining upward in a cycle with more clayey tops and a faint grading in basal muddy sands. Most of the sediment is homogeneous silty clay. No reaction with HCl drops.

Thin sand

Section 3, 130 cm to Section 4, 122 cm: thick **MUD TURBIDITE** with clean, sorted sandy base (matrix) followed by very poorly sorted muddy sand, then a zone with parallel laminated sands capped by a massive moderate olive brown (5Y 4/4) hard silty clay which fines upward faintly. Diatoms abundances diminish.

Section 4, 124 cm to Section 5, 10 cm: burrowed, hard brown gray (5YR 4/1) **CLAY** with glauconite and abundant zeolites(?). Small <10 μm rod shaped, low bifringeance, R.I. Pyrite framboids and crystals abundant.

Light olive blotch

Section 5, 10 to 42 cm: dusky yellow (5Y 6/4) **GLAUCONITIC, DOLOMITIC; MUDSTONE**, limpid, euhedral dolomite matrix, friable, soft, and burrowed. Large matrix supported glauconite pellets.

TS 17-5 to 12 cm: dolomite, soft uniform crystals ~16 micron, euhedral, limpid-clear, with few inclusions. Green glauconite pellets ~1 mm matrix supported. Scattered minor detrital fragments of chert(?).

Muddy sand

Glauconite - pyrite

Gray sand

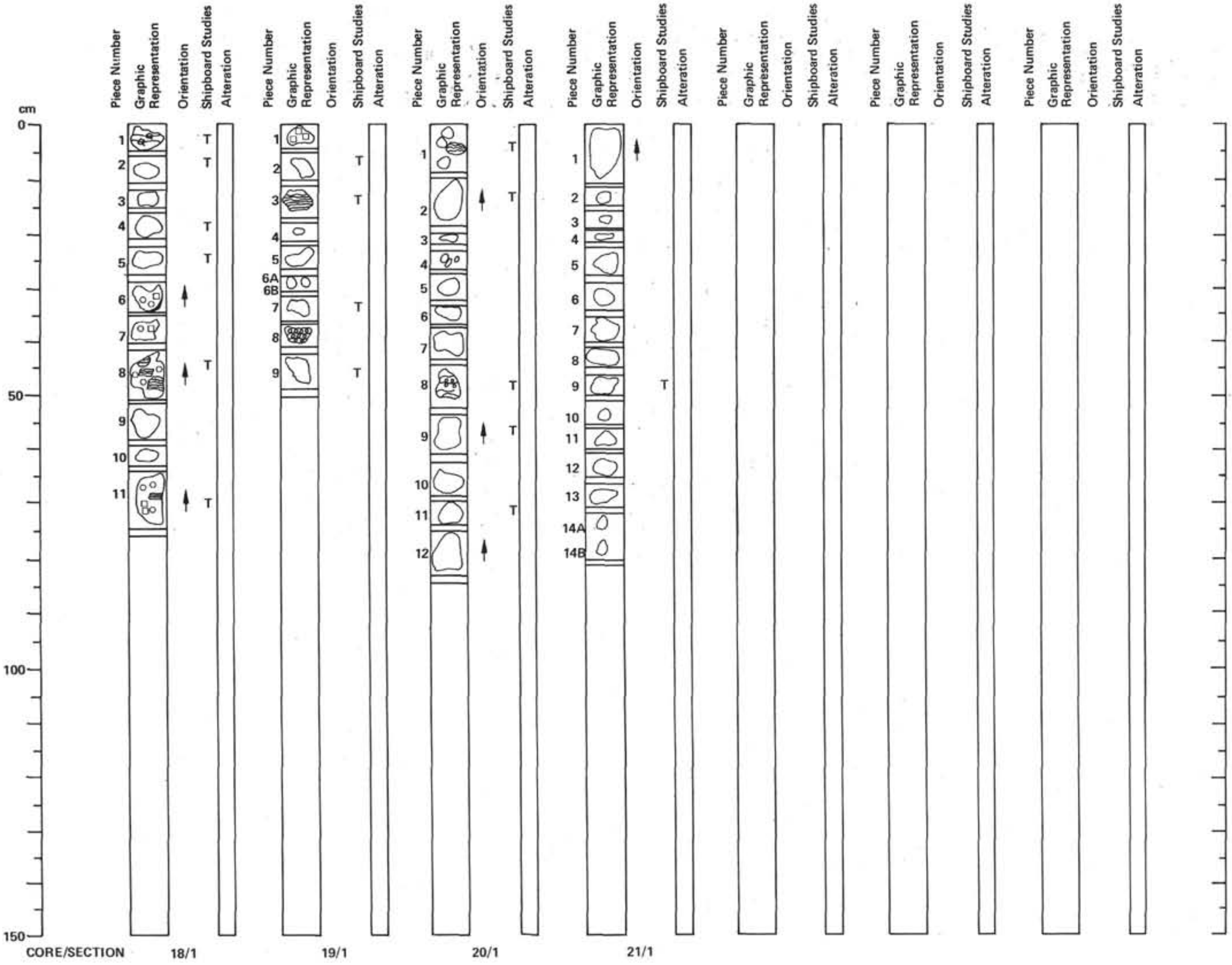
Brown clay (5YR 4/1)

Dolomite-mud (5Y 6/4)

SMEAR SLIDE SUMMARY

	1-70 (D)	3-48 (D)	4-100 (M)	4-122 (M)	5-5 (M)	5-12 (M)
TEXTURE:						
Sand	10	5	15	60	–	2
Silt	30	60	25	30	40	48
Clay	60	35	60	10	60	50
COMPOSITION:						
Quartz	25	10	10	30	15	3
Feldspar	5	10	10	25	5	1
Mica	1	1	1	5	–	1
Heavy minerals	2	–	–	–	1	–
Clay	40	30	30	5	60	20
Glauconite	–	1	10	–	–	10
Pyrite	–	2	10	10	2	3
Opaques	–	2	5	–	–	–
Zeolite	–	–	–	25	15	5
Carbonate unspec.	10	5	10	–	2	–
Calc. nannofossils	1	TR	–	–	1	–
Diatoms	25	35	2[(a)]	–	–	–
Radiolarians	–	1	1- 2	–	–	–
Sponge spicules	–	1	1- 2	–	–	–
Silicoglagellates	4	3	1- 2	–	–	–
Plant debris	–	2	TR	–	2	2
Dolomite	–	–	–	–	2	60

CARBONATE BOMB: 1-70 = 2%
4-131 = 0%
5-5 = 1%


Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
cm
0
50
100
150
CORE/SECTION
18/1
19/1
20/1
21/1
6A
6B
14A
14B
T

64-475-18 **Depth 158.0 to 167.5 m**

SECTION 1: DOMINANT LITHOLOGY: pebbles of mostly metamorphic rocks.

Macroscopic Description

Metavolcanic and metasedimentary clasts POLYGENETIC boulder to pebble CONGLOMERATE comprising mostly medium grade metamorphic clasts including meta-ignimbrites, fine-grained volcanics, graywacke, perlitic rhyolite, quartzite, shale, schist, quartz-metaconglomerate.

Piece 1: METAVOLCANICS, fine-grained, light medium gray. Thin subparallel quartz-filled fractures (< 1 mm). Orthogonal joint pattern.

Piece 2: METAQUARTZITE: light beige.

Pieces 3 and 4: coarse-grained, 1–2 mm, peppered-green, low-grade QUARTZ SANDSTONE.

Piece 5: greenish gray METAVOLCANIC.

Pieces 6, 7, 8, and 11: METAMORPHOSED grain-supported CONGLOMERATE, large fractured clasts of feldspar, quartz, volcanic and lath-shaped minerals, up to 1 cm; reddish hue.

TS (Piece 1): metabasalt altered fine groundmass with abundant opaques, altered clinopyroxene and olivine phenocrysts. Small calcite veins. No foliation.

TS (Piece 2): quartz grains, 80%, ~250 µm, ragged edges, recrystallized, undulating extinction. Set in lacy mica framework, some epidote.

TS (Piece 4): cemented by altered clay, some silica; feldspar-rich scattered pyroxene. Grains rounded subhedral, or angular, many highly weathered to sericite.

TS (Piece 5): recrystallized trachyte(?), fine-grained pilotaxitic, porphyritic. Phenocrysts: 3%, 0.1–0.5 mm, cubic to irregular reddish sphene (replace Ti-Magn.); 10%, 0.5–2 mm, orthoclase or sanidine, subhedral to euhedral, altered. Groundmass: 40%, < 0.4 mm, feldspar laths; 30%, < 0.2 mm, quartz interstitial, mesh with feldspar; 15%, 0.05–0.5 mm, chlorite(?) elongate strands, pleochroic green. Some possible amphibole (5%) alteration with prehnite.

TS (Pieces 8 and 11): mostly rock fragments, metamorphic, low-grade; clasts include laminated quartz siltstone, coarse weathered granite, quartz-mica schist. Most fractured, broken. Trace of black bitumen in pregnation. Clay mineral and quartz cement.

64-475-19 **Depth 167.5 to 177.0 m**

SECTION 1: DOMINANT LITHOLOGY: varied polygenetic boulder to pebble conglomerate-cobbles varying from metavolcanic to metasedimentary rock.

Macroscopic Description

Piece 1: metagraywacke similar to Pieces 3 and 4 in Core 18, Section 1.

Piece 2: grayish-orange pink (5YR 7/2) subrounded cobble with quartz and feldspar crystals randomly set in the pinkish, fine-grained matrix.

Piece 3: strongly banded pinkish-gray to gray blue bands.

Piece 4: small pebble similar to Piece 1.

Piece 5: light gray METAVOLCANIC?

Pieces 6A and B: small, moderate borwn (5YR 3/4) purplish pebble.

Piece 7: pale red (10R 6/2) cobble with light colored inclusions (not crystals).

Piece 8: coarse-grained rock, grayish, composed of subrounded rock clasts (2-5 mm) crudely aligned at times.

Piece 9: grayish-pale red (10R 6/2), fine-grained rock with feldspar clasts, subhedral to anhedral, set in a gray-pinkish fine matrix with biotite flakes in a crude, poorly-defined parallel alignment.

TS (Piece 2): QUARTZ FELDSPAR PORPHYRY (metarhyolite); porphyritic, recrystallized groundmass of quartz, feldspar (epidtoe?). Rock may have been a tuff, but no lineation. Some fibrous chlorite. Phenocrysts: 10% quartz, 0.5–2.5 mm, subhedral to euhedral, rounded; 15%, 0.5–3 mm orthoclase and albite; subhedral, in glomerocrystic aggregates.

TS (Piece 3): RHYOLITE IGNIMBRITE or flow banded rhyolite. Recrystallized groundmass, fine-grained, banded, commonly opaques, quartz, feldspar. Flow diverted around phenocrysts: (10%), ~ 1–2 mm albite or orthoclase, subhedral, sericitized.

TS (Piece 7): RHOLITE; recrystallized but almost aphyric groundmass partially amorphous; quenched. Quartzose estimated 80% silica. Less than 3%, < 2 mm, orthoclase which were subhedral. Scattered fibrous clusters.

TS (Piece 9): RHYOLITE TUFF. Scattered angular quartz shards with subhedral (albite, orthoclase) and plagioclase grains (1–2 mm) in a fine-grained, recrystallized groundmass, chlorite, quartz alteration. Weathered rind with iron oxides, many grains show sericitization. Some faint grain imbrication.

64-475-20 **Depth 177.0 to 186.5 m**

SECTION 1: DOMINANT LITHOLOGY: cobbles to pebbles of volcanic-sedimentary rock showing low to medium grade metamorphism.

Macroscopic Description

Piece 1: several pebble fragments; one shows boudinage and fractured clasts aligned in crude bedding.

Piece 2: polygenetic CONGLOMERATE similar to Pieces 3 and 4 in Core 18 Section 1 and Piece 1 in Core 19 Section 1.

Piece 3: dark gray with white inclusions.

Piece 4: pink pebbles similar to Core 18 Section 1, Pieces 6, 7, 8, and 11 (rhyolite).

Pieces 5 and 6: dense grayish olive green (5GY 3/2) rounded cobbles with pink veins.

Piece 7: metaconglomerate.

Piece 8: IGNIMBRITE, RHYOLITIC.

Piece 9: fine-grained, VOLCANIC rock, very dusky red (10R 2/2) with green specks.

Pieces 10 and 11: pinkish, poorly sorted, VOLCANIC with green specks.

Piece 12: grayish-blue metagraywacke(?) bimodal sorting; feldspar and quartz clasts.

TS (Piece 1): QUARTZITE, grain-supported, rounded, angular and microcrystalline-aggregate clasts (0.2–1.0 mm) with fibrous mica envelopes. Siliceous cement, many grains intergrown. Poor lineation. Deformed, quartz with undulating extinction.

TS (Piece 2): clasts are angular rock fragments to breccia (1–10 mm); include mica-schist, quartzite, granite, large quartz and mica fragments. Grain supported; matrix siliceous (clay and quartz), some mica envelopes, 5% opaques.

TS (Piece 8): flow-banded with fiamme, (80%) very fine groundmass mosaic of quartz, feldspar and minor micasand opaques. Shards, recrystallized, reaction rims. Phenocrysts: 10%, ~ 1 mm orthoclase (Ab) subhedral, sericitized 5% ~1 mm, quartz, subhedral, embayed. Rare high bifringence, euhedral scalenohedra (epidote?) along well-developed, glassy flow laminations.

TS (Piece 9): feldspar (plagioclase-K-feldspar) phenocrysts and fragments (30%); euhedral to subhedral altered pyroxene (5%), sphene (3%), quartz (10%) (~1 mm) in a light brown, partly devitrified glass (much isotopic) groundmass (40%). TRACHYTE(?).

TS (Piece 11): as above. GLASSY VOLCANIC EFFUSIVE (50%) euhedral to fragmentary to subhedral to globular feldspar (plagioclase and K-feldspar), and quartz with (50%) light brown isotopic groundmass. Some devitrification to chlorite(?).

64-475-21 **Depth 186.5 to 196.0 m**

SECTION 1:

Macroscopic Description

Piece 1: 1–2 mm grain-sized silica-cemented graywacke. Grains include quartz, feldspar and lithic fragments. Narrow calcite band.

Piece 2: purplish colored feldspathic tuff(?) with equal proportions of clasts and aphanitic groundmass.

Piece 3: very fine-grained light yellow (5YR 5/2) rhyolite with orange 1.0–1.5 mm yellow phenocrysts.

Piece 4: same as Piece 1.

Piece 5: very coarse polymictic breccia, with quartz (up to 5 mm) and lithic fragments (up to 2 cm) in a siliceous brown groundmass.

Piece 6: coarse polymitic conglomerate. Large quartzite pebbles (>0.5 mm) in siliceous matrix.

Piece 7: 0.5–4.0 mm grain-sized silica-cemented graywacke with quartz-rich bands. Some lithic fragments.

Piece 8: ? medium-grained metasediment(?).

Piece 9: ?siliceous vein material.

Piece 10: similar to Piece 2.

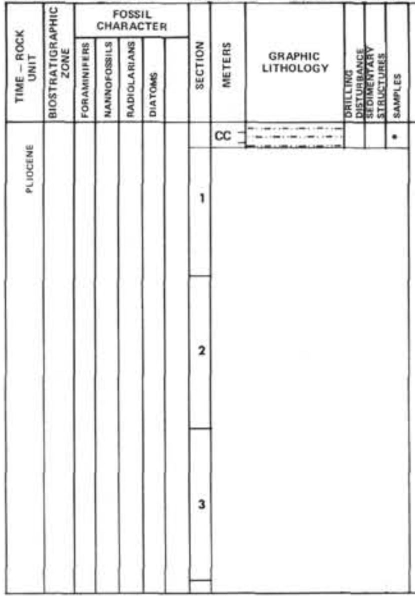
Piece 11: fine-grained dark gray quartzitic sandstone.

Piece 12: fine-grained graywacke(?) or poorly sorted sandstone with foliation (probably depositional) shown by biotite.

Piece 13: medium-grained pale gray quartzitic sandstone.

Piece 14: polyjmictic conglomerate containing 0.2–3 cm clasts of quartzite and pelites.

SITE 475 HOLE A CORE 1 CORED INTERVAL 0.0–9.5 m



LITHOLOGIC DESCRIPTION

Chunks of mainly olive gray (5Y 3/2) hard **CLAYEY SILT TO SILTY CLAY.** Scattered mica flakes, quartzose. High level of *induration of this mudstone matches most closely with mud turbidites* at the base of Core 17, Hole 475.

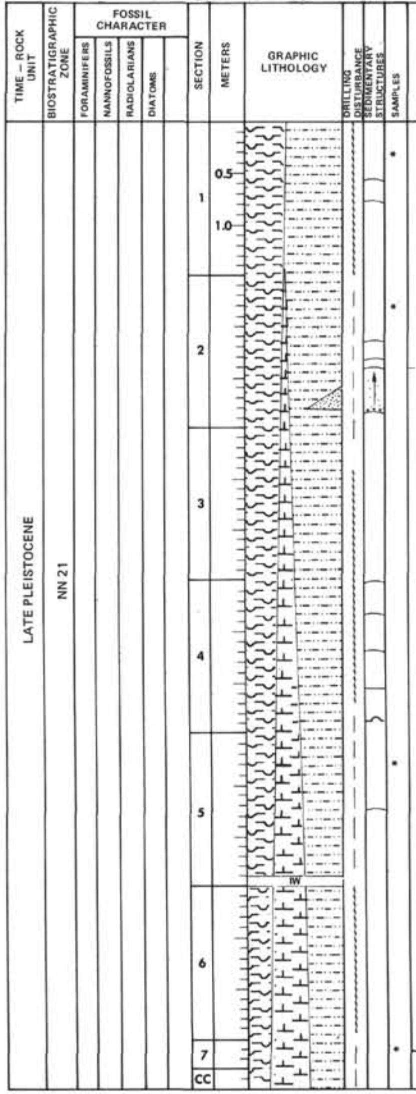
In the Core-Catcher teeth there was one tiny chip of greenish-gray silicified meta-siltstone similiar to some cored in Hole 475 – cobble zone. Heavy mineral suite curiously dominated by mafics. Feldspars are highly weathered.

SMEAR SLIDE SUMMARY

	CC (D)	
TEXTURE:		
Sand	5	
Silt	40	
Clay	55	
COMPOSITION:		
Quartz	15	
Feldspar	8	
Mica	6	
Heavy minerals	6	(Zr = 2, Ap = 1, Hbl = 2, Pyrx = 1)
Clay	60	
Glauconite	2	
Pyrite	2	
Foraminifers	1	
Calc. nannofossils	TR	(discoasters)
Plant debris	2	

CARBONATE BOMB: <1%

SITE 475 HOLE B CORE 1 CORED INTERVAL 0.0–9.5 m



LITHOLOGIC DESCRIPTION

5Y 3/2

10Y 4/2

Gray olive (10Y 5/4)

5Y 4/4

10Y 5/2

10Y 4/2

10Y 5/2

10Y 7/2

5Y 3/2

10Y 6/2

5Y 4/2

Very pale
10Y 8/2

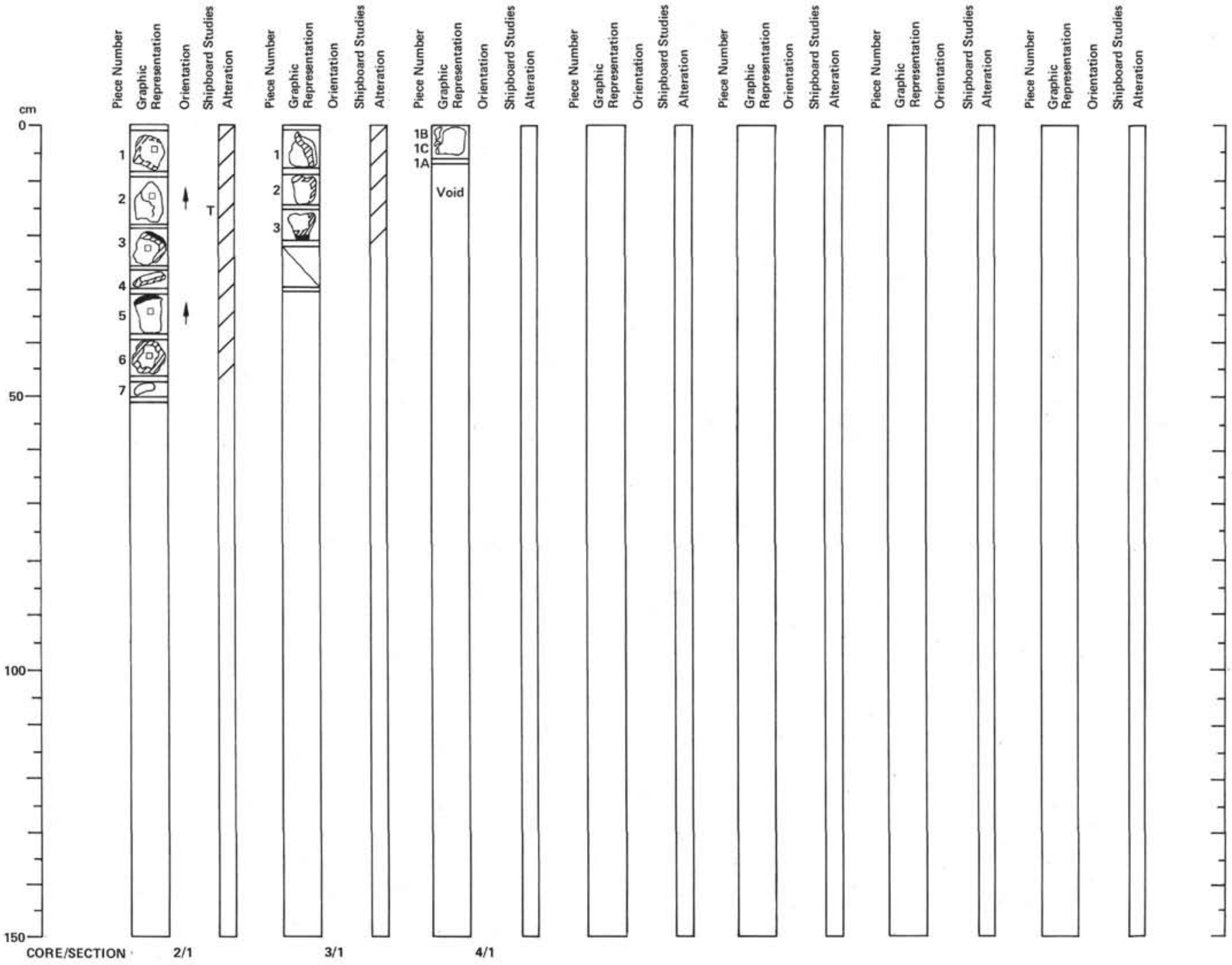
Moderate to intensely disturbed olive gray brown (5Y 3/2) **DIATOMACEOUS OOZE TO MUD**, nannofossil and radiolarian-bearing. Downward increase to nannofossil muds to ooze, very fossil rich. Colors define bands of olive gray brown (5Y 3/2), gray olive (10Y 3/2) and pale olive to very pale olive (10Y 5/2–7/2). Lightly mottled. Paler layers and lower brown layers have more nannofossils. Various dark streaks, burrow fills.

Section 2, 130 to 190 cm: a layer graded bed with thin sand layer; olive brown. Decimeter-thick sands define productivity variations.

SMEAR SLIDE SUMMARY

	1-30 (D)	2-30 (D)	5-30 (D)	7-60 (D)
TEXTURE:				
Sand	5	7	2	1
Silt	40	45	60	60
Clay	55	48	40	40
COMPOSITION:				
Quartz	} 10	} 15	5	5
Feldspar			–	3
Mica	2	–	–	2
Heavy minerals	5	3	1	1
Clay	50	40	30	30
Pyrite	1	2	2	3
Carbonate unspec.	2	3	–	–
Foraminifers	1	TR	TR	3
Calc. nannofossils	3	3	20	40
Diatoms	25	25	35	15
Radiolarians	5	5	1	5
Sponge spicules	3	2	–	2
Silicoflagellates	2	3	–	–
Plant debris	2	1	–	–

CARBONATE BOMB: 5-39 = 6.5%
5-42 = 6%



64-475B-2 **Depth 76.0 to 77.5 m**

SECTION 1: DOMINANT LITHOLOGY: olivine basalt.

Macroscopic Description

Very fine-grained dark gray (N4) basalt with about 3% plagioclase microphenocrysts and rather more (fresh, apple green) (~5%) olivine microphenocrysts. None of the phenocrysts exceeds 20 mm, and generally they are less than 0.5 mm. The rock has a heavy feel.

Glassy selvages (fresh) occur in Pieces 3 and 5. Mostly the rock is very fresh, but slightly brown rims occur on Pieces 1, 3, and 6. The peripheral nature of the alteration suggests that these fragments are probably cobbles lying exposed to sediments and/or water.

Fractures in Piece 2 contain calcite.

Fractures on Pieces 5 and 7 are covered with green vein material and ?zeolite(Piece 5).

TS 14 cm (Piece 2): fine-grained olivine basalt. Texture: quenched: variolitic and intersertal, porphyritic. Phenocrysts: olivine 10%, 0.2–2.0 mm, anhedral to subhedral crystals, many of which are broken, Very fresh, with evidence of only very slight alteration. No plagioclase phenocrysts seen in this thin section. Groundmass: olivine ~5%, <0.2 mm skeletal, elongate crystallites growing in situ; plagioclase 50%, 0.1–0.3 mm long microlites, some of which lie in variolitic clusters. Approximately 20% clinopyroxene, ~5% magnetite, and ~5% ilmenite lie in about 10% mesostasis. Alteration: apart from slight alteration in olivine, none. No vesicles.

64-475B-3 **Depth 85.5 to 87.0 m**

SECTION 1: DOMINANT LITHOLOGY: olivine basalt.

Macroscopic Description

Very fine-grained dark gray (N4) basalt with <3% plagioclase microphenocrysts and rather more (apple green) fresh olivine (~ 5%) microphenocrysts. The microphenocrysts are generally less than 0.5 mm in diameter.

Slight alteration rims indicate that these are small individual cobbles.

Glassy selvages found on Pieces 1 and 3.

Indistinguishable from the basalt of Core 2.

64-475B-4 **Depth 95.0 to 96.5 m**

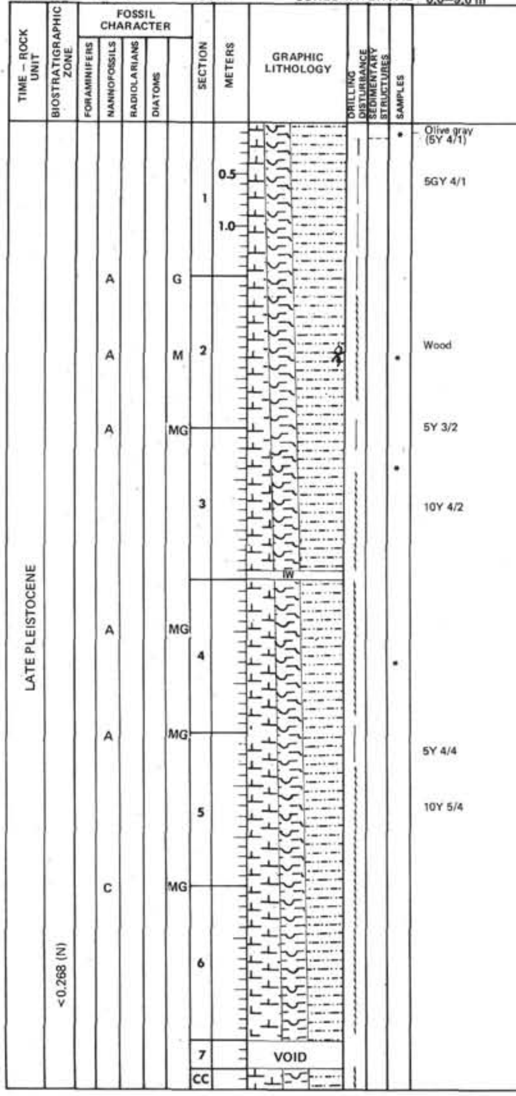
SECTION 1: DOMINANT LITHOLOGY: sparsely phyric olivine basalt.

Macroscopic Description

Very fine-grained dark gray (N4) basalt with <3% plagioclase microphenocrysts and rather more (apple green) fresh olivine (< 5%) microphenocrysts. Microphenocrysts generally <0.5 mm in diameter.

Indistinguishable from basalts in Cores 2 and 3.

SITE 476 HOLE CORE 1 CORED INTERVAL 0.0–9.0 m



LITHOLOGIC DESCRIPTION

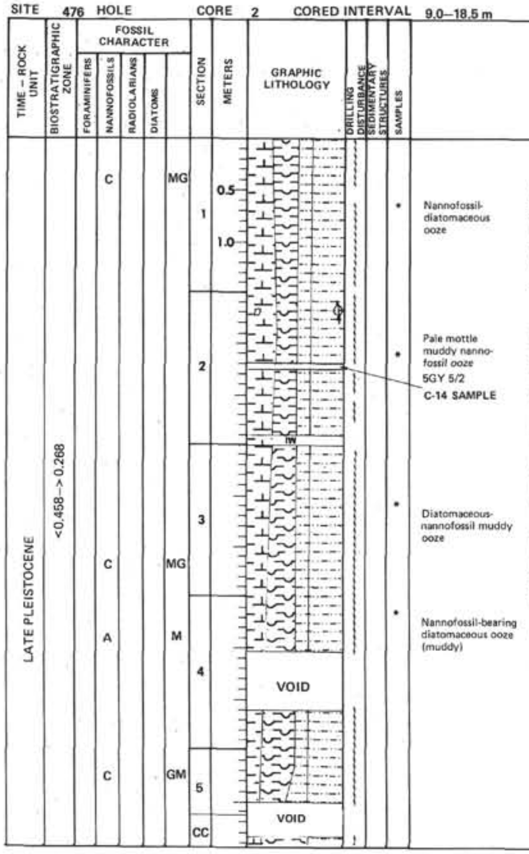
Very disturbed grayish-olive green (5GY 3/2) to moderate olive brown (5Y 4/4) **MUDDY NANNOFOSSIL-DIATOMACEOUS OOZE.** Hemipelagic sediment; colors alternate frequently, indicative of changes in biogenic components. Nannofossil-rich layers are lighter in color; diatom-rich layers relatively darker. Contacts are gradational. Biogenic component increases down core. H_2S prevalent throughout core. Reduction streaks and spots common. Siliceous components fragmented.

SMEAR SLIDE SUMMARY

	1-10 (D)	2-80 (D)	3-40 (M)	4-80 (D)
TEXTURE:				
Sand	2	2	5	5
Silt	40	35	40	40
Clay	58	63	55	55
COMPOSITION:				
Quartz	5	15	5	} 10
Feldspar	3	2	1	
Mica	3	1	2	–
Heavy minerals	1	1	2	–
Clay	30	30	10	30
Pyrite	2	1- 2	2	1
Carbonate unspec.	3	2	5	5
Foraminifers	5	5	5	3
Calc. nannofossils	10	25	35	25
Diatoms	15	20	30	20
Radiolarians	5	5	5	15
Sponge spicules	2	2	5	–
Silicoflagellates	2	2	2	3
Plant debris	3	1	1	–

CARBONATE BOMB: 2-61 = 5%

SITE 476 HOLE CORE 2 CORED INTERVAL 9.0–18.5 m



LITHOLOGIC DESCRIPTION

Intensely disturbed, dusky yellow green (5GY 5/2) to grayish-olive green (5GY 3/2) muddy **NANNOFOSSIL-DIATOMACEOUS OOZE.** Some alternating darker and lighter coloring indicating nannofossil-rich (light) or diatom-rich (dark) sediments. H_2S present., reduction streaks and spots common, slight coarsening (addition of silt) downward in the core.

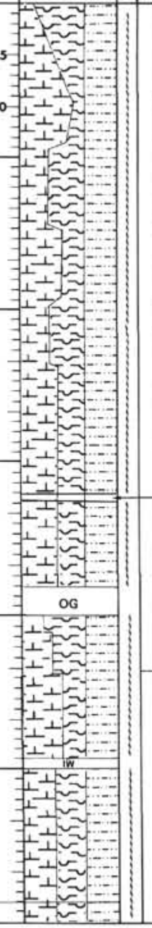
SMEAR SLIDE SUMMARY

	1-60 (D)	2-62 (M)	3-60 (D)	4-13 (D)
TEXTURE:				
Sand	2	–	–	–
Silt	38	40	60	60
Clay	60	60	40	40
COMPOSITION:				
Quartz	15	8	20	10
Feldspar	3	2	2	5
Mica	1	2	–	1
Heavy minerals	1	–	–	1
Clay	25	40	20	30
Glauconite	–	TR	–	–
Pyrite	1	2	4	4
Carbonate unspec.	2	1	–	2
Foraminifers	–	–	2	–
Calc. nannofossils	15	35	25	15
Diatoms	40	10	20	35
Radiolarians	3	} frag- ments	2	3
Sponge spicules	1		1	1
Silicoflagellates	1		1	TR
Plant debris	2	–	–	TR

CARBONATE BOMB: 2-19 = 6%
3-75 = 13%

SITE 476 HOLE CORE 3 CORED INTERVAL 18.5–28.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS		SECTION	METERS	SAMPLES	
LATE PLEISTOCENE	<0.458– >0.268 (N)		A			GM	1	0.5 1.0	• •	Nannofossil ooze Sandy 5Y 5/2
			A			M	2			10Y 5/2 5Y 4/4 10Y 5/2 5Y 4/4
			A			M	3		•	5Y 4/4
			R			G	4			C-14 SAMPLE
			A			GM	5			Greenish gray (5GY 6/1) 10Y 6/2
			A			GM	6		•	
							CC			



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES

LITHOLOGIC DESCRIPTION

Highly disturbed, olive gray (5Y 3/2 to 2/2) to moderate olive brown (5Y 4/4) muddy **NANNOFOSSIL-DIATOMACEOUS OOZE**, pulses of lighter (nannofossil-rich) and darker (diatom-rich) hemipelagic mud on a 20 to 50 cm scale. Some pale light olive (10Y 6/2) to grayish olive (10Y 4/2) mottling in Section 6. Contacts between color (nannofossil-diatomaceous-nannofossil) changes gradational, lighter upwards, may represent fine-grained mud turbidites. Sponge spiculite blebs common. H_2S present.

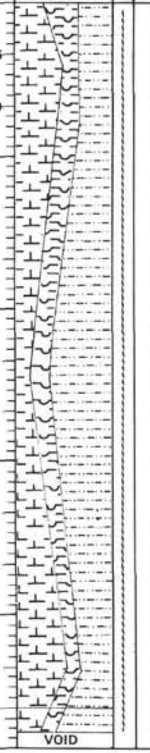
SMEAR SLIDE SUMMARY

	1-90 (D)	3-100 (D)	6-70 (D)	1-110 (CF)
TEXTURE:				
Sand	5	–	2	–
Silt	25	30	53	–
Clay	70	70	45	–
COMPOSITION:				
Quartz	5	5	12	20
Feldspar	10	5	3	10
Mica	3	3	5	5
Heavy minerals	–	1 (Zr)	1 (Ap)	?
Clay	5	10	10	–
Glauconite	–	–	–	5
Pyrite	TR	5	7	–
Carbonate unpsec.	5	3	5	–
Foraminifers	3	–	5	15 (large benthic) 18 (planktonic)
Calc. nannofossils	60	20	35	–
Diatoms	10	40	20	)
Radiolarians	1	1- 2	3	–
Sponge spicules	1	1- 2	2	2
Silicoflagellates	1	1- 2	2	–
Plant debris	–	3	1	–

CARBONATE BOMB: 4-120 = 4% (darker)
6-57 = 21% (light)

SITE 476 HOLE CORE 4 CORED INTERVAL 28.0–37.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS		SECTION	METERS	SAMPLES	
EARLY PLEISTOCENE	<1.7–>0.458 (N)		A			M	1	0.5 1.0	•	Nannofossil ooze
			A			G	2			
			C			M	3		•	
			C			M	4			
			A			GM	5		•	
							CC			



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES

LITHOLOGIC DESCRIPTION

Intensely disturbed, marbled, light olive (10Y 5/4), to grayish olive (10Y 4/2) muddy **NANNOFOSSIL OOZE (MARL) TO DIATOM-BEARING SILTY CLAY.** Mud has very little silt, dark and light bands with transitional and sharp contacts but not graded beds. Light olive layers are nannofossil-rich. Grayish-olive are moderately nannofossil-rich. Some darker brown sediments (minor) are nannofossil poor. H_2S present. Color wisps suggest former decimeter to centimeter bedding.

