6. SITE 471: OFFSHORE MAGDALENA BAY[1]

Shipboard Scientific Party[2]

HOLE 471

Date occupied: 9 November 1978

Date departed: 15 November 1978

Position: 23°28.93′N, 112°29.78′W

Water depth (sea level; corrected m, echo-sounding): 3101

Bottom felt (m, drill pipe): 3115.5

Penetration (m): 823

Number of cores: 88

Total length of cored section (m): 823

Total core recovered (m): 356.4

Core recovery (%): 43

Oldest sediment cored:
Depth sub-bottom (m): 741.5
Nature: Metalliferous sediment
Chronostratigraphy: Middle Miocene (14.5 to 15 m.y. old)

Basement:
Depth sub-bottom (m): 741.5
Nature: Altered diabase

Principal results: Hole 471 was drilled on the distal portion of a deep-sea fan west of the foot of the continental slope off Baja California. Five sedimentary units were delineated. Unit 1, from mudline to 63.5 meters, is nannofossil silty clay with minor ash that was deposited during the Quaternary and Pliocene at a rate of 15 m/m.y. Unit 2 is diatomaceous clay and silty clay and clayey diatomaceous ooze to a depth of 155.2 meters. It was deposited principally in the late Miocene at a rate of 35 m/m.y.; the Miocene/Pliocene boundary is in the uppermost part of the unit. Units 1 and 2 have densities of 1.5 g/cm^3 and velocities of 1.55 km/s. Unit 3 extends to a depth of 304 meters and is porcellanite and porcellaneous silty claystone with fragments of opal-CT (cristobalite) chert and thin beds of clayey dolomite. Core recovery averaged 5% in this unit; the Density and Neutron Logs suggest the presence of softer sediment interbeds in the unit that were not recovered. The top of Unit 3 is a diagenetic break marked by a sharp increase in density to 1.6 to 2 g/cm^3 for porcellanite and up to 2.8 g/cm^3 for dolomite; velocity increases sharply to 1.8 to 2.8 km/s (porcellanite) and 4 to 6 km/s (dolomite). Fossils are upper Miocene, but most samples are barren.

Unit 4 comprises the main part of the deep-sea fan and extends from 304 to 735.7 meters depth. It is bioturbated silty claystone with thin interbeds of calcareous sandstone and minor clayey carbonate and vitric ash. Faunal control is poor but indicates that deposition took place during the middle Miocene, with a sharp increase in sedimentation rate from 50 m/m.y. to 200 m/m.y. at about 360 meters depth. The seismic record shows an angular unconformity at this boundary; and the biostratigraphic record is consistent with a hiatus at the Unit 3/Unit 4 boundary. Sediment densities average about 2 g/cm^3 with somewhat higher values (2.4–3 g/cm^3) for carbonates and carbonate-cemented sandstone layers. Velocities are 2 km/s, increasing downsection to 2.3 km/s; carbonate and sandstone layers are as high as 4.9 km/s.

Unit 5 consists of hemipelagic claystone from 735.7 to 741.3 meters depth and altered sediment to the top of the diabase at 741.5 meters depth. The unit is intensely burrowed and contains microfaults and calcite veins. The altered sediment includes chalcopyrite- and sphalerite-bearing claystone, black quartzose chert, and red brown metalliferous sediment. Velocities and densities are the same as those in Unit 4 but without the high carbonate or sandstone values. Intercalations of metalliferous sediment also occur within the diabase, which is altered and consists of at least two or three sills. Fragmental texture may be the result of emplacement into soft sediment, although slickensides indicate some shearing after consolidation. Density varies from 2.3 to 2.8 g/cm^3, and velocity from 3.1 to 5.4 km/s; variability is in part caused by different degrees of alteration. The age of the oldest sediments above basement is 14.5 to 15.0 m.y., considerably older than the age extrapolated from the nearest striped magnetic anomalies.

A full suite of downhole logs was run from about the top of Unit 3 (top porcellanite) to total depth (T.D.). The Density and Sonic Logs clearly show the soft sediment in Unit 3 not recovered by coring; the porcellanite and dolomite beds are high values on both logs. Metalliferous sediment interbeds in diabase are also clearly indicated. The Density Log may demonstrate a correlation with degree of alteration of diabase. The conductivity curve on the Neutron Log best indicates the resolution of thin sandy beds in Unit 3. The Neutron Log shows considerable character in the diabase and may indicate fracture porosity or degree of alteration. Two Temperature Logs and two heat-probe measurements indicate high geothermal gradient and high heat flow; temperature is 12.5°C at a depth of 95 meters and 24.0°C at 142.5 meters. Assuming a conductivity of 2.5, heat flow at the site is 1.8 heat flow units (HFU) based on downhole logs and 3.9 HFU based on heat probe.

BACKGROUND AND OBJECTIVES

The Franciscan-like terrain of the California Continental Borderland reappears on Cedros and San Benito islands, westernmost Vizcaino Peninsula, and Magdalena and Santa Margarita islands west of Magdalena Bay (Fig. 1). The rocks of the Magdalena Bay islands include sheared gabbro, serpentinite, and variegated thin-bedded chert, an ophiolite assemblage that is highly sheared and locally a melange. Blueschist is rare at Magdalena Bay, although it is fairly abundant in the islands off Vizcaino Peninsula. The terrain is characterized by a strong free-air gravity high, which extends

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south-southeast from Magdalena Bay (Figs. 1 and 2), and high-relief magnetic anomalies, which extend seaward somewhat west of the gravity high (Figs. 1-3).

East of Magdalena Bay, Paleogene shallow-water sandstone (Tepetate Formation) is overlain by Oligocene and Miocene marine strata (San Ysidro and Monterey Formations), which are themselves overlain by the late Tertiary Comondu Volcanics, which form the mountainous backbone of Baja California del Sur, the Sierra Giganta. The Mesozoic batholithic terrain that dominates the high ground of Baja California del Norte may be buried beneath the Comondu. At this latitude, it appears at the surface only in the islands of the Gulf of California. Southeast of La Paz, granitic rocks also compose the Cape massif, a mountainous uplift separated from the Sierra Giganta by a north-south lowland that may be controlled by a fault.

Farther east is the Gulf of California, which underwent most of its rifting from mainland Mexico in the last 4 m.y., although a proto-gulf may have existed

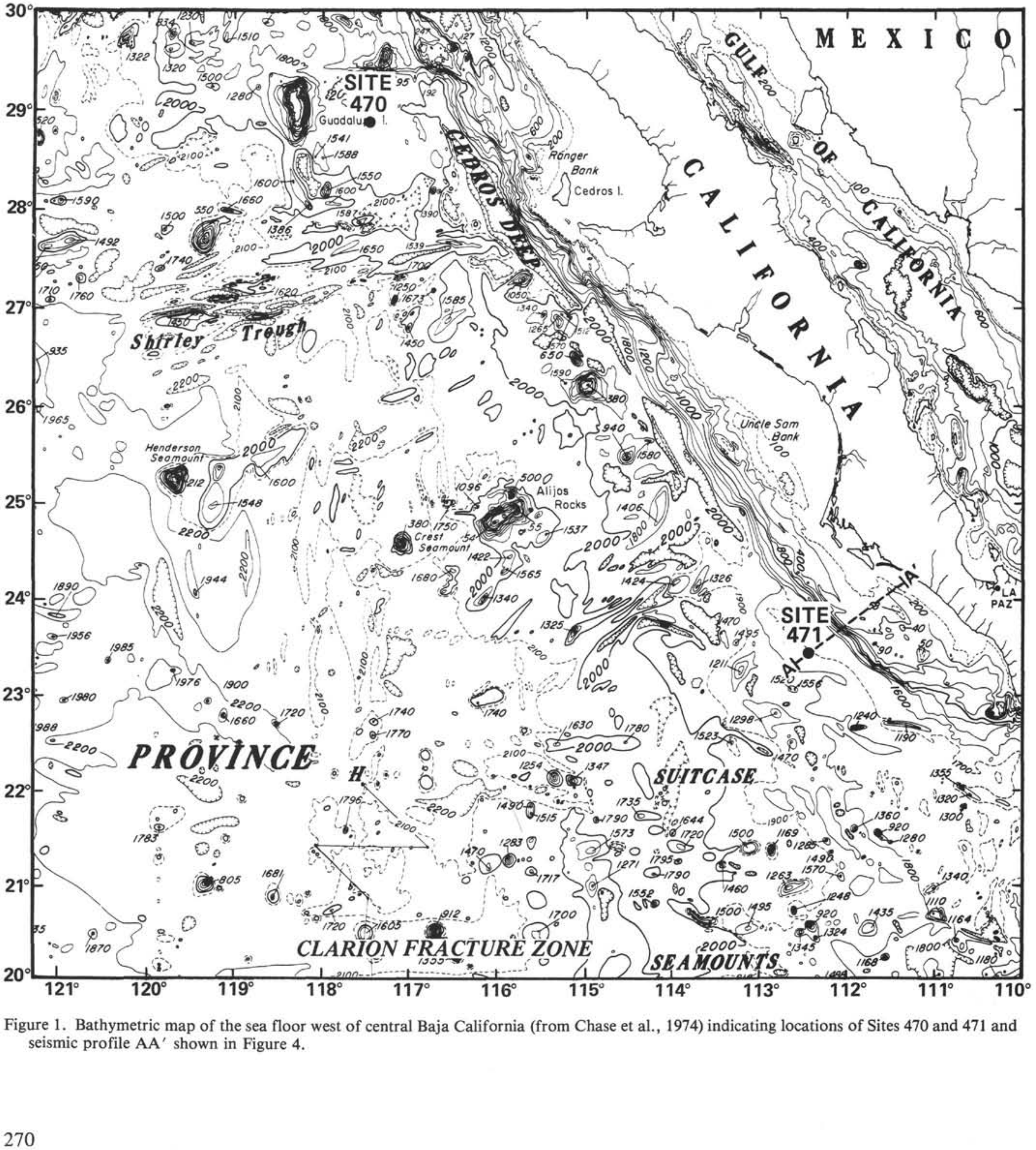

Figure 1. Bathymetric map of the sea floor west of central Baja California (from Chase et al., 1974) indicating locations of Sites 470 and 471 and seismic profile AA′ shown in Figure 4.

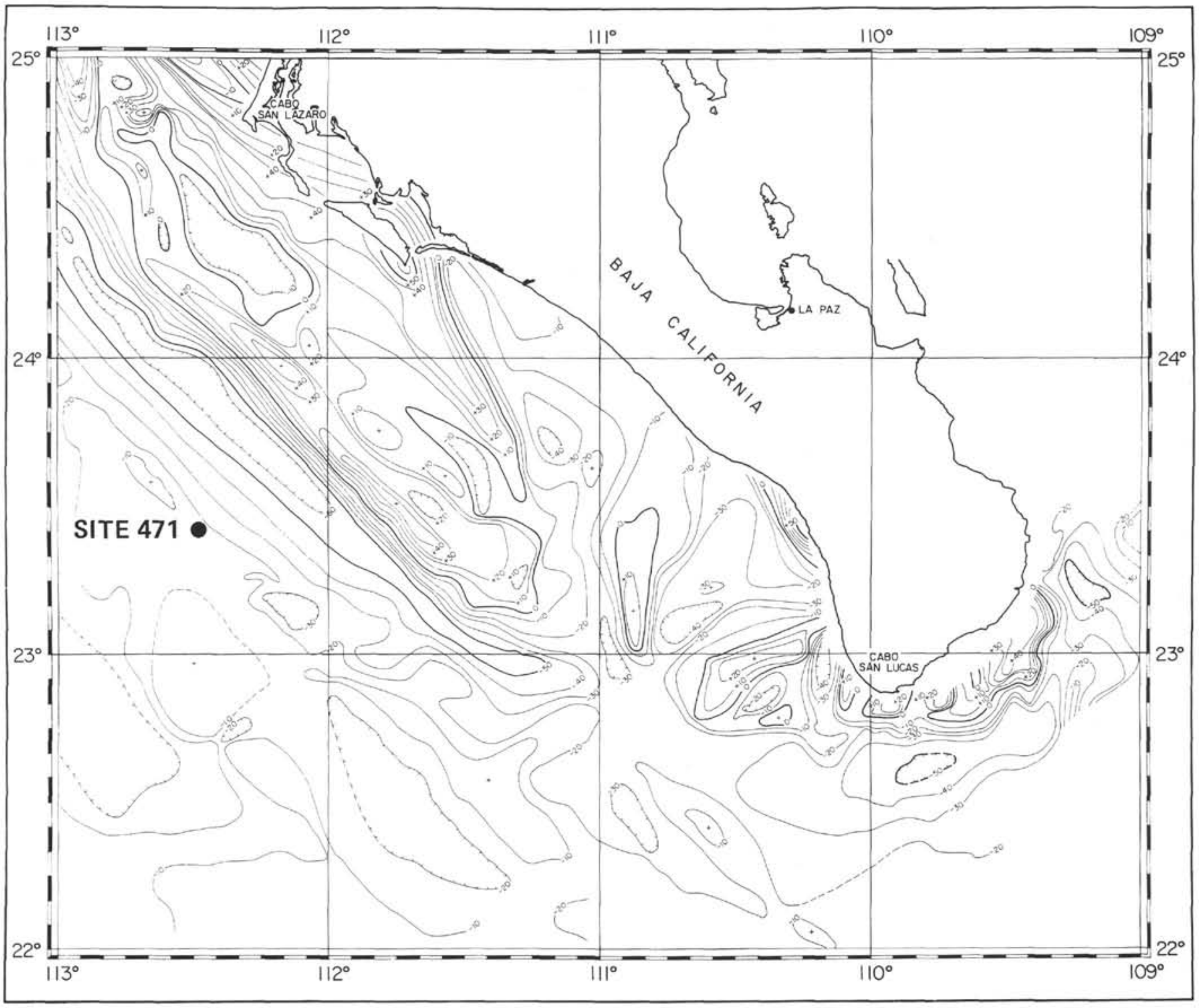

Figure 2. Free-air gravity anomaly map of the western continental margin of southern Baja California (from Huehn, 1977). (Contour interval is 10 mgal.)

earlier. The timing of initial separation of Baja California from the mainland is important to determine, because it would indicate when at this site a large source terrain, including the main Sierra Madre Occidental of Mexico, changed to a more restricted Baja California source terrain.

West of the ophiolitic zone of Magdalena Bay, the continental shelf is underlain by broadly folded Neogene sedimentary rocks (Fig. 4) that may overlie a ductile "Franciscan" or accretionary-wedge basement. The shelf is marked by linear highs and lows on the free-air gravity map and local magnetic highs suggestive of the high-amplitude anomalies of the islands off Magdalena Bay (Figs. 2 and 3). The shelf edge is marked by a linear gravity high that is flanked by a linear gravity low at the foot of the slope (Fig. 2).

A gravity low is associated with the Cedros deep, a feature that is topographically prominent from about 29°N south to about 24°30′N (Figs. 1 and 5). At these latitudes, the deep appears as a graben downfaulted against the continental slope on the east and against the abyssal sea floor on the west. The Cedros deep gravity low persists southeast to the latitude of the site and beyond to 23°N (Fig. 2). However, the topographic low is not present; instead, there is broad topographic bulge underlain by abyssal sea-floor sediments that dip gently to the east. The younger flat-lying sediments of Cedros deep and its southward continuation appear to overlie the pelagic sediments of the abyssal sea floor, but this relationship is not clearly established by reflection profiles. The Cedros deep does not appear to have a magnetic signature.

Site 471 is located in an area that is quiet in terms of gravity and magnetics (Figs. 1 and 3). Striped magnetic anomalies to the southwest were correlated to the geomagnetic time scale by Chase et al., (1970); their magnetic anomaly ages are shown in Figure 3. As Chase et al. (1970) pointed out, anomalies 12 m.y. of age and

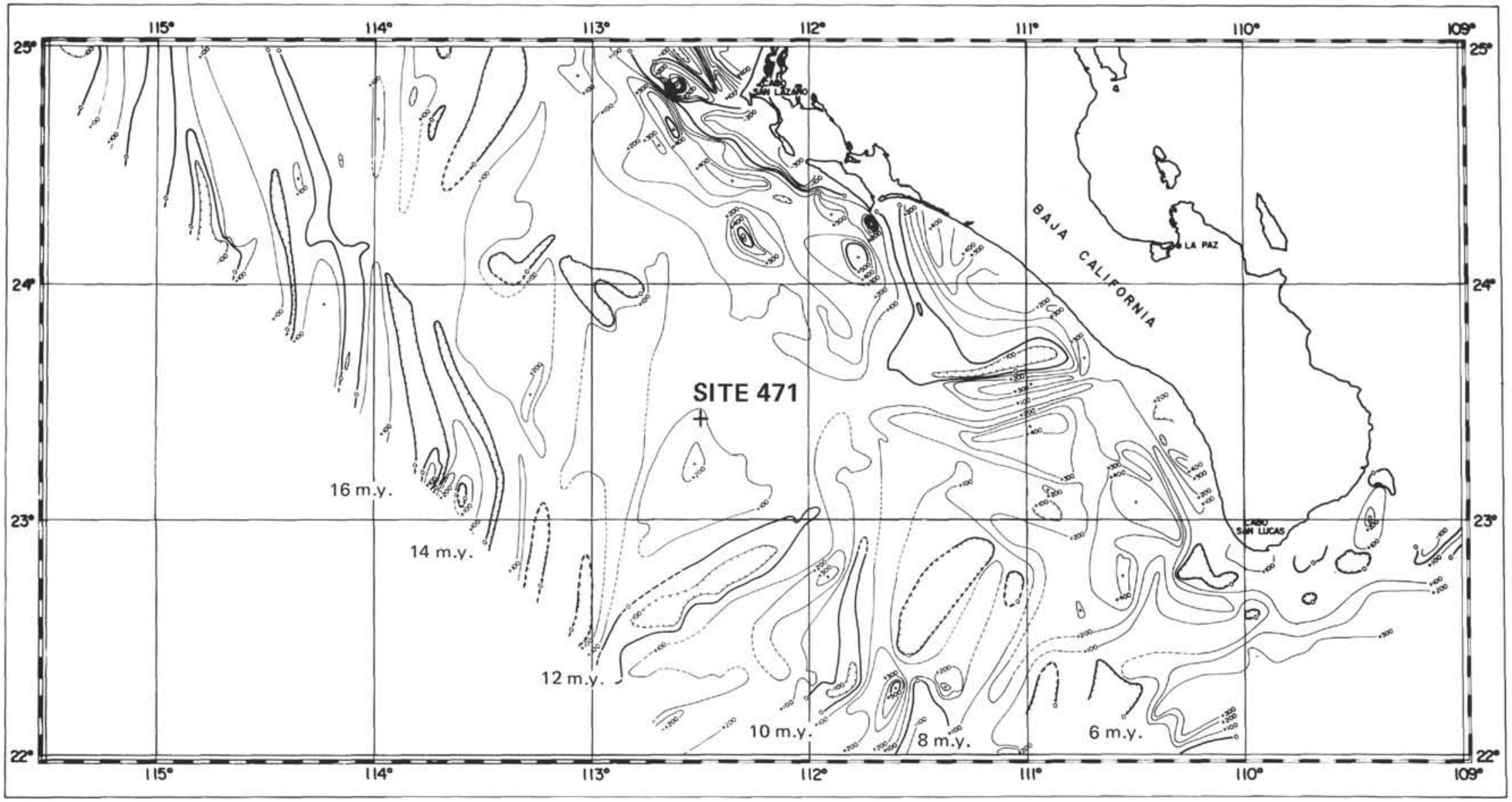

Figure 3. Total magnetic-field anomaly map of the western continental margin of southern Baja California from Huehn (1977); contour interval is 100 gammas. (Ages of magnetic stripes are after Chase et al. [1970].)

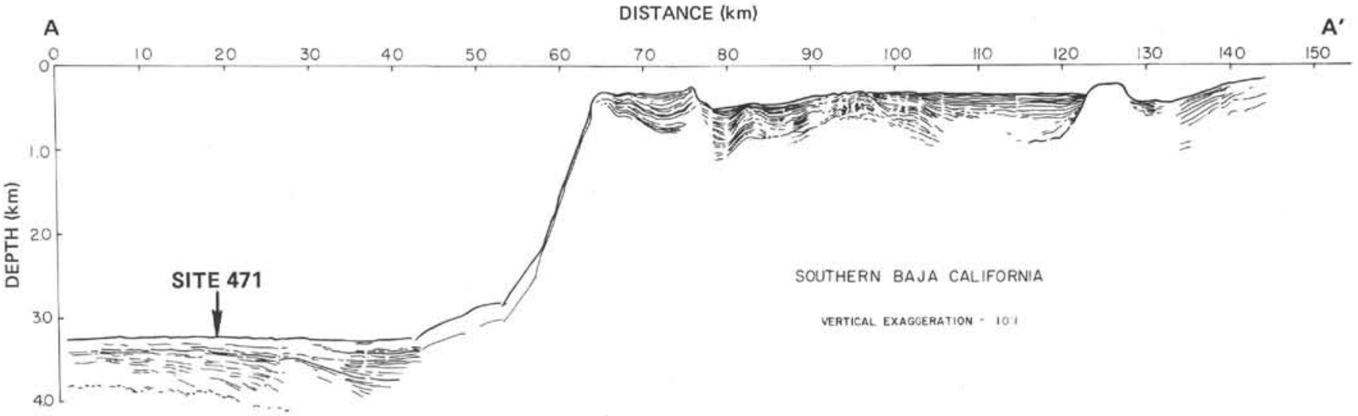

Figure 4. Line drawing of seismic-reflection profile AA′ through Site 471. (Vertical scale in kilometers assumes 1.5 km/s for the velocity of sand in water [from Huehn, 1977]. Deepest short-dashed line below site is basement reflector.)

older trend north-northwest, roughly parallel to the continental slope, but younger anomalies produce a fan pattern—such that those 8 m.y. old and younger are parallel to the present spreading center at the mouth of the gulf. The fan pattern of the magnetics makes estimating the magnetic-anomaly age of the crust at Site 471 somewhat ambiguous; the best guess is 11 m.y.

The thicker sediment section closer to the continental slope must indicate an increase in terrigenous input compare with Site 470. The eastward dip of the basement surface toward the foot of the slope (Fig. 4) suggests that the Sclater age-depth curve may be unusable in this case, because basement slopes downward in the direction of younger crust, the opposite effect of the Sclater age-depth relation. (Interestingly, the *Glomar Challenger* track from Site 470 to the Cedros deep shows the basement rising eastward in the direction of younger crust, as predicted by the Sclater curve, reversing only fairly close to the trench.) The deepening of the basement toward the continental slope may be the result of the vertical load of the continent, as suggested by the gravity low at the foot of the slope.

Site 471 is located, as are the more northerly sites, near a continental margin that was once a subducting margin, indicated by the "Franciscan" and ophiolite terrain; this would imply that the east slope of the Cedros deep was once a trench slope and that the deep itself is a fossil trench. The orientation of magnetic anomalies swung from north-south to northwest by 12 m.y. ago, an effect that Menard (1978) suggests may have been caused by the Farallon plate subducting only where there was sufficient thermal contrast between the cold, sinking plate and the surrounding asthenosphere for the plate to sink gravitationally. Where the rise crest intersected the trench obliquely, the Farallon plate would have been of near zero age at the time of subduction, and it would not have sunk because of a lack of thermal and density contrast; instead, the plate and its trailing rise crest would have pivoted counterclockwise parallel to the continental slope. The subsequent clockwise swing between 12- and 10-m.y.-old magnetic stripes may have been the result of a triple junction involving a small plate to the north, as Chase et al. (1970) suggested.

Whether the foot of the continental slope was a transform boundary 60 to 10 m.y. ago is not clear, but it is now a passive margin with low seismicity, just as it is farther north off southern California.

The oceanic front migrated approximately 10° of latitude in the northeastern Pacific during the Neogene in response to major climatic oscillations (Ingle, 1973). The location of Site 471, just south of the present-day mixing zone between distal California Current and equatorial waters and about 5° south of Site 470 (Figs. 2, 5), is well-suited for the study of the extent of southward penetration of higher-latitude assemblages during cold pulses in the paleoclimatic history of the area. The 800 meters of sediments overlying the basement were expected to contain a middle Miocene to Holocene planktonic record of mostly temperate elements, with influx of cooler, higher-latitude elements during times of climatic deteriorations and/or intensification of oceanic circulation.

OPERATIONS

The track from Site 470 to 471 was designed to determine the relations of both sites to the continental slope off Baja California. Accordingly, we took a slightly zigzag course to cross the Cedros deep twice, then steamed northeast across Site 471 to the continental slope, then returned on our track and dropped the beacon as we headed southwest down the broad apron of a deep-sea fan at the foot of the slope (Figs. 6 and 7).

Continuous coring was routine, with moderate to high recovery to 161.5 meters (Table 1). The heat-flow probe was run twice; the criterion for running the probe was that sediment be firm enough to take weight, but not so hard that the probe would not penetrate it. With a planned 50 meters between probe runs, it was possible to run the probe only twice, once at 95 meters and again at 155 meters. The sand line just above the heat probe was found to be knotted after the second run, requiring that about 150 meters of sand line be cut off before the next core.

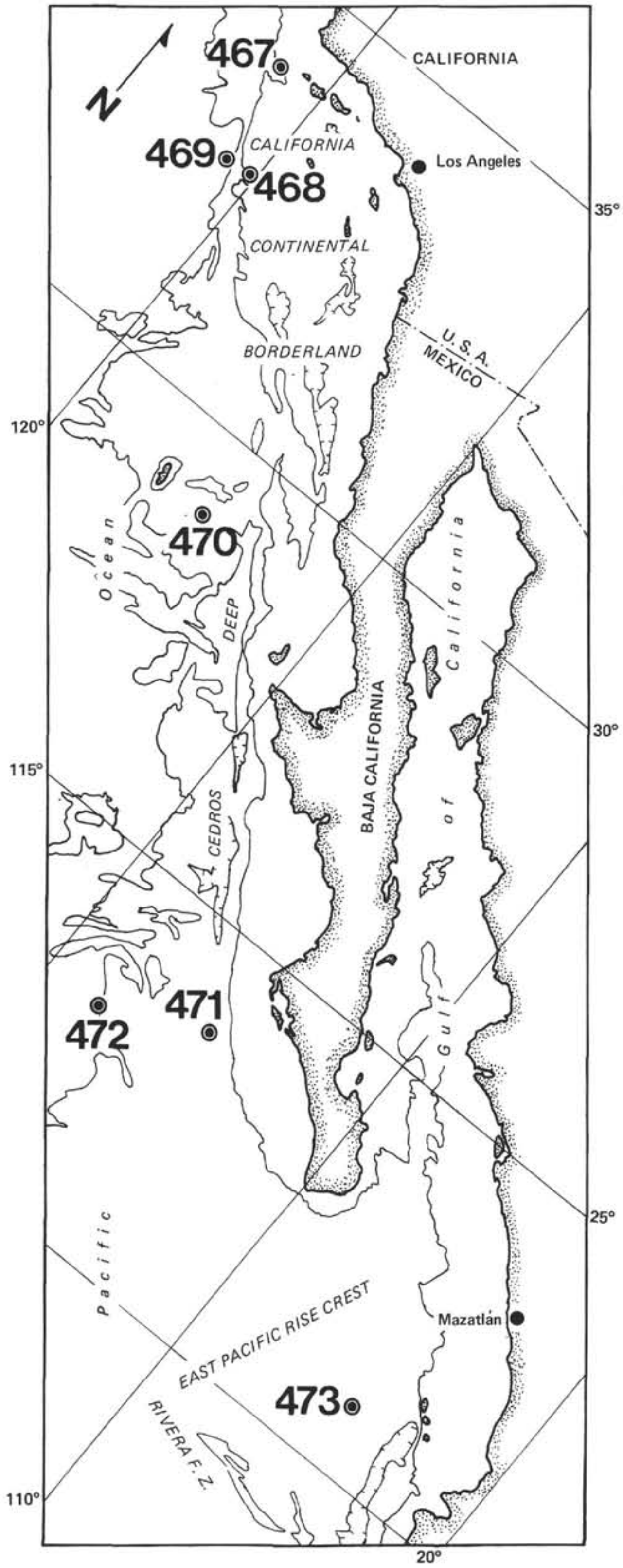

Figure 5. Location of Leg 63 sites.

Beginning with Core 18 at 161.5 meters, recovery dropped to about 5%, and the coring rate decreased from less than 10 min per core to 20 to 50 min per core. This zone of low recovery corresponds to Lithologic Unit 3, characterized by porcellanite alternating with softer sediments that were not recovered in cores but were identified on downhole logs. Recovery improved beginning with Core 34 at a depth of 313.5 meters, the approximate top of Lithologic Unit 4—the distal turbidite fan sequence. In the past, turbidites have been difficult for DSDP to drill and to recover in cores. Our favorable experience here may have been caused by the low porosity resulting from carbonate cement and to the lack of interbedded cherts or porcellanites. Core recovery was moderately high in Unit 4, with an occasional empty core barrel (Cores 55 and 67) and some recoveries limited to core catchers (in Cores 40, 49, 54, 56, 61, 62, and 68). There is no obvious correlation between core recovery and lithology in Unit 4. Coring rates in Units 4 and 3 were about the same. Other problems included bit plugging: a piece of core would lodge in the throat of the bit, which had to be dislodged with a center bit. Some torquing was noted in Unit 3, probably caused by fractured porcellanite falling in the hole. Frequent mud flushes in this interval cleaned up the hole, and few problems occurred at greater depths in sediment. Small amounts of gas bleeding from the cores were monitored on the Carle and HP gas chromatographs.

Diabase was encountered in Core 79, and coring continued through Core 88. Recovery was fairly good, and cores were close to gauge even at the bottom of the hole. The diabase occurs as altered sills, a lithology that has much higher recovery than pillow basalts, according to experience at previous DSDP sites. The center bit had to be run after Cores 79, 80, and 85, following indications of a plugged bit; otherwise operations were fairly routine. Coring time ranged from 26 minutes for Core 86 to 197 minutes for Core 84; there was no significant decrease in coring rate with depth. Our most trying moments were a stuck core barrel at Core 88, which finally released after once shearing the pin on the fishing neck. "Clay" at the bottom of the hole was in part fill and in part altered, fractured diabase.

The hole was flushed with 30 barrels of gel mud and 20 barrels of guartec in preparation for logging. The hydraulic bit release (HBR) go-devil was pumped down and the bit released at 1600 psi. The hole was filled with 300 barrels of gel mud, and the drill pipe was pulled to 158 meters below the mudline, near the top of Unit 3 (containing porcellanite). We set the pipe this deep to avoid losing the hole in sediments as unconsolidated as those in Units 1 and 2. (We attribute the failure of the logging tool to penetrate the sediment at Site 470 to the fact that sediments below the drill pipe were so unconsolidated that the hole was lost simply by motion of the drill pipe related to heaving of the ship.)

The Sonic, Caliper, and Gamma-Ray Logs were run, and the hole was found to be clean to bottom. The

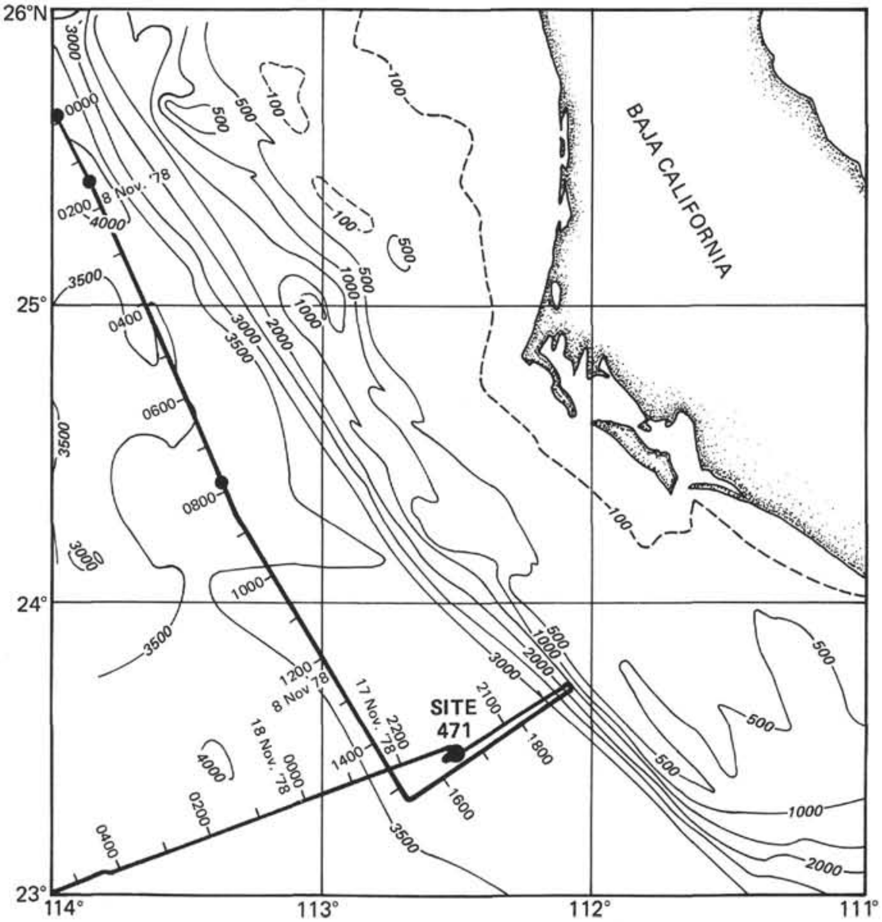

Figure 6. *Challenger* track approaching and departing Site 471. (Small concentric circles on track lines are satellite fixes. Bathymetry [in meters] was contoured aboard ship on the basis of data from *Baja 75* and *Baja 76* cruises, Oregon State University.)

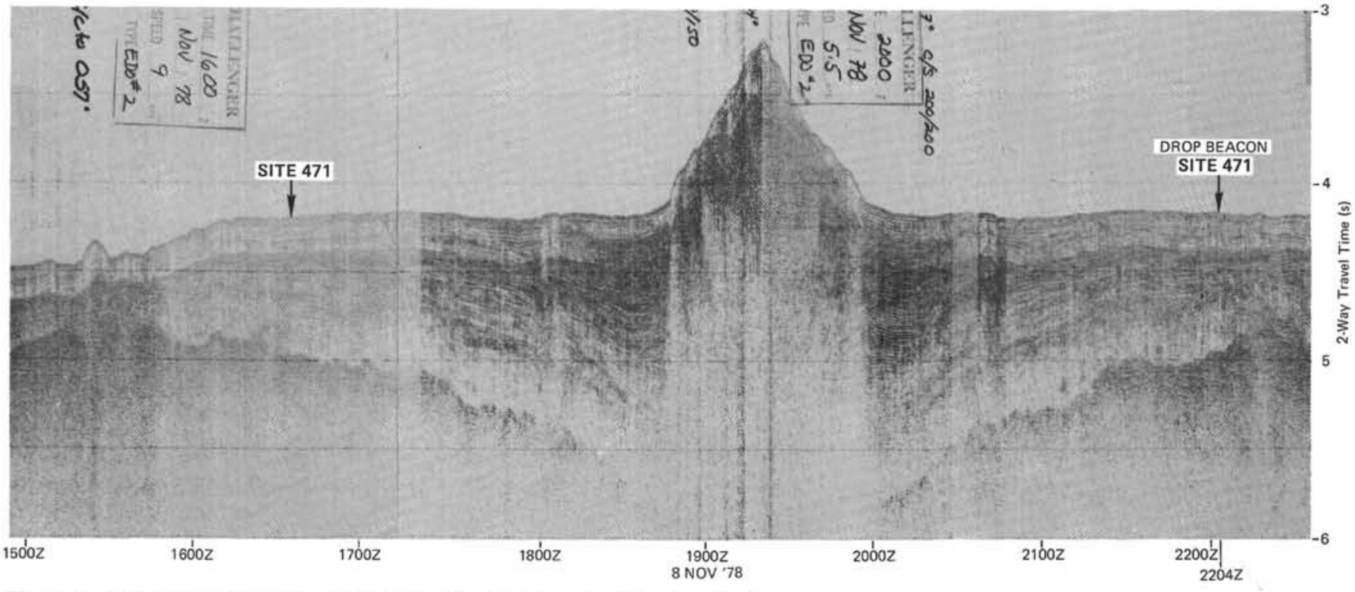

Figure 7. *Challenger* seismic line approaching Site 471. (See Fig. 6 for location.)

Table 1. Coring summary, Site 471.

Core No.	Date (Nov. 1978)	Time	Depth from Drill Floor (m)	Depth below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Core Recovered (%)
1	9	0108	3115.5–3125.0	0.0–9.5	9.5	9.87	100+
2	9	0204	3125.0–3134.5	9.5–19.0	9.5	Trace	0
3	9	0259	3134.5–3144.0	19.0–28.5	9.5	6.00	63
4	9	0350	3144.0–3153.5	28.5–38.0	9.5	10.34	100+
5	9	0450	3153.5–3163.0	38.0–47.5	9.5	10.83	100+
6	9	0548	3163.0–3172.5	47.5–57.0	9.5	9.75	100+
7	9	0645	3172.5–3182.0	57.0–66.5	9.5	10.12	100+
8	9	0736	3182.0–3191.5	66.5–76.0	9.5	7.80	82
9	9	0840	3191.5–3201.0	76.0–85.5	9.5	3.48	37
10	9	0935	3201.0–3210.5	85.5–95.0	9.5	9.75	100+
11	9	1215	3210.5–3220.0	95.0–104.5	9.5	9.82	100+
12	9	1320	3220.0–3229.5	104.5–114.0	9.5	9.56	100+
13	9	1412	3229.5–3239.0	114.0–123.5	9.5	10.26	100+
14	9	1507	3239.0–3248.5	123.5–133.0	9.5	7.95	84
15	9	1600	3248.5–3258.0	133.0–142.5	9.5	10.30	100+
16	9	1942	3258.0–3267.5	142.5–152.0	9.5	5.84	61
17	9	2101	3267.5–3277.0	152.0–161.5	9.5	3.25	34
18	9	2217	3277.0–3286.5	161.5–171.0	9.5	0.20	2
19	10	0039	3286.5–3296.0	171.0–180.5	9.5	0.26	3
20	10	0227	3296.0–3305.5	180.5–190.0	9.5	0.50	5
21	10	0550	3305.5–3315.0	190.0–199.5	9.5	0.78	8
22	10	0720	3315.0–3324.5	199.5–209.0	9.5	0.39	4
23	10	0840	3324.5–3334.0	209.0–218.5	9.5	0.53	6
24	10	1005	3334.0–3343.5	218.5–228.0	9.5	0.00	0
25	10	1145	3343.5–3353.0	228.0–237.5	9.5	0.03	0.3
26	10	1326	3353.0–3362.5	237.5–247.0	9.5	0.83	9
27	10	1451	3362.5–3372.0	247.0–256.5	9.5	0.20	2
28	10	1630	3372.0–3381.5	256.5–266.0	9.5	0.50	5
29	10	1839	3381.5–3391.0	266.0–275.5	9.5	0.19	2
30	10	2008	3391.0–3400.5	275.5–285.0	9.5	1.03	11
31	10	2150	3400.5–3410.0	285.0–294.5	9.5	1.32	14
32	10	2326	3410.0–3419.5	294.5–304.0	9.5	0.94	10
33	11	0110	3419.5–3429.0	304.0–313.5	9.5	0.91	10
34	11	0233	3429.0–3438.5	313.5–323.0	9.5	3.27	34
35	11	0402	3438.5–3448.0	323.0–332.0	9.5	3.98	42
36	11	0525	3448.0–3457.5	332.5–342.0	9.5	1.78	19
37	11	0710	3457.5–3467.0	342.0–351.5	9.5	2.98	31
38	11	0825	3467.0–3476.5	351.5–361.0	9.5	2.93	31
39	11	0952	3476.5–3486.0	361.0–370.5	9.5	6.10	64
40	11	1120	3486.0–3495.5	370.5–380.0	9.5	0.04	0.4
41	11	1235	3495.5–3505.0	380.0–389.5	9.5	6.52	69
42	11	1345	3505.0–3514.5	389.5–399.0	9.5	1.25	13
43	11	1500	3514.5–3524.0	399.0–408.5	9.5	6.63	70
44	11	1618	3524.0–3533.5	408.5–418.0	9.5	3.82	40
45	11	1735	3533.5–3543.0	418.0–427.5	9.5	3.19	34
46	11	1907	3543.0–3552.5	427.5–437.0	9.5	2.36	25
47	11	2026	3552.5–3562.0	437.0–446.5	9.5	2.53	27
48	11	2143	3562.0–3571.5	446.5–456.0	9.5	4.05	43
49	11	2303	3571.5–3581.0	456.0–465.5	9.5	0.32	3
50	12	0045	3581.0–3590.5	465.5–475.0	9.5	5.47	58
51	12	0212	3590.5–3600.0	475.0–484.5	9.5	4.46	47
52	12	0332	3600.0–3609.5	484.5–494.0	9.5	4.65	49
53	12	0452	3609.5–3619.0	494.0–503.5	9.5	6.82	72
54	12	0615	3619.0–3628.5	503.5–513.0	9.5	0.14	1
55	12	0735	3628.5–3638.0	513.0–522.5	9.5	0.00	0
56	12	0910	3638.0–3647.5	522.5–532.0	9.5	0.12	1
57	12	1030	3647.5–3657.0	532.0–541.5	9.5	6.75	71
58	12	1205	3657.0–3666.5	541.5–551.0	9.5	6.40	67
59	12	1326	3666.5–3676.0	551.0–560.5	9.5	3.59	38
60	12	1450	3676.0–3685.5	560.5–570.0	9.5	2.65	28
61	12	1612	3685.5–3695.0	570.0–579.5	9.5	0.09	1
62	12	1733	3695.0–3704.5	579.5–589.0	9.5	0.12	1
63	12	1856	3704.5–3714.0	589.0–598.5	9.5	5.95	63
64	12	2031	3714.0–3723.5	598.5–608.0	9.5	7.46	79
65	12	2159	3723.5–3733.0	608.0–617.5	9.5	4.17	44
66	12	2337	3733.0–3742.5	617.5–627.0	9.5	0.13	1
67	13	0135	3742.5–3752.0	627.0–636.5	9.5	0.00	0
68	13	0345	3752.0–3761.5	636.5–646.0	9.5	0.10	1
69	13	0715	3761.5–3771.0	646.0–655.5	9.5	5.67	60
70	13	0930	3771.0–3780.5	655.5–665.0	9.5	6.48	68
71	13	1123	3780.5–3790.0	665.0–674.5	9.5	6.10	64
72	13	1452	3790.0–3799.5	674.5–684.0	9.5	7.55	79
73	13	1632	3799.5–3809.0	684.0–693.5	9.5	7.59	80
74	13	1812	3809.0–3818.5	693.5–703.0	9.5	7.00	74
75	13	1948	3818.5–3828.0	703.0–712.5	9.5	6.96	73
76	13	2145	3828.0–3837.5	712.5–722.0	9.5	7.35	77
77	13	2350	3837.5–3847.0	722.0–731.5	9.5	8.63	91
78	14	0221	3847.0–3856.5	731.5–741.0	9.5	7.71	81
79	14	0547	3856.5–3866.0	741.0–750.5	9.5	2.23	23
80	14	1105	3866.0–3875.5	750.5–760.0	9.5	3.48	37
81	14	1440	3875.5–3884.5	760.0–769.0	9.0	4.35	48
82	14	1705	3884.5–3893.5	769.0–778.0	9.0	2.12	24
83	14	1934	3893.5–3902.5	778.0–787.0	9.0	3.65	41
84	15	0000	3902.5–3911.5	787.0–796.0	9.0	2.22	25
85	15	0334	3911.5–3920.5	796.0–805.0	9.0	2.41	27
86	15	0720	3920.5–3922.5	805.0–807.0	2.0	0.50	25
87	15	1045	3922.5–3929.5	807.0–814.0	7.0	5.06	72
88	15	1515	3929.5–3938.5	814.0–823.0	9.0	4.99	55
Total					823.0	356.40	43

variable Density–Sonic (Wave–Train) Log was then run, followed by the Temperature–Density–Gamma-Ray Log; temperature was logged going down and the Density–Gamma-Ray Log was taken coming up. This was followed by the Guard–Neutron–Gamma-Ray Log, which was followed by the Induction–Gamma-Ray Log. A final Temperature Log was taken after pulling a stand of pipe while the log was in the hole, thereby allowing another 28 meters of open hole to be logged.

The hole was then cemented because of the gas shows monitored in the cores, the pipe was pulled, and we left for the next site at 1327 hours,[3] 18 November, 1978.

LITHOLOGY

Sediments and Sedimentary Rocks

Site 471 is characterized by a thick section of interbedded silty claystone and sandstone overlain by a thinner section of sediments and sedimentary rocks, including porcellanite, diatomaceous clay, and nannofossil silty clay. We defined five lithologic units above altered diabase at this site (Fig. 8; Table 2).

Unit 1: Nannofossil Silty Clay (0–63.5 m)

Unit 1 is mainly composed of grayish olive green nannofossil silty clay. The abundance of nannofossils ranges from 15% to 40%. Grains of angular silt-size quartz and feldspar are less common, 3% to 12% and 1% to 6%, respectively. Siliceous microfossils are rare. In addition to nannofossil silty clay, this unit also contains layers of olive gray to dark greenish gray silty clay. Angular, silt-size grains of quartz and feldspar average 20% and 8%, respectively. Small patches of pinkish gray vitric ash and dusky yellow green calcareous ooze are scattered throughout this unit. Dark reduction spots and streaks of finely disseminated pyrite are also present. The boundary with the underlying diatomaceous sediment of Unit 2 is gradational, marked by a distinct increase in the abundance of diatoms in Core 6.

Unit 2: Variegated Diatomaceous Clay and Ooze (63.5–155.2 m)

Unit 2 consists of diatomaceous clay, diatomaceous silty clay, and clayey diatomaceous ooze. These sediments vary from dusky yellow green and olive gray to dark yellowish brown and grayish olive green. The darker colors correspond to greater proportions of diatoms in the sediment (e.g., Cores 9–10 and 16–17). Silt-size grains of quartz and feldspar decrease in abundance downhole in this unit, and diatomaceous silty clay grades into the underlying diatomaceous clay and clayey diatomaceous ooze in Core 8. Correspondingly, the abundance of diatoms increases downhole from 15% to 70%. Grayish purple reduction spots and streaks of finely disseminated pyrite as well as dusky yellowish

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[3] Times specified in the text are local times in hours, and those in the seismic-section figures are Zulu (Z) times.

