4. SITE 515: BRAZIL BASIN[1]

Shipboard Scientific Party[2]

HOLES 515, 515A, 515B

Date occupied: 29 February 1980

Date departed: 9 March 1980

Time on site: 212.7 hr.

Number of holes: 3

Position: 515 26°14.33′S; 36°30.17′W
515A 26°14.31′S; 36°30.17′W
515B 26°14.32′S; 36°30.19′W

	515	515A	515B
Water depth (sea level; corrected m, echo-sounding):	4250.4	4252.0	4252.0
Water depth (rig floor; corrected m, echo-sounding):	4260.4	4262.0	4262.0
Bottom felt (m, drill pipe):	4265.0	4266.6	4266.6
Penetration (m):	55.5	107.9	636.4
Number of cores:	3	27	57
Total length of cored section (m):	17.5	107.9	541.5
Total core recovered (m):	5.45	95.69	429.10
Core recovery (%):	31	89	79

Oldest sediment cored:

Depth sub-bottom (m): 636.4
Nature: Zeolite-rich calcareous mudstone
Age: early Eocene
Measured velocity (km/s): 1.87 to 2.14

Principal results: Hole 515 was rotary drilled and washed to 55 m, but the drilling was terminated when the pressure core barrel jammed in the bottom-hole assembly. In Hole 515A, the hydraulic piston corer (HPC) was used to core to 107.9 m, with 89% recovery. Hole 515B was washed to 94.9 m, rotary drilled to 636.4 m, with 79% recovery. The lithologic section is divided into three lithologic units.

Unit 1 consists of 180 m of grayish brown terrigenous mud of Quaternary to middle Miocene age, with occasional nannofossil-rich and foraminifer-rich layers in the upper part. Subunit 2a is 351 m of dark greenish gray biosiliceous mud and mudstone of middle Miocene to late Oligocene age with occasional nannoplankton-rich and rare foraminifer-rich horizons. Subunit 2b contains 84 m of dark greenish gray terrigenous mudstone of late Oligocene age, with only traces of siliceous microfossils and evidence of silica diagenesis. Unit 3 is 20 m (minimum) of lower Eocene greenish gray calcareous zeolitic mudstone.

Site 515 was chosen to study the onset and variability of the flow of Antarctic Bottom Water (AABW) through the Vema Channel into the Brazil Basin. The 22 Ma hiatus between Subunits 2b and 3 includes the Eocene/Oligocene boundary, which might correspond with the onset of AABW production. The lithologic boundary between Subunit 2b and Unit 3 corresponds precisely to a sharp and strongly discordant acoustic reflector, which extends throughout the Brazil Basin. The overlying sediments of Units 1 and 2 are fine grained.

Early Eocene. Pelagic carbonates accumulated at normal rates of approximately 4 m/Ma during the early Eocene (Cores 515B-56 and 515B-57). Core 515B-56 grades upward from a pelagic carbonate to a dissolution facies consisting of a zeolitic clay with detrital mineral grains. The core contains thin laminations and cross laminations and a weak magnetic grain fabric aligned in a north-northeast direction, all evidence of active bottom currents beginning in the early Eocene.

Early Oligocene to middle Miocene. Biosiliceous and terrigenous mudstones accumulated rapidly (approximately 40 m/Ma). Considerable amounts of detrital minerals and intermittent laminated intervals indicate persistent bottom-current activity. The cessation of siliceous sedimentation during the middle Miocene is an oceanwide event in the tropical and temperate Atlantic and reflects a major threshold event of paleocirculation. That event is probably related to the widening of Drake Passage and consequent deepening of the eastward circumpolar flow, which may in turn have shifted the South Atlantic circulation from a pattern of meridional flow to one of zonal flow. The initiation of strong eastward circumpolar flow may have blocked the entry of cold and productive Antarctic and sub-Antarctic waters into the South and central Atlantic, and siliceous sedimentation abruptly ceased in the lower and middle latitudes.

Middle Miocene to middle Pleistocene. Terrigenous mudstones and intermittent layers of biogenic carbonate accumulated at rates of about 20 m/Ma. Absence of significant quantities of displaced Antarctic diatoms before the middle Pleistocene suggests that AABW flow was relatively weak before the middle Pleistocene at Site 515 or that the disappearance of diatoms downcore is due to postdepositional dissolution of siliceous tests. Alternatively, there may be an overprint of postdepositional dissolution of silica in the depth intervals of the Vema Channel above the regions of the strongest flow. Hence, the *absence* of displaced Antarctic diatoms is not necessarily evidence against the flow of AABW, if such a dissolution effect can be documented.

Middle Pleistocene to Recent. Abrupt changes in sediment facies occur on a time scale of 10^4 to 10^5 yr., indicating that strong fluctuations in depositional mechanisms, particularly turbidity currents and thermohaline bottom currents, also occur on such time scales. Carbonate spikes indicating as much as 30% $CaCO_3$ occur intermittently within carbonate-free terrigenous mud. These spikes do not generally correspond to peak abundances of displaced Antarctic diatoms. Two independent processes of redeposition have influenced the late Pleistocene and Recent depositional history at Site 515. Calcareous debris is probably reworked downslope from the northern flanks of the Rio Grande Rise or from the São Paulo Plateau, and the finer components of that sediment, perhaps distal

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[1] Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office).

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turbidites, produced the carbonate spikes. Pulses of AABW from the south are recorded by the presence of displaced Antarctic diatoms.

BACKGROUND AND OBJECTIVES

Site 515 lies in the southern Brazil Basin about 200 km north of the northern exit of the Vema Channel (Fig. 1). The site is located near the crest of a sediment drift and lies within a broad field of sediment waves. Thick sediments (about 1.6 s total thickness) overlie oceanic basement of Cenomanian-Turonian age (approximately 95 Ma). The main objective of drilling was to determine the history of Antarctic Bottom Water (AABW) flow through the Vema Channel during the Cenozoic, at a location sufficiently far north of the Channel exit to represent a clear depositional environment. The upper part of the sediment pile was expected to include sediment eroded from the Vema Channel area and regions much farther south, then entrained in AABW flow and transported northward (Ewing et al., 1971; Le Pichon et al., 1971). Fluctuations in the strength and volume of AABW flow should relate to global climatic changes; and they should be represented in the sediments by changes in accumulation rate, depositional fabric, carbonate content, the proportion of reworked sediment (including volcanic and other terrigenous debris, and microfossils), and grain size (Johnson et al., 1977; Ellwood and Ledbetter, 1977).

A consensus is developing that deep thermohaline convection began in the latest Eocene or earliest Oligocene and was responsible for greatly invigorating the oceanic thermohaline circulation (Benson, 1975; Savin et al., 1975; Kennett and Shackleton, 1976). Even if this is true for high southern latitudes, the northward movement of AABW into the Brazil Basin may have been delayed until much later by the presence of topographic barriers in the Falkland/Scotia Arc complex or in the Vema Channel itself. We planned to drill into the Eocene at Site 515 or until AABW was clearly no longer an effective control on sedimentation, whichever occurred deeper in the sediment pile. The Eocene sediment was expected to be pelagic or hemipelagic clay, representing a much quieter depositional environment, and reflection profiles across the site suggested a downward transition from higher energy conditions of sedimentation at a reflector at about 0.7 s (about 600 m) sub-bottom (Gamboa et al., this volume). We anticipated drilling to 700 to 800 m sub-bottom depth.

Relatively undisturbed hydraulic piston corer (HPC) samples facilitated studies of AABW fluctuations on the scale of the orbitally induced climatic variations (10^4 to 10^5 yr.). In addition, detailed studies of HPC samples at

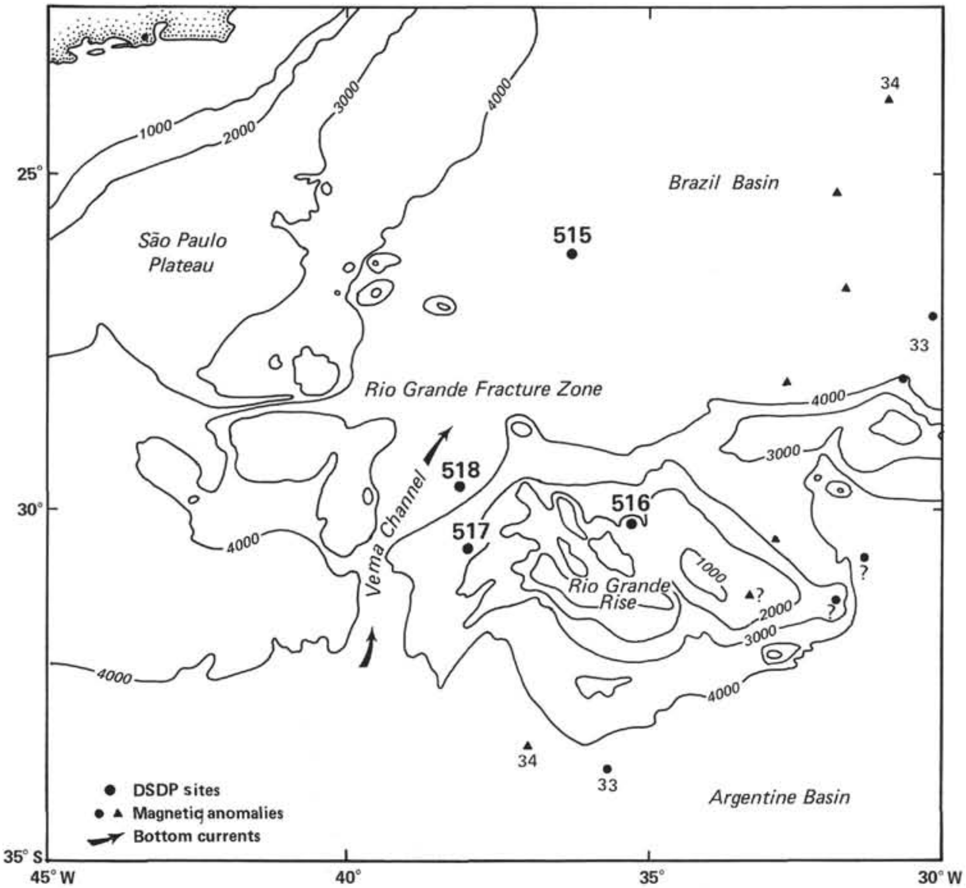

Figure 1. Location map showing positions of Leg 72 sites, marine magnetic anomalies, and generalized bathymetry.

all four Leg 72 sites were intended to interpret fluctuations in deep and bottom water flow on the basis of the lithologic, paleontologic, paleomagnetic, and stable isotopic evidence present in the cores.

OPERATIONS

Leg 72 commenced when *Glomar Challenger* left Santos, Brazil, late in the evening of 26 February enroute to Site 515 in the Brazil Basin at 26°14.33′S, 36°30.17′W. We approached the site on heading 091° at about 6 knots, dropped the beacon at 1820Z on 29 February, and continued on course for 30 minutes to extend the precision depth recorder (PDR) and reflection records beyond the site (Fig. 2). *Glomar Challenger* was on site at 2020Z, 29 February.

We planned to begin with rotary drilling operations, then drop the bit and sample the upper 100 or 200 m of the sedimentary section with the hydraulic piston corer. The first core from Hole 515 arrived on deck at 0849Z, 1 March. After two cores, the pressurized core barrel (PCB) jammed at 55 m sub-bottom forcing us to pull the drill string commencing at 1600Z, 1 March. Because any time gained by not tripping the pipe would be largely offset by the frequent spot rotary coring required to ascertain the ultimate depth of HPC penetration, we abandoned our original drilling plan. We decided to use the HPC for Hole 515A.

The location of the ship was offset 50 m to the northeast, and the mudline core of Hole 515A was recovered at 1206Z on 2 March. In general, the HPC worked very well and operations proceeded smoothly to a depth of 107.9 m sub-bottom, at which point Hole 515A was abandoned because of HPC refusal. We began pulling pipe at 0445Z on 4 March. Twenty-seven HPC cores were cut at 515A, and 95.69 m of unconsolidated sediment was recovered.

Hole 515B was washed to a sub-bottom depth of 94.9 m below mudline, and then the section was cored continuously. The first core arrived on deck at 0054Z, 5 March. Our objective was to penetrate a midsection reflector of regional extent at a time-depth of about 0.74 s, which was expected to represent the onset of AABW flow into the Brazil Basin. At 617 m, we penetrated the reflecting horizon in the form of a transition from Oligocene mudstone to Eocene zeolitic mudstone and continued drilling to a depth of 636.4 m. Because the Planning Committee objectives were fulfilled, operations at Site 515 were terminated with the recovery of Core 57 at 0126Z, 9 March. A total of 541.5 m of sediment was cored in Hole 515B, with a total recovery of 429.1 m (Table 1).