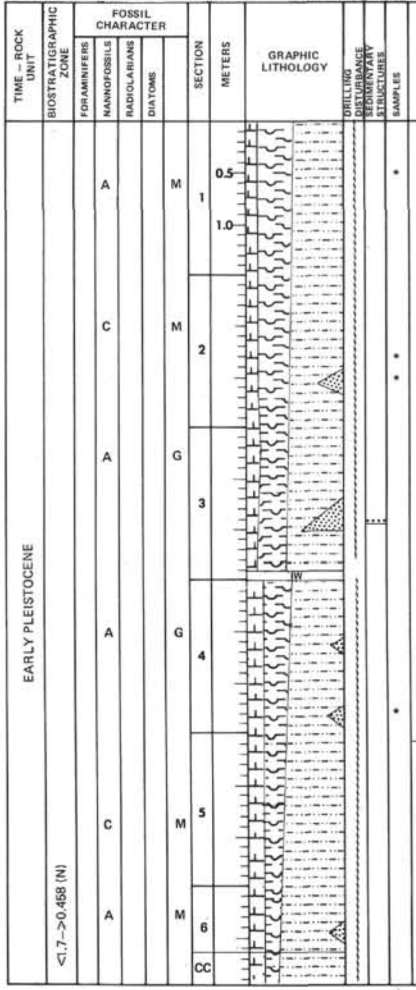
CF 1 – mixture:
10% quartz, 5% feldspar, 5% biotite, 4% glauconite pellets, 40% planktonic foraminifers, 25% benthonic foraminifers, 10% pyritized burrows and wood fragments, and 1% ostracod and pteropod.

SMEAR SLIDE SUMMARY

	1-50 (D)	3-50 (M)	5-50 (M)
TEXTURE:			
Sand	TR	TR	–
Silt	35	40	50
Clay	65	60	50
COMPOSITION:			
Quartz Feldspar	{15	{30	{15
Mica	–	2	2
Heavy minerals	–	2	3
Clay	25	35	15
Pyrite	1	–	2
Carbonate unspec.	3	5	–
Foraminifers	3	1	3
Calc. nannofossils	40	5	50
Diatoms	15	10	5
Radiolarians	1	3	2
Sponge spicules	1	1	1
Silicoflagellates	1	2	2
Plant debris	TR	–	–
Discoasters	–	–	TR

CARBONATE BOMB: 5-26 = 12%

SITE 476 HOLE CORE 5 CORED INTERVAL 37.5–47.0 m



LITHOLOGIC DESCRIPTION

Moderate olive brown

10GY 5/2

Dusky yellow green

CF (yellowish foraminiferal sand)

Grayish green

10GY 5/2

5GY 5/2

Intensely disturbed, marbled, dusky yellow green (5GY 5/2) to moderate olive brown (5Y 4/4) **NANNOFOSSIL-DIATOMACEOUS MUD TO MUDDY DIATOMACEOUS NANNOFOSSIL OOZE.** May have been alternatively color layered (nannofossil-diatomaceous oozes and silty clays). Biogenic components decrease to bottom of core. H_2S present; reduction streaks and spots common. Some mottling present.

Section 2, 100 cm; Section 3, 30 to 90 cm; and Section 4: dusky yellow (5Y 6/4) **SAND** patches, highly disturbed. Very clean, well-sorted medium- to fine-sand with benthonic and planktonic foraminifers, quartz, feldspar. May have been a basal sand of a mud turbidite or a burrowed sand filling.

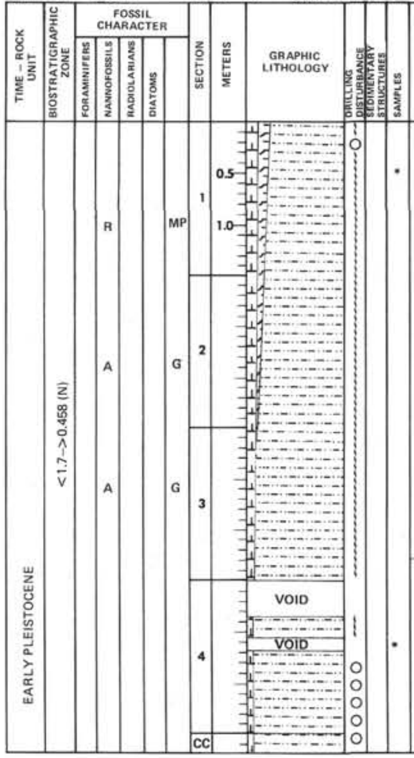
SMEAR SLIDE SUMMARY

	1-50 (D)	2-80 (D)	2-100 (CF)	4-130 (D)
TEXTURE:				
Sand	4	–	100	–
Silt	45	70	–	35
Clay	5	30	–	65
COMPOSITION:				
Quartz	10	8	40	10
Feldspar	10	3		5
Mica	5	2	–	3
Heavy minerals	2	1	–	1
Clay	38	20	–	60
Glauconite	–	–	2	–
Pyrite	6	3	–	3
Carbonate unspec.	3	–	5	2
Foraminifers	2	5	30[a]	–
Calc. nannofossils	15	35	–	7
Diatoms	20	20	–	10
Radiolarians	–	5	–	2
Sponge spicules	1	1	2	2
Silicoflagellates	–	TR	–	–
Plant debris	6	–	–	2
Coal?	–	–	2	–

[a] benthic 15% and planktonic 15%

CARBONATE BOMB: 3-136 = 12%
3-138 = 12%

SITE 476 HOLE CORE 6 CORED INTERVAL 47.0–56.5 m



LITHOLOGIC DESCRIPTION

5GY 5/2

Pale olive 10Y 6/2

5Y 4/2

Intensely disturbed, dusky yellow green (5GY 5/2) to light olive gray (5Y 4/2) **NANNOFOSSIL-DIATOM-BEARING SILTY CLAY TO CLAYEY SILT.** Hemipelagic mud. Biogenic component decreases to bottom of core. Compaction increasing; with darker layers are firmer than lighter layers. Wood fragments, H_2S odor. Reduction spots and streaks common.

Section 4 and Core-Catcher: almost entirely terrigenous sediment.

SMEAR SLIDE SUMMARY

	1-50 (D)		4-68 (M)
TEXTURE:			
Sand	–		–
Silt	30		45
Clay	70		55
COMPOSITION:			
Quartz	15		15
Feldspar	8		8
Mica	2		2
Heavy minerals	2 (Ep, Ap)		4
Clay	40		55
Glauconite	TR		–
Pyrite	1		1
Carbonate unspec.	–		1
Foraminifers	–		3
Calc. nannofossils	12		2
Diatoms	5	fragments	3
Radiolarians	2		1
Sponge spicules	2		1
Plant debris	2		2

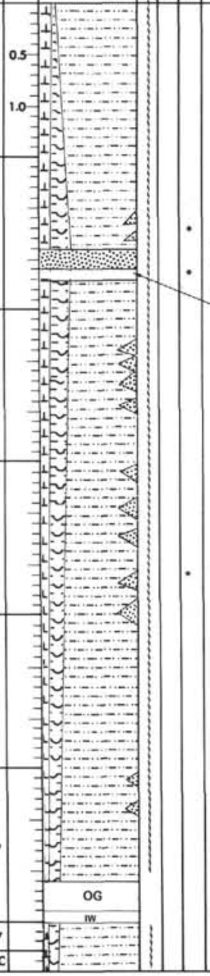
CARBONATE BOMB: 2-32 = 13%

SITE 476 HOLE CORE 7 CORED INTERVAL 56.5–66.0 m

TIME – ROCK UNIT: EARLY PLEISTOCENE

BIOSTRATIGRAPHIC ZONE: <1.7–>0.458 (N)

SECTION	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	
1		C			GM
2		C			G
2		C			G
3		C			G
4		R			M
5					
6		A			P
7		R			P
CC					



10Y 4/2

Silty clay

CF (foraminiferal sand)

C-14 SAMPLE

Clayey silt

10GY 5/2

5GY 6/2

LITHOLOGIC DESCRIPTION

Highly disturbed, grayish olive (10Y 4/2) diatom-bearing **SILTY CLAY** and dusky yellow (5Y 6/4) **SAND**. Sections 3 and 4: scattered large blebs (former layers) of **SAND**; well-sorted and very clean. Contains ~50% broken foraminifers (benthic and planktonic), quartz, feldspar, and biotite. Some mottling of silty clay. H_2S present; reduction spots and streaks common. Colors lighten to grayish yellow green (5GY 6/2) at bottom of core.

SMEAR SLIDE SUMMARY

	2-70 (D)	2-111 (CF)	4-110 (D)
TEXTURE:			
Sand	2	–	5
Silt	35	–	35
Clay	63	–	60
COMPOSITION:			
Quartz	20	20	25
Feldspar		10	
Mica	3	1	3
Heavy minerals	2	2	1
Clay	40	–	50
Glauconite	–	TR	–
Pyrite	2	–	3
Carbonate unspec.	2	20	5
Foraminifers	–	40 (a)	–
Calc. nannofossils	10	–	3
Diatoms	20	–	10
Radiolarians	3	–	1
Sponge spicules	3	TR	2
Silicoflagellates	1	–	2

(a) Benthic and planktonic

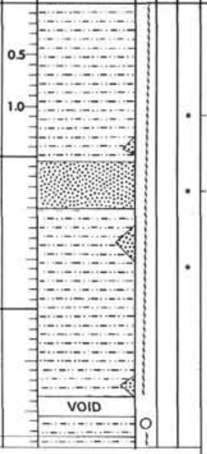
CARBONATE BOMB: 2-103 = 40% (sand)
6-108 = 7% (mud)

SITE 476 HOLE CORE 8 CORED INTERVAL 66.0–75.5 m

TIME – ROCK UNIT: EARLY PLEISTOCENE

BIOSTRATIGRAPHIC ZONE: <1.7–>0.458 (N)

SECTION	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	
1		A			M
2		A			M
3		A			M
CC					



5GY 3/2

Silty clay

CF (5Y 6/4 yellow sand)

Silty clay 10GY 5/2

10Y 4/2

LITHOLOGIC DESCRIPTION

Intensely disturbed, homogenized grayish-olive green (5GY 3/2) slightly siliceous **SILTY-CLAY**. Some evidence of lighter layer but badly disturbed. Slight H_2S present. Some reduction streaks and spots. Well-sorted, coarse, dusky yellow (5Y 6/4) **SAND** prevalent in Section 2, 10 to 50 cm, and scattered blebs.

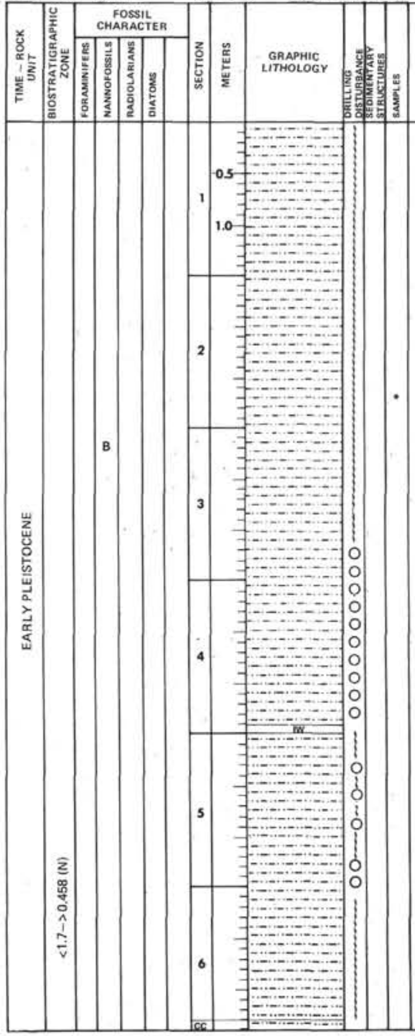
SMEAR SLIDE SUMMARY

	1-110 (D)	2-110 (D)
TEXTURE:		
Sand	–	2
Silt	30	38
Clay	70	65
COMPOSITION:		
Quartz	20	
Feldspar	5	7
Mica	2	3
Heavy minerals	2 (Hbl, Ap)	3 (Ap)
Clay	60	60
Glauconite	1	–
Pyrite	2	2
Carbonate unspec.	TR	5
Foraminifers	2	3
Calc. nannofossils	1	7
Diatoms (poor siliceous fossil preservation)	2	5
Radiolarians	3	1
Sponge spicules	2	2
Silicoflagellates	1	3

COARSE FRACTIONS: 2-34

Quartz	30
Feldspar	
Plagioclase	2
Planktonic foraminifers	20
Benthic foraminifers	25
Large wood	2
Unspec. carbonate shell	10
Sponge spicules	2
Heavy minerals	2 (Ap, Zr, Ep)
Pollen	1
Mica	2

SITE 476 HOLE CORE 9 CORED INTERVAL 75.5–85.0 m



LITHOLOGIC DESCRIPTION

5GY 3/2

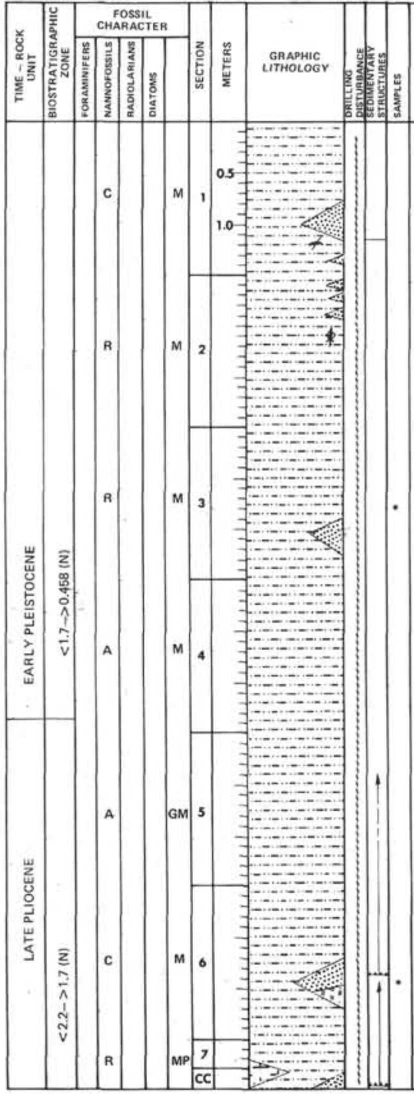
Intensely disturbed to drill breccia of uniform grayish-olive green (5GY 3/2) hemipelagic **SILTY CLAY**. No sand present, slight H_2S odor, rare sponge spiculites. Some darker mottling, noted trace occurrence of zeolite and carbonate (dolomite) rhombs.

SMEAR SLIDE SUMMARY

	2-120 (D)
TEXTURE:	
Sand	2
Silt	28
Clay	70
COMPOSITION:	
Quartz	20
Feldspar	10
Mica	1
Heavy minerals	2 (Ap, Fe, Sphene)
Clay	60
Glauconite	TR
Pyrite	3
Zeolite	1
Carbonate unspec.	1 (dolomite?)
Foraminifers	1
Calc. nannofossils	1
Diatoms	
Radiolarians	5
Sponge spicules	
Silicoflagellates	
Plant debris	7

CARBONATE BOMB: 2-52 = 4%

SITE 476 HOLE CORE 10 CORED INTERVAL 85.0–94.5 m



LITHOLOGIC DESCRIPTION

5GY 3/2

5Y 4/4

Wood

10GY 5/2

Silty clay

Sand

Ash

5GY 3/2

5Y 4/4

10GY 5/2

Intensely disturbed, grayish-olive green (5GY 3/2) to grayish-green (10GY 5/2) **SILTY CLAY**, firmer. Moderate mottling. Mica increases with depth to Section 2, 50 cm. Moderate olive brown (5Y 4/4) **SAND** patches in Sections 1, 2, 3, and 6 (distorted). These may be basal sands of mud turbidites. Sands are fine-grained, with significant clay fraction.

Section 6, 95 to 97 cm: small **VITRIC ASH** blebl, clear angular shards up to 8.4 mm R. I. 1.51 to 1.50, more cohesiveness and less disturbance with depth, Alternating color layers appear in bottom of core. Coarser into Core-Catcher but no basal sand present.

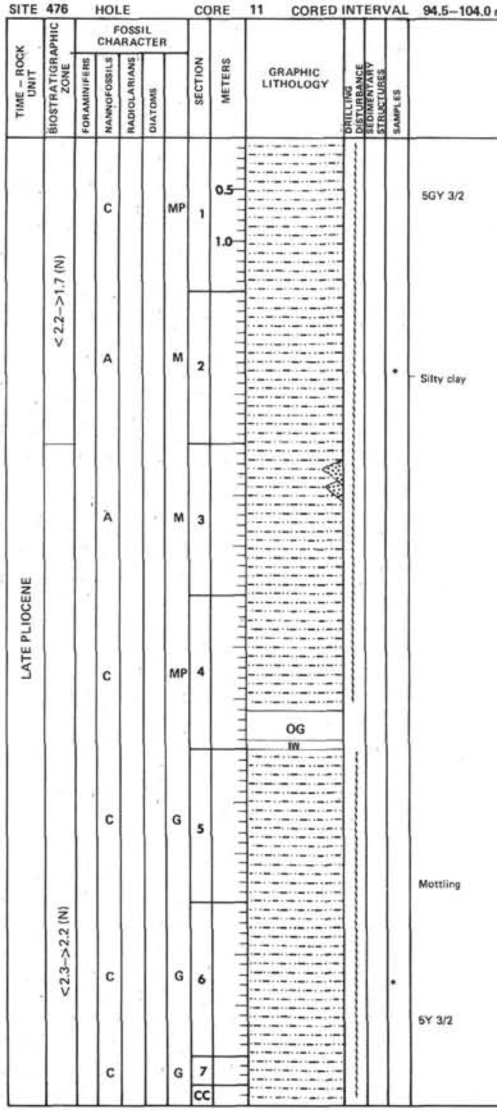
Section 7 and Core-Catcher show a turbidite with basal sand and gradual lightening of color upwards. Section 7, 51 cm: lighter layers more nannofossil-rich.

SMEAR SLIDE SUMMARY

	3-81 (D)	6-95 (M)	7-51 (M)
TEXTURE:			
Sand	TR	–	TR
Silt	30	–	45
Clay	70	–	55
COMPOSITION:			
Quartz	15	–	5
Feldspar		–	
Mica	3	–	2
Heavy minerals	5	–	3
Clay	65	–	45
Pyrite	1	–	1
Micronodules	2	–	2
Carbonate unspec.	5	–	5
Calc. nannofossils	1	–	15
Diatoms	2	–	TR
Radiolarians	1	–	–
Sponge spicules	1	–	1
Plant debris	1	–	–
Vitric ash	–	100	–

CARBONATE BOMB: 6-114 = 2%

SITE 476 HOLE CORE 11 CORED INTERVAL 94.5–104.0 m



LITHOLOGIC DESCRIPTION

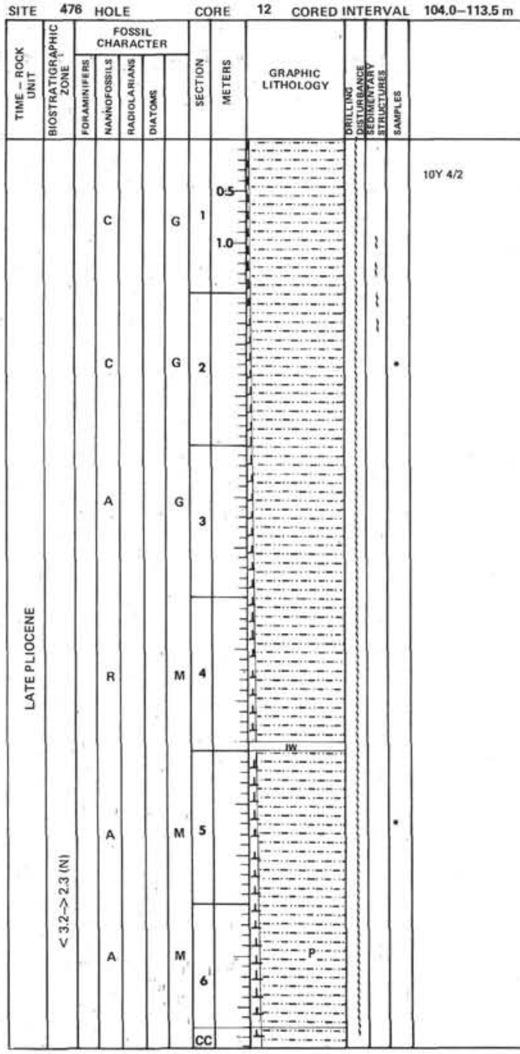
Intensely disturbed, grayish-olive green (5GY 3/2) firm **SILTY CLAY**, terrigenous mud. Small gradational color change throughout the core. Scattered mica flakes common, disappears in Section 4. No H_2S or sand layers; small sand blebs in Section 4. Section 5: darker mottling common at bottom.

SMEAR SLIDE SUMMARY

	2-80 (D)	6-80 (D)
TEXTURE:		
Sand	–	–
Silt	25	30
Clay	75	70
COMPOSITION:		
Quartz Feldspar	12	20
Mica	1	–
Heavy minerals	5	2
Clay	70	65
Pyrite	3	–
Zeolite	1	–
Carbonate unspec.	2	1
Calc. nannofossils	7	41
Diatoms	1	3
Radiolarians	TR	1
Sponge spicules	TR	1
Silicoflagellates	–	TR

CARBONATE BOMB: 4-109 = 3%

SITE 476 HOLE CORE 12 CORED INTERVAL 104.0–113.5 m



LITHOLOGIC DESCRIPTION

Intensely disturbed terrigneous mud, grayish-olive (10Y 4/2) **SILTY CLAY TO NANNOFOSSIL-BEARING SILTY CLAY**. No sand patches or H_2S. Small amount of mica visible in discrete layers (40 cm thickness). Some darker mottling in Sections 1 and 2. Reduction streaks or spots common. Faint indication of possible graded cycles of fine-grained mud turbidites.

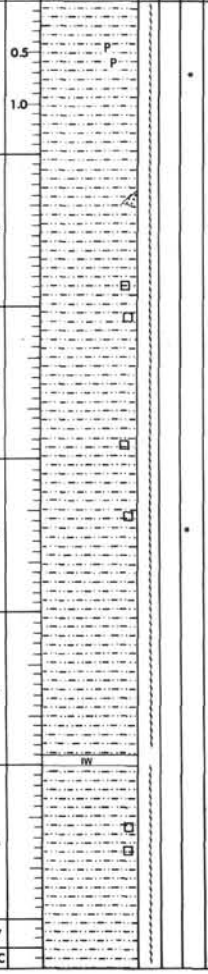
Section 5: some small pyrite nodules as burrow fillings cemented with pyrite. Scattered pumice chips also present.

SMEAR SLIDE SUMMARY

	2-70 (D)	5-70 (D)
TEXTURE:		
Sand	TR	–
Silt	35	35
Clay	65	65
COMPOSITION:		
Quartz Feldspar	10	12
Mica	–	2
Heavy minerals	2	2
Clay	60	60
Pyrite	5	1
Carbonate unspec.	2	10
Foraminifers	2	–
Calc. nannofossils	13	10
Diatoms	5	3
Radiolarians	2	1
Sponge spicules	–	1
Silicoflagellates	–	TR
Plant debris	–	TR
Discoasters	3	–

SITE 476 HOLE CORE 13 CORED INTERVAL 113.5–123.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS		SECTION
LATE PLIOCENE	<3.2–>2.3		A			M	1
							2
			A			MP	3
			A			M	4
			C			MP	5
			R			G	6
			C			G	7
							CC



LITHOLOGIC DESCRIPTION

10Y 4/2

Nannofossil-bearing silty clay

Highly disturbed uniform mud, grayish-olive (10Y 4/2) to dusky yellow green (5GY 5/2) to grayish-green (10GY 5/2) firm **SILTY CLAY**. No H_2S or sand layers. Pyritized burrow fillings and pebbles of andesite tuff common. Reduction streaks and spots common. Small sand blebs (1 to 2 cm) could be burrow filling. More mica and darker color at bottom of core.

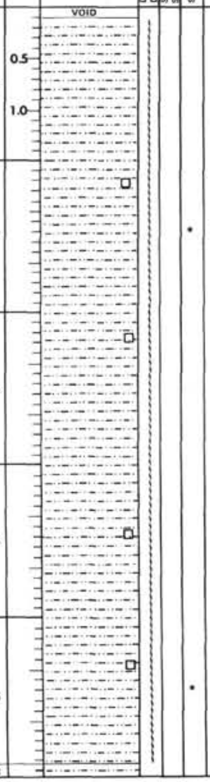
SMEAR SLIDE SUMMARY

	1-70 (D)	4-70 (D)
TEXTURE:		
Sand	–	–
Silt	30	25
Clay	70	75
COMPOSITION:		
Quartz Feldspar	20	20
Mica	2	1
Heavy minerals	3	2
Clay	60	65
Pyrite	1	1
Carbonate unspec.	3	3
Calc. nannofossils	5	5
Diatoms	2	5
Radiolarians	TR	TR
Sponge spicules	TR	1- 2
Silicoflagellates	–	TR
Discoasters	1	1

CARBONATE BOMB: 1-61 = 2%

SITE 476 HOLE CORE 14 CORED INTERVAL 123.0–132.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS		SECTION
LATE PLIOCENE	<3.2–>2.3		C			M	1
							2
			A			G	3
			A			MP	4
			A			M	5
							CC



LITHOLOGIC DESCRIPTION

10GY 5/2

Silty clay

Highly disturbed, homogeneous, grayish-green (10GY 5/2) **SILTY CLAY**; hemipelagic mud with minor, poorly preserved siliceous debris. No evidence for sand, or H_2S. Bioturbation mottles, scattered reduction specks and streaks common. Some scattered tuff pebbles.

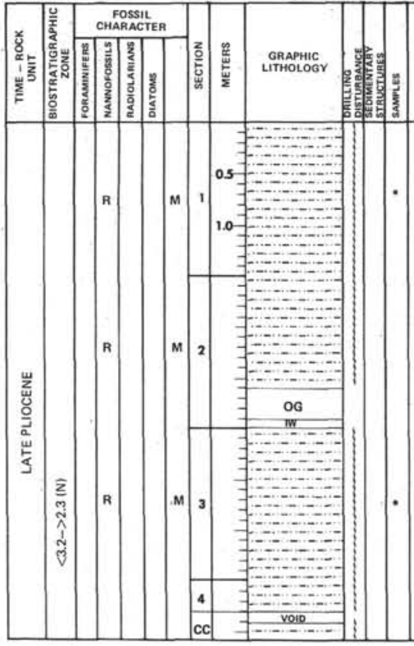
SMEAR SLIDE SUMMARY

	2-70 (D)		5-70 (D)
TEXTURE:			
Sand	1		–
Silt	40		40
Clay	60		60
COMPOSITION:			
Quartz	20		15
Feldspar			3
Mica	3		2
Heavy minerals	–		1
Clay	65		60
Glauconite	TR		–
Pyrite	2		2
Carbonate unspec.	1		5
Foraminifers	–		1
Calc. nannofossils	2		4
Diatoms	5		5
Radiolarians	1	(a)	1
Sponge spicules	2		3
Silicoflagellates	–		1

[a] Siliceous components as debris fragments.

CARBONATE BOMB: No HCl reaction

SITE 476 HOLE CORE 15 CORED INTERVAL 132.5–142.0 m



LITHOLOGIC DESCRIPTION

Intense drilling disturbance, dusky yellow green (5GY 5/2) **SILTY CLAY.** Bioturbation, reduction streaks common. No H_2S at sandy layers. Hemipelagic mud containing some poorly preserved siliceous fossil debris.

Section 3, 74 cm: bleb, gritty white silt as a burrow filling(?) containing very angular fragments of a low R.I. (~1.52). Low bifringence clear mineral (quartz?). Some crystal faces, choncoidal fracture.

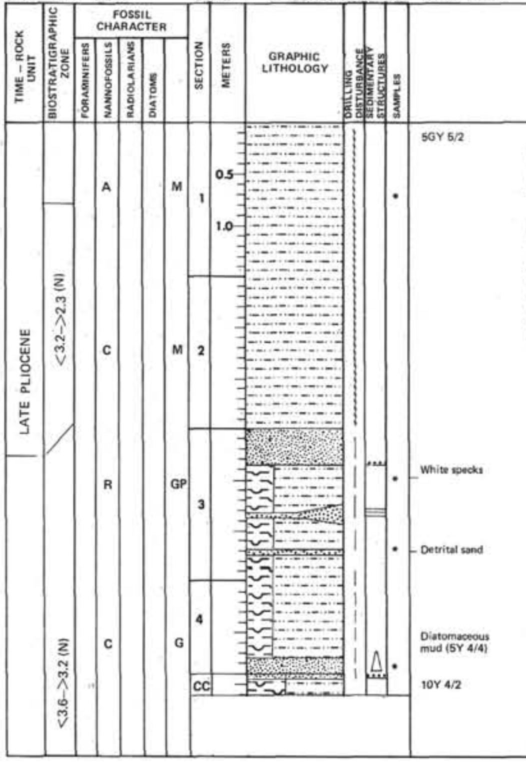
SMEAR SLIDE SUMMARY

	1-70 (D)	3-74 (M)	
TEXTURE:			
Sand	1	85	
Silt	39	15	
Clay	60	–	
COMPOSITION:			
Quartz	25	70?	
Feldspar		20	
Mica	3	2	
Heavy minerals	1	2	
Clay	65	5	
Pyrite	3	–	
Carbonate unspec.	1	–	
Calc. nannofossils	2	1	
Diatoms	3		
Radiolarians	2		Siliceous preservation
Sponge spicules	1		poor

CARBONATE BOMB: No HCl reaction
2-108 = 1%

	3, 77–79
Lithology	Silty sand
Sand	58.94
Silt	35.98
Clay	5.08

SITE 476 HOLE CORE 16 CORED INTERVAL 142.0–151.5 m



LITHOLOGIC DESCRIPTION

Sections 1 and 2, intensely disturbed, firm, grayish-green (5GY 5/2) **SILTY CLAY** with some streaks and patches of slightly more olive. No evidence for sand or carbonate. Minor reduction spots. Minor siliceous debris present.

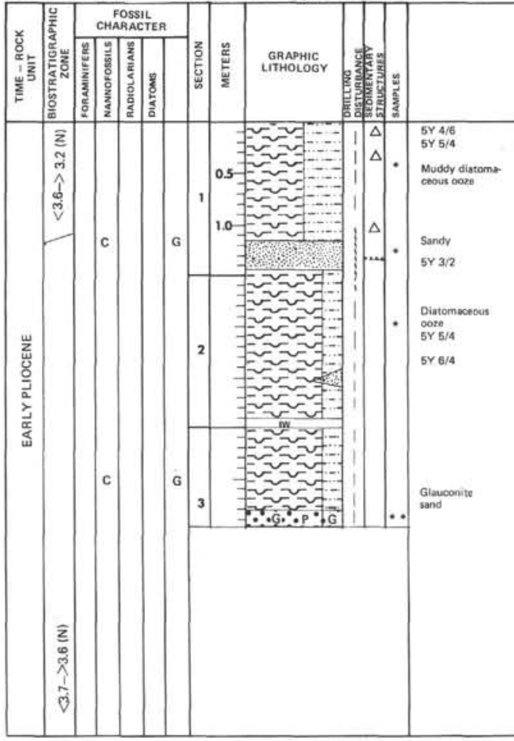
Sections 3 and 4: change to less disturbed, hard, **DIATOMACEOUS MUD,** dusky yellow green (5GY 5/2) to grayish-olive (10Y 5/2) with faint pale olive (10Y 6/2) mottles. Structureless, without carbonate. Well-preserved diatoms. Moderately well-sorted grain-supported **SANDS** as discrete beds (1 to 2 cm thick). Quartz-biotite-feldspar variety, accessory foraminifers, lower contact sharp. Possibly some heavily burrowed silty, faintly graded. Muds are redeposited. Rare white, (?) **SAND SPECKS** as burrow fillings at Section 3, 50 cm.

SMEAR SLIDE SUMMARY

	1-70 (D)	3-50 (M)	3-120 (CF)	4-84 (D)
TEXTURE:				
Sand	2	50	90	5
Silt	28	50	10	60
Clay	70	–	–	35
COMPOSITION:				
Quartz	15	60	75	15
Feldspar	10	30	10	10
Mica	2	3	5	1
Heavy minerals	2	–	–	1
Clay	60	–	–	40
Glauconite	–	–	–	TR
Pyrite	6	–	–	3
Opaques	–	2	–	–
Zeolites	–	2(?)	–	–
Carbonate unspec.	–	–	–	2
Foraminifers	–	–	10	–
Calc. nannofossils	4	–	–	3
Diatoms	2	–	–	25
Radiolarians	2	–	–	1
Sponge spicules	1	–	–	1
Silicoflagellates	–	–	–	5
Plant debris	2	–	–	–

CARBONATE BOMB: No HCl reaction

SITE 476 HOLE CORE 17 CORED INTERVAL 151.5–161.0 m



LITHOLOGIC DESCRIPTION

Uniform, firm, moderate olive brown (5Y 5/4), light olive brown (5Y 4/6) to light olive gray (5Y 5/2) and dusky yellow (5Y 6/4) shades of **MUDDY DIATOMACEOUS OOZE** faintly mottled. Darker layers are slightly siltier with gradational contacts but upward fining. Scattered poorly-sorted sandier zones. Slightly calcareous with discoasters and coccoliths corroded.

Section 3, 86 to 87 cm: thin dark gray (N2) **GLAUCONITE SAND**, well-sorted with abundant benthic foraminifera, partly glauconite filled. Quartzose sand above and below.

CF 1, 120 cm: well-sorted, angular quartz, sand, and rock fragments.

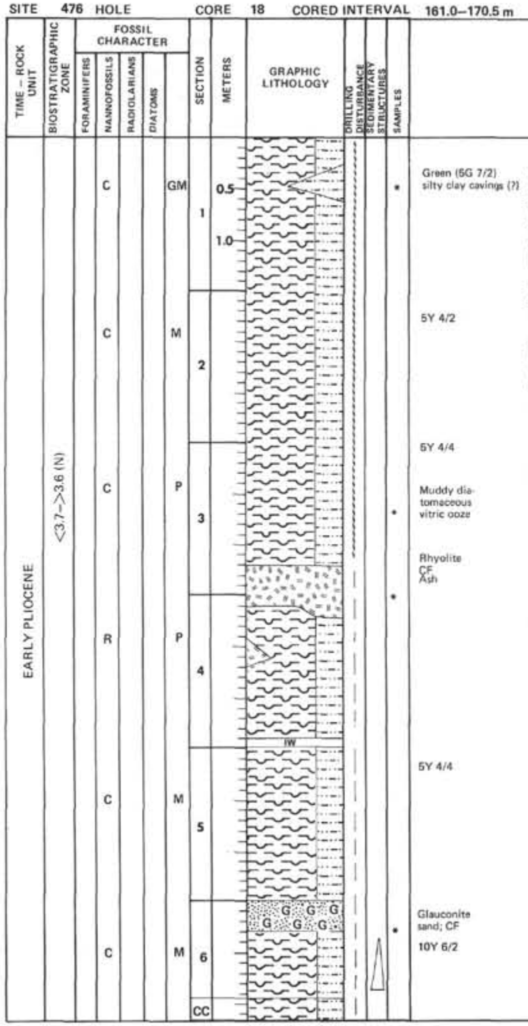
SMEAR SLIDE SUMMARY

	1-42 (D)	1-128 (D)	2-49 (D)	3-86 (M)	3-86 (CF)
TEXTURE:					
Sand	5	70	–	65	–
Silt	70	20	80	30	–
Clay	25	–	10	5	–
COMPOSITION:					
Quartz	15	65	3	50	30
Feldspar	10				
Mica	2	–	–	2	–
Heavy minerals	1 [a]	–	1	3	–
Clay	25	–	10	5	–
Glauconite	1	1	–	30	40
Pyrite	4	3	2	2	–
Carbonate unspec.	3	20	20	–	–
Foraminifers	–	5	–	5	30
Calc. nannofossils	–	–	5	1	–
Diatoms	35	5	60	2	–
Radiolarians	2	2	3	–	–
Sponge spicules	2	–	–	–	–
Silicoflagellates	3	1	1	–	–

[a] Includes several saw-tooth pyroxenes.