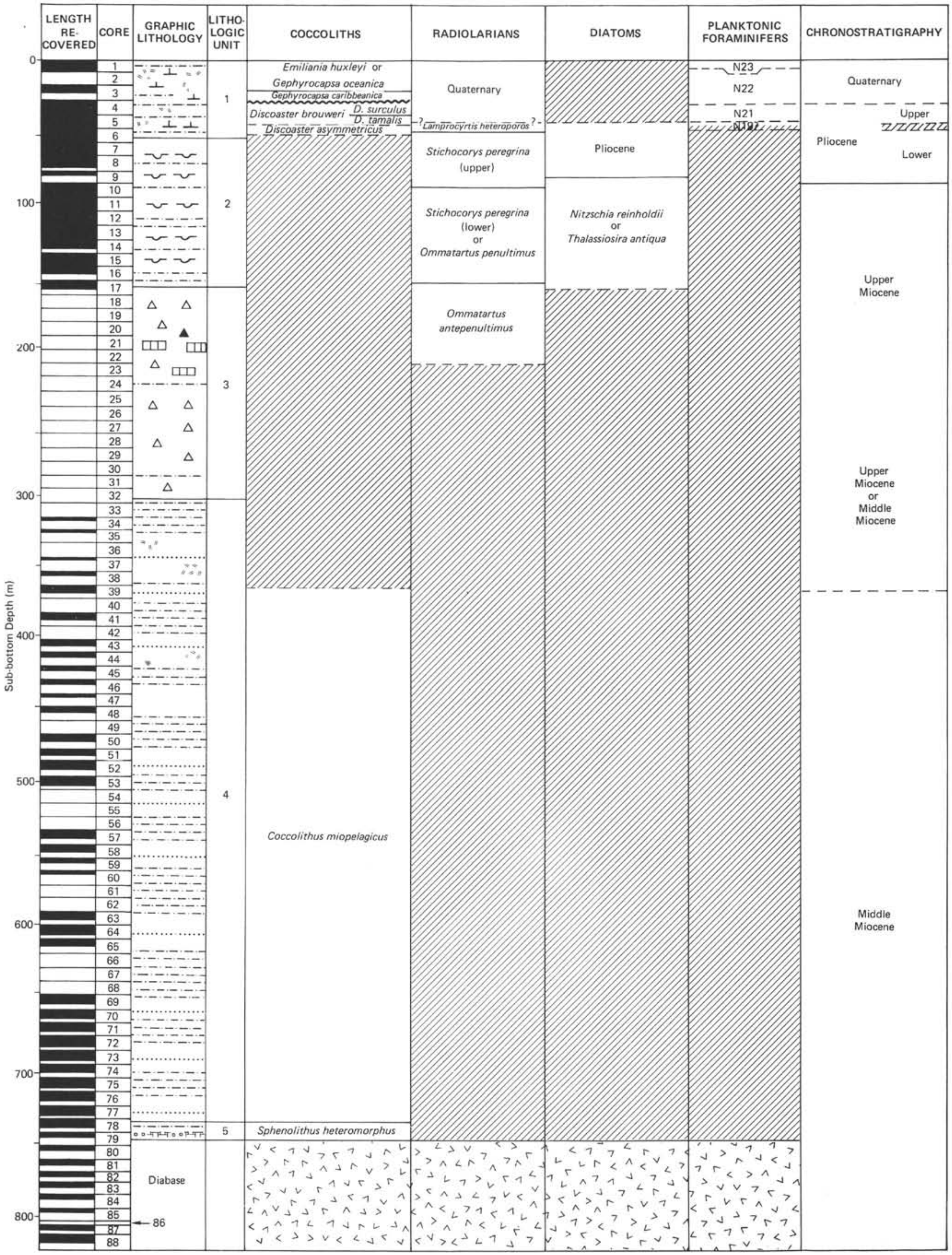


Figure 8. Lithologic and biostratigraphic summary, Site 471.

Table 2. Summary of lithologic units, Site 471.

Unit or Sub-unit	Core Number	Depth below Sea Floor (m)	Chrono-stratigraphy	Lithology
1	1–6, Section 3	0.0–63.5	Quaternary-Pliocene	Nannofossil silty clay, silty clay, and scattered patches of vitric ash.
2	6, Section 3–17,CC	63.5–155.2	upper Miocene	Diatomaceous clay, diatomaceous silty clay, and clayey diatomaceous ooze.
3	17,CC–32	155.2–304.0	upper Miocene	Porcellanite and porcellaneous silty claystone with a few fragments of opal-CT chert and several clayey limestone layers.
4	33–78 Section 3	304.0–735.7	middle Miocene	Bioturbated silty claystone with thin interbeds of calcareous sandstone. Sandstone becomes less abundant near base of unit. Several layers of clayey carbonate and vitric ash.
5a	78, Section 3–79, Section 1	735.7–741.3	middle Miocene	Chalcopyrite- and sphalerite-bearing rock, quartzose chert, and metalliferous sediment above altered diabase.
5b	79, Section 1	741.3–741.5		

green patches of vitric ash also occur in this unit. Although the gradational lower boundary of Unit 2 was not recovered intact, the few fragments of porcellanite that occur with pieces of firm clayey diatomaceous ooze in Sample 17,CC mark the base of the unit.

Unit 3: Porcellanite and Silty Claystone (155.2–304.0 m)

Unit 3 is olive gray to olive black opal-CT porcellanite and porcellaneous silty claystone. A few fragments of olive black opal-CT chert and several thin interbedded layers of light olive gray silicified dolomite also occur. Recovery was extremely poor in this interval, averaging only 5%. Most cores consist of fragments of hard porcellanite that have been broken and brecciated by drilling. Downhole logs (especially the Density and Neutron Logs) and several pieces of firm silty clay within the sequence (as in Cores 26, 27, and 29–31), however, suggest that these hard siliceous rocks are interbedded with softer sediment. Slabbed surfaces of the porcellanite display abundant burrows.

In thin section, the porcellanite consists dominantly of clay cemented by silica. X-ray diffraction data show the siliceous cement to be opal-CT. Minor chalcedony-filled molds of diatoms, radiolarians, and sponge spicules also occur, as well as scattered rhombs of carbonate. Silt-size grains of quartz and feldspar are present in rare laminae within the porcellanite fragments. A few pieces of chert occur near the top of the unit; they are conchoidally fractured, have a vitreous luster, and are composed mostly of opal-CT with minor clay minerals.

The siliceous dolomite interbeds in Unit 3 are intensely bioturbated. In thin section, the dolomite consists of micrite or sugary-textured dolomite and clay minerals that have been cemented with opal-CT.

Porcellanite grades downhole to porcellaneous silty claystone, then to silty claystone at the base of Unit 3. This gradual change makes it difficult to place a lower boundary on these siliceous rocks. The boundary between Units 3 and 4 is placed between Cores 32 and 33, where the claystone becomes noticeably less siliceous. Density and Sonic Logs also display a distinct break at about 304 meters, near the base of Core 32.

Unit 4: Interbedded Silty Claystone and Sandstone (304.0–735.7 m)

Unit 4 is a thick, well-bedded sequence of olive gray silty claystone containing numerous thin interbeds of bluish gray calcite-cemented sandstone and light gray, structureless silty claystone. A few beds of light gray altered vitric tuff and several thin layers of clayey dolomite and a limestone (Core 37) occur near the top of the unit. The dark olive gray claystone, in beds 4 to 15 cm thick, is thoroughly bioturbated. Large lenticular burrows are filled with light olive gray silty claystone. Other burrow forms include *Zoophycos* and possible *Condrites*. The claystone is uniform in composition and is composed of angular silt-size grains of quartz (3–15%) and feldspar (2–7%), clay minerals (60–80%), nannofossils (2–10%), and scattered white sponge spicules (<1%). The siliceous sponge spicules are cigar-shaped and 2 to 5 mm long, have dark claystone-filled interiors, and are commonly coated with a thin film of dark organic material.

Sandstone interbeds first appear in Core 35 as thin laminae within the bioturbated silty claystone sequence and become thicker and more abundant in Core 47. These persist through Core 77 but are not present in Core 78 immediately above the claystone of Unit 5. Most sandstone layers range from 1 to 4 cm thick, although some attain a maximum thickness of 10 cm. The spacing and frequency of these layers are also variable. Generally, they occur at least 5 to 10 cm apart. A core may contain as many as 30 to 40 thin sandstone beds (e.g., Core 64).

The sandstone is mostly fine-grained and moderately well sorted. It consists of angular grains of polycrystalline and unstrained monocrystalline quartz and chert (15–20%), albite twinned plagioclase (2–15%), rock fragments (10–20%), and coated pellets (2–10%). Biotite (2%), hornblende (2%), pyroxene (trace), and foraminifers (1%) are accessory components. Rock fragments are chiefly silicic volcanics such as dacite and rhyolite. Some coarse sand-size polycrystalline quartz grains may be metaquartzite. Fine sand-size pelletal grains contain cores of angular quartz or feldspar; the coating is opaque or, less commonly, light brown and may be a mixture of phosphate and manganese oxides–hydroxides. Abundant calcite, in large, optically continuous patches, is a cement and partially replaces framework grains in these calcareous sandstones.

Many sandstone layers display Bouma d,e sequences (i.e., parallel laminations gradationally overlain by thicker and finer-grained burrowed, sandy, silty claystone). In some, an intervening layer of micro-cross-laminations (division c) is also present, forming Bouma b,c,d or c,d,e sequences. Commonly, the upper few centimeters of each sandstone bed are intensely bioturbated, creating the appearance of distorted ripple cross-laminations. Compact lenticular concentrations of dark gray, silt- and sand-size faecal pellets are abundant in the burrows in the sandstone and also in the overlying thicker, sandy, silty claystone. It is possible that some of the sandstone layers may have been ripple cross-laminated and only partially disrupted by burrowing. Some sandstone layers have load structures, and most have sharp basal contacts. The underlying claystone, which has only a few burrows, is generally lighter gray and thinner (< 2 cm) than the more extensively burrowed silty claystone that immediately overlies each sandstone layer.

Thin layers of altered vitric tuff occur near the top of Unit 4. In Core 44, a 7-cm-thick, biotite-bearing, light gray tuff is present. It has a sharp basal and gradational upper contact and is graded.

Some sandstone layers are present in Cores 78 and 79 near the base of the unit, although there is a regular alternation of light and dark gray silty claystone beds, especially in Core 78. The boundary between Unit 4 and the underlying claystone of Unit 5 is placed at the last occurrence of calcite-cemented sandstone in Core 78.

Unit 5: Claystone and Sulfide-Bearing Sediment (735.7–741.5 m)

Unit 5 is a thin sequence of claystone that is hydrothermally altered at its base. We divide it into two parts: Sub-unit 5a, claystone, and Sub-unit 5b, sulfide-bearing sediment, quartzose black chert, and metalliferous sediment overlying altered diabase.

Sub-unit 5a is greenish gray claystone. It is intensely mottled by burrows and contains abundant microfaults and some calcite-filled veins. Reduction streaks and spots of finely disseminated, dark gray pyrite are common. Except for a few scattered silty layers, this unit contains significantly fewer silt-size grains of quartz and feldspar than does the overlying silty claystone of Unit 4. The clay to silt ratio is about 9:1. Nannofossils are present in the claystone at the top of this sub-unit but decrease and finally disappear at its base. Several scattered grayish blue green streaks may be altered vitric ash.

Sub-unit 5b is a potpourri of sediments and sedimentary rocks including chalcopyrite- and sphalerite-bearing claystone, black quartzose chert, and metalliferous sediment. Chalcopyrite- and sphalerite-bearing rocks form the upper part of this unit. Rock fragments recovered in the brecciated base of this sequence consist of claystone, chalcopyrite–sphalerite, and black quartzose chert. The chert is conchoidally fractured and veined by calcite. A thin (2-cm) layer of dusky yellowish brown metalliferous sediment overlying altered diabase forms the base of Unit 5. Clay, X-ray amorphous iron-rich material, and minor carbonate rhombs are dominant components of this sediment. Similar sediment occurs within fractures and between altered diabase in Section 82-1 and Section 88-1. Where metalliferous sediment fills some fractures in the diabase, it has been thermally altered to red brown jasper.

Igneous Rocks

Diabase (and its fine-grained equivalent along chilled zones) and brecciated diabase are the two igneous rock types recovered at Site 471. Thin intercalations of claystone at depths of 750.5 meters and 769.5 meters provide convenient boundaries for dividing these rocks into three sequences (Fig. 9). The upper sequence (741.5–750 m) is mainly fine- to medium-grained, aphyric diabase having a chilled margin of aphyric basalt at the upper contact with the overlying sediment. Grain size increases away from this contact. Plagioclase is the only remaining primary constituent in these rocks, occurring as euhedral laths (< 2 mm). The texture is intersertal. Clays, calcite, and zeolite are the common alteration minerals; neither primary mafic minerals nor any pseudomorphs after them are found.

The middle diabase sequence (750.6–769.6 m) coarsens slightly away from the bounding claystone layers over an interval of about 1 meter. The upper part of this sequence (Core 80) is mostly altered brecciated diabase consisting of angular to subangular fragments of altered diabase and clayey chert generally less than 2 cm across. Slickensides mark the face of one diabase fragment. The lower part of this sequence is highly altered, medium-grained diabase composed of subhedral plagioclase and clinopyroxene with intersertal to subophitic textures. Faint purple pink tints indicate some clinopyroxenes may be titaniferous. Clay, calcite, and an unidentified zeolite are common alteration minerals.

The lower diabase sequence (769.6–820 m) may be further subdivided into two portions. The upper part (Cores 82–83) contains a distinct chilled zone with grain size gradually decreasing in the first 1.5 meters below the claystone. This part is compositionally similar to the middle sequence, except that chert fragments are absent in the brecciated diabase. The lower part is distinct in that it contains significant amounts of biotite, quartz, and K-feldspar(?). In this respect it is similar to the up-

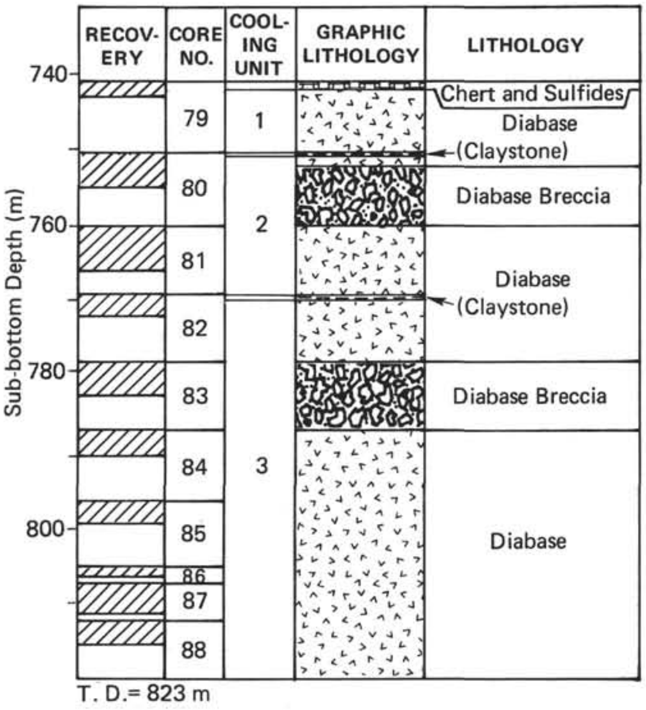


Figure 9. Igneous rock sequence at Site 471.

per portion of the diabase sill at Site 469. The mineralogic constituents of this lower part include, in decreasing order of abundance, plagioclase, clinopyroxene, brownish green smectite, opaque minerals, biotite, quartz, K-feldspar(?), colorless amphibole, sphene, calcite, and zeolite. Intersertal to subophitic textures prevail, with euhedral to subhedral plagioclase laths partly embayed into anhedral clinopyroxenes. Plagioclase is strongly zoned and ranges in grain size from 0.5 to 4 mm. Clinopyroxene has faint purple pink tints; several grains are further fringed by pale green clinopyroxene rinds. Biotite, quartz, K-feldspar(?), and colorless amphibole all occur in the interstices between plagioclase laths and clinopyroxenes. Intense alteration of K-feldspars to clays precludes their positive identification; however, they appear to be confined to Cores 84 to 86. Despite the distinct mineralogy of this lower part of the lower diabase sequence, we make no further subdivision because of the absence of a chilled zone.

The brecciated diabase could have formed by intense weathering along incipient fractures. In addition, some of these rocks (Core 83) have a laminated fabric similar to cataclastic rocks, although microscopically, constituent minerals do not show such strain effects as marginal granulation, undulatory extinction, or bending of cleavage cracks or twin lamellae. Some fragmented crystals of plagioclase do occur, however, suggesting minor cataclastic deformation. Possibly these diabase breccias formed by autobrecciation, a fragmentation process whereby portions of the first-consolidated crusts of intrusions or flows are incorporated into the still-molten interior.

Because of the absence of pillow structure, the absence of microscopic quench texture that would indicate rapid chilling of magma against cool water, the coarse grain size, ore mineralization in the overlying sedimentary rocks, and the inclusion of sedimentary rock fragments in the brecciated diabase, the diabase sequence at Site 471 is probably intrusive. This sequence is probably a composite of three or four cooling units, with each unit representing a thin sill or sheet. Alternatively, these cooling units may correspond to offshoots of a single, larger intrusive.

BIOSTRATIGRAPHY

Pleistocene through middle Miocene sediments were recovered at Site 471. Planktonic foraminifers and coccoliths are common to abundant and provide stratigraphic control in the upper 45 meters (Cores 1-5) and 58 meters (Cores 1-6) respectively. In Cores 7 through 17, calcareous microfossils are absent, and radiolarians and diatoms provide stratigraphic control (Fig. 10). Microfossils are essentially absent from Cores 18 through 38, although sparse radiolarian assemblages provide some stratigraphic control. Coccoliths reappear in Core 39 and are sporadically present to the bottom of the sedimentary section. Benthic and planktonic foraminifers are present but they are extremely sparse in this interval.

Coccoliths suggest placement of the Pliocene/Quaternary boundary just below Sample 3,CC and the lower Pliocene/upper Pliocene boundary between Cores 5 and 6. Figure 8 summarizes zone determinations for Site 471. The top of the *Sphenolithus heteromorphus* Zone is in Core 78, about 3 meters above the uppermost igneous rock. The age of the oldest sediment at Site 471 is thus estimated to be about 15 m.y.

Coccoliths

Coccoliths recovered at Site 471 represent only short intervals of time. In Core 79, just above basalt, the oldest assemblages belong to the upper *Sphenolithus heteromorphus* Zone (approximately 14 m.y. of age; Bukry, 1975). The overlying *Coccolithus miopelagicus* Subzone (approximately 13.4 to 14 m.y. old) extends through a thick interval from Core 39 to Core 78 (368–737 m), but the short time span involved yields an exceptionally high sedimentation rate (383 m/0.6 m.y. = 640 m/m.y.). Reworked Cretaceous and Paleogene coccoliths occur (Fig. 11) in this interval (Lithologic Unit 4), which is characterized by turbid flow sedimentary structures. An equally thick interval in Cores 6 to 39 (55–368 m) is barren of coccoliths. Pleistocene to lower Pliocene coccoliths are sparse to abundant in the upper cores, Sample 1,CC to Core 6 (9.5–52 m), representing the interval from approximately 0.5 m.y. to 4 m.y. ago. The upper part of Core 1 was not investigated.

All sediment layers intercalated with the igneous rocks of Cores 80 to 88 that were examined for coccoliths are barren. The lower middle Miocene *Sphenolithus heteromorphus* Zone assemblages of Cores 78 and 79 are similar to overlying assemblages, except for the presence of *Sphenolithus heteromorphus* Deflandre and the more common *Cyclicargolithus floridanus* (Roth and Hay); and these assemblages show the only notation for overgrowth (+2 to +3; Bukry, 1973) at Site 471, in Sample 471-79-1, 7 cm (at a depth of 751 m). This sample also contains some fragments of pyritized centric diatoms.

Dark olive clay-rich siltstone directly above blue gray turbiditic sandstones of Cores 39 to 78 are in the *Coccolithus miopelagicus* Subzone and yield the largest, most diverse coccoliths. Lighter-color claystone from higher in the turbidite sequences yields mostly smaller, less diverse coccoliths. Many sediment layers are barren or poor, producing an uneven record of abundance and preservation through the subzone (Fig. 10). Reworked Cretaceous coccoliths in Cores 39 to 79 appear to represent Campanian to Maestrichtian horizons (Fig. 11). Similar coccoliths occur onshore near San Diego, California (Bukry and Kennedy, 1969). Paleocene coccoliths, such as *Discoaster multiradiatus*, are from upper Paleocene strata.

Lower Pliocene coccoliths of Cores 5 and 6 are sparse to common and etched. The assemblages are assigned to the *Sphenolithus neoabies* Subzone, because *Reticulofenestra pseudoumbilica* (Gartner) and *Sphenolithus abies* Deflandre are present and *Discoaster tamalis*

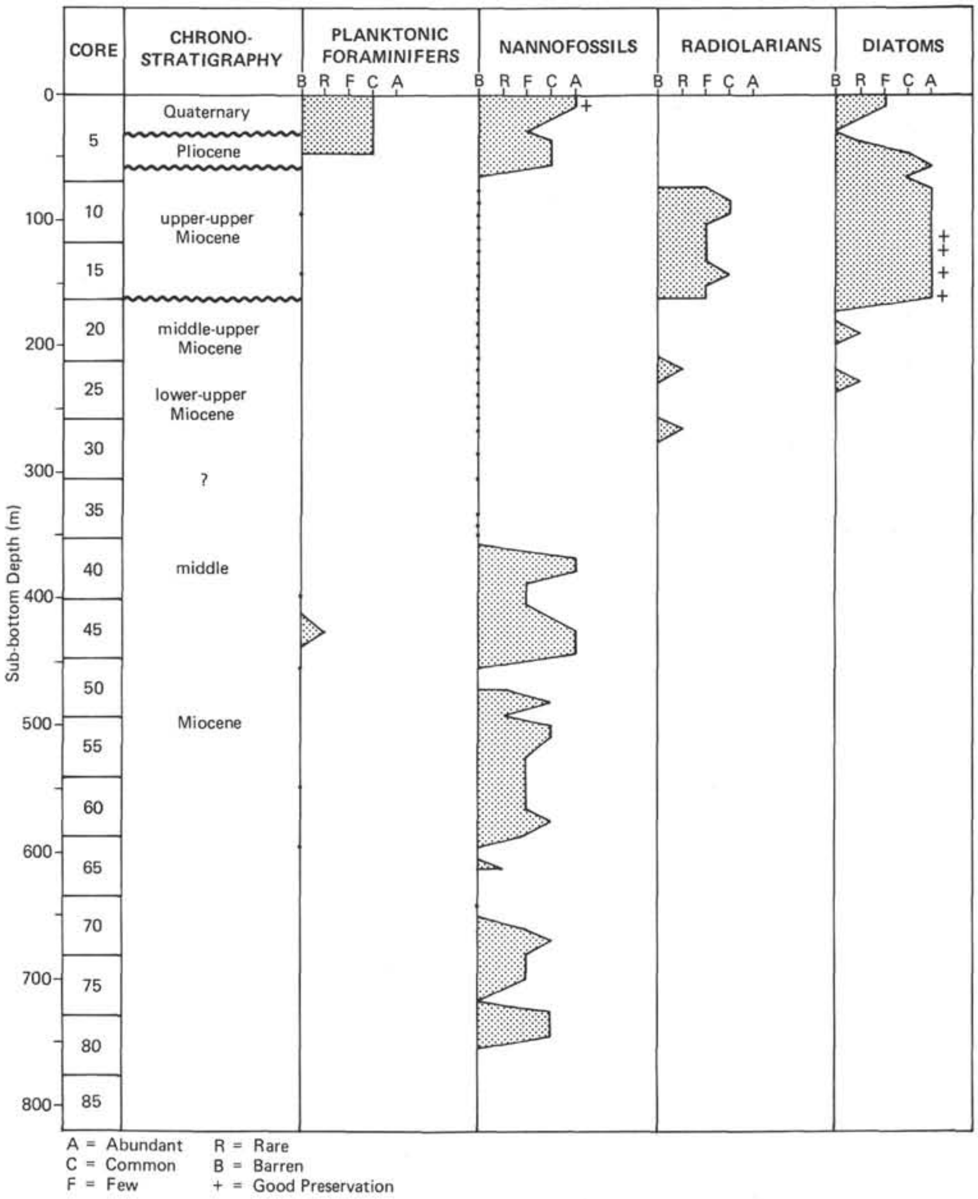


Figure 10. Plots of relative abundances of planktonic microfossils at Site 471.

Kamptner and *Amaurolithus* spp. absent. One reworked *A. delicatus* Gartner and Bukry occurs in Sample 471-5,CC.

The Pliocene/Pleistocene boundary may be in a condensed section or cut out by a hiatus, because the *Gephyrocapsa caribbeanica* Subzone of Sample 471-4-1, 0 cm (28.5 m depth) overlies the *Discoaster surculus* Subzone of Sample 471-4-2, 52–53 cm (32 m depth).

Pleistocene assemblages contain *Gephyrocapsa oceanica* Kamptner with high-angle bars and *Coccolithus pelagicus* (Wallich), indicating temperate conditions.

Silicoflagellates

Lower Pliocene and upper Miocene silicoflagellates are sparse to common and well preserved in Cores 6 to 18. They are absent in the calcareous Quaternary and Pliocene silty clay of Cores 1 to 5 and in the Miocene silty clays of Cores 19 to 78, although sparse fragments of diatoms *Coscinodiscus marginatus* Ehrenberg and *Thalassiothrix longissima* Cleve and Grunow as well as pyritized centric diatoms occur through Cores 20 to 28. The upper silicoflagellate assemblages of Cores 8 and 9 are especially diverse, and some reworking is suggested by the presence of *Distephanus mesophthalmus* (Ehrenberg) (upper middle to lower upper Miocene, according to Dumitrică, 1973) and the diatom *Craspedodiscus coscinodiscus* Ehrenberg (lower or middle Miocene). Terrestrial opal addition to the sediment is indicated by the presence of sparse panicoid opal phytoliths in Sample 471-8,CC. *Mesocena* sp. aff. *M. quadrangula* Ehrenberg ex Haeckel and *Dictyocha* sp. (naviculopsoid) in Core 8 suggest correlation with the upper Miocene upper *Discoaster quinqueramus* Zone of coccoliths at DSDP Site 158 in the eastern equatorial Pacific

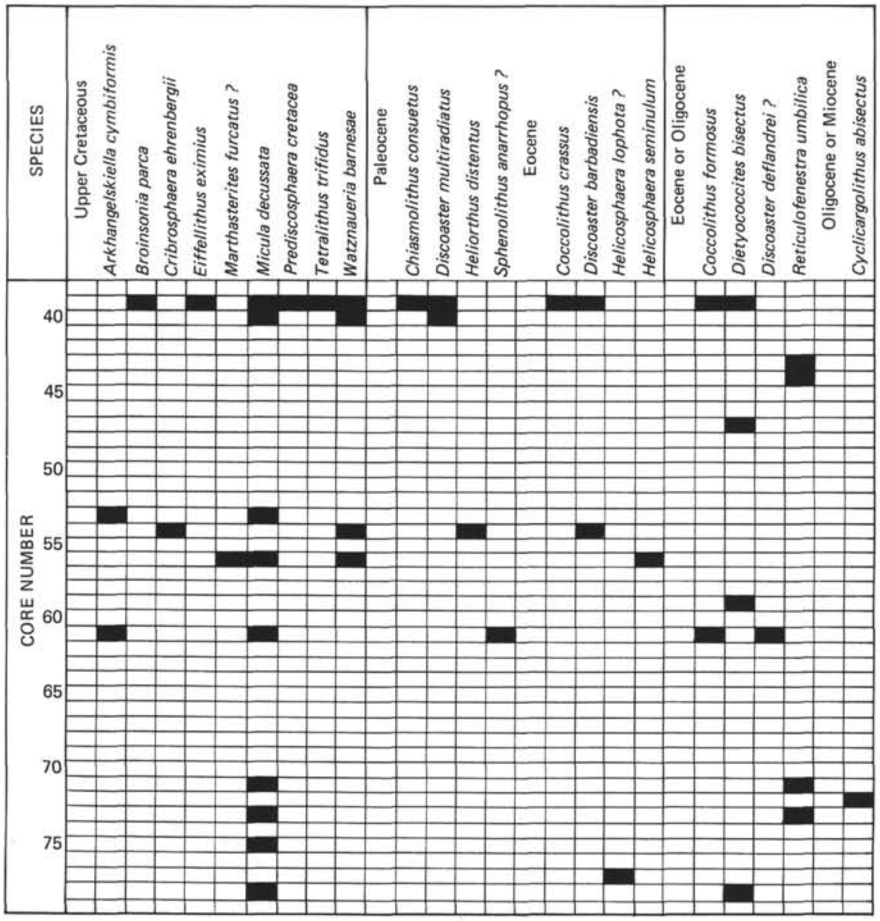


Figure 11. Upper Cretaceous and Paleogene reworked coccoliths at Site 471.

(Bukry, 1973). Although silicoflagellates are generally common in Cores 10 to 18, diversity is low and assemblages are composed mainly of *Dictyocha brevispina* (Lemmermann), *D. fibula* Ehrenberg, and *Distephanus speculum* (Ehrenberg). In most samples *Dictyocha fibula* predominates over *D. brevispina*, suggesting the warm-water *Dictyocha fibula* Zone of Martini (1971). Samples 471-13,CC and 471-15,CC, however, have more *D. brevispina* than *D. fibula*, possibly indicating the top of the *D. brevispina* Zone, a unit correlative with the upper *Discoaster quinqueramus* Zone or upper *D. neohamatus* Zone of coccoliths in the eastern equatorial Pacific (approximately 7 m.y. old) (Bukry and Foster, 1973; Bukry, 1973).

Radiolarians

At Site 471, the interval between Cores 1 and 5 is nearly barren of radiolarians. Sections 3 and 5 of Core 1 contain only rare, nondiagnostic radiolarians, and Section 1 yielded *Amphirhopalum ypsilon* and (?)*Ommatartus tetrathalamus*, two Quaternary to Pliocene species. Because the latter section does not contain any older radiolarians other than rare individuals of *Stichocorys peregrina*, it is tentatively assigned to the Quaternary. The boundary between the Quaternary and Pliocene is placed immediately above the youngest fossiliferous layers (Core 5, Section 6) with *Lamprocyrtis heteroporos*. It must be emphasized, however, that the true position of that boundary at Site 471 cannot be found by means of radiolarians.

Deposition during the late Pliocene is indicated for Core 5, Section 6 through Core 6, Section 1 by rare occurrences of *L. heteroporos* and the absence of *Eucyrtidium matuyamai*. The extinction of *Stichocorys peregrina* marks the boundary between the upper Pliocene *L. heteroporos* Zone and the lower Pliocene *S. peregrina* Zone (upper part), which comprises the interval between Core 6, Section 3 and Core 10, Section 1. Mostly few to common, moderately to well preserved radiolarians typify the lower Pliocene succession. Its lower limit is indicated by the first appearance of *L. heteroporos*. Besides rare to abundant *S. peregrina, Ommatartus penultimus* is another rare to common species that survived above the Miocene/Pliocene boundary.

The upper Miocene cores of Hole 471 contain a radiolarian assemblage rather rich in species that are almost exclusively warm-water varieties. The equatorial zonation is therefore applicable. The presence of *S. peregrina, S. delmontensis, S. wolffii, O. penultimus,* and *O. antepenultimus* and the absence of *L. heteroporos* suggest that Core 10, Section 3 through Core 17, Section 1 are upper upper Miocene (lower part of the *S. peregrina* Zone). A separation of the upper upper Miocene *S. peregrina* Zone and the middle upper Miocene *O. penultimus* Zone is not possible at Site 471, because the first appearances of *S. peregrina* and *O. penultimus* nearly coincide, and because the occurrences of *S. delmontensis* and *S. peregrina* overlap considerably. There are no radiolarian species remaining to define the upper limit of a possible *O. penultimus* Zone. The lower boundary can be defined exactly, however, by the extinction of *Ommatartus hughesi* and the first appearance of *O. penultimus* and can be placed below Core 17, Section 1, provided that the two events are not affected by dissolution or reworking. Besides several nondiagnostic species, Sample 471-17,CC contains *S. delmontensis, S. wolffii,* and *O. antepenultimus*, and Core 23, Section 1 yielded rare to few specimens of *O. antepenultimus, O. hughesi*, and *Cannartus petterssoni* (*O. antepenultimus* Zone). Samples 471-23,CC and 471-28,CC contain very rare and poorly preserved radiolarian assemblages deposited during the early late Miocene. All of the remaining cores of Site 471 lack radiolarians or bear only indeterminable fragments, frequently with heavy crystalline overgrowths.

Diatoms

Few to abundant Pliocene to upper Miocene diatoms are present in Cores 6 through 18 at Site 471. Nearshore diatoms, such as *Actinocyclus ehrenbergii, Rhaphoneis* spp., and *Thalassiosira* spp., are present in Core 1 but are not age-diagnostic. Diagenesis, which is first evident in Cores 17 and 18, removed all but robust, non-age-diagnostic diatoms below Core 18.

The first occurrence of *Thalassiosira oestrupii* in Sample 471-9-1, 58–60 cm is indicative of a horizon slightly higher than the Miocene/Pliocene boundary. Sample 471-10-1, 20–22 cm contains relatively common *Dictyocha navicula*, a silicoflagellate with an acme across the Miocene/Pliocene boundary.

Planktonic diatoms that are used in biostratigraphy are relatively rare and sporadic in the upper Miocene of Site 471. *Thalassiosira miocenica* and *Nitzschia miocenica* in Sample 471-11-1, 20–22 cm suggest correlation with paleomagnetic Epoch 5 or uppermost Epoch 6. The last occurrence of *Cussia praepaleacea* in Sample 471-13-2, 20–22 cm indicates equivalence with the upper part of Epoch 6. *Nitzschia miocenica* is recorded from Sample 471-17,CC and argues for correlation with a level no older than the upper part of Epoch 7. Benthic diatoms are especially common in Core 12, where they mask many of the planktonic forms.

Foraminifers

Planktonic foraminifers are common and well to moderately well preserved in the upper 44.8 meters of Hole 471 (Samples 471-1,CC through 471-5-5, 80 cm). Cores 1 through 3 are assigned to the Quaternary because of the occurrence of *Globorotalia truncatulinoides* in Sample 471-1,CC, and *Neogloboquadrina dutertrei* in Samples 471-1,CC through 471-3,CC. An upper Pliocene assemblage containing *Neogloboquadrina humerosa, N.* aff. *N. atlantica*, and *Globorotalia inflata* was recovered from Sample 471-4,CC, whereas Sample 471-5-2, 80–82 cm, with *Globoquadrina altispira* and transitional forms between *Globorotalia puncticulata* and *G. inflata*, is considered close to the Zone N21/Zone N19 boundary.

Planktonic assemblages in Samples 471-1,CC through 471-5-2, 80–82 cm are diverse, and tropical to subtropical taxa such as *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens* as well as keeled *Globorotalia* and *Globigerinoides* occur throughout this interval.

Sample 471-5-5, 80–82 cm yields a sparse, strongly dissolved assemblage, and no foraminifers are present in Sample 471-5,CC. Foraminifers are absent from Cores 6 through 37. From Core 38 to Core 78, occasional foraminifers were seen on cut surfaces of cores. Examination of selected samples from this interval revealed rare, poorly preserved planktonic foraminifers; only long-ranging taxa such as *Globigerina bulloides* and *Globigerinoides trilobus* were found.

Benthic foraminifers are sparse but well preserved in the first five cores of Hole 471. *Uvigerina senticosa, Pullenia bulloides*, and *Melonis barleeanus* are consistent members of the assemblage in this interval and indicate lower middle to lower bathyal water depths. Benthic foraminifers are absent or extremely rare in Cores 6 through 37.

Below Core 37, representatives of *Gyroidina, Pyrgo, Stilostomella, Globulimina* and (?)*Bolivina* were occasionally seen on cut surfaces of cores. Benthic foraminifers are sometimes concentrated toward the top of sandstone layers in the turbidite sequence of Cores 38 to 78, but they are poorly preserved, and most specimens appear to be internal casts. Occasional specimens of *Pullenia bulloides* and *Gyroidina soldanii* in samples from fine-grained sediments of Cores 37 to 78 suggest this sequence was deposited in bathyal water depths.

SEDIMENT ACCUMULATION RATES

The sediment accumulation rate curve (Fig. 12) for Site 471 was constructed from selected radiolarian (R) and coccolith (C) events. The plot indicates rates of ~20 m/m.y. for the Quaternary into the late Miocene, ~50 m/m.y. for the early late to late middle Miocene, and ~200 m/m.y. for the early middle Miocene. No stratigraphically diagnostic microfossils are present for more than 100 meters above the coccolith control point at 360 meters sub-bottom (Fig. 8). Thus the accumulation rate calculated for the lower portion of Site 471 represents a minimum estimate.

GEOCHEMICAL MEASUREMENTS

Interstitial Water

The salinity, chlorinity, pH, alkalinity, and calcium and magnesium concentrations of interstitial waters from nine depths at Site 471 were determined on board. The results are plotted versus depth at the site in Figure 13. No samples were taken between 125 and 360 meters sub-bottom depth; in this interval, only porcellanites and dolomites were recovered. Although the calcium concentration profile at Site 471 shows a gradual increase downcore, the magnesium concentration profile

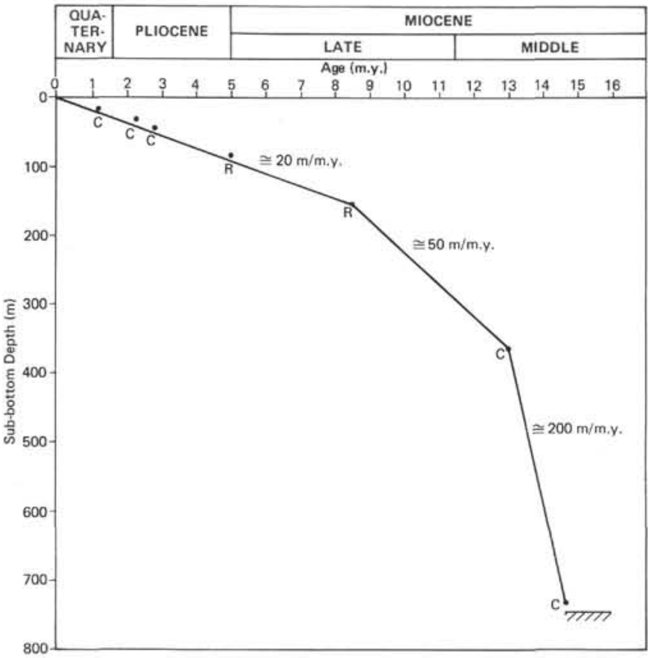


Figure 12. Sediment accumulation rates, Site 471.

shows a marked discontinuity between normal sea water magnesium concentrations above the porcellanites and very low magnesium concentrations below the porcellanites. Salinity and chlorinity also decrease markedly over the same depth interval. The change in magnesium concentration over the interval from which porcellanites were recovered suggests that the decrease was the result of diagenetic reactions involved in the transformation of biogenic opal to opal-CT porcellanite and/or in the formation of dolomite.

Calcium Carbonate Content

The calcium carbonate concentration in samples from Site 471 was determined on board by the carbonate bomb technique. The results of these determinations are included in the core descriptions in this chapter and plotted in Figure 14. Most of the sediment column at this site is noncalcareous. There are, however, a few dolomite interbeds in Unit 3 that had carbonate contents of 99% to 100%. The silty claystones of Unit 4 are also noncalcareous, but they are interbedded with calcareous sandstones that contain 14% to 21% $CaCO_3$.

PHYSICAL PROPERTIES AND DOWNHOLE LOGS

Figure 14 plots the physical-properties data for Site 471, and Table 3 summarizes these data. Figure 15 displays the downhole logs obtained at this site. Relatively constant values of density (~1.5 g/cm^3) and velocity (~1.5 km/s) characterize the upper 150 meters of soft nannofossil silty clay and diatomaceous clay. A sharp increase in both parameters occurs at 155 meters, the depth at which soft diatomaceous sediment begins to convert to harder porcellanite. The density of the porcellanite at this depth is about 2.0 g/cm^3 but decreases slightly to 1.7 g/cm^3 at about 317 meters. Sonic velocities show a similar trend, decreasing in this interval from 3.6 km/s to 2.1 km/s. This change corresponds to a noticeable decrease in the siliceous character of the

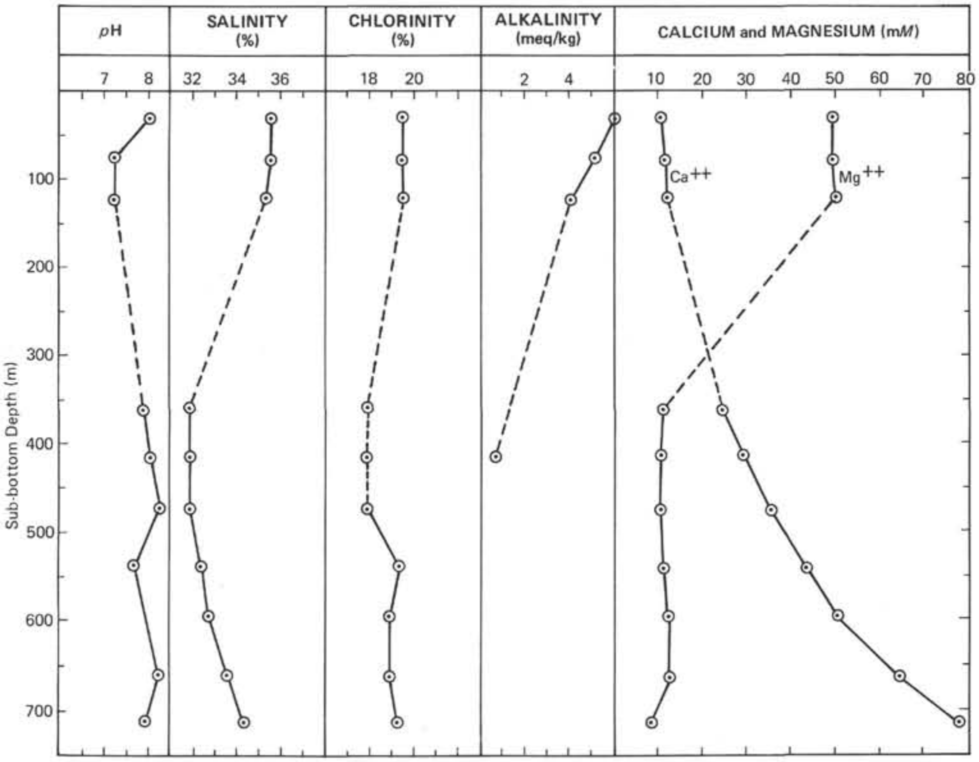


Figure 13. Interstitial water profiles, Site 471.

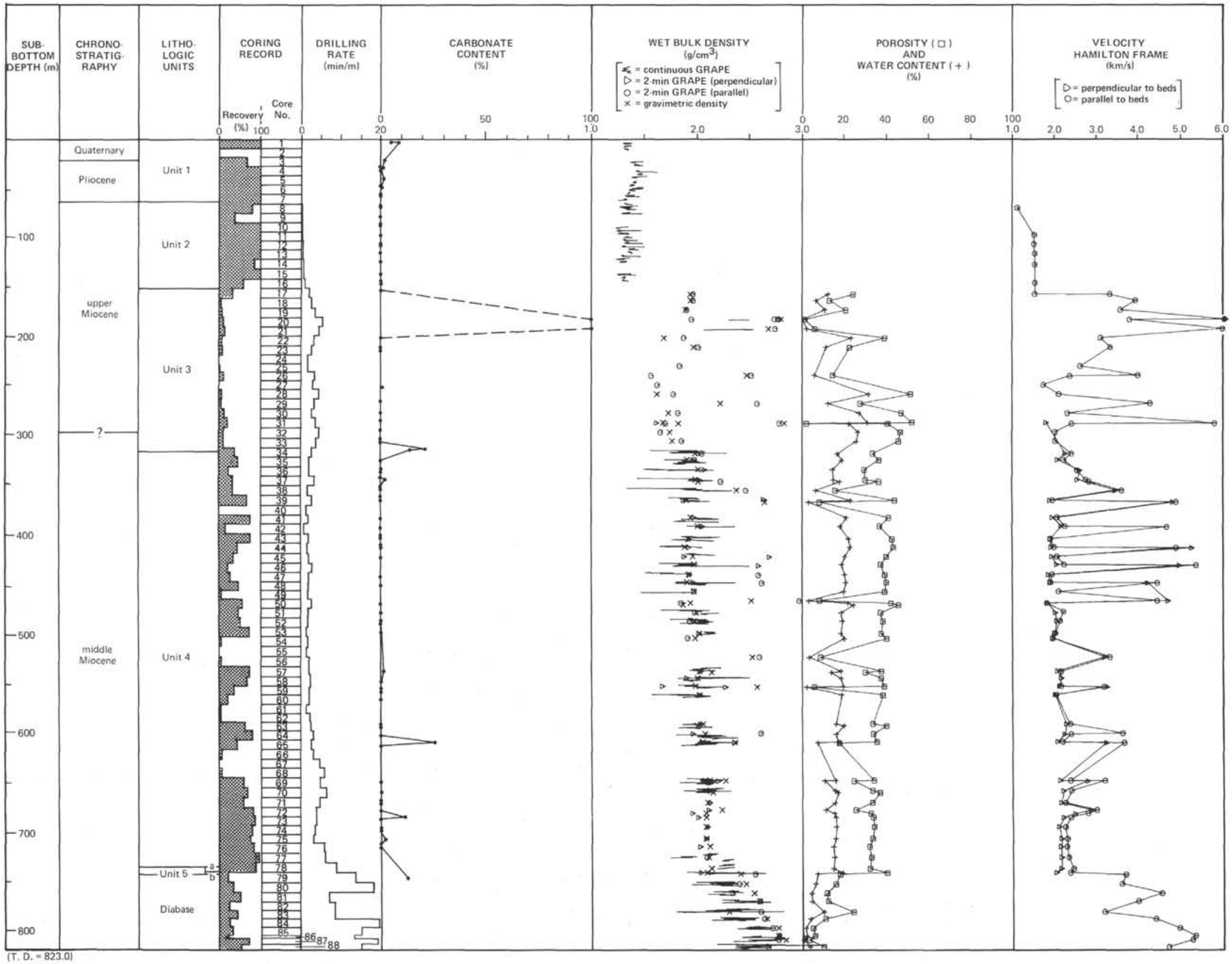


Figure 14. Summary of physical properties, Site 471.

Table 3. Summary of laboratory measurements of velocity and density and calculated impedance contrasts of rocks and sediments recovered at Site 471.

Lithology	Sub-bottom Depth (interval in m)	Density (g/cm^3)		Velocity (km/s)		Average Impedance Contrast
		Range	Average	Range	Average	
Silty clay	0.0–63.5	1.4–1.5	1.5	—	1.5	0.01
Clayey diatomaceous ooze	63.5–155.2	1.4–1.5	1.5	1.52–1.55	1.54	0.36
Porcellanite/chert	155.2–304	1.62–2.07	1.82	1.74–3.93	2.70	0.48
Carbonate layers	180–450	2.52–2.79	2.68	3.99–6.09	5.24	0.52
Silty claystone	304–741	1.68–2.13	2.07	1.85–2.75	2.13	0.32
Calcareous sandstone layers	445–741	2.12–2.98	2.48	2.80–4.71	3.46	0.43
Altered diabase	741–T.D.	2.29–2.78	2.58	3.19–5.35	4.36	

rocks—porcellanite changes downhole to less siliceous porcellaneous silty claystone. The Sonic and Density Logs show these variations most clearly. Moreover, all logs demonstrate the occurrence of soft sediment interbedded with porcellanite between 155 and 317 meters. Recovery was only about 5% in this interval, and much of this soft sediment was not recovered.

The thick monotonous sequence of silty claystone below 317 meters has fairly uniform physical-properties profiles, except where it is punctuated by thin layers of clayey dolomite and calcite-cemented sandstone. The Neutron Log gives the best resolution of the thin sandy layers. The two peaks at about 598 meters on this log correspond to thin sandstone layers. The Density and Sonic Velocity Logs also delineate these thin layers. From a physical-properties standpoint, the pelagic claystone at the base of this section of silty claystone is indistinguishable from the overlying unit.

A sharp increase in density and velocity occurs at 741 meters, the top of the altered diabase. These two parameters fluctuate significantly with depth in the diabase and probably correspond to variations in the degree of alteration and fracturing of this unit (see also the Seismic-Spectrum Log, Figure 15). The Neutron Log is also quite variable in this unit. A thin interval of metalliferous sediment occurring at about 780 meters in the diabase shows clearly on the Density, Sonic, and Neutron Logs. Below about 812 meters, neutron, velocity, and density values decrease, perhaps marking an interval of more altered diabase extending to the bottom of the hole.

Table 3 lists impedance contrasts calculated from the laboratory determinations of density and velocity. Clearly the boundary between the porcellanite of Unit 3 and the overlying soft diatomaceous clay is a strong reflector. The carbonate layers should also be good reflectors if numerous or thick enough. The claystone/diabase contact has a high impedance contrast and is a prominent reflector on the seismic profile.