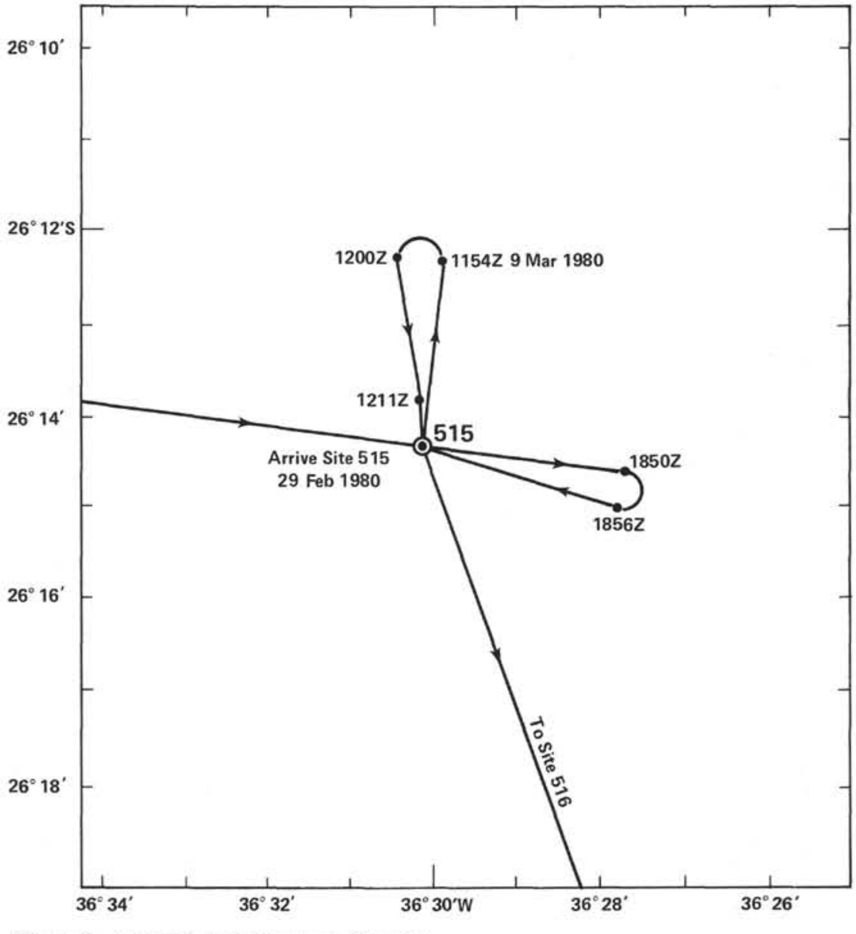

Figure 2. Approach and departure, Site 515.

Table 1. Coring summary, Site 515.

Core	Date (March 1980)	Time (Z)	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Core recovered (%)
Hole 515							
1	1	0849	4265.0–4266.5	0.0–1.5	1.5	1.50	100
2	1	1220	4304.5–4314.0	39.5–49.0	9.5	3.95	42
3	1	2200	4314.0–4320.5	49.0–55.5	6.5	0.00	0
					17.5	5.45	31
Hole 515A							
1	2	1206	4266.6–4270.9	0.0–4.3	4.3	4.25	98
2	2	1337	4270.9–4275.3	4.3–8.7	4.4	4.09	93
3	2	1505	4275.3–4279.7	8.7–13.1	4.4	4.41	100+
4	2	1621	4279.7–4284.1	13.1–17.5	4.4	4.41	100+
5	2	1736	4284.1–4288.5	17.5–21.9	4.4	4.25	97
6	2	1844	4288.5–4292.9	21.9–26.3	4.4	4.53	100+
7	2	1951	4292.9–4297.3	26.3–30.7	4.4	4.43	100+
8	2	2115	4297.3–4301.7	30.7–35.1	4.4	4.60	100+
9	2	2227	4301.7–4306.1	35.1–39.5	4.4	4.39	100
10	2	2349	4306.1–4310.5	39.5–43.9	4.4	4.27	97
11	3	0255	4310.5–4314.9	43.9–48.3	4.4	4.30	98
12	3	0430	4314.9–4319.3	48.3–52.7	4.4	4.16	95
13	3	0613	4319.3–4323.7	52.7–57.1	4.4	4.34	99
14	3	0750	4323.7–4328.1	57.1–61.5	4.4	4.36	99
15	3	1026	4328.1–4332.5	61.5–65.9	4.4	0.00	0
16	3	1146	4332.5–4336.5	65.9–69.9	4.0	4.10	100+
17	3	1306	4336.5–4340.5	69.9–73.9	4.0	3.81	95
18	3	1434	4340.5–4344.5	73.9–77.9	4.0	3.68	92
19	3	1548	4344.5–4348.5	77.9–81.9	4.0	1.86	46
20	3	1310	4348.5–4352.5	81.9–85.9	4.0	0.00	0
21	3	1828	4352.5–4355.5	85.9–88.9	3.0	3.19	100+
22	3	1941	4355.5–4357.5	88.9–90.9	2.0	1.92	96
23	3	2101	4357.5–4361.5	90.9–94.9	4.0	4.01	100+
24	3	2239	4361.5–4365.5	94.9–98.9	4.0	4.03	100+
25	4	0015	4365.5–4369.0	98.9–102.4	3.5	3.37	96
26	4	0154	4369.0–4372.0	102.4–105.4	3.0	2.50	83
27	4	0326	4372.0–4374.5	105.4–107.9	2.5	2.45	98
					107.9	95.69	89
Hole 515B							
Wash	4	—	4266.6–4361.5	0.0–94.9	—	—	—
1	4	2454	4361.5–4371.0	94.9–104.4	9.5	5.60	59
2	4	0223	4371.0–4380.5	104.4–113.9	9.5	3.12	33
3	5	0407	4380.5–4390.0	113.9–123.4	9.5	9.15	96
4	5	0546	4390.0–4399.5	123.4–132.9	9.5	9.40	99
5	5	0728	4399.5–4409.0	132.9–142.4	9.5	5.47	58
6	5	0900	4409.0–4418.5	142.4–151.9	9.5	9.64	100+
7	5	1035	4418.5–4428.0	151.9–161.4	9.5	6.67	70
8	5	1211	4428.0–4437.5	161.4–170.9	9.5	5.47	58
9	5	1335	4437.5–4447.0	170.9–180.4	9.5	0.05	0.5
10	5	1535	4447.0–4456.5	180.4–189.9	9.5	5.45	57
11	5	1709	4456.5–4466.0	189.9–199.4	9.5	9.35	96
12	5	1841	4466.0–4475.5	199.4–208.9	9.5	4.40	46
13	5	2013	4475.5–4485.0	208.9–218.4	9.5	9.37	99
14	5	2134	4485.0–4494.5	218.4–227.9	9.5	9.81	100+
15	5	2301	4494.5–4504.0	227.9–237.4	9.5	6.71	71
16	6	0035	4504.0–4513.5	237.4–246.9	9.5	4.55	48
17	6	0202	4513.5–4523.0	246.9–256.4	9.5	4.64	49
18	6	0340	4523.0–4532.5	256.4–265.9	9.5	2.35	25
19	6	0520	4532.5–4542.0	265.9–275.4	9.5	5.77	61
20	6	0653	4542.0–4551.5	275.4–284.9	9.5	9.13	96
21	6	0825	4551.5–4561.0	284.9–294.4	9.5	9.20	97
22	6	1010	4561.0–4570.5	294.4–303.9	9.5	8.50	89
23	6	1147	4570.5–4580.0	303.9–313.4	9.5	9.24	97
24	6	1320	4580.0–4589.5	313.4–322.9	9.5	0.27	3
25	6	1501	4589.5–4599.0	322.9–332.4	9.5	9.30	98
26	6	1640	4599.0–4608.5	332.4–341.9	9.5	9.20	97
27	6	1813	4608.5–4618.0	341.9–351.4	9.5	9.17	97
28	6	1941	4618.0–4627.5	351.4–360.9	9.5	9.93	100+
29	6	2114	4627.5–4637.0	360.9–370.4	9.5	9.80	100+
30	6	2235	4637.0–4646.5	370.4–379.9	9.5	9.73	100+
31	7	0002	4646.5–4656.0	379.9–389.4	9.5	9.73	100+
32	7	0031	4656.0–4665.5	389.4–398.9	9.5	9.79	100+
33	7	0309	4665.5–4675.0	398.9–408.4	9.5	9.77	100+
34	7	0455	4675.0–4684.5	408.4–417.9	9.5	9.90	100+
35	7	0630	4684.5–4694.0	417.9–427.4	9.5	9.77	100+
36	7	0803	4694.0–4703.5	427.4–436.9	9.5	9.40	99
37	7	0925	4703.5–4713.0	436.9–446.4	9.5	9.77	100+
38	7	1110	4713.0–4722.5	446.4–455.9	9.5	9.81	100+
39	7	1251	4722.5–4732.0	455.9–465.4	9.5	9.71	100+
40	7	1436	4732.0–4741.5	465.4–474.9	9.5	8.33	88
41	7	1601	4741.5–4751.0	474.9–484.4	9.5	9.93	100+
42	7	1721	4751.0–4760.5	484.4–493.9	9.5	0.10	1
43	7	1848	4760.5–4770.0	493.9–503.4	9.5	9.81	100+
44	7	2018	4770.0–4779.5	503.4–512.9	9.5	8.52	90
45	7	2000	4779.5–4789.0	512.9–522.4	9.5	9.15	96
46	8	0005	4789.0–4798.5	522.4–531.9	9.5	9.78	100+
47	8	2336	4798.5–4808.0	531.9–541.4	9.5	7.60	80
48	8	0526	4808.0–4817.5	541.4–550.9	9.5	5.96	63
49	8	0730	4817.5–4827.0	550.9–560.4	9.5	7.68	81
50	8	0940	4827.0–4836.5	560.4–569.9	9.5	8.75	92
51	8	1148	4836.5–4846.0	569.9–579.4	9.5	6.44	68
52	8	1343	4846.0–4855.5	579.4–588.9	9.5	1.10	12
53	8	1551	4855.5–4865.0	588.9–598.4	9.5	9.20	97
54	8	1748	4865.0–4874.5	598.4–607.9	9.5	2.13	22
55	8	2007	4874.5–4884.0	607.9–617.4	9.5	8.47	89
56	8	2244	4884.0–4893.5	617.4–626.9	9.5	9.35	98
57	9	0126	4893.5–4903.0	626.9–636.4	9.5	8.71	92
					541.5	429.10	79

After 9 days, we left Site 515 at 1130Z on 9 March heading 000° at a speed of approximately 6 knots; we streamed profiling gear, turned, and approached the site on heading 180°. As we passed over the beacon at 1219Z, we changed course to 164° enroute to Site 516 on the Rio Grande Rise.

SEDIMENT LITHOLOGY

Three units can be defined at Site 515 on the basis of lithology and color (Fig. 3). These units are described from top to bottom of the site. (Depths in parentheses are sub-bottom depths).

Unit 1: Terrigenous Mud and Clay (0–180 m)

This unit (Cores 515A-1 to 515A-27 and Cores 515B-1 to 515B-9) is composed of grayish brown terrigenous mud and clay with occasional nannofossil-rich layers and some foraminifer-rich layers. Throughout most of this unit, clay content is 75–85%, quartz plus feldspar 10%, pyrite and micronodules 2%, heavy minerals 2%, and mica about 1%. The average texture is 3% sand, 20% silt, and 77% clay. Unit 1 is homogeneous except for a few dark spots and laminations that occur throughout. Dark spots are probably burrows, indicating a small amount of bioturbation, which increases towards the base of this unit. The paucity of laminations throughout this section suggests little variation in the flow regime at the bottom during its deposition. Unit 1 was HPC sampled at Hole 515A and rotary cored at Hole 515B. HPC samples are far less deformed than their counterparts from 515B.

The carbonate-free muds of Unit 1 are interbedded with thin zones slightly enriched in $CaCO_3$ (Fig. 4). Peak values of the carbonate-bearing zones vary from values of only 1–5% to maxima of 25–30% (Shor et al., this volume). The zones occur throughout the Pleistocene and Holocene sections (from the top of the cored section to approximately 44 m sub-bottom in 515A-11), but these carbonate-rich zones are more rare below the Pleistocene. The relation of carbonate preservation at this deep site to the strength of flow through the Vema Channel, erosion of exposed carbonates, and corrosiveness of bottom water in the Brazil Basin is the subject of a separate chapter (Shor et al., this volume).

An increase in the abundance of the biogenic component marks the transition of Unit 1 to Unit 2.

Unit 2: Siliceous Mud and Siliceous and Terrigenous Mudstone (180–617 m)

This unit (Cores 515B-10 to 515B-55) consists of dark greenish gray siliceous mud grading down to a siliceous and terrigenous mudstone. Unit 2 is divided into two subunits on the basis of biogenic silica content.