CARBONATE BOMB: 3-82 = 4%

SITE 476 HOLE CORE 18 CORED INTERVAL 161.0–170.5 m



LITHOLOGIC DESCRIPTION

Drill hash in Sections 1 and 2, then uniform, moderate olive brown (5Y 5/4–4/4) **MUDDY DIATOMACEOUS OOZE** with some scattered sand-filled burrows, diffuse olive gray (5Y 3/2) zones (Section 4, 64–85 cm and Sections 5, 77, 101–103, and 140–150 cm). Traces of possible grading with gradationally darker colors downward (Section 6, 33–96 cm) and a pale olive (10Y 6/2) top.

Section 3, 130 cm to Section 4, 15 cm: dark gray (N2–N4), well-sorted, thick **VITRIC ASH**, no feldspar fragments, rhyolitic, R.I. ~1.50, grain-size – 100 to 300 microns, clear shards.

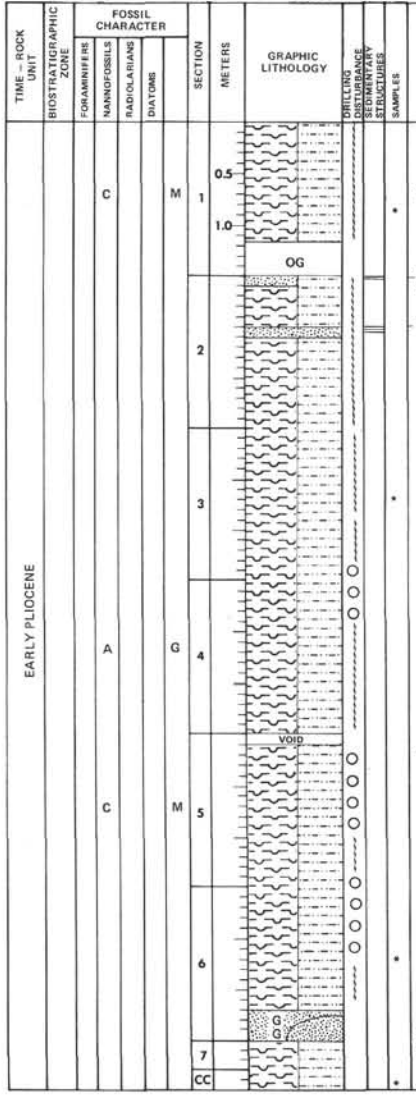
Section 6, 0 to 33 cm: very sandy mud from **FINE GLAUCONITE SANDY MUD**, quartzose with benthic foraminifers. Pelagic foraminifers are filled with glauconite. A 2 cm basal band of well-sorted glauconite sand occurs. Not graded.

SMEAR SLIDE SUMMARY

	1-50 (M)	3-70 (D)	4-2 (M)	6-30 (CF)
TEXTURE:				
Sand	2	5	30	–
Silt	60	55	60	–
Clay	38	40	10	–
COMPOSITION:				
Quartz	15	15	–	30
Feldspar				
Mica	–	3	–	3
Heavy minerals	–	1	–	–
Clay	65	20	–	–
Volcanic glass	–	2	95	–
Glauconite	–	–	–	30
Pyrite	1	5	–	10
Micronodules	2	–	–	–
Carbonate unspec.	5	3	–	–
Foraminifers	–	–	–	20 (benthic)
Calc. nannofossils	2	5	–	–
Diatoms	15	–	5	45
Radiolarians	–	–	–	1
Sponge spicules	–	–	–	TR
Silicoflagellates	1	–	–	6
Plant debris	–	1	–	–
Rock fragments	–	–	–	5

CARBONATE BOMB: 5-40 = 4%
6-88 = 3%

SITE 476 HOLE CORE 19 CORED INTERVAL 170.5–180.0 m



LITHOLOGIC DESCRIPTION

Slightly sandy diatomaceous mud

N4

5Y 4/4

N4

5Y 5/4

Diatomaceous mud

Uniform, firm but disturbed moderate olive brown (5Y 4/4 to 5/4) **MUDDY DIATOMACEOUS OOZE**. Scattered specks and blebs of sandy, white silt, in burrows. Massive, without HCl reaction. A few zones of darker gray (N2–N4) fine ungraded glauconitic sand at Section 2, 0 to 12 cm and 55 to 70 cm, and Section 6, 135 to 150 cm. Scattered tiny vitric patches.

CF 19, CC: Radiolaria, diatoms, 50% small foraminifers, 30% glauconite, 1% biotite, and 10% quartz.

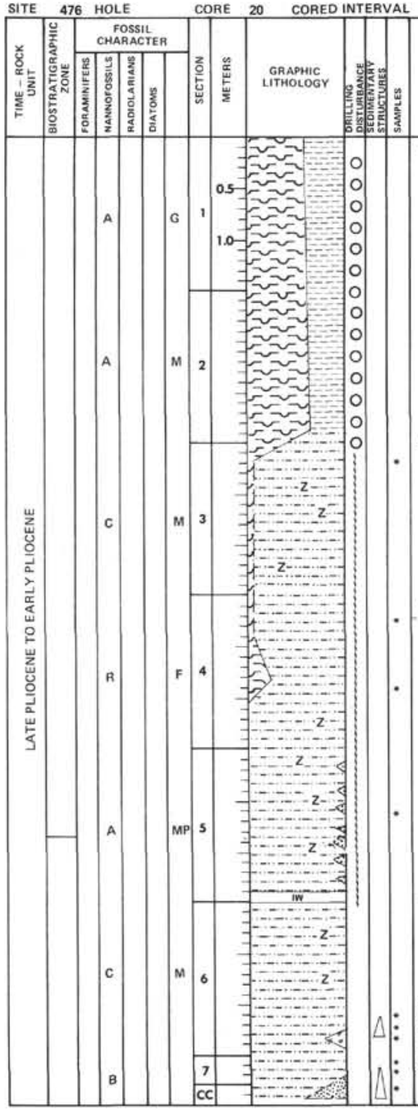
SMEAR SLIDE SUMMARY

	1-87 (D)	3-70 (D)	6-70 (D)
TEXTURE:			
Sand	20	TR	TR
Silt	70	40	50
Clay	10	60	50
COMPOSITION:			
Quartz }	40	5	5
Feldspar }		3	2
Heavy minerals	3 [(a)]	–	–
Clay	10	35	20
Volcanic glass	–	2	–
Glauconite	–	2	–
Pyrite	3	5	5
Carbonate unspec.	2	3	3
Calc. nannofossils	–	1	1
Diatoms	30	40	60
Radiolarians	–	TR	TR
Sponge spicules	1	1	1
Silicoflagellates	5	2	2
Plant debris	–	1	1

(a) Possible monazite

CARBONATE BOMB: No HCl reaction
1-96 = 1%
1-106 = 3%

SITE 476 HOLE CORE 20 CORED INTERVAL 180.0–189.5 m



LITHOLOGIC DESCRIPTION

5Y 5/2

5Y 5/2

Hard silt

10Y 4/2

Dark mottled
Light top
Ash graded cycles
Top
Middle
Base

Sections 1 and 2, homogeneous, light olive gray (5Y 5/2) **MUDDY DIATOMACEOUS OOZE** – almost a drilling breccia. Some mottles and traces of former sandy layers.

Section 3: change in lithology to hard, light olive gray (5Y 5/2) **SILTY CLAY TO ZEOLITIC MUD** with a brownish cast. Smear slides show a very fine-grained low R. I., low bifringence elongated ragged mineral (~4 microns) identified as **ZEOLITE** AND a dwindling of siliceous debris. Bedding is disturbed to vertical. Some sandier zones with glauconite (Section 5, 31 to 32, 45 to 47, 65 to 66, 82 to 84, 93 to 94, 110 to 112, and 120 cm) are more calcareous.

Section 6, 99 to 150 cm: 3 rhythmic units present. Grading color shades continuing into Section 7 and Core-Catcher. One typical unit (Section 7, 10 to 28 cm) sampled from gray (N2) silty sand to olive gray (10Y 4/2) to grayish-olive green (5GY 3/2) to dusky yellow green (5GY 5/2) zeolitic silty clay. One thin bed (Section 6, 134 cm) possibly **ASH**; with small amount of glass, mostly opaques and clear sanadine fragments.

SMEAR SLIDE SUMMARY

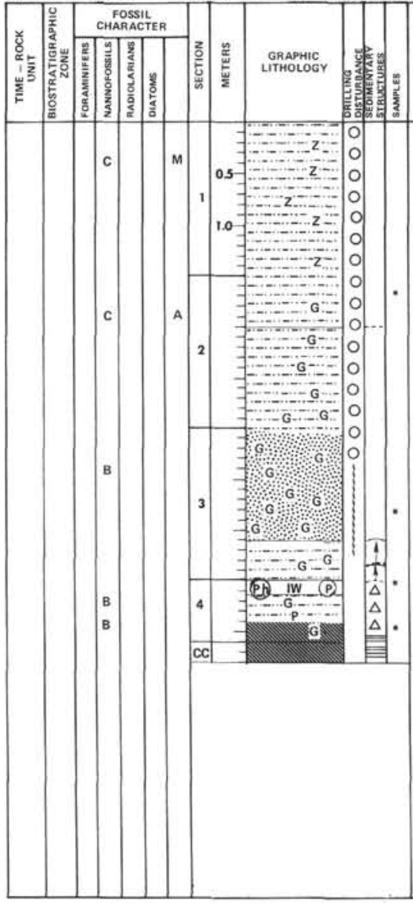
	3-70 (D)	4-28 (D)	4-91 (D)	5-64 (D)	6-112 (D)	6-127 (D)	6-134 (M)	7-11 (D)	7-19 (D)	7-28 (M)
TEXTURE:										
Sand	3	10	TR	2	1	–	–	–	–	–
Silt	27	40	40	23	15	20	75	30	80	35
Clay	70	50	60	75	84	80	25	70	20	65
COMPOSITION:										
Quartz	3	10	20	10	10	5	10	7	35	7
Feldspar	3[(a)]	10	5	5	5	3	30	3		3
Mica	2	5	2	2	1	2	2	2	–	1
Heavy minerals	1	1	–	1	–	–	2	1-	–	15
Clay	35	20	35	40	40	25	30	35	20	25
Volcanic glass	1	–	–	–	–	–	–	2	–	–
Glauconite	2	5	3	5	–	–	–	–	–	
Pyrite	6	5	1	1	2	2	–	10	3	20
Micronodules	2	–	1	–	–	–	–	–	–	–
Zeolite	20[(b)]	25	10	35	35	40	5	30	15	30
Carbonate unspec.	–	13	4	3	10	5	–	–	–	–
Calc. nannofossils	3	3	TR	2	3	15	–	TR	2	TR
Diatoms	5	5	15	2	TR	–	–	–	–	–
Radiolarians	TR	–	TR	–	–	–	–	–	–	–
Sponge spicules	1	–	1	–	–	–	–	–	–	–
Silicoflagellates	1	–	1	–	–	–	–	–	–	–
Plant debris	1	5	–	–	–	–	–	–	5	–
Opaque	–	–	–	–	–	–	50	–	–	2

(a) K-Fe

(b) Zeolites very small ~4 µm, may in part contain fine siliceous debris.

CARBONATE BOMB: 3-120 = 11%
4-48 = 12%

SITE 476 HOLE CORE 21 CORED INTERVAL 189.5–199.0 m



LITHOLOGIC DESCRIPTION

5Y 5/2

5Y 5/2

5G 3/2
Glauconite sand

5Y 5/2
Phosphorite

Organic claystone
5Y 2/1

Section 1 and 2: mostly drilling breccia of fine light olive gray (5Y 5/2) **ZEOLITIC SILTY CLAY** with minor silt.

Section 2: spaces between firm clay "biscuits" is filled with **GLAUCONITIC SAND,** grayish olive green (5G 3/2) well-sorted, loose, with little or no matrix. Increases to Section 3 to a thick uniform medium fine sand bed including abundant quartz and glauconite.

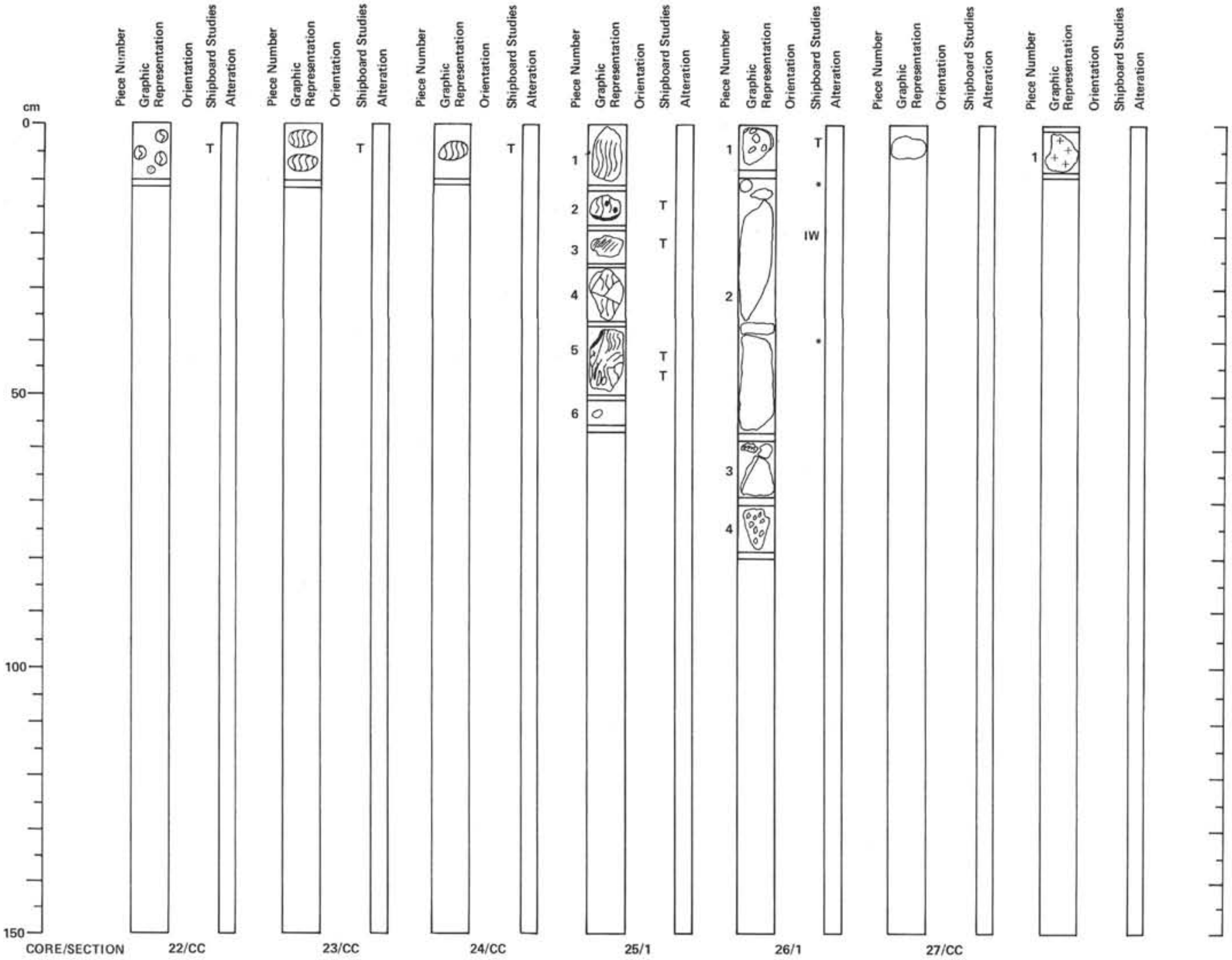
From Section 3, 110 cm to Core-Catcher: complex zone with olive gray (5Y 5/2) clayey silt with white specks, organic-rich with a thin hard **PHOSPHORITE** (Section 4, 2 cm), poorly graded beds with glauconite. A **PYRITE-CEMENTED SILTSTONE** (Section 4, 15 cm), and at Section 4, 18 to 52 cm cycle rhythms with burrow fills, pyrite. A green **CEMENTED SILTSTONE** at Section 4, 52 cm. At Section 4, 52 to 72 cm, olive black (5Y 2/1) **ORGANIC CLAYSTONE TO SAPROPEL** with microlaminations, petroliferous odor, quartz silt, glauconite, and pyrite.

TS 4, 50 cm: Quartz (70%)—mica (15%) siltstone. Low-grade metamorphic, undulating extinction, irregular grains. Relict plagioclase, granoblastic rare amphibole, no linerar texture, equigranular.

SMEAR SLIDE SUMMARY

	2-79 (D)	3-83 (M)	4-2 (M)	4-48 (M)	CC (M)	CC (M)
TEXTURE:						
Sand	–	50	–	10	–	5
Silt	40	15	–	60	–	55
Clay	60	35	–	30	–	40
COMPOSITION:						
Quartz	20	15	TR	30	20	50
Feldspar	10	10	–	20	3	
Mica	3	5	–	2	–	2
Heavy minerals	5	–	1	1	3	2
Clay	25	15	–	30	30	35
Volcanic glass	–	–	5	–	–	–
Glauconite	10	30	–	2	20	–
Pyrite		10	–	3	–	5
Zeolite	15	15	–	–	–	–
Carbonate unspec.	5	–	–	1	–	2
Calc. nannofossils	10	–	–	–	–	2
Radiolarians	–	–	–	–	–	TR
Plant debris	–	–	–	20	–	5
Phosphorite	–	–	60	2	30	TR
Opaque specks	–	–	20	–	20	–

CARBONATE BOMB: 3-46 = 0%
4-43 = 0%
CC = 0%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CORE/SECTION
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23/CC
24/CC
25/1
26/1
27/CC

64-476-22 **Depth 199.0 to 208.5 m**

CORE-CATCHER:

Macroscopic Description

Recovery was only a few specks of well-sorted, sand with numerous, cloudy, gray rounded quartz and some pink, possibly weathered K-feldspars. Rare augite, minor carbonate, and specks of grayish green. A tiny fragment of possibly quartz-albite-epidote-chlorite-staurolite(?) metasiltstone.

TS CC: granoblastic; micaceous QUARTZITE, cataclastic, recrystalized, some zones with fabric.

50% irregular broken quartz grains, 1–2 mm, stressed, mosaic fragments, angular, fractured
20% muscovite as cement and grain envelopes
2% relict plagioclase
5% replace; altered feldspar
2% rock fragments (quartz schist)

64-476-23 **Depth 208.5 to 218.0 m**

CORE-CATCHER:

Macroscopic Description

One cored piece of a large METAMORPHIC COBBLE. Part of a conglomerate bed. Light bluish gray (5B 7/1) green schist facies, silicified sandstone, fine-grained. May contain albite, brown mica, but 75% quartz. Some graphite, pyrite.

TS CC: metasandstone; granoblastic coarse micaceous, QUARTZITE.
35% quartz grains, broken, angular, stressed 0.25–0.50 mm
35% muscovite, (0.025 m) stressed, deformed
30% quartz-mica mesh work (0.025 m) matrix
Scattered relict grain boundaries, feldspars, cataclastic zones.

64-476-24 **Depth 218.0 to 227.5 m**

CORE-CATCHER:

Macroscopic Description

Hard, metasandstone, greenish gray (5G 4/1) quartzitic, pyrite seams, calcite veins, fine-grained components. Possible volcanic sources.

TS CC: QUARTZ-mica-chlorite, felsigranoblastic
10% relict grain outlines replaced by a fine quartz mosaic (~ 0.025 mm)
20% grain outlined by mica sheaves, bent, deformed (chlorite?) brownish in TS
10% quartz grains, recrystallized
35% fine quartz mosaic groundmass with mica
15% subhedral opaque grains
Similar to Core 23, Core-Catcher.

64-476-25 **Depth 227.0 to 237.5 m**

SECTION 1: DOMINANT LITHOLOGY: Polygenetic CONGLOMERATE of metamorphic and igneous rock components.

Macroscopic Description

Poor recovery, any matrix would have been washed out.
Piece 1: light colored weathered QUARTZITE; poorly-sorted, low-grade, friable, wih quartz, feldspar, chlorite, some talc, calcite. Rounded.
Piece 2: low-grade, altered, recrystallized VOLCANIC TUFF(?) andesitic(?). Fine (0.01–0.1 mm) meshwork of relict grains (0.2–0.3 mm), altered to quartz-feldspar-chlorite(?) and spears of newly formed micas. Much occluded opaque or iron-hydroxide. One calcite pseudomorph after olivine. Some possible epidote; large relict altered plagioclase phenocryst.
Piece 3: coarse-grained highly weathered GRANITIC ROCK: granoblastic, equigranular
Pieces 4 and 5: METABASALT or diabase: quartz-albite-epidote-chlorite feldspar.
At 55 cm: base has a bleb of medium dark gray (N4) to dark gray (N3) quartz-silt with (barite mud). Mostly weathered grains, angular quartz (50%), iron oxides (10%) and clay (30%).

TS Piece 3:
50% quartz (2–4 mm) stressed, fractured, veins, subangular
20% perthitic feldspars weathered to fine (0.02 mm) quartz, mica, clays
3% carbonate vein filling
2% amphibole
2% plagioclase
20% undifferentiated groundmass, fine-grained mica-quartz-macroscopically rock similar to Piece 1

TS Piece 5: mostly fine groundmass equigranular meshwork (0.05–0.1 mm) of 30% relict and replaced plagioclase, 25% mica (chlorite?) and high bf epidote needles, 10% larger quartz (0.150 mm) grains, 15% opaques. Brecciated zones criss-crossed by carbonate-filled, irregular veins, commonly lined by a quartz mosaic. Scattered pyrite crystals.

SS 1-45:
50% Quartz (angular, inclusions)
5% Feldspar (pitted, inclusions)
2% Heavy minerals (hematite, rutile)
30% Clay
1-% Fe-opaques
TR Carbonate unspec.

64-476-26 **Depth 237.5 to 247.0 m**

SECTION 1: DOMINANT LITHOLOGY: CONGLOMERATE COBBLES and GRAY SANDY CLAY.

Macroscopic Description

Piece 1: speckled greenish – WEATHERED GRANITIC ROCK. Large (5–7 mm) K-feldspar phenocrysts. Altered mafics.
Piece 2: milky white quartz pebbles (~2 cm) subangular.
Sediment – 1, 12–55 cm: medium dark gray (N4–N3) QUARTZ-ILLITE-RICH GRITTY CLAY. 5% sand, 40% silt, 55% clay, rough plastic texture, poorly sorted.
Pieces 3 and 4: altered quartz-feldspar-amphibole rock (granodioritic?) greenish-white, friable patina. Speckled. Mafics altered, replaced by chlorite(?).

TS Piece 1: granolblastic texture (1-3 mm) with many minerals altered to fine (0.01–0.02 mm) groundmass. Extensive sericitization of feldspars and mafics:
40% quartz, 1 mm, irregular, equigranular, clear, some subhedral faces interlocking mosaics. Some stressed.
20% quartz in fine groundmass meshwork
10% plagioclase albite twinned (1–2 mm) partial relict, sericitized
15% large K-feldspars, perthitic, twinned, largely altered
5% opaques as alteration of mafics
5% relicts of hornblende completely altered
15% clear mica (muscovite), as 0.5–1 mm sheaves, and alteration products in groundmass

SS Piece 2: white mud; 30% sand; 50% silt; 20% clay; 10% feldspars, highly altered; 30% 10 µm ragged crystals, low bf R.I. 1.64–1.55 (illite); 40% angular to subrounded quartz-silt; 2% calcite; 1% apatite rods; 1% rutile needles; and 10% barite from drill mud.

SS 1-40:
50% quartz, mostly silt-size, angular to subrounded, many stressed, dark inclusions
45% clay mineral, R.I. 1.55–1.57, bf = 0.10 ragged laths 1–10 µm hydromuscovite
5% feldspars, opaques, heavy minerals, and other specks
Compositionally equivalent to fault gauge of weathered granite or local pond receiving granitic debris.

64-476-27 **Depth 247.0 to 256.5 m**

CORE-CATCHER:

Macroscopic Description

Small bleb (10 cc) of greenish gray (5G 5/2) and white poorly sorted, weathered QUARTZ-FELDSPAR PEBBLE. Smashed by drilling into a coarse angular sand hash.

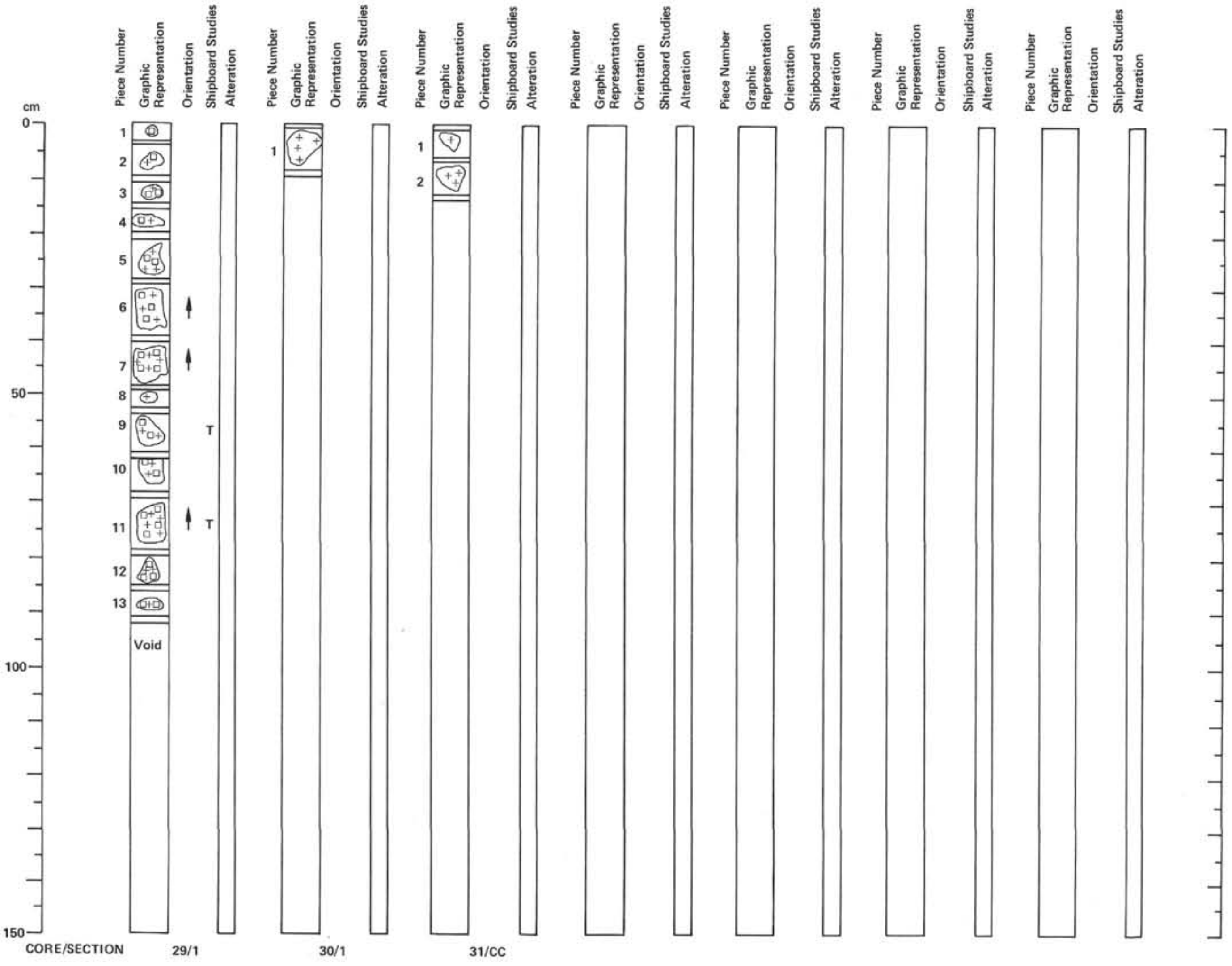
SS Core-Catcher:
30% Quartz (micromosaic)
30% Feldspar (weathered pervasive sericite)
2% Mica (chlorite)
2% Heavy minerals (opaques)
20% Clay (illite? other)
10% Other

64-476-28 **Depth 256.0 to 265.5 m**

CORE-CATCHER: DOMINANT LITHOLOGY: hornblende-biotite-granite.

Macroscopic Description

Medium-grained (largest grain size ~8 mm) light gray (~ 5B 7/1) inequigranular granitic rock.
Comprises slightly altered white feldspar (–60%) anhedral quartz (30%)(?). Equant and acicular dark green hornblende (5%) crystals, and biotite (5%) and muscovite (5%) are also present. There appears to be slight chloritization of the mafic minerals.
Pyrites are present in several patches. The uncut and cut surfaces show miarolitic cavities containing quartz (drusy). These cavities are approximately 5x2 mm in size, or smaller.
Quartz crystals appear to be fractured, and perthites can be seen in the feldspars.



64-476-29 **Depth 265.5 to 275.0 m**

SECTION 1: DOMINANT LITHOLOGY: granite.

Macroscopic Description

Light bluish gray (5B 7/1), inequigranular GRANITIC-altered with all or most of the biotite and hornblende having been chloritized. Some flow structures are seen in hand specimen – a sort of banding of the whitish feldspar separated by the grayish quartz. Flow lines could represent syn-cooling movement of crystalized masses within the mush. Alternatively the deformations could result from the rock being proximate to a fault. Some pyrite present in small veins. Pieces 5 and 12 appear to be much fresher and alteration of the mafic minerals has not progressed very far, and no flowage is visible on the cut faces.

TS Piece 9: CATACLASTIC GRANITE: silicified cataclastic matrix containing hypidiomorphic granite. Interspersed between blocks of fresher hypidiomorphic granite (5–30 mm) are zones comprising small angular fragments of quartz (0.02–1.0 mm) and feldspar in a very fine-grained opaque-rich matrix.

Composition: for hypoidiomorphic fragments:
15% plagioclase (–2 mm), albite, an- to subhedral, sericitized
40% quartz (1–3 mm) anhedral, rounded, fractured
40% alkali feldspar (1–3 mm) orthoclase, subhedral, perthite
1% zircon (0.02 mm) subhedral, in chlorite or biotite
1% sericite in feldspars
5% pseudomorphs of chlorite after biotite and hornblende

TS Piece 11: CATACLASTIC GRANITE: hypidiomorphic fragments in a cataclastic matrix (silicified). Blocks (5–30 mm) set in zones of small (0.02–10 mm) angular fragments of quartz and feldspar in a fine-grained opaque-rich matrix.
15% albite (up to 2 mm) subhedral, sericitized
40% quartz (up to 3 mm) anhedral, rounded, fractured
40% alkali feldspar (1–3 mm) subhedral, perthitic orthoclase
1% zircon (0.2 mm) subhedral, inclusion in micas
1% sericite in albites
5% pseudomorphs of chlorite after biotite and hornblende

64-476-30 **Depth 275.0 to 275.1 m**

SECTION 1: DOMINANT LITHOLOGY: HORNBLENDE-BIOTITE GRANITE

Macroscopic Description

Medium-grained (largest grain size ~6–8 mm) light gray (~5B 7/1) inequigranular granitic rock. Very similar to Core 28, Core-Catcher, Piece 1.

Comprises slightly altered white feldspars (~ 60%), anhedral quartz (~ 30%?). Equant and acicular dark green hornblende (5%) crystals, and biotite (5%), a muscovite (5%) are also present. There appears to be slight chloritization of the mafic minerals.

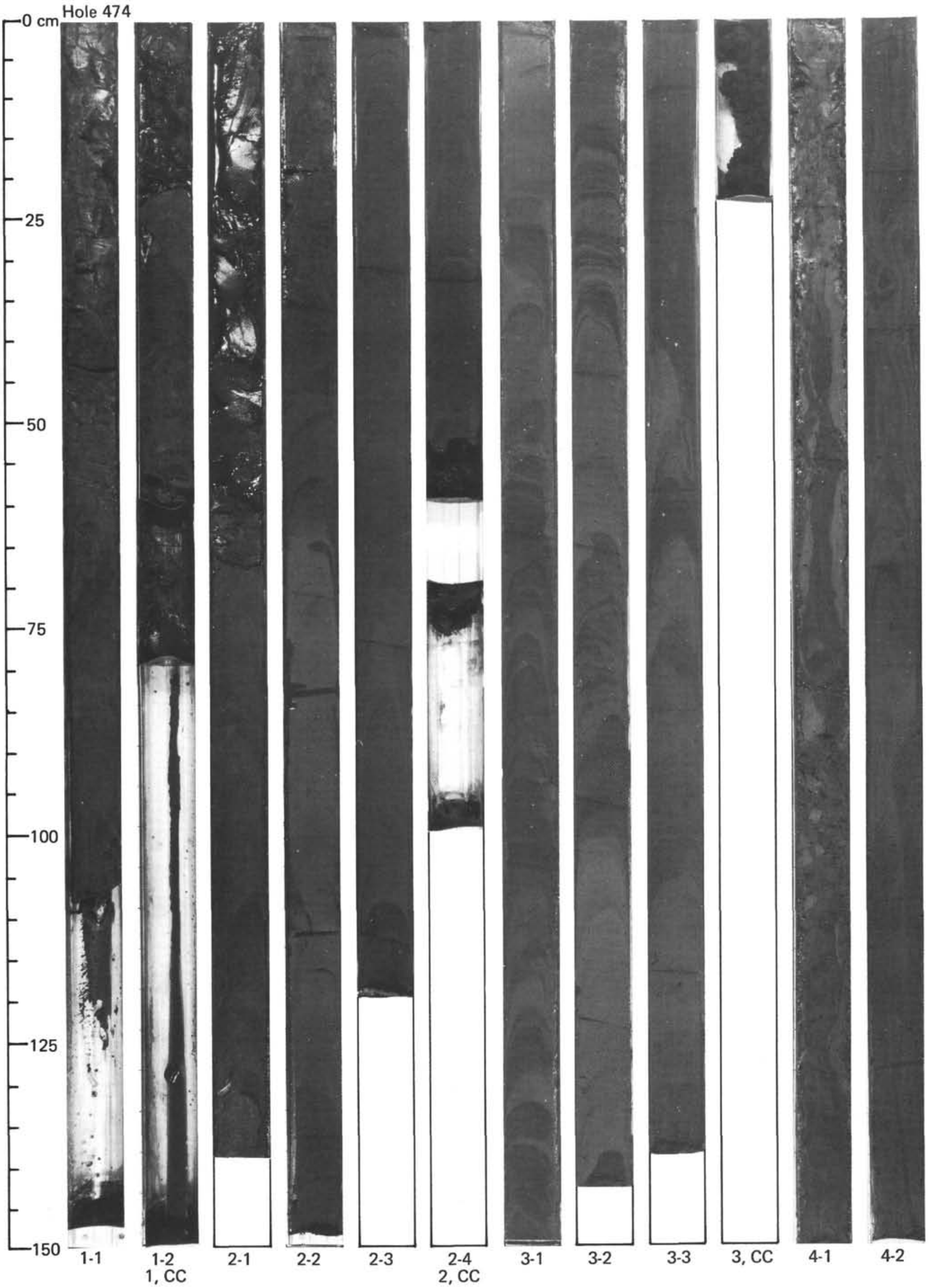
Pyrites are present in several patches. Miarolitic cavities are not seen in the piece, unlike Core 28, Core-Catcher, Piece 1.