Estimates of *in situ* temperatures and geothermal gradients at Site 471 come from three sources: (1) heat flow probe measurements made during drilling; (2) two Temperature Logs run about 18 hours apart in the open hole after completion of drilling, and (3) bottom-hole temperatures recorded with a set of three maximum temperature thermometers attached to each logging tool. Figure 16 illustrates the results of the two heat flow probe measurements made at Site 471. The instrument used was the Uyeda/Kinoshita probe first tested on DSDP Leg 60 (see Hussong, Uyeda, et al., in press for details and discusssion of this instrument). We made two measurements with the probe in the sediment at 95 meters and 142.5 meters, with additional stations in the pipe at mudline to estimate the temperature of the bottom water. Both runs show a similar pattern of decreasing temperature as the probe is lowered to the sea floor, an increase as it approaches the maximum drilled depth, a plateau corresponding to penetration into the sediment, then cooling and finally warming trends as the probe is pulled from the hole. The interval labeled "on bottom" in each run corresponds to the time the probe was actually in the sediment. Hyndman et al. (1974) note that temperature decreases (cooling curve) when frictional heating brings the temperature of the probe above that of surrounding sediment; temperature increases (warming curve) when frictional heating is insufficient to raise the temperature of the probe above that of the sediment. Throughout the measurement at 95 meters, the pipe was lowered gradually to maintain pressure on the bit. The cooling curve shown in Figure 16 suggests that frictional heating affects the temperature measurement. For the measurement at 142.5 meters, the constant temperature (prevailing 42 minutes after the last lowering of the pipe) indicates frictional heating is not important.

In situ sediment temperatures estimated from Figure 16 are about 12.5°C at 95 meters and about 24.0°C at 142.5 meters. Using a bottom-water temperature of 2.0°C, we determined that the geochemical gradients are 110°C/km and 154°C/km, with an average of 132°C/km.

We also estimated the geothermal gradient at Site 471 using the Temperature Logs (Figure 15). Both Temperature Logs show initially steep gradients in the porcellanite, ~40°C/km for the first run and ~74°C/km for the second. A distinct change to lower gradients (30°C/km and 67°C/km, respectively) occurs below about 345 meters. These latter values remain fairly uniform through the thick section of silty claystone, except for an interval between 520 and 570 meters, where gradients decrease slightly. This interval corresponds to the first show of gas in the cores; gas escaping into the open hole and expanding could explain this zone of lower gradients. The second Temperature Log probably more closely approximates the equilibrium gradient than does

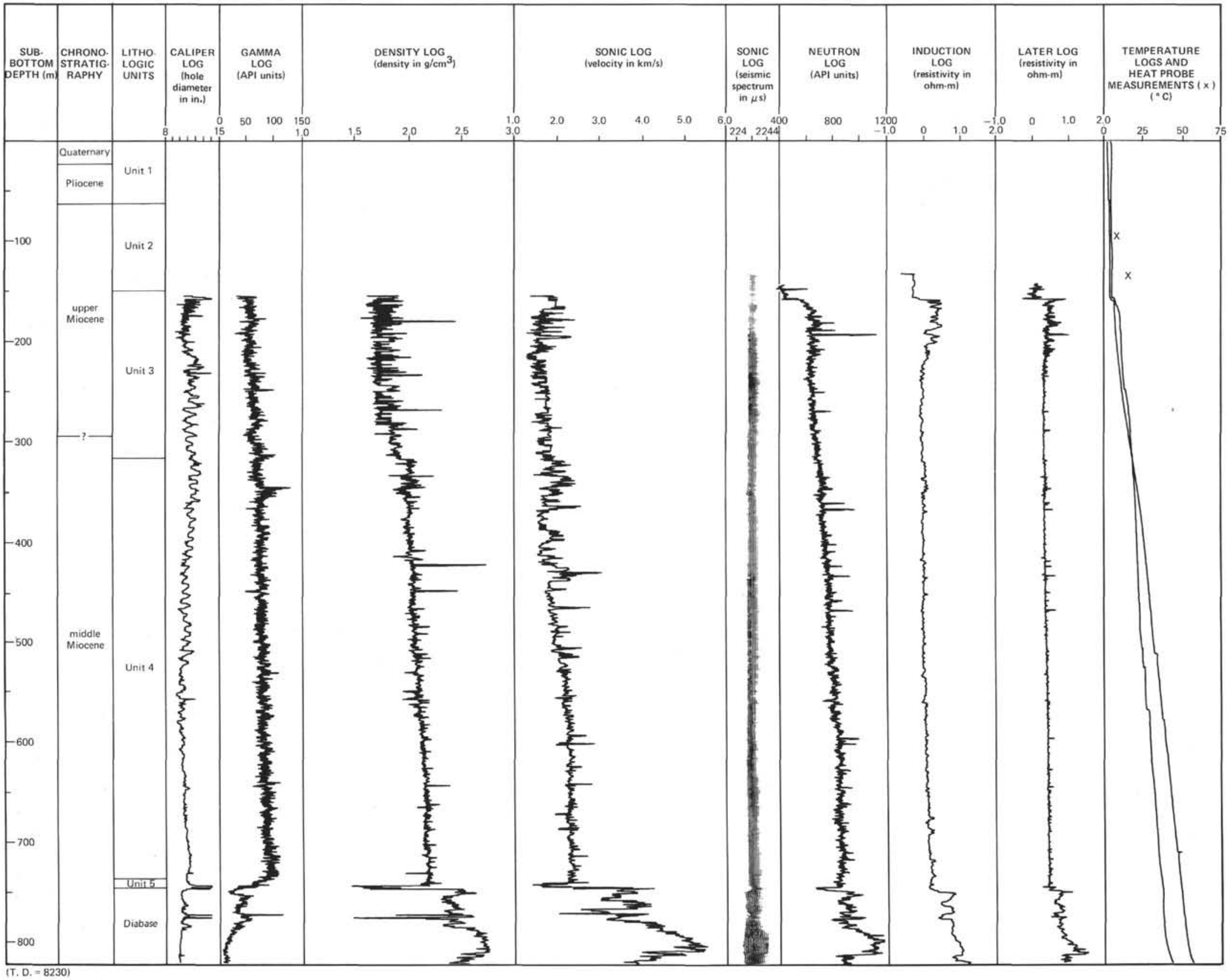


Figure 15. Summary of downhole logs, Site 471.

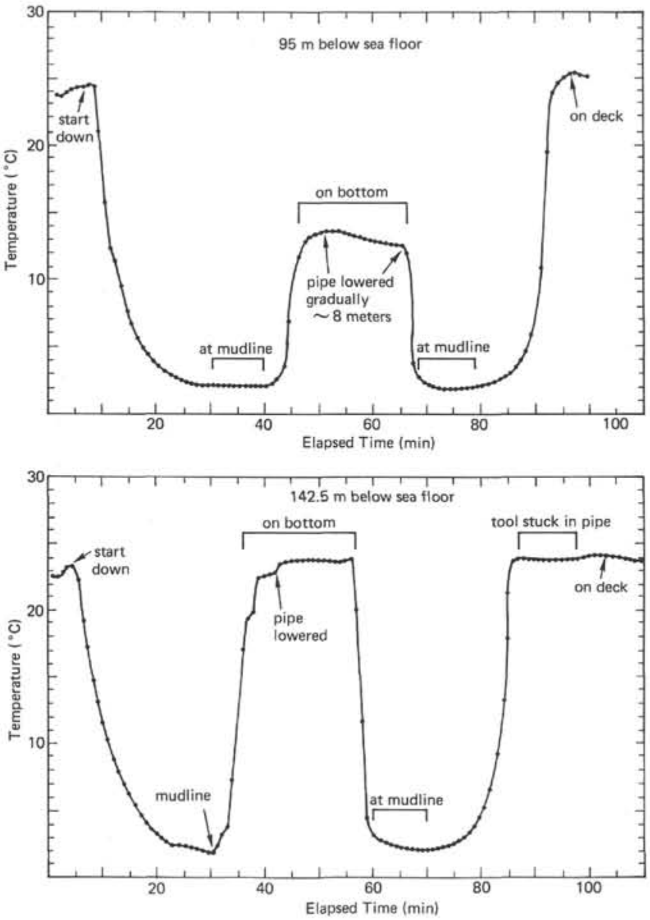


Figure 16. Heat-flow-probe runs and equilibrium temperatures at Site 471. (See text for explanation.)

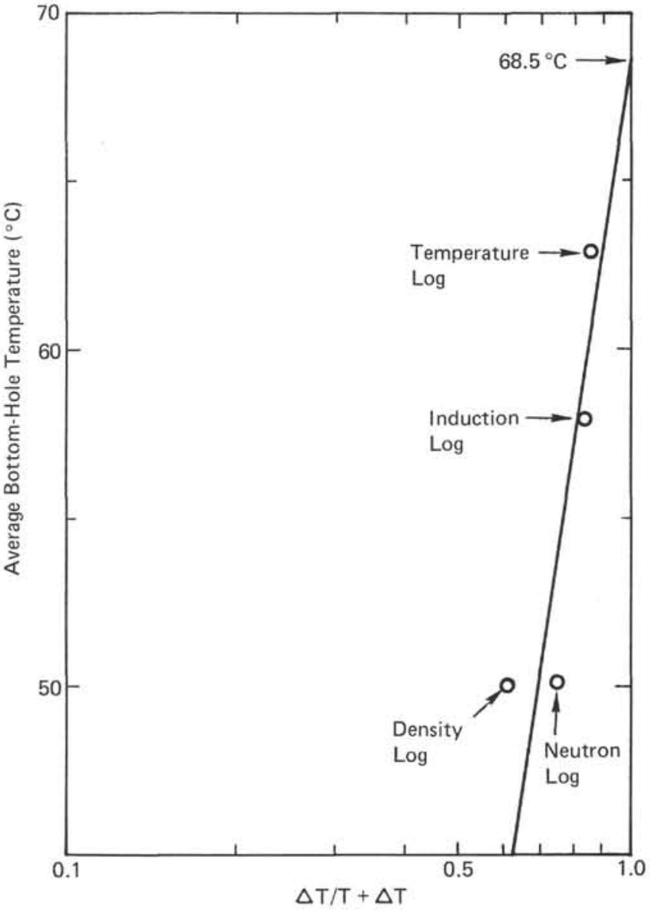


Figure 17. Equilibrium bottom-hole temperature estimated from successive logging runs at Site 471. (See text for explanation.)

the first run because of the added time between the last circulation and logging. From this reasoning, the average minimum gradient is 70°C/km. This value is lower than the estimates made from heat probe measurements, because the logging tool does not actually penetrate the sediment and because of the thermal disturbance created by the drilling process (Jaeger, 1965). Note that the second Temperature Log recorded lower values than did the first log in the upper 150 meters of open hole and higher values below this, an indication of how the hole re-equilibrates following drilling.

A third estimate of the geothermal gradient at Site 471 comes from extrapolating maximum bottom-hole temperatures recorded during each of the logging runs; this was done according to the method described by Timko and Fertl (1972). Figure 17 illustrates this method for Site 471, and Tables 4 and 5 list the pertinent data. From this method the equilibrium bottom-hole temperature is about 68.5°C. Using a 2.0°C bottom-water temperature and a total depth of 817 meters for the hole, the geothermal gradient is 81°C/km. Again, thermal disturbance resulting from drilling and the lack of penetration of the logging tool tend to make this value a minimum.

From these three methods the range in geothermal gradient at Site 471 is 70°C/km to 154°C/km. These values are approximate because both heat probe data and Temperature Logs suggest a nonlinear gradient. A single value is difficult to estimate, because both methods have significant uncertainties—heat flow data suffer from the effects of frictional heat generated by lowering the probe and drill pipe in the sediment, and logging data are nonequilibrium values influenced by thermal disturbances associated with drilling. The average value from the four estimates is 100°C/km.

We did not measure the thermal conductivity of the sediment cored at Site 471 and therefore can only estimate heat flow. Using the range in gradients listed above and an average thermal conductivity of 2.5 mcal/cm s °C estimated from water content, we deduce that the range in estimated heat flow values at Site 471 is 1.8 to 3.9 HFU.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

Figure 18 correlates the seismic-reflection profile obtained by the *Glomar Challenger* while approaching Site 471 (Fig. 7) with the lithology at Site 471. Above acoustic basement, two acoustic units are recognized:

1) An upper acoustic unit of strong, continuous, evenly spaced, and somewhat indistinct reflectors about 0.19 s thick.

Table 4. Chronology of logging operations.

Date	Time	Operation
Nov. 15	1730	Last circulation of mud.
	2038	Start down with sonic tool.
Nov. 16	0030	End Sonic Log, begin Wave-Train Log.
	0050	Start up with Wave-Train Log; 1st maximum bottom hole temperature (max BHT).
	0325	Tool on deck, log complete.
	0340	Start down with temperature-density tool, logging temperature on way down.
	0745	Start up with Density Log; 2nd max BHT.
	1035	Tool on deck.
	1100	Start down with guard Neutron Log.
	1310	Start up with Neutron Log; 3rd max BHT.
	1550	Tool on deck.
	1610	Start down with Induction-Gamma-Ray Log.
	1930	Start up with Induction Log; 4th max BHT.
	1945	Raise pipe 1 stand (28.5 meters) to log soft sediment above porcellanite; Gamma-Ray Log run in pipe to mudline.
	2150	Tool on deck.
	2205	Start down with final Temperature Log.
	2304	Begin recording at 100 meters (water column).
Nov. 17	0015	Repair cable.
	0050	Continue logging.
	0200	End Temperature Log; final max BHT.
	0406	Temperature tool on deck. Rig down.

2) A darker, lower acoustic unit of very strong, continuous reflectors about 0.58-s thick that becomes transparent in the lower part.

The upper acoustic unit correlates with the Quaternary to upper Miocene nannofossil and diatomaceous silty clay and ooze of Lithologic Units 1 and 2. The discordant cutting of reflectors in this upper unit by the underlying acoustic unit correlates with the marked lithologic and diagenetic change from diatomaceous ooze to porcellanites at Site 471. This break marks a bottom-simulating reflector (BSR) similar to that described at DSDP Sites 184, 185, and 188 (Scholl and Creager, 1973). This BSR can be traced laterally on the approaching *Challenger* profile for more than 80 km.

Beginning with the BSR, the lower acoustic unit correlates with the upper to middle Miocene porcellanite and silty claystone and interbedded sandstone (turbidite) sequence of Lithologic Units 3 and 4. A slight angular unconformity at about 0.35 s sub-bottom may correlate with the boundary between these two lithologic units.

The lower acoustic unit becomes increasingly more transparent near its base, which may be the result of a corresponding decrease in the frequency of carbonate-cemented sandstone and carbonate beds downsection in Lithologic Unit 4. The corresponding Sonic and Density Logs (Fig. 15) show only minor density and velocity variations within the lower half of Lithologic Unit 4.

Acoustic basement at 0.77 s sub-bottom correlates with basalt, which can easily be traced landward on the seismic-reflection profile to the base of the continental slope. The landward thickening wedge defined by the sea-floor acoustic basement may be an older trench sequence that has undergone only mild deformation since the cessation of subduction along this portion of the margin. Its remarkably well-preserved character suggests that the ancestral East Pacific Rise never intersected the trench along this portion of the Baja California margin.

CONCLUSIONS

1. The oldest sediments overlying diabase at Site 471 are located in the *Sphenolithus heteromorphus* Zone and are about 15 m.y. of age. These sediments are older than a magnetic anomaly 12 m.y. old that was recognized west of the site by Chase et al. (1970). Magnetic anomalies at the site are low in amplitude and have not been dated. Extrapolation of ages eastward from areas of recognizable magnetic anomalies would predict an age of 11 m.y. at the site. It is demonstrated, therefore, that the age of oceanic crust is older eastward toward the continental escarpment off southern Baja California. This region where oceanic crust is older to the east may be a fragment of the Farallon plate that was not subducted beneath Baja California. The interaction between the East Pacific Rise and North America is more complex at this latitude than previously believed.

2. The lower sedimentary sequence contains 13 to 15 m.y. old distal turbidites (predominantly Bouma d,e sequences) that were deposited at a rate of about 200 m/m.y.; these turbidites are overlain by hemipelagic sediments deposited in the latest middle Miocene and later at rates decreasing upsection from 50 to 20 m/m.y. The siliceous component (altered diatomaceous sediments) is more pronounced upsection, with lower sedi-

Table 5. Bottom-hole temperatures from three maximum reading thermometers mounted on the logging tools, Site 471.

Date	Time	Tool	Distance of Thermometers above Base of Tool (m)	Depth of Measurements (m) below Rig Floor	Depth of Measurements (m) below Sea Floor	Temperature (°F)	Temperature (°C)
Nov. 16	0050	Wave Train	5.5	3932	817	95,95,95	35,35,35
	0745	Temperature-Density	3.1	3935	819	122,122,122	50,50,50
	1310	Neutron	7.3	3933	817	117,122,126	47,50,52
	1930	Induction	6.1	3932	817	136,136,138	58,58,59
Nov. 17	0200	Temperature	5.8	3932	817	144,145,146	62,63,64

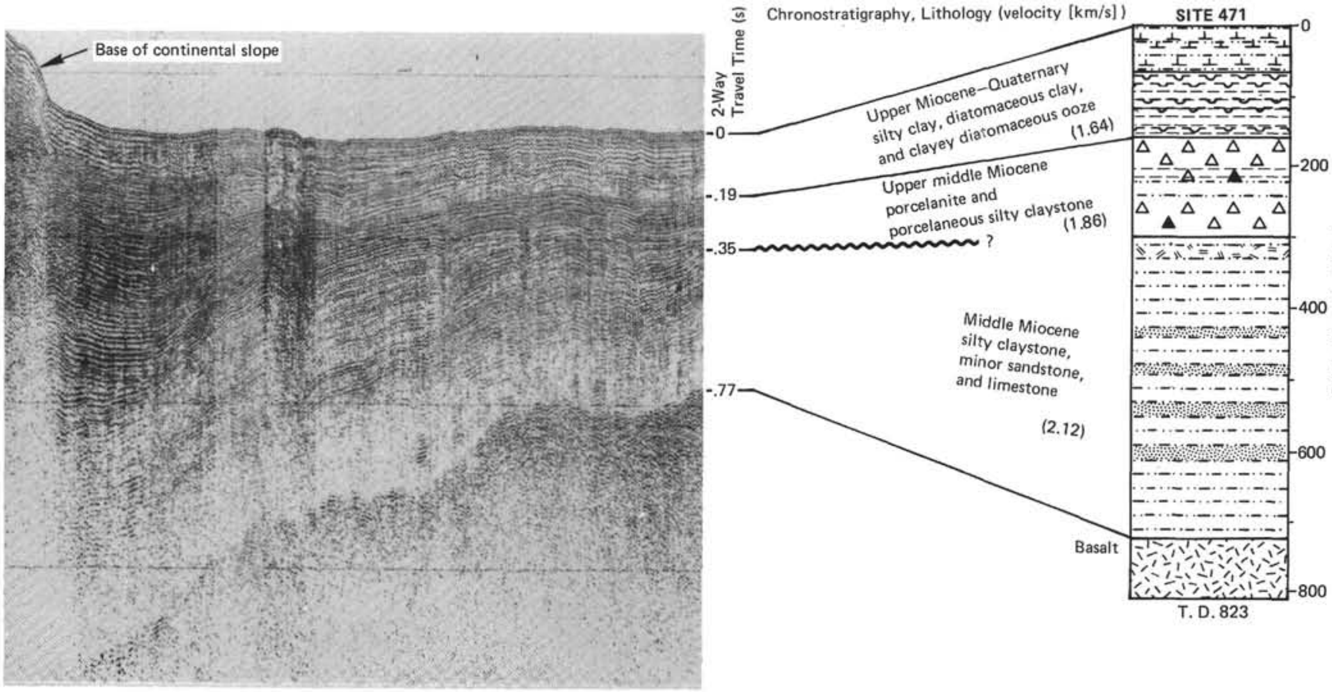


Figure 18. Correlation of *Challenger* seismic-reflection profile with lithology at Site 471.

mentation rates. This change reflects a decrease in the supply of terrigenous material, which may have resulted from a change in vertical uplift rates of the adjacent margin or translation of the site away from major river sources. Alternatively, the increase upsection of siliceous sediments may reflect increased productivity in surface waters.

3. Chalcopyrite- and sphalerite-bearing sediments occur at the base of the sediment section; this occurrence may be an ancient analog to sulfide deposits found on the East Pacific Rise Crest and in related fracture zones.

4. The sediments are underlain by 81.5 meters of diabase with two thin intercalations of metalliferous sediment. The diabase is extensively altered, with common brecciated structures that probably resulted from the intrusion of magma into the sediment; this is indicated by the presence of clayey to cherty inclusions in the breccia. Slickensides show some faulting after consolidation. Fracturing in the diabase, as observed in cores, is substantiated by the Sonic Wave-Train Log and the Density Log.

5. The change from diatomaceous ooze to opal-CT porcellanite and porcellaneous rocks occurs at 155 meters at a present subsurface temperature of about 20°C. The transition is reflected in downhole logs and is in agreement with diagenetic changes in siliceous sediments that were observed at other Leg 63 sites (467, 468, 469, and 473).

REFERENCES

Bukry, D., 1973. Coccolith stratigraphy, Eastern Equatorial Pacific, Leg 16 Deep Sea Drilling Project. *In* van Andel, Tj. H., Heath, G. R., et al., *Init. Repts. DSDP*, 16: Washington (U.S. Govt. Printing Office), 653–711.

________, 1975. Silicoflagellate and coccolith stratigraphy, Deep Sea Drilling Project, Leg 29. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 845–872.

Bukry, D., and Foster, J. H., 1973. Silicoflagellate and diatom stratigraphy, Leg 16, Deep Sea Drilling Project. *In* van Andel, Tj. H., Heath, G. R., et al., *Init. Repts. DSDP*, 16: Washington (U.S. Govt. Printing Office), 815–871.

Bukry, D., and Kennedy, M. P., 1969. Cretaceous and Eocene coccoliths at San Diego, California. *Calif. Div. Mines Geol. Spec. Rep.* 100:33–40.

Chase, C. G., Menard, H. W., Larson, R. L., et al., 1970. History of sea floor spreading west of Baja California. *Bull. Geol. Soc. Am.*, 81:491–498.

Chase, T. E., Menard, H. W., and Mammerickx, J., 1974. Bathymetry of the North Pacific. Scripps Inst. Oceanogr. and Inst. of Marine Resources Chart No. 9 of 10.

Coperude, S. P., 1978. Geologic structures of the western continental margin of south central Baja California based on seismic and potential field data [M.S. thesis]. Oregon State University, Corvallis, p. 27.

Dumitrică, P., 1973. Paleocene, late Oligocene, and post-Oligocene silicoflagellates in southwestern Pacific sediments cored on DSDP Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 837–883.

Huehn, B., 1977. Crustal structure of the Baja peninsula between latitudes 22°N and 25°N [M.S. thesis]. Oregon State University, Corvallis.

Hussong, D., Uyeda, S., et al., in press. *Init. Repts. DSDP*, 60: Washington (U.S. Govt. Printing Office).

Hyndman, R. D., Erickson, A., and von Herzen, R. P., 1974. Geothermal measurements on DSDP Leg 26. *In* Davies, T. A., Luyendyk, B. P., et al., *Init. Repts. DSDP*, 26: Washington (U.S. Govt. Printing Office), 451–463.

Ingle, J. C., Jr., 1973. Summary comments on Neogene biostratigraphy, physical stratigraphy, and paleoceanography in the marginal Northeastern Pacific Ocean. *In* Kulm, L. D., von Huene, R., et al., *Init. Repts. DSDP*, 18: Washington (U.S. Govt. Printing Office), 949–960.

Jaeger, J. C., 1965. Application of the theory of heat conduction to geothermal measurements. *In* Lee, W. H. K. (Ed.), *Terrestrial Heat Flow: Am. Geophys. Union, Geophys. Mon. Series*, 8:7–23.

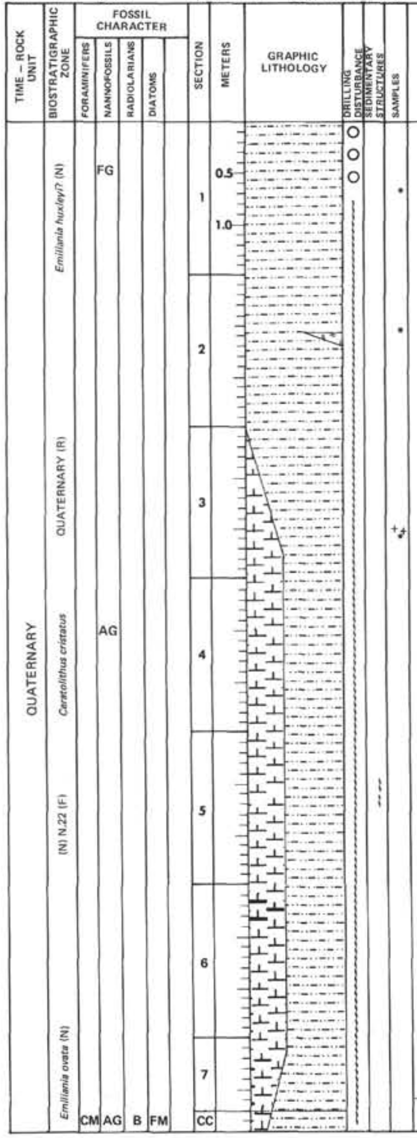
Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceedings of the Second Planktonic Conference, Roma 1970*, 2:739–785.

Menard, H. W., 1978. Fragmentation of the Farallon plate by pivoting subduction. *J. Geol.*, 86:99–110.

Timko, D. J., and Fertl, W. H., 1972. How downhole temperatures, pressures affect drilling. *World Oil*, October: 73–74.

Scholl, D. W., and Creager, J. S., 1973. Geologic synthesis of Leg 19 (DSDP) results; far North Pacific, and Aleutian Ridge, and Bering Sea. *In* Creager, J. S., Scholl, D. W., et al., *Init. Repts. DSDP*, 19: Washington (U.S. Govt. Printing Office), 897–913.

SITE 471 HOLE CORE 1 CORED INTERVAL 0.0–9.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAY and **NANNOFOSSIL SILTY CLAY**, dark grayish yellow green (5GY 6/2) to light grayish olive green (5GY 4/2), lighter colors indicate more nannofossil-rich sediment; large burrows Section 5 deformed by drilling. Several patches of pinkish gray (5YR 8/1) and dusky yellow (5Y 6/4) **VITRIC ASH** Section 2. Intense drilling deformation.

Ash-rich layer

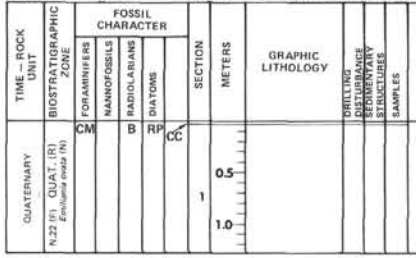
ORGANIC CARBON AND CARBONATE

	3-107	3-108
% Organic Carbon	–	0.89
% $CaCO_3$	8	5

SMEAR SLIDE SUMMARY

	1-70 (D)	2-60 (M)	3-110 (D)
TEXTURE:			
Sand	3	5	–
Silt	35	85	20
Clay	62	10	80
COMPOSITION:			
Quartz	20	1	4
Feldspar	8	–	1
Mica	1	TR	TR
Heavy minerals	2	TR	TR
Clay	61	1	63
Volcanic glass	1	98	–
Glauconite	–	–	TR
Carbonate unspec.	1	–	–
Foraminifers	1	–	2
Calc. Nannofossils	1	–	30
Diatoms	TR	–	TR
Radiolarians	TR	TR	TR
Sponge spicules	1	–	TR
Plant debris	–	–	TR

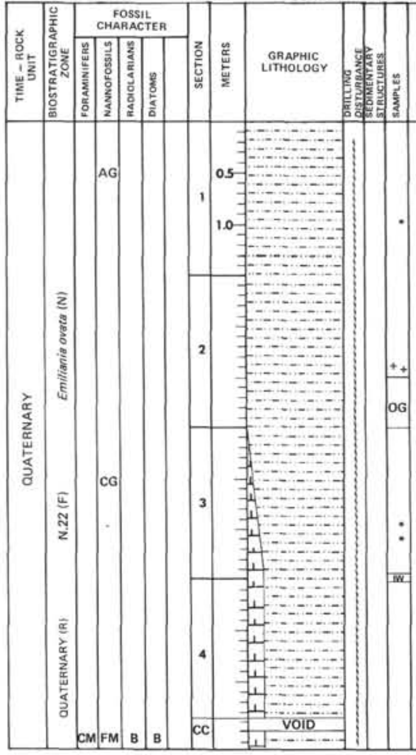
SITE 471 HOLE CORE 2 CORED INTERVAL 9.5–19.0 m



LITHOLOGIC DESCRIPTION

*Trace of **SILTY CLAY** in Core-Catcher.*

SITE 471 HOLE CORE 3 CORED INTERVAL 19.0–28.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAY and **NANNOFOSSIL SILTY CLAY**, grayish olive green (5GY 4/2) to dusky yellow green (5GY 5/2); nannofossils increase in Section 3. Dark gray and grayish purple pyrite-rich(?) streaks scattered throughout core. Ash-rich patches in Sections 3 and 4. Intense drilling deformation.

Ash-rich zone

Ash-rich zone

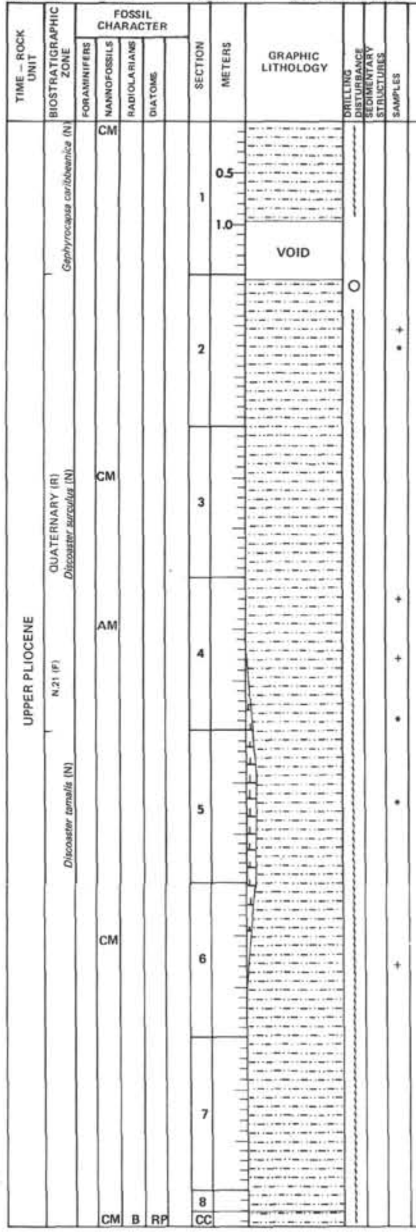
ORGANIC CARBON AND CARBONATE

	2-94	2-97
% Organic Carbon	–	0.85
% $CaCO_3$	3	3

SMEAR SLIDE SUMMARY

	1-100 (D)	3-100 (D)	3-113 (M)
TEXTURE:			
Sand	3	–	–
Silt	27	35	10
Clay	70	65	90
COMPOSITION:			
Quartz	12	7	3
Feldspar	6	1	TR
Mica	1	TR	TR
Heavy minerals	1	1	TR
Clay	66	59	60
Volcanic glass	9	–	20
Pyrite	TR	–	–
Carbonate unspec.	–	1	2
Foraminifers	TR	5	–
Calc. Nannofossils	5	26	15
Radiolarians	TR	–	–
Sponge spicules	–	–	TR
Dolomite	–	TR	TR

SITE 471 HOLE CORE 4 CORED INTERVAL 28.5–38.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAY, medium greenish gray (5GY 5/1) to grayish green (5G 5/1), mottled with dark pyrite-rich streaks. Nannofossils relatively more abundant in Section 5 than rest of core. Intense drilling deformation.

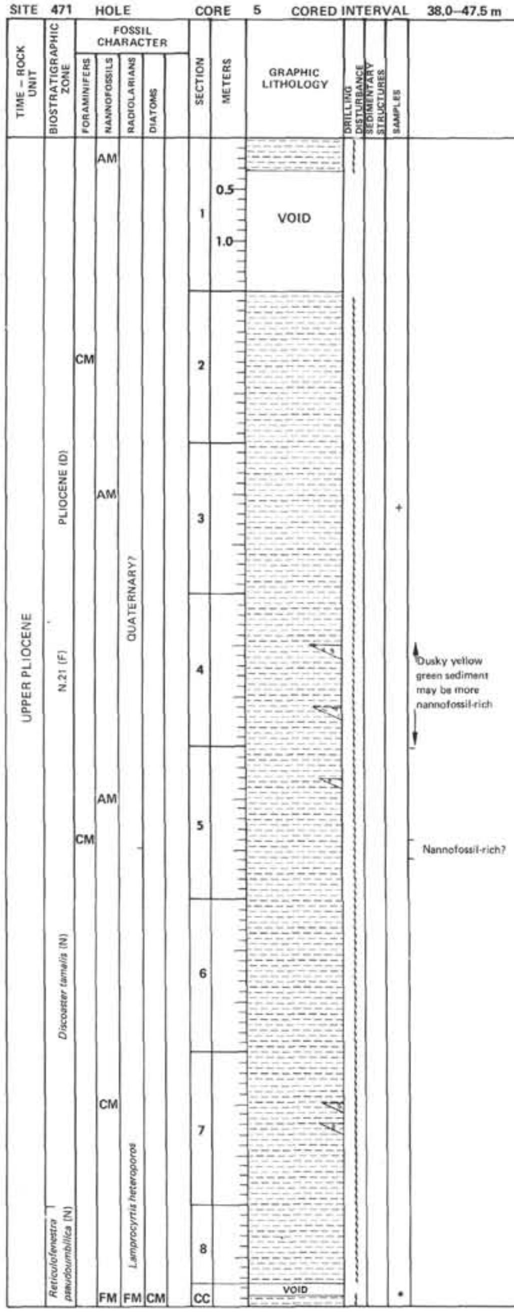
ORGANIC CARBON AND CARBONATE

	2-58	4-23	4-85	5-70
% Organic Carbon	–	1.38	–	–
% $CaCO_3$	0	3	2	4

SMEAR SLIDE SUMMARY

	2-75 (D)	4-140 (D)	5-75 (D)
TEXTURE:			
Sand	2	–	–
Silt	30	10	10
Clay	68	90	90
COMPOSITION:			
Quartz	14	10	6
Feldspar	6	1	1
Mica	TR	TR	TR
Heavy minerals	1	TR	TR
Clay	63	77	75
Pyrite	1	–	TR
Foraminifers	1	1	–
Calc. Nannofossils	5	10	15
Radiolarians	TR	–	–
Sponge spicules	TR	–	–

SITE 471 HOLE CORE 5 CORED INTERVAL 38.0–47.5 m



Dusky yellow green sediment may be more nannofossil-rich

Nannofossil-rich?

LITHOLOGIC DESCRIPTION

CLAY, medium greenish gray (5G 5/1), silty in places; average nannofossil content 3–4%. Patches of dark gray **VITRIC ASH** scattered in Sections 4, 5, and 7. Intense drilling deformation.

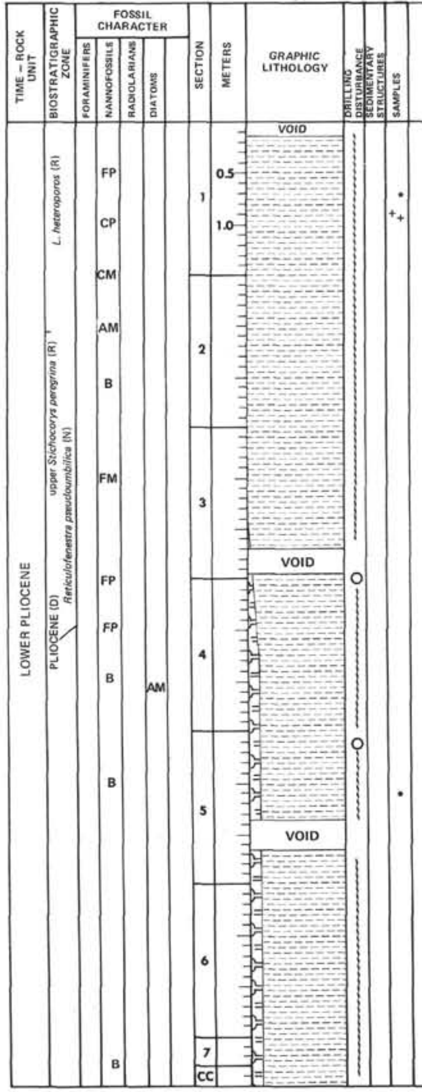
ORGANIC CARBON AND CARBONATE

	3-62
% Organic Carbon	–
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	CC-15 (D)
TEXTURE:	
Sand	–
Silt	3
Clay	97
COMPOSITION:	
Quartz	10
Feldspar	1
Heavy minerals	1
Clay	72
Pyrite	1
Carbonate unspec.	1
Foraminifers	5
Calc. Nannofossils	5
Radiolarians	TR
Sponge spicules	4
Silicoflagellates	TR

SITE 471 HOLE CORE 6 CORED INTERVAL 47.5–58.0 m



LITHOLOGIC DESCRIPTION

CLAY changing downcore to **SILICEOUS CLAY**, dusky yellow green (5GY 5/2) to greenish gray (5G 5/1), mottled with scattered pyrite-rich streaks. Siliceous microfossils, mainly diatoms, increase in abundance below Section 4. Intense drilling deformation.

No Core-Catcher.

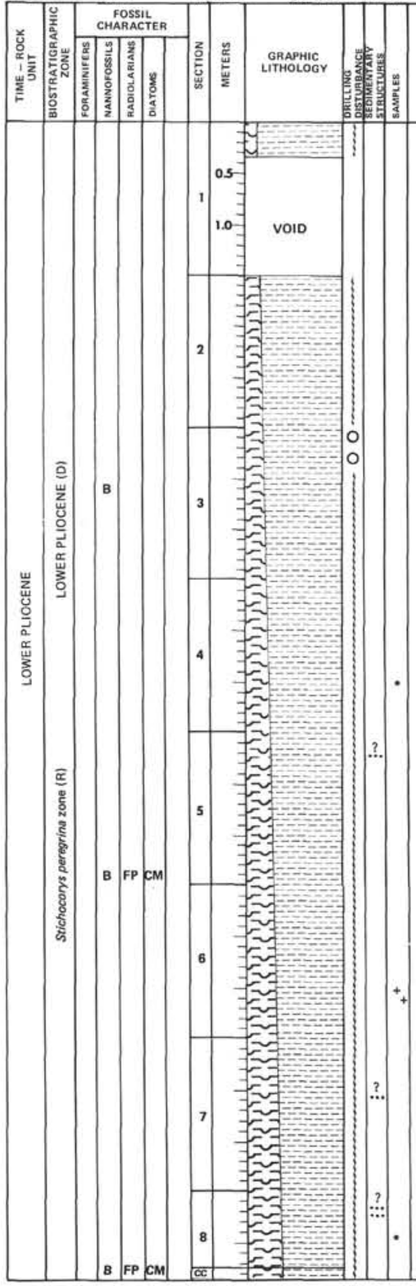
ORGANIC CARBON AND CARBONATE

	2-93	2-95
% Organic Carbon	0.86	–
% $CaCO_3$	0	1

SMEAR SLIDE SUMMARY

	1-75 (D)	5-62 (D)
TEXTURE:		
Sand	–	–
Silt	18	32
Clay	82	68
COMPOSITION:		
Quartz	12	7
Feldspar	3	1
Mica	TR	TR
Heavy minerals	TR	TR
Clay	80	67
Volcanic glass	TR	–
Pyrite	–	1
Carbonate unspec.	–	6
Foraminifers	TR	2
Calc. Nannofossils	2	TR
Diatoms	2	9
Radiolarians	TR	4
Sponge spicules	–	2
Silicoflagellates	–	TR

SITE 471 HOLE CORE 7 CORED INTERVAL 57.0–66.5 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, mottled, light grayish olive green (5GY 3/2) and grayish green (10GY 5/2); diatoms more abundant downcore. Scattered dark gray pyrite-rich patches. Possible deformed laminations/lenticular bedding Sections 5–7. Intense drilling deformation.

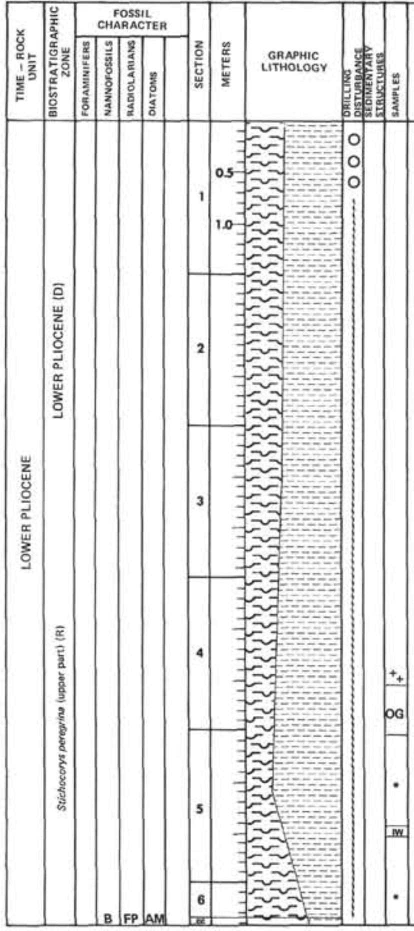
ORGANIC CARBON AND CARBONATE

	6-105	6-113
% Organic Carbon	–	1.04
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	4-90 (D)	8-41 (D)
TEXTURE:		
Sand	–	–
Silt	30	30
Clay	70	70
COMPOSITION:		
Quartz	10	5
Feldspar	2	1
Mica	TR	TR
Heavy minerals	1	1
Clay	49	49
Volcanic glass	TR	–
Glauconite	TR	TR
Pyrite	2	–
Carbonate unspec.	1	1
Diatoms	25	40
Radiolarians	3	1
Sponge spicules	8	1
Silicoflagellates	TR	1

SITE 471 HOLE CORE 8 CORED INTERVAL 66.5–76.0 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, mottled grayish green (10GY 5/2), dusky yellow green (5GY 5/2), and medium olive gray (5Y 4/2); mottling apparently reflects relative amounts of diatoms in sediments. Diatomaceous clay changes to **CLAYEY DIATOMACEOUS OOZE** in Section 6. Intense drilling deformation.

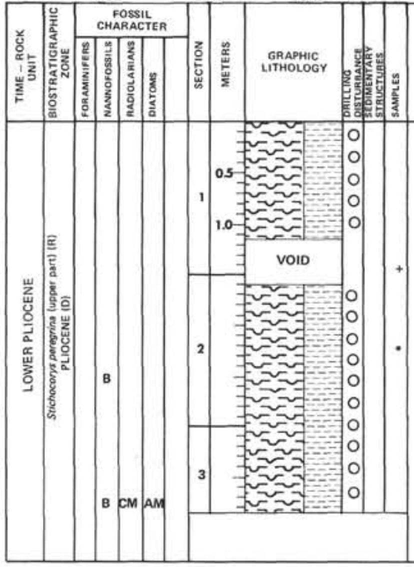
ORGANIC CARBON AND CARBONATE

	4-96	4-98
% Organic Carbon	–	1.41
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	5-54 (D)	6-13 (D)
TEXTURE:		
Sand	–	–
Silt	5	15
Clay	95	85
COMPOSITION:		
Quartz	5	3
Feldspar	1	TR
Mica	TR	TR
Heavy minerals	TR	TR
Clay	59	34
Pyrite	2	–
Diatoms	25	60
Radiolarians	2	2
Sponge spicules	3	1
Silicoflagellates	TR	TR

SITE 471 HOLE CORE 9 CORED INTERVAL 76.0–85.5 m



LITHOLOGIC DESCRIPTION

CLAYEY DIATOMACEOUS OOZE, grayish olive green (5GY 3/2). Drilling deformation intense.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-41
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	2-78 (D)
TEXTURE:	
Sand	–
Silt	63
Clay	27
COMPOSITION:	
Quartz	2
Feldspar	TR
Mica	TR
Heavy minerals	TR
Clay	27
Pyrite	2
Carbonate unspec.	2
Foraminifers	TR
Diatoms	60
Radiolarians	5
Sponge spicules	1
Silicoflagellates	1

SITE 471 HOLE CORE 10 CORED INTERVAL 85.5–95.0 m

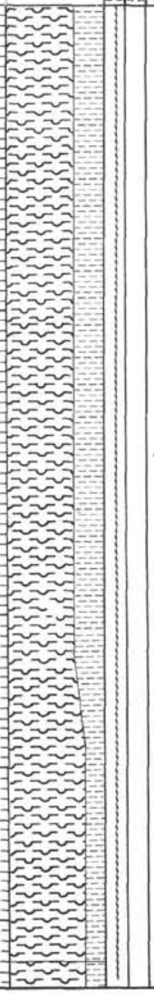
TIME – ROCK UNIT: LOWER PLIOCENE; UPPER MIOCENE

BIOSTRATIGRAPHIC ZONE: *S. peregrina* (upper part) (R); *Ommatartus penultimus* to *Stichocorys peregrina* (lower part) (R); UPPER MIOCENE – *Nitzschia miocenica* to *Thalassiosira convexa* (lower part) (D)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): B; B FM; B FM AM

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

METERS: 0.5, 1.0



5Y 3/4

Yellow green layer

5Y 3/4

5Y 3/4 with 10GY 5/2 mottles

5Y 3/4 changing to 5GY 6/1

LITHOLOGIC DESCRIPTION

CLAYEY DIATOMACEOUS OOZE, dark olive brown (5Y 3/4) with dusky yellow green (5GY 5/2), grayish *green (10GY 5/2) and light olive gray mottles (5Y 6/1);* lighter colored sediment more diatom-rich. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	3-74	3-133
% Organic Carbon	–	2.83
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	3-134 (D)
TEXTURE:	
Sand	–
Silt	80
Clay	20
COMPOSITION:	
Quartz	3
Feldspar	2
Mica	TR
Heavy minerals	TR
Clay	13
Volcanic glass	TR
Pyrite	2
Calc. Nannofossils	TR
Diatoms	70
Radiolarians	3
Sponge psicules	2
Silicoflagellates	5

SITE 471 HOLE CORE 11 CORED INTERVAL 95.0–104.5 m

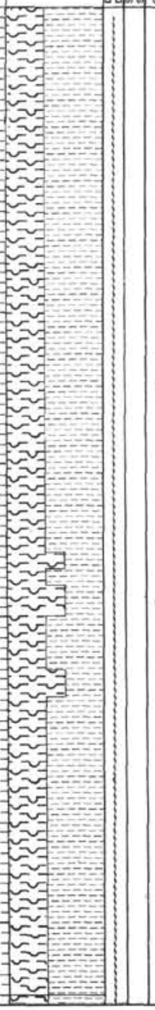
TIME – ROCK UNIT: UPPER MIOCENE

BIOSTRATIGRAPHIC ZONE: UPPER MIOCENE (D); *Ommatartus penultimus* to *Stichocorys peregrina* (lower part) (R); *Stichocorys peregrina* (lower part) (R)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): B FM AM

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

METERS: 0.5, 1.0



5GY 5/2

5G 6/1
5G 5/2
5G 6/1

5G 5/2

5G 6/1

5G 5/2

LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY AND CLAYEY DIATOMACEOUS OOZE, dusky yellow green (5GY 5/2 – clay) to greenish gray (5G 6/1 – ooze). Some scattered dark pyrite-rich(?) streaks. Intense drilling deformation.