Subunit 2a (180–531 m sub-bottom depth, Cores 515B-10 to 515B-46) consists of dark greenish gray siliceous mud and mudstone. In general, the clay content of this unit is about 75%; quartz and feldspar about 5%; siliceous biogenic remains (diatoms, radiolarians, and sponge spicules) about 15%; and micronodules, pyrite, heavy minerals, and mica together about 5%. Calcareous nannofossils reach 10% in abundance in some

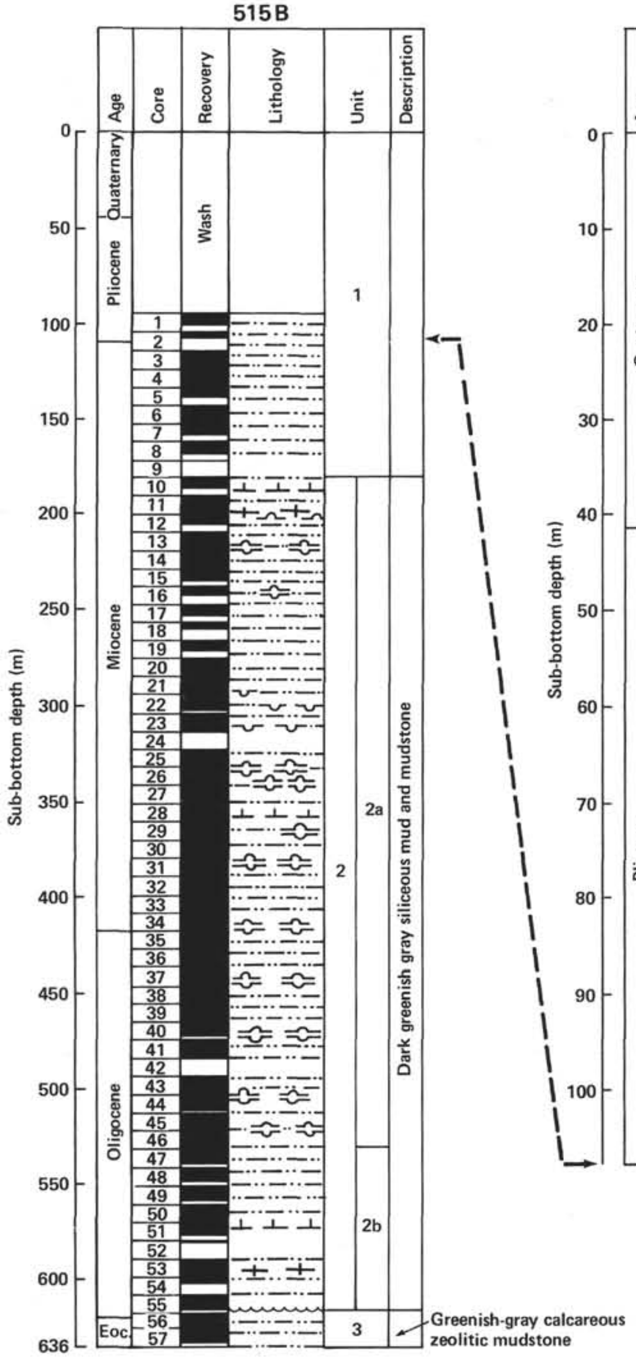

Figure 3. Major lithologic units, Site 515.

layers. Chamosite is abundant in spherules, and these gradually increase downward.

Sedimentary structures appear with increasing frequency in the lower portion of Unit 2. The lithified portions of Unit 2 (below Core 515B-18) contain faults (not due to drilling) and flattened burrows, suggesting compaction. Scattered parallel and cross laminations, possible ripple marks, silty laminae (perhaps evidence of winnowing), sedimentary folds and rip-up clasts (Fig. 5), indicate an increase in the flow regime and perhaps higher sedimentation rates during deposition of the lower part of Subunit 2a. At the base of Subunit 2a, siliceous microfossils are calcified.

Subunit 2b (531–615 m sub-bottom depth, Cores 515B-47 to 515B-55) contains dark greenish gray terrigenous mudstones. Siliceous microfossils are absent or present only in traces. Well-defined, light greenish gray laminated layers about 10 to 15 cm in thickness occur in Subunit 2b, but are rare. Lighter-colored layers are rich in nannofossils and often are altered to chert at their base. These layers have sharp basal contacts in contrast to gradational contacts at their tops. The basal contacts

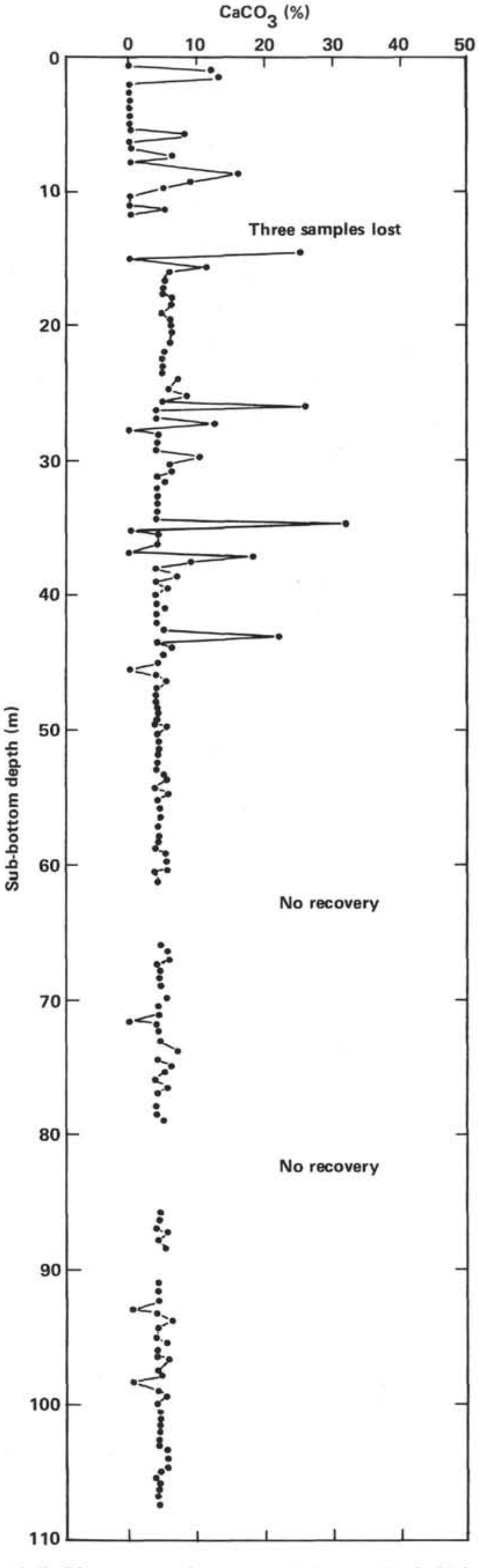

Figure 4. CaCO$_3$ concentration versus sub-bottom depth, Hole 515A.

may indicate pulses of bottom water flow that transported siliceous and calcareous organisms into the Brazil Basin, or distal members of turbidites deposited by flows from the Rio Grande Rise.

A well-defined unconformity spanning approximately 22 Ma and represented by a lag deposit at the base of Core 515B-55 (617 m sub-bottom) marks the contact between Unit 2 and Unit 3. The lag deposit consists of subrounded to subangular grains of fine sand, composed mainly of quartz, fish teeth, glauconite, biotite, and assorted heavy minerals, including zircon. Many of the quartz grains have rutile inclusions. The base of Unit 2 changes to a brown-gray color close to the contact with Unit 3.

Unit 3: Calcareous Zeolitic Mudstone (617–636.4 m)

Unit 3 (Cores 515B-56 and 515B-57) contains greenish gray calcareous zeolitic mudstone. Color varies considerably within this unit; both the color range and patterns are striking. The top of Unit 3 is yellowish brown and changes downward to a greenish gray color, perhaps indicating exposure of the top portion of Unit 3 to currents at the seafloor. The average grain size is about 2% sand, 42% silt, and 56% clay. Clay-rich layers become dark gray to black at the top of the unit and alternate with silty layers. The dark clay-rich layers contain biotite and are very poor in organic matter. Carbonate content is low in the upper 4 m of Unit 3, but below that level calcareous nannofossils reach concentrations of 20% or more. Zeolites are abundant throughout, reaching a maximum of 15% (visual estimates). Parallel bedding, cross laminations (515B-56-5, 0–10 cm), and possible climbing ripples or current ripples are also present (Fig. 6). Winnowing occurs, and bioturbation is extensive. Burrows are flattened parallel to bedding and often resemble laminations.

Calcite Compensation Depth

The calcite compensation depth (CCD) may be estimated by backtracking from the early Eocene (about 52 Ma) sediments directly beneath the hiatus at 617 m, and the middle Oligocene (about 30 Ma) sediments directly above. The former contain 10–20% carbonate, but poor preservation and low diversity suggest that the site lay not too far above the early Eocene CCD. Calcareous microfossils occur only sporadically in the basal Oligocene sediments, therefore the mid-Oligocene CCD lay, for the most part, above the site.

Based on ocean-floor subsidence curves (Parsons and Sclater, 1977), and assuming a basement age of 98 Ma subsidence through cooling is estimated as 820 m since the early Eocene (52 Ma), but only about 410 m since the middle Oligocene (30 Ma).

Calculation of the isostatic response to post-Eocene sedimentation depends upon assumptions about the effect of that load on the compaction and diagenetic alteration of the underlying sediment. If these effects are neglected, removal of 617 m of sediment of mean density 1.65 g/cm^3 would lower the seabed by about 448 m. Assuming, more realistically, that post-Eocene deposition

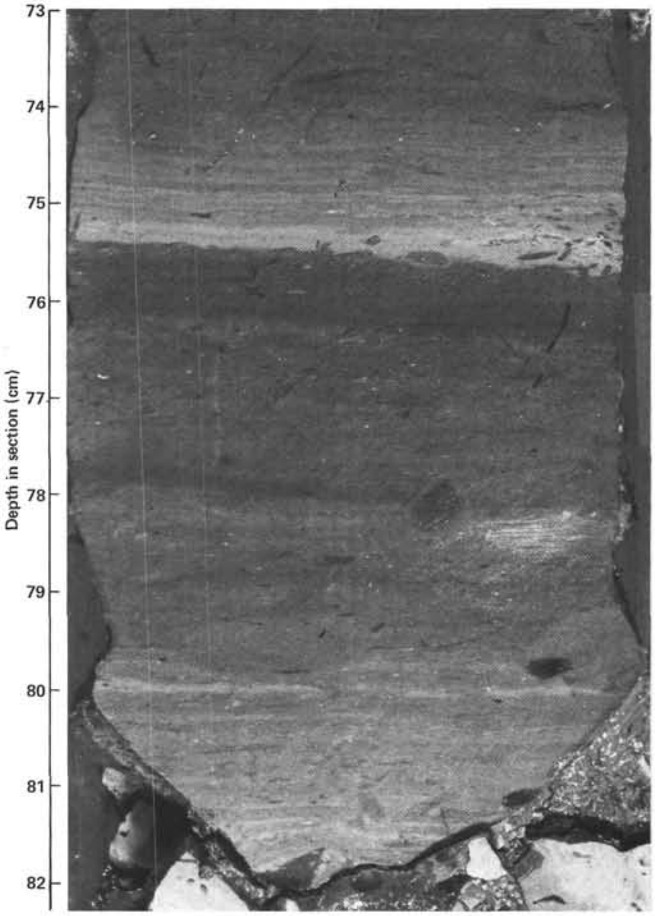

Figure 5. Cross laminations and rip-up clasts in Sample 515B-46-1, 73–82 cm.

has affected the underlying sediment, then it is more reasonable to strip off the same weight of sediment, but in a more compacted state. In this case, that is equivalent to extracting a central or a lower section of the sediment pile, here more than 1.6 km thick, rather than the uppermost. Assuming a density of 2.0 g/cm^3 for that interval, the seabed is only depressed by 225 m. This value is appropriate for both the lower Eocene and middle Oligocene, assuming that compaction occurs mainly under nonhydrostatic load.

Combining the cooling and the isostatic effects, the early Eocene CCD (52 Ma) at Site 515 was below 3665 m (= 4260 + 225 − 820), and in the middle Oligocene (30 Ma) the CCD was above 4075 m (= 4260 + 225 − 410). The Eocene value is considerably deeper than that determined by van Andel and others (1977) for the Pacific but close to that of Berger (1972). The Oligocene depth agrees with most models.

SEDIMENTARY GEOCHEMISTRY

Results of the shipboard geochemical analyses are given in Table 2 and in Figure 7. Salinity and the calcium and magnesium ion concentrations are uniformly related to sub-bottom depth. Salinity and Mg^{+2} decrease, but Ca^{+2} increases.

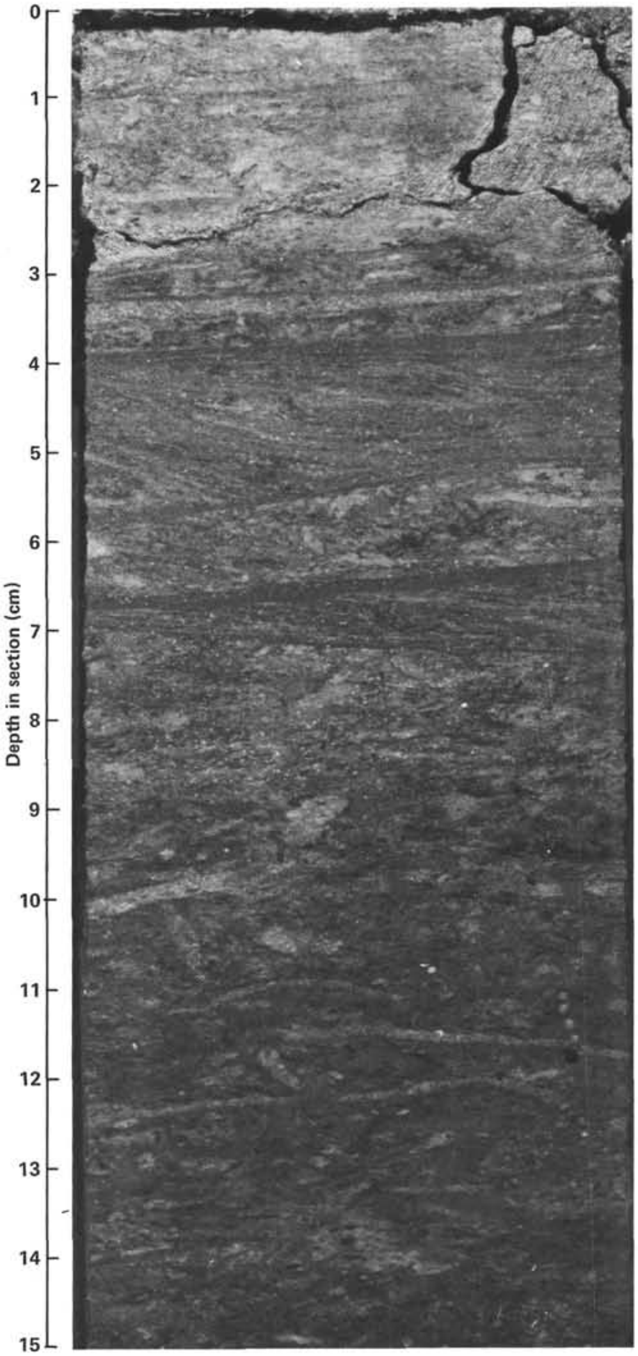

Figure 6. Parallel bedding and cross laminations in Sample 515B-56-5, 0–15 cm.