64-476-31 **Depth 284.5 m**

CORE-CATCHER: DOMINANT LITHOLOGY: GRANITE.

Macroscopic Description

Macroscopically identical to Core 30, Section 1, Piece 1.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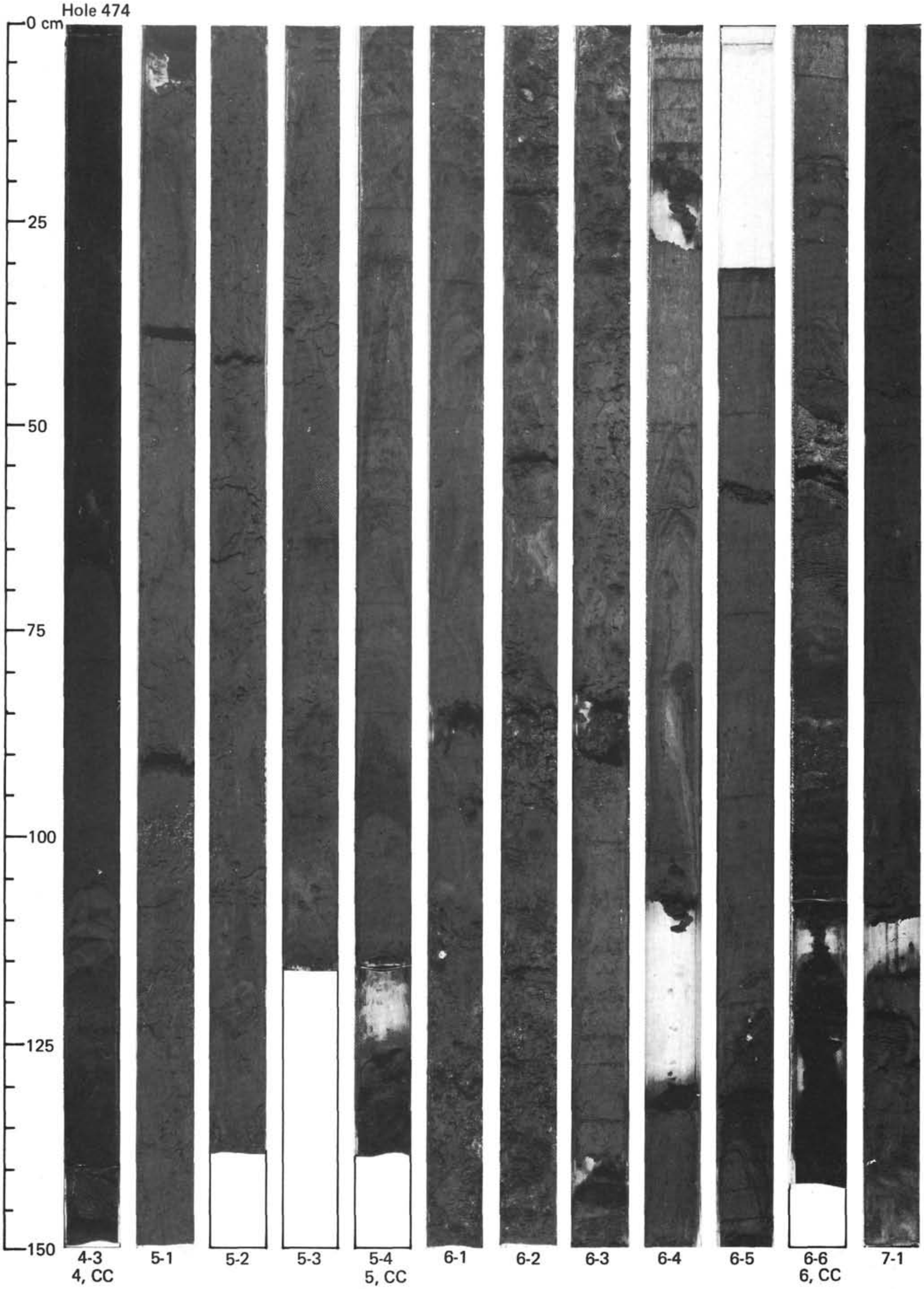
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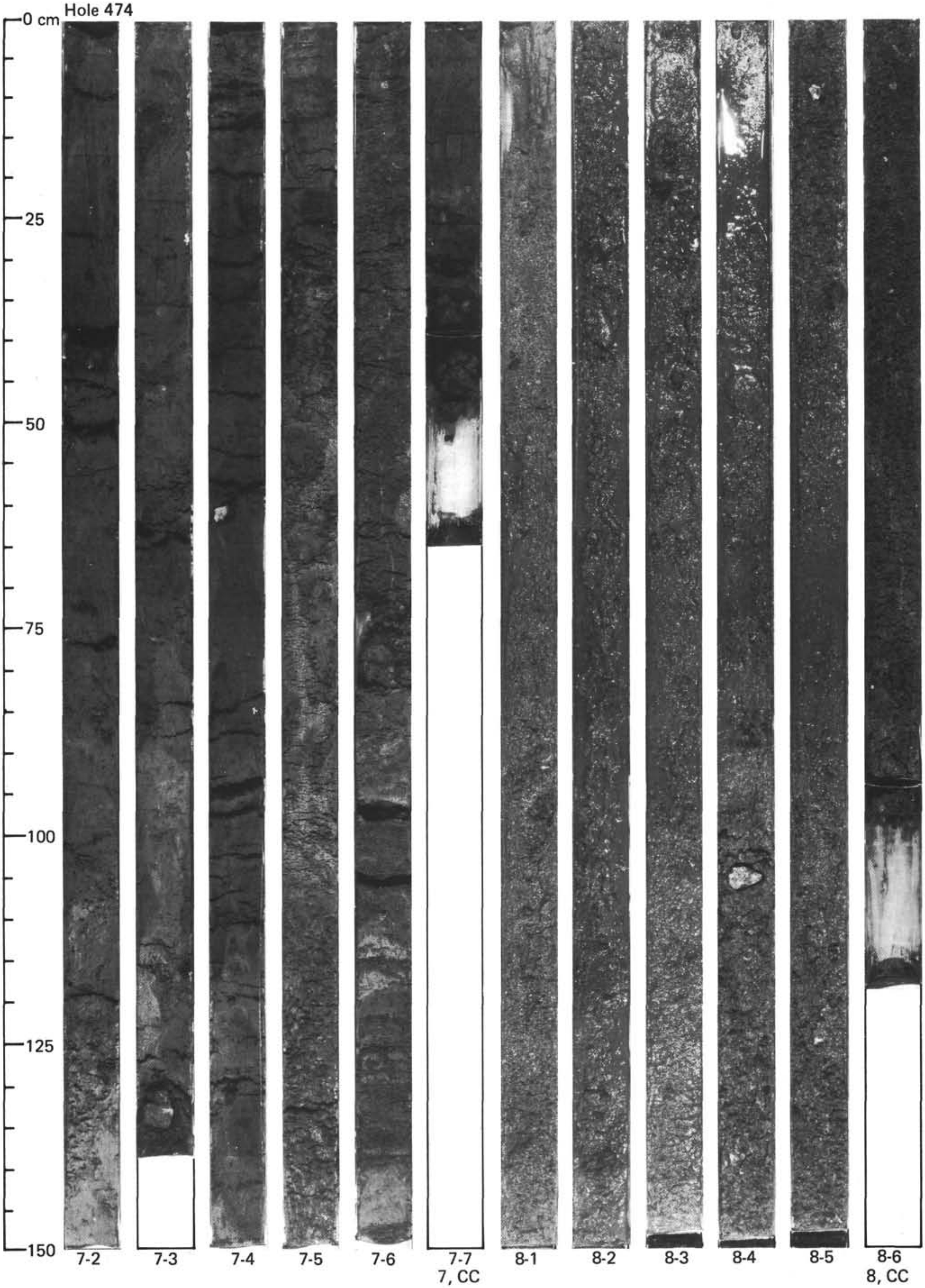
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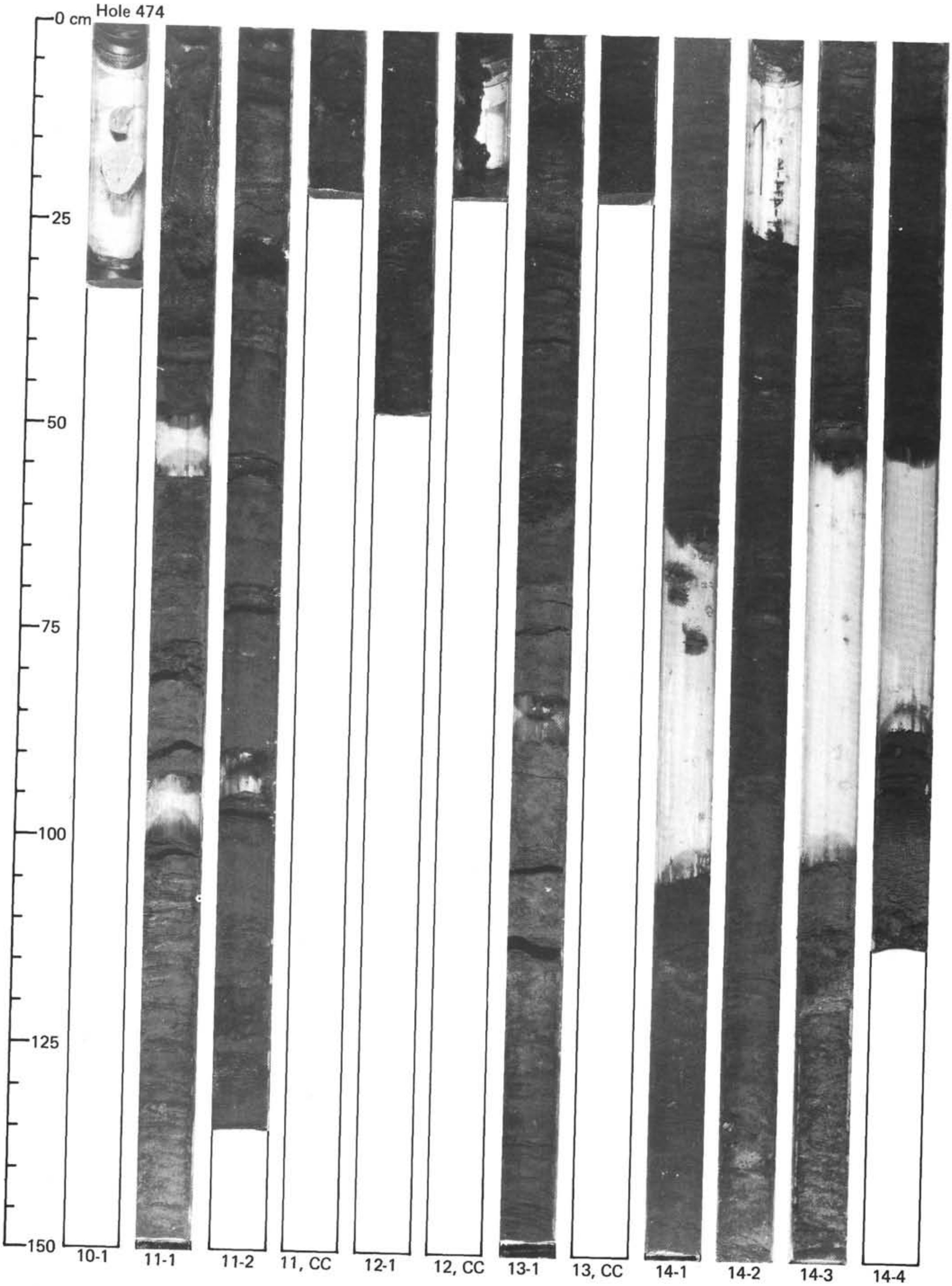
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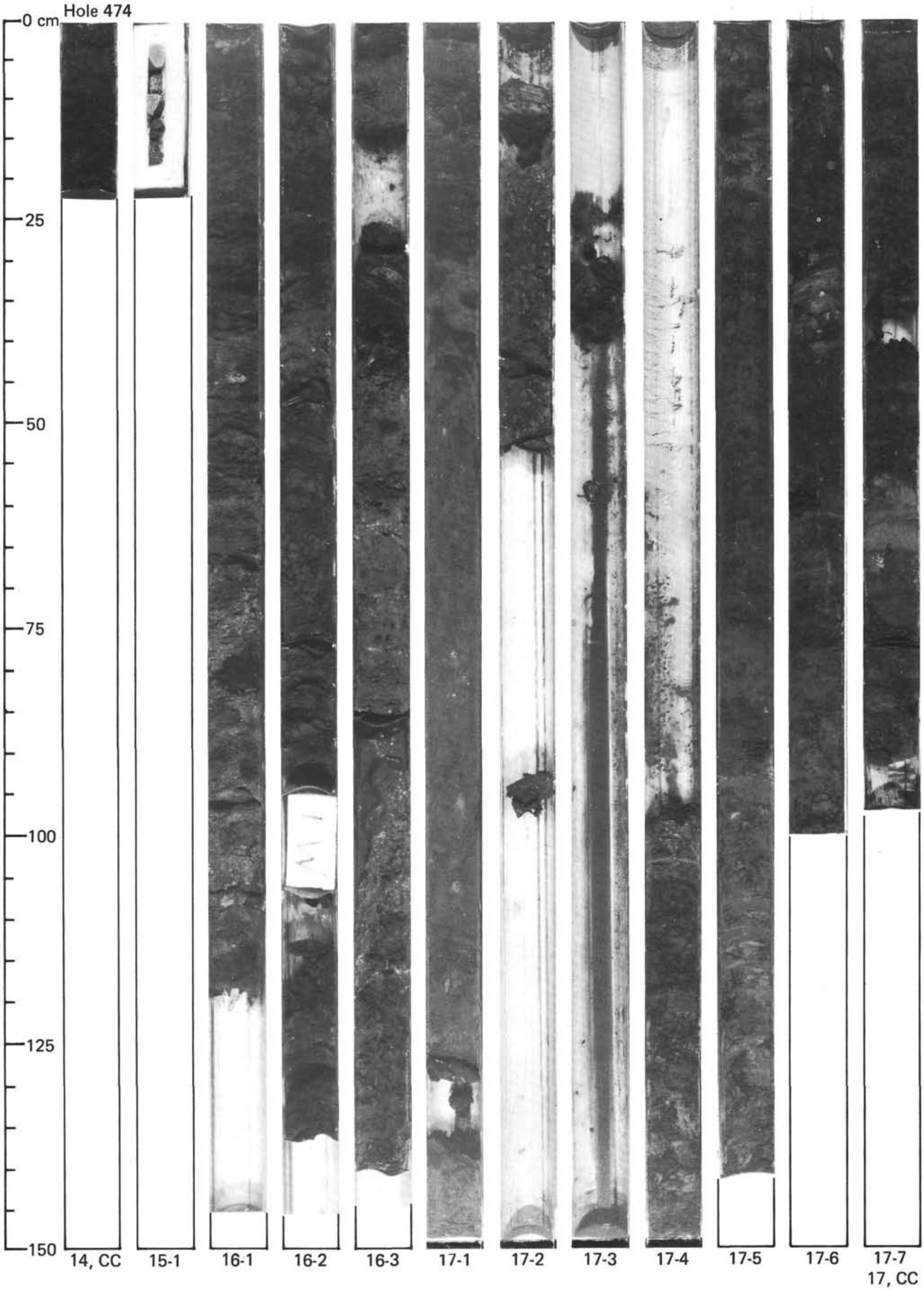
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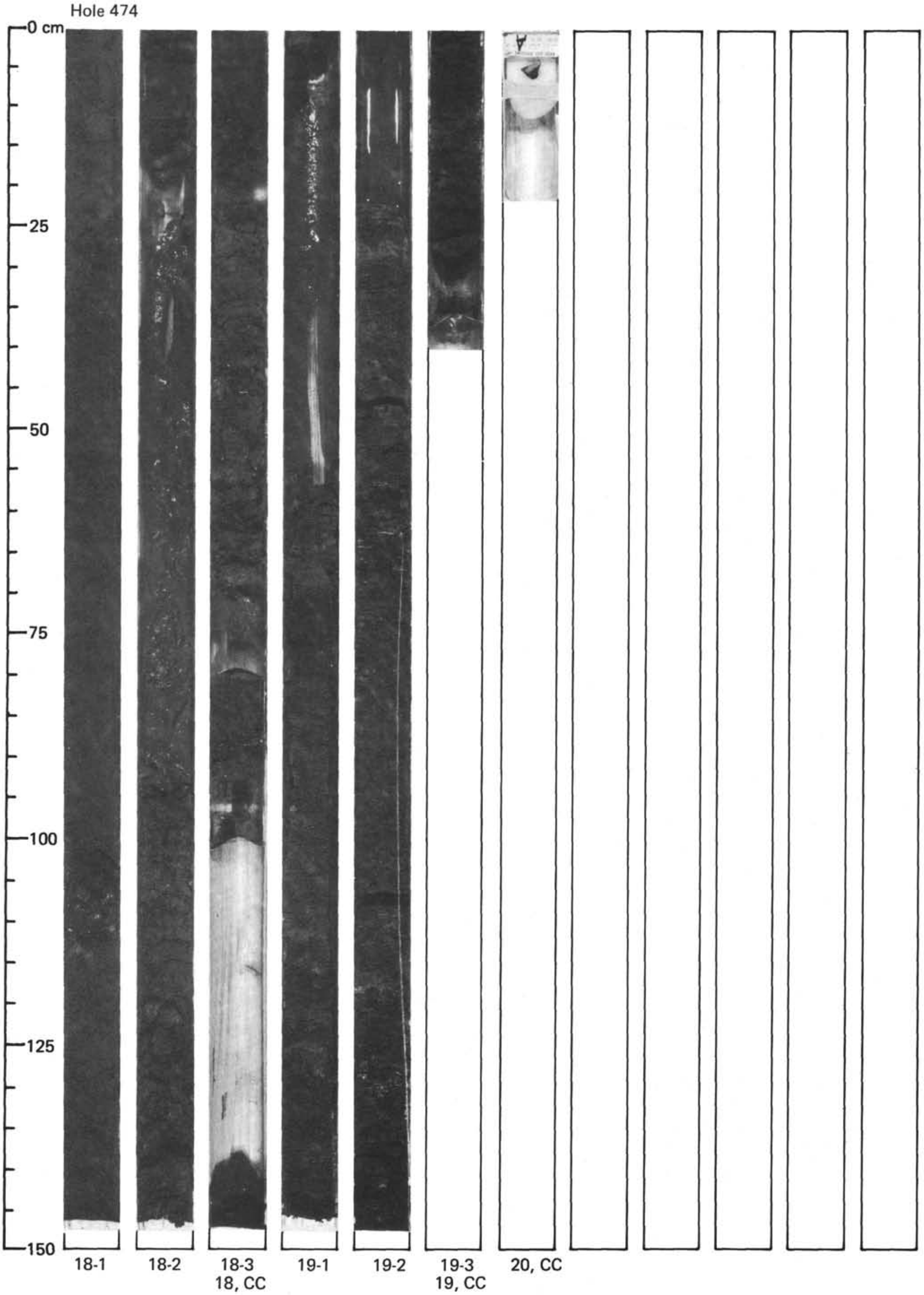
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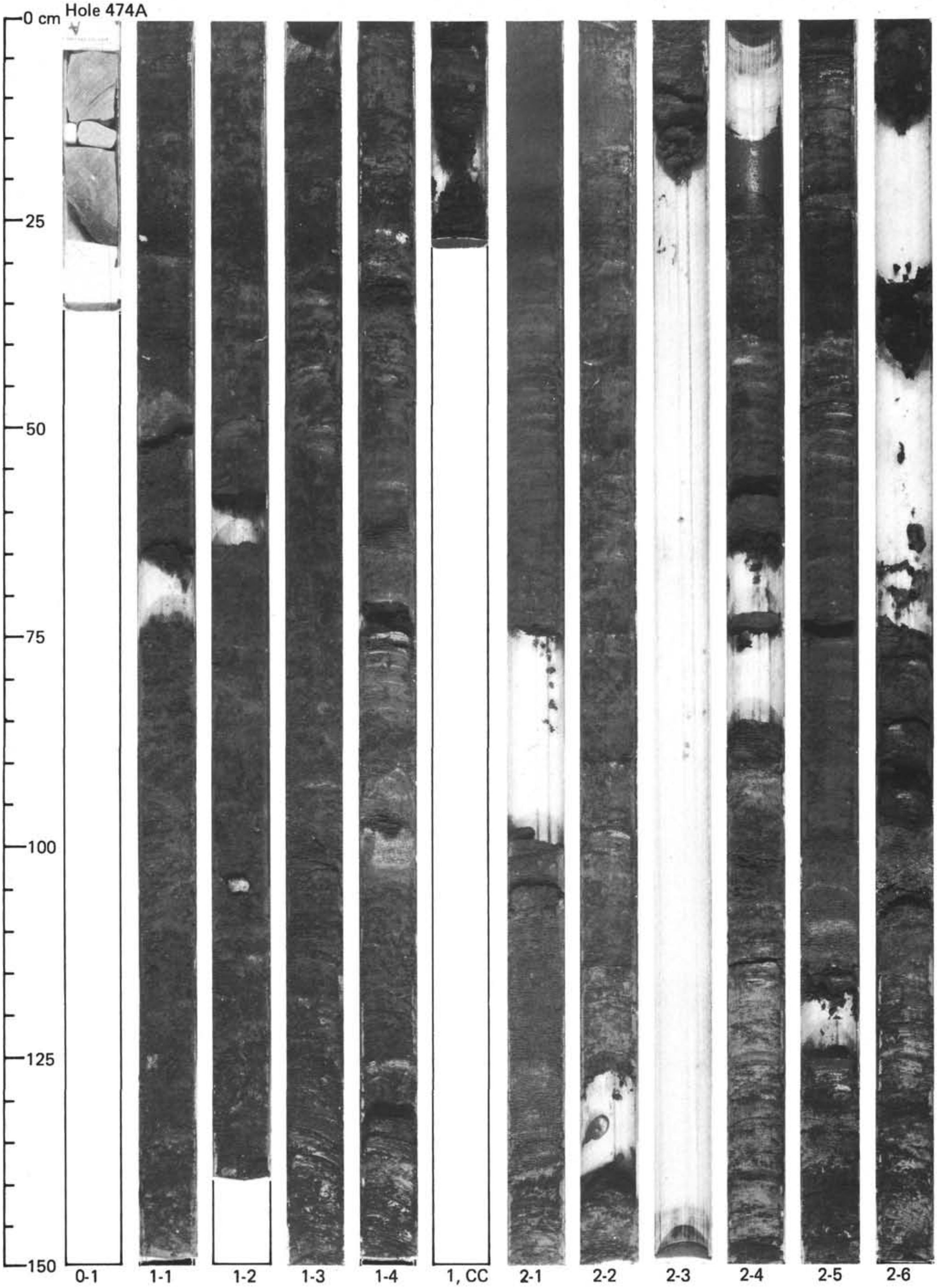
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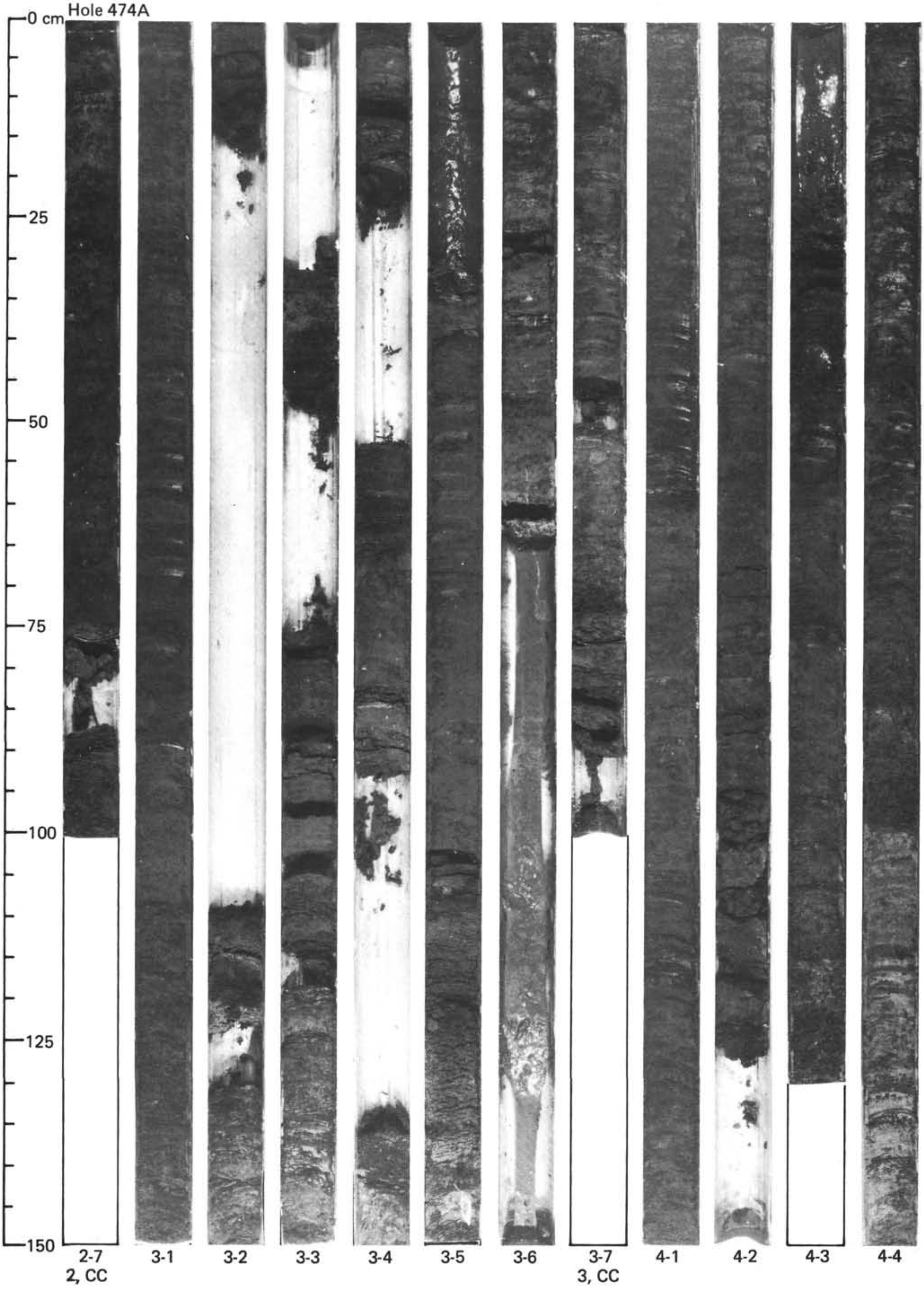
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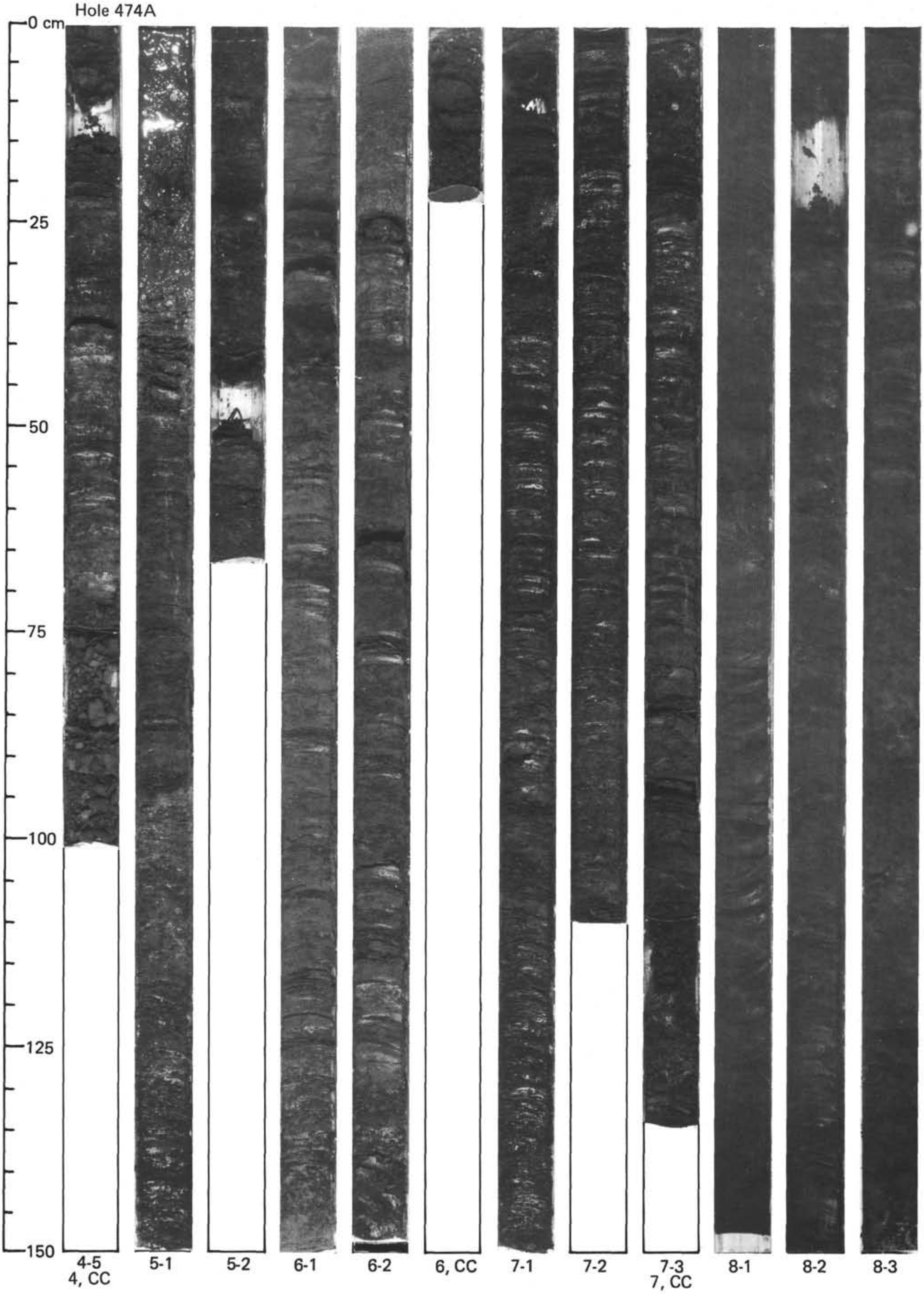
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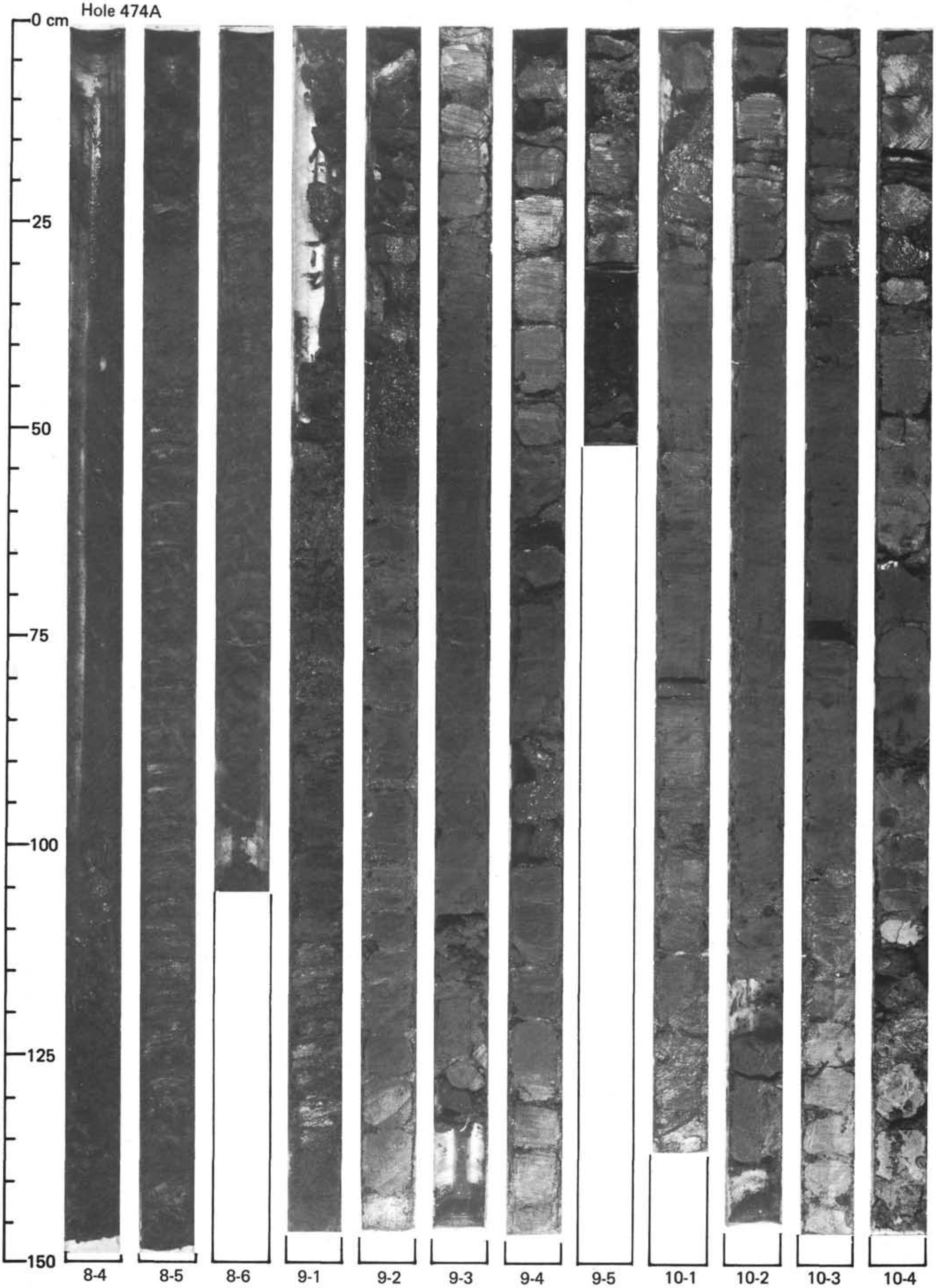
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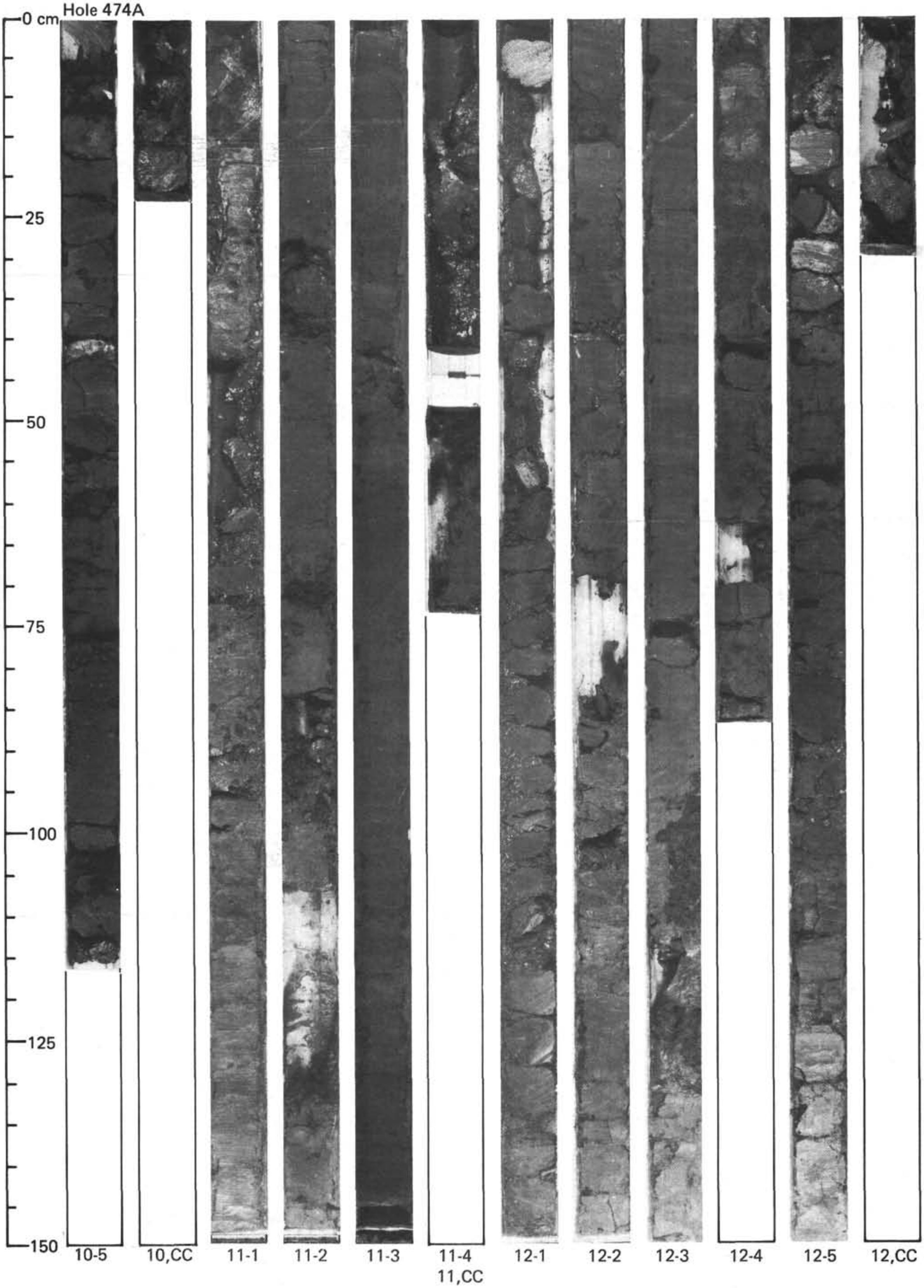
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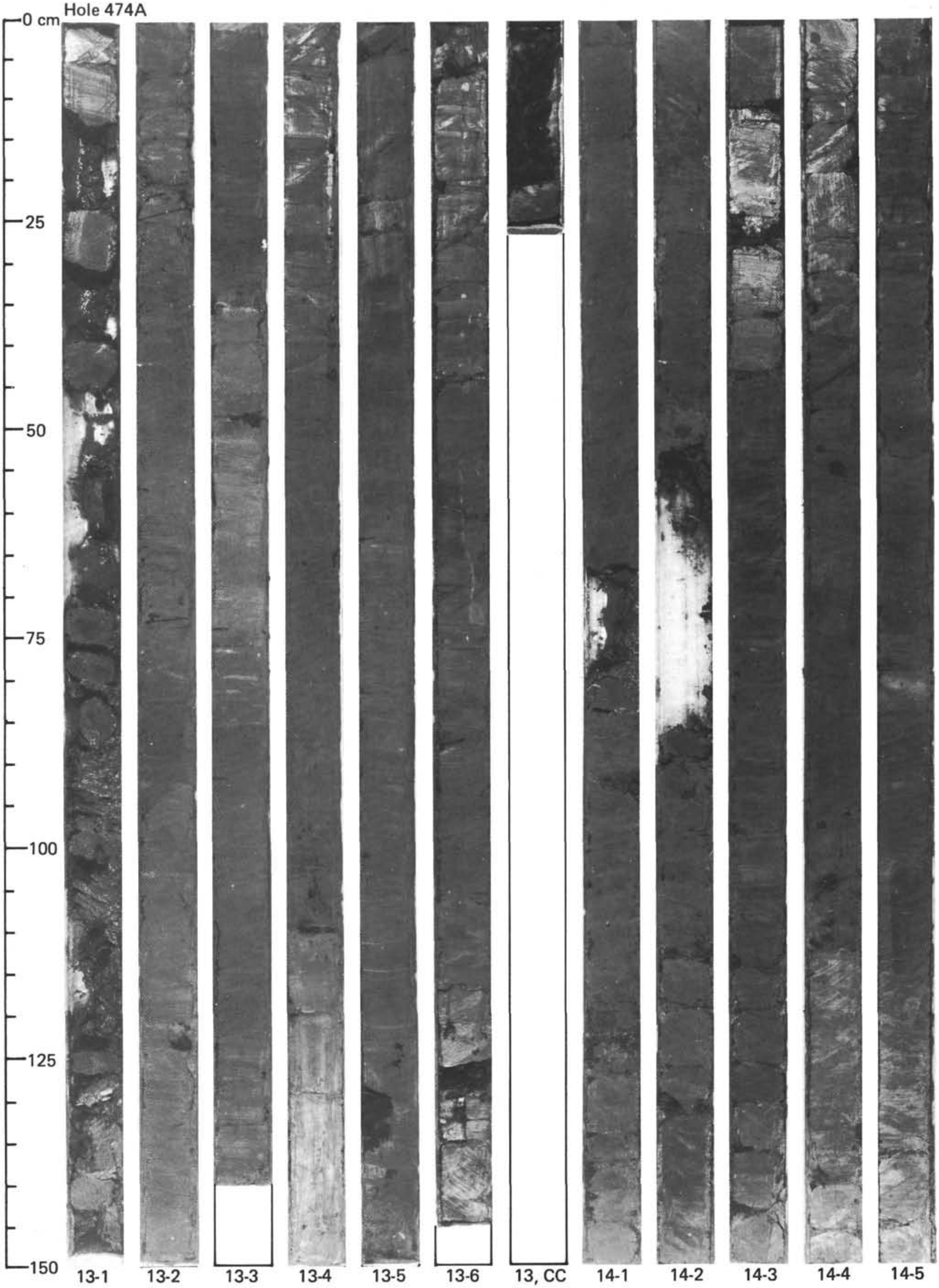
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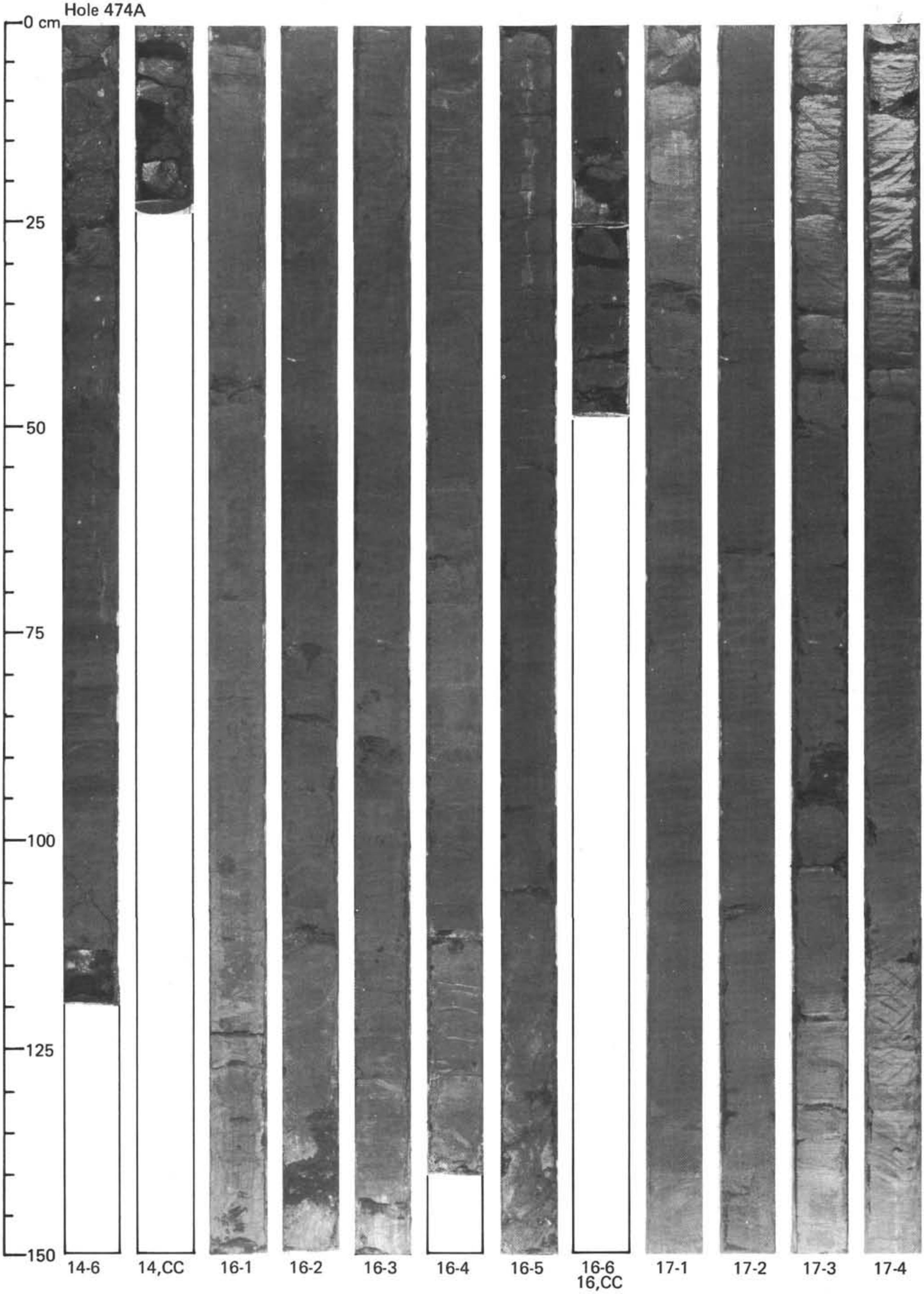