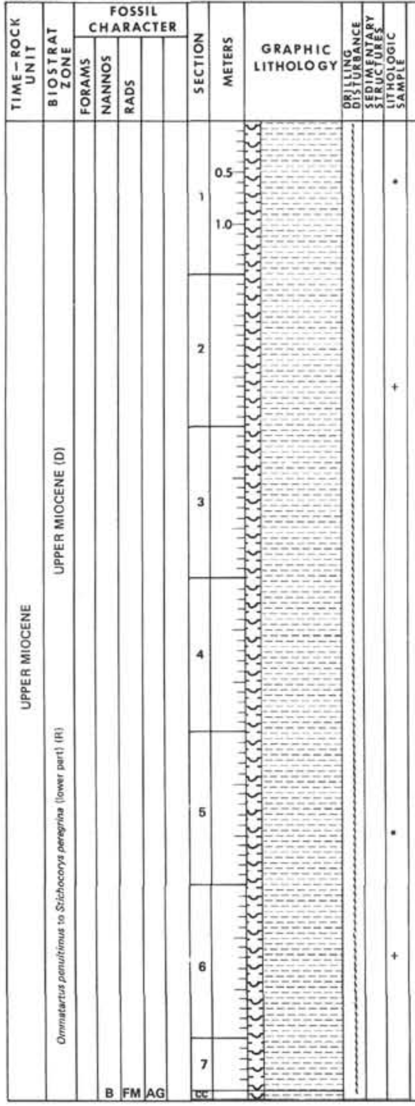
ORGANIC CARBON AND CARBONATE

	3-80
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-79 (D)	4-133 (D)
TEXTURE:		
Sand	–	–
Silt	30	30
Clay	70	70
COMPOSITION:		
Quartz	4	4
Feldspar	3	3
Mica	TR	TR
Heavy minerals	TR	TR
Clay	45	20
Volcanic glass	–	TR
Pyrite	2	3
Carbonate unspec.	TR	–
Diatoms	40	60
Radiolarians	3	5
Sponge spicules	TR	5
Silicoflagellates	2	TR
Plant debris	TR	–

SITE 471 HOLE CORE 12 CORED INTERVAL: 104.5–114.0 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, dusky yellow green (5GY 5/2) mottled with dark yellowish brown (10YR 4/2) patches. Grayish purple (5P 4/2) pyrite-rich streaks scattered throughout. Intense drilling deformation has homogenized lithology and destroyed sedimentary structures.

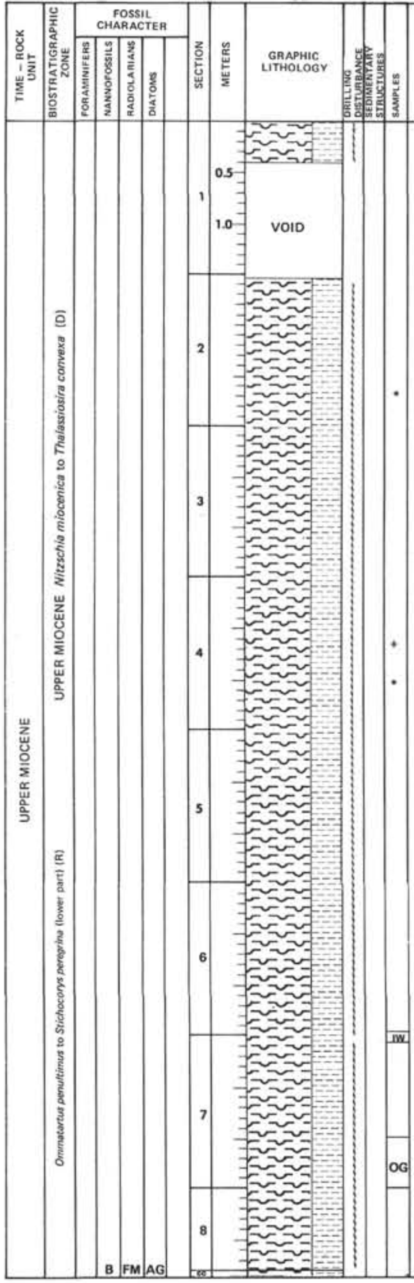
ORGANIC CARBON AND CARBONATE

	2-118	6-70
% Organic Carbon	1.04	–
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	1-65 (D)	5-100 (D)
TEXTURE:		
Sand	–	–
Silt	30	30
Clay	70	70
COMPOSITION:		
Quartz	3	5
Feldspar	2	2
Mica	TR	TR
Heavy minerals	TR	TR
Clay	70	70
Volcanic glass	TR	–
Pyrite	3	2
Calc. Nannofossils	1	–
Diatoms	15	15
Radiolarians	3	3
Sponge spicules	1	1
Silicoflagellates	2	2

SITE 471 HOLE CORE 13 CORED INTERVAL 114.0–123.5 m



LITHOLOGIC DESCRIPTION

CLAYEY DIATOMACEOUS OOZE, dusky yellow green (5GY 5/2) to grayish green (10GY 5/2) with some yellowish brown (10YR 4/2) mottles. Structures and lithology homogenized by intense drilling deformation.

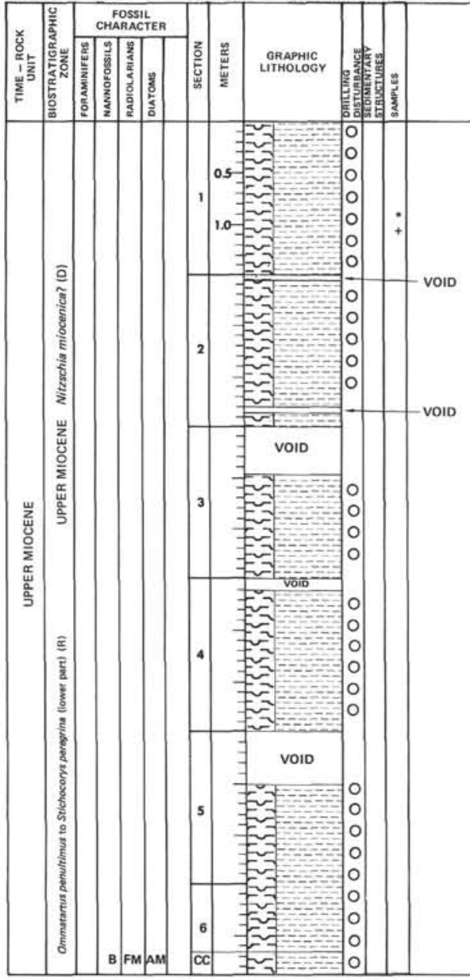
ORGANIC CARBON AND CARBONATE

	4-70
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	2-120 (D)	4-106 (D)
TEXTURE:		
Sand	– –	–
Silt	50	80
Clay	50	20
COMPOSITION:		
Quartz	3	3
Feldspar	2	2
Mica	TR	TR
Heavy minerals	TR	TR
Clay	50	20
Volcanic glass	TR	–
Pyrite	1	2
Carbonate unspec.	1	–
Diatoms	35	65
Radiolarians	5	5
Sponge spicules	TR	TR
Silicoflagellates	3	3
Plant debris	–	TR

SITE 471 HOLE CORE 14 CORED INTERVAL 123.5–133.0 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, dusky yellow green (5GY 5/2) with few dark yellowish brown (10YR 4/2) mottles. Structures and lithology homogenized by drilling.

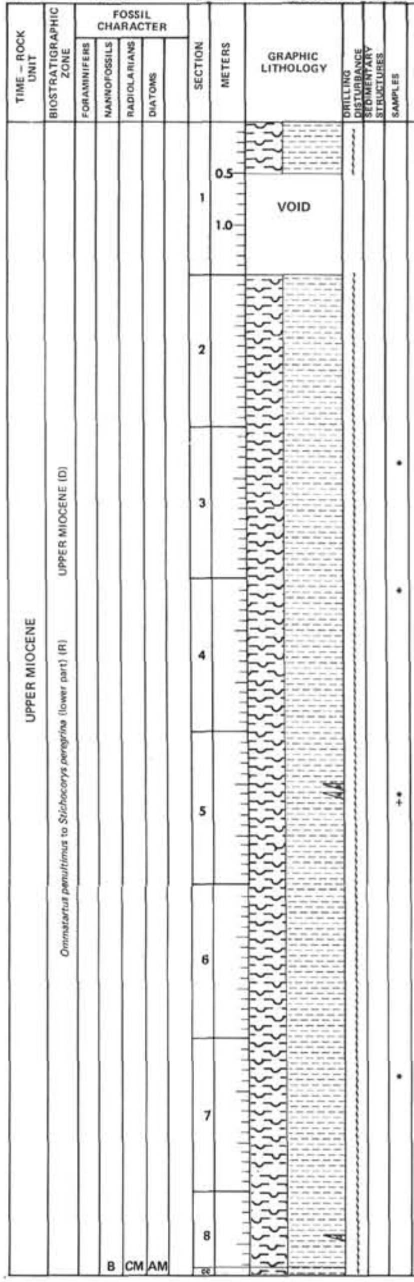
ORGANIC CARBON AND CARBONATE

	1-110
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-90 (D)
TEXTURE:	
Sand	–
Silt	50
Clay	50
COMPOSITION:	
Quartz	3
Feldspar	2
Mica	TR
Heavy minerals	TR
Clay	50
Pyrite	5
Carbonate unspec.	1
Diatoms	30
Radiolarians	5
Sponge spicules	TR
Silicoflagellates	4

SITE 471 HOLE CORE 15 CORED INTERVAL 133.0–142.5 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, dusky yellowish green (5GY 5/2) with some pale green (10G 6/2) patches and streaks, especially Sections 3 and 4. Several patches of dusky yellowish green **VITRIC ASH** in Sections 5 and 8. Structures and lithology homogenized by drilling.

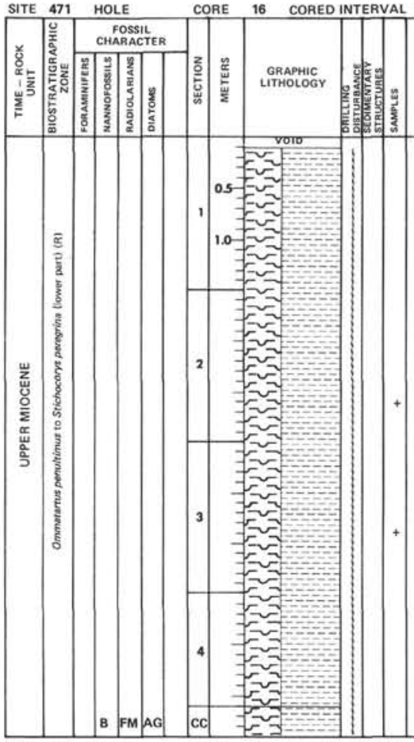
ORGANIC CARBON AND CARBONATE

	5-70
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	3-40 (D)	4-17 (D)	5-65 (M)	7-40 (D)
TEXTURE:				
Sand	–	–	–	–
Silt	40	35	65	40
Clay	60	65	35	60
COMPOSITION:				
Quartz	3	3	TR	7
Feldspar	2	2	1	5
Mica	TR	TR	–	TR
Heavy minerals	TR	TR	–	TR
Clay	45	45	–	40
Volcanic glass	TR	–	99	TR
Glauconite	–	TR	–	–
Pyrite	4	2	–	2
Carbonate unspec.	1	–	–	
Calc. Nannofossils	TR	–	–	–
Diatoms	35	40	–	39
Radiolarians	5	5	–	5
Sponge spicules	TR	–	–	–
Silicoflagellates	5	3	–	2

SITE 471 HOLE CORE 16 CORED INTERVAL 142.5–152.0 m



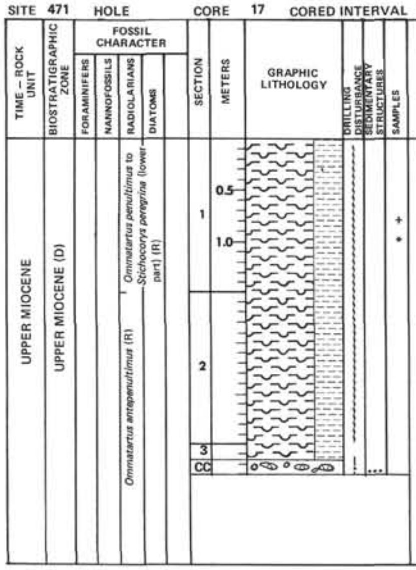
LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY, dusky yellowish green (5GY 5/2) with some dark yellow brown (10YR 4/2) streaks. Structures and lithology homogenized by drilling.

ORGANIC CARBON AND CARBONATE

	2-118	3-90
% Organic Carbon	1.04	–
% $CaCO_3$	0	0

SITE 471 HOLE CORE 17 CORED INTERVAL 152.0–161.5 m



LITHOLOGIC DESCRIPTION

CLAYEY DIATOMACEOUS OOZE, mottled dark yellowish brown (10YR 4/2), moderate yellowish brown (10YR 5/4) and pale olive; homogenized by drilling. Core-Catcher contains several pieces of greenish black (5GY 2/1) **PORCELLANITE.** Slabbed surfaces show burrows and lenticular laminations.

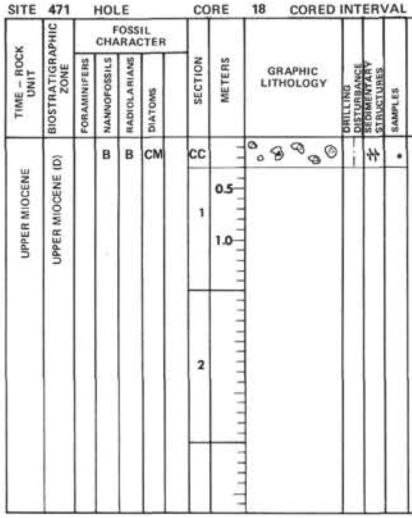
ORGANIC CARBON AND CARBONATE

	1-80
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-100 (D)
TEXTURE:	
Sand	–
Silt	90
Clay	10
COMPOSITION:	
Quartz	3
Feldspar	2
Mica	TR
Heavy minerals	TR
Clay	15
Pyrite	2
Diatoms	70
Silicoflagellates	3

SITE 471 HOLE CORE 18 CORED INTERVAL 161.5–171.0 m



LITHOLOGIC DESCRIPTION

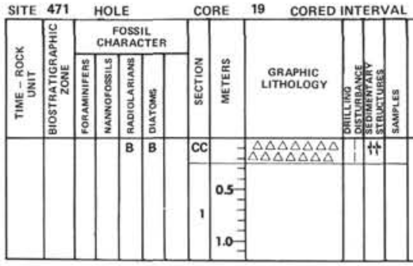
Fragments of olive black (5Y 2/1) **CHERT AND PORCELLANITE.** Both lithologies have conchoidal fracture; chert is vitreous. Burrows and lenticular bedding common.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	1-24 (T)
TEXTURE:	
Sand	–
Silt	8
Clay	92
COMPOSITION:	
Quartz	2
Feldspar	1
Clay	12
Pyrite	2
Carbonate unspec.	1
Diatoms	2
Radiolarians	TR
Sponge spicules	1
Opal-CT	80
Chalcedony	TR

SITE 471 HOLE CORE 19 CORED INTERVAL 171.0–180.5 m

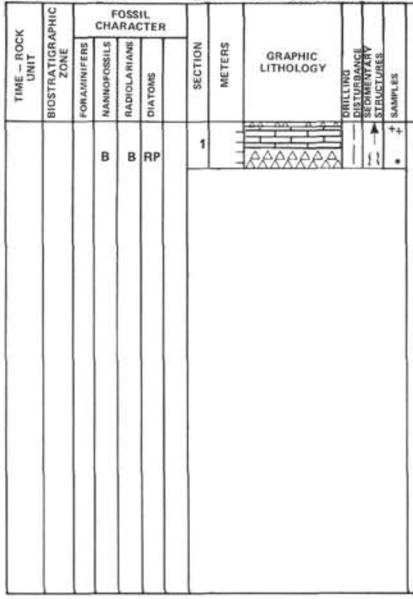


LITHOLOGIC DESCRIPTION

PORCELLANITE, grayish olive (10Y 4/2) to olive black (5Y 2/1); common burrows and some lenticular bedding. Scattered sponge fragments and silty layers. Core brecciated by drilling.

Core-Catcher only.

SITE 471 HOLE CORE 20 CORED INTERVAL 180.5–190.0 m



LITHOLOGIC DESCRIPTION

CLAYEY LIMESTONE AND PORCELLANITE. Limestone is light olive gray (5Y 5/2), intensely burrowed and partly silicified(?). Porcellanite is grayish olive (10Y 4/2) to olive black (5Y 2/1), burrowed and fractured by drilling. In contrast limestone part of core is more intact.

No Core-Catcher.

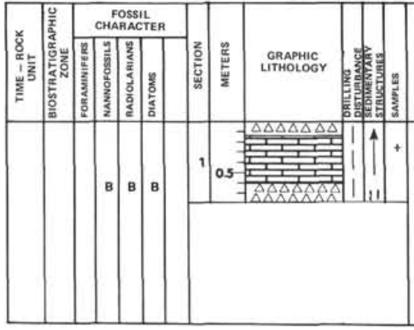
ORGANIC CARBON AND CARBONATE

	1-8	1-10
% Organic Carbon	3.98	–
% $CaCO_3$	100	100

SMEAR SLIDE SUMMARY

	1-45 (D)
TEXTURE:	
Sand	–
Silt	20
Clay	80
COMPOSITION:	
Quartz	TR
Feldspar	TR
Mica	TR
Heavy minerals	TR
Clay	15
Pyrite	2
Carbonate unspec.	14
Radiolarians	2
Sponge spicules	2
Opal-CT	65

SITE 471 HOLE CORE 21 CORED INTERVAL 190.0–199.5 m



LITHOLOGIC DESCRIPTION

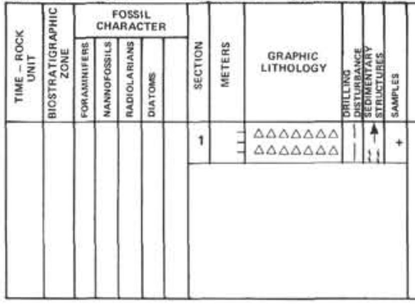
CLAYEY LIMESTONE AND PORCELLANITE. Limestone is light olive gray (5Y 5/2) and intensely burrowed. Porcellanite is medium olive gray (5Y 4/2) and also burrowed as in Core 20, porcellanite is completely fractured and broken by drilling while limestone is intact.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-23
% Organic Carbon	–
% $CaCO_3$	99

SITE 471 HOLE CORE 22 CORED INTERVAL 199.5–209.0 m



LITHOLOGIC DESCRIPTION

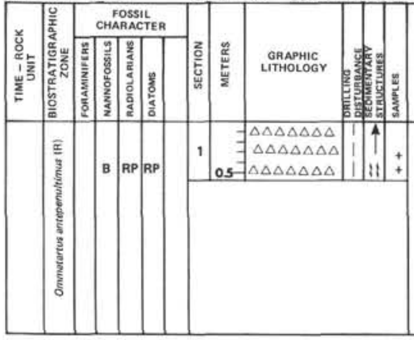
PORCELLANITE, medium olive gray (5Y 4/2), intensely burrowed. Core consists of porcellanite fragments brecciated by drilling.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-21
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 23 CORED INTERVAL 209.0–218.5 m



LITHOLOGIC DESCRIPTION

PORCELLANITE, medium olive gray (5Y 4/2), intensely burrowed. Core highly fractured by drilling.

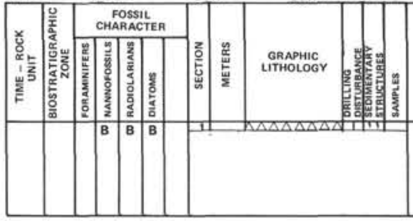
No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-37	1-50
% Organic Carbon	0.34	–
% $CaCO_3$	–	0

NOTE: Core 24, 218.5–228.0 m: NO RECOVERY.

SITE 471 HOLE CORE 25 CORED INTERVAL 228.0–237.5 m

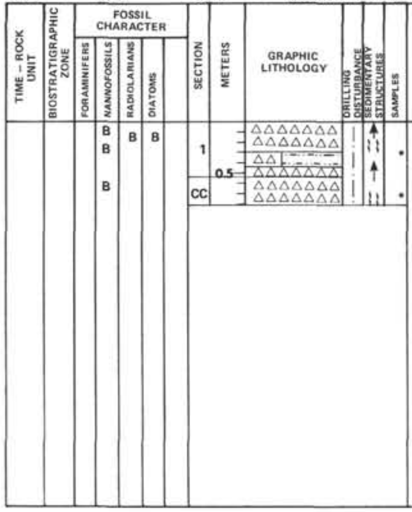


LITHOLOGIC DESCRIPTION

PORCELLANITE, olive gray (5Y 3/2) to light olive gray (5Y 5/2), intensely burrowed. Conchoidally fractured.

No Core-Catcher.

SITE 471 HOLE CORE 26 CORED INTERVAL 237.5–247.0 m



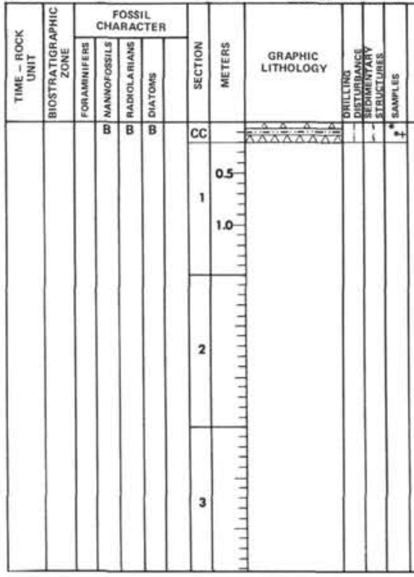
LITHOLOGIC DESCRIPTION

PORCELLANITE, olive gray (5Y 3/2) to light olive gray (5Y 5/2), intensely burrowed. Most of core is highly brecciated by drilling. Interval between 32–42 cm is a drilling breccia of porcellanite chips and calcareous silty clay fragments. Pumice fragments also occur in Core-Catcher (e.g. Smear Slide CC-29).

SMEAR SLIDE SUMMARY

	1-38 (M)	CC-29 (M)
TEXTURE:		
Sand	–	–
Silt	30	–
Clay	70	–
COMPOSITION:		
Quartz	5	TR
Feldspar	2	TR
Mica	TR	–
Heavy minerals	TR	–
Clay	38	–
VOlcanic glass	–	100
Glauconite	TR	–
Pyrite	5	–
Carbonate unspec.	15	–
Opal-CT(?)	35	–

SITE 471 HOLE CORE 27 CORED INTERVAL 247.0–256.5 m



LITHOLOGIC DESCRIPTION

PORCELLANITE AND SILTY CLAY. Porcellanite is olive gray (5Y 3/2), burrowed, and brecciated by drilling. Silty clay is light olive gray (5Y 5/2) and contains some fine sandy laminations.

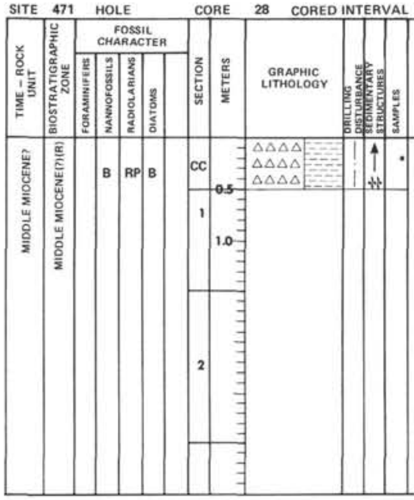
ORGANIC CARBON AND CARBONATE

	CC-20
% Organic Carbon	–
% $CaCO_3$	1

SMEAR SLIDE SUMMARY

	1-9 (D)	1-17 (D)
TEXTURE:		
Sand	–	–
Silt	48	13
Clay	52	87
COMPOSITION:		
Quartz	20	7
Feldspar	15	3
Mica	1	1
Heavy minerals	3	TR
Clay	45	87
Volcanic glass	1	1
Glauconite	TR	TR
Pyrite	5	–
Carbonate unspec.	–	1
Diatoms	TR	–
Sponge spicules	TR	TR

SITE 471 HOLE CORE 28 CORED INTERVAL 256.5–266.0 m



LITHOLOGIC DESCRIPTION

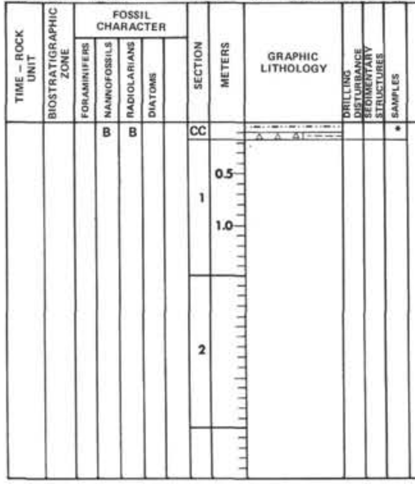
PORCELLANITE–PORCELANEOUS CLAYSTONE, olive gray (5Y 3/2) to greenish gray (5G 6/1), abundant burrows and lenticular bedding. Core highly brecciated by drilling.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-18 (D)
TEXTURE:	
Sand	–
Silt	15
Clay	85
COMPOSITION:	
Quartz	5
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	70
Pyrite	5
Carbonate unspec.	2
Opal-CT	15?

SITE 471 HOLE CORE 29 CORED INTERVAL 266.0–275.5 m



LITHOLOGIC DESCRIPTION

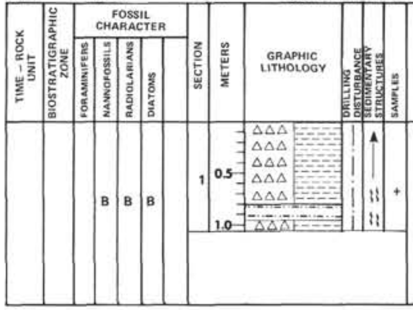
SILTY CLAYSTONE AND PORCELLANITE-PORCELANEOUS CLAYSTONE. Silty claystone is grayish olive (10Y 4/2) and structureless. Porcelaneous rocks are olive gray (5Y 3/2) to light olive gray (5Y 5/2), and burrowed mottled. Core brecciated by drilling.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-5 (D)
TEXTURE:	
Sand	–
Silt	13
Clay	87
COMPOSITION:	
Quartz	7
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	88
Glauconite	TR
Pyrite	2

SITE 471 HOLE CORE 30 CORED INTERVAL 275.5–285.0 m



LITHOLOGIC DESCRIPTION

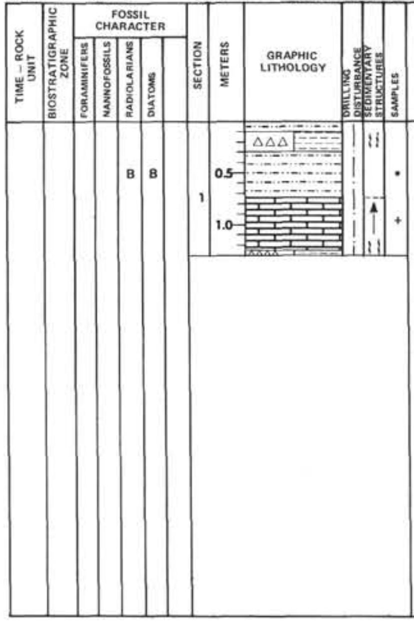
PORCELLANITE–PORCELANEOUS CLAYSTONE AND SILTY CLAY. Porcelaneous rocks are olive gray (5Y 3/2) to light gray (5Y 5/2) and burrowed. Silty clay is olive gray (5Y 3/2). Core composed of drilling fragments.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-70
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 31 CORED INTERVAL 285.0–294.5 m



LITHOLOGIC DESCRIPTION

PORCELANEOUS CLAYSTONE, SILTY CLAY, AND CLAYEY LIMESTONE. Porcelaneous rocks are olive gray (5Y 3/2) and burrowed; silty clay also olive gray (5Y 3/2), structureless; limestone is light olive gray (5Y 6/1) and burrowed. Core consists of fragments brecciated by drilling.

No Core-Catcher.

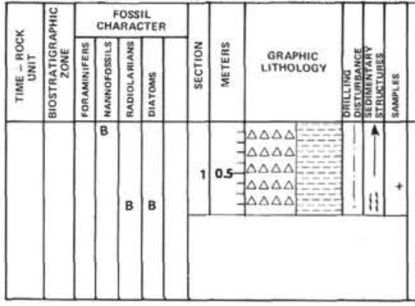
ORGANIC CARBON AND CARBONATE

	1-96
% Organic Carbon	0.80
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-55 (D)
TEXTURE:	
Sand	–
Silt	15
Clay	85
COMPOSITION:	
Quartz	7
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	60
Glauconite	TR
Pyrite	2
Diatoms	1
Sponge spicules	2
Opal-CT(?)	25

SITE 471 HOLE CORE 32 CORED INTERVAL 294.5–304.0 m



LITHOLOGIC DESCRIPTION

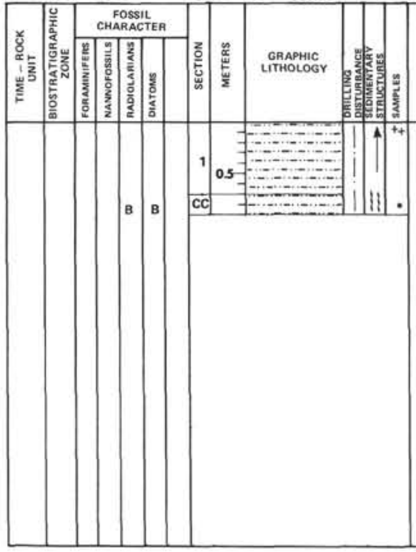
PORCELANEOUS CLAYSTONE, olive gray (5Y 3/2), intensely burrowed. Most of core brecciated by drilling.

No Core-Catcher.

ORGANIC CARBON AND CARBONATE

	1-61
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 33 CORED INTERVAL 304.0–313.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, dark greenish gray (5GY 4/1), burrowed. Core consists of several intact pieces set in drilling breccia of same lithology. Claystone possibly siliceous.

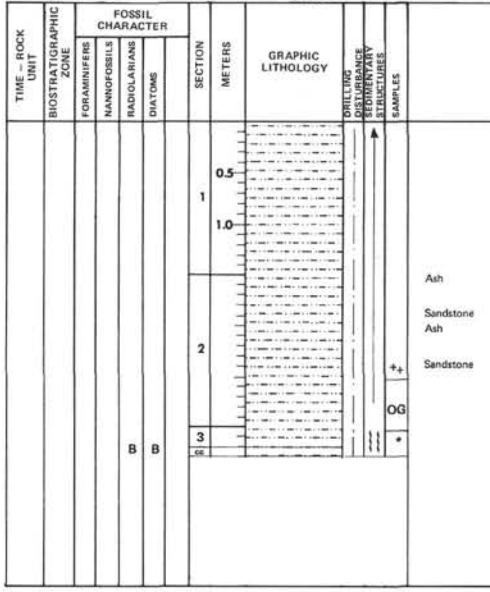
ORGANIC CARBON AND CARBONATE

	1-0	1-4
% Organic Carbon	0.86	–
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	CC-18 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	15
Feldspar	2
Mica	1
Clay	70
Pyrite	1
Carbonate unspec.	2
Diatoms	5
Radiolarians	2
Sponge spicules	2

SITE 471 HOLE CORE 34 CORED INTERVAL 313.5–323.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, grayish olive (10Y 4/2) with dusky yellow green (5GY 5/2) mottles. Intensely burrowed throughout with many burrows filled with silt and fine sand. Thin (~1 cm thick) sandy layers in Section 2 as marked. Altered ash layers also occur in Section 2 as noted. Some claystone is slightly calcareous.

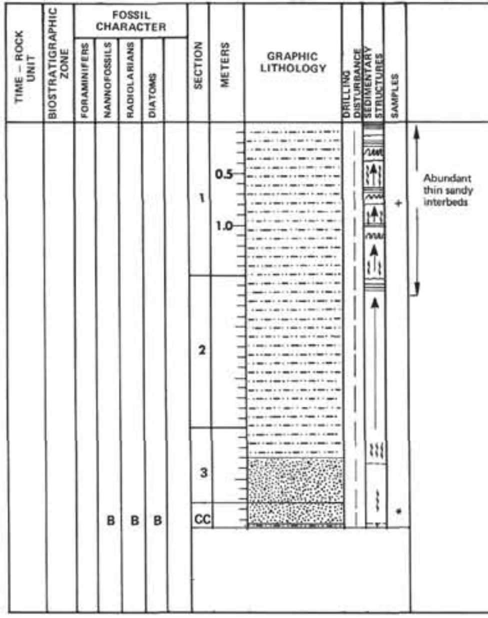
ORGANIC CARBON AND CARBONATE

	2-95	2-98
% Organic Carbon	–	0.62
% $CaCO_3$	21	14

SMEAR SLIDE SUMMARY

	3-18 (D)
TEXTURE:	
Sand	–
Silt	30
Clay	70
COMPOSITION:	
Quartz	25
Feldspar	5
Mica	1
Heavy minerals	TR
Clay	59
Pyrite	2
Carbonate unspec.	3
Radiolarians	TR
Sponge spicules	TR

SITE 471 HOLE CORE 35 CORED INTERVAL 323.0–332.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, olive gray (5Y 4/1), burrowed. Section 1 and Section 2 (0–23 cm) contain abundant thin interbeds of medium bluish gray (5B 5/1) **SANDY SILTSTONE.** Siltstone has wavy bedding on very fine scale – possibly due to burrowing. Claystone grades to greenish gray (5G 6/1) **SANDY SILTSTONE** in Section 3 then back to claystone in base of Core-Catcher.

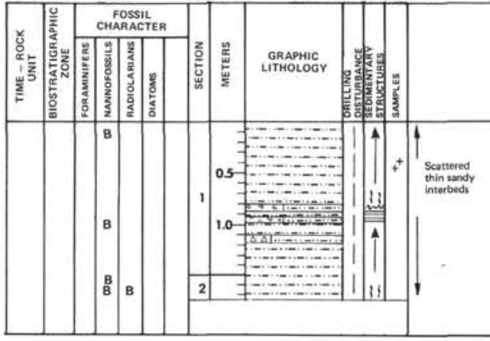
ORGANIC CARBON AND CARBONATE

	1-83
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	CC (D)
TEXTURE:	
Sand	48
Silt	43
Clay	9
COMPOSITION:	
Quartz	35
Feldspar	28
Mica	1
Heavy minerals	2
Clay	9
Volcanic glass	1
Glauconite	TR
Pyrite	5
Lithic fragments	9
Opal-CT(?)	10

SITE 471 HOLE CORE 36 CORED INTERVAL 332.5–342.0 m



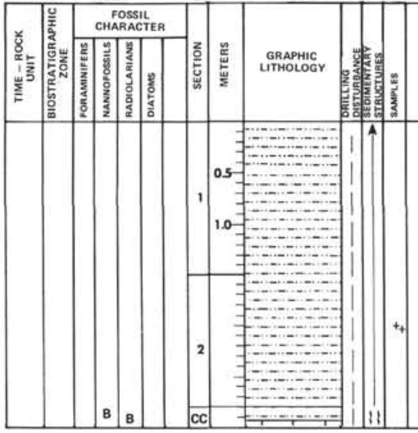
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), with many thin interbeds of silt and silty sandstone. Burrows common; many filled with silt- or sand-size material. Two thin layers of **VITRIC ASH** mixed with claystone occur in Section 1 as marked. Contorted laminations and plane laminations noted. Thin interval of medium olive gray (5Y 4/2) **PORCELANEOUS SILTY CLAYSTONE** in Section 1.

ORGANIC CARBON AND CARBONATE

	1-42	1-43
% Organic Carbon	1.46	–
% $CaCO_3$	0	0

SITE 471 HOLE CORE 37 CORED INTERVAL 342.0–351.5 m



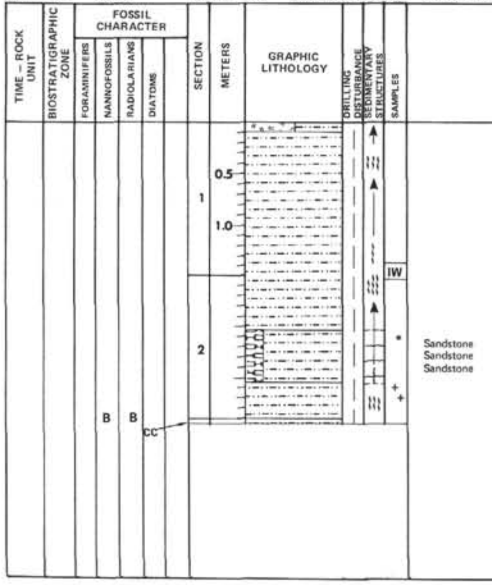
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2) to olive gray (5Y 4/1), burrowed throughout; some burrows filled with sand and silt. Thin silty interbeds scattered throughout. **CLAYEY LIMESTONE** in Core-Catcher.

ORGANIC CARBON AND CARBONATE

	2-51	2-53
% Organic Carbon	0.84	–
% $CaCO_3$	0	1.5

SITE 471 HOLE CORE 38 CORED INTERVAL 351.5–361.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2) to olive gray (5Y 3/2), intensely bioturbated with many thin silty and sandy lenses. Burrows often filled with silt and fine sand. Section 2, 54–105 cm, is calcareous silty claystone with three thin layers of calcite-cemented sandy claystone (as marked) with wavy bedding. Calcareous interval boundaries are gradational. First 8 cm of core is mixed altered **VITRIC ASH** and silty claystone.

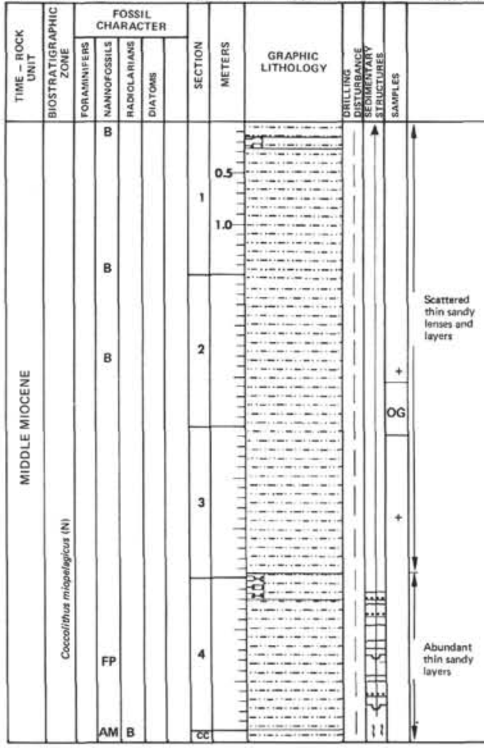
ORGANIC CARBON AND CARBONATE

	2-112	2-128
% Organic Carbon	–	0
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	2-69 (D)
TEXTURE:	
Sand	35
Silt	9
Clay	56
COMPOSITION:	
Quartz	20
Feldspar	7
Mica	TR
Heavy minerals	1
Clay	52
Carbonate unspec.	20
Calc. Nannofossils	TR

SITE 471 HOLE CORE 39 CORED INTERVAL 361.0–370.5 m



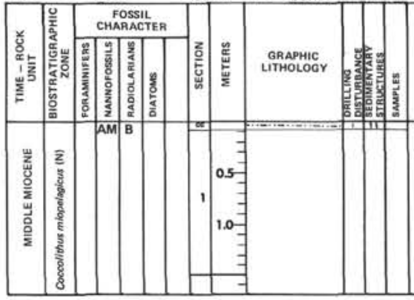
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 5/2) to light olive gray (5Y 3/2), intensely bioturbated; many burrows filled with silt and fine sand. Thin lenses and layers of calcite-cemented silt and fine sand mixed with clay (**SANDY CLAYSTONE**) are scattered throughout core (especially Section 4). Sandy layers sometimes graded with load cast and wavy bedding (burrowing?). Several intervals of silty claystone near tops of Sections 1 and 4 are calcareous.

ORGANIC CARBON AND CARBONATE

	2-98	3-90
% Organic Carbon	0.79	–
% $CaCO_3$	0	0

SITE 471 HOLE CORE 40 CORED INTERVAL 370.5–379.5 m

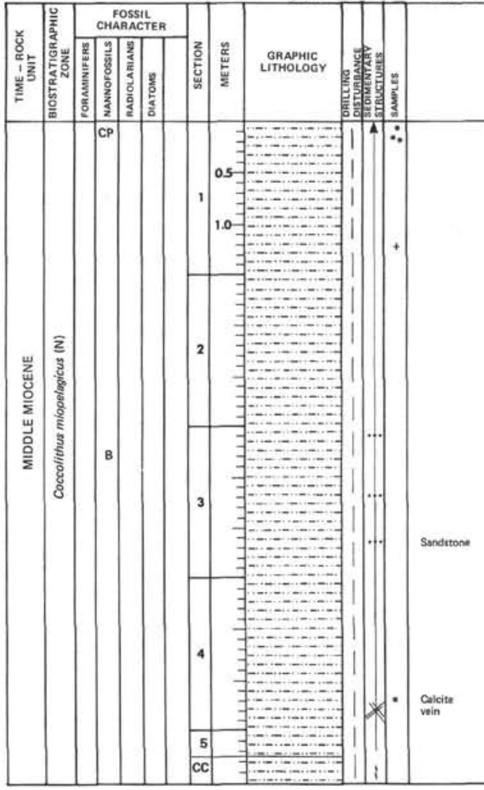


LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed.

Core-Catcher only.

SITE 471 HOLE CORE 41 CORED INTERVAL 379.0–389.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), bioturbated throughout with minor zones of lenticular bedding. Scattered sandy-silty lenses with several thin continuous layers of medium bluish gray (5B 5/1) clayey siltstone in Sections 1 and 3. Yellowish gray (5Y 8/1) sparry calcite fills fracture in claystone near base of Section 4. Core broken into drilling biscuits.

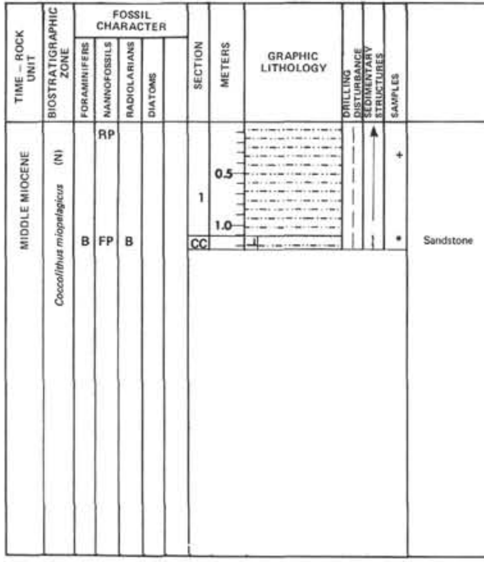
ORGANIC CARBON AND CARBONATE

	1-128
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-4 (M)	1-20 (M)	1-25 (D)	4-12 (M)
TEXTURE:				
Sand	–	10	–	–
Silt	15	40	25	–
Clay	85	50	75	–
COMPOSITION:				
Quartz	5	20	10	–
Feldspar	3	10	3	–
Mica	TR	TR	TR	–
Heavy minerals	TR	TR	TR	–
Clay	75	50	80	–
Volcanic glass	1	5(?)	2(?)	–
Glauconite	TR	TR	TR	–
Zeolite	–	TR	–	–
Carbonate unspec.	2	TR	–	100
Calc. Nannofossils	10	–	TR	–
Lithic fragments	2	10	3	–

SITE 471 HOLE CORE 42 CORED INTERVAL 389.0–398.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed. Nannofossils detectable in Core-Catcher. Thin sandy layer as marked.

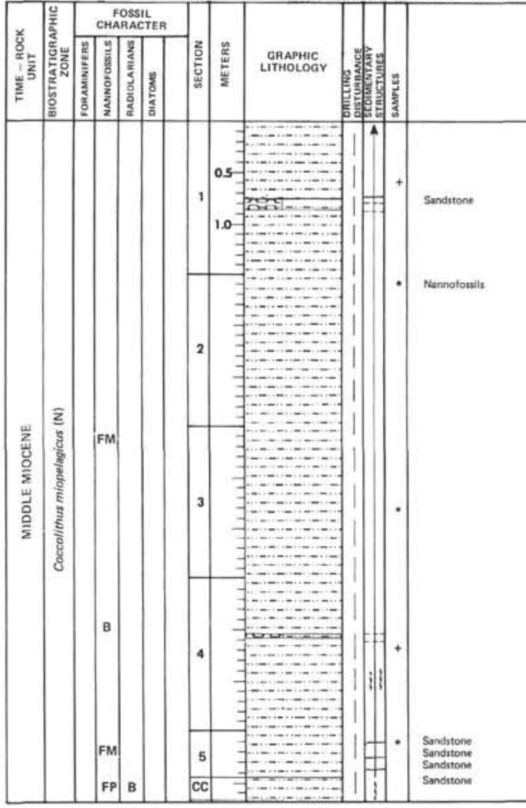
ORGANIC CARBON AND CARBONATE

	1-32
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	CC-9 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	7
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	70
Volcanic glass	TR
Pyrite	2
Carbonate unspec.	5
Foraminifers	TR
Calc. Nannofossils	10
Lithic fragments	3

SITE 471 HOLE CORE 43 CORED INTERVAL 398.5–408.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout (faint lenticular bedding). Scattered thin sandy layers in Sections 1 and 5 as marked. **SANDY INTERVALS** usually less than 1 cm thick, medium bluish gray (5B 5/1), calcite-cemented, and wavy bedding (burrowed?). Two intervals of **CALCAREOUS SILTY CLAYSTONE** occur in Sections 1 and 4 as marked; gradational contacts with non-calcareous claystone above and below. Core broken into drilling biscuits.

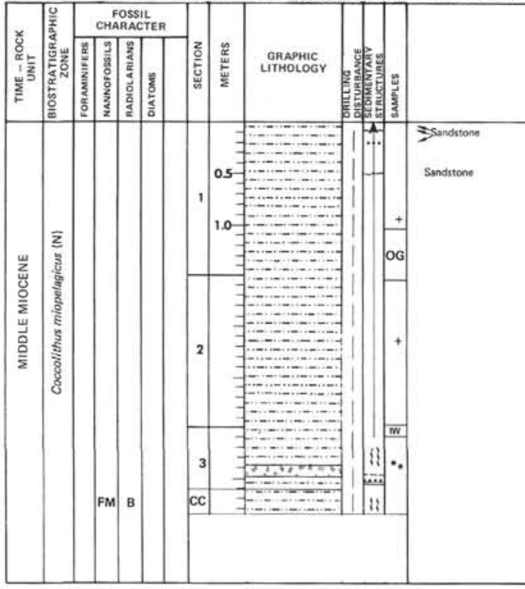
ORGANIC CARBON AND CARBONATE

	1-61	4-66
% Organic Carbon	0.70	–
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	2-15 (D)	3-82 (D)	5-12 (M)
TEXTURE:			
Sand	–	–	80
Silt	15	13	20
Clay	85	87	–
COMPOSITION:			
Quartz	7	5	40
Feldspar	3	3	20
Mica	TR	TR	TR
Heavy minerals	TR	TR	11
Clay	70	87	–
Pyrite	2	2	–
Carbonate unspec.	2	1	14
Calc. Nannofossils	15	TR	–
Lithic fragments	2	15	–

SITE 471 HOLE CORE 44 CORED INTERVAL 408.5–418.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 5/2) burrowed throughout with minor lenticular bedding. Some burrows filled with fine sand others with calcareous clay. Thin sandy layers with wavy bedding common in Section 1 as marked. Layer of medium light gray (N6) altered **VITRIC TUFF** in Section 3 is graded with sharp lower and gradational upper contact. Tuff altered mainly to clay minerals. Core broken into drilling biscuits.