Carbonate Analysis

Routine carbonate bomb analyses were performed on samples obtained at 50-cm intervals (3 per section) in HPC cores from Hole 515A, and on one sample per core for the remainder of the site (Holes 515 and 515B). Values are listed on the core description forms accompanying this chapter. Shore laboratory analyses were made on samples from Hole 515A, Cores 1 to 14, at 10-cm intervals (Shor et al., this volume).

Table 2. Shipboard geochemical analyses for Site 515 samples.

Core-section (interval in cm)	Sub-bottom depth (m)	pH	Salinity (‰)	Chlorinity (‰)	Alkalinity (meq/l)	Calcium (mmoles/l)	Magnesium (mmoles/l)
Hole 515A							
2-2, 143–140	42.43–42.50	7.588	35.2	19.48	3.954	14.71	44.88
Hole 515B							
1-3, 140–150	99.30–99.40	7.396	34.4	19.51	3.881	17.09	38.10
6-3, 144–150	146.04–146.90	7.156	34.1	19.28	4.843	18.32	32.88
11-5, 140–150	197.30–197.40	7.211	34.1	19.38	5.879	19.98	26.67
16-2, 140–150	240.30–240.40	7.404	34.1	19.41	7.087	21.12	23.32
21-4, 140–150	290.80–290.90	7.913	33.6	19.31	7.103	22.20	20.08
26-1, 140–150	333.80–333.90	7.502	33.3	19.68	4.381	22.22	18.20
31-4, 140–150	385.80–385.90	7.872	33.3	19.51	6.516	24.13	15.22
36-4, 140–150	433.30–433.40	7.916	33.3	19.41	6.334	25.83	14.02
39-5, 140–150	463.30–463.40	7.676	33.0	19.58	1.301	22.81	12.42
41-5, 140–150	482.20–482.40	7.899	33.0	19.55	4.164	24.38	12.07
46-5, 140–150	529.80–529.90	7.985	32.7	19.28	3.204	25.76	11.48
51-3, 140–150	574.30–574.40	8.054	31.6	19.21	—	24.90	10.56
55-5, 140–150	615.30–615.40	—	31.1	18.17	—	25.36	11.03

Note: Dashes indicate that information was not available.

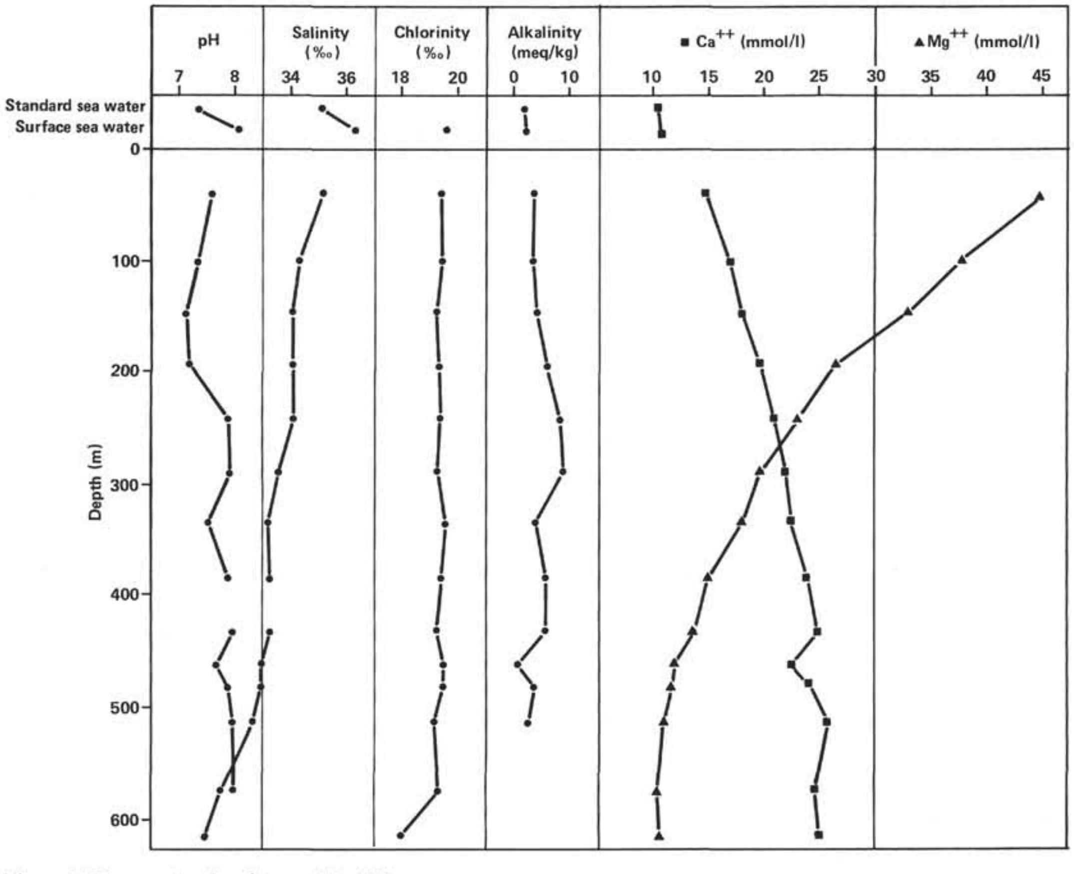

Figure 7. Pore water chemistry at Site 515.

The low carbonate contents of sediments from this site are near the precision of the bomb method (±1%). The minimum detection level in the present case is limited by the detection limit of the pressure sensor for the given size of sample and varies from 3 to 4%.

X-Ray Diffraction (XRD) Analysis

X-ray diffractograms were routinely generated by a Rigaku machine fitted with a Cu tube emitting CuKα radiation at 30 kV, 10 mA. For an introduction to some of the operational peculiarities of the shipboard system and methods of sample preparation and analysis, see Coulbourn, this volume.

Interpretation of 108 X-ray diffractograms for Hole 515B indicates a major break in clay mineral composition within Core 56 between 618 and 620 m sub-bottom. Above that level, peaks suggest that montmorillonite, illite, quartz, and phillipsite are most characteristic of the section cored. Kaolinite is abundant at Hole 515A and in the uppermost cores at 515B. Calcite is present in the lighter-colored laminations; fluorapatite occurs in burrows at 515B-23-1, 94 cm, and 515B-39-2, 90 cm, and the microspherules described from burrows at 515B-22-3, 14 cm are chamosite oolites. The major lithologic break sampled by the core catcher of Core 515B-55 (boundary between Units 2 and 3) corresponds to an abrupt change in XRD patterns from montmorillonitic clays of Unit 2 to clinoptilolite-rich sediments of Unit 3. The change is spread over the first four sections of Core 515B-56.

Below 620 m sub-bottom (Sample 515B-56-21, 70 cm) clinoptilolite, calcite, and quartz are the dominant mineral components of the section. Montmorillonite and illite either are absent or occur as minor components of the sediment. A cherty horizon occurs at Sample 515B-57-1, 38 cm.

BIOSTRATIGRAPHY

Recent to lower Eocene sediments were recovered at Site 515. Abundant diatoms and radiolarians are present within middle Miocene to upper Oligocene samples from Cores 515B-8 through 515B-44. Based on the frequency and preservation of the calcareous microfossils, a twofold subdivision of the stratigraphic section is apparent.

The Quaternary to lower Oligocene sediment, from 0 to 617 m sub-bottom depth, contains low relative abundances of calcareous microfossils, perhaps the result of dilution by the rapid accumulation of transported terrigenous bottom sediments. The preservation of the calcareous microfossils is generally poor; strong effects of carbonate dissolution are visible at most levels. Dilution and dissolution are predominant over the effects of surface productivity at this site, and barren intervals separate intervals with calcareous microfossils throughout. As a result, it is impossible to determine whether the sedimentation in this part of the section is continuous.

At 541 m sub-bottom (Core 515B-47), a concentration of fish debris and a decrease in the abundance and preservation of siliceous microfossils indicate an environmental change. Slightly lower in the section (Core 515B-48), well-preserved planktonic foraminifers are associated with an unusual assemblage of benthic foraminifers dominated by the genera *Pyrulina, Lagena*, and *Ellipsoidella.* Farther down the section, this assemblage alternates with a second assemblage containing simple-structured, agglutinated benthic foraminifers. The oldest event in this stratigraphic interval is the gradual disappearance of nannofossils near Core 515B-52.

The concentration of fish debris suggests slow sedimentation, indicating dissolution of the remaining biogenic fraction. Predominance of simple-agglutinated foraminifers is also related to carbonate dissolution, typical in regions of great water depth where the tests of calcareous benthic foraminifers cannot remain intact after their death (e.g., the North Pacific today). The high abundance of fish debris and the presence of the assemblage of simple-agglutinated foraminifers between Cores 515B-47 and 515B-55 coincides with the intervals that are barren of other calcareous microfossils. At intervals where planktonic foraminifers are abundant, the assemblage of simple-agglutinated foraminifers is replaced by the calcareous benthic assemblage. This faunal periodicity is related to variations in the CCD and accumulation rate. The barren intervals represent episodes of relatively slow accumulation and, conversely, the calcareous intervals represent episodes of faster accumulation, effectively protecting the local (*in situ*) calcareous fauna from dissolution. In the upper part of the section (Cores 515B-1 to 515B-46), the absence of simple-agglutinated foraminifers and concentrations of fish remains suggests a different depositional history. There, faunal abundance may be related to CCD fluctuations only, while the sedimentation rate remained consistently high.

The biostratigraphic subdivision of Unit 3, from 623 to 636 m sub-bottom, is based on abundant lower Eocene calcareous microfossils with variable, but mostly good, preservation. Recognition of three successive biozones within this unit indicates continuous sedimentation at slow rates. Lithologic Unit 1 and Subunits 2a and 2b are separated from Unit 3 by a major hiatus of about 22 Ma duration from the early Eocene (52 Ma) to middle Oligocene (30 Ma).

Nannoplankton

Unless otherwise noted, age determination and zonal boundaries are based upon smear slides of core catcher samples. The standard Cenozoic zonations of Martini (1971) and Gartner (1977) were used for stratigraphic age determination. Seven biostratigraphic intervals were identified based on investigation of 153 samples:

1) Quaternary (Cores 515-1 and 515-2; 515A-1 to 515A-10)
2) lower Pliocene to middle Miocene (Cores 515B-6 to 515B-10)
3) middle Miocene (Core 515B-11)
4) lower Miocene (Cores 515B-22 to 515B-35)
5) upper Oligocene (Cores 515B-37 to 515B-48)
6) ?upper Oligocene (Core 515B-52)
7) lower Eocene (Cores 515B-56 to 515B-57)

Quaternary

Quaternary sediments were recovered only in the HPC cores of Holes 515 and 515A. Rare to common but poorly preserved assemblages were found throughout the Quaternary section. The assemblages in Cores 515-1 and 515A-1 belong to *Emiliania huxleyi/Gephyrocapsa oceanica* zones (NN21/20). The distinction between the *E. huxleyi* and *G. oceanica* zones is difficult because of the close resemblance of the nominal species when they are analyzed by light microscope only. The last occurrence of *Pseudoemiliania lacunosa* marks the base of Zone NN20. Principal floral components include *Gephyrocapsa oceanica, Ceratolithus cristatus, C. telesmus, Cyclococcolithus leptoporus, Helicopontosphaera kamptneri*, and *Rhabdosphaera clavigera.*

The assemblages from Cores 515-2 and 515A-3 contain Pseudoemiliania lacunosa but lack discoasters, indicating the *P. lacunosa* Zone s.l. (NN19). Core 515A-3 belongs to the *P. lacunosa* Zone s.s., which according to Gartner (1977) equals the upper part of Martini's (1971) *P. lacunosa* Zone s.l. *Cyclococcolithina macintyrei* and *Helicopontosphaera sellii* occur together in Core 515-2.

This interval represents the *C. macintyrei* Zone, which is the base of Martini's (1971) *P. lacunosa* Zone.

Lower Pliocene to Middle Miocene

Lower Pliocene (NN16) to ?upper Miocene floras were recovered in Cores 515B-6 to 515B-10. The top of this interval is drawn at the last occurrence of *Discoaster challengeri* (middle part of *D. surculus* Zone—NN16) and the base at the co-occurrence of *D. deflandrei* and *D.* cf. *pentaradiatus.* The samples are often barren.

Middle Miocene

Middle Miocene sediments were recovered only in Core 515B-11. The range of *Discoaster kugleri* restricts this poorly preserved assemblage to NN7 or the lower part of NN8.

Lower Miocene

Generally few to common and poorly preserved lower Miocene assemblages occur in the interval 515B-23 to 515B-27 with the index species *Cyclococcolithus neogammation, D. druggi,* and *Sphenolithus heteromorphus.* These assemblages indicate the *S. belemnos* Zone (NN3) to the *S. heteromorphus* Zone (NN5) of the early Miocene. Cores 515B-28 to 515B-34 are barren of coccoliths. *D. druggi* and *Triquetrorhabdulus carinatus* cooccur in the poorly preserved assemblages of Core 515B-35. This interval represents the *D. druggi* Zone (NN2).