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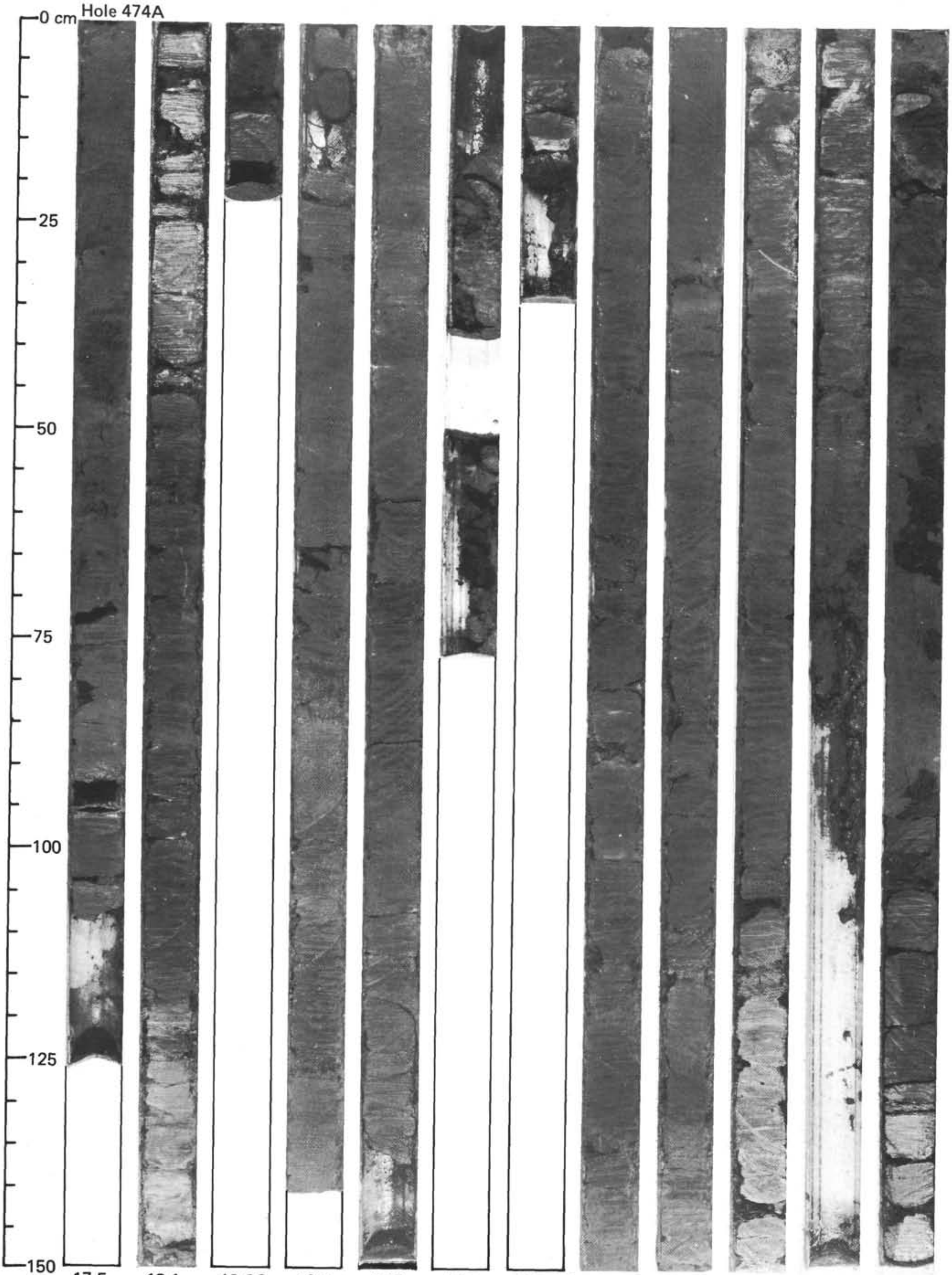
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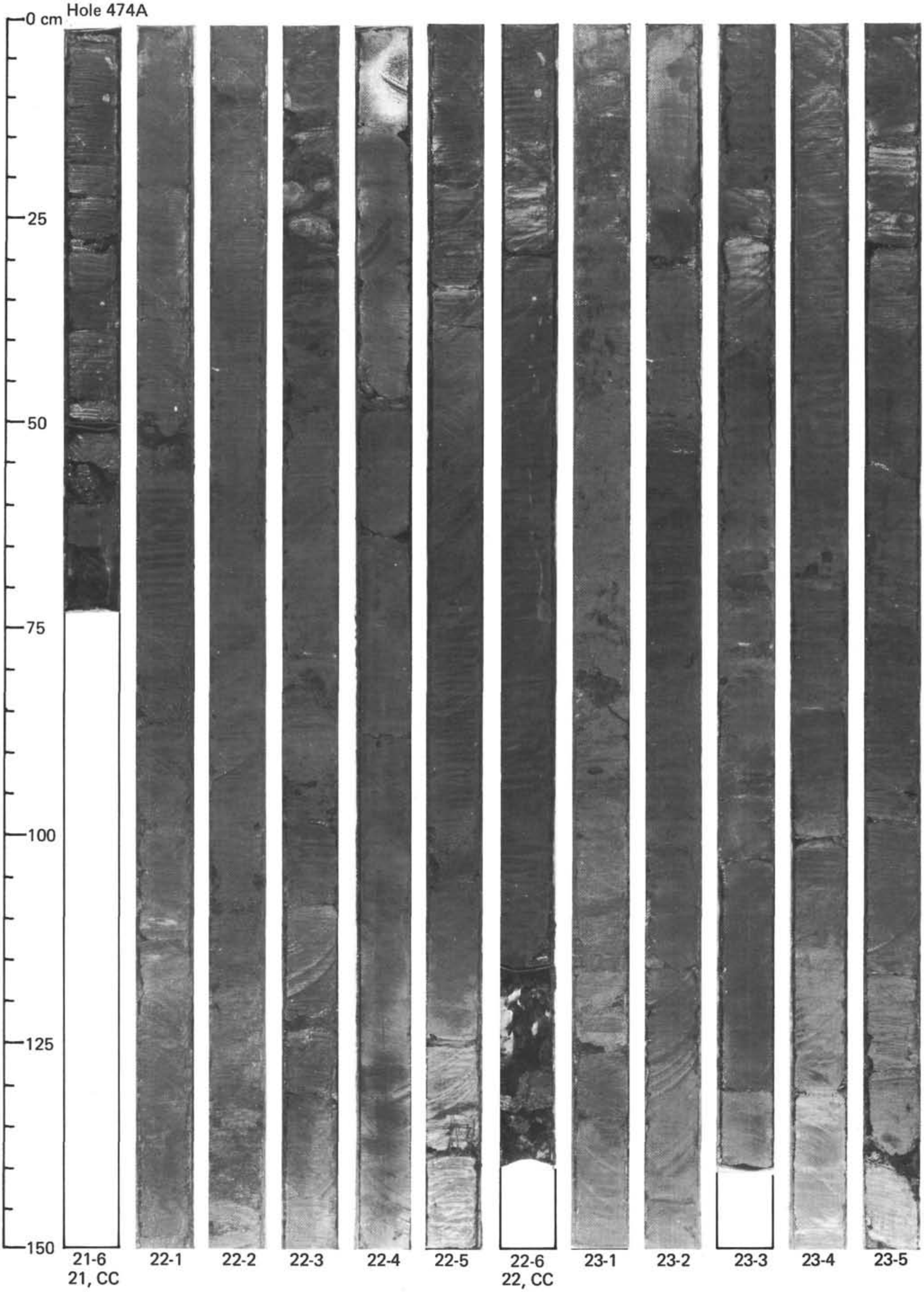
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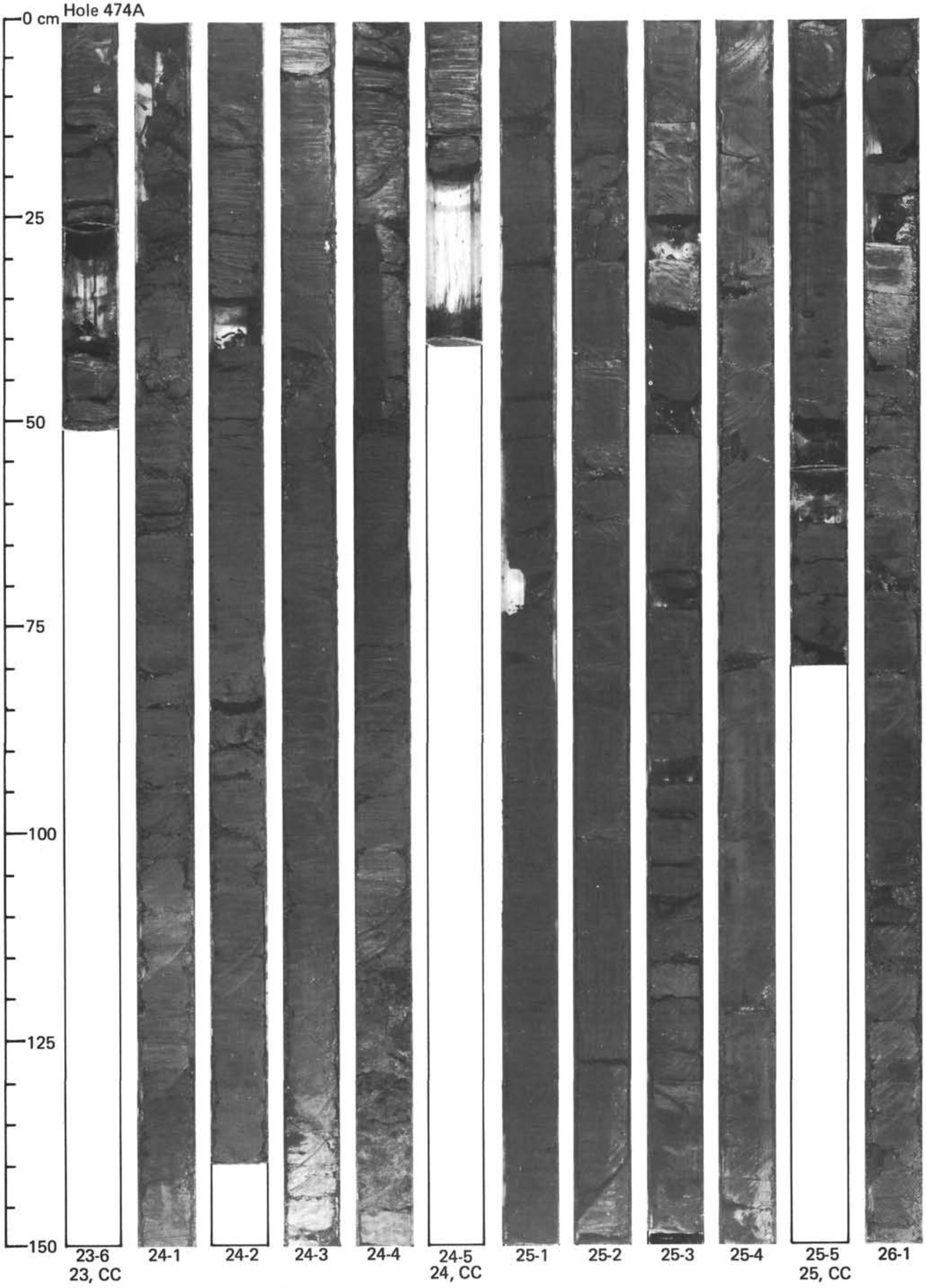
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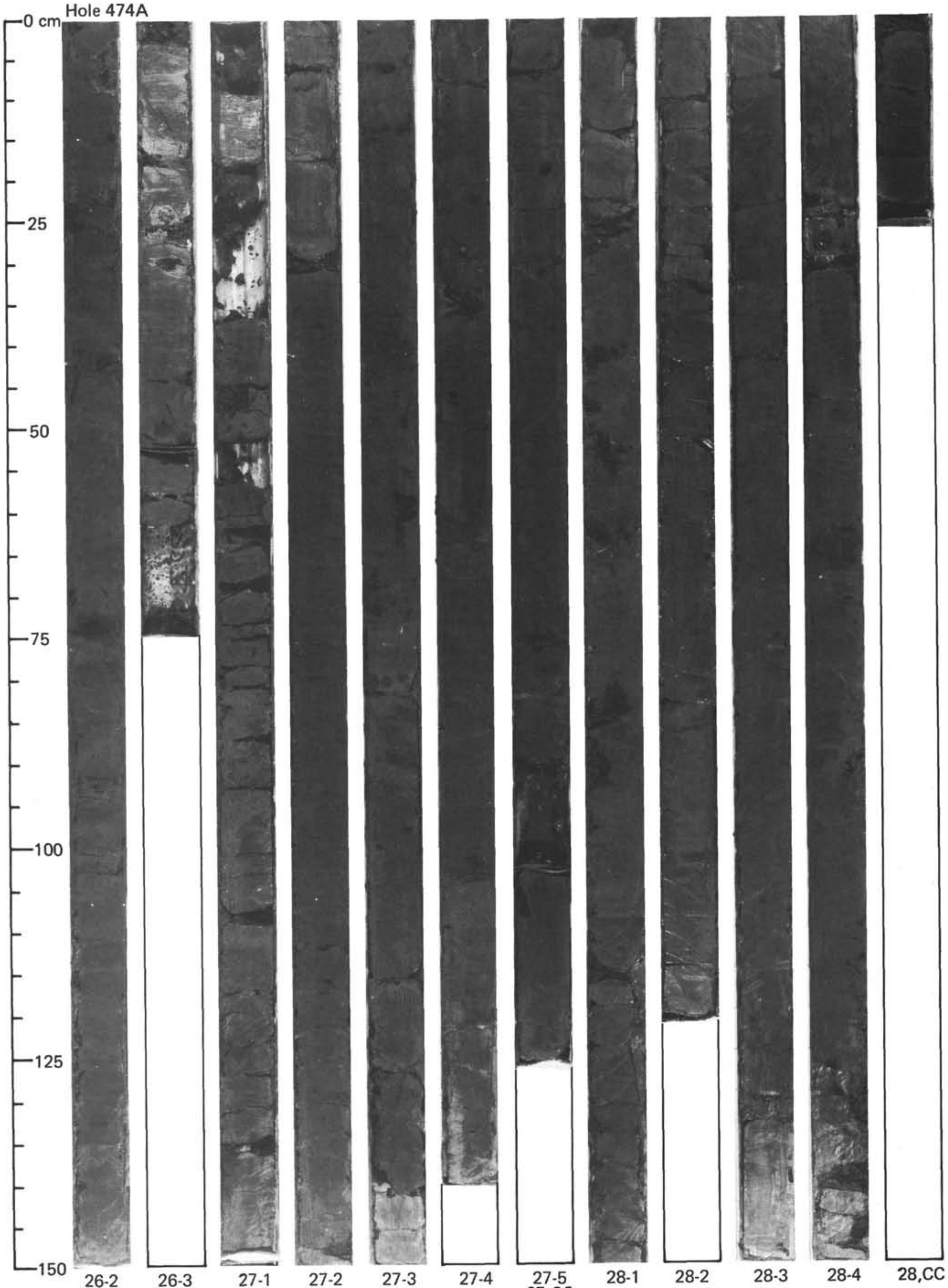
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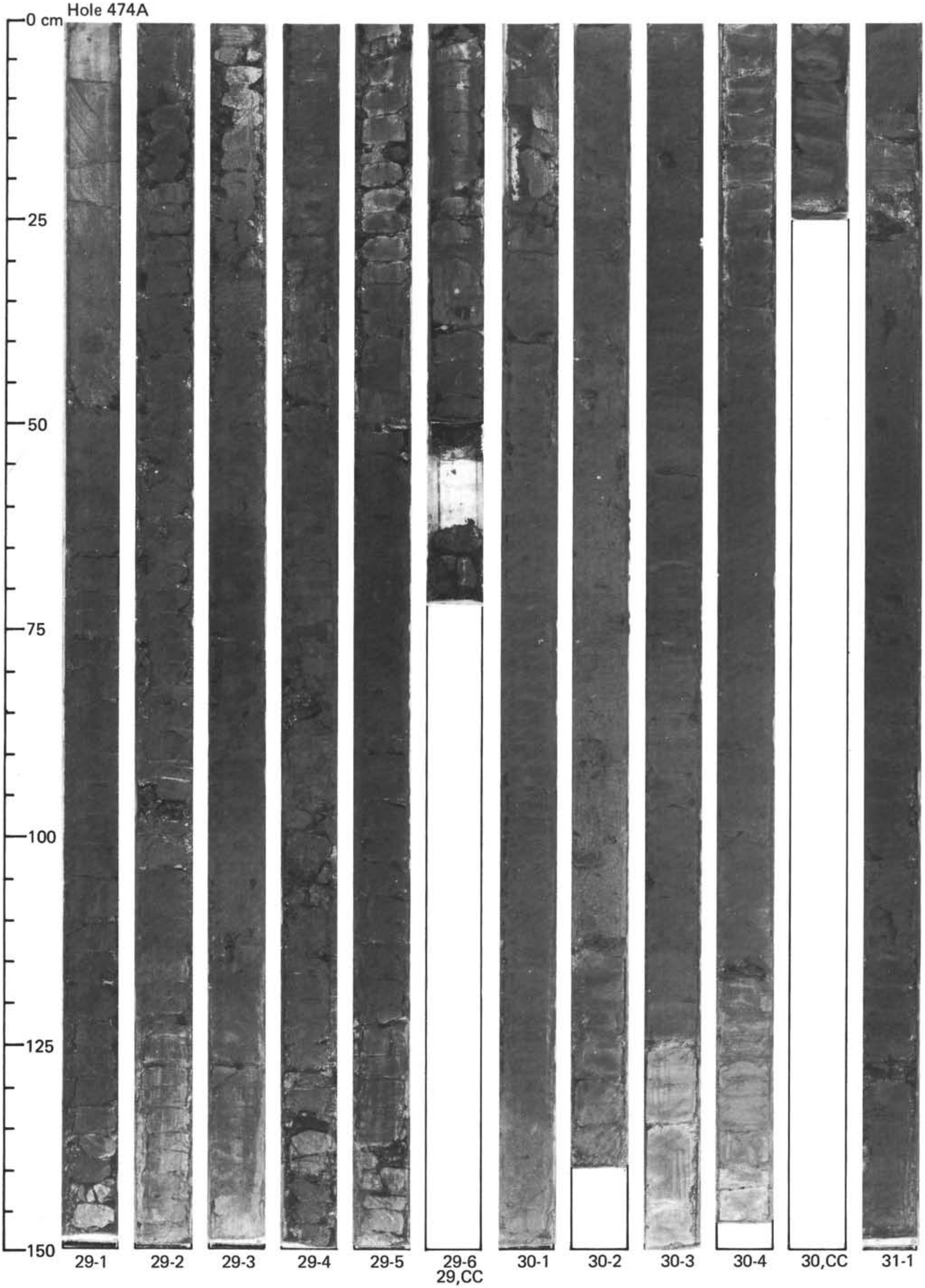
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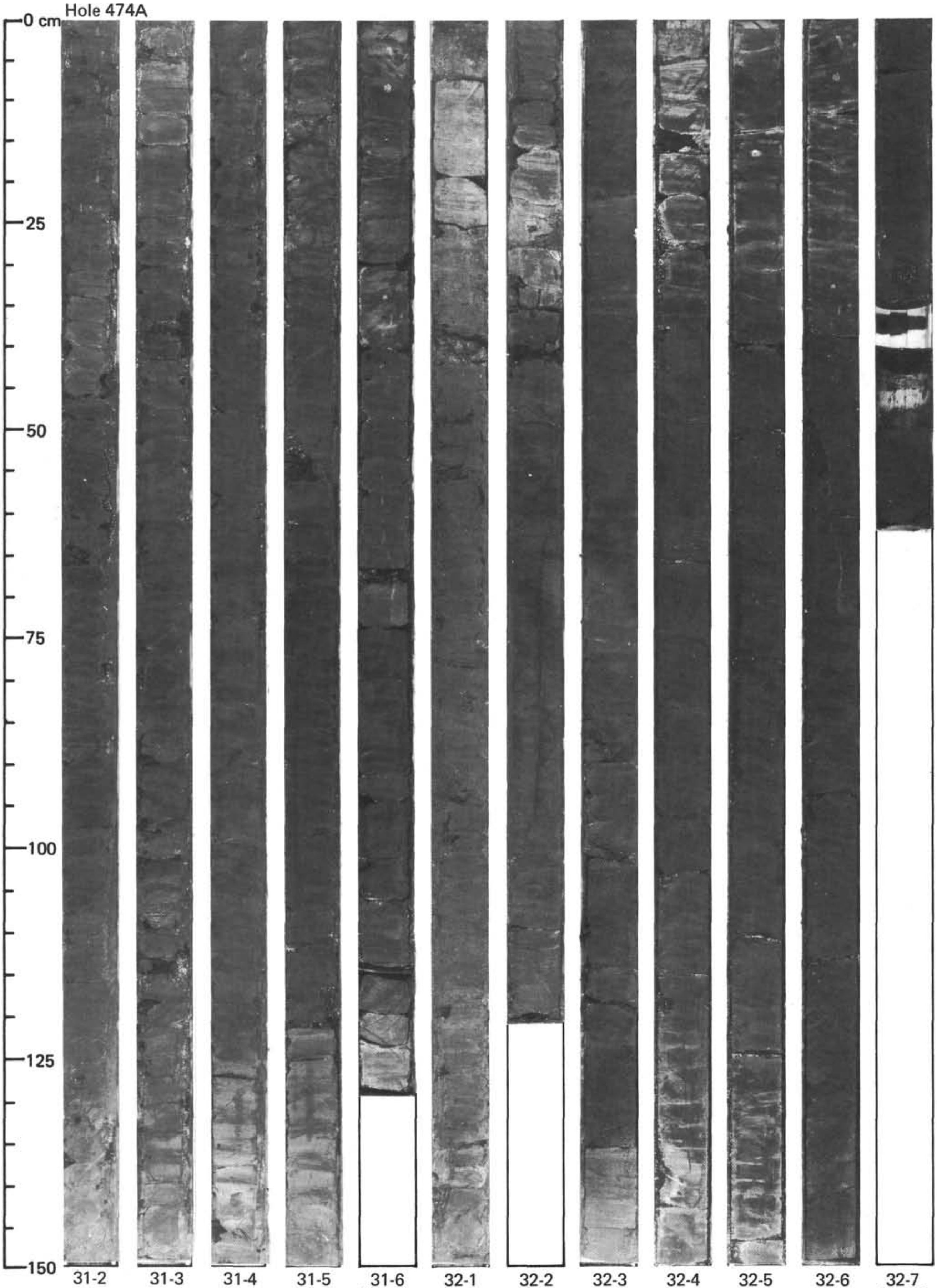
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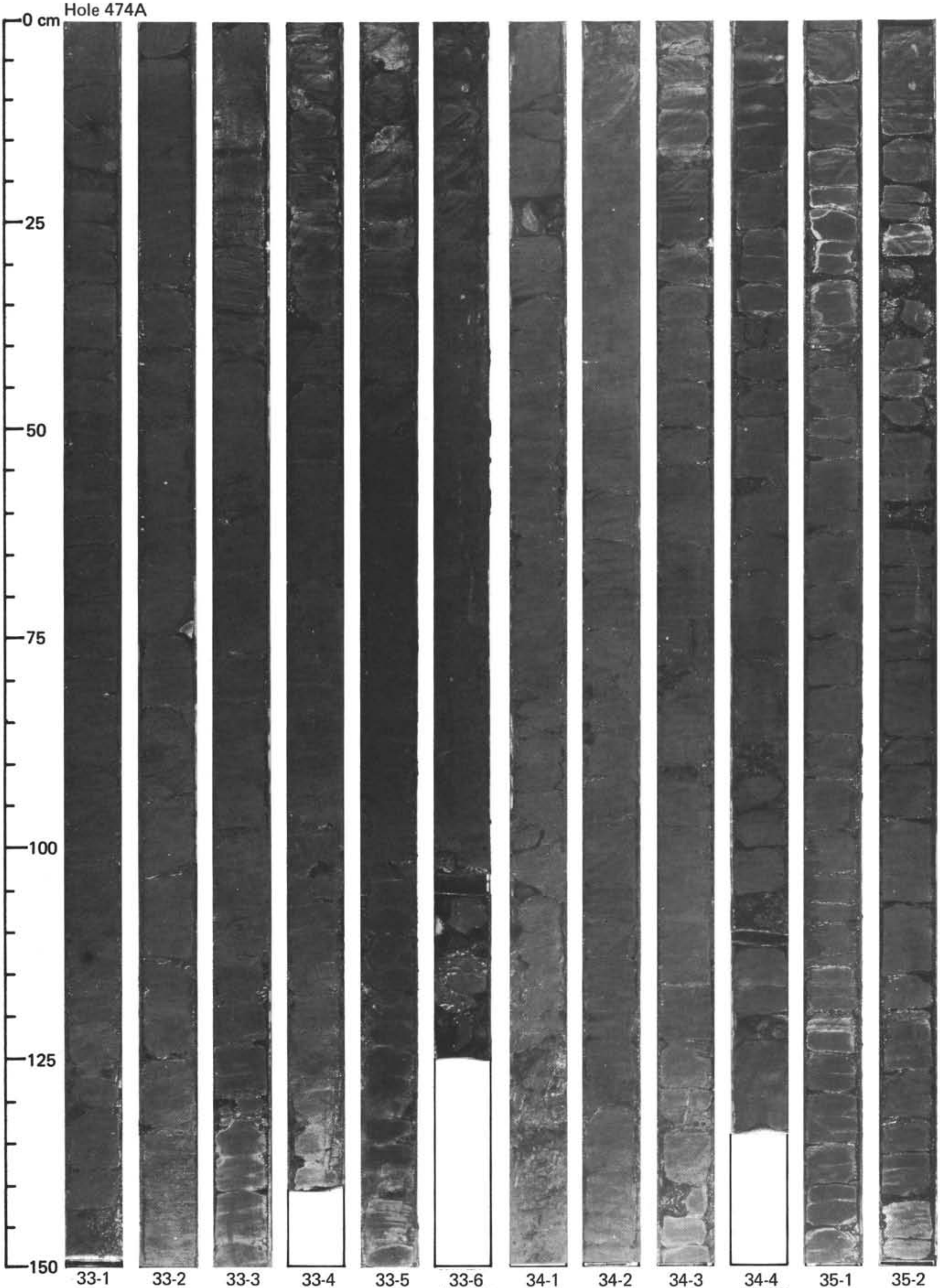
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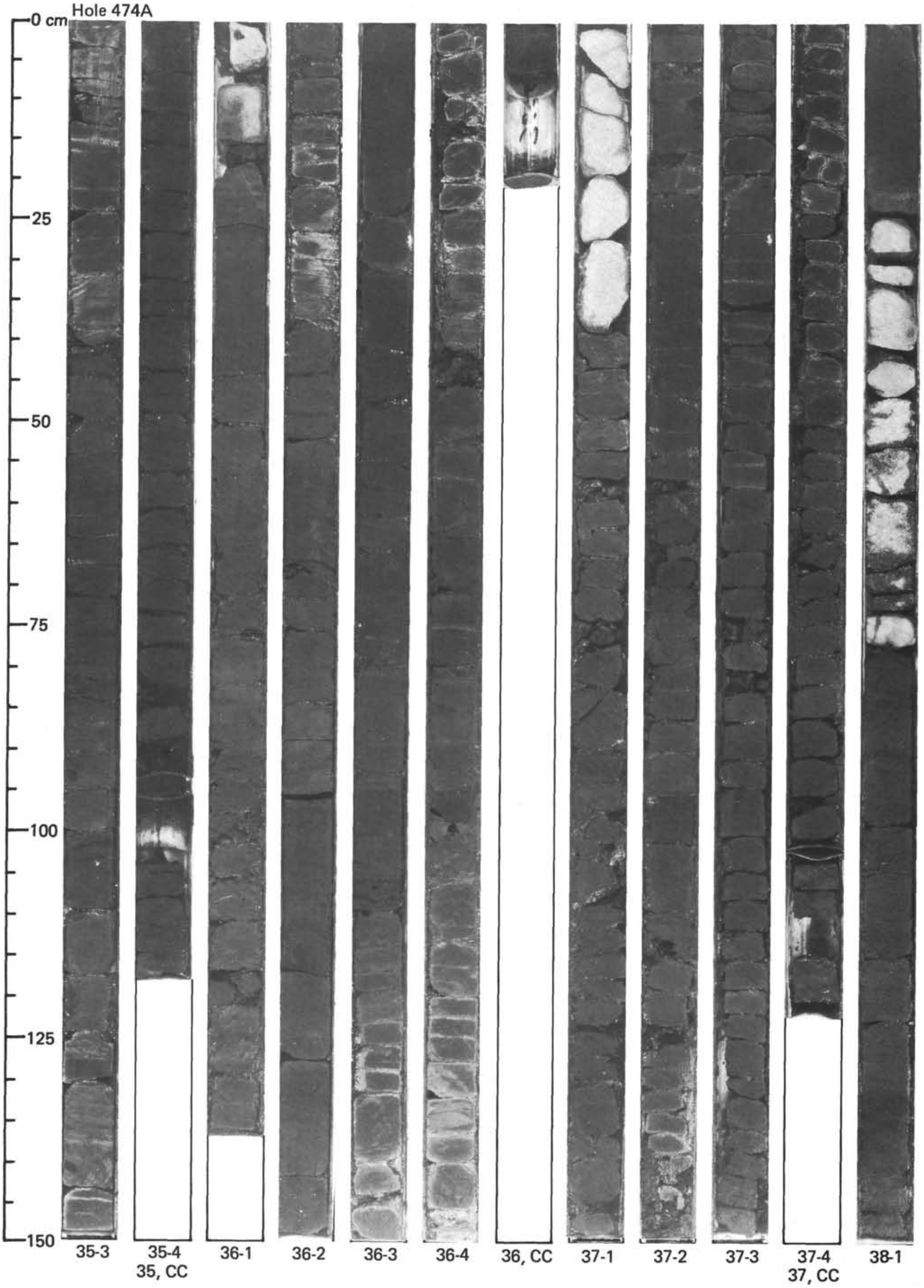
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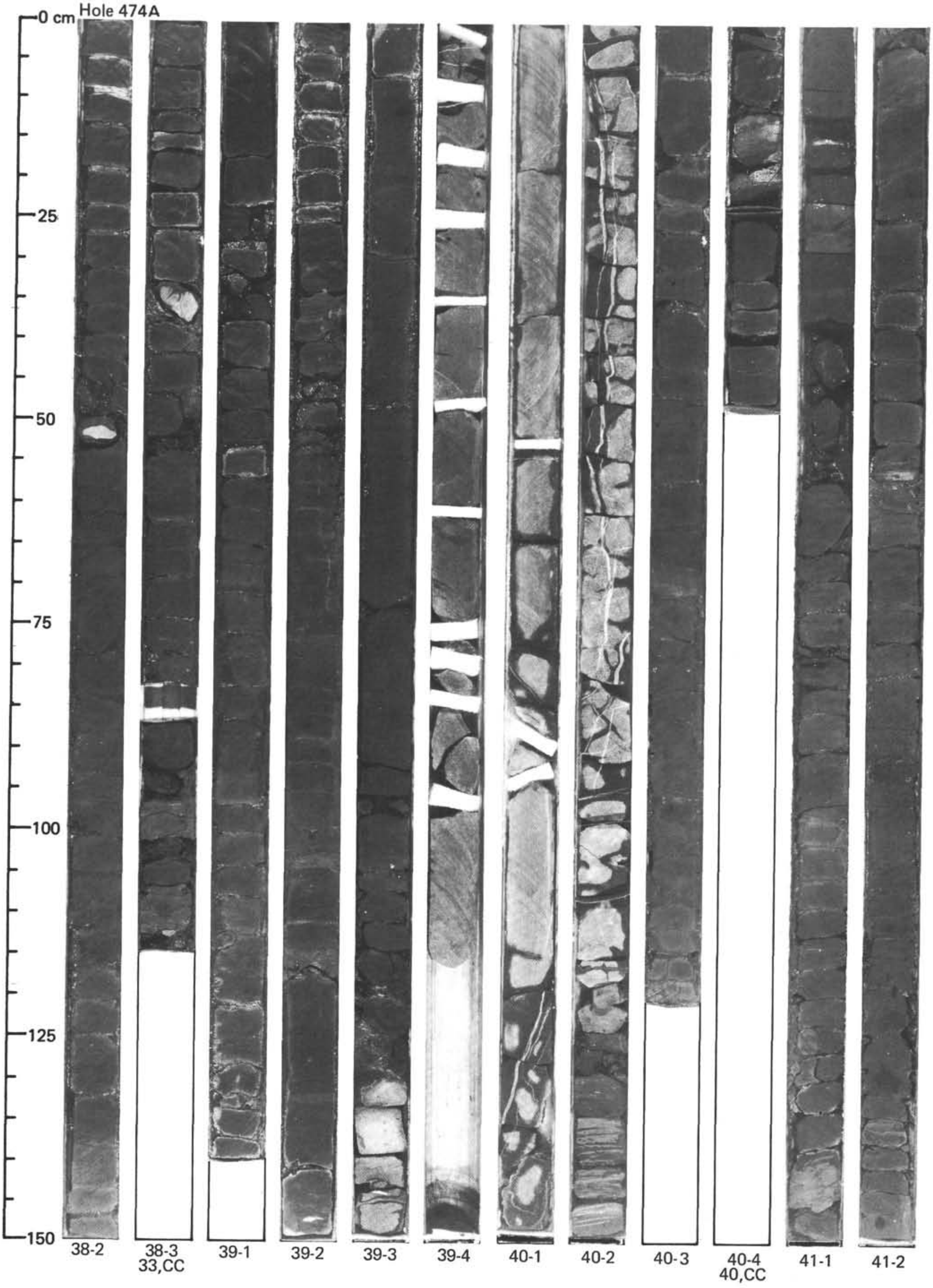
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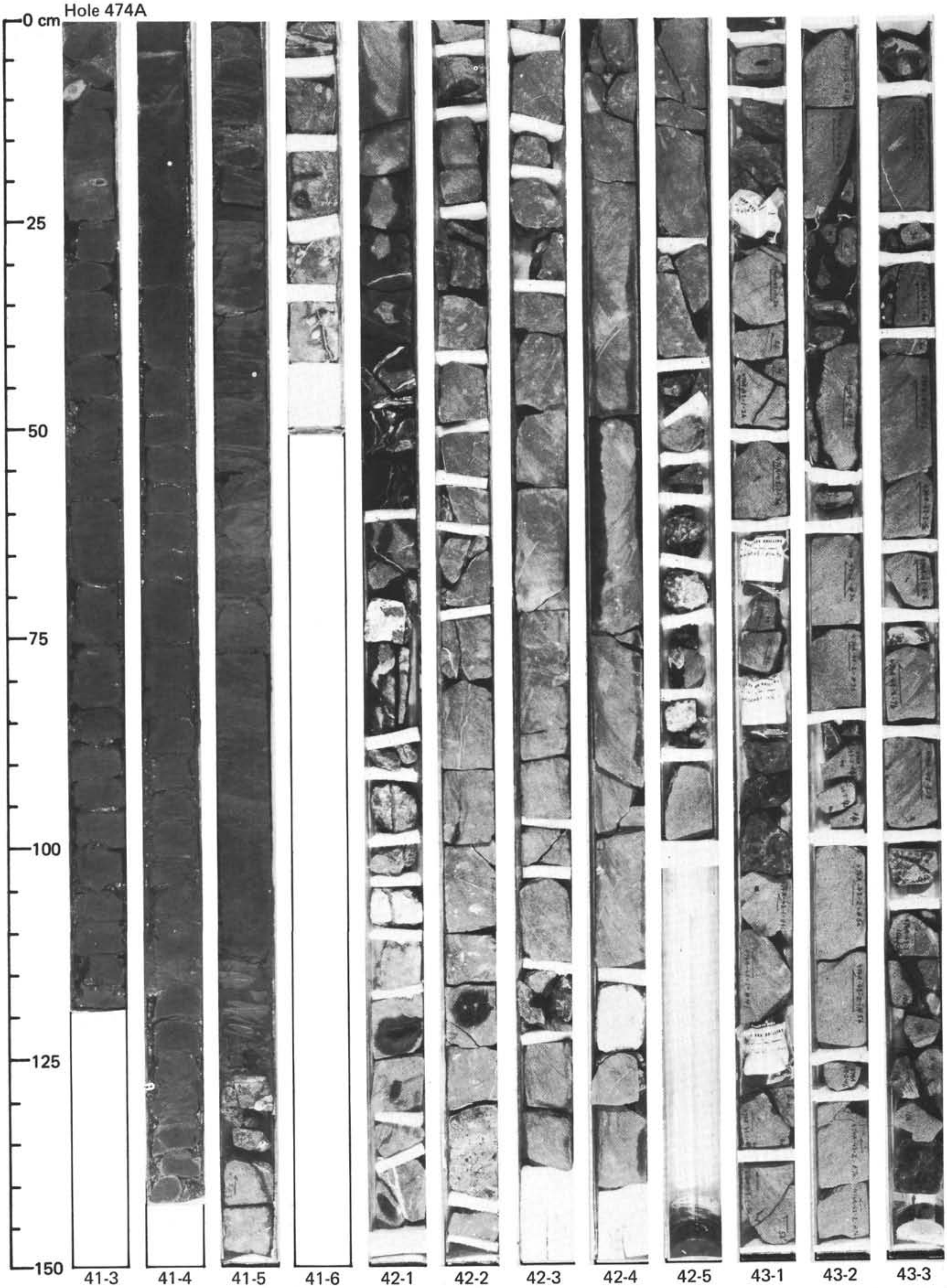
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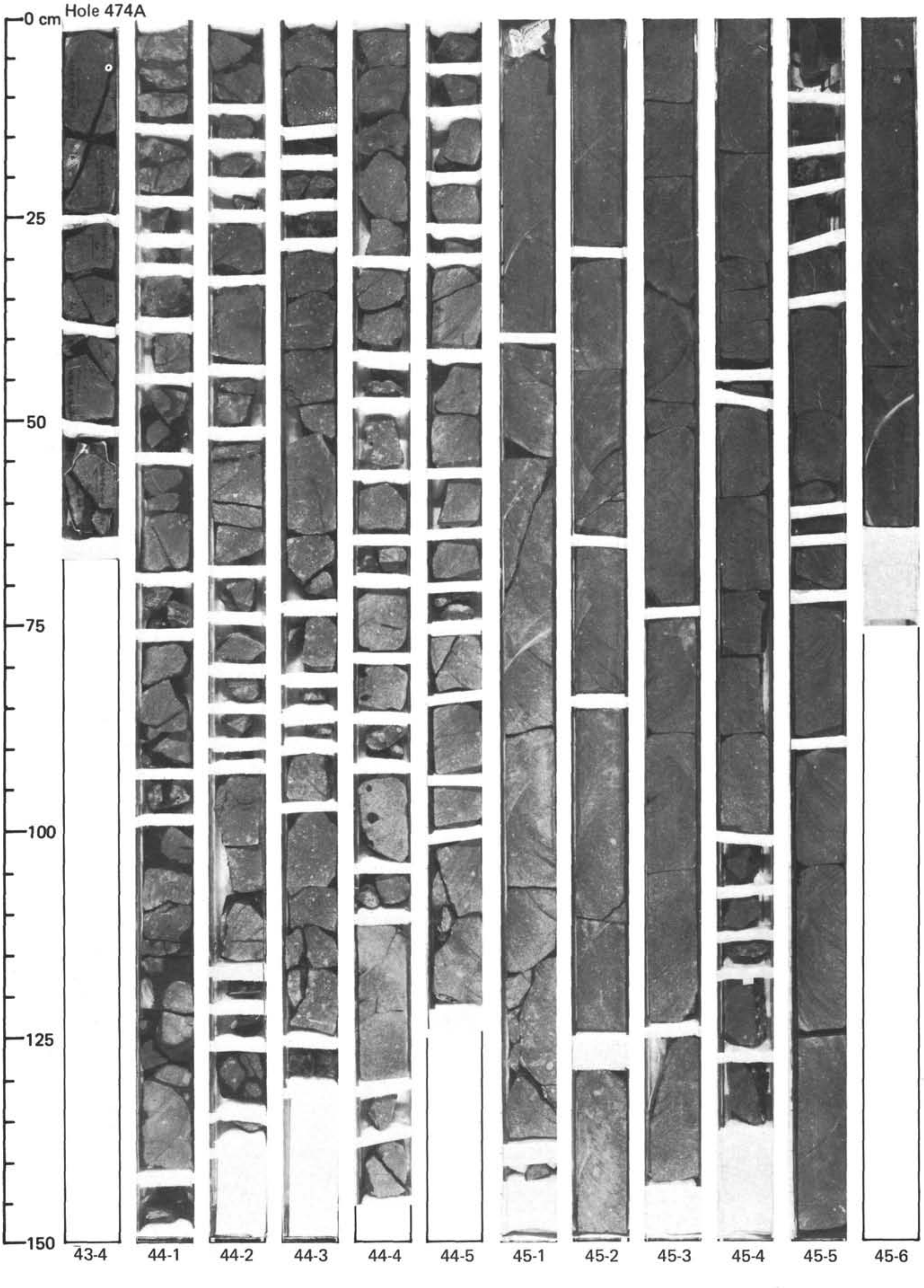
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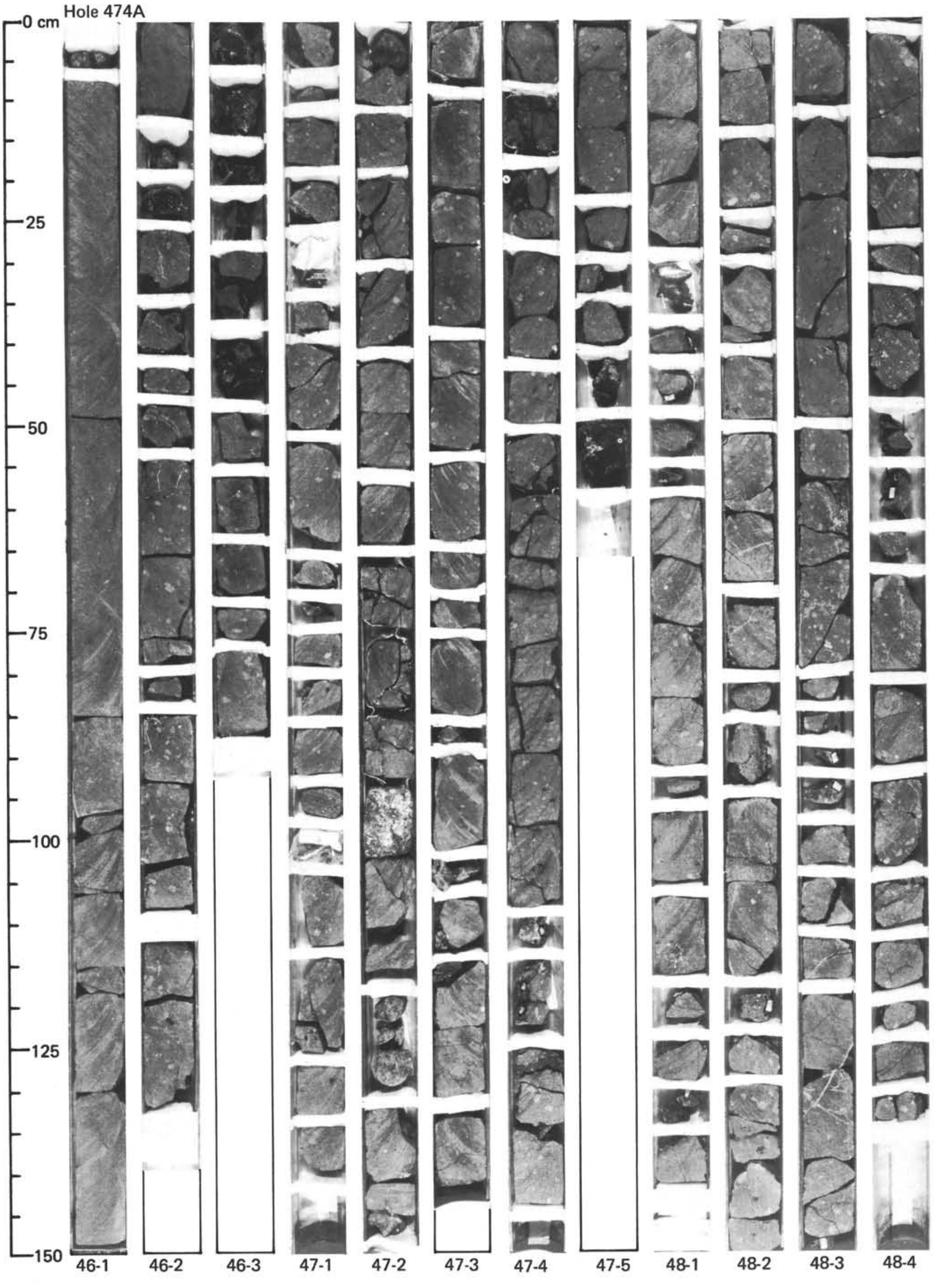
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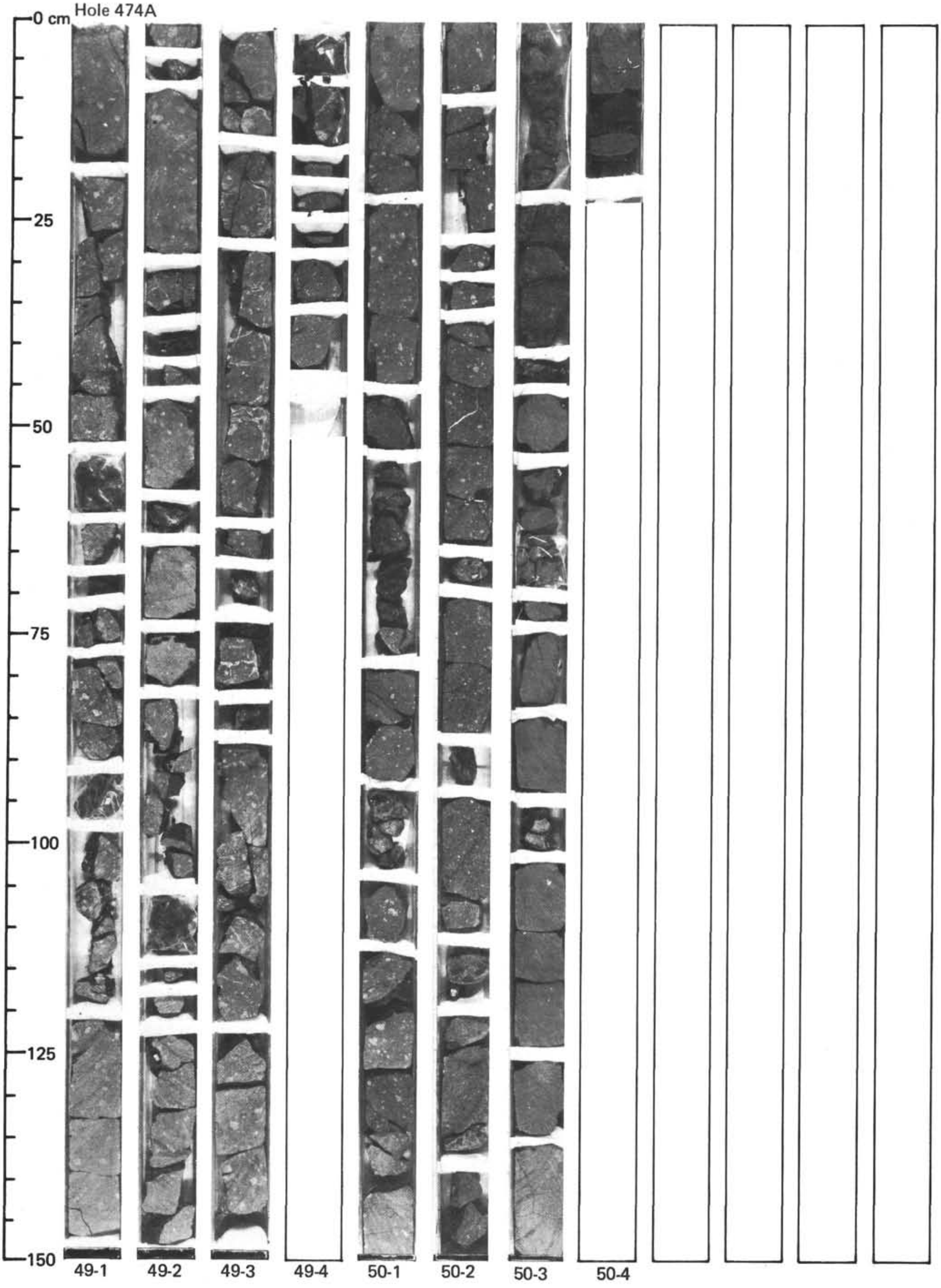