ORGANIC CARBON AND CARBONATE

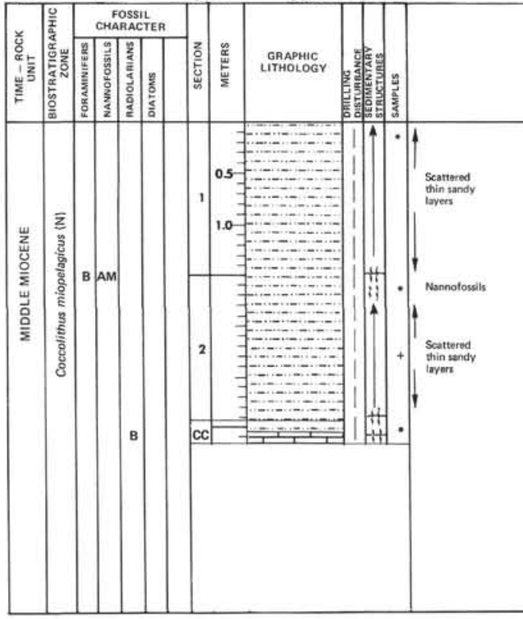
	1-98	2-77
% Organic Carbon	0.88	–
% $CaCO_3$	0-1	1

SMEAR SLIDE SUMMARY

	3-42 (M)	3-44 (M)
TEXTURE:		
Sand	50	60
Silt	40	30
Clay	10	10
COMPOSITION:		
Quartz	2	2
Feldspar	2	3
Biotite	1	5
Volcanic glass [†]	95	90
Apatite	–	TR
Zircon	–	TR

[†] Almost completely altered to clays

SITE 471 HOLE CORE 45 CORED INTERVAL 418.0–427.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout. Thin, calcite-cemented **SANDY LAYERS** scattered throughout Section 1 and most of Section 2 as marked. Sandy layers <1 cm thick with wavy bedding (burrowed?). Burrowed, light olive gray (5Y 6/1) **CLAYEY LIMESTONE** in Core-Catbher has gradational contact with overlying silty claystone. Core broken into drilling biscuits.

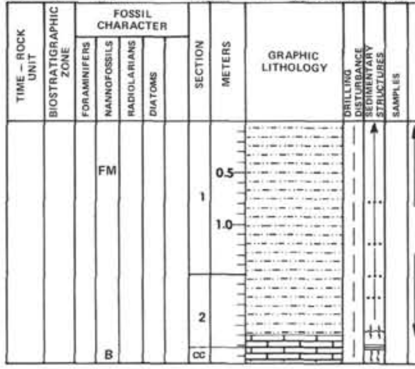
ORGANIC CARBON AND CARBONATE

	2-85
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-20 (M)	2-15 (D)	CC-15 (D)
TEXTURE:			
Sand	55	–	–
Silt	20	15	–
Clay	25	85	–
COMPOSITION:			
Quartz	40	7	1
Feldspar	10	3	1
Mica	–	TR	–
Heavy minerals	11	TR	–
Clay	19	70	16
Glauconite	TR	–	–
Pyrite	–	2	2
Carbonate unspec.	5	3	80
Calc. Nannofossils	–	15	–
Lithic fragments	10	–	–

SITE 471 HOLE CORE 46 CORED INTERVAL 427.5–437.0 m

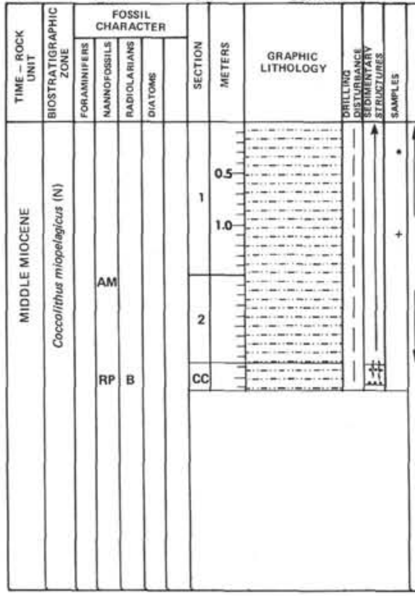


Scattered thin sandy layers

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout with scattered thin sandy layers (wavy bedding). Some burrows filled with fine sand. Light olive gray (5Y 5/2) **CLAYEY LIMESTONE** at base of core is burrowed but contains one interval of fine laminations.Core broken into drilling biscuits.

SITE 471 HOLE CORE 47 CORED INTERVAL 437.0–446.5 m



Scattered thin sandy layers and nannofossil-rich lenses

Sandstone

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed. Contains scattered thin lenticular layers of medium gray (N5) calcite-cemented **SANDSTONE** and minor lenticular zones of light olive gray (5Y 5/2) **NANNOFOSSIL SILTY CLAYSTONE** – possibly burrow fill material. Sand also fills some burrows. Sandy layer in Core-Catcher shows indistinct grading.

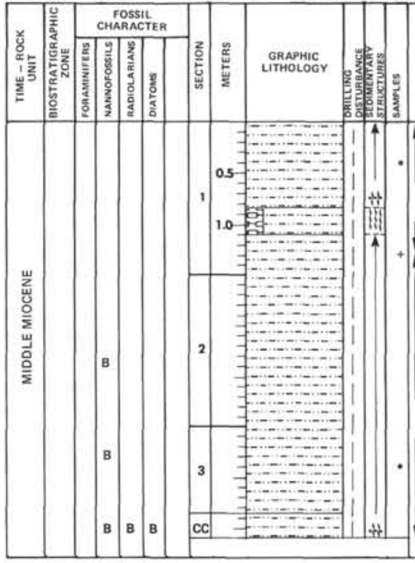
ORGANIC CARBON AND CARBONATE

	1-110
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-37 (D)
TEXTURE:	
Sand	–
Silt	11
Clay	89
COMPOSITION:	
Quartz	5
Feldspar	3
Mica	TR
Heavy minerals	TR
Clay	77
Volcanic glass	TR
Glauconite	TR
Pyrite	1
Carbonate unspec.	2
Calc. Nannofossils	12

SITE 471 HOLE CORE 48 CORED INTERVAL 446.5–456.0 m



Scattered thin sandy layers

Abundant thin sandy layers

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout; calcareous interval in Section 1 is intensely burrowed. Thin, wavy layers of gray calcite-cemented sand occur every 5–10 cm throughout the core. Sandy layers usually <1 cm thick and spaced every ~5-10 cm.

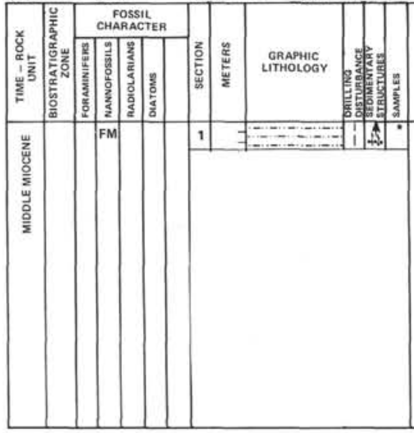
ORGANIC CARBON AND CARBONATE

	1-139
% Organic Carbon	0.61
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-47 (M)	3-45 (D)
TEXTURE:		
Sand	100	–
Silt	–	17
Clay	–	83
COMPOSITION:		
Quartz	40	7
Feldspar	20	5
Mica	–	TR
Heavy minerals	15	TR
Clay	–	83
Pyrite	–	2
Carbonate unspec.	–	3
Lithic fragments	25	–

SITE 471 HOLE CORE 49 CORED INTERVAL 456.0–465.5 m



LITHOLOGIC DESCRIPTION

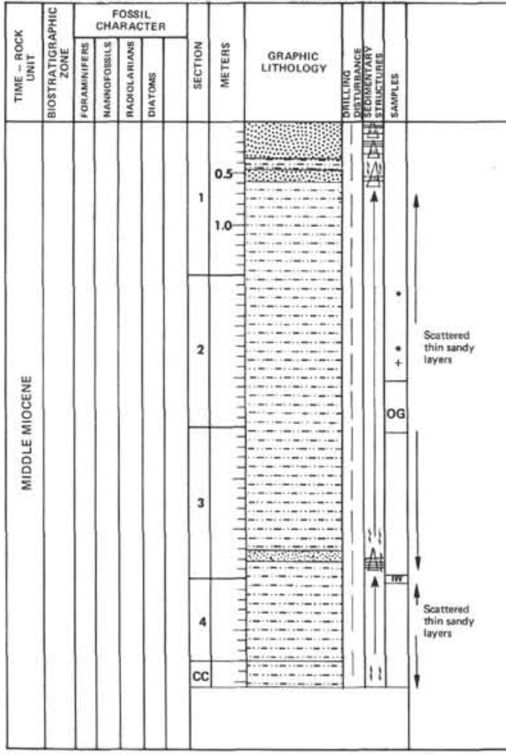
SILTY CLAYSTONE, olive gray (5Y 3/2), burrowed throughout. Contains scattered, thin silty sandy layers. Some burrows filled with fine sand.

No Core-Catcher.

SMEAR SLIDE SUMMARY

	1-8 (D)
TEXTURE:	
Sand	–
Silt	14
Clay	86
COMPOSITION:	
Quartz	5
Feldspar	7
Mica	TR
Heavy minerals	TR
Clay	86

SITE 471 HOLE CORE 50 CORED INTERVAL 465.5–475.0 m



LITHOLOGIC DESCRIPTION

Interbedded **SILTY CLAYSTONE AND CALCITE-CEMENTED SANDSTONE AND SILTY SANDSTONE.** Claystone is medium olive gray (5Y 4/2), intensely bioturbated throughout, and contains scattered thin (1–2 cm) sandy layers that have been mixed with claystone by burrowing. Sandstones are medium gray (N4), quartzo-feldspathic and calcite-cemented. Cross and parallel laminations and fining upwards (graded) sequences are common (several Bouma B–D sequences noted). Lower sand in Section 3 contains more silt and is more extensively burrowed than those in Section 1 where burrows confined mainly to upper parts of sand layers. Basal contact of these sandstones with underlying claystones is sharp; upper contact is gradational, partly homogenized by burrowing.

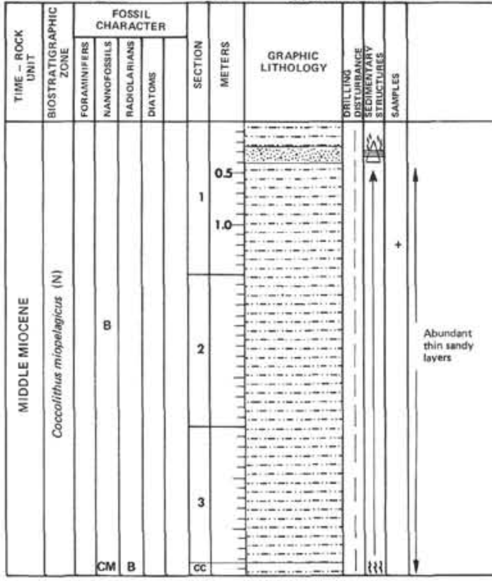
ORGANIC CARBON AND CARBONATE

	2-90
% Organic Carbon	0.59
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	2-24 (D)	2-74 (D)
TEXTURE:		
Sand	62	–
Silt	29	15
Clay	9	85
COMPOSITION:		
Quartz	50	10
Feldspar	20	3
Mica	TR	TR
Heavy minerals	1	TR
Clay	9	84
Volcanic glass	TR	TR
Pyrite	1	–
Carbonate unspec.	3	2
Foraminifers	6	2
Calc. Nannofossils	–	1
Lithic fragments	10	–

SITE 471 HOLE CORE 51 CORED INTERVAL 475.0–484.5 m



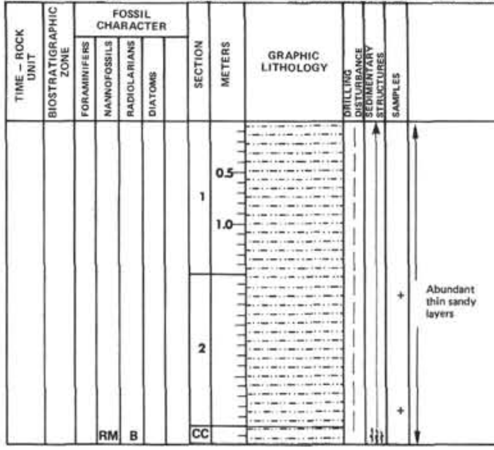
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), intensely burrowed throughout; silty sand fills some burrows. Thin, calcite-cemented sandy layers (1–2 cm thick) occur every 5–10 cm throughout core. **SILTY SANDSTONE** near top Section 1 is laminated near its base and fines upward to burrowed silty clay. Sandstone is medium gray and calcite-cemented. Scattered sponge fragments also occur in this core.

ORGANIC CARBON AND CARBONATE

	1-121
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 52 CORED INTERVAL 484.5–494.0 m



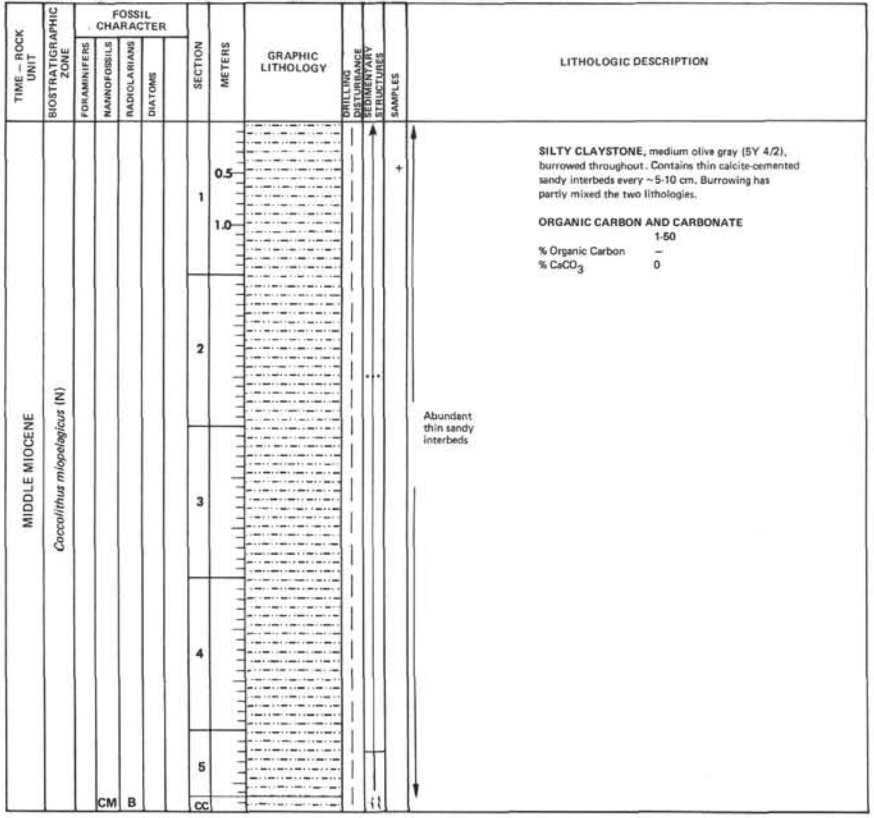
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout. Contains abundant thin calcite-cemented sandy layers (1–2 cm thick) spaced ~5–10 cm apart. Sands are partly homogenized with surrounding claystone by burrowing.

ORGANIC CARBON AND CARBONATE

	2-28	2-137
% Organic Carbon	–	0.58
% $CaCO_3$	0	0-1

SITE 471 HOLE CORE 53 CORED INTERVAL 494.0–503.5 m

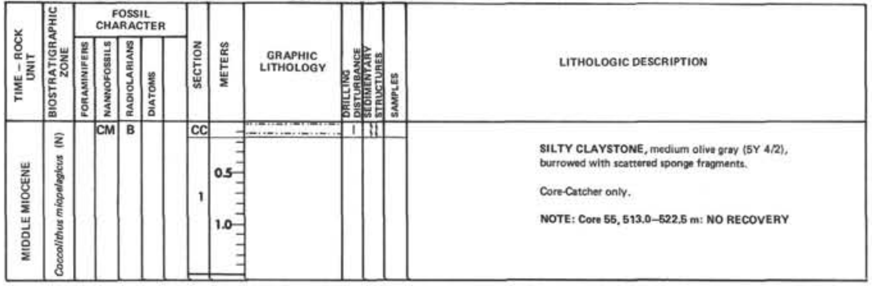


SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed throughout. Contains thin calcite-cemented sandy interbeds every ~5-10 cm. Burrowing has partly mixed the two lithologies.

ORGANIC CARBON AND CARBONATE

	1-50
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 54 CORED INTERVAL 503.5–513.0 m

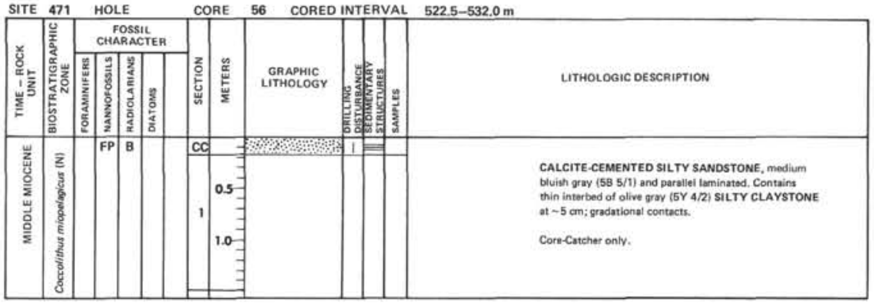


SILTY CLAYSTONE, medium olive gray (5Y 4/2), burrowed with scattered sponge fragments.

Core-Catcher only.

NOTE: Core 55, 513.0–522.5 m: NO RECOVERY

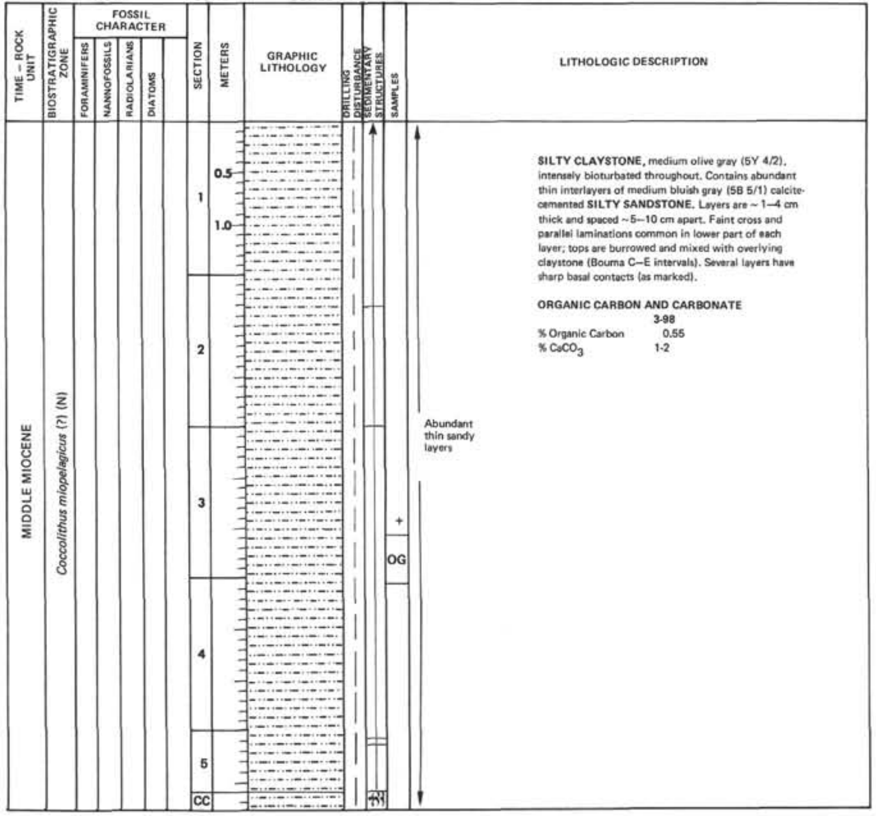
SITE 471 HOLE CORE 56 CORED INTERVAL 522.5–532.0 m



CALCITE-CEMENTED SILTY SANDSTONE, medium bluish gray (5B 5/1) and parallel laminated. Contains thin interbed of olive gray (5Y 4/2) **SILTY CLAYSTONE** at ~5 cm; gradational contacts.

Core-Catcher only.

SITE 471 HOLE CORE 57 CORED INTERVAL 532.0–541.5 m

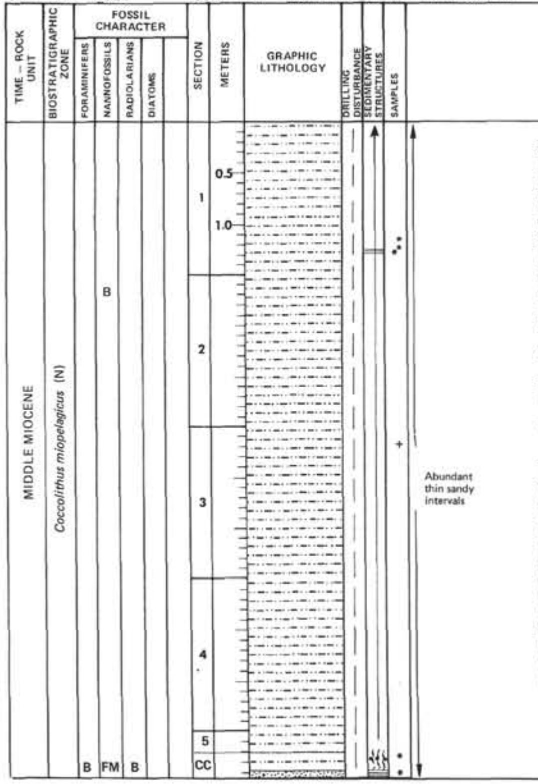


SILTY CLAYSTONE, medium olive gray (5Y 4/2), intensely bioturbated throughout. Contains abundant thin interlayers of medium bluish gray (5B 5/1) calcite-cemented **SILTY SANDSTONE.** Layers are ~ 1–4 cm thick and spaced ~5–10 cm apart. Faint cross and parallel laminations common in lower part of each layer; tops are burrowed and mixed with overlying claystone (Bouma C–E intervals). Several layers have sharp basal contacts (as marked).

ORGANIC CARBON AND CARBONATE

	3-98
% Organic Carbon	0.55
% $CaCO_3$	1-2

SITE 471 HOLE CORE 58 CORED INTERVAL 541.5–551.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin lenticular interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is medium olive gray (5Y 4/2) and intensely bioturbated and non-calcareous. Sandstone is medium bluish gray (5B 5/1) and is composed mainly of moderately well-sorted quartz, feldspar, clay and calcite-cement. Some parallel and microcross-laminations present in sandy layers but most bedding is lenticular and is caused by partial mixing of the sandy layers with the clay by a burrowing fauna (only trace fossils found; no body fossils). Base of core contains a thicker layer of **SILTY SANDSTONE** with faint parallel and microcross-laminations.

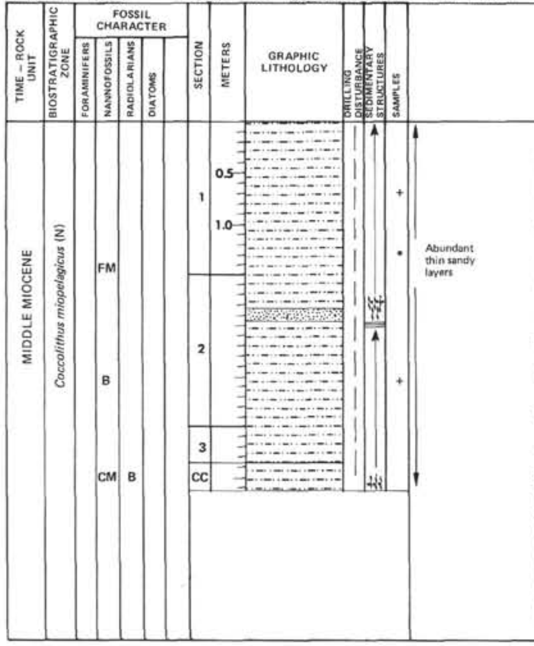
ORGANIC CARBON AND CARBONATE

	3-20
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-122 (D)	1-125 (D)	1-128 (D)	CC-10 (D)	CC-21 (D)
TEXTURE:					
Sand	–	11	70	8	50
Silt	13	14	20	20	30
Clay	87	75	10	73	20
COMPOSITION:					
Quartz	5	10	35	10	30
Feldspar	3	5	20	5	–
Mica	TR	TR	TR	TR	TR
Heavy minerals	TR	TR	3	TR	TR
Glauconite	–	TR	TR	TR	–
Pyrite	2	2	1	2	2
Carbonate unspec.	3	1	15	5	68
Foraminifers	–	TR	1	TR	–
Calc. Nannofossils	5	TR	–	–	–
Fish remains	–	–	TR	TR	–
Lithic fragments	2	7	15	–	–

SITE 471 HOLE CORE 59 CORED INTERVAL 551.0–560.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is medium olive gray (5Y 4/2) with some light and dark olive gray (5Y 5/2–5Y 3/2) mottles, non-calcareous and intensely burrowed. Sandstone is medium bluish gray (5B 5/1), quartzo-feldspathic and calcareous. Two liths are partly homogenized by burrowing that has destroyed original sedimentary contacts. Sandy intervals are 1–4 cm thick, spaced ~5–10 cm. Few have parallel laminations and faint microcross-laminations. 13 cm thick layer of **SILTY SANDSTONE** in Section 2 is laminated near its base and burrowed near its top.

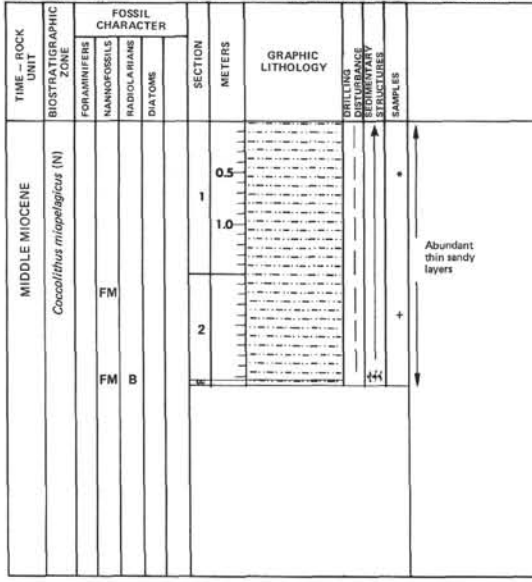
ORGANIC CARBON AND CARBONATE

	1-72	2-109
% Organic Carbon	–	0.43
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	1-135 (Sandstone)
TEXTURE:	
Sand	80
Silt	20
Clay	–
COMPOSITION:	
Quartz	30
Feldspar	7
Mica	TR
Heavy minerals	3
Glauconite	TR
Carbonate unspec.	50
Foraminifers	TR
Lithic fragments	10

SITE 471 HOLE CORE 60 CORED INTERVAL 560.5–570.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is medium olive gray (5Y 4/2), sandstone is medium bluish gray (5B 5/1). Lithologies partly mixed by intensive burrowing. Sandy intervals 1–4 cm thick, spaced ~5–10 cm.

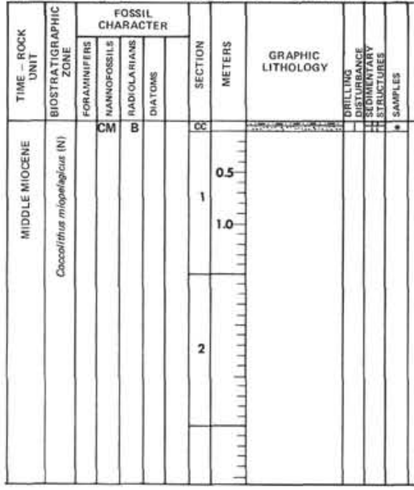
ORGANIC CARBON AND CARBONATE

	2-41
% Organic Carbon	–
% $CaCO_3$	0.5

SMEAR SLIDE SUMMARY

	1-54 (D)
TEXTURE:	
Sand	–
Silt	16
Clay	84
COMPOSITION:	
Quartz	7
Feldspar	5
Mica	TR
Heavy minerals	TR
Clay	84
Glauconite	TR
Pyrite	2
Carbonate unspec.	2
Foraminifers	TR
Calc. Nannofossils	2

SITE 471 HOLE CORE 61 CORED INTERVAL 570.0–579.5 m



LITHOLOGIC DESCRIPTION

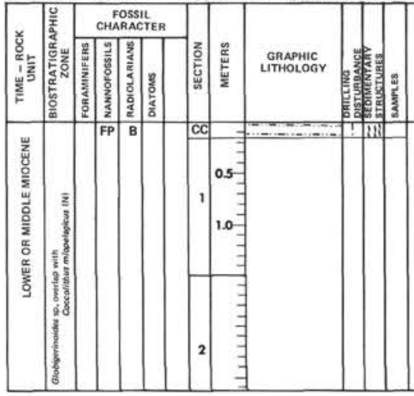
SILTY CLAYSTONE, medium olive gray (5Y 4/2) intensely burrowed. Claystone underlain by piece of medium bluish gray (5B 5/1) calcite-cemented **SILTY SANDSTONE.** Moderate sharp contact.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-4 (D)
TEXTURE:	
Sand	5
Silt	15
Clay	80
COMPOSITION:	
Quartz	7
Feldspar	5
Mica	TR
Heavy minerals	TR
Clay	80
Pyrite	2
Carbonate unspec.	3
Calc. Nannofossils	3

SITE 471 HOLE CORE 62 CORED INTERVAL 579.5–589.0 m

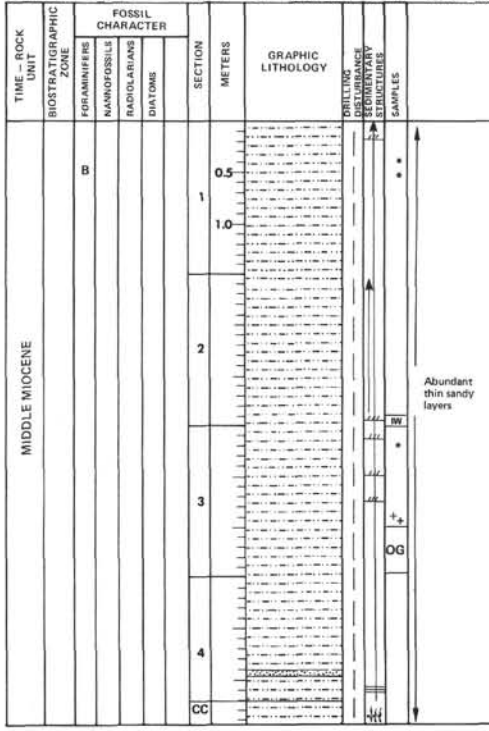


LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE and calcite-cemented **SILTY SANDSTONE** mixed by burrowing. Colors and structures as in previous core. Core consists of fragments broken by drilling.

Core-Catcher only.

SITE 471 HOLE CORE 63 CORED INTERVAL 589.0–598.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is medium olive gray (5Y 5/3) with light and dark olive gray (5Y 5/2–5Y 5/4) mottles; sandstone is medium bluish gray (5B 5/1). Two lithologies partially homogenized by intensive burrowing. Some sandy layers have sharp, loaded basal contacts followed by microcross-laminations, then an intensely burrowed interval mixed with claystone. Lenticular bedding common throughout core. Scale and frequency of sandy layers as in previous cores. A thicker plane laminated layers silty sandstone occurs in Section 4.

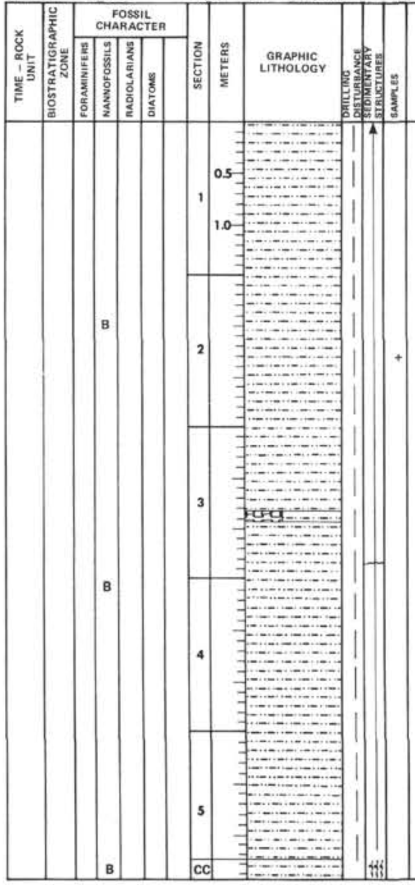
ORGANIC CARBON AND CARBONATE

	3-91	3-100
% Organic Carbon	–	0.81
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	1-44 (D)	1-55 (D)	3-23 (D)
TEXTURE:			
Sand	5	80	80
Silt	20	20	20
Clay	75	–	–
COMPOSITION:			
Quartz	10	25	30
Feldspar	5	5	10
Mica	TR	TR	TR
Heavy minerals	TR	TR	TR
Clay	75	–	–
Glauconite	–	–	TR
Pyrite	2	–	TR
Carbonate unspec.	2	60	–
Calc. Nannofossils	1	–	–
Lithic fragments	5	10	60

SITE 471 HOLE CORE 64 CORED INTERVAL 598.5–608.0 m



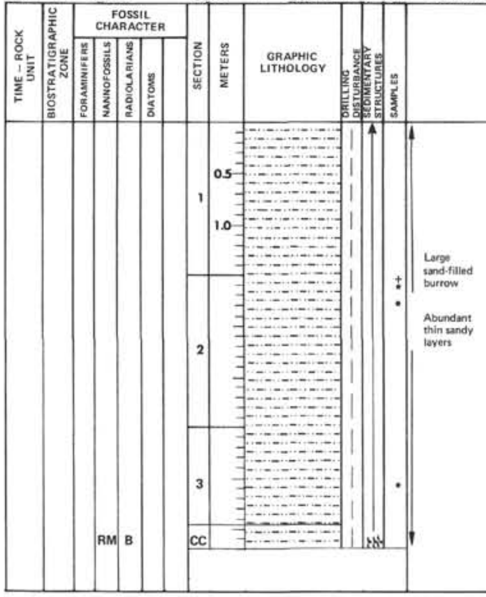
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Colors, structures, composition, and bioturbation same as preceding core. Spacing and frequency of sandy layers also similar. 10 cm thick calcareous silty claystone in Section 3 is burrowed. Scattered sponge fragments throughout core.

ORGANIC CARBON AND CARBONATE

	2-84
% Organic Carbon	–
% $CaCO_3$	0

SITE 471 HOLE CORE 65 CORED INTERVAL 608.0–617.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Intensely burrowed throughout. Bedding, structures, colors and compositions same as in preceding core. As before typical cycle is basal sand with sharp, loaded lower contact, plane and/or microcross-laminated interval, a sand/claystone interval homogenized by burrowing, capped by claystone. Cycles average 2–5 cm thick.

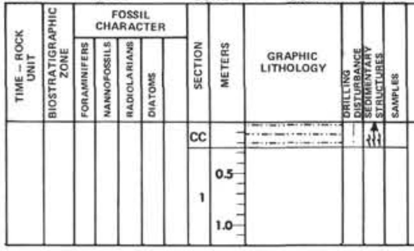
ORGANIC CARBON AND CARBONATE

	2-5	3-63
% Organic Carbon	–	0.73
% $CaCO_3$	26	0

SMEAR SLIDE SUMMARY

	2-15 (D)	2-32 (D)
TEXTURE:		
Sand	–	60
Silt	15	30
Clay	85	10
COMPOSITION:		
Quartz	7	30
Feldspar	3	5
Mica	TR	–
Heavy minerals	TR	–
Clay	85	–
Pyrite	2	5
Carbonate unspec.	–	50
Lithic fragments	3	10

SITE 471 HOLE CORE 66 CORED INTERVAL 617.5–627.0 m



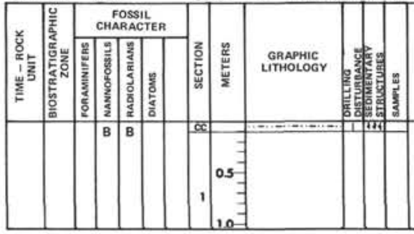
LITHOLOGIC DESCRIPTION

Drilling breccia of burrowed medium olive gray **SILTY CLAYSTONE** and minor **SILTY SANDSTONE**.

Core-Catcher only.

Core 67, 627.0–636.5 m: NO RECOVERY

SITE 471 HOLE CORE 68 CORED INTERVAL 636.5–646.0 m

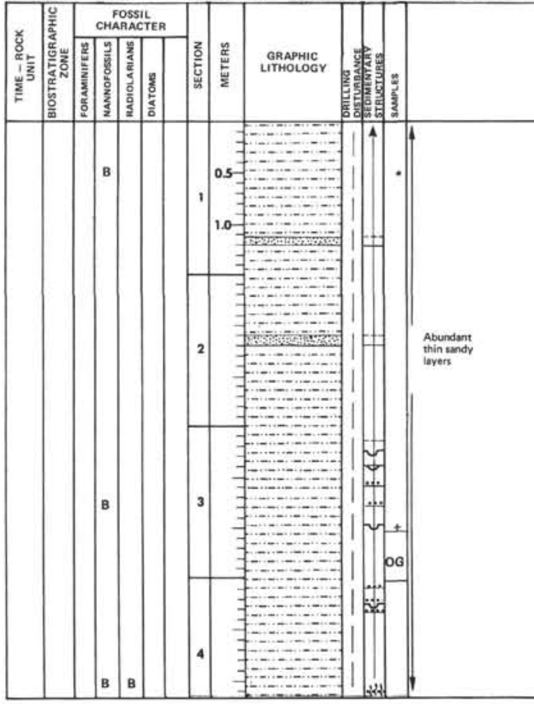


LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium olive gray (5Y 4/2), mixed by burrowing with minor calcite-cemented medium bluish gray (5B 5/1) silty sandstone.

Core-Catcher only.

SITE 471 HOLE CORE 69 CORED INTERVAL 646.0–655.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is medium olive gray (5Y 4/2) with light and dark olive gray mottles (5Y 3/2 –5Y 5/2) and intensely burrowed throughout. Sandstone is medium gray (N4) with sharp basal contacts (load casts, scours, and graded beds noted) and gradational upper contacts where it has been mixed with overlying claystone by burrowing fauna. Frequency and thickness of sandy beds as in previous cores. Scattered sponge fragments throughout claystone.

No Core-Catcher.

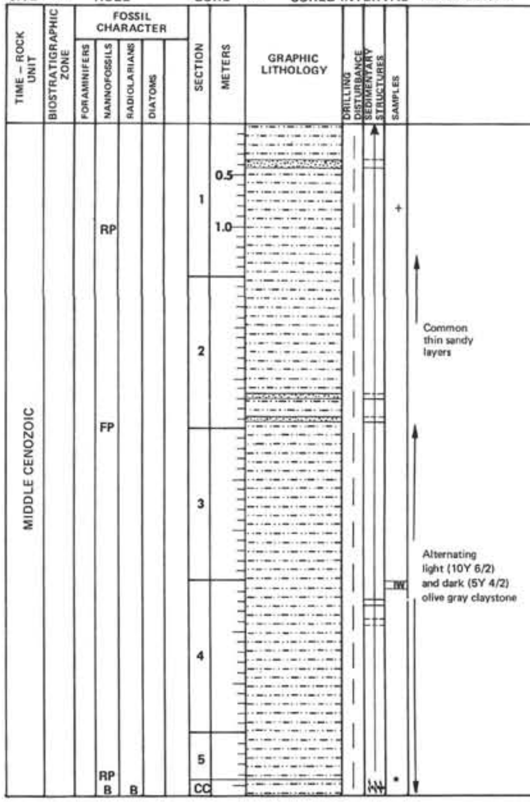
ORGANIC CARBON AND CARBONATE

	3-97
% Organic Carbon	0.69
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-56 (D)
TEXTURE:	
Sand	–
Silt	26
Clay	74
COMPOSITION:	
Quartz	13
Feldspar	5
Mica	TR
Heavy minerals	TR
Clay	74
Glauconite	TR
Pyrite	TR
Carbonate unspec.	1
Lithic fragments	6

SITE 471 HOLE CORE 70 CORED INTERVAL 655.5–665.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with thin interbeds of calcite-cemented **SILTY SANDSTONE,** claystone is medium olive gray (5Y 4/2) with light and dark olive gray (5Y 3/2–5Y 5/2) mottles and intensely burrowed throughout. Claystone in Sections 3–5 have rhythmic light olive (10Y 6/2) and dark olive (5Y 4/2) color alterations every 2–4 cm. Each color change marked by thin sandy layer at the base. Sandstone is medium gray (N4) and occurs as thin (~1 cm, up to 5 cm) interbeds in claystone. Basal contacts often sharp, upper contacts gradational as result of burrowing. Bouma D and E sequences common. Thicker sandy layers as marked.

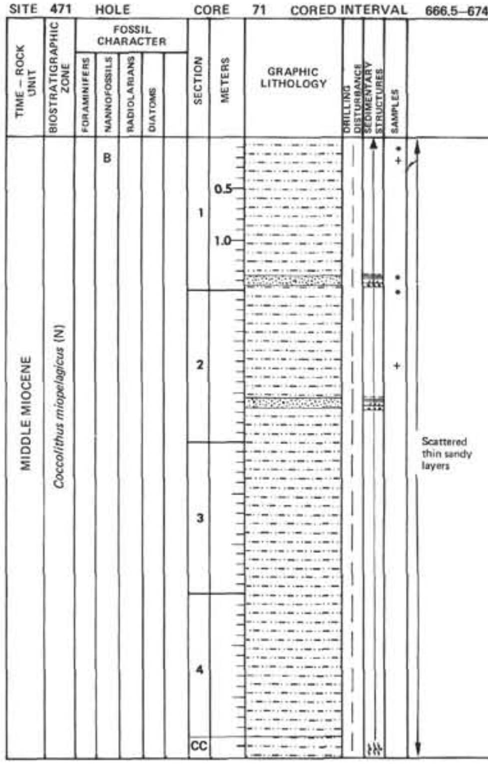
ORGANIC CARBON AND CARBONATE

	1-87
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	CC-4 (D)
TEXTURE:	
Sand	3
Silt	25
Clay	72
COMPOSITION:	
Quartz	15
Feldspar	2
Mica	1
Heavy minerals	2
Clay	72
Glauconite	TR
Lithic fragments	6

SITE 471 HOLE CORE 71 CORED INTERVAL 666.5–674.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with scattered thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone shows regular (2–4 cm thick) light olive gray (5Y 5/2) and medium olive gray (5Y 4/2) alternations throughout core and is intensively burrowed. Darker intervals appear to be more bioturbated than lighter zones and contain abundant fecal pellets. Burrows elongate and sub-parallel to bedding giving lenticular-bedded appearance to core. Sandstone is medium gray (N4) and occurs as scattered thin (~1 cm) layers often mixed by burrowing with surrounding claystone. Two thicker sandstone layers in Sections 1 and 2 are graded near base, overlain by microcross- then a plane-laminated zone. Basal contacts sharp, upper contacts gradational and burrowed.

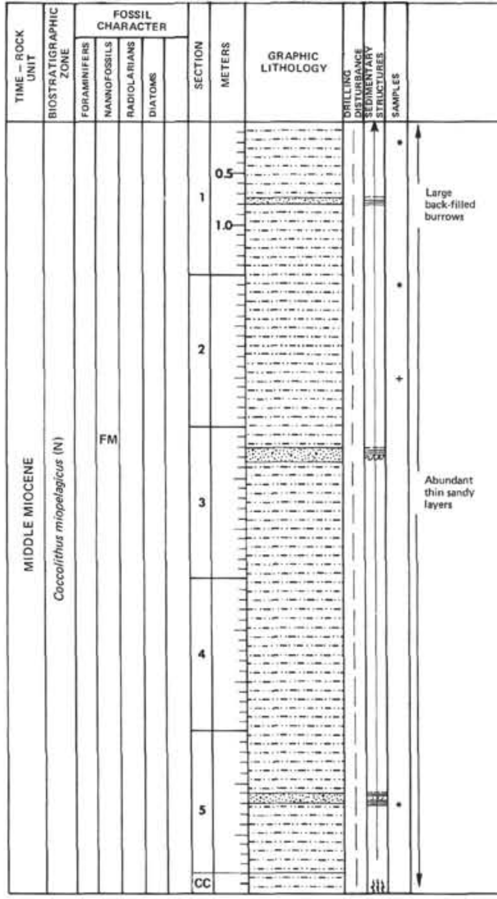
ORGANIC CARBON AND CARBONATE

	1-26	3-77
% Organic Carbon	0.41	–
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	1-17 (M)	1-140 (D)	2-5 (D)
TEXTURE:			
Sand	–	70	–
Silt	11	20	16
Clay	89	10	84
COMPOSITION:			
Quartz	5	25	7
Feldspar	3	5	5
Mica	TR	TR	TR
Heavy minerals	TR	2	TR
Clay	89	–	84
Glauconite	TR	TR	–
Pyrite	2	2	2
Carbonate unspec.	1	60	2
Lithic fragments	–	6	–

SITE 471 HOLE CORE 72 CORED INTERVAL 674.5–684.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone has regular light and medium olive gray (5Y 5/2–5Y 4/2) alternation and intensely burrowed throughout. Abundant burrows give claystone lenticular bedded appearance. Sandstone is medium gray (N4) and occurs as abundant thin interbeds ~1–2 cm thick throughout core; basal contacts sharp, upper contacts gradational and burrowed. Several thicker sandy layers (as marked) have planar and microcross-laminations, convolute bedding, and indistinct grading. Basal contacts sharp, upper contacts gradational and burrowed. Sandy layers occur every 5–10 cm.

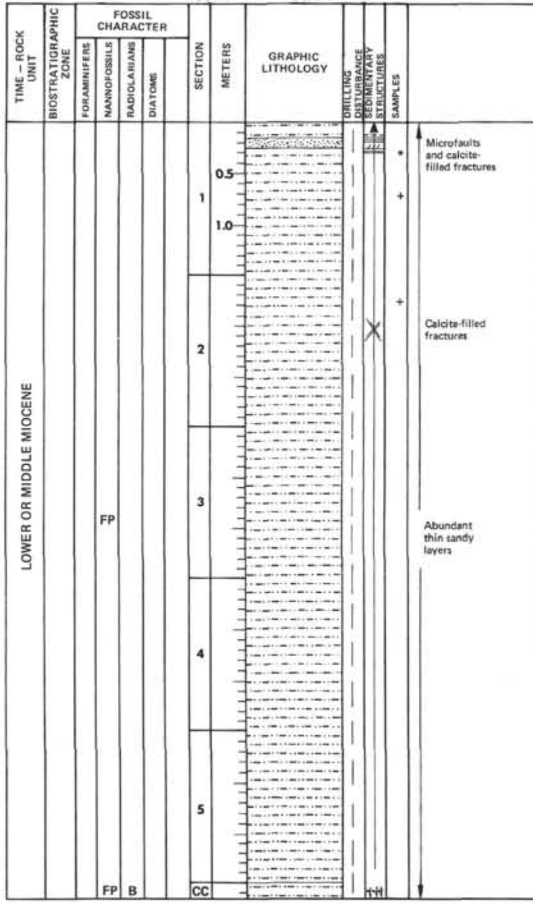
ORGANIC CARBON AND CARBONATE

	2-106
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-22 (D)	2-11 (M)	5-72 (M)
TEXTURE:			
Sand	–	80	80
Silt	25	20	20
Clay	75	–	–
COMPOSITION:			
Quartz	10	35	25
Feldspar	5	5	5
Mica	TR	TR	–
Heavy minerals	TR	TR	7
Clay	75	–	–
Glauconite	TR	TR	–
Pyrite	2	–	–
Carbonate unspec.	2	45	53
Lithic fragments	6	15	10

SITE 471 HOLE CORE 73 CORED INTERVAL 684.0–693.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Claystone is alternating light and medium olive gray (5Y 5/2–5Y 4/2) and intensely burrowed throughout. Sandstone is medium gray (N4) occurring as abundant thin (~1 cm) interbeds throughout. Thicker sandstone in Section 1 is planar and microcross-laminated and broken by microfaults and calcite-filled fractures. Thin interval of calcite-filled fractures also occurs in Section 2 (sandy claystone). Sandy layers have sharp basalt contacts and gradational, burrowed tops.