Lower Miocene to Upper Oligocene

The Miocene/Oligocene boundary corresponds approximately with the last occurrences of *S. ciperoensis* and *H. recta* (Martini, 1971). The preservation of the assemblages is poor and, as a result, both index species are missing. *T. carinatus,* which ranges from upper Oligocene (NP25) to lower Miocene (NN2), marks the upper part of this interval (Cores 515B-37 to 515B-41). For the lower part of this interval (Cores 515B-44 to 515B-48), *T. carinatus* was used for the lower boundary (NP25), and *D. adamanteus* and *Dictyococcites dictyodus* were used for the top (NN1).

Upper Oligocene

Sample 515B-52-1, 20–21 cm, contains a poorly preserved nannoplankton assemblage with *Helicopontosphaera* cf. *recta,* which has a known range from NN24 to NN25. The observed specimen is poorly preserved, therefore the age determination of late Oligocene is a "best guess" that is consistent with the paleomagnetic stratigraphy of this interval.

Lower Eocene

Lower Eocene sediments were recovered only in the last two cores at Hole 515B, Cores 56 and 57. The nannofossil assemblages belong to three lower Eocene zones. The interval from Sample 515B-56-3, 77 cm to 515B-56-4, 14 cm contains *Discoaster lodoensis* but lacks *Marthasterites tribrachiatus,* and it belongs to the *D. lodoensis* Zone (NP13). The co-occurrence of *D. lodoensis* and *M. tribrachiatus* assigns the interval from 515B-56-4, 40 cm to 515B-57-4, 86 cm to the *M. tribrachiatus* Zone (NN12). The *D. binodosus* Zone (NN11) represents the oldest interval at this site, Samples 515B-57-4, 135 cm to 515B-57,CC. The stratigraphic age determination is based on the occurrence of *M. tribrachiatus* in the absence of *D. lodoensis.* Calcareous nannofossils are common in the lower Eocene but their preservation is poor, being slightly better in Core 515B-56 than in 515B-57.

Planktonic Foraminifers

Site 515 was drilled in the Brazil Basin at a water depth of 4250 m. The following discussion is based on microscopic examination of each core catcher and at least one sample per section. As expected for this deep-water site, planktonic foraminifers are partially or entirely dissolved. Only few benthic foraminifers remain, except in the lower cores of Hole 515B where the planktonic foraminifers are moderately well preserved. For the more recent sediment, the amount of dissolution can be estimated, but estimation of this phenomenon for the deeper samples, particularly in Hole 515B where the majority of the samples are barren, is difficult.

The zonations of Blow (1969) for the upper Tertiary and Berggren (1971) for the lower Tertiary were used for stratigraphic age determination by planktonic foraminifers, and species ranges are from Blow (1969) and Stainforth and others (1975). Five biostratigraphic intervals were identified:

1) Quaternary (Cores 515-1 and 515-2; 515A-1 to 515A-10)

2) Pliocene/Pleistocene to upper Miocene (Cores 515B-4 to 515B-7)

3) lower Miocene (Cores 515B-22 to 515B-23)

4) lower Miocene to lower Oligocene (Cores 515B-24 to 515B-55)

5) lower Eocene (Cores 515B-56 and 515B-57)

Quaternary

Quaternary sediments were recovered in the HPC cores of Holes 515 and 515A. The assemblage is strongly dissolved in these cores. On the basis of *Globorotalia truncatulinoides* and/or *G. tumida/menardii* (left coiling), this assemblage is assessed to be of the late Pleistocene. Holocene sediments are not represented in the upper part of these two holes. Subtropical and tropical species dominate the planktonic assemblage, but the presence of sub-Antarctic species (*Globigerina pachyderma*) suggests the mixing of water masses during the Quaternary.

Plio/Pleistocene to Upper Miocene

The upper part of Hole 515B (Cores 4 to 7) contains a few individuals of the species *G. pachyderma, Globoquadrina dehiscens, Globorotalia inflata/puncticulata,* and *G. sphericonomiozea.* A precise age could not be assigned to this impoverished assemblage, but it is probably no older than the late Miocene.

Lower Miocene

Below a long sequence without any planktonic foraminifers (Cores 515-5 to 515-21), lower Miocene microfauna were retrieved in Cores 515B-22 to 515B-23. That assemblage contains *Globigerinoides primordius, Globoquadrina dehiscens, Catapsydrax dissimilis* s.l., and few *Globigerina* sp., indicating Zones N4 to N6.

Oligo/Miocene and Upper Oligocene

Cores 515-24 to 515-37 contain very few specimens of *Globigerina woodi* and *G. praebulloides.* This poor assemblage of long-ranging species is probably indicative of the late Oligocene to early Miocene.

A typical Oligocene assemblage is found in Cores 515B-48 to 515B-55. The presence of *Globorotalia opima opima* and *Globigerina angulisuturalis* in Cores 515B-49 to 515B-54 suggests a late Oligocene age, probably Zone P21 at the oldest.

Probably because of dissolution, Core 515B-55 contains a very poor assemblage, including *Catapsydrax unicavus, G. dissimilis,* and *Globorotaloides suteri.* These species indicate the late Eocene to early Miocene, but a specimen of *Globorotalia cerroazulensis* places this core below Zone P17 to P18.

Lower Eocene

Cores 515B-56 and 515B-57 contain a large early Eocene assemblage with improved preservation. The succession of the microfauna in these two cores allows the differentiation of Zones P9 to P6b as follows:

Depth (m)	Core-section (interval in cm)	Zones
622.7	56-4, 80–85	P9
624.8	56-5, 142–147	P8
625.3	56-6, 47–52	P8
626.9	56,CC	P8
629.1	57-2, 78–85	P7
632.3	57-4, 92–98	P6b
634.9	57-6, 32–37	P6b
636.4	57,CC	P6b

Globorotalia bullbrooki in association with *G. aragonensis, Globigerina higginsi,* and *G. senni* suggests Zone P9, in spite of the zonal marker species in 515B-56-4, 80–85 cm. Below, in Sample 515B-56,CC, the species *Globigerinatheka senni, Globorotalia broedermanni,* and *G. aragonensis* indicate Zone P8. In the upper part of Core 515B-57 (Sections 1 and 2) the appearance of *G. aragonensis* suggests Zone P7; at the bottom of the hole, its absence and the association of *Globorotalia subbotinae* and *G. lensiformis* in Sections 515B-57-3 to 515B-57-6 indicates Zone P6b.

Composition of Planktonic Assemblages

Generally, when planktonic foraminifers are abundant, as in Cores 515B-56 or 515B-57, the assemblages are highly diversified and contain the various species normally used for determining the conventional biozones. In this case, however, although the association of the middle part of Core 515B-56 seems to be representative of the upper part of the lower Eocene (Zone P9) with *Globigerina higginsi* and *Globorotalia* gr. *bullbrooki*, it is only represented by atypical species like *G.* gr. *nitida/crassaformis* and the zonal marker is absent. This impoverishment is caused by selective dissolution and/or by a surface circulation in the South Atlantic that, during the Eocene, may have been quite different from that of today.

Benthic Foraminifers

Benthic foraminifers are common and well preserved in Core 1 of Hole 515 and in Cores 1 through 9 of Hole 515A.

Nuttalides umbonifera dominates these Recent and Quaternary assemblages; *Epistominella exigua, Oridorsalis umbonatus, Globocassidulina subglobosa, Pullenia bulloides, P. quinqueloba, Planulina wuellerstorfi, Pyrgo, Eggerella bradyi,* and *Fissurina* spp. occur at a much lower relative abundance.

In a study of the distribution of benthic foraminifers in core-top samples of the Rio Grande Rise, Vema Channel, and the southern Brazil Basin, Lohmann (1978) found that the AABW is characterized by a fauna dominated primarily by *N. umbonifera.* In contrast, a more evenly distributed and diverse fauna of miliolids (including *Pyrgo*), and *G. subglobosa, P. wuellerstorfi, Uvigerina peregrina, Cibicidoides kullenbergi*, and *Hoeglundina elegans* characterizes the overlying North Atlantic Deep Water (NADW). The transition between the two water masses occurs at about 4 km water depth (Johnson, this volume).

Counts of benthic foraminifers in the greater-than-250-micron fraction and in the greater-than-149-micron fraction were made for Samples 515-1-1, 0–2 cm; 515A-1-2, 27–30 cm; and 515A-9,CC. In the top 2 cm of Hole 515, Core 1, *Nuttalides umbonifera* reaches a maximum of 70% in the coarse fraction, which compares well with Lohmann's (1978) values for samples from the Vema Channel. He recorded an increase in relative abundance of that species to about 30% in core-top samples from below 3400 m, and a dramatic increase to a maximum of 90% below 4100 m. In the two deeper samples from Hole 515A, abundance of *N. umbonifera* decreases from 46 to 30% in the coarse fraction, but the decrease is less distinct in the greater-than-149-micron fraction.

In Hole 515B, benthic foraminifers were found at only four intervals: Cores 4 to 6, 22 to 27, 48 to 55, and 56 (lower part) to 57. The Miocene-Pliocene(?) assemblages in Cores 4 to 6 and 22 to 27 resemble much those of the Quaternary, except for the addition of *Cibicidoides cicatricosus, Stilostomella subspinosa, S. aculeata, Bulimina* cf. *grata*, and *Pleurostomella.* With exception of Core 6, benthic foraminifers are rare and are only moderately to poorly preserved. Two distinct assemblages characterize the Oligocene interval, Cores 515B-48 to 515B-55. The first, an assemblage of calcareous species composed of *Pyrulina, Lagena, Fissurina, Ellipsoidella, Nuttalides umbonifera, Oridorsalis umbonatus, Pullenia eocaenica*, and *P. quinqueloba*, has not been recorded previously for samples from the Atlantic Basin and differs markedly from South Atlantic Oligocene assemblages present in DSDP Sites 14, 20, and 360. The second is an arenaceous assemblage containing simple forms such as *Bathysiphon, Glomospira*, and *Hormosina.* Other samples contain a mixture of the two assemblages.

The benthic assemblages in Cores 515B-56 to 515B-57 are characteristic of the early Eocene. During that time, speciation in deep-sea benthics was relatively high, following extinctions during the latest Paleocene (54 Ma). As a result, biostratigraphic resolution is relatively good for the lower Eocene. Sample 515B-57,CC is assigned to Zone P6b, based on the overlap of *Anomalina praeacuta* and *Tappanina selmensis* with *Clinapertina inflata* (new gen., new sp.). Despite succession of forms, diversity is low, only 10–14 species, in Cores 515B-56 to 515B-57. The assemblages in these cores differ slightly, with the lowest diversity in Core 515B-57. Abundant are *Nuttallides truempyi* (predecessor of *N. umbonifera*, highest abundances in the deep Eocene DSDP sites), *Anomalina praeacuta*, and *Clinapertina inflata*, with lower concentrations of *Oridorsalis umbonatus, Alabamina dissonata*, and (in some samples) *Cibicidoides havanensis*. Other characteristic species are *Tappanina selmensis, Quadrimorphina profunda* (n. sp.), *Abyssamina poagi* (new gen., new sp.), *Nodosaria velascoensis*, and *Bulimina bradburyi*. The absence of representatives of *Lenticulina* and *Osangularia* and the very low abundance of buliminids suggest a paleodepth of 4 km or more. The strong resemblance to lower Eocene assemblages of Site 358 in the Argentine Basin (with paleodepth of about 4.5 km) supports this depth estimate.

Radiolarians

Radiolarian preparations were made for all core catcher samples from Holes 515, 515A, and 515B. More closely spaced sampling was then carried out in all cored intervals where identifiable radiolarian taxa were observed. Even in intervals where radiolarians are relatively common, the noncalcareous coarse fraction (more than 62 μm) is dominated by detrital mineral grains and by fecal pellet aggregates that are not readily disaggregated, even under persistent treatment by H_2O_2 and sonification. Consequently, nonskeletal grains or aggregates dominate many of the radiolarian preparations.

Radiolarians are totally absent in samples prepared from Core 515-1 (0–1.5 m sub-bottom) and Core 515-2 (39.5–49.0 m sub-bottom). In Hole 515A (Cores 1 to 27, 0–107.9 m sub-bottom), radiolarians are absent in Cores 1, 2, and most of 3. The base of Core 3 and all of Core 4 contain a diverse and well-preserved assemblage of the latest Pleistocene, based on the common occurrence of *Collosphaera tuberosa*. Other common Pleistocene forms include *Amphirhopalum ypsilon, Pterocanium praetextum, Spongaster tetras tetras, Ommatartus tetrathalamus, Theocorythium trachelium*, and *Eucyrtidium hexagonatum*. On the basis of paleomagnetic stratigraphy, the mean accumulation rate in the upper part of Hole 515A is 21 m/m.y., confirming that the radiolarian-rich interval in Cores 515A-3 and 515A-4 is of the latest Pleistocene, approximately 0.5 to 0.7 Ma. The remainder of Hole 515A (Cores 5 to 27, 17.5–107.9 m sub-bottom) is barren of radiolarians. Siliceous spines are present in Cores 5 and 6, but identifiable radiolarian taxa are absent. The coarse fraction consists almost exclusively of detrital mineral grains and fecal pellets.

In Hole 515B, radiolarians are absent in samples from Cores 1 to 7. In Cores 8 through 49 (161–560 m sub-bottom), radiolarians are sufficiently abundant and well preserved to allow the use of a biostratigraphic zonation comparable in some respects to a scheme developed for tropical and subtropical Cenozoic radiolarians (Riedel and Sanfilippo, 1978). This interval at Hole 515B is the only significant interval of radiolarian-bearing sediment encountered at the four sites occupied on Leg 72. Cores 8 through 49 span the middle Miocene (*Dorcadospyris alata* Zone) through upper Oligocene (*D. ateuchus* Zone). The zonation sequence and the diagnostic radiolarian taxa in this interval at Hole 515B are different in some respects from those of Riedel and Sanfilippo's (1978) low-latitude zonation for the Oligocene-Miocene. *Calocycletta costata* and *D. dentata* are missing entirely, and virtually all assemblages are of much lower diversity than those of corresponding age from equatorial latitudes. The absence of those key indicator species may not be due to unconformities at Hole 515B, but may reflect a significantly different zonation succession in the subtropical South Atlantic from that in equatorial latitudes.