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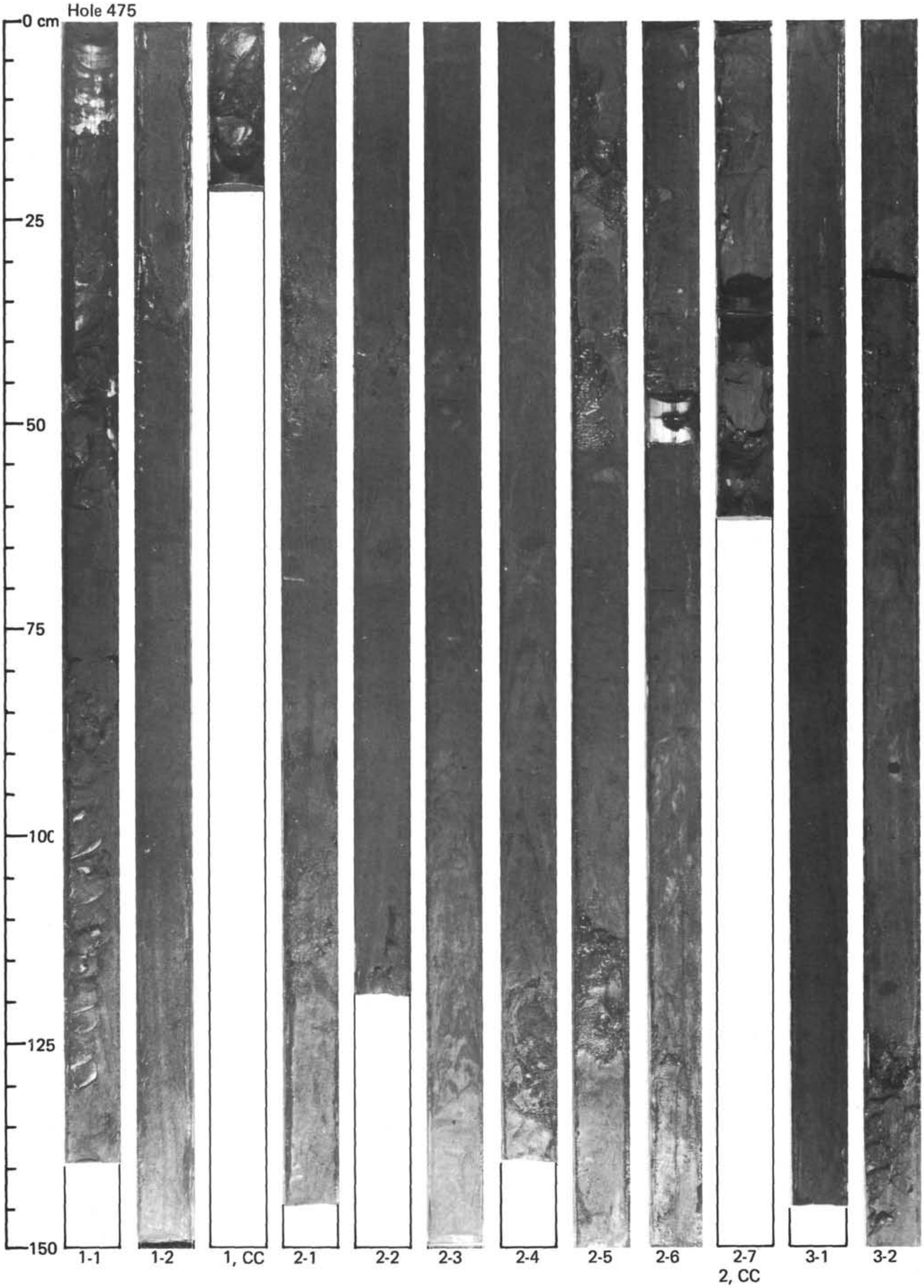
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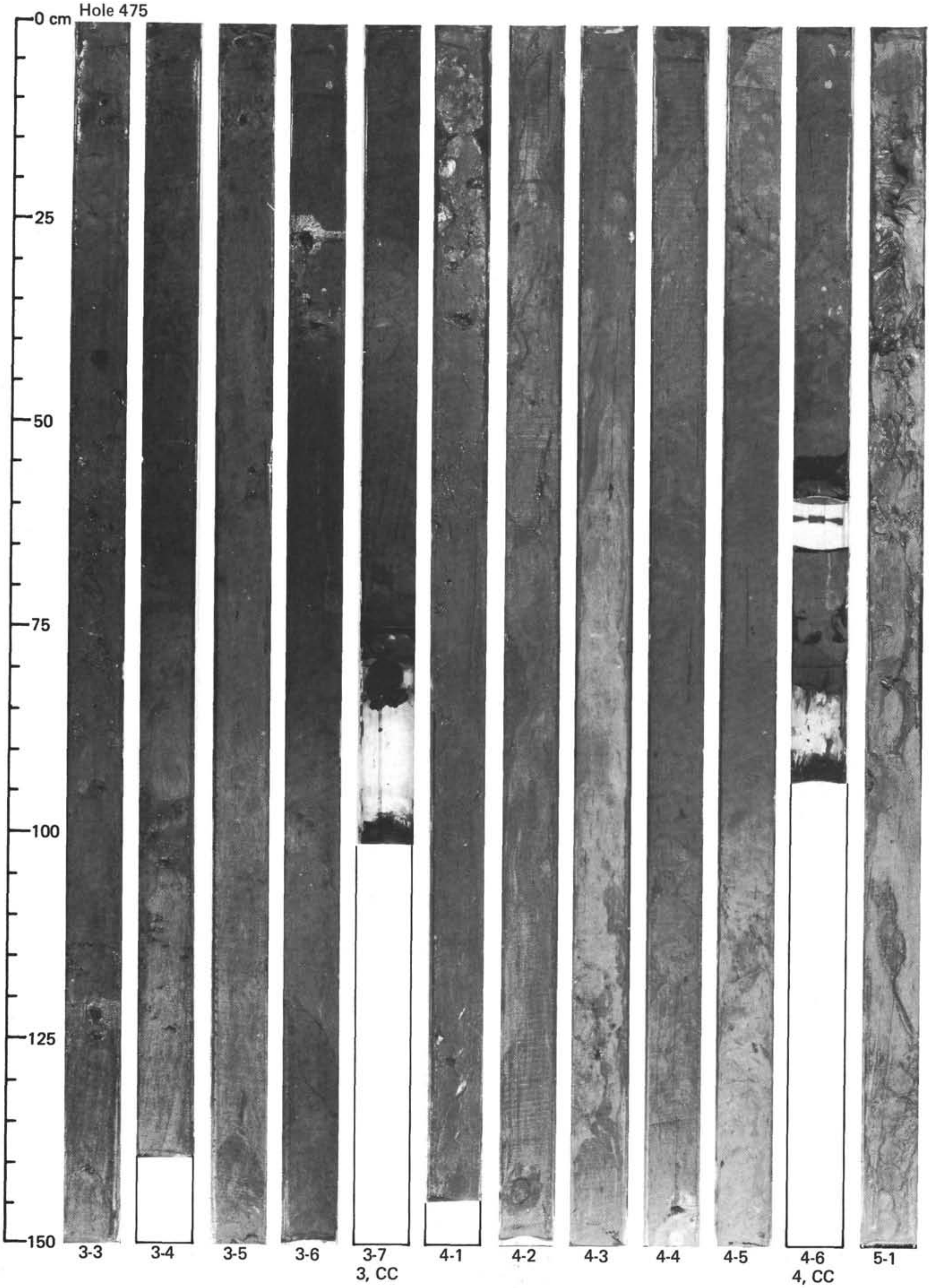
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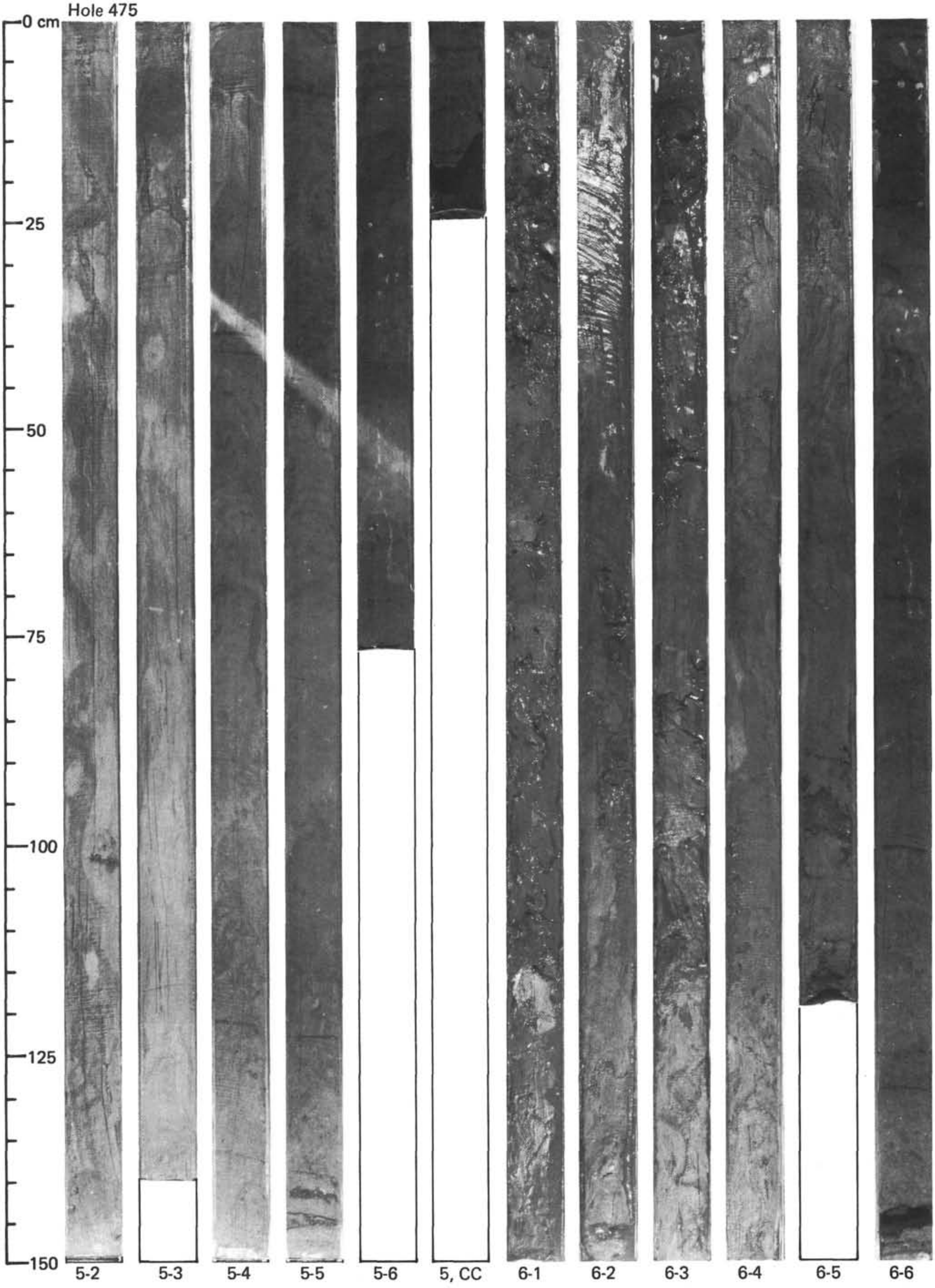
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75
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6-5
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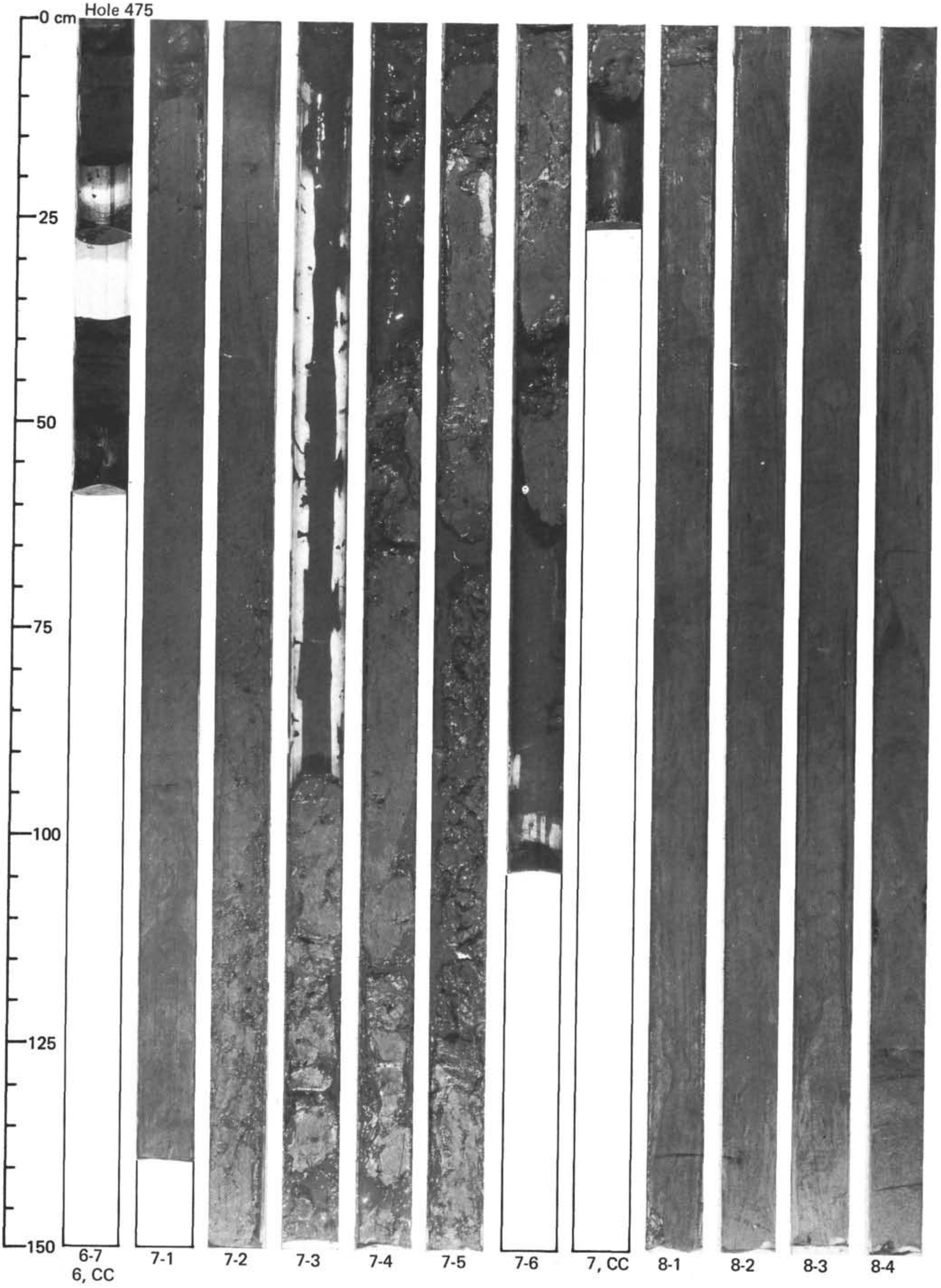
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7, CC
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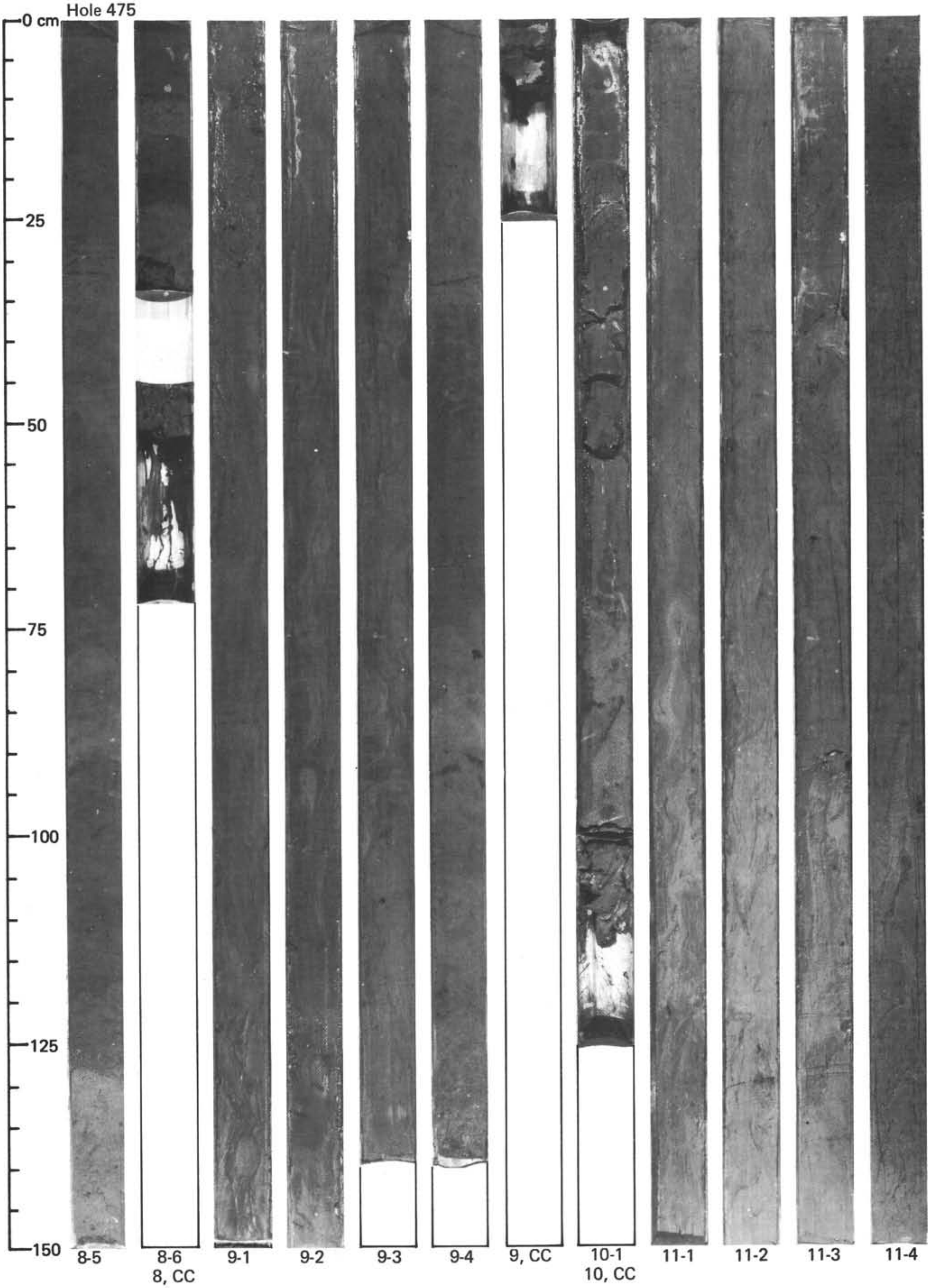
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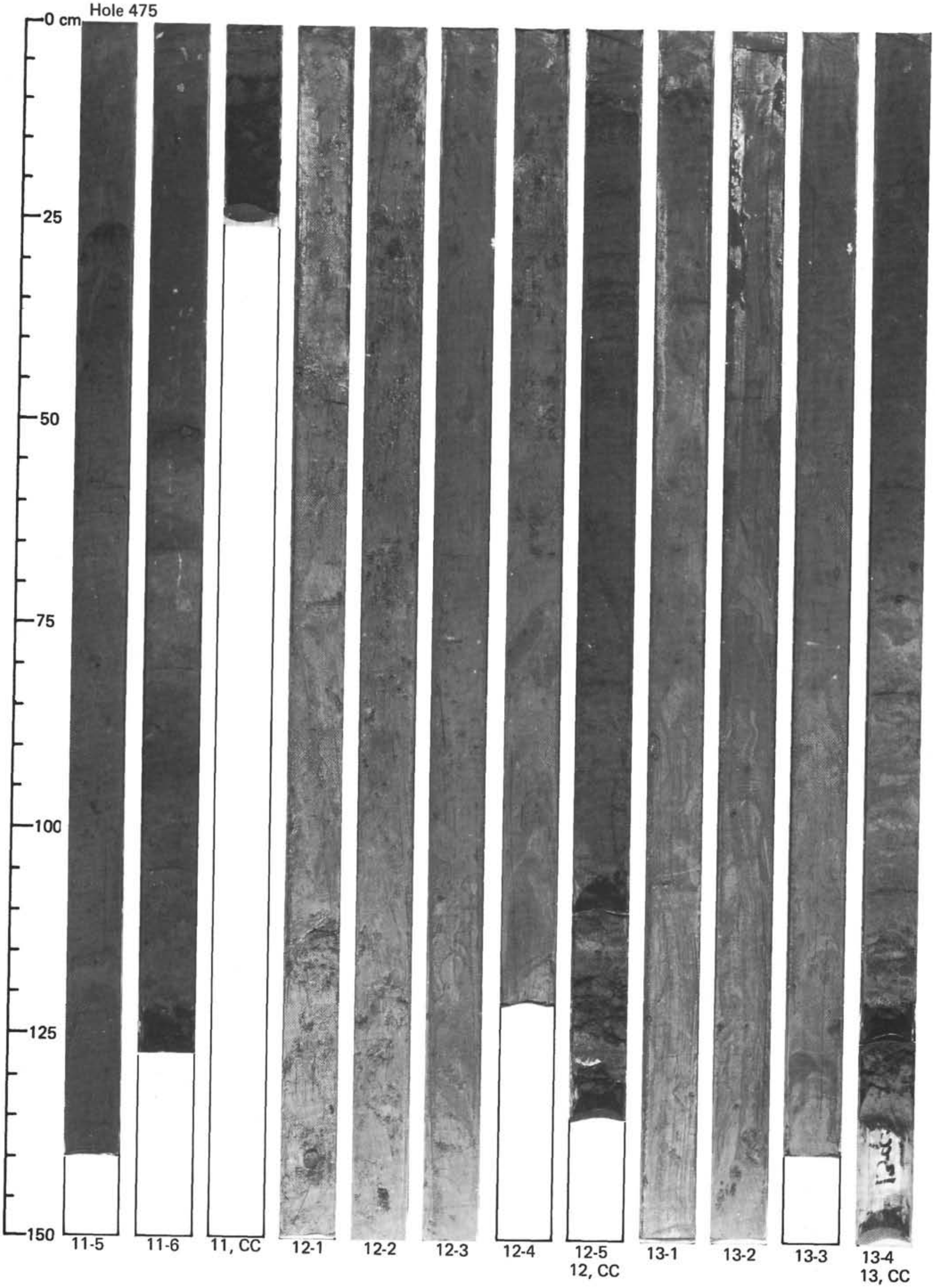
11-4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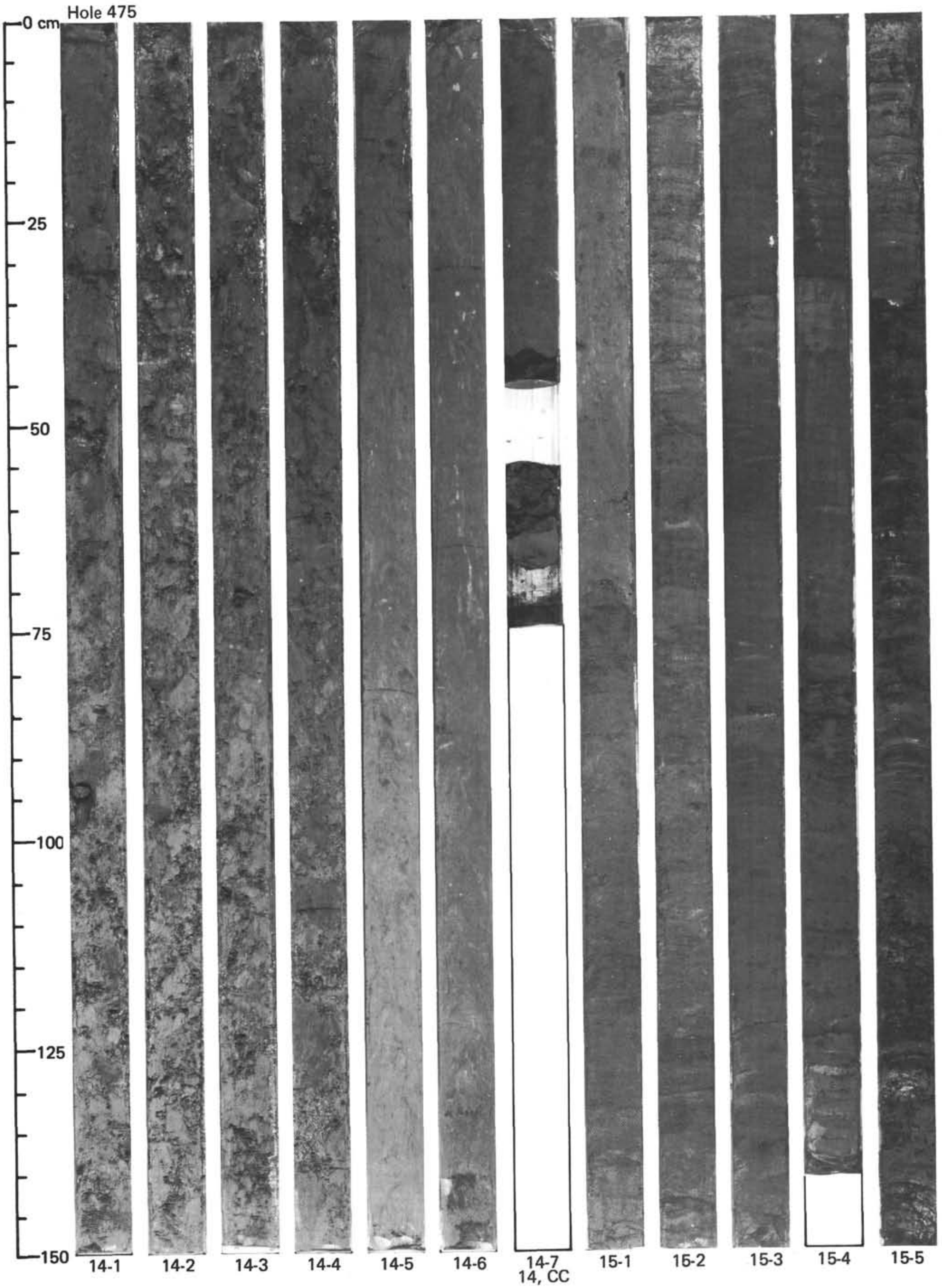
13, CC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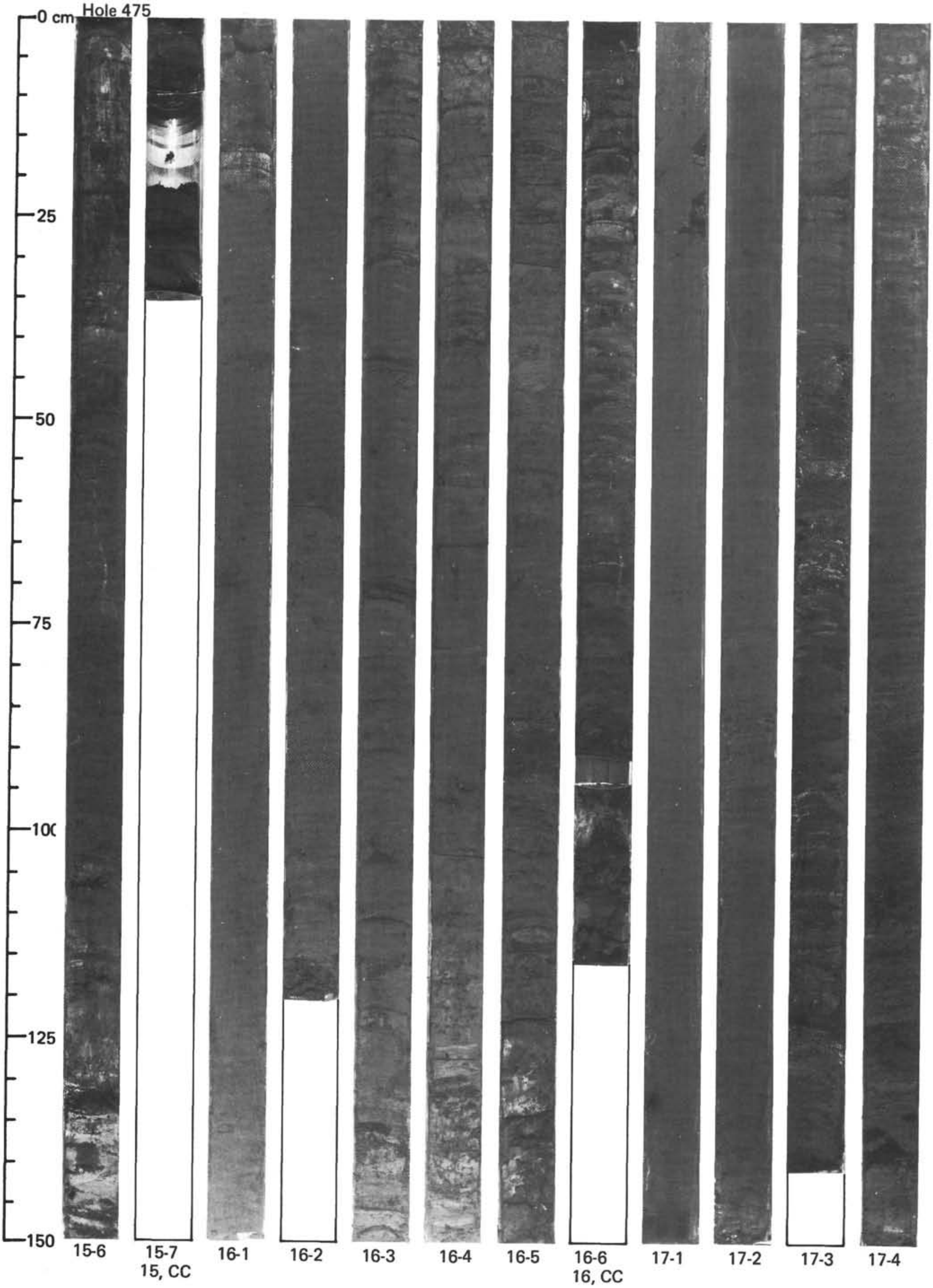
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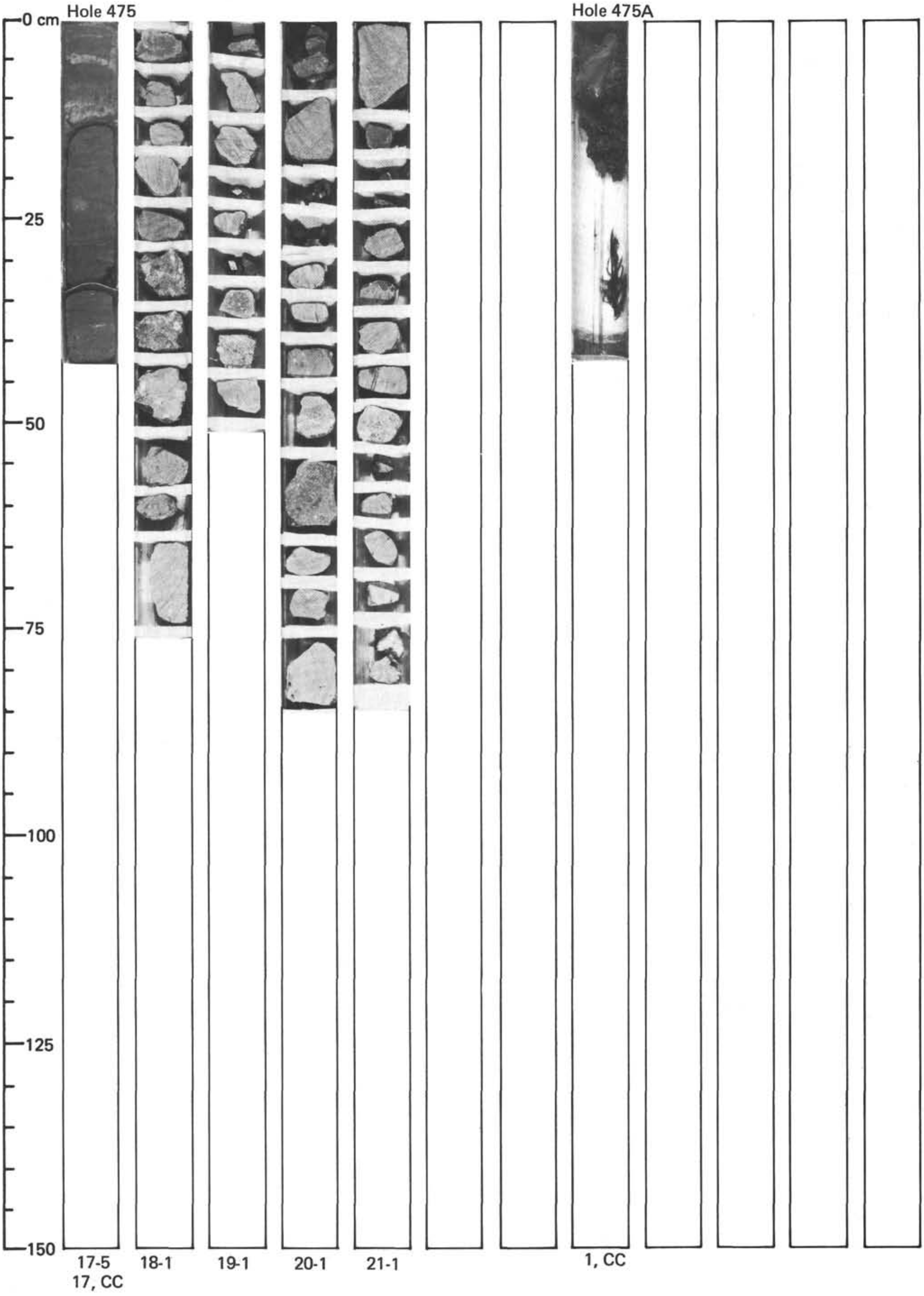
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Hole 475A
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19-1
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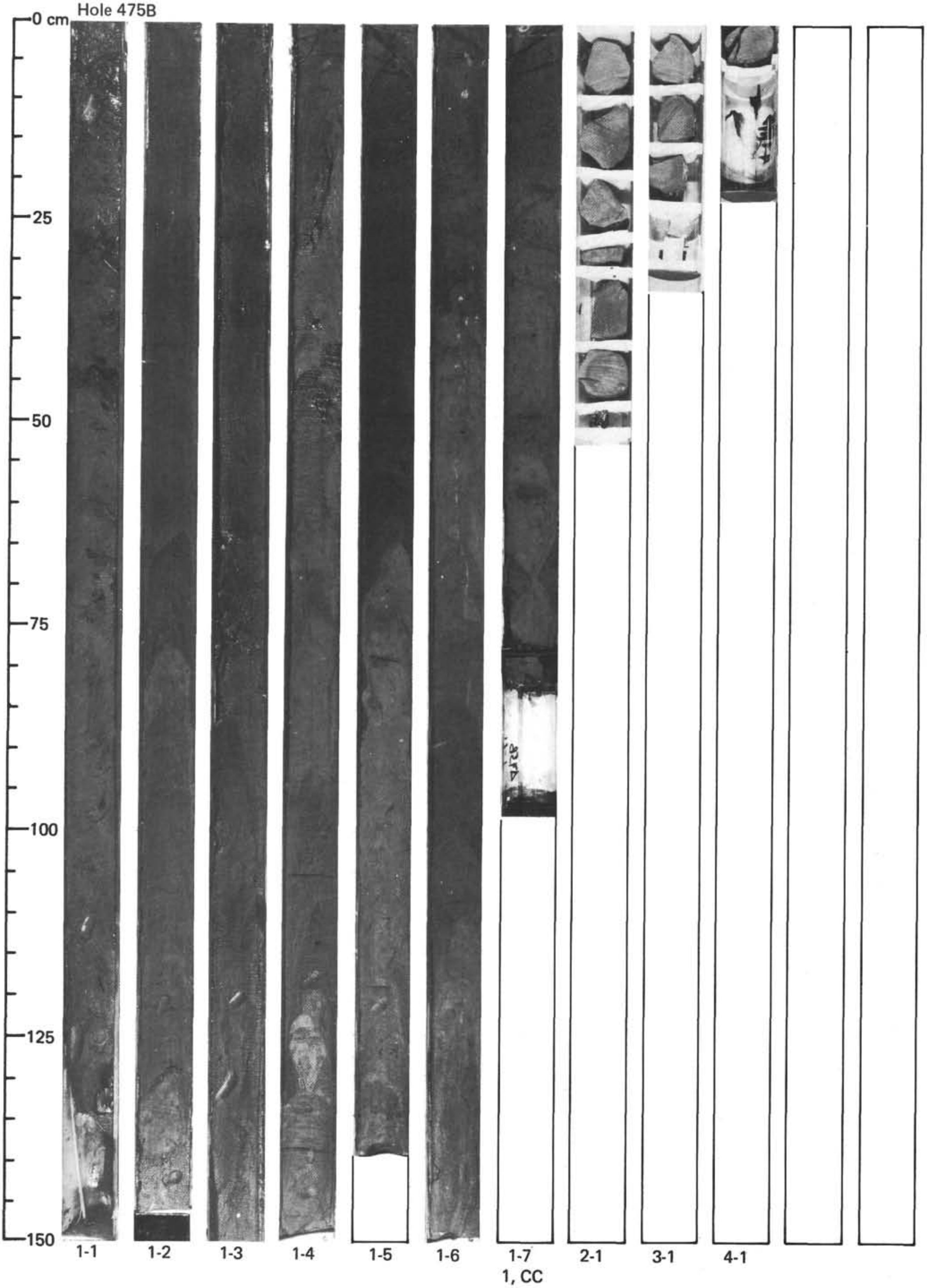
21-1