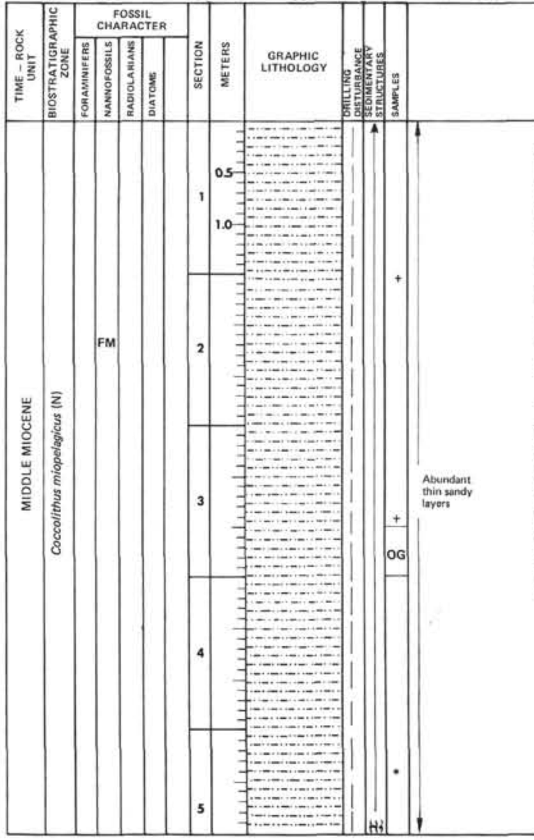
ORGANIC CARBON AND CARBONATE

	1-74	2-30
% Organic Carbon	–	0.60
% $CaCO_3$	12	0

SMEAR SLIDE SUMMARY

	1-35 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	10
Feldspar	5
Mica	TR
Heavy minerals	1
Clay	75
Glauconite	TR
Pyrite	2
Carbonate unspec.	2
Calc. Nannofossils	TR
Lithic fragments	5

SITE 471 HOLE CORE 74 CORED INTERVAL 693.5–703.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Claystone is alternating light and medium olive gray (5Y 5/2–5Y 4/2) and intensely burrowed throughout. Sandstone is medium gray (N4) and occurs as thin (1–2 cm) interbeds every ~5–10 cm with sharp basal contacts and burrowed tops. Indistinct parallel laminations common in sandstones.

No Core-Catcher.

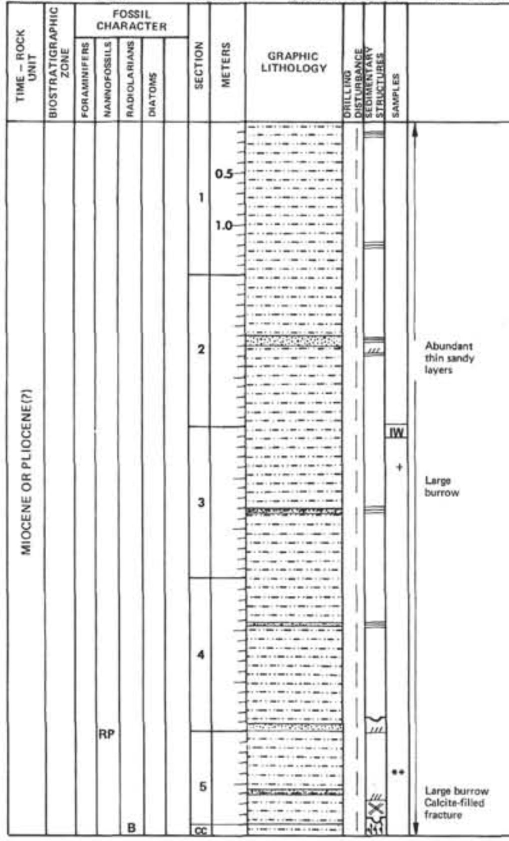
ORGANIC CARBON AND CARBONATE

	2-3	3-98
% Organic Carbon	–	0.54
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	5-45 (D)
TEXTURE:	
Sand	20
Silt	30
Clay	50
COMPOSITION:	
Quartz	20
Feldspar	5
Mica	TR
Heavy minerals	2
Clay	49
Glauconite	TR
Pyrite	1
Carbonate unspec.	3
Lithic fragments	20

SITE 471 HOLE CORE 75 CORED INTERVAL 703.0–712.5 m



SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Claystone is alternating light and medium olive gray and intensely burrowed throughout. Sandstone is medium gray (N4) and occurs as regular thin interbeds (~1 cm thick), most are plane laminated but some thicker layers are microcross-laminated as well (as marked). Load casts common in sandy layers in Sections 4 and 5. Calcite-filled fracture in Section 5. Some layering/lenticular bedding in this core is slightly inclined.

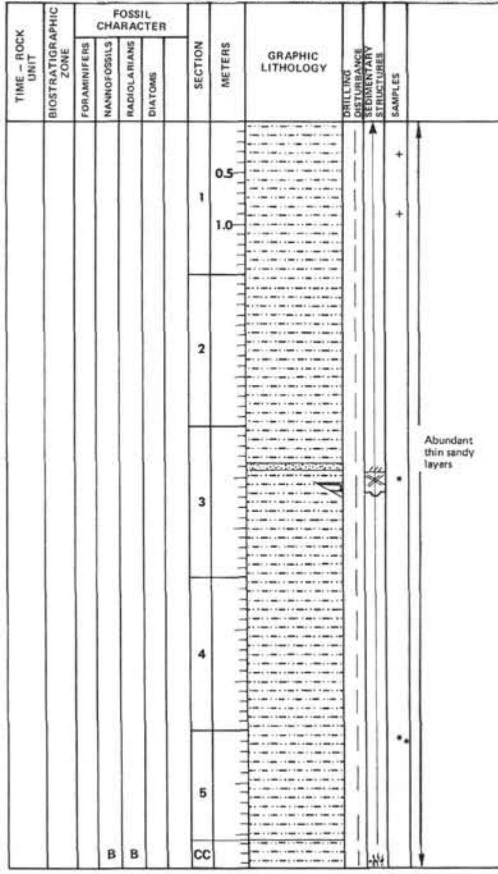
ORGANIC CARBON AND CARBONATE

	3-43
% Organic Carbon	–
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	5-47A (claystone) (D)	5-47B (sandstone) (D)
TEXTURE:		
Sand	–	60
Silt	20	30
Clay	80	10
COMPOSITION:		
Quartz	7	20
Feldspar	3	5
Mica	3	TR
Heavy minerals	TR	TR
Clay	80	53
Glauconite	TR	TR
Pyrite	3	2
Carbonate unspec.	2	–
Foraminifers	–	TR
Plat debris	1	–
Lithic fragments	1	13
Phos/MnO_2 - coated grains	–	7

SITE 471 HOLE CORE 76 CORED INTERVAL 712.5–722.0 m



SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE.** Color, bedding characteristics and composition of claystone and sandstone identical to previous cores. Thicker sandy layer in Section 3 is microcross-laminated. It occurs above a fractured, carbonate-cemented or limey claystone interval. Fractures filled with reddish brown clay(?).

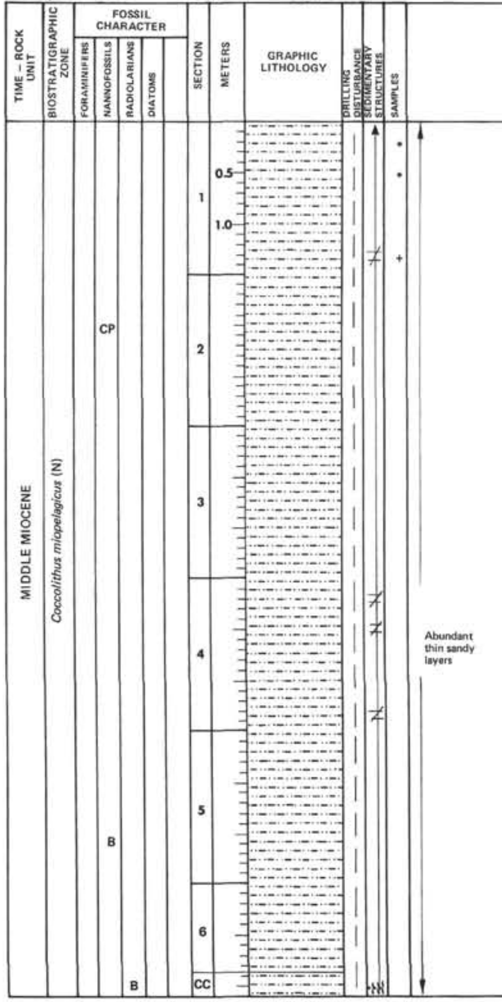
ORGANIC CARBON AND CARBONATE

	1-39	1-89
% Organic Carbon	0.51	–
% $CaCO_3$	0	0

SMEAR SLIDE SUMMARY

	3-57 (M)	5-10 (D)	5-13 (D)
TEXTURE:			
Sand	–	–	–
Silt	–	25	20
Clay	–	75	80
COMPOSITION:			
Quartz	3	10	10
Feldspar	TR	5	5
Mica	–	TR	TR
Heavy minerals	–	TR	TR
Clay	10	70	80
Glauconite	–	TR	TR
Pyrite	2	2	2
Carbonate unspec.	85	5	–
Lithic fragments	–	3	3

SITE 471 HOLE CORE 77 CORED INTERVAL 722.0-731.5 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with thin interbeds of **SILTY SANDSTONE**. Color, composition and bedding characteristics as in preceding cores. Sandy layers average <1 cm thick and are basal parts of 2–5 cm sandstone–claystone cycles. Burrowed zone overlies each sandy layer. Sections 1–4 have scattered microfaults with offsets up to 2 cm.

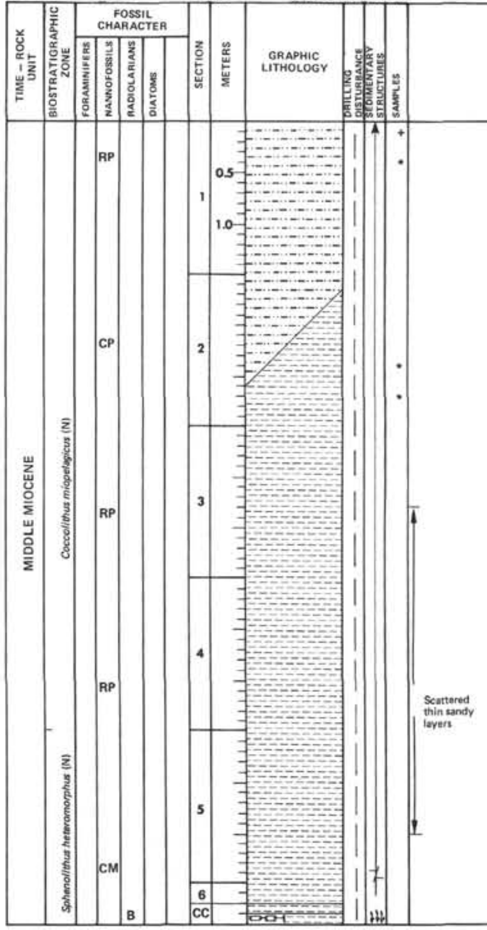
ORGANIC CARBON AND CARBONATE

	1-135
% Organic Carbon	–
% $CaCO_3$	0

SMEAR SLIDE SUMMARY

	1-27	1-58
TEXTURE:		
Sand	7	–
Silt	50	28
Clay	43	72
COMPOSITION:		
Quartz	34	12
Feldspar	14	6
Mica	TR	TR
Heavy minerals	TR	–
Clay	43	72
Pyrite	2	1
Carbonate unspec.	2	2
Calc. Nannofossils	TR	TR
Lithic fragments	5	7

SITE 471 HOLE CORE 78 CORED INTERVAL 731.5–741.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE grading to **CLAYSTONE** in Section 2. Both lithologies are dark olive gray (5Y 4/1) to dark greenish gray (5G 4/1). Claystone grades to medium greenish gray (5G 5/1) in Section 5. Intensively burrowed and lenticularly bedded throughout; claystone contains several thin (<1 cm) layers of calcite-cemented silty sandstone in Sections 3–5. Microfaults and fractures scattered throughout; some are calcite-filled. Streaks and small patches of pyrite common in base Section 5, Section 6, and Core-Catcher. Calcareous claystone in Core-Catcher.

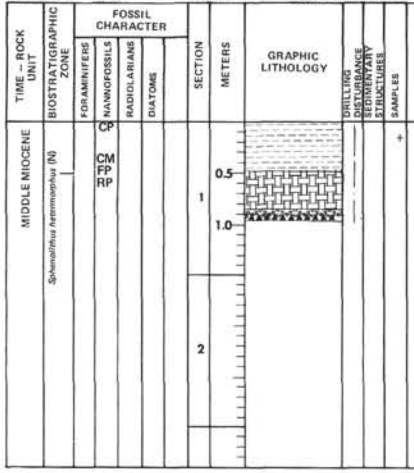
ORGANIC CARBON AND CARBONATE

	1-12	2-98
% Organic Carbon	0.43	–
% $CaCO_3$	14	6

SMEAR SLIDE SUMMARY

	1-44 (D)	2-129 (D)
TEXTURE:		
Sand	–	6
Silt	13	6
Clay	87	94
COMPOSITION:		
Quartz	12	5
Feldspar	1	1
Mica	TR	TR
Heavy minerals	TR	–
Clay	87	94
Glauconite	TR	–
Calc. Nannofossils	TR	TR
Plant debris	TR	–

SITE 471 HOLE CORE 79 CORED INTERVAL 741.0–741.9 m



LITHOLOGIC DESCRIPTION

Sedimentary sequence overlying altered diabase includes:

1 **CALCAREOUS CLAYSTONE** (0–48 cm) – medium greenish gray (5G 5/1), intensely burrowed with pyrite-rich patches and streaks.

2 **SULFIDE-BEARING ROCKS** (48–87 cm) – pyrite-chalcopyrite- sphalerite-rich sediment; also with abundant calcite and plagioclase.

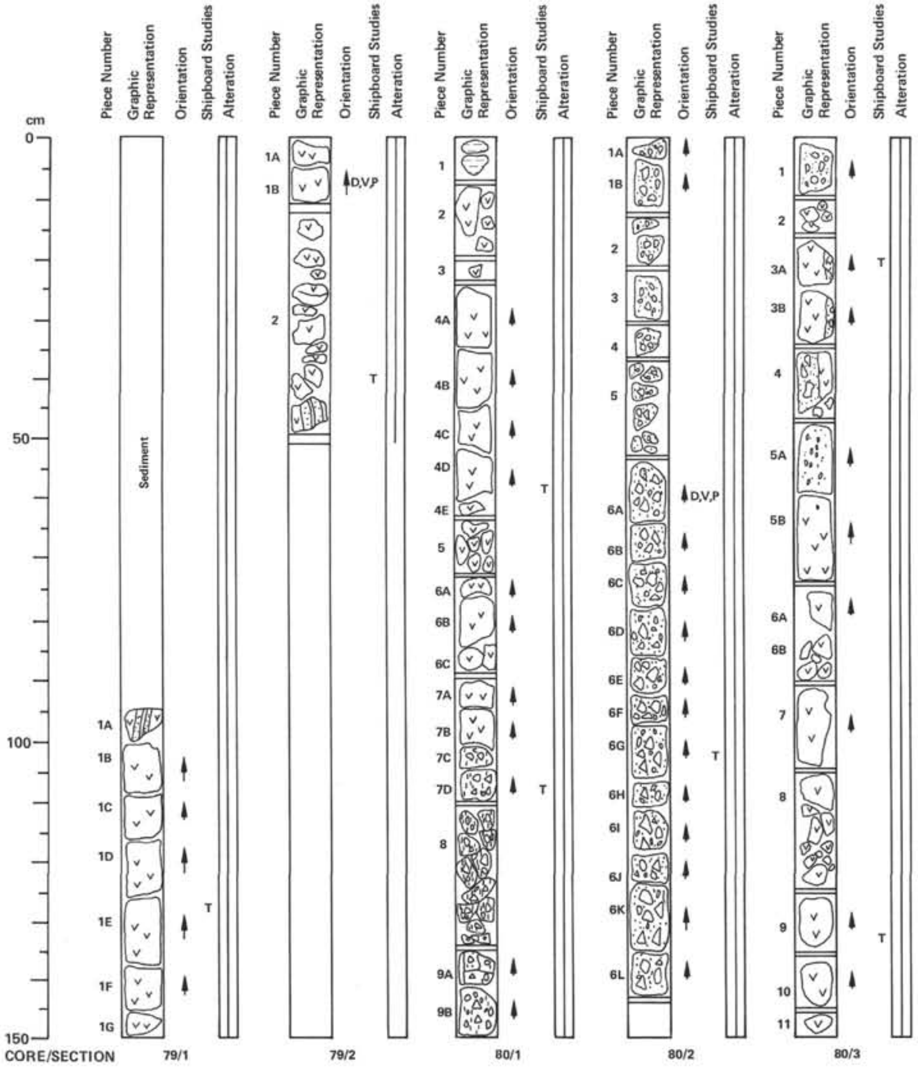
3 **METALIFEROUS SEDIMENT** (87–90 cm) – dusky yellowish brown iron-rich clay.

4 **CHERT** (91–94 cm) – one piece of black quartzose chert with thin quartz veins.

Altered diabase occurs below chert see igneous forms.

ORGANIC CARBON AND CARBONATE

	1-18
% Organic Carbon	–
% $CaCO_3$	13



SITE 471, CORE 79, SECTIONS 1–2, 741.5–743.0 m

MAJOR ROCK TYPE – ALTERED DIABASE

MINOR ROCK TYPES – CLAYSTONE, SULFIDES, METALLIFEROUS SEDIMENT AND CHERT (= "sediment" in Section 1; descriptions on preceding core form)

Macroscopic Description (diabase only)

Medium gray (N5), fine-grained, massive, aphyric diabase. Prismatic plagioclase crystals up to 2 mm; slight increase in grain size from top to base of Section 1. Badly altered with calcite filled veins in Piece 1A, Section 1, and Piece 2, Section 2.

Thin Section Descriptions

Diabase – Section 1, Piece 1E, 127–128 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 30%, 0.2–1.0 mm, euhedral, lath shaped; opaques, 5%, 0.05 mm
Alteration: calcite (35%) as vein fill; brownish green clays (20%) replace groundmass between plagioclase crystals; some plagioclase (10%) zeolitized(?)

Diabase – Section 2, Piece 2, 40–42 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 20%, 0.5–2 mm, euhedral, laths; opaques, 5%, 0.1–0.2 mm
Alteration: calcite (30%) as vein fill; brownish green clays (20%) between plagioclase; zeolites(?) (10%) replace plagioclase

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 1B, 8 cm	2.47	3.70	–	16

SITE 471, CORE 80, SECTIONS 1–3, 750.5–755.0 m

MAJOR ROCK TYPE – ALTERED DIABASE, DIABASE BRECCIA

MINOR ROCK TYPE – CLAYSTONE

Macroscopic Descriptions

Altered Diabase (Section 1, 0–100 cm; Section 3, 0–45 cm [with breccia] and 60–150 cm) – medium-grained, aphyric and badly altered to greenish clays. Calcite-filled voids in Section 1, 48–49 cm

Diabase Breccia (Section 1, 100–150 cm; Section 2, 0–150 cm; Section 3, 0–60 cm [with altered diabase]) – angular and subangular fragments (<5 cm) of diabase and minor sediment (clayey chert, set in an aphanitic, dark green clayey matrix. Fragments are fine- to medium-grained with plagioclase crystals up to 2 mm. Some fragments almost completely altered to clays.

Claystone (Section 1, 0–8 cm) – light olive gray (5Y 5/2), laminated, with two dark red (5Y 2/6) lenses or layers ~0.5 cm thick

Thin Section Descriptions

Altered Diabase – Section 1, Piece 4D, 55–58 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 45%, 0.5–3 mm, subhedral; clinopyroxene, 15%, 0.5–3 mm, anhedral; opaques, 7%, 0.2–1 mm
Alteration: brownish green clays (30%) between plagioclase laths; calcite (3%)

Diabase Breccia – Section 1, Piece 7D, 105–109 cm
Texture: clastic
Composition: diabase fragments (60%), <15 mm across, angular to subangular; matrix (10%), zeolites and clays
Alteration: greenish clays (10–20%) form matrix and replace groundmass in altered diabase fragments; white mica (TR)

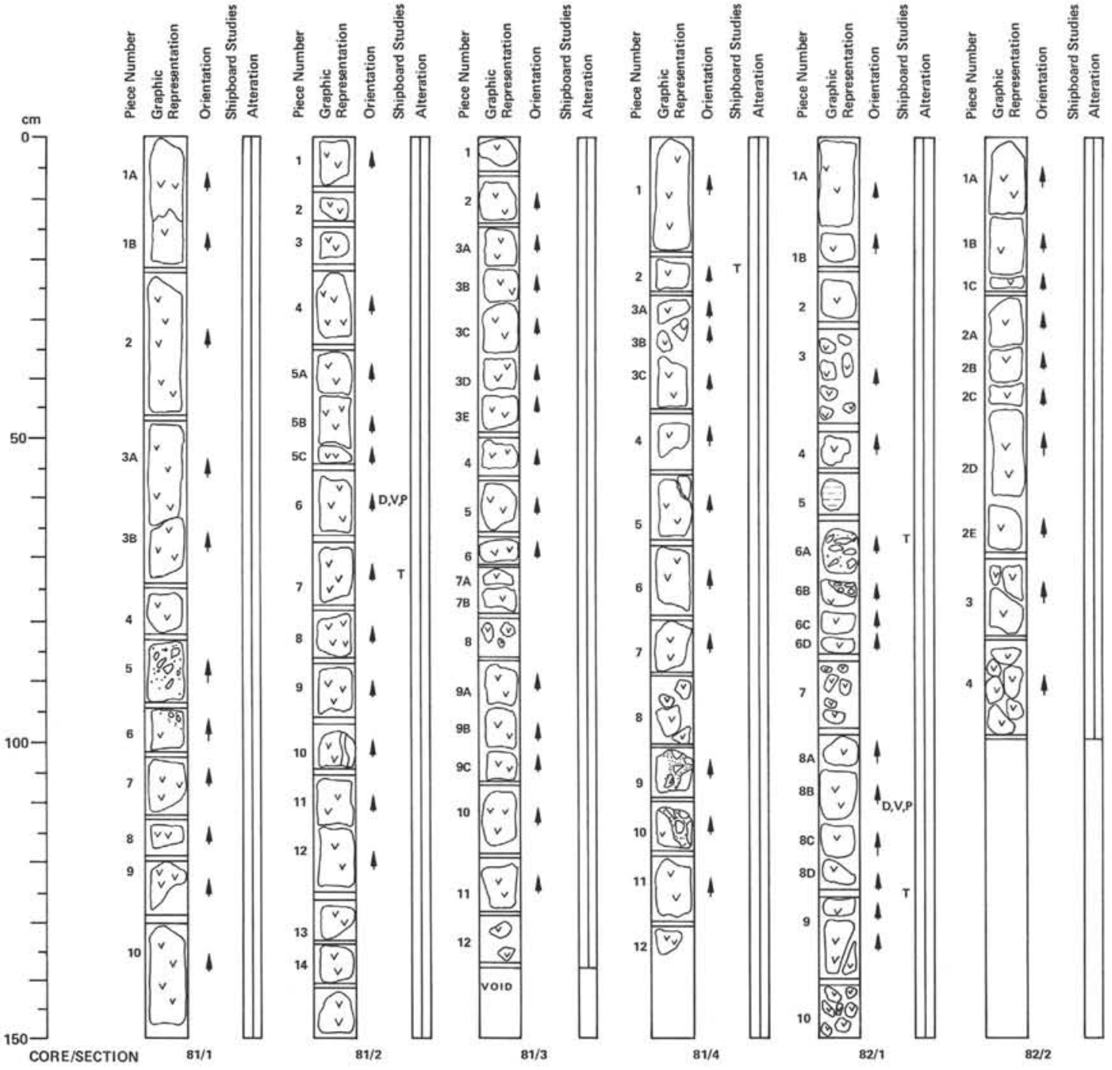
Diabase Breccia – Section 2, Piece 6G, 102–105 cm (diabase fragments)
Texture: intersertal (fragments only)
Phenocrysts: –
Groundmass: plagioclase, 45%, 1–2 mm, subhedral, laths; clinopyroxene, 5%, 0.5–1 mm, subhedral; opaques, 7%, 0.2–1 mm, anhedral, irregular
Alteration: brownish green clays in groundmass; calcite (10%) in veins; zeolite(?) (3%) replacing plagioclase; white mica (TR)

Diabase Breccia – Section 3, Piece 3A, 21–24 cm
Texture: clastic, intersertal (fragments)
Composition: aphanitic green clay matrix (41%) altered diabase fragments (30%), <10 mm across, subangular; plagioclase (20%), 1–3 mm, subhedral laths, in groundmass of fragments and in matrix; opaques (2%) in fragments; clinopyroxene (TR), in fragments
Alteration: green clays (41%) in matrix and in groundmass of diabase fragments; zeolites(?) (7%) replaces plagioclase in veins

Altered Diabase – Section 3, Piece 9, 133–135 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 45%, 1–3 mm, subhedral, some crystals are zoned; opaques, 5%; clinopyroxene (TR), 0.2–0.5 mm, anhedral
Alteration: brownish green clays (46%) and zeolites(?) (4%) replacing groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 6A, 60 cm	2.47	3.60	–	16



SITE 471, CORE 81, SECTIONS 1–4, 760.0–766.0 m

MAJOR ROCK TYPE – ALTERED DIABASE

MINOR ROCK TYPE – DIABASE BRECCIA

Macroscopic Descriptions

Altered Diabase – fine- to medium-grained and aphyric. Grain size decreases slightly, 0–83 cm in Section 1; slight grain size increase from top to base, Section 3. Common alteration to green clays with plagioclase laths (up to 3 mm long) often set in green clay matrix. Clay alteration occurs as irregular patches or along fractures. Apparent layering (<0.5–1 mm thick) in Piece 7B, Section 3, caused by alternations of altered (green clay) and less altered diabase. Calcite-filled veins and voids scattered throughout. Pyrite crystals at 22–26 cm, Section 3.

Diabase Breccia (Pieces 5–6, Section 1; Pieces 3–5 and 9–11, Section 4) – angular fragments of altered diabase set in green clay matrix.

Thin Section Descriptions

Altered Diabase – Section 2, Piece 7, 73–76 cm
Texture: intersertal
Phenocrysts: –
Groundmass: greenish clays, 32%; zeolites 20%; clinopyroxene, 30%, 0.5–3 mm, subhedral; plagioclase, 15%, 0.5–3 mm; opaques, 2%; sphene, 1%
Alteration: greenish clays (32%) and zeolites(?) (20%) replace groundmass

Altered Diabase – Section 4, Piece 2, 20–24 cm
Texture: intersertal to subophitic
Phenocrysts: –
Groundmass: clinopyroxene, 35%, 0.5–3.5 mm, anhedral; plagioclase, 15%, 0.5–3 mm, subhedral; opaques, 5%; sphene, TR; green clays, 30%; zeolite(?), 5%
Alteration: green clays (30%) and zeolite(?) (5%) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 6, 53 cm	2.55	4.56	–	12

SITE 471, CORE 82, SECTIONS 1–2, 769.0–771.5 m

MAJOR ROCK TYPE – ALTERED DIABASE

MINOR ROCK TYPES – DIABASE (BASALTIC?) BRECCIA, CLAYSTONE

Macroscopic Descriptions

Altered Diabase – fine- to medium-grained, massive and aphyric. Grain size decrease, 0–55 cm, Section 1 then increases from 60–150 cm. Extensive green clay alteration of groundmass; plagioclase laths (up to 2 mm long) set in clay matrix. Green clay also fills some fractures. Slickenside on Piece 3, Section 2.

Diabase (Basaltic?) Breccia (Section 1, Pieces 6A–B) – angular fragments of altered diabase (basalt?) set in green clay matrix.

Claystone (Section 1, Piece 5) – grayish brown (5YR 3/2), massive.

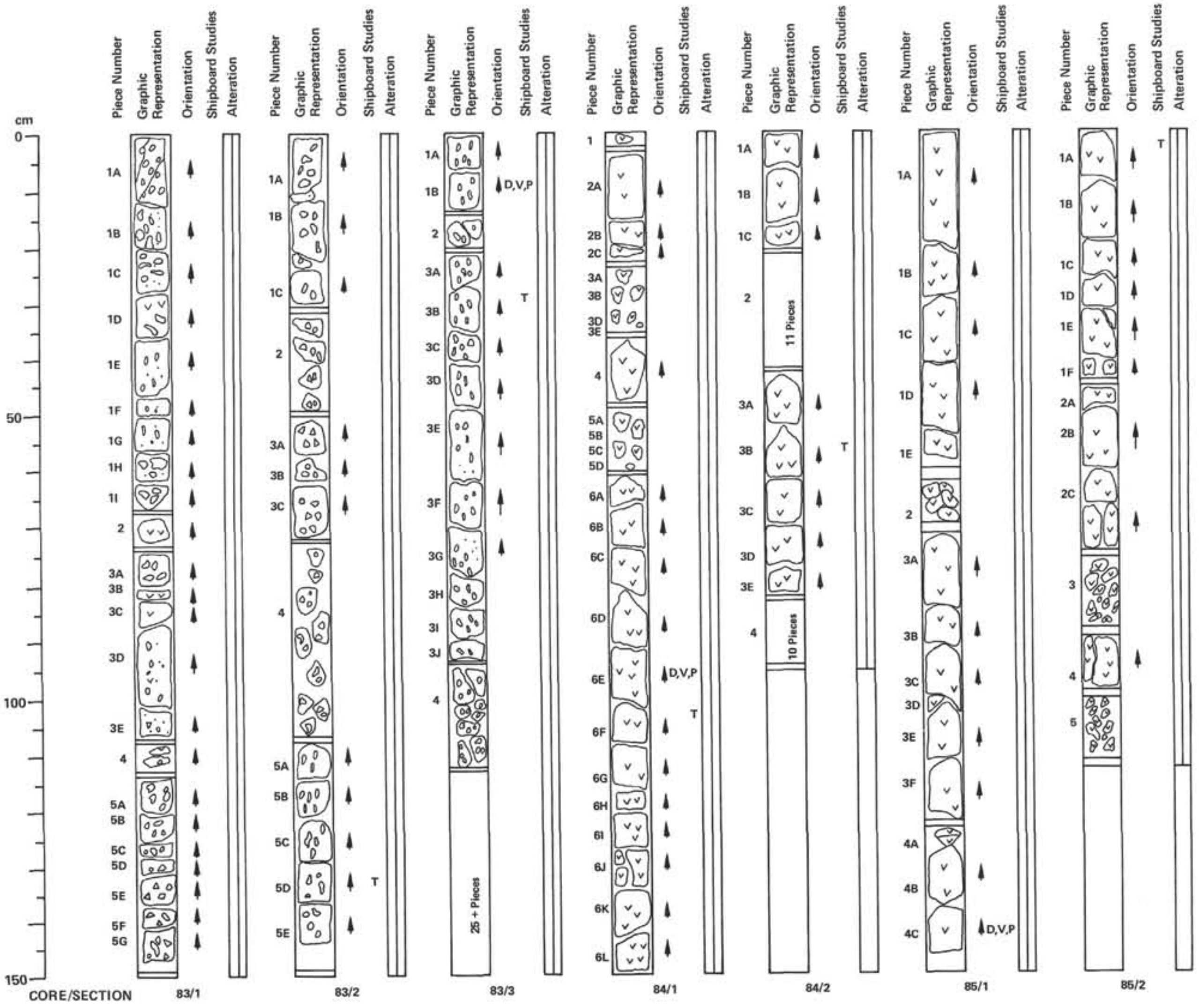
Thin Section Descriptions

Diabase (Basaltic?) Breccia – Section 1, Piece 6A, 65–68 cm
Texture: clastic, hyaloophitic (fragments)
Composition: altered cryptocrystalline fragments (originally basaltic glass[?]), 60%, <10 mm across, angular to subangular; green clay, 11%; plagioclase, 10%, 0.02–0.1 mm, prismatic; clinopyroxene, 10%, 0.05–0.2 mm, prismatic; opaques, 4%, 0.05–0.1 mm; zeolites(?), 5%
Alteration: green clay matrix (11%); zeolite (?) (5%) replacing plagioclase and groundmass

Altered Diabase – Section 1, Piece 9, 124–127 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 30%, 0.5–3 mm, subhedral; clinopyroxene, 30%, 0.5–3.5 mm, subhedral; clays, 30%; zeolites, 10%; opaques, 5%; sphene, TR
Alteration: green clays (30%) and zeolites (10%) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 8D, 111 cm	2.60	4.00	–	12



SITE 471, CORE 83, SECTIONS 1–3, 778.0–782.1 m

MAJOR ROCK TYPE – DIABASE BRECCIA

Macroscopic Description

Diabase Breccia – angular to subangular fragments of altered, vesicular, fine- to medium-grained diabase set in dark gray (N3), aphanitic clayey matrix. Most fragments are <5 cm across. In Section 2, below 110 cm and in Section 3 the long dimension of fragments is aligned subparallel to core axis (i.e. vertical). Plagioclase laths in diabase fragments are up to 3 mm long.

Thin Section Descriptions

Diabase Breccia – Section 2, Piece 5D, 132–133 cm
Texture: clastic, intersertal (fragments)
Composition: plagioclase crystal fragments (angular to subangular, 0.1–0.7 mm) form about 40% of specimen; unbroken plagioclase crystals, 20%, 0.5–3.5 mm, subhedral; clinopyroxene, 3%, 0.5–1 mm, anhedral; clays, 32%; opaques, 5%, 0.2–0.5 mm; sphene, TR, calcite TR
Alteration: greenish clays (32%) replace groundmass; calcite (TR)

Diabase Breccia – Section 3, Piece 3B, 29–33 cm
Texture: clastic
Composition: plagioclase, 50%, 0.1–1.0 mm, subangular, fragmented crystals; clinopyroxene, TR, 0.2–1.0 mm, subangular, fragmented; opaques, 4%, 0.5–1.0 mm; sphene, 2%; matrix (clays 14%)
Vesicles: 15%, 0.5–2 mm, irregular
Alteration: clays (10%) replace groundmass; calcite (3%)

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 3, Piece 1B, 11 cm	2.31	3.19	–	25

SITE 471, CORE 84, SECTIONS 1–2, 787.0–789.5 m

MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description

Altered Diabase – fine- to medium-grained, massive, and aphyric. Scattered dark green to black prismatic pyroxene crystals and plagioclase laths up to 5 mm long

Thin Section Descriptions

Altered Diabase – Section 1, Piece 6F, 102–106 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 32%, subhedral; clinopyroxene, 15%, 0.5–2 mm, subhedral to anhedral; opaques, 15%, 0.5–1.5 mm, anhedral, quartz, 3%, 0.1–0.2 mm, anhedral; sphene, 1%, 0.05 mm, anhedral; amphibole, TR, 0.05–0.1 mm, acicular prismatic, colorless; biotite, TR, 0.1–0,2 mm, platy, brown to dark green
Alteration: clays (30%) and calcite (4%) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 6E, 94 cm	2.67	4.41	–	11

SITE 471, CORE 85, SECTIONS 1–2, 796.0–798.6 m

MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description

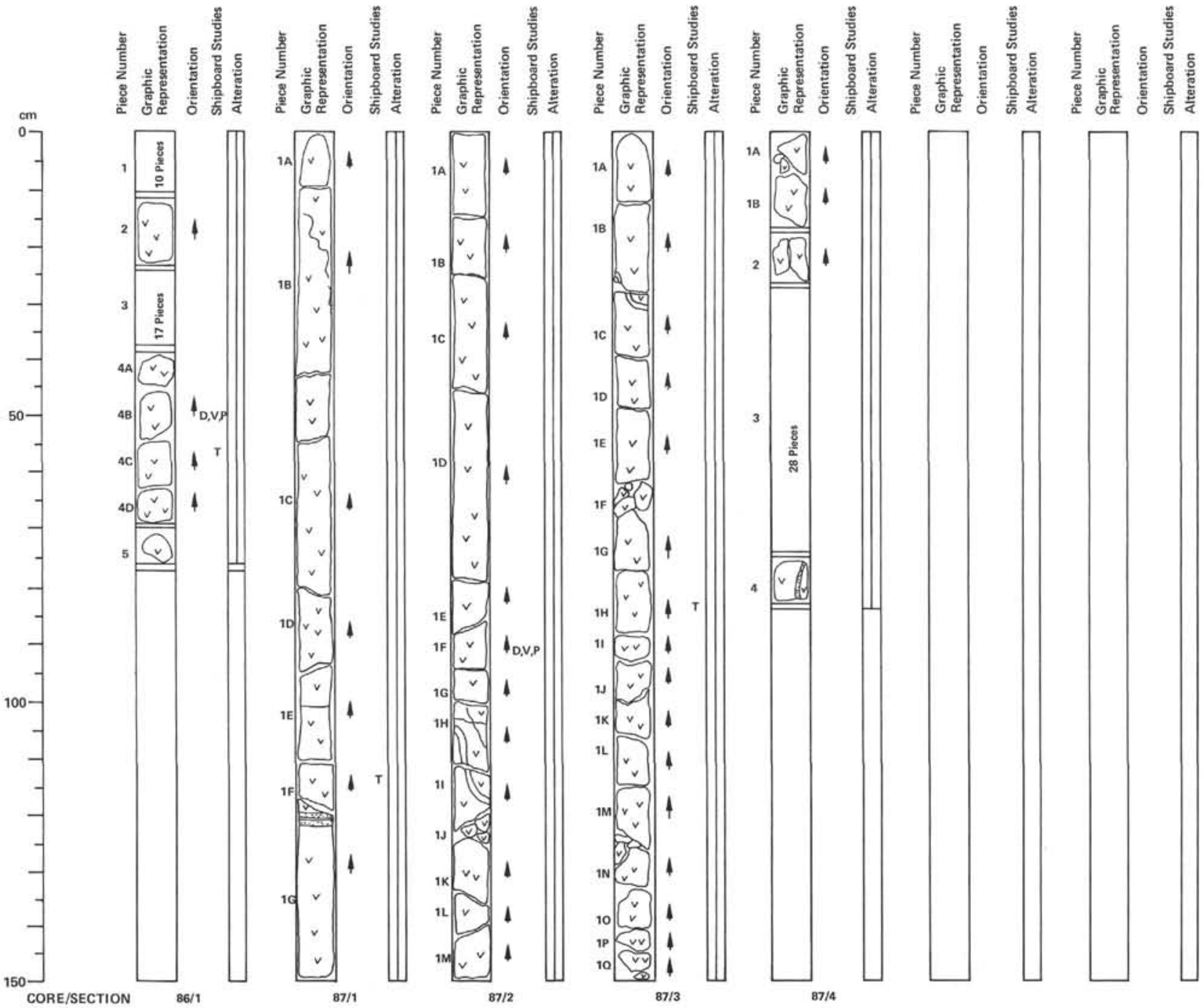
Altered Diabase – massive, fine- to medium-grained and aphyric. Plagioclase laths and dark green to black prismatic pyroxene crystals up to 5 mm long scattered throughout.

Thin Section Description

Altered Diabase – Section 2, Piece 1A, 0–4 cm
Texture: subophitic to intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 1–4 mm, euhedral to subhedral; clinopyroxene, 35%, 1–5 mm, anhedral; opaques, 4%, 0.2–1 mm, anhedral; alkali feldspar, 3%, 0.2–1 mm, anhedral; quartz, 1%, 0.2–0.5 mm, anhedral; amphibole, TR, prismatic, colorless; biotite, TR, 0.1 mm, platy, brown
Alteration: clays (15%) and calcite (2%) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 4C, 140 cm	2.78	4.97	–	3



SITE 471, CORE 86, SECTION 1, 805.0–805.7 m

MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description

Altered Diabase – massive, fine- to medium-grained, aphyric, and holocrystalline. Plagioclase laths and black prismatic pyroxene crystal up to 5 mm long scattered throughout.

Thin Section Description

Altered Diabase – Section 1, Piece 4C, 57–60 cm

Texture: subophitic to intersertal

Phenocrysts: –

Groundmass: plagioclase, 40%, 0.5–2 mm, euhedral to subhedral; clinopyroxene, 0.5–2 mm, anhedral, greenish tint along rims; alkali feldspar, 5%, 0.1–0.3 mm, anhedral; opaques, 4%, 0.1–0.5 mm, anhedral; quartz, 1%, 0.1–0.2 mm, anhedral; biotite, TR, 0.1–0.5 mm, platy; apatite, TR, equant

Alteration: clays (15%) and calcite (TR) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 4B, 49 cm	2.78	5.35	–	6

SITE 471, CORE 87, SECTIONS 1–4, 807.0–810.8 m

MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description

Altered Diabase – massive, fine- to medium-grained, aphyric and holocrystalline aggregates ~2 mm across of dark green clays are scattered throughout the core. Calcite- and/or green clay-filled fractures and veins common in all sections as marked. Core is fairly homogeneous throughout.

Thin Section Descriptions

Altered Diabase – Section 1, Piece 1F, 113–117 cm

Texture: subophitic to intersertal

Phenocrysts: –

Groundmass: plagioclase, 40%, 0.5–2 mm, euhedral; clinopyroxene, 35%, 0.5–2 mm, anhedral, greenish tint along rims; opaques, 5%, 0.1–0.5 mm, anhedral; quartz, 2%, 0.1–0.2 mm; biotite, 1%, 0.2–0.5 mm, platy; hornblende, TR, 0.5–0.1 mm, brown

Alteration: clays (17%) replace groundmass

Altered Diabase – Section 3, Piece 1H, 83–86 cm

Texture: subophitic to intersertal

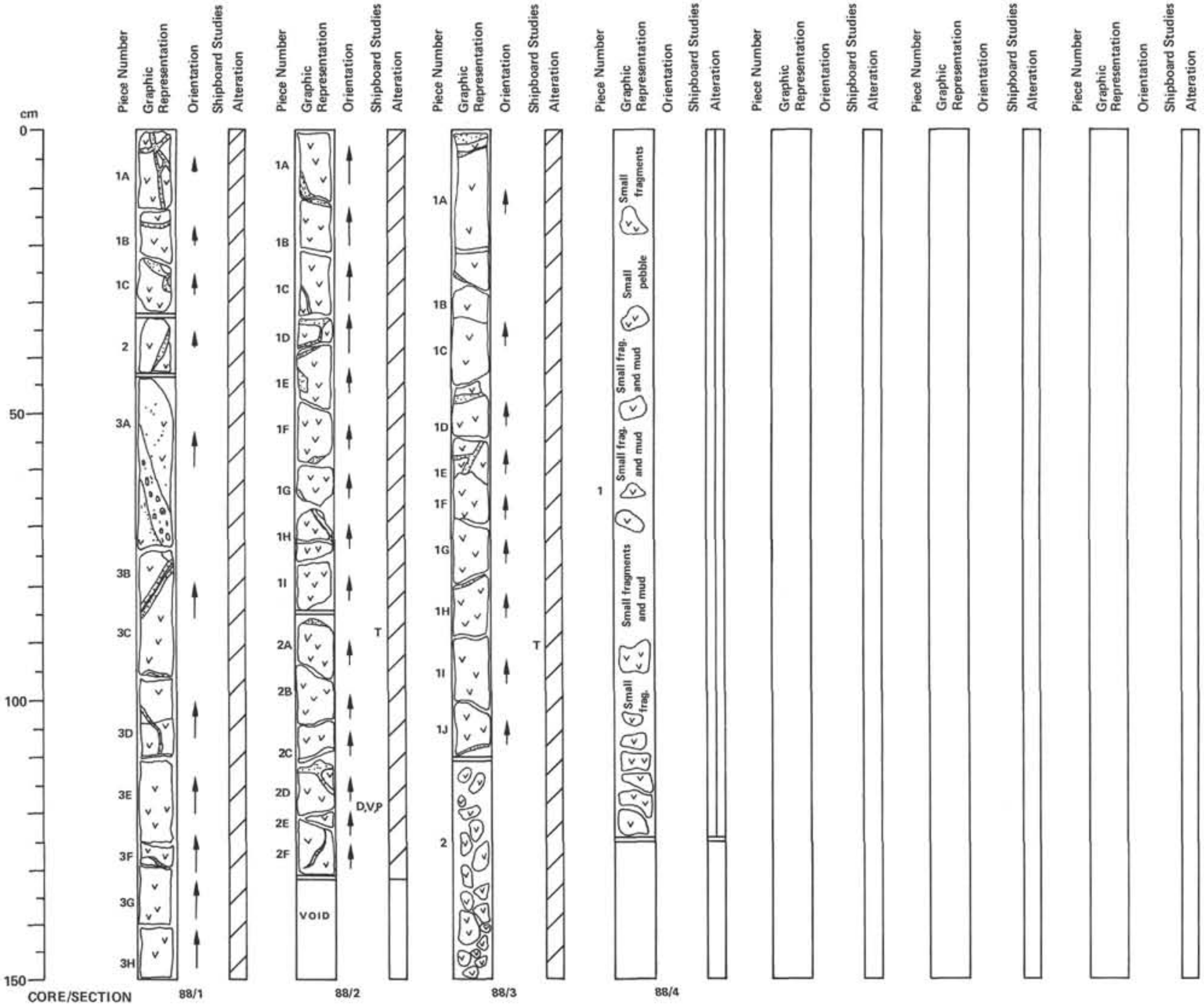
Phenocrysts: –

Groundmass: plagioclase, 40%, 0.5–3 mm, euhedral to subhedral; clinopyroxene, 25%, 0.5–5 mm, anhedral; biotite, 10%, 0.3–0.5 mm, platy, brown to dark green; opaques 4%, 0.1–0.5 mm

Alteration: clays (20%) replace groundmass; zeolite(?) (1%) in vein

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 1F, 91 cm	2.85	5.29	–	3



SITE 471, CORE 88, SECTIONS 1–4, 814.0–819.8 m

MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description

Altered Diabase – massive, fine- to medium-grained, aphyric, and holocrystalline. Many calcite- and clay-filled fractures and veins as marked. Large fractured/brecciated zone between 44–73 cm, Section 1, contains many angular fragments of diabase cemented together with calcite. Most veins and fractures are less than 1 cm wide and are bordered by a zone of alteration. Section 4 is a drilling breccia consisting of large diabase fragments and many ground up small pieces.