The Oligocene/Miocene boundary occurs between Cores 515B-34 and 515B-35, or near the boundary between the *Cyrtocapsella tetrapera* Zone and the *Lychnocanoma elongata* Zone, corresponding to the position of the boundary based on diatoms (see Diatoms section).

The presence of radiolarians at Site 515 agrees with the pattern previously established for other Atlantic drill sites in low and middle latitudes. Radiolarians are sparsely present through the Holocene and uppermost Pleistocene, and absent in the upper Pleistocene to middle Miocene. They appear in the middle Micoene down into the Oligocene, with abundance and preservation decreasing markedly toward the lower Oligocene. The oceanographic significance of this pattern is not clear, yet it persists in virtually all drill sites in the tropical and temperate Atlantic.

The lower Eocene interval below the unconformity at Hole 515B (Cores 55 to 57, 608–636 m sub-bottom) is barren of radiolarians.

Diatoms

Forty-three samples from Cores 515B-8 through 515B-57, approximately one sample per core, were prepared and examined according to the procedure outlined by Gombos and Ciesielski (in press). Diatoms occur consistently in Cores 8 through 44, but generally the abundance is low and preservation is poor. Cores 45 through 57 are barren of diatoms. Gombos and Ciesielski (in press) defined 12 diatom biostratigraphic zones for the upper Eocene to lower Miocene in a composite section from Leg 71, Holes 511 and 513A. These same zones were applied to the cores from Hole 515B. Cores 8 through 14 contain scattered diatoms, but none are sufficient to allow a diagnostic age assignment to these cores; Cores 15 to 16 are assigned to the *Coscinodiscus rhombicus* zone; Cores 17 to 44 are assigned to the *Rocella gelida* Zone.

Based on the occurrence of *Craspedodiscus elegans* and *Coscinodiscus praenitidus*, the Oligocene/Miocene boundary should fall between Cores 23 and 35. Furthermore, the apparent acme of *Rocella gelida* in Core 36 suggests the placement of the boundary higher in the section. Thus the Oligocene/Miocene boundary in Hole 515B is tentatively placed between Cores 32 and 33. This placement agrees with the more detailed diatom abundance data presented by Gombos (this volume) and is in fairly close agreement with the ages determined by calcareous microfossils and radiolarians.

PALEOMAGNETICS

Introduction

Site 515, located in the southern Brazil Basin, affords an unusually good opportunity to develop a high resolution magnetic polarity reversal stratigraphy for part of the Cenozoic sedimentary record in the southwestern Atlantic, because the sedimentation rate in almost all of the sedimentary section above a hiatus at 617 m subbottom is moderately high. The lower Eocene sediments encountered below the hiatus accumulated much more slowly.

The long-core spinner magnetometer system was utilized onboard *Glomar Challenger* to determine the downhole variation in relative declination and intensity of the horizontal component of the natural remanent magnetization (NRM) of the hydraulic piston cores. Measurements were made on 65 whole-core sections from a total of 27 HPC cores from Hole 515A. Additionally, remanence measurements, on the standard Digico spinner magnetometer, of 183 cylindrical samples taken at an approximate frequency of 50 cm downhole supplement the whole-core investigations. For Hole 515B, drilled by rotary coring, 270 shipboard NRM measurements were completed. Preliminary investigations of magnetic stability were made on samples chosen as representative of the major lithologic types encountered. Incremental alternating field (AF) demagnetizations up to 60 mT peak field value were completed using the Schoenstedt single-axis demagnetizer. The bulk of the demagnetizations were undertaken as part of the shore-based paleomagnetic investigations.

Long-Core Spinner Magnetometer Studies

Sediments that possess a stable primary magnetization retain the potential for detection of polarity reversal boundaries from whole-core spinning. Ideally, relative azimuthal orientation must be preserved between individual core sections, as well as between individual cores, so that 180° declination changes can be reliably used as a criterion for detecting polarity boundaries. The technique of whole-core spinning also affords the opportunity to recognize significant magnetic intensity changes, which often correlate to lithologic change. Thus, this technique has a part to play in the initial shipboard reconnaissance of the properties of the sedimentary sequence being penetrated.

The upper 50 cm of the first section from each HPC core often give anomalous declination and intensity values during whole-core spinning. These aberrant values correlate with visual evidence of core disturbance and anomalous GRAPE density determinations. Below 50 cm depth, generally consistent declination and intensity readings are obtained. Occasional single anomalous values can be referred to rust particles from pipe scale, as recognized during previous legs.

Several individual sections were subjected to repeat measurements. Declination values were confirmed to with ±5°, but intensities usually were within ±10%. The range of intensities encountered was normally between 3 and 40 mA/m; a few high values in excess of 100 mA/m correlated with core tops.

Despite some problems in the core-orientation system used with the HPC, soft sediment deformation related to coring disturbance, and a few void intervals, use of whole-core spinning detected a number of polarity reversal boundaries. These are best seen in the Matuyama Reversed Epoch recognized between 17 to 52 m depth. A detailed synthesis of the whole-core spinning results at this site, together with those obtained at Sites 517 and 518, is the subject of another chapter (Suzyumov and Hamilton, this volume).

Discrete Sample Remanence Measurements—Shipboard and Shore-based Studies

The majority of shipboard NRM measurements of discrete samples taken from the split cores used a signal integration over 2^6 spins on the standard spinner magnetometer. A few weaker samples were measured over 2^7 spins; because of the large number of samples processed, however, it was considered more useful to take replicate measurements over 2^6 spins for those samples with remanent intensities normally less than 1.5 mA/m rather than employ longer signal integration times. Repeat remanence measurements made during shore-based studies employed both a standard Digico spinner magnetometer (using 2^7 spins) and a three-axis CCL cryogenic magnetometer.

Lithologic Unit 1 (gray terrigenous mud, 0 to 180 m) is characterized by NRM intensities in the range between 0.3 and 4.6 mA/m. The more siliceous nature of the underlying Lithologic Unit 2 (dark-gray-green mud-mudstone) is reflected in a narrower range of intensity value; a majority of the samples had intensities of the order of 0.5 mA/m. There are some noticeable intensity fluctuations, however, suggesting some pulsating input of ferromagnetic material. The lowermost unit in Hole 515B, Unit 3 (calcareous zeolitic mudstone), shows a significant increase in NRM intensity; values fall within the range from 3 to 30 mA/m.

Volume susceptibility, measured on a Highmoore susceptibility bridge, shows values in the range 0.7 to 58.0×10^{-5} for this site. Highest susceptibility values are associated with the lower Eocene zeolitic mudstones. Lowest values occur in the Miocene siliceous muds. The three major lithologic units recognized at this site correspond closely to the magnitude of the magnetic susceptibility.

Some marked fluctuations in susceptibility are seen in the upper 160 m at this site. These fluctuations are best identified in the HPC recovery at Hole 515A but are also recognizable in the upper part of the rotary drilled interval (96–100 m sub-bottom). On the basis of inferred magnetostratigraphy (see Magnetostratigraphy section), tentative dating of these episodes of susceptibility variation is possible. For example, a susceptibility maximum between 75 and 80 m (Core 515A-18) can be correlated with the base of the Gauss Epoch, about 3.4 Ma. There is a trend to lower susceptibility in the Brunhes Epoch (the Brunhes/Matuyama boundary is located at 17.0 m depth) than in the underlying Matuyama and Gauss sediments. The NRM intensity and susceptibility record together suggest that episodes of pronounced bottom-current activity occurred during the late Neogene and Quaternary in the southern Brazil Basin.

Magnetostratigraphy

A comparison of the NRM inclinations of discrete samples from Hole 515A with those measured after AF demagnetization at a peak field value of 20 mT shows broadly similar values. This correspondence suggests that the dominantly terrigenous lithologies encountered in Unit 1 possess a stable remanence and will therefore have preserved a fair record of the magnetic polarity stratigraphy. Magnetic cleaning is effective in removing a normal overprint in the interval from approximately 50 m sub-bottom to the terminal depth for this HPC hole (Fig. 8).

The first well-defined reversal boundary occurs at the depth of 17 m and is assigned to the Brunhes/Matuyama boundary. A single sample of positive inclination occurs at 4.5 m depth, perhaps correlative with the Blake Event (about 100,000 yr.), if we assume a linear sediment accumulation rate. Surprisingly, the Jaramillo Event is not easily recognized in the cleaned remanence data, but an indication of this event occurs in the whole-core spinning data around 25 m sub-bottom. The Olduvai Event is detected at a depth of 39.5–42.0 m. An interval of dominantly normal polarity between 52.0 and 77.0 m is assigned to the Gauss Epoch. Despite some sampling gaps, the normal polarity intervals detected to the base of this HPC hole are probably those of the Gilbert Epoch. On the basis of these tentative assignments, the average sediment accumulation rate over the past 5 Ma is inferred to be 22 m/Ma.

At Hole 515B, we continued the investigation of the magnetostratigraphy for Neogene and Paleogene sediments. Apart from some sampling gaps, a good polarity

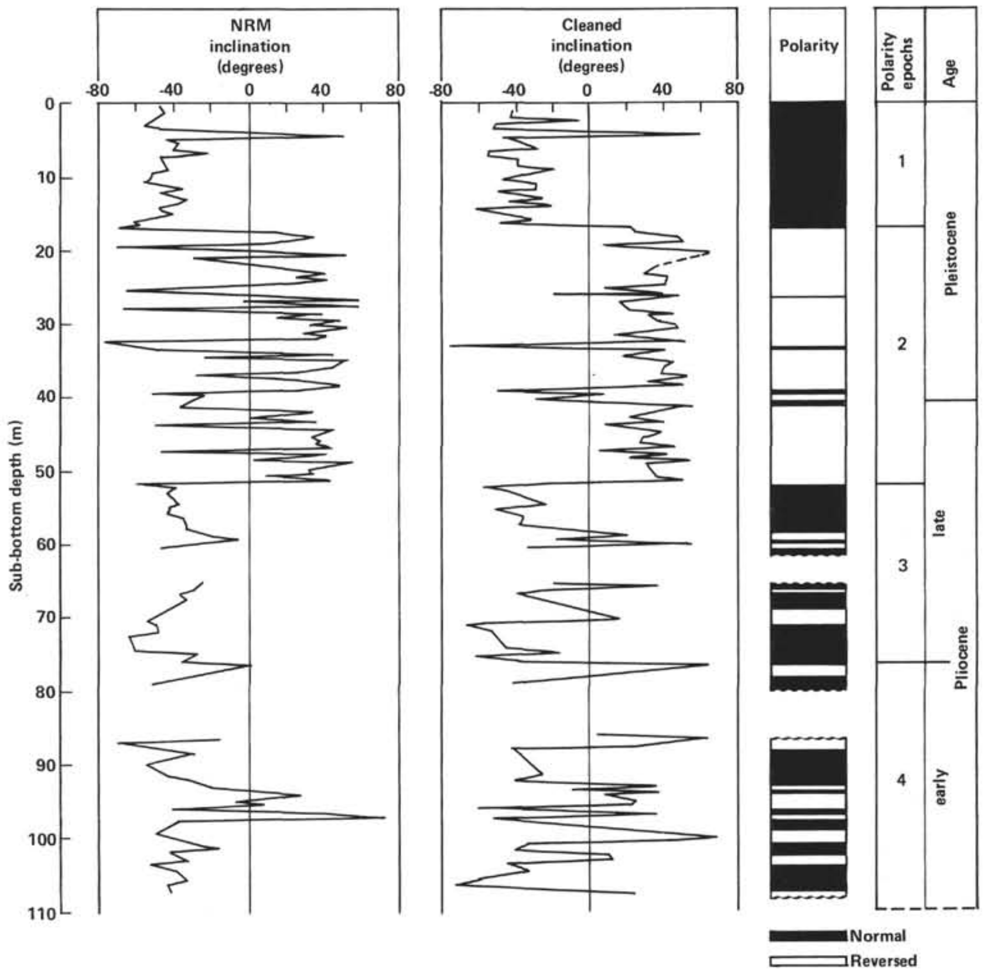

Figure 8. Downhole inclination variation before and after magnetic cleaning together with inferred magnetic polarity for Hole 515A.

stratigraphy can be determined down to the major hiatus at 617 m and into the lower Eocene sequence below this unconformity (Fig. 9).

The assignment of the observed downhole polarity reversal sequence to established geomagnetic time scales requires use of the available biostratigraphic control. The interval 115–168 m depth is assigned to Epochs 5–7. Sampling gaps occur between 170 and 190 m depth. An interval of dominantly normal polarity follows, down to 283 m. Within the sampling gaps, a hiatus may account for the missing part of Epoch 8 and for the absence of Epochs 9–12. The underlying normal polarity interval is best correlated with Epochs 13–16.

A normal-to-reversed polarity boundary identified at 283 m sub-bottom depth is assigned to the base of Anomaly 5C within Epoch 16. Below this depth, longer intervals of reversed polarity dominate down to a depth of 485 m. Intervening normal polarity intervals suggest a tentative assignment of this part of the sub-bottom sequence to Epochs 16–23. The polarity sequence is, however, not complete; another hiatus may be present at 408 m depth. This gap would account for part of Epoch 20 and all of Epochs 21 and 22 missing at this site. One key feature of this assignment is the problematic recognition of the normal interval between 417 and 424 m as the normal event of Anomaly 6C.