1, CC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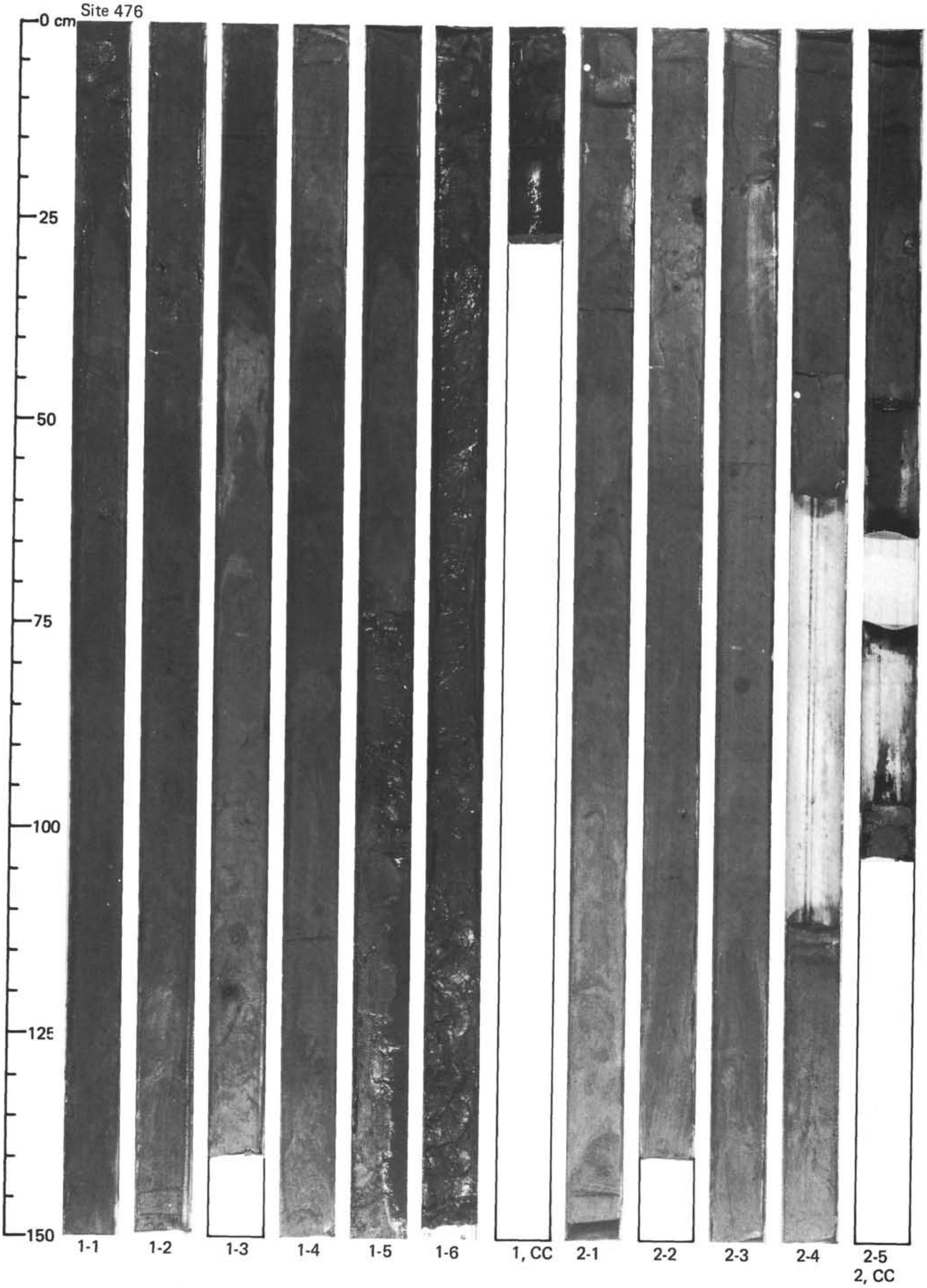
3-1
4-1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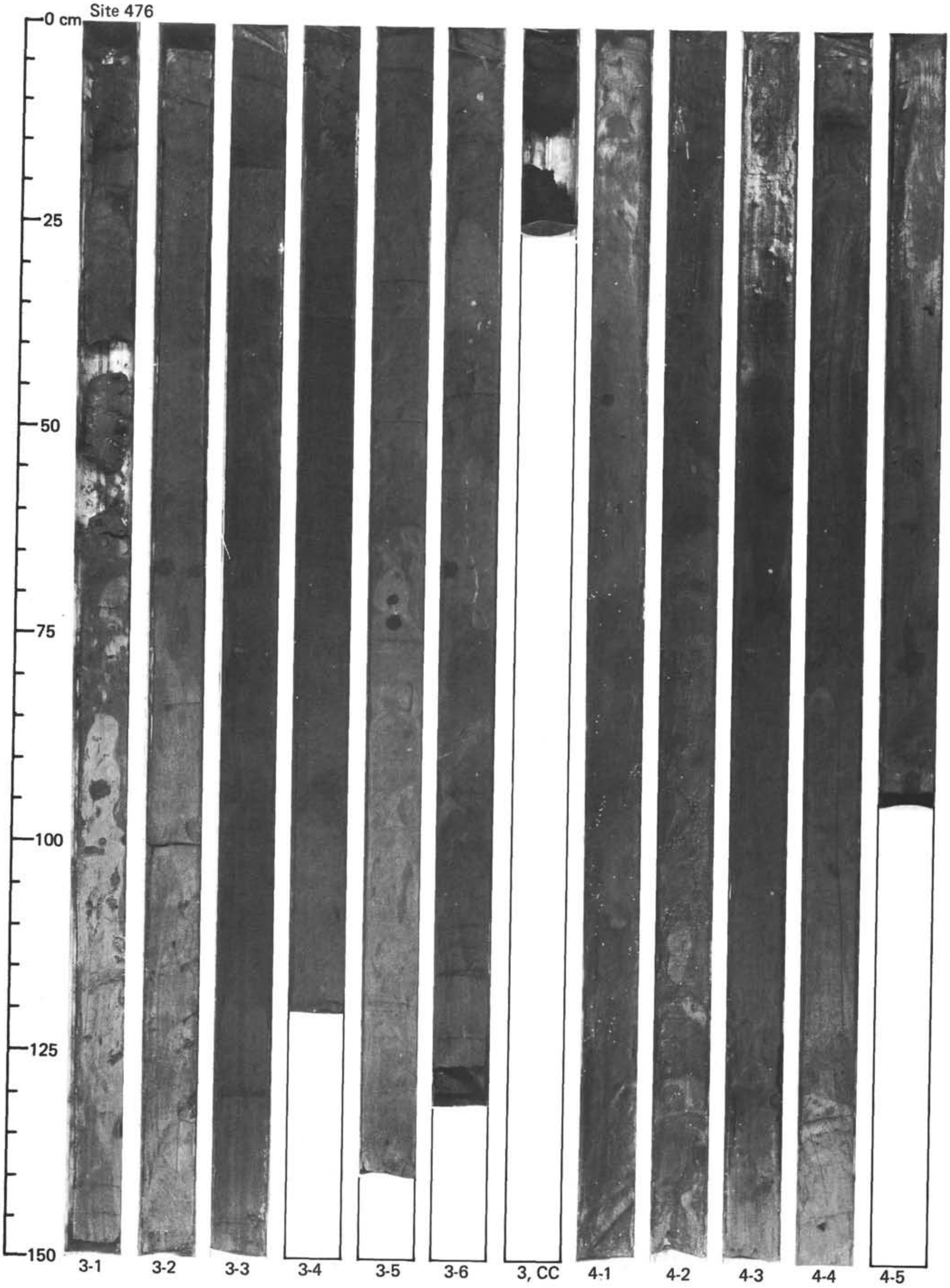
2, CC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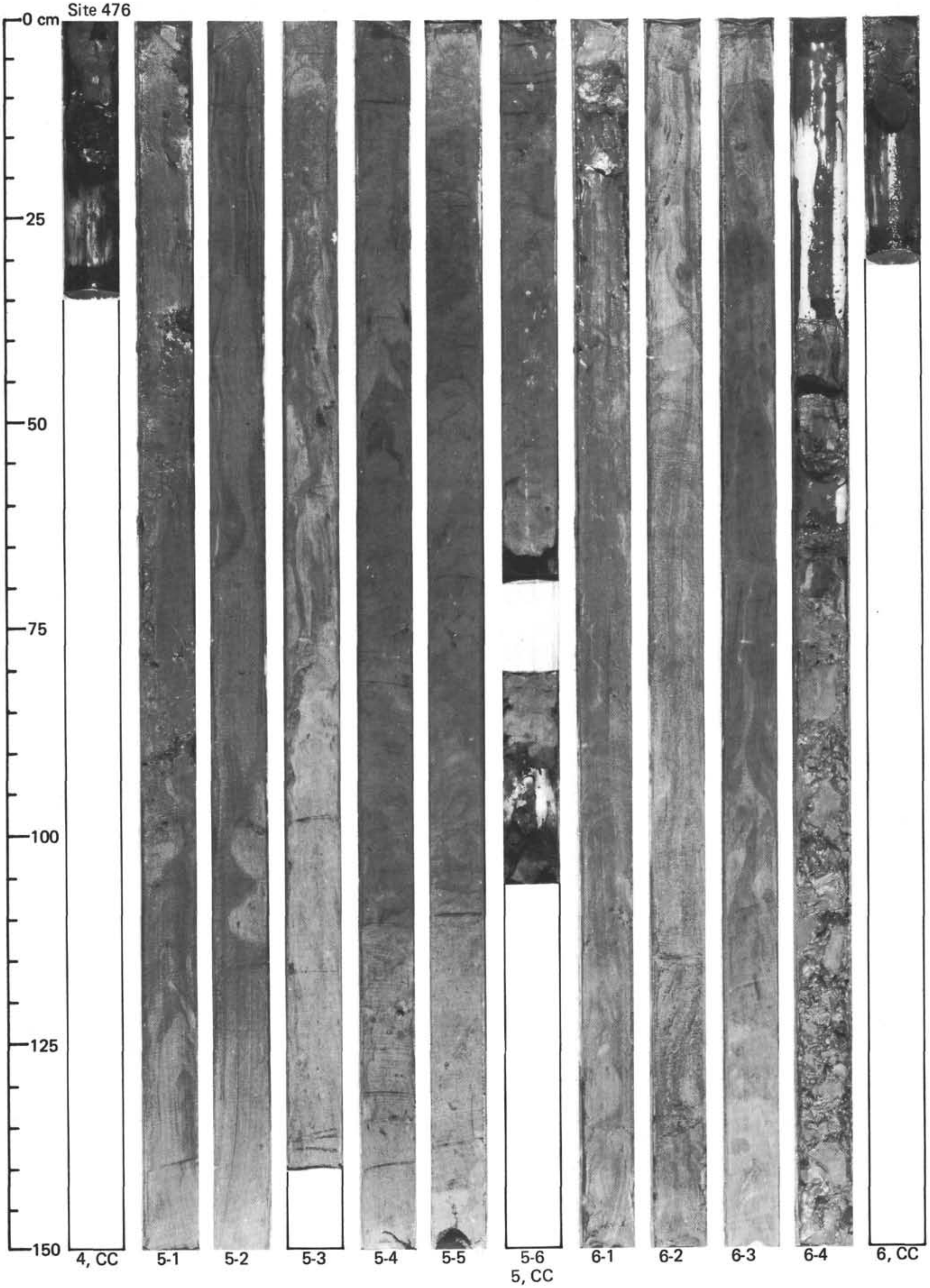
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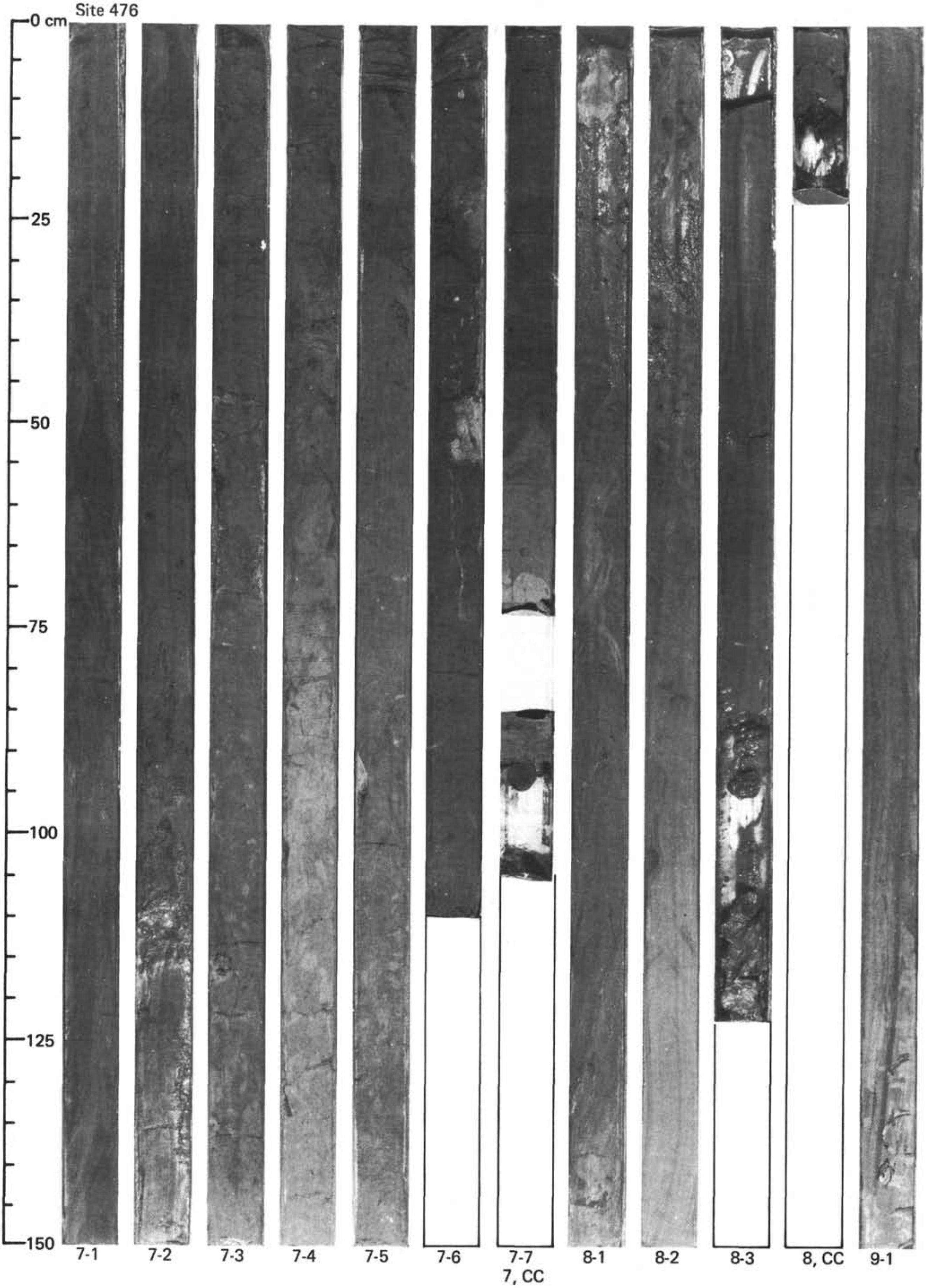
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8-1
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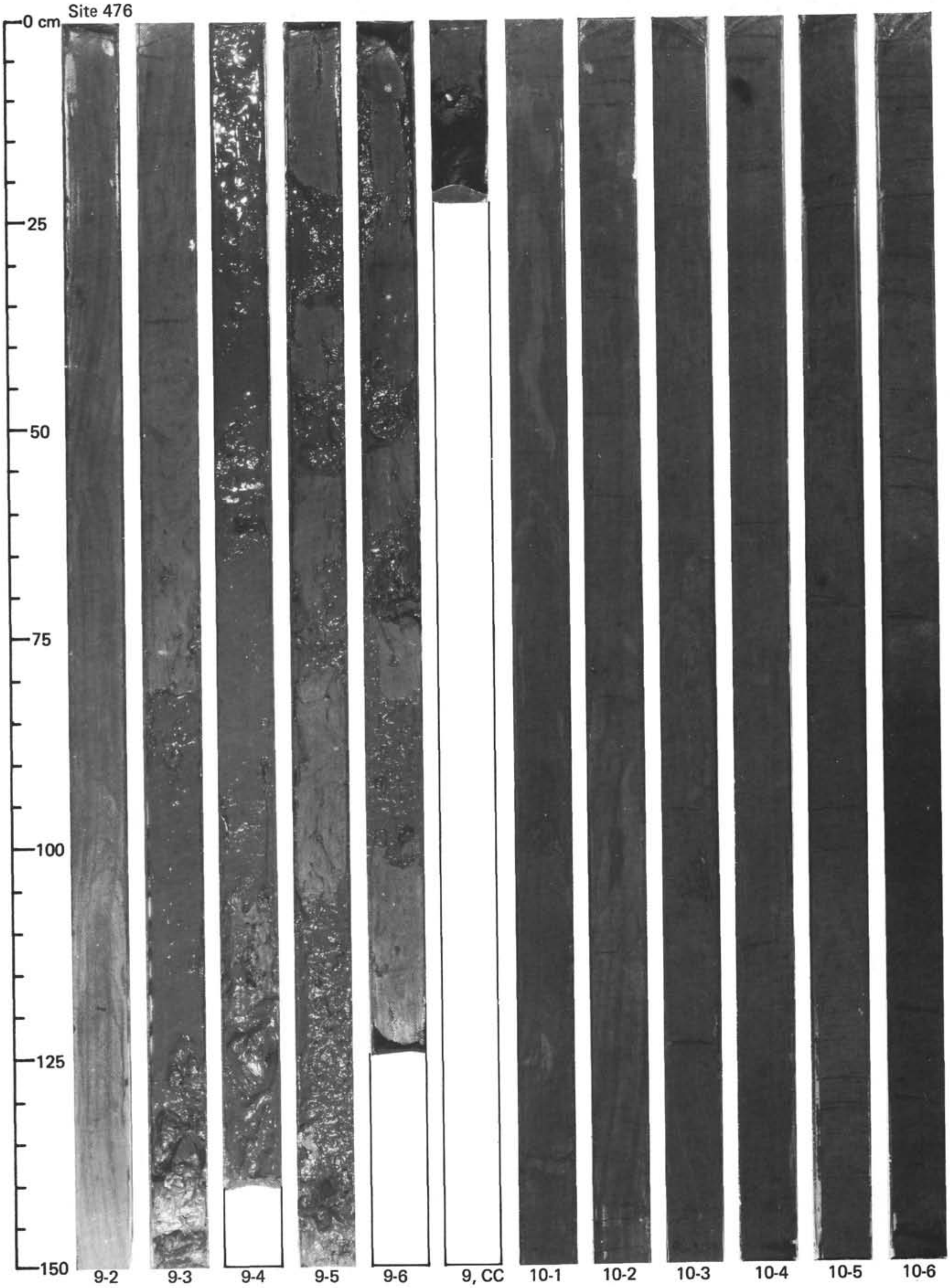
9-1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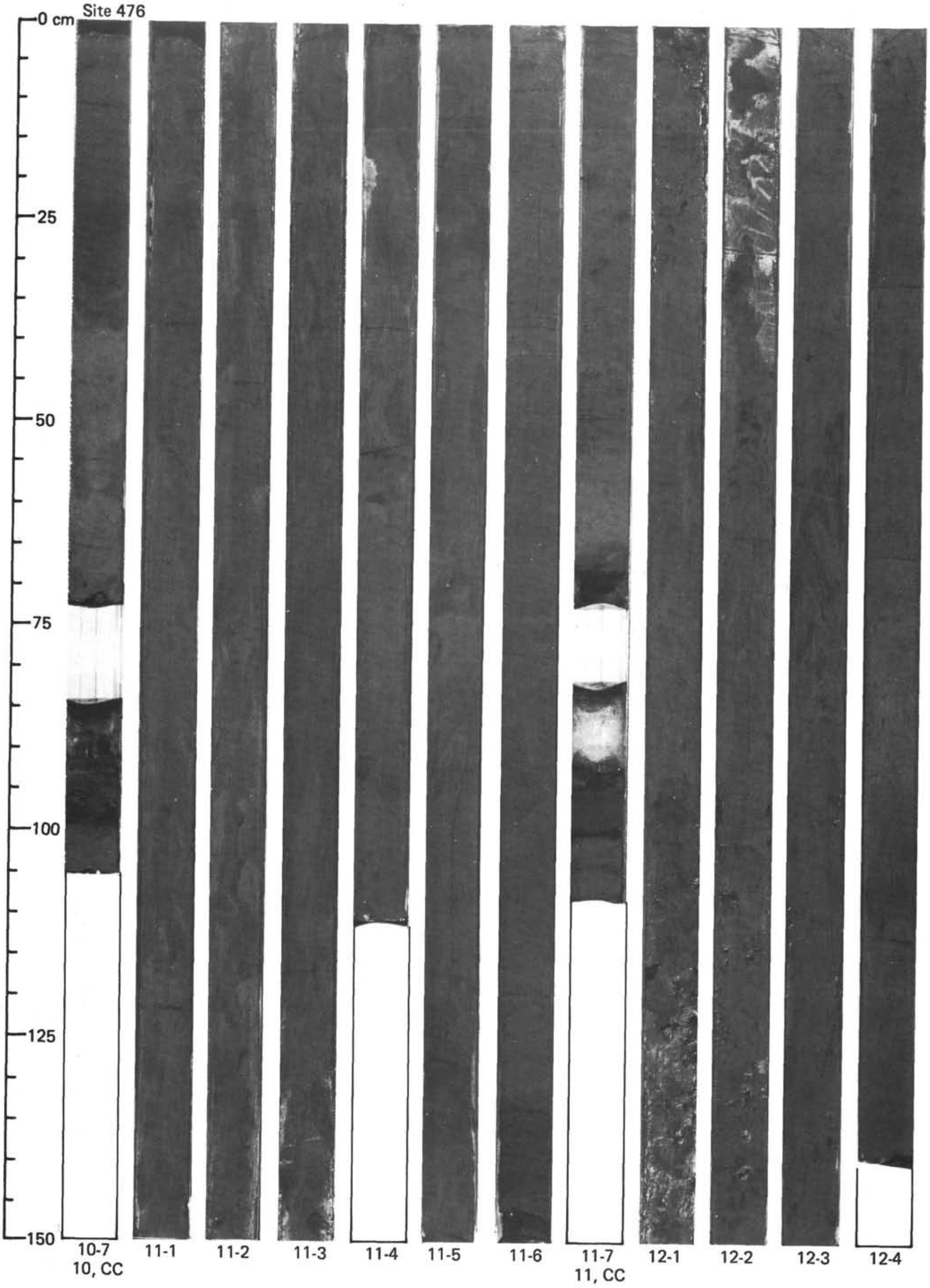
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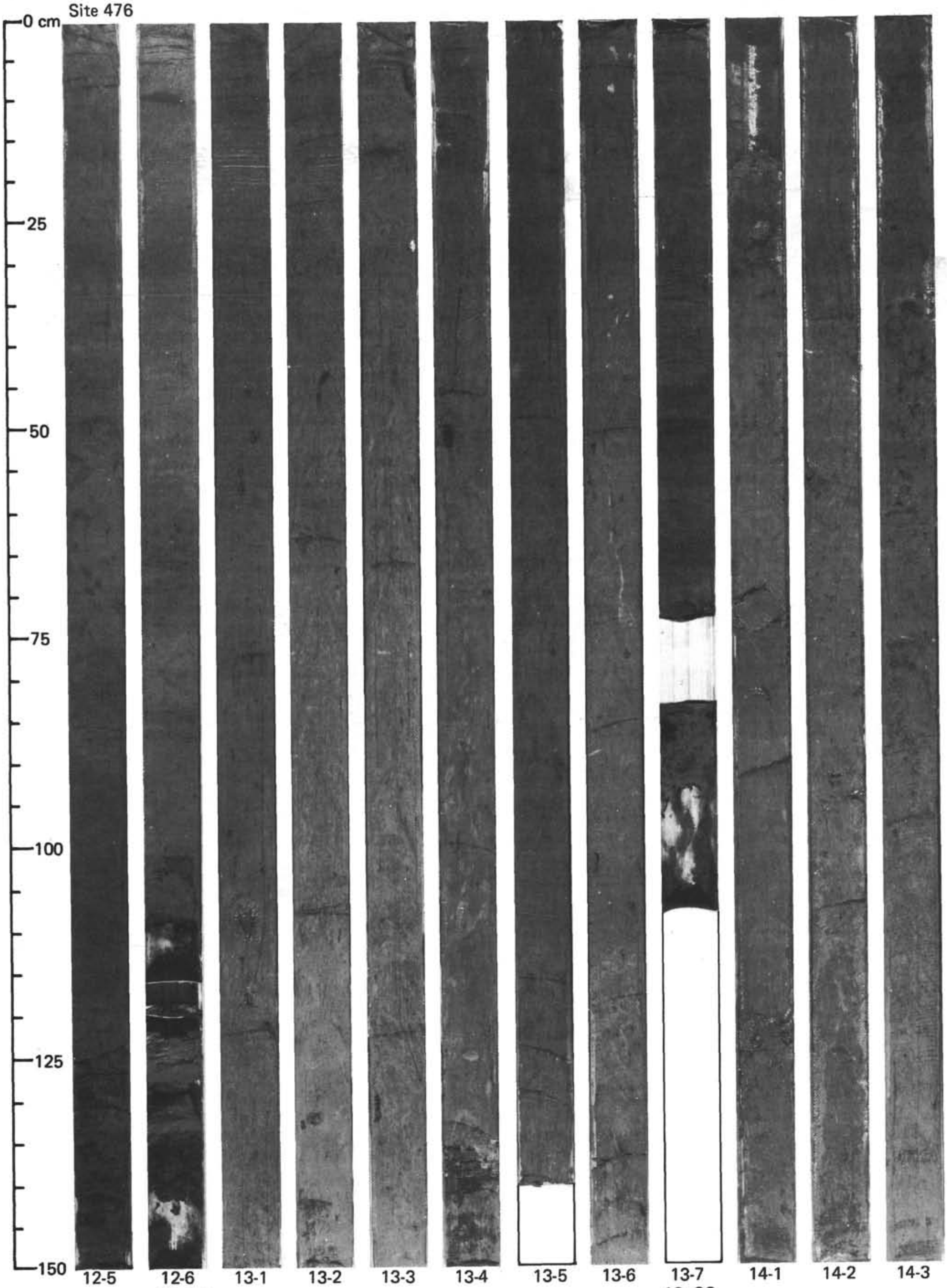
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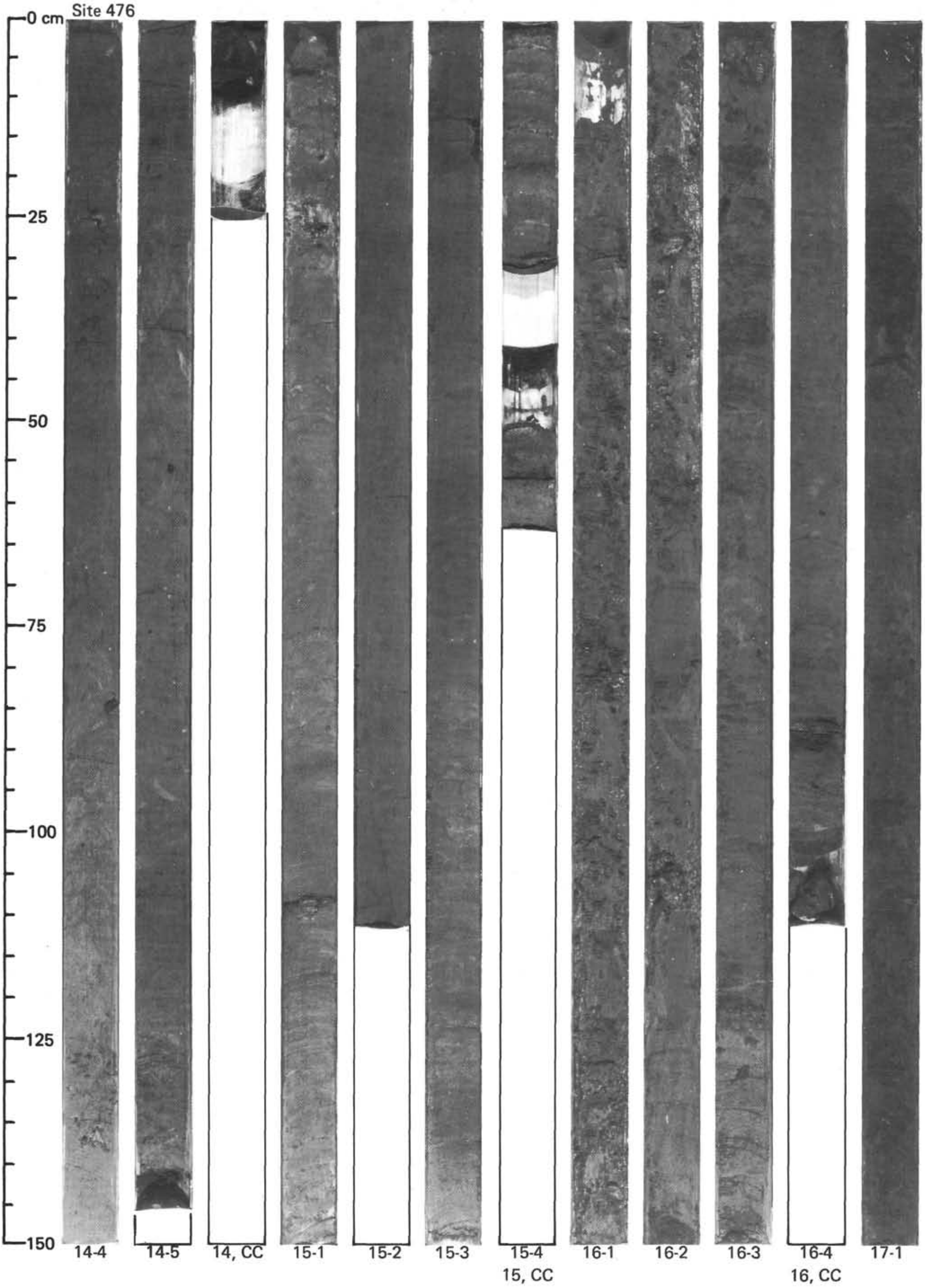
14-3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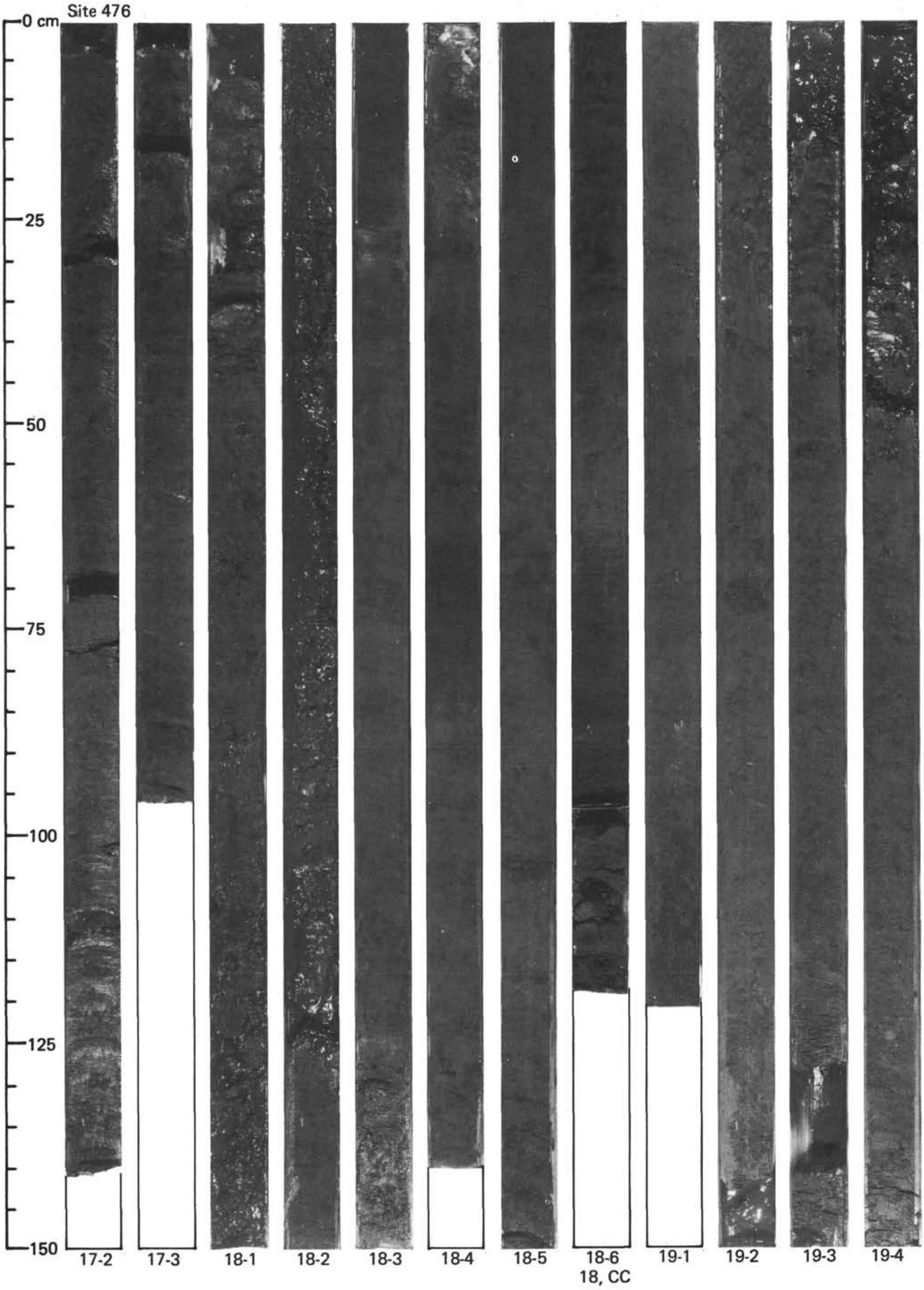
16, CC
17-1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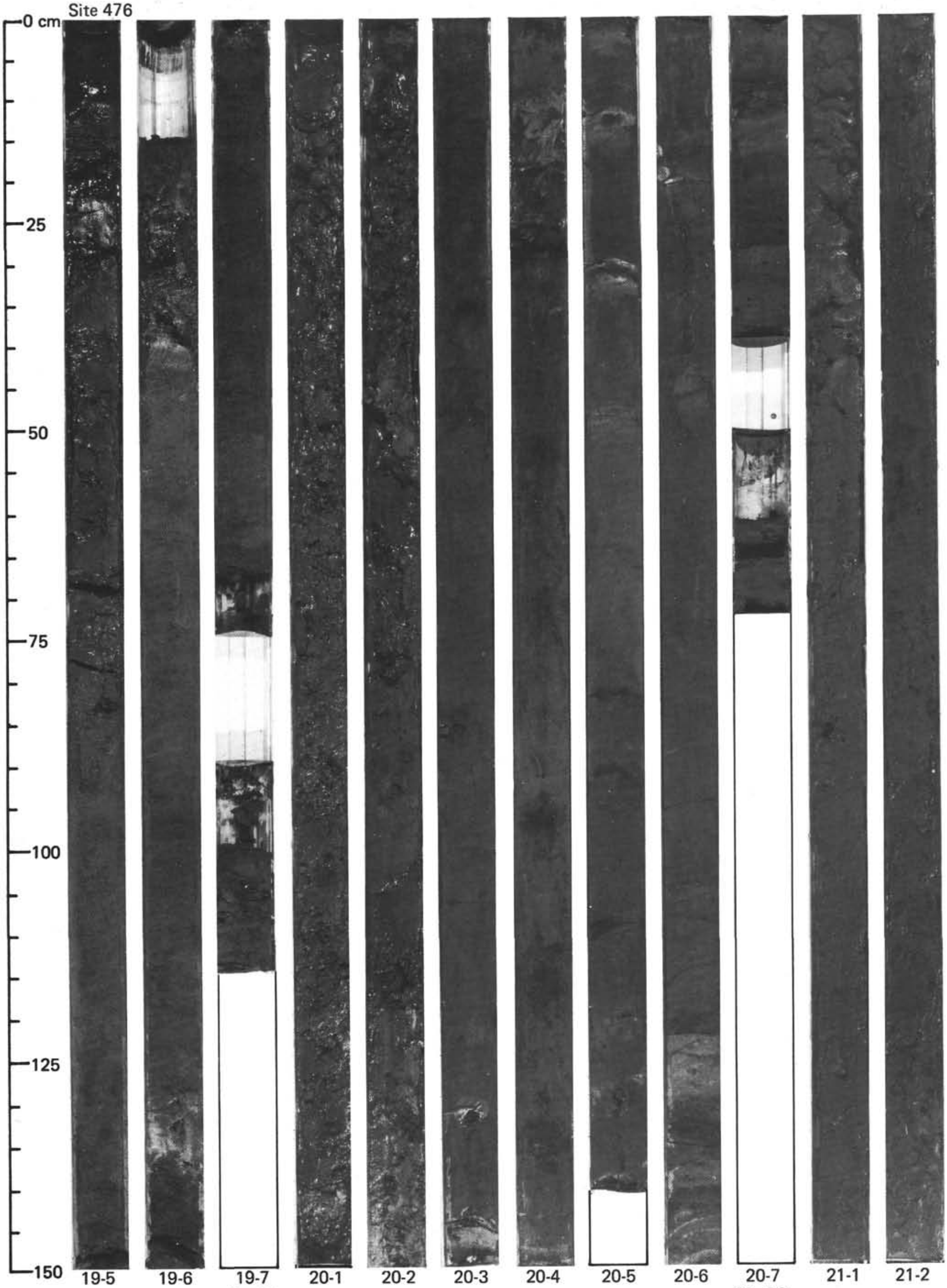
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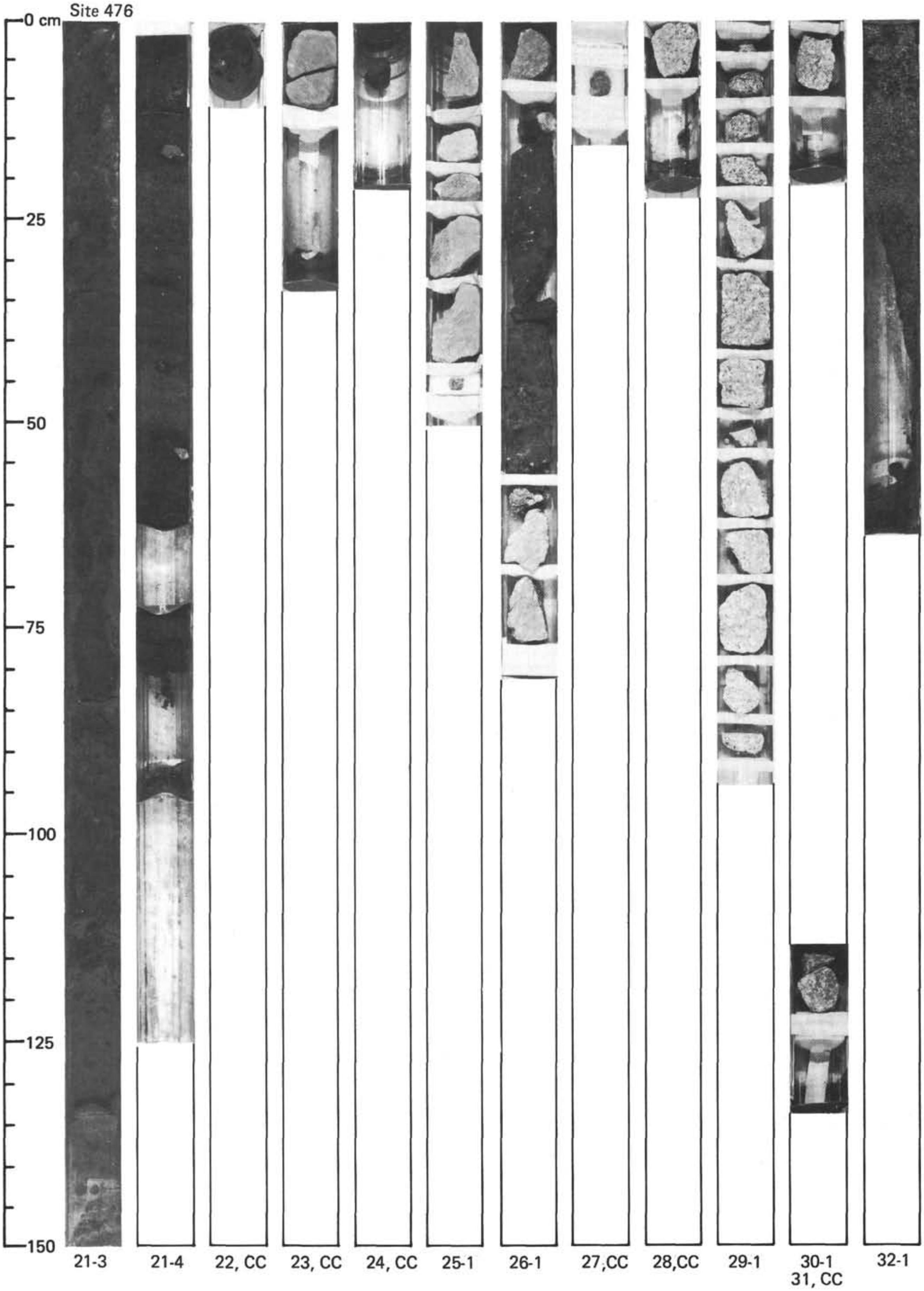
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21-3
21-4
22, CC
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24, CC
25-1
26-1
27,CC
28,CC
29-1
30-1
31, CC
32-1