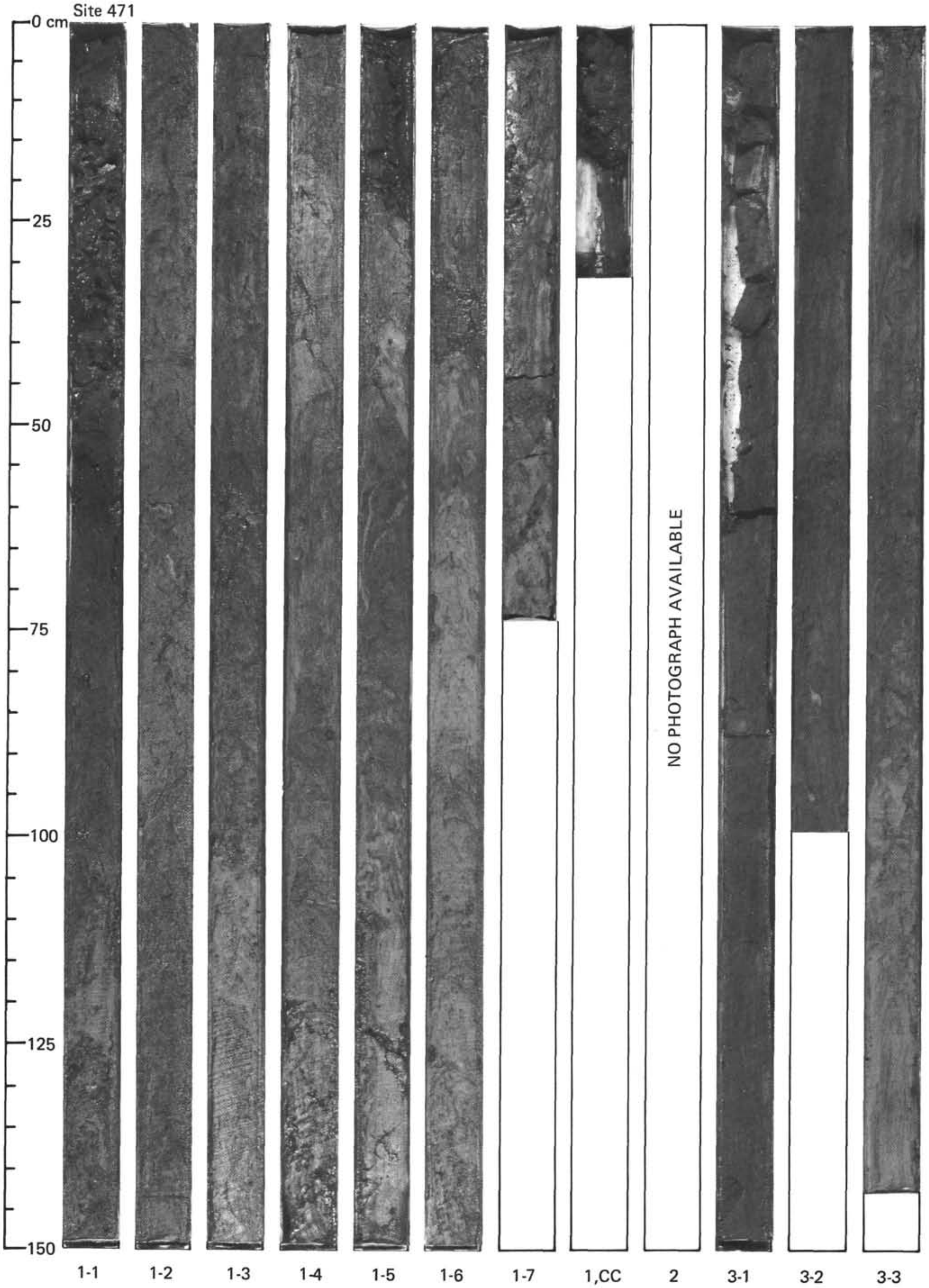
Thin Section Descriptions

Altered Diabase – SEction 2, Piece 2A, 89–92 cm
Texture: subophitic to intersertal
Phenocrysts: –
Groundmass: plagioclase, 35%, 0.5–2 mm, subhedral; clinopyroxene, 30%, 0.5–3.5 mm, anhedral; biotite, 7%, 0.1–0.5 mm, platy, brown to dark green; opaques, 4%, 0.05–0.01 mm; amphibole, TR, 0.02–0.1 mm, prismatic, colorless
Alteration: clays (21%) replace groundmass; calcite (2%) and zeolites(?) (1%) in veins