At 498 m depth, a normal-to-reversed boundary is correlated with Anomaly 7A. The underlying sequence down to the major unconformity at 617 m sub-bottom appears to correspond best to the polarity sequence associated with Anomalies 8, 9, and 10. Directly above the unconformity, the sediments are reversely magnetized.

Beneath the unconformity, the quartz-rich zeolitic mudstones are typified by variable magnetic stability. Approximately half of the samples studied paleomagnetically for this part of the sequence are associated with low-median destructive fields (less than 5 mT). For the majority that were AF demagnetized to 30 mT, well-defined stable endpoints were not always reached, but polarities are assigned to these samples. A number of samles from Sections 515B-57-2 and 515B-57-3 appear to be reversed, but samples from Section 515B-57-1 show very low negative inclination values. Thus at least one interval of reversed polarity from about 627 to 631.5 m sub-bottom occurs in the lower Eocene penetrated at Site 515. The sediments encountered just below the unconformity probably acquired their magnetization in a period of normal polarity.

The combination of magnetostratigraphic studies and biostratigraphic assignments indicate that these sediments span the sequence from Anomaly 24 through to the early part of Anomaly 23 (using the revised Cenozoic polarity time scale of Hailwood et al., 1979). The main reversed zone described above occurs in calcareous nannofossil Zone NP12 and is correlated with the interval of reversed polarity between Anomalies 23 and 24. The problematic low inclinations in Section 515B-57-6 at the base of this hole may correlate to the upper part of the zone of reversed polarity that is dominantly present in NP11.

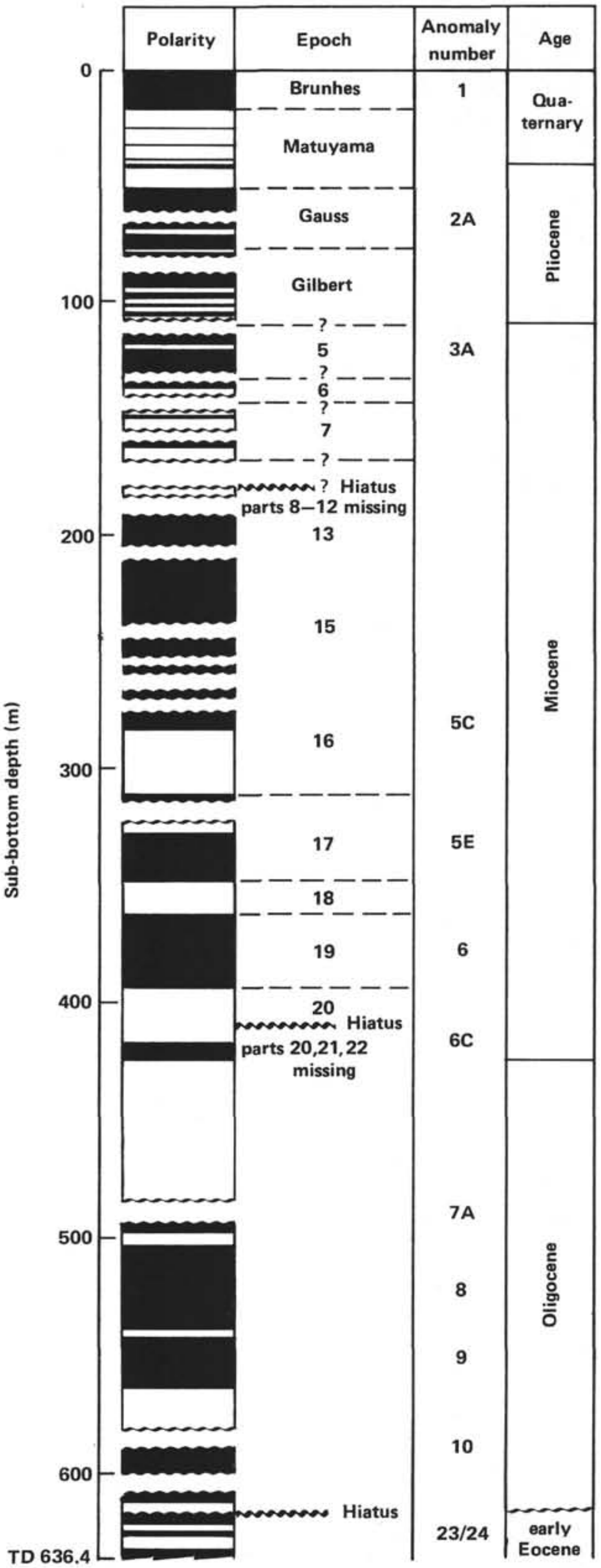

Figure 9. Magnetic polarity stratigraphy for Hole 515. TD = termination depth.

SEDIMENTATION RATES

Sedimentation rate estimates at Site 515 are based on calcareous nannofossil, planktonic foraminiferal, and radiolarian stratigraphy and magnetic reversals, combined by means of the time scales of Berggren, Kent, and Van Couvering (in press) for the Neogene, and Berggren, Kent, and Flynn (in press) for the Paleogene. The quality of the stratigraphic control is not uniformly high. Calcareous fossils are sparse and poorly preserved, except in Eocene sediments below 617 m. Radiolarians are abundant between 170 and 510 m (late Oligocene through middle Miocene) but are of lower diversity than the equatorial assemblages (Riedel and Sanfilippo, 1978) on which the zonation is based, and lack some key indicator species. Recovery at Site 515 is high and many magnetic reversals have been detected, but without sufficient biostratigraphic control there is a risk of ambiguity in their identification. It is not certain which of these deficiencies causes the age discrepancies apparent in Figure 10, so the chosen age-depth curve and conclusions drawn from it, below, should be treated with caution.

For the Pliocene-Pleistocene, the main control (the magnetic reversal stratigraphy) is reasonably unambiguous back to 6 Ma. Extrapolation downwards at the same rate (27 m/Ma) is only possible to 167 m, where middle Miocene radiolarians are found. A hiatus, if it occurs, cannot then be located as deep as 180 m, where the lithologic change occurs that marks the boundary between Units 1 and 2a. Sedimentation rates within Unit 2 range between 10 and 50 m/Ma, averaging 24 m/Ma. The hiatus between deposition of Units 3 and 2b extends from 52 to 30 Ma. Calcareous microfossils are abundant within Unit 3, but the estimated 4 m/Ma sedimentation rate has a large uncertainty because of the age offset between the nannofossil and planktonic foraminiferal zonations.

Sedimentation rates are uncorrected for compaction. Correction may be made by use of the extensive suite of shipboard measurements of wet-bulk density or porosity, but care is needed because of possible alteration of physical properties by the coring process and because of

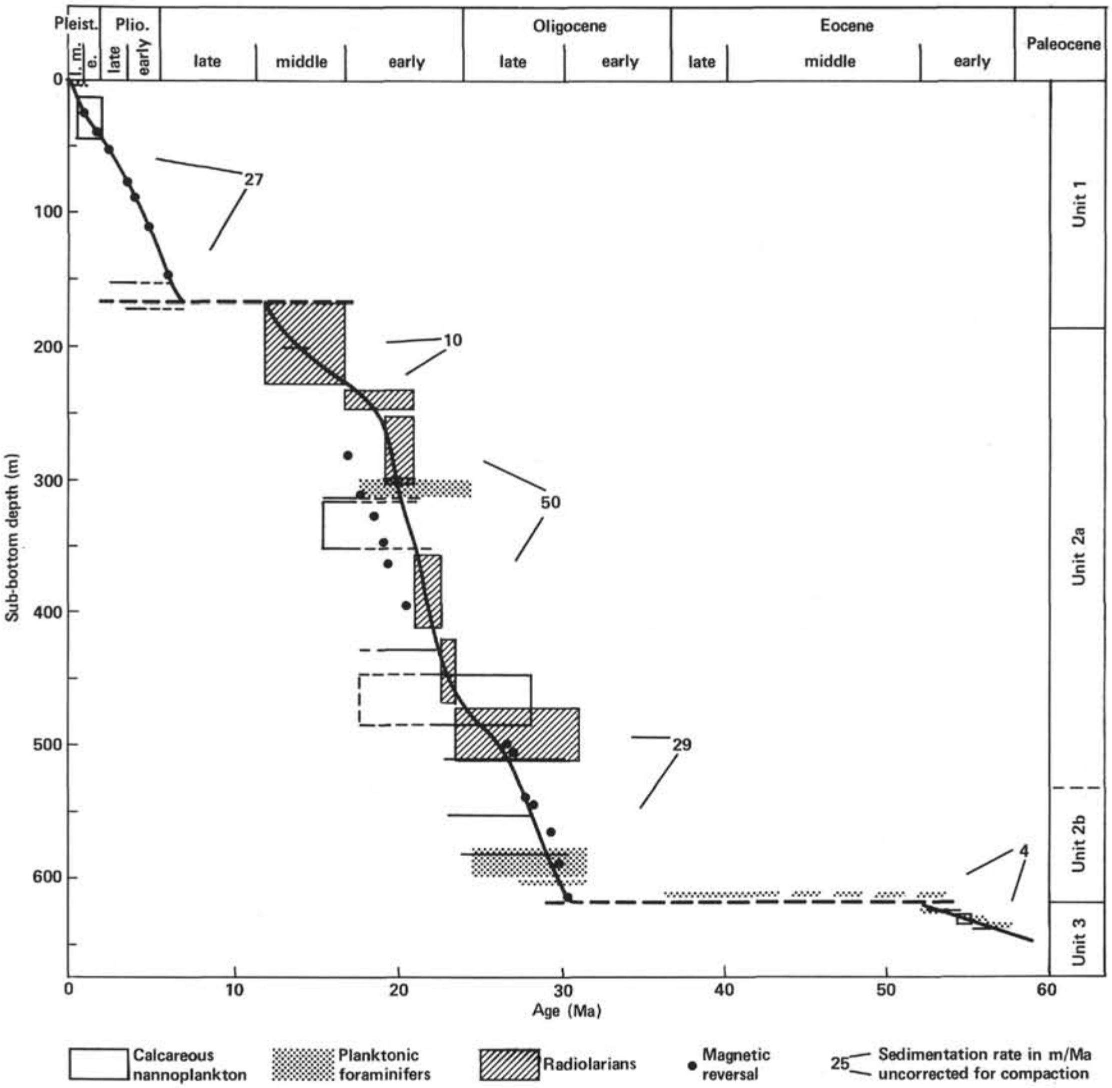

Figure 10. Sedimentation rates at Site 515.

variability in grain density (see Walton et al., Schaftenaar et al., this volume).

PHYSICAL PROPERTIES

Measurements of acoustic (compressional-wave) velocity, wet-bulk density, water content, and porosity were made routinely at Site 515. For the HPC hole, acoustic velocities were measured through the core liner. Densities, water contents, and porosities were determined by the syringe method. The variations of selected physical properties with depth are illustrated in detail in Figure 11; tabulated values are given in Walton and others (this volume).

Rotary coring (Hole 515B) began at a depth of about 95 m, but the recovered sediments were so badly disturbed that no meaningful measurements of physical properties were possible higher than approximately 200 m sub-bottom. Trimmed samples were used to measure acoustic velocities parallel and perpendicular to bedding below 250 m; the same samples were used to estimate densities, water contents, and porosities. Densities were estimated by the immersion and 2-minute GRAPE methods. Their variations with depth are shown in Figure 11.

Unit 1 (0–180 m) is a terrigenous mud. The only physical properties measured in this interval are from the

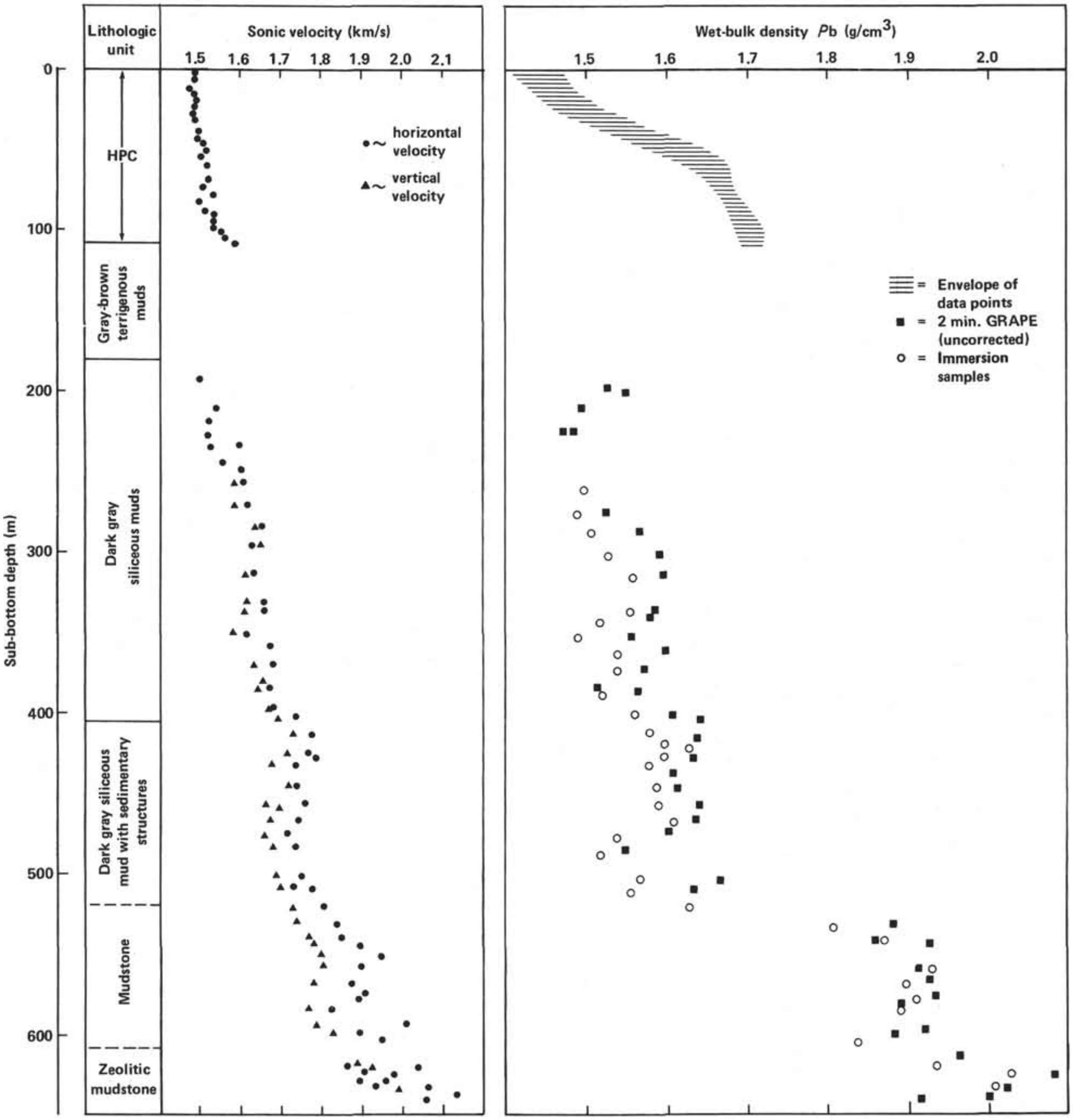

Figure 11. Physical properties at Site 515.