HOLE 478

Date occupied: 24 December 1978

Date departed: 28 December 1978

Time on hole: 4 days

Position: 27°08.51′N; 111°30.46′W

Water depth (sea level; corrected m, echo-sounding): 1889

Water depth (rig floor; corrected m, echo-sounding): 1899

Bottom felt (m, drill pipe): 1913

Penetration (m): 464

Number of cores: 54

Total length of cored section (m): 464

Total core recovered (m): 310.25

Core recovery (%): Average 67; 72 in sediments; 61 in basalt

Oldest sediment cored:
Depth sub-bottom (m): 336
Nature: Nannofossil mudstone
Age: Late Pleistocene NN20

Basement: Not reached

Principal results: Hole 478, 12.1 km northwest of the spreading rift in the southern Guaymas Basin, was drilled to compare the geology and processes of an older flanking site to those of the active rift drilled at Site 477. On the basis of postulated spreading rates Site 478 is estimated to be 400,000 yr. old. Multichannel seismic data suggest that the acoustic basement here is contiguous to that of the modern rift zone.

Four lithologic units are assigned the section. The first, from 0.0 to 188.2 meters, comprises latest Pleistocene (NN21) muddy diatomaceous ooze to diatom mud with episodic gray sandy turbidites. Unit II, from 188.2 to 260 meters, is also of NN21 age and comprises dolomitic siltstones and diatomaceous mudstones intruded by two dolerite sills with contact aureoles. The third unit, from 260 to 342 meters, is made up of uniform diatom mudstone overlying laminated diatom mud with dolomite over siltstone in basal contact with the dolerite intrusion below. Diatoms indicate that the section above 310 meters is less than 260,000 yr. old. Rate of sedimentation in Units I-III is about 1300 m/m.y. This very high rate makes it possible to detect nonsteady-state conditions in the pore water chemistry of the sediments. From 342.5 to 464 meters is Unit IV, a complex intrusion of doleritic to basaltic texture. Drilling stopped in the basalt because of time limitations. The relatively young age of the oldest sediments, the state of their physical properties, and the lack of alteration of the sediments in general all suggest that deeper drilling would probably have again encountered sediment. Heat flow was 3.66 HFU.

HOLES 481 AND 481A

Date occupied: 3 January 1979 (481); 4 January 1979 (481A)

Date departed: 4 January 1979 (481); 8 January 1979 (481A)

Time on hole: 1 day, 7 hr., 40 min. (481); 3 days, 22 hr., 32 min. (481A)

Position: 27°15.18′N; 111°30.46′W (481 and 481A)

Water depth (sea level; corrected m, echo-sounding): 1998 (481 and 481A)

Water depth (rig floor; corrected m, echo-sounding): 2008 (481 and 481A)

Bottom felt (m, drill pipe): 2016.5 (481 and 481A)

Penetration (m): 52.25 (481); 384 (481A)

Number of cores: 11 (481); 37 (481A)

Total length of cored section (m): 52.25 (481), 338 (481A)

Total core recovered (m): 33.70 (481); 161.12 (481A)

Core recovery (%): 64 (481); 47, 56 through 481A-30 (481A)

Oldest sediment cored:
Depth sub-bottom (m): 52 (481); 364 (481A)
Nature: Thick turbidite (481); claystone (481A)
Age: Late Quaternary (481 and 481A)

Basement: Not reached (481 and 481A)

Principal results: Site 481 lies near the southwestern end of the northern active spreading rift of the Guaymas Basin in a situation analogous to that of Site 477—located near hydrothermal deposits observed during a submersible dive. Heat flow in the area, although high in places, is generally lower than at Site 477. Heat flow in Hole 481A was 4 HFU. Hole 481 was piston cored to 52 meters to allow detailed studies of early changes in physical and chemical properties. Hole 481A was conventionally cored from 42 to 384 meters. The sediment section for the two holes includes four alternating interbedded diatomaceous depositional types: 2 distinctive turbidite types, mass flow deposits, laminated sediments, and "host" sediments. The turbidite types imply different source terrains. Four igneous units, sills or sill groups, were encountered intruded into the soft young sediments, but recovery was only <1-40%, averaging about 33%. The sills range in texture from basalt to gabbro. Altered zones at sill/sediment contacts were thicker above than below the sills and hydrothermal fluids were probably heated pore waters, as dissolution of calcareous nannofossils is observed only in a 7-meter-thick zone above Igneous Unit 1.

Sediments at this site were deposited very rapidly. No depositional rates were calculated as no fossil boundaries were crossed, but we estimate that they must exceed 1000 m/m.y. These high rates of deposition yielded extremely high alkalinities and ammonia contents from the pore water. Hydrocarbon gases of the sediments are mainly biogenic CH_4, CO_2, and H_2S with traces of C_2H_6. Between the sills, a large thermogenic component is superimposed on the biogenic.

Note: Site summary for Site 477 appears on pp. 219–220.