Altered Diabase – Section 3, Piece 1I, 87–91 cm
Texture: subophitic to intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.5–2 mm, subhedral; clinopyroxene, 30%, 0.5–3.5 mm, anhedral; biotite, 7%, 0.1–0.5 mm, platy, brown to dark green; opaques, 4%, 0.05–0.2 mm; amphibole, TR, 0.02–0.1 mm
Alteration: clays (17%) and zeolites(?) (1%) replace groundmass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 2D, 115 cm	2.68	4.72	–	10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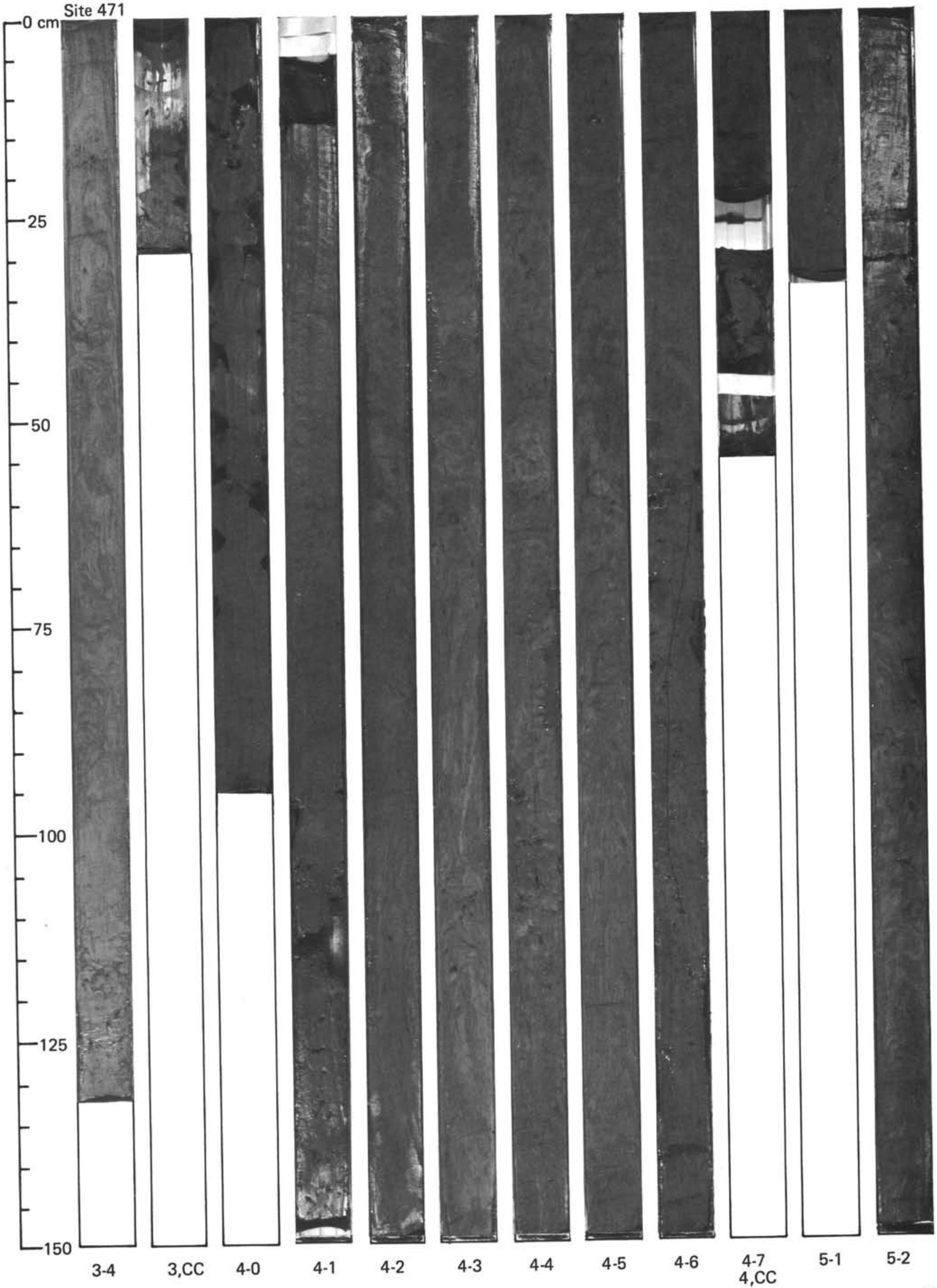
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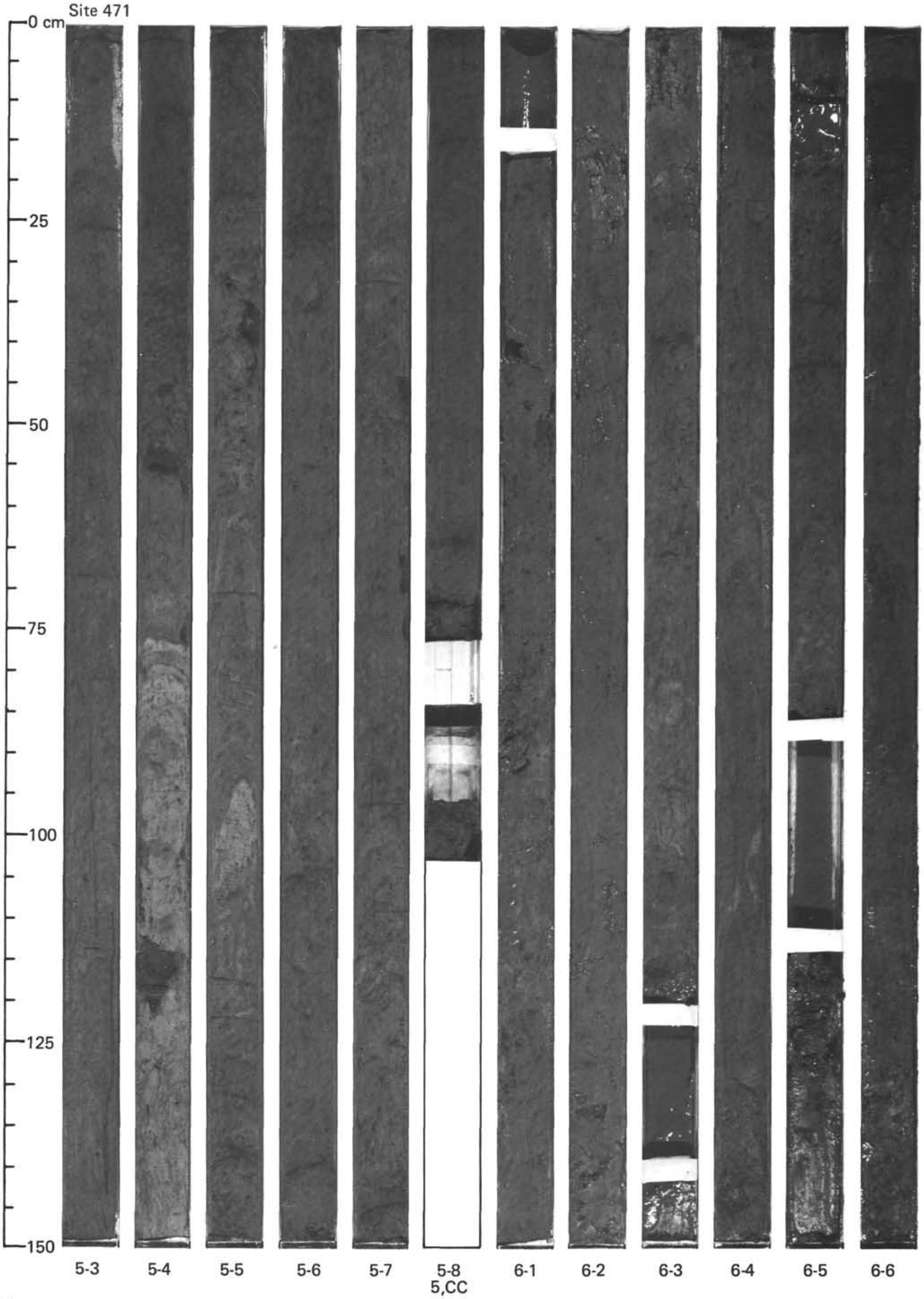
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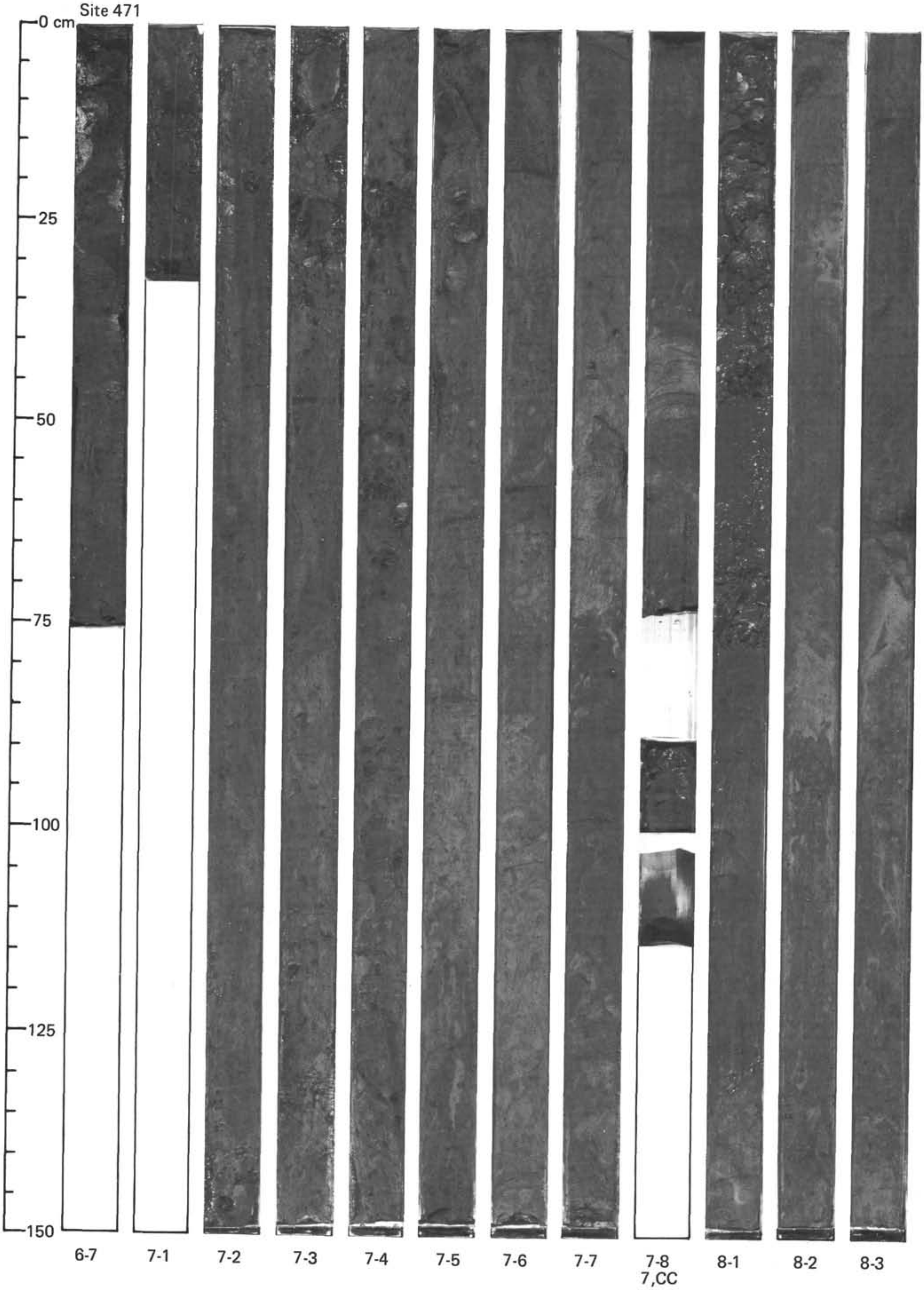
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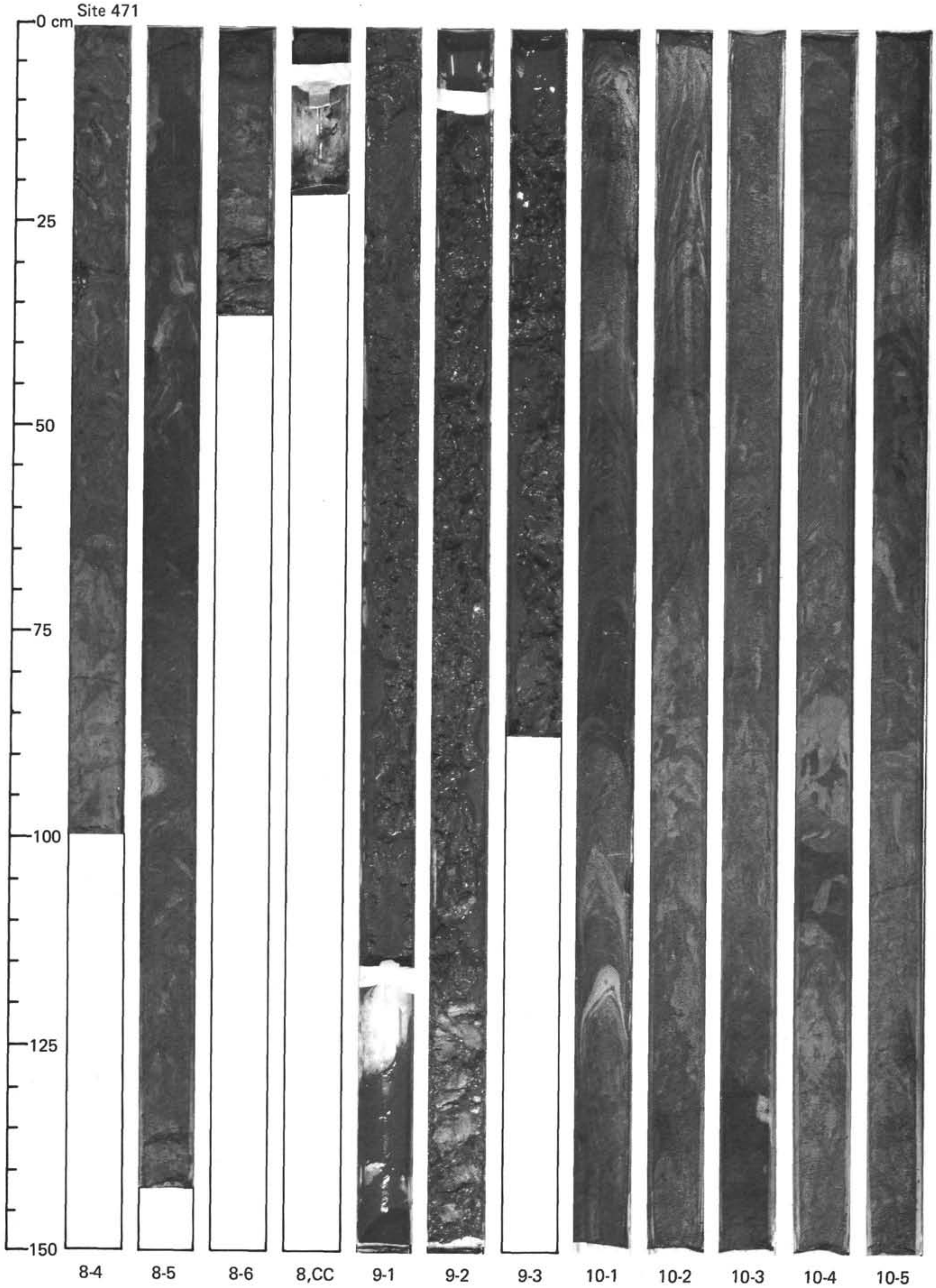
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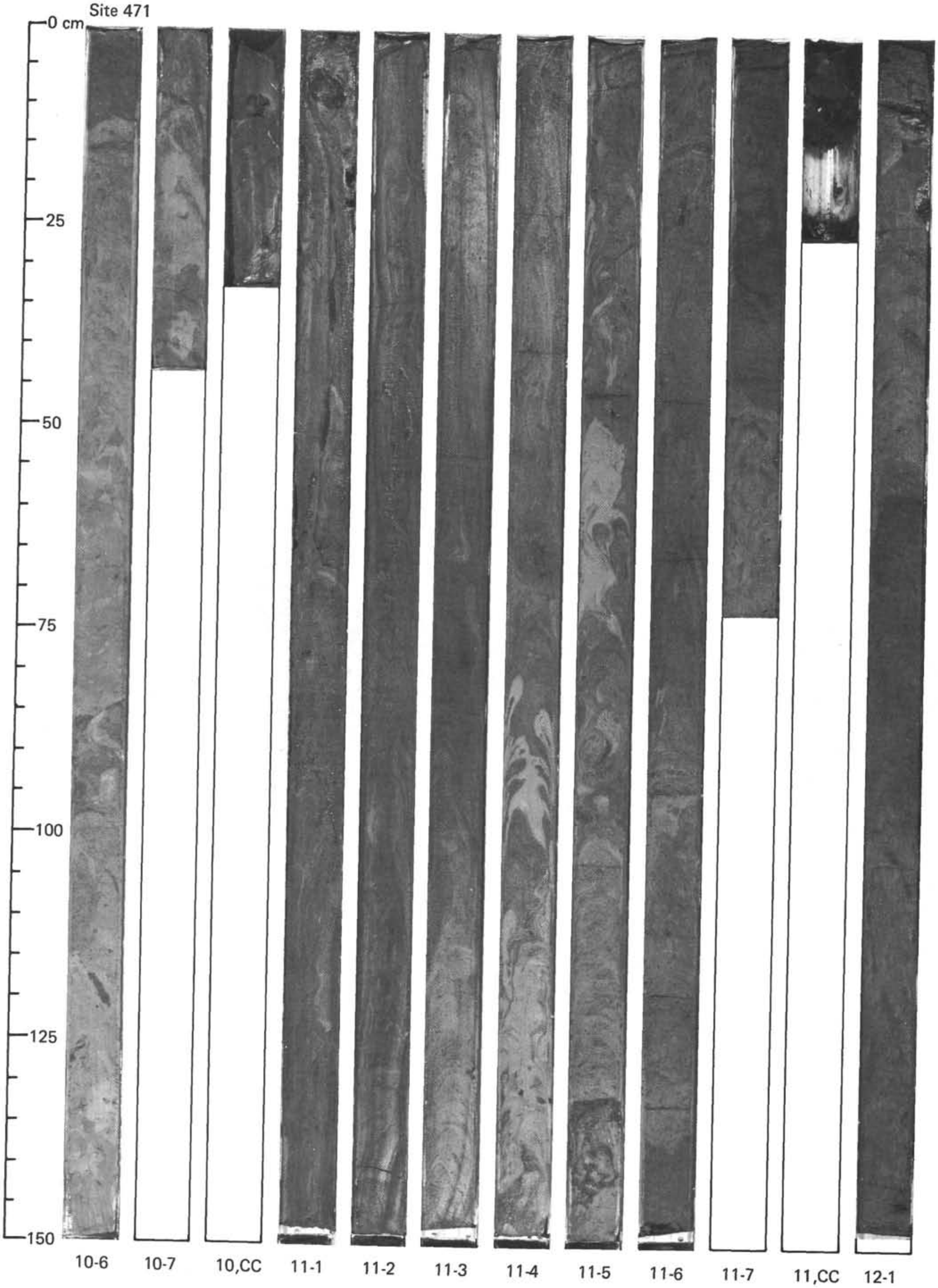
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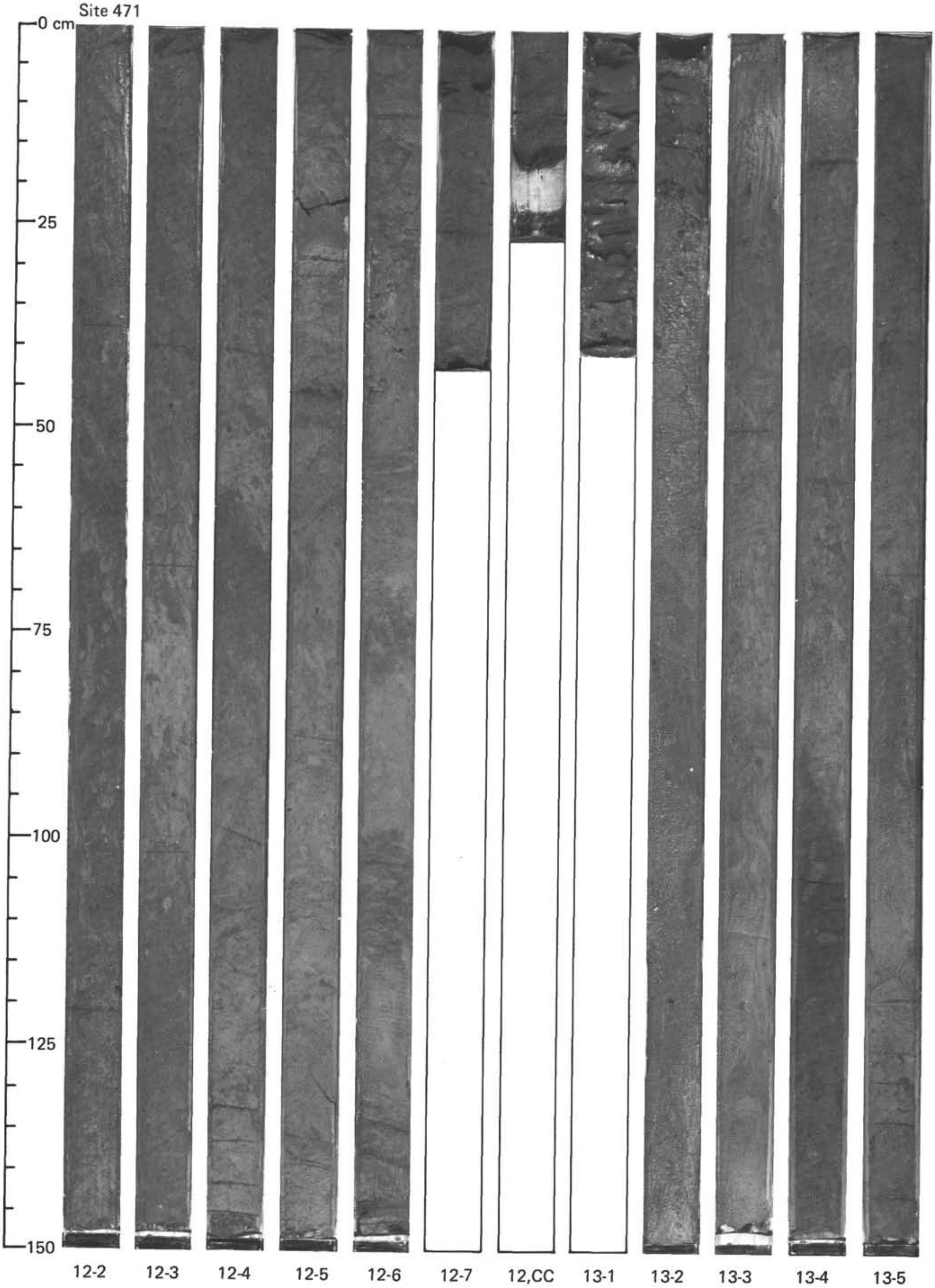
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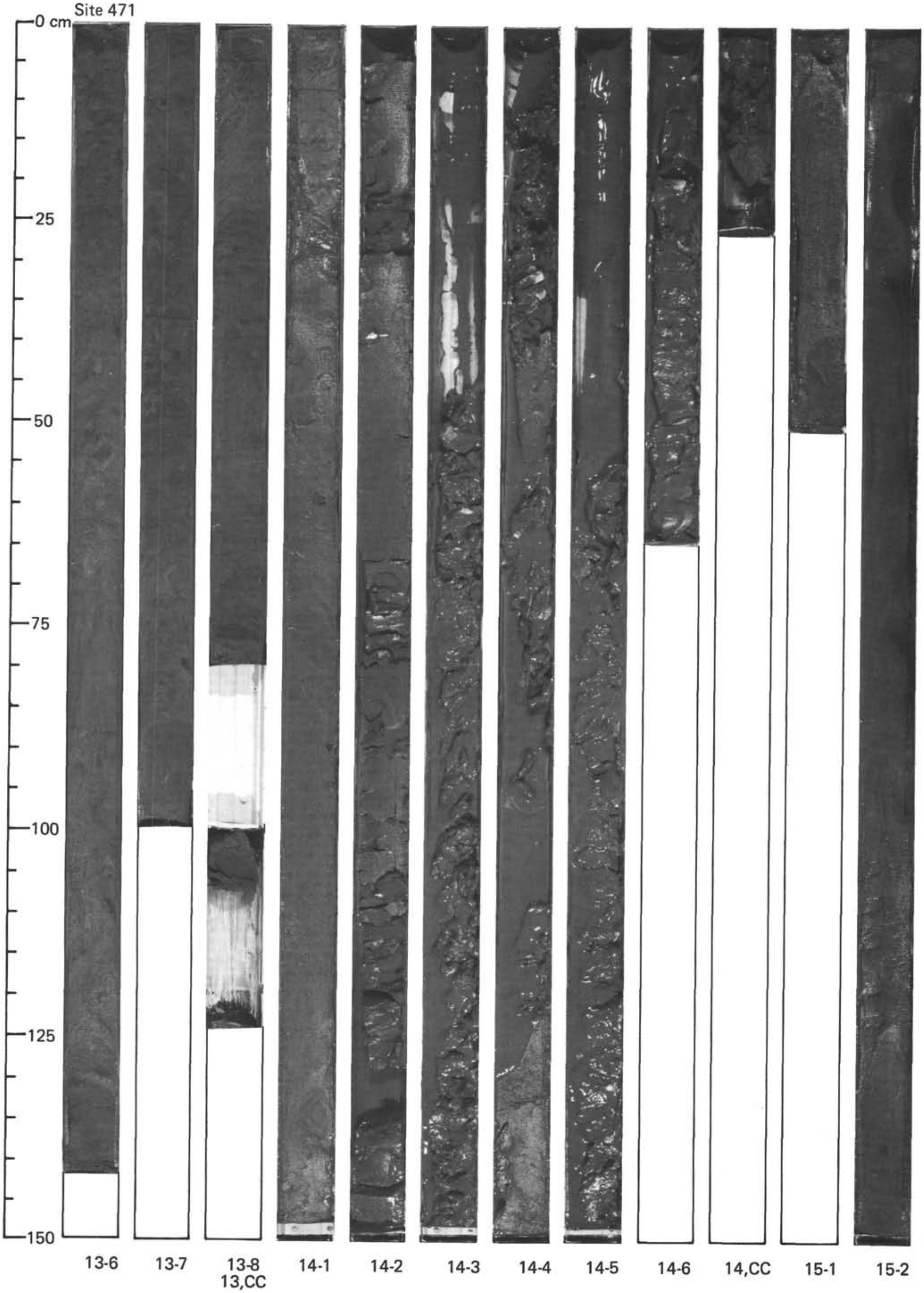
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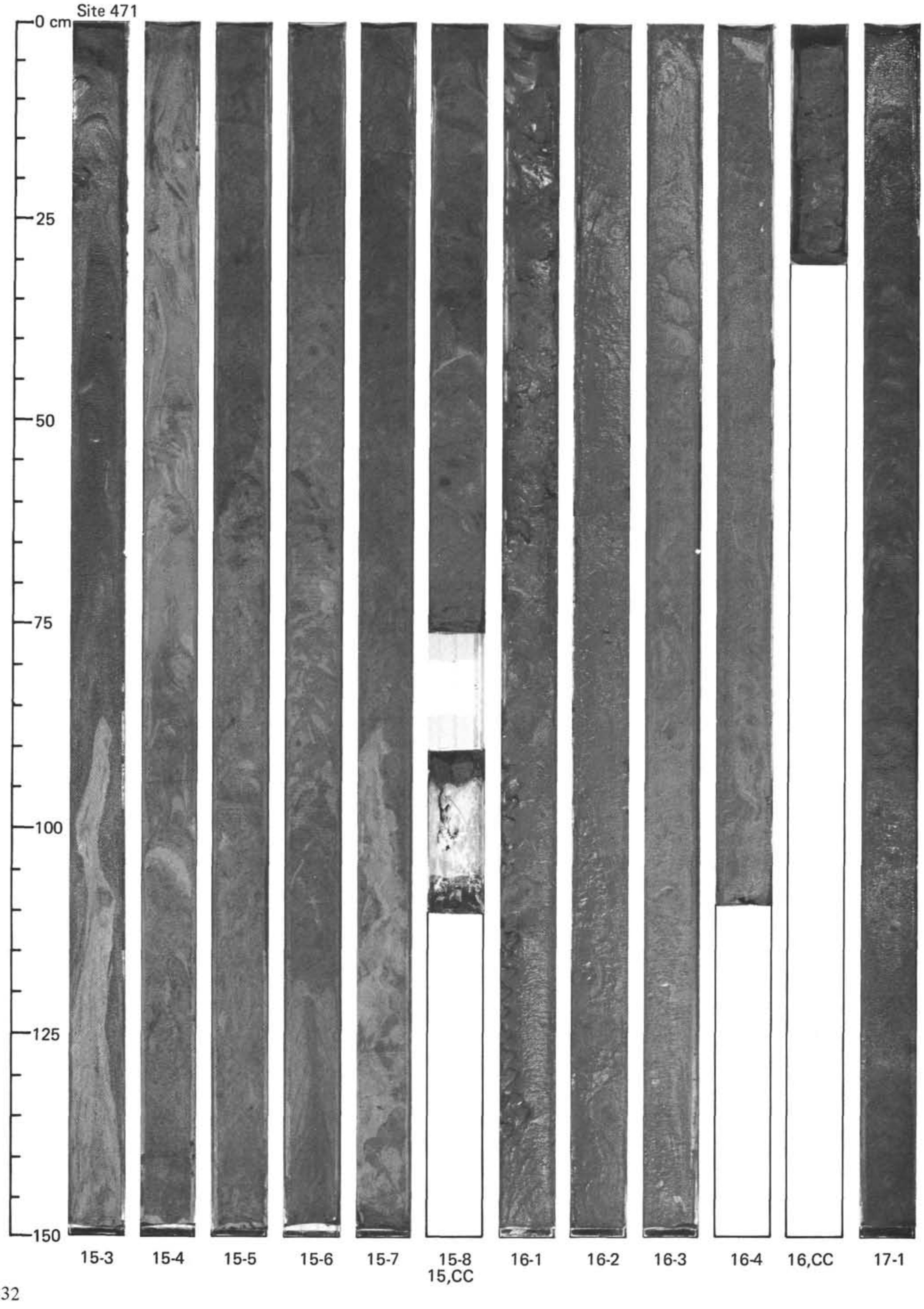
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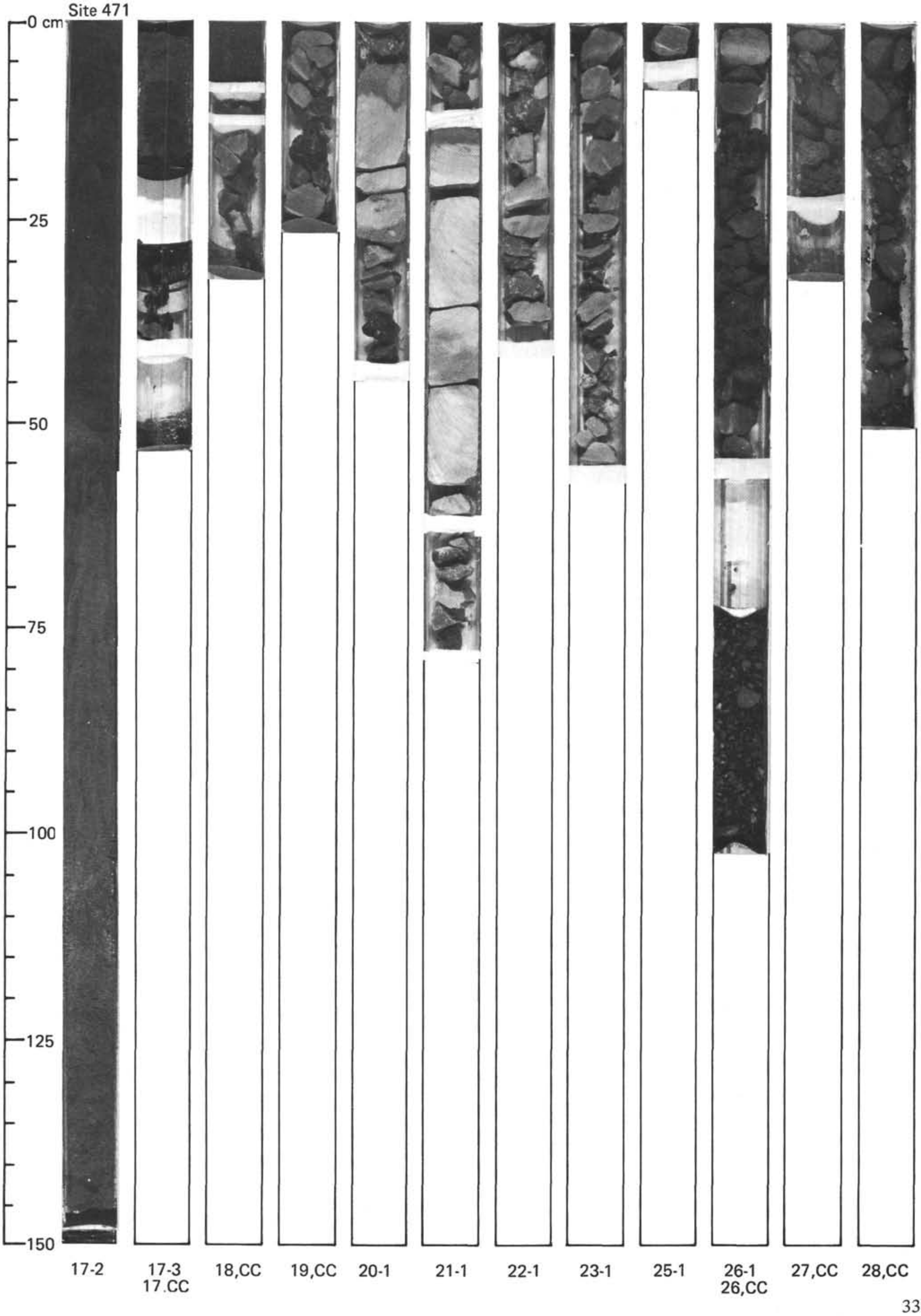
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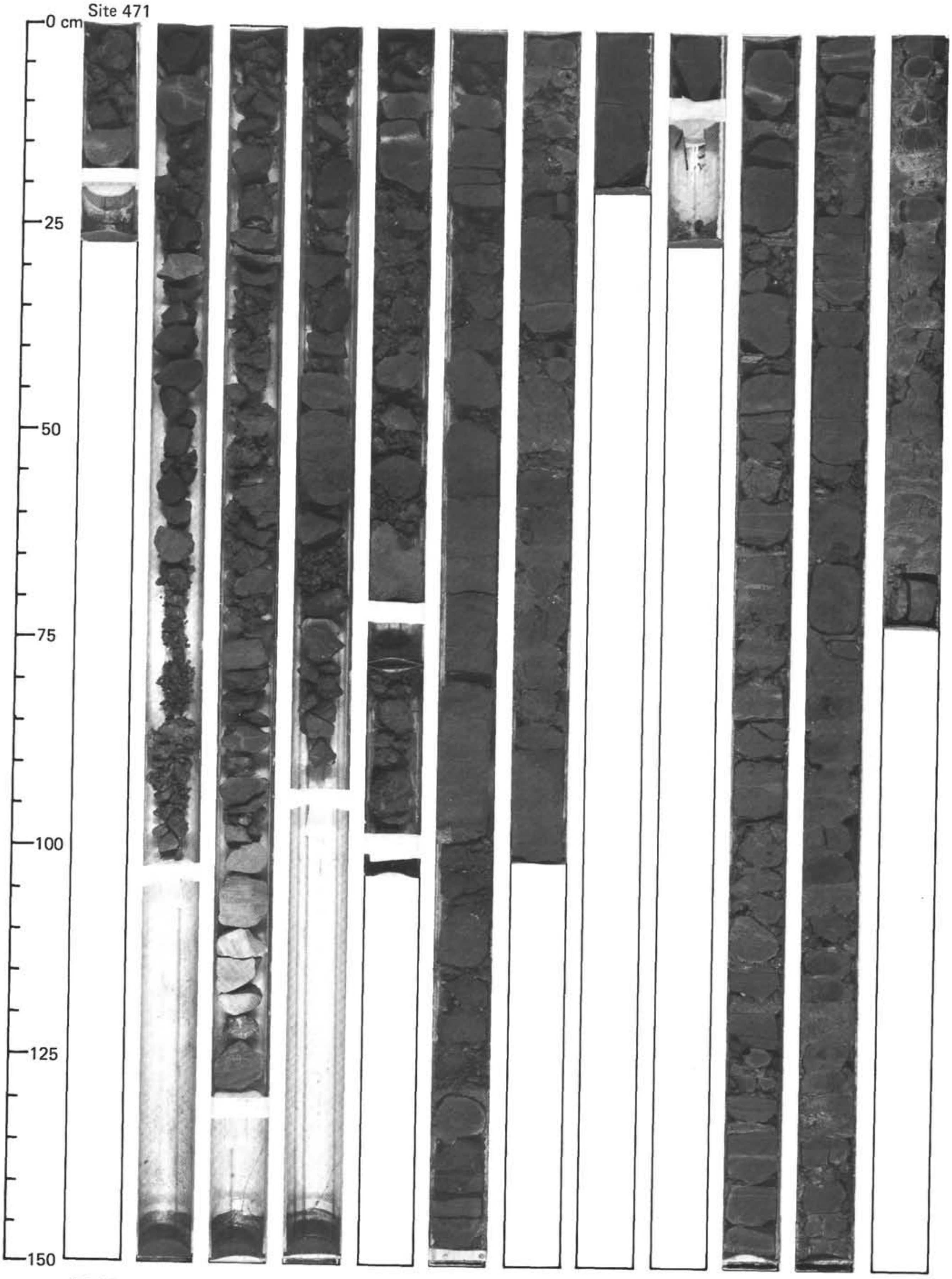
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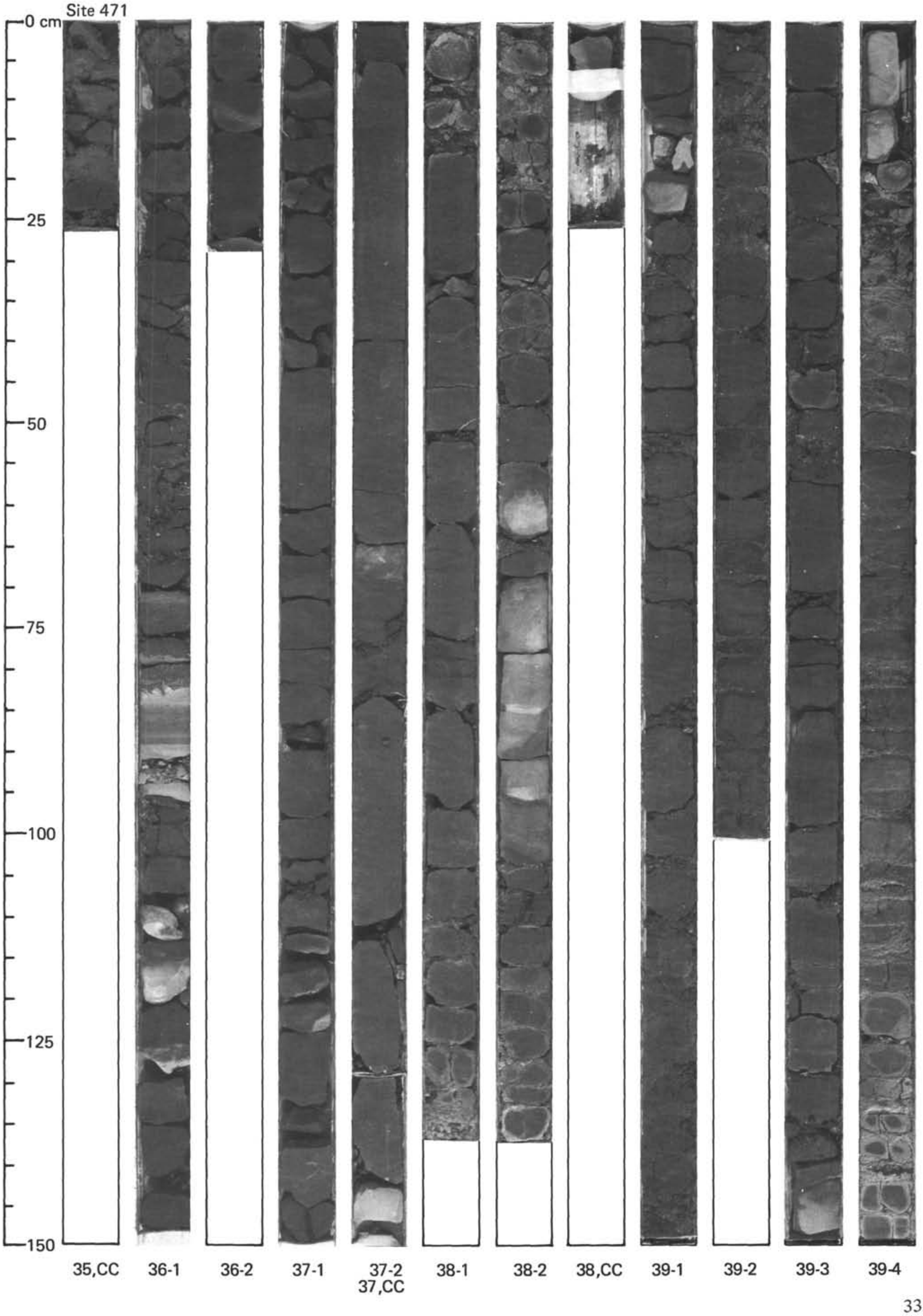
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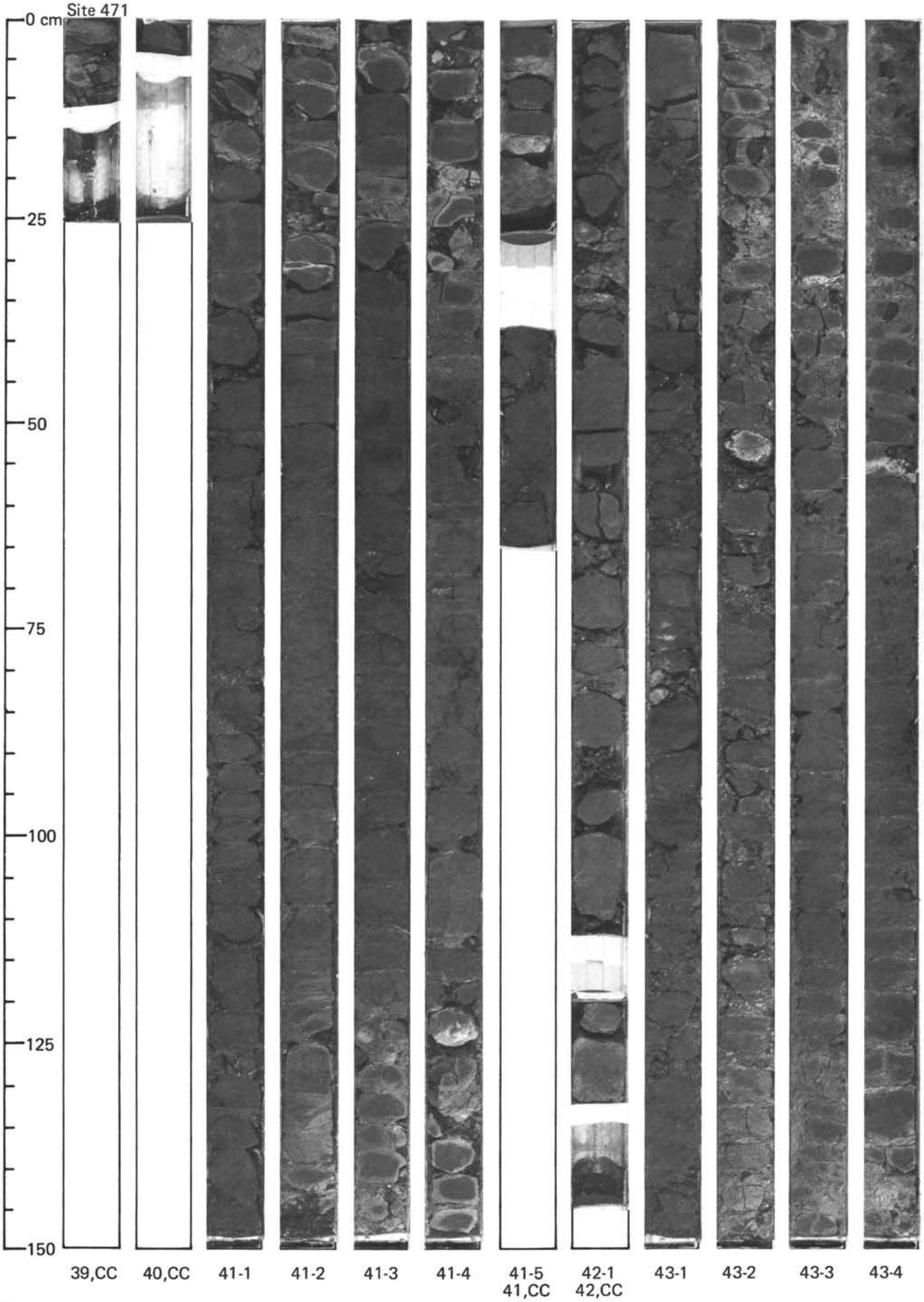
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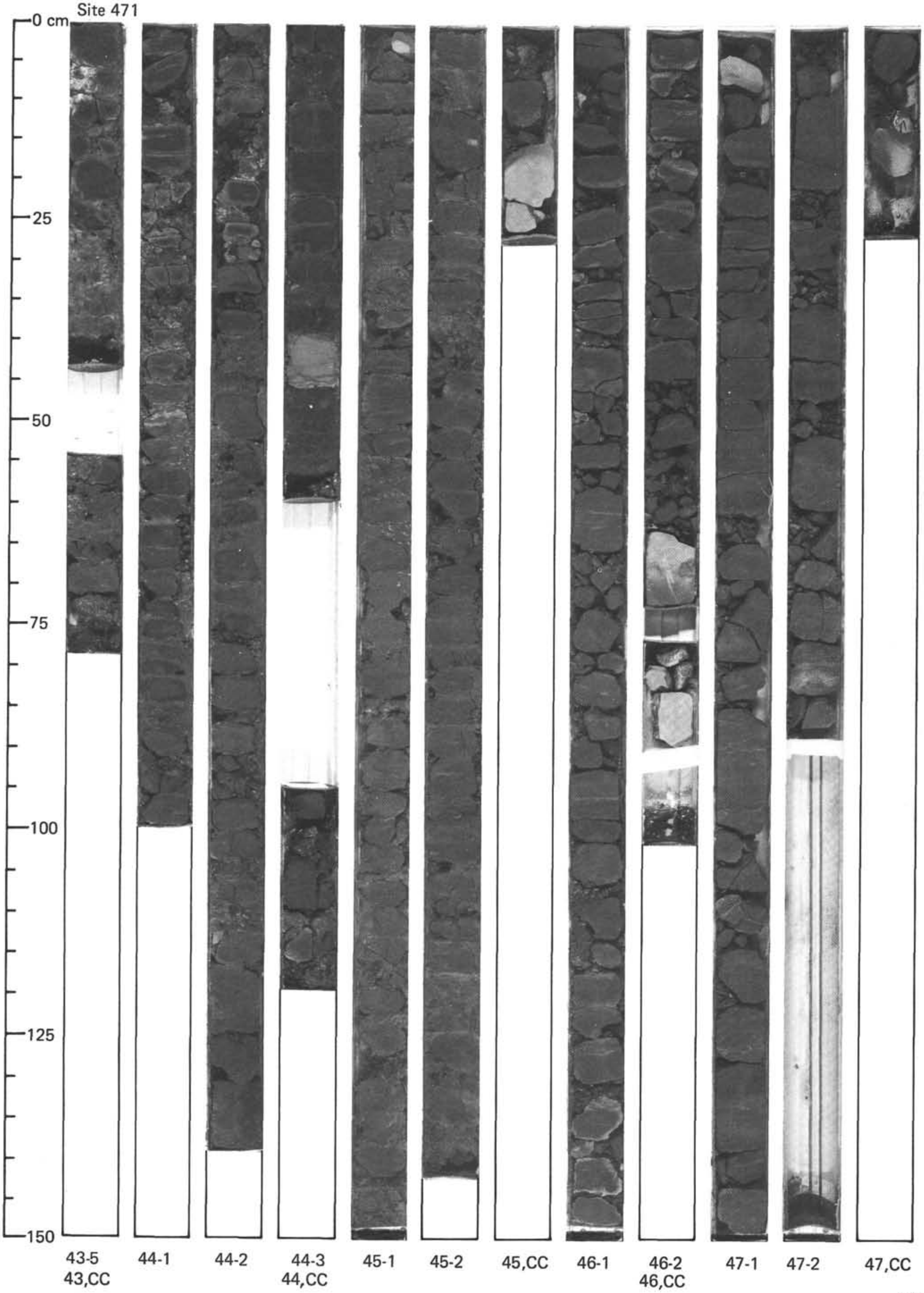
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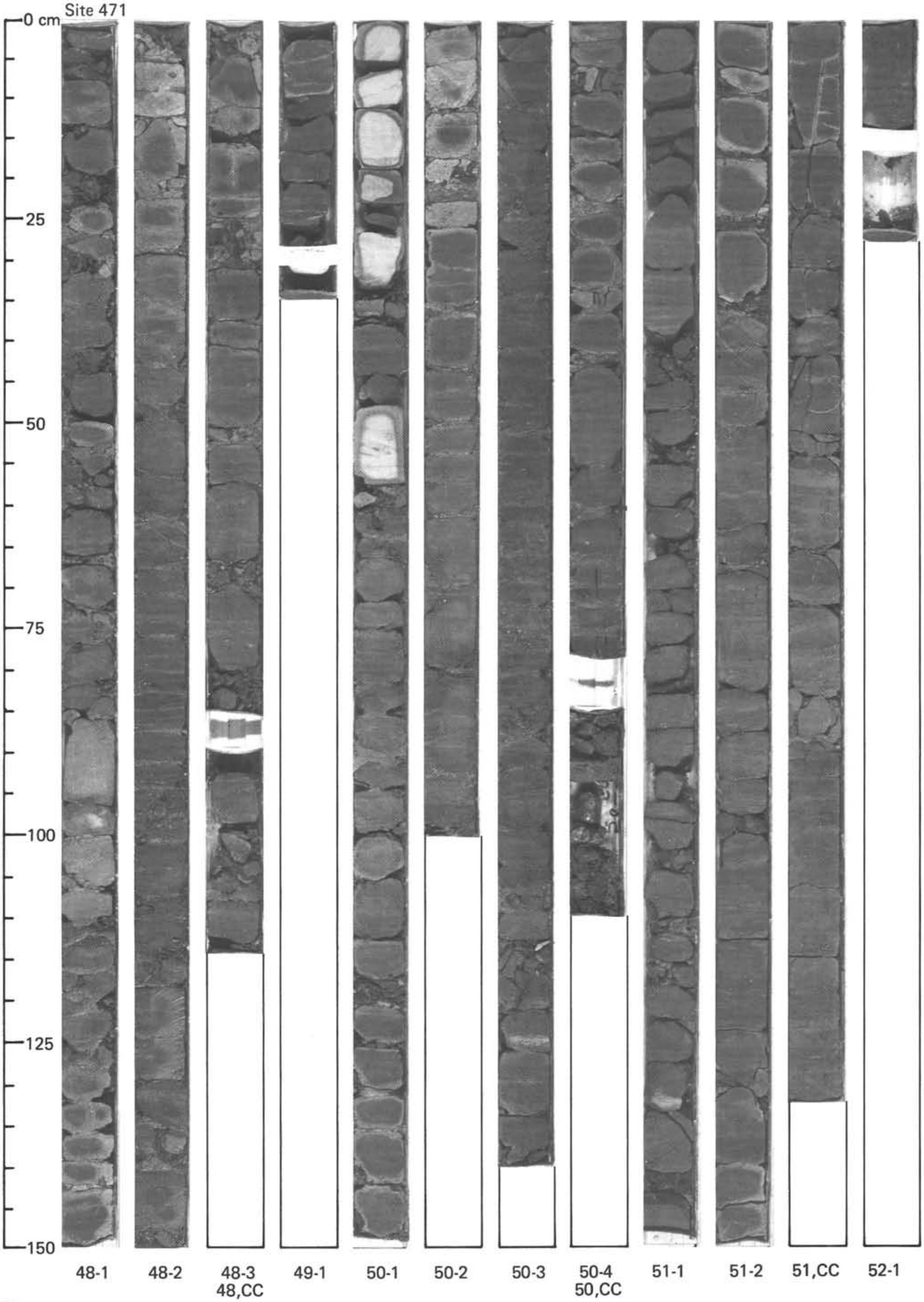
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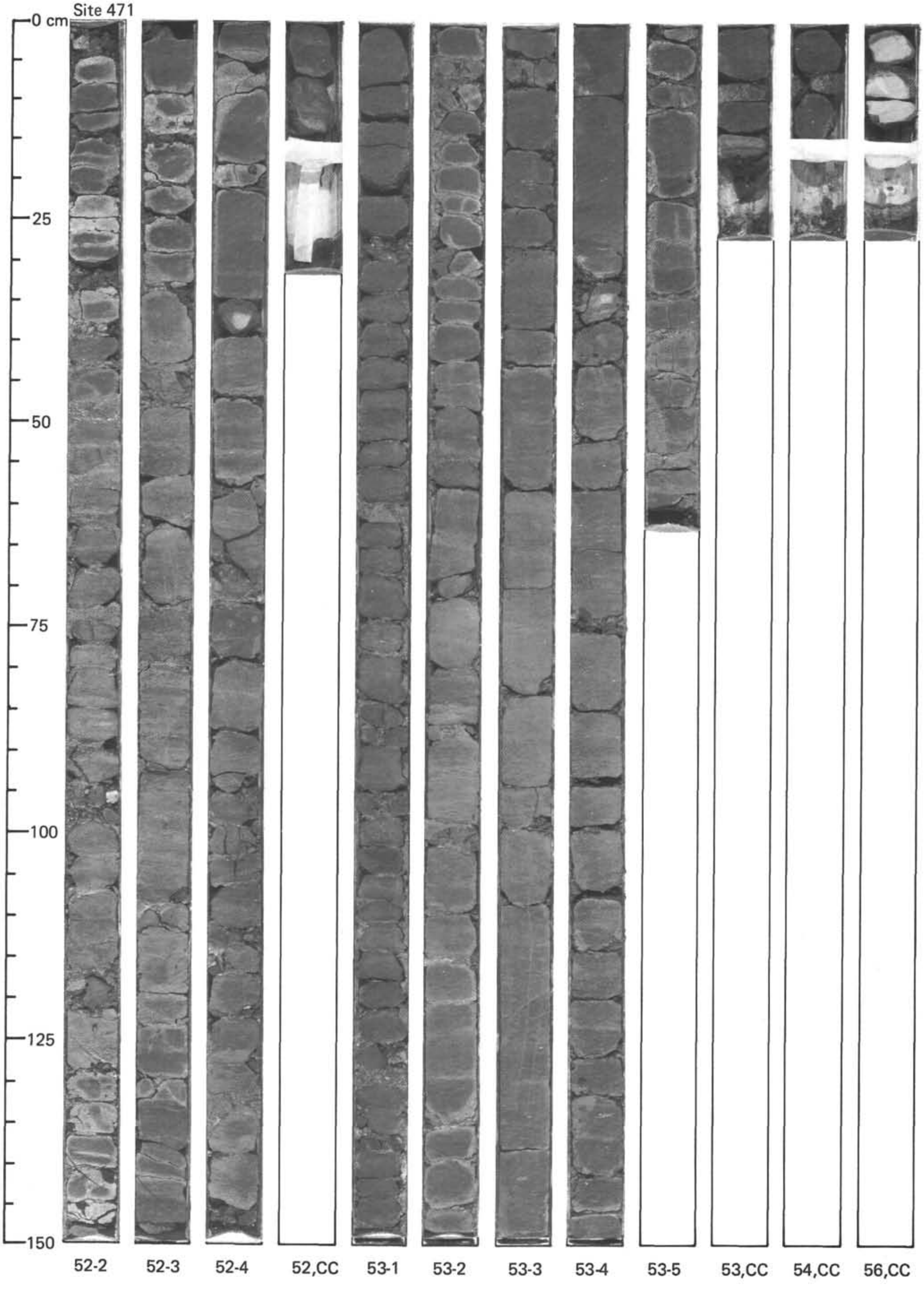
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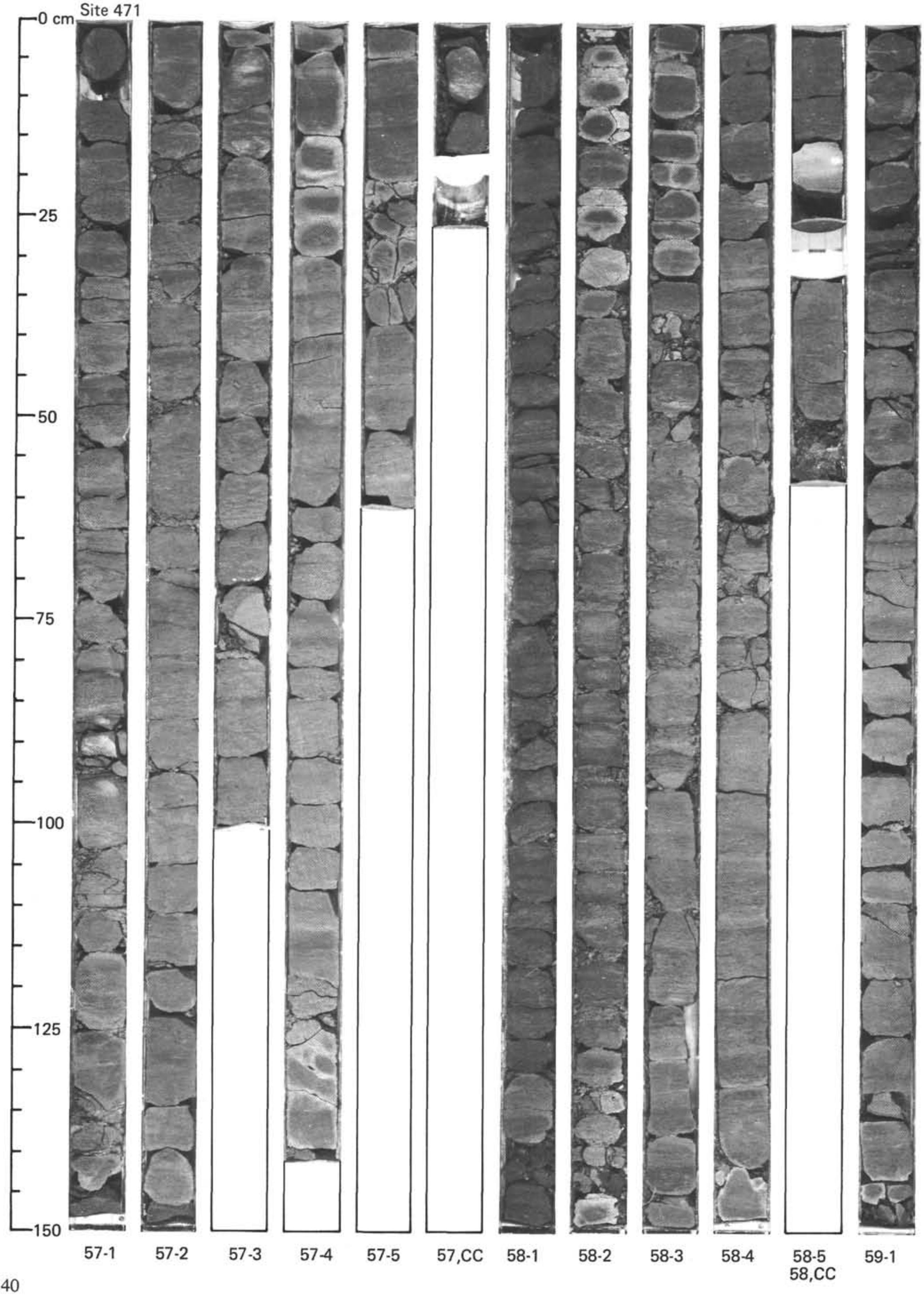
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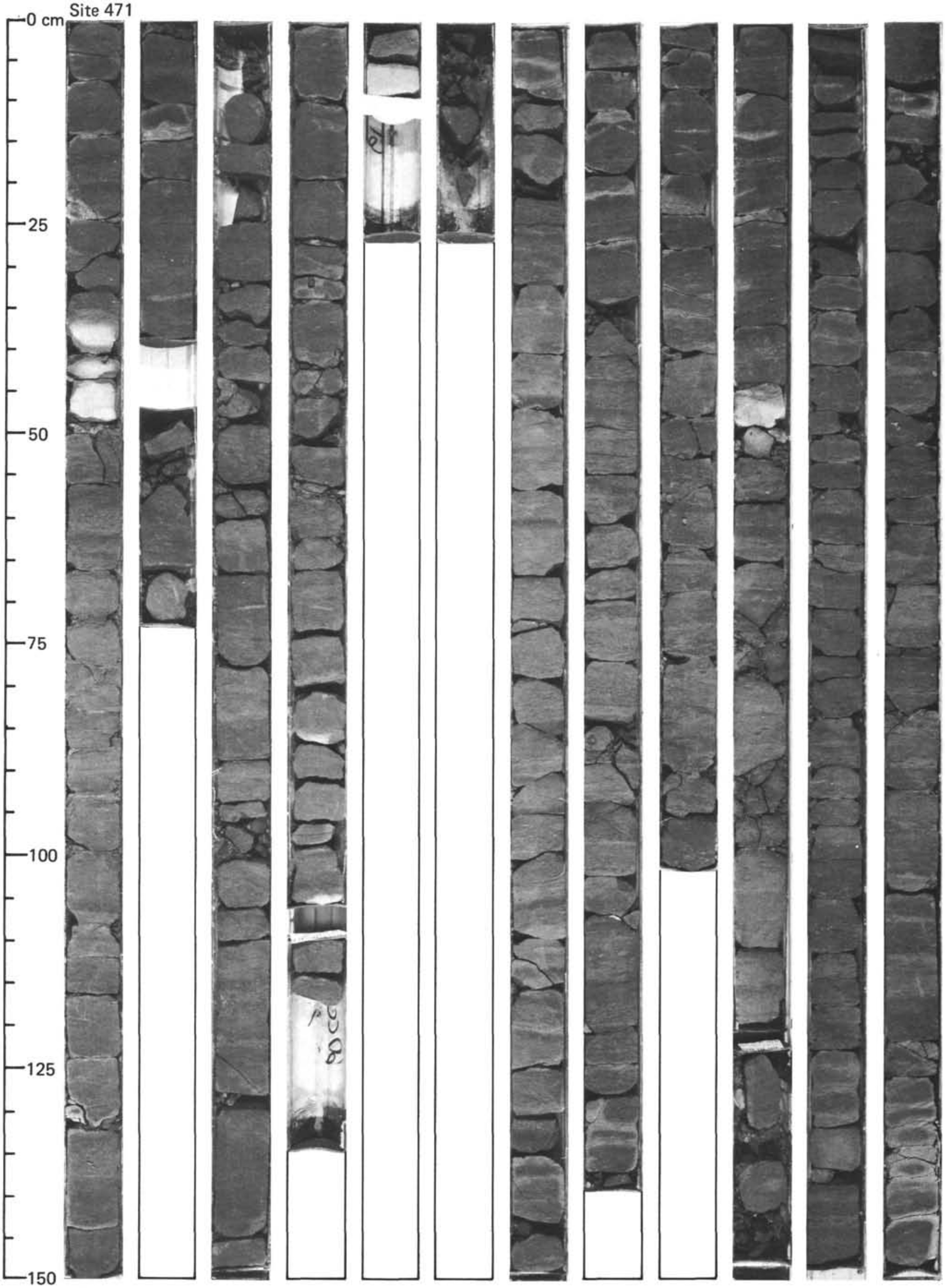
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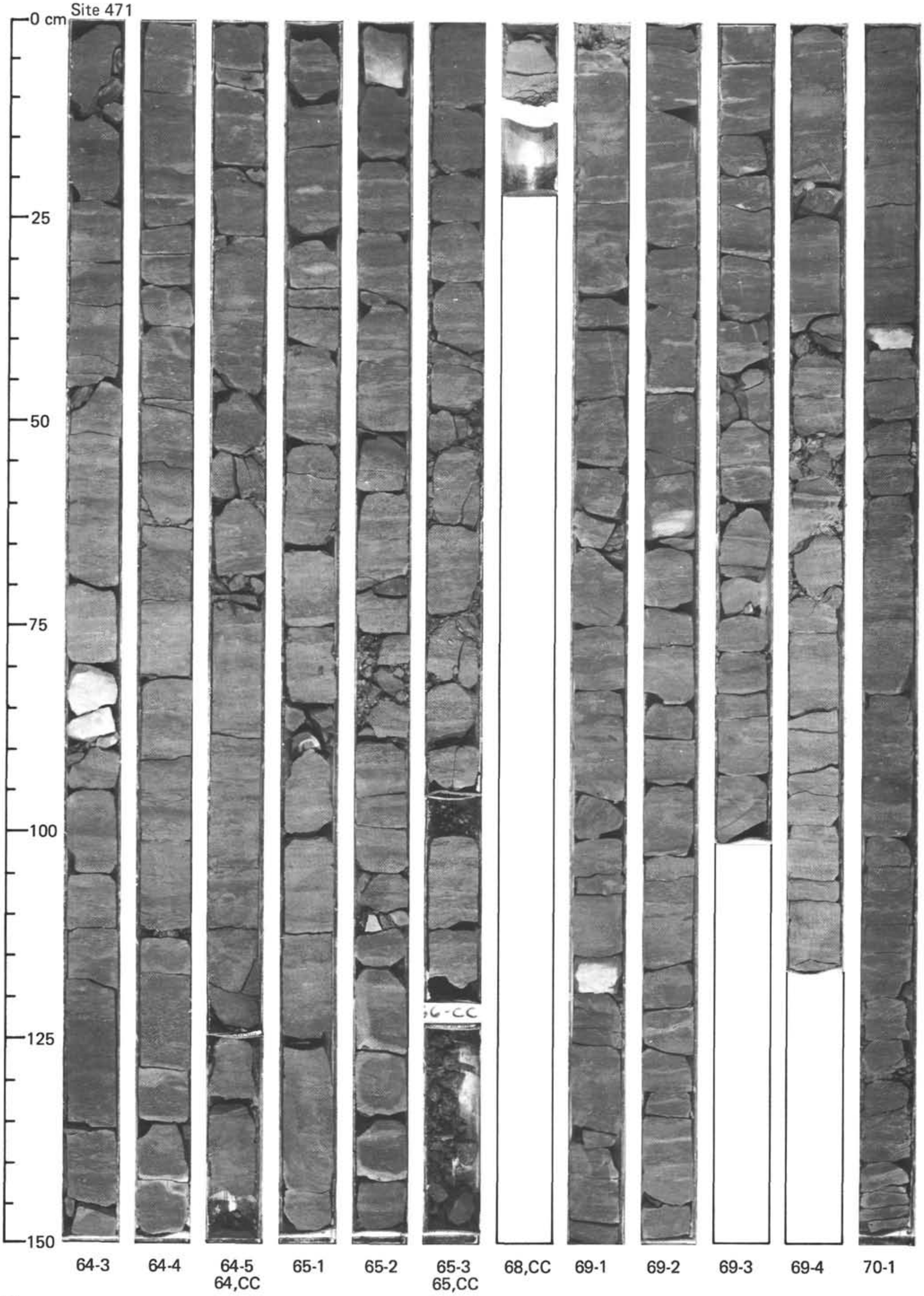
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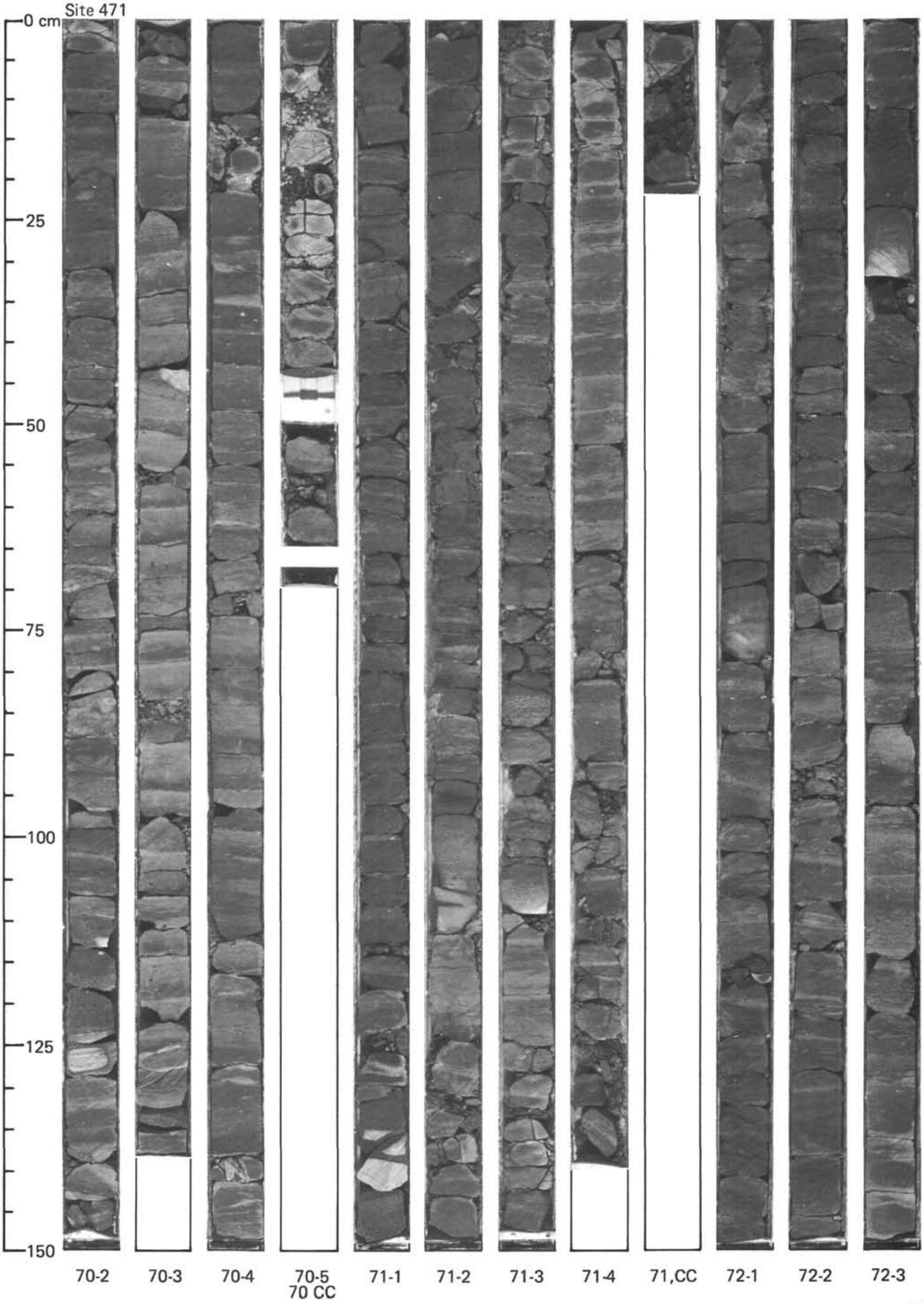
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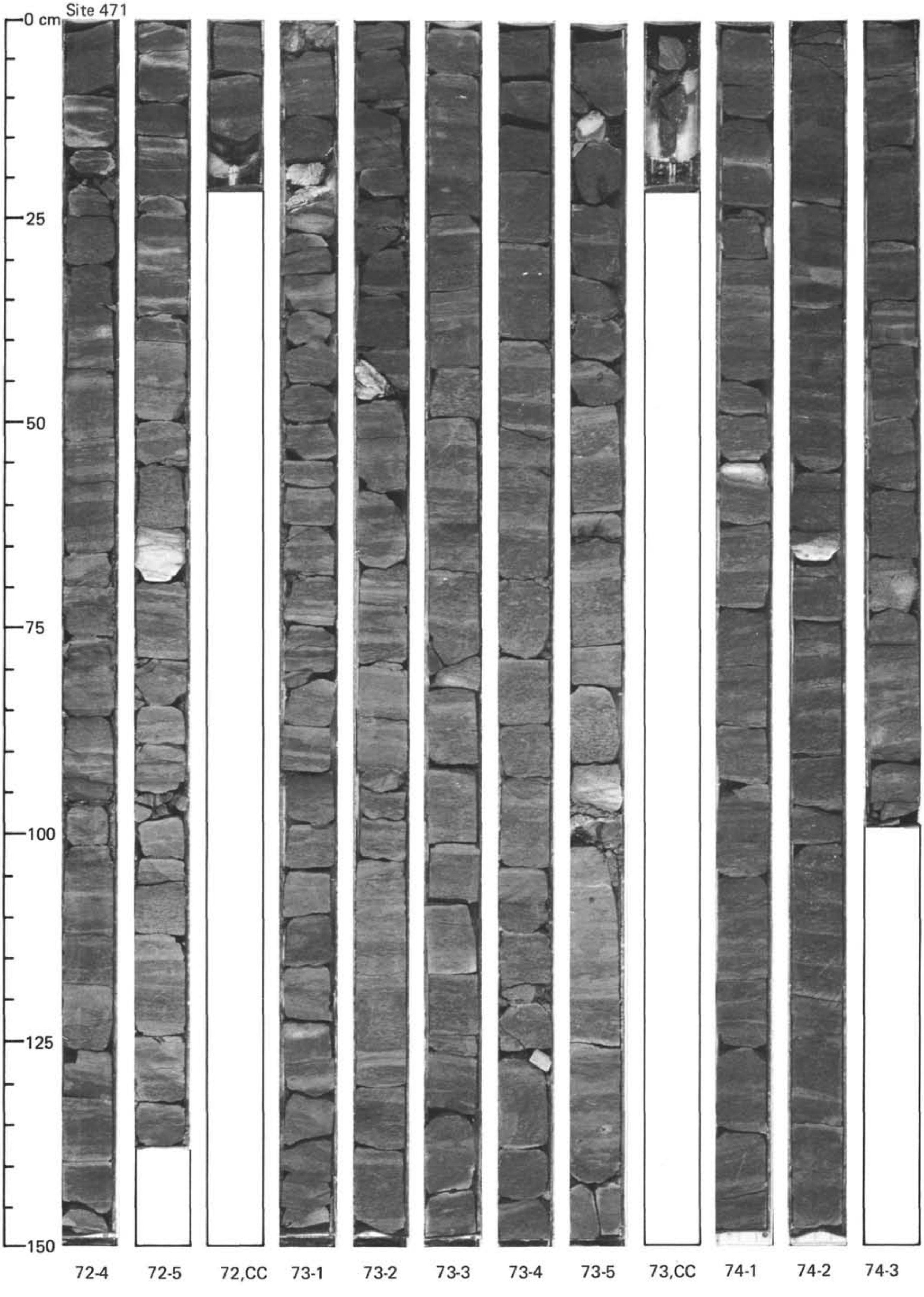
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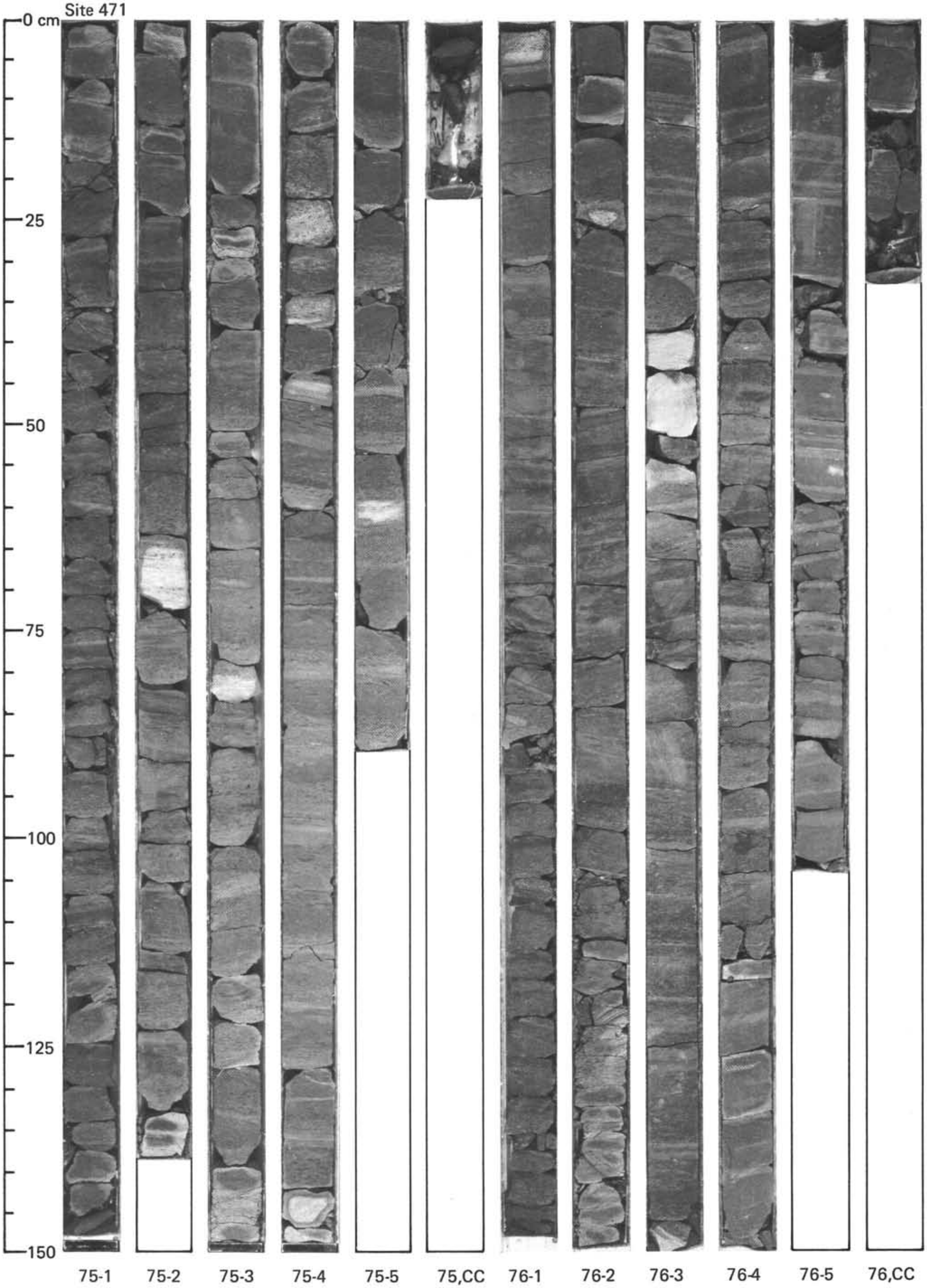
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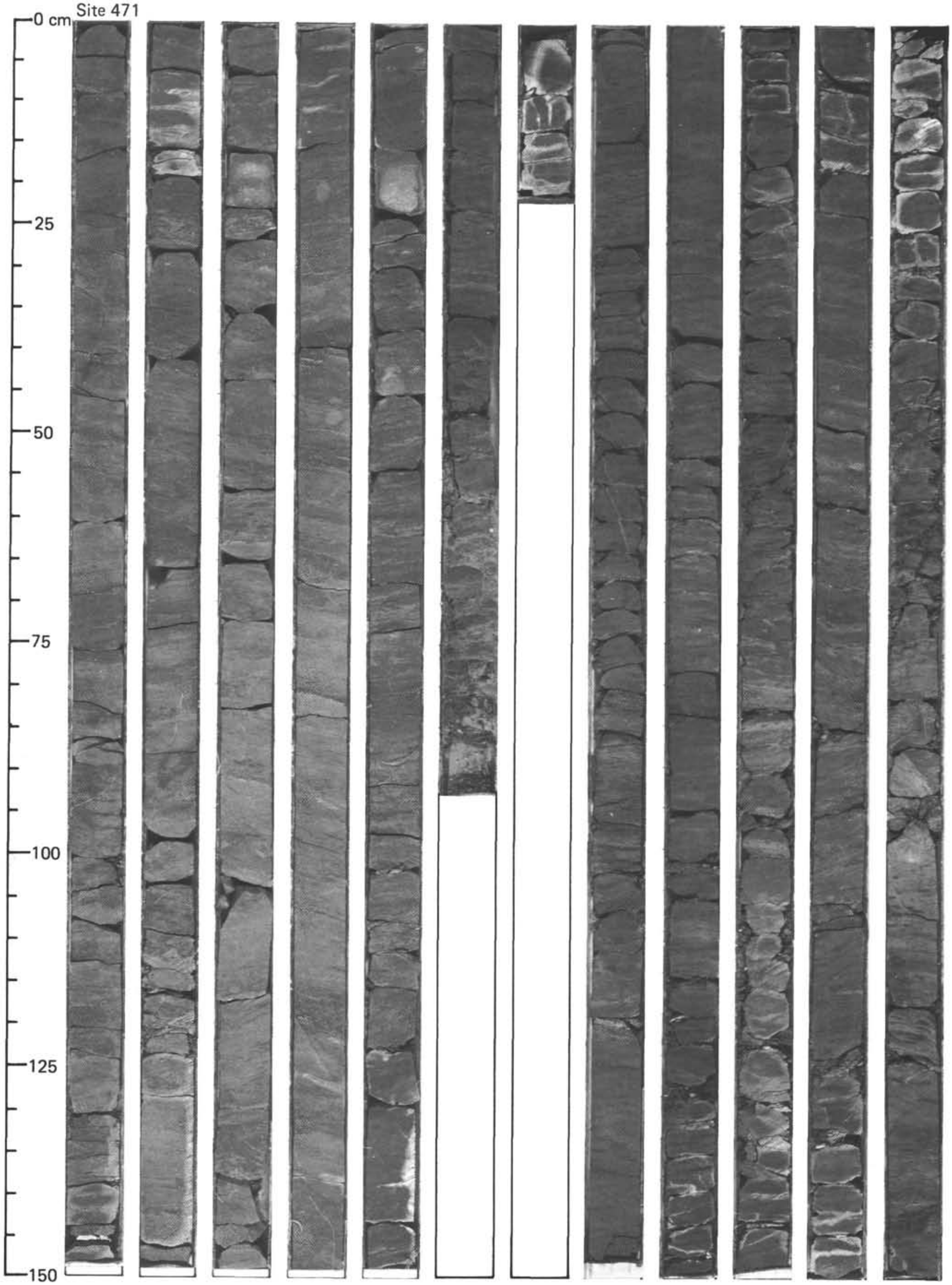
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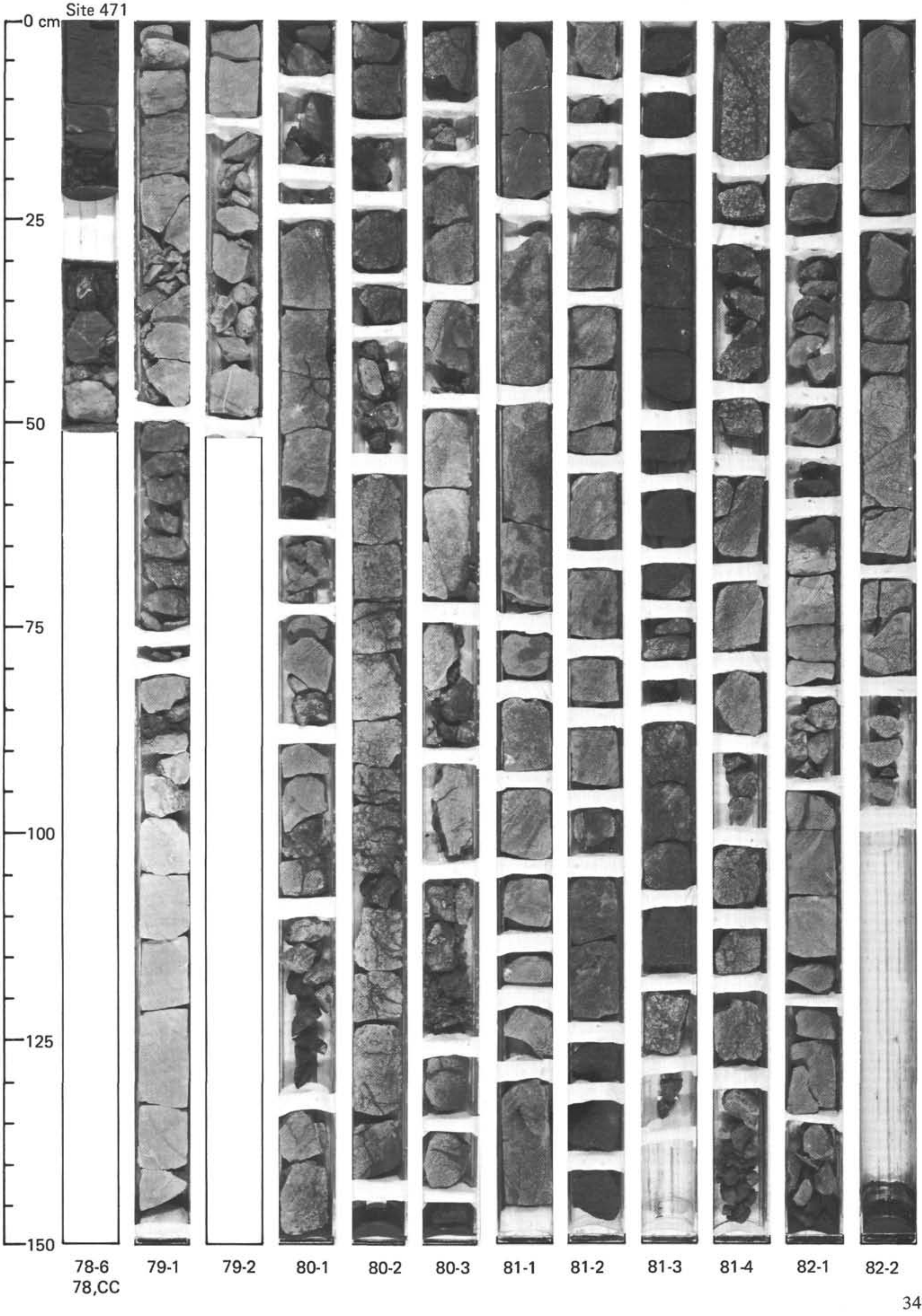
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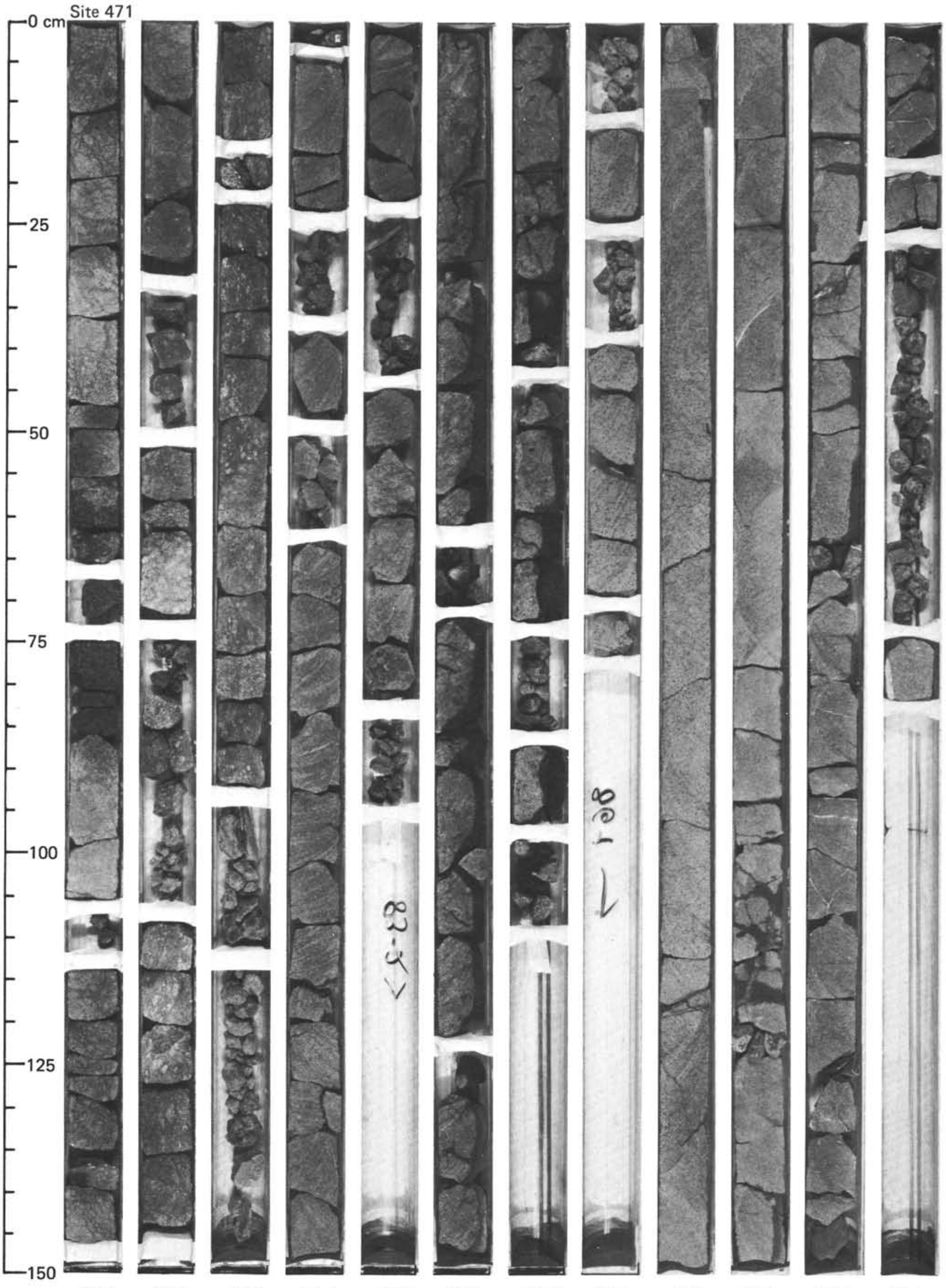
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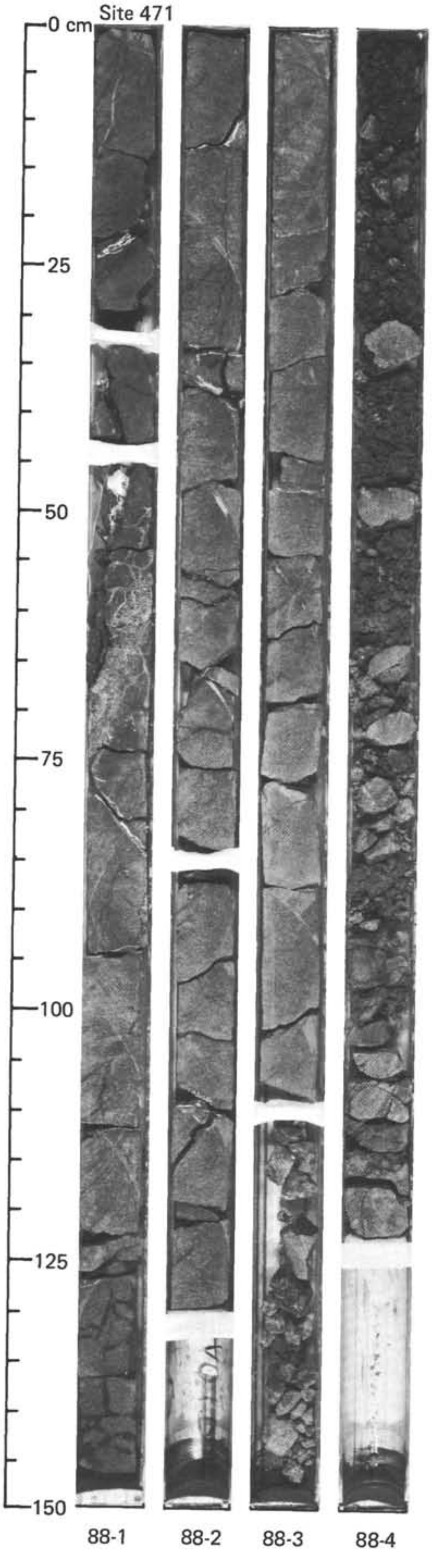
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