HPC hole (515A), and we had hoped, because of the relatively undisturbed appearance of the recovered sediments, that the measured physical properties might be representative of *in situ* conditions. Sonic velocities increase from 1.47 to 1.59 km/s, densities range from 1.45 to 1.75 g/cm^3, and porosities decrease from about 75 to 55% at a depth of 108 m (the bottom of the HPC hole). These strong trends, and the relatively low degree of scatter in the data are encouraging; the properties of better consolidated samples recovered from greater depths in Hole 515B suggest, however, that the properties measured in the HPC cores may not be representative.

Subunit 2a (180–518 m) is a dark greenish gray siliceous mud and mudstone sequence sampled by rotary coring (Hole 515B). From about 250 m (where measured values are thought to be reliable) to ~410 m sub-bottom, acoustic velocities increase from 1.6 to 1.7 km/s, densities increase from 1.5 to 1.6 g/cm^3, and porosities decline from 70 to about 65%. Velocity increases slightly in the lower part of Subunit 2a (to 518 m) at 410 m to 1.75 km/s, and ranges from 1.7 to 1.8 km/s. Horizontal velocities exceed vertical velocities by about 0.1 km/s. Wet bulk densities and porosities are about 1.6 g/cm^3 and 65%, respectively, in the interval extending to 518 m depth.

The transition from Subunit 2a to 2b is characterized by a zone in which acoustic velocities increase from 1.75 to about 1.9 km/s. Horizontal velocities are 0.1 to 0.2 km/s higher than vertical velocities. Densities near 1.91 g/cm^3, and porosities of about 50% characterize Subunit 2b.

Unit 3 (615 m) is a greenish gray calcareous zeolitic mudstone. Acoustic velocities increase rapidly within Unit 3, from 1.9 km/s at 615 m to more than 2.1 km/s at the bottom of the hole. Densities increase to about 2.05 g/cm^3, and porosities decline rapidly to about 40%.

On the whole, the measured physical properties of sediments recovered from depths greater than 250 m (Hole 515B) correspond to variations in lithology and correlate well with the reflection profile (see below), but the properties of the sediments recovered from the HPC hole (515A) are probably not reliable. The apparent density gradient in the HPC interval (Fig. 11) is an order of magnitude steeper than the gradient in the indurated samples lower in the section, and the measured densities at 100 m are greater than the densities found anywhere in Subunit 2a, much of which is sufficiently well consolidated to subsample with minimal disturbance. These observations suggest that sediments sampled using the HPC at Site 515 are overcompacted. Based on the shipboard shear strength data and decompaction analysis, Faas and Crocket (this volume) have also concluded that the sediments recovered from the interval between 38 and 104 m sub-bottom are slightly overcompacted, though Walton and others (this volume) consider these sediments to be normally compacted.

CORRELATION OF REFLECTION PROFILER DATA WITH DRILLING RESULTS

Correlation of the reflection profiles with the cored section at Site 515 is straightforward. The reflection profile obtained on approach of the *Glomar Challenger* to the site (Fig. 12) resembles that obtained during the University of Texas Marine Science Institute (UTMSI) site survey (see the stacked, deconvolved UTMSI multichannel record WSA20, Fig. 13). At the position of the beacon drop, the reflector assumed to represent oceanic crust lies at about 1.65 s (two-way travel time) and a strong overlying reflector of regional extent occurs at 1.35 s; both of these lie far beneath the target depth of the hole. A second strong reflector of regional extent occurs at 0.74 s and was presumed, before drilling, to represent the onset of AABW flow and extensive sediment redeposition in the southern Brazil Basin. Above it, at about 0.64 s, lies a more diffuse reflector, which merges with it farther to the southeast where the deeper reflector shoals. A discontinuous and even more diffuse reflector at about 0.50 to 0.53 s may arise from focusing topography at the seabed. Finally, a shallow reflector is seen most clearly on the WSA20 profile (Fig. 13). Near the site, it is masked by the wave train of the seabad reflection, but farther away, to the southeast on WSA20 and possibly to the west on the *Glomar Challenger* approach track, it deepens to as much as 0.3 s sub-bottom.

Measurements of sonic velocities parallel to bedding (horizontal) were made on both HPC and rotary drilled sediment throughout the section, except for a gap between 110 and 190 m. Velocities normal to bedding (vertical) were measured only for the more consolidated sediment from beneath 250 m. In Figure 14, horizontal velocities are plotted against depth, using a simplified velocity-depth model. The model was fitted by eye, assuming a small bias in the data from rotary drilled samples towards low velocities, because of undetected but slight drilling disturbance. In Figure 14, the dashed line is a plot of time down the section, against depth. For a linear increase of velocity (v) with depth (x) $V_x = V_o + ax$, the time t_x is given by

$$t_x = \frac{1}{a} \ln\left(1 + \frac{ax}{V_o}\right)$$

Changes in velocity occur at 400–420, 510–540, and 610–620 m sub-bottom. Changes in density and acoustic impedance match these increases and should, therefore, correspond to reflecting horizons. Equivalent times on the time-depth plot are 0.505–0.525, 0.630–0.660, and 0.735–0.745 s, respectively. The correspondence between these and the times to the major reflectors noted above is excellent.

The velocity changes coincide with the main lithologic boundaries in the sediments (Fig. 11). The discontinuous and diffuse reflector at 0.50–0.53 s sub-bottom corresponds to the subtle change at about 408 m within Subunit 2a, a dark greenish gray biosiliceous mud and mudstone. A pronounced increase in the frequency of occurrence of small-scale sedimentary structures below this depth indicates a stronger and more variable bottom-current regime. At about this depth, reflectors shown in the multichannel WSA20 profile (Fig. 13) have a hummocky or lenticular character, better developed than in the overlying beds.

Lack of siliceous microfossil fragments and chertified intervals distinguish the dark greenish gray mud-

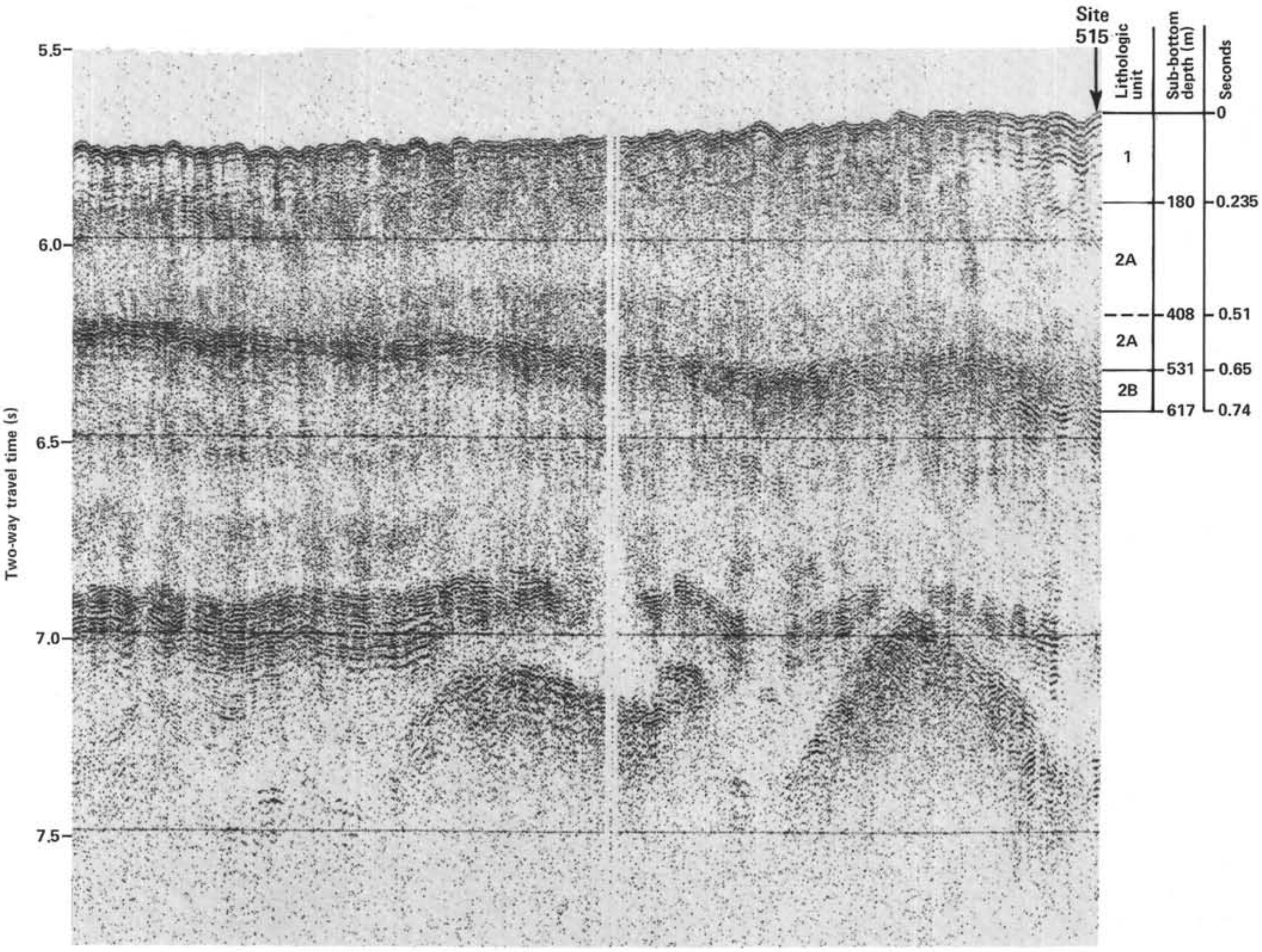

Figure 12. Correlation of the lithologic section of Site 515 with *Glomar Challenger* seismic reflection profile.

stones of Subunit 2b from those of Subunit 2a, changes correlative with a diffuse but continuous reflector at about 0.64 s. The diffuse nature of this reflector and its tendency to conform with the present seabed (it merges with the underlying reflector when that reflector shoals) are consistent with its inferred diagenetic origin.

A hiatus of about 22 Ma duration between the lower Oligocene and lower Eocene marks the base of Unit 2, at 617 m sub-bottom. Velocities and densities are higher in the underlying Unit 3, a greenish gray calcareous zeolitic mudstone, that is silty at its very top. Those sudden increases correspond to the strong, sharp reflector of regional extent seen at 0.74 s.

In the topmost part of the stratigraphic section, there is no strong reflector corresponding to the boundary between Unit 1 and Subunit 2a, at 180 m (0.23 s) sub-bottom. This sub-bottom depth is beyond the range of the seabed reflection wave train, and a reflector should be distinguishable, if it exists. This lithologic change occurs in the upper part of the rotary drilled section where, because of drilling disturbance, no velocity measurements were made. The change is from a dominantly terrigenous mud to a mud with up to 15% of biosiliceous fragments, which at the low level of consolidation observed may not produce a large change in physical properties. Similarly, within the topmost 100 m of Unit 1, there is no obvious lithologic change that might permit some speculative tracing of the shallowest reflector noted earlier. That reflector is stronger farther away from the site, where it lies deeper, but at the site is camouflaged by a long wave train of the seabed reflection. A sharp velocity increase at the base of the HPC hole (105 m or 0.14 s) is probably an artifact of the coring method, because it is not accompanied by a marked lithologic change.

The close correspondence between the seismic and the sedimentary sections supports the validity of correlations that use horizontal velocity measurements uncorrected for pressure and temperature effects, rather than corrected vertical velocities. The essential assumption, that uncorrected horizontal velocities provide reasonable, unbiased approximations to corrected vertical velocities, appears vindicated, at least for the lithologies and depths of burial encountered at Site 515.

SUMMARY AND CONCLUSIONS

Site 515 was designed to sample sediment deposited under the influence of AABW, which enters the Brazil Basin through the Vema Channel, some 200 km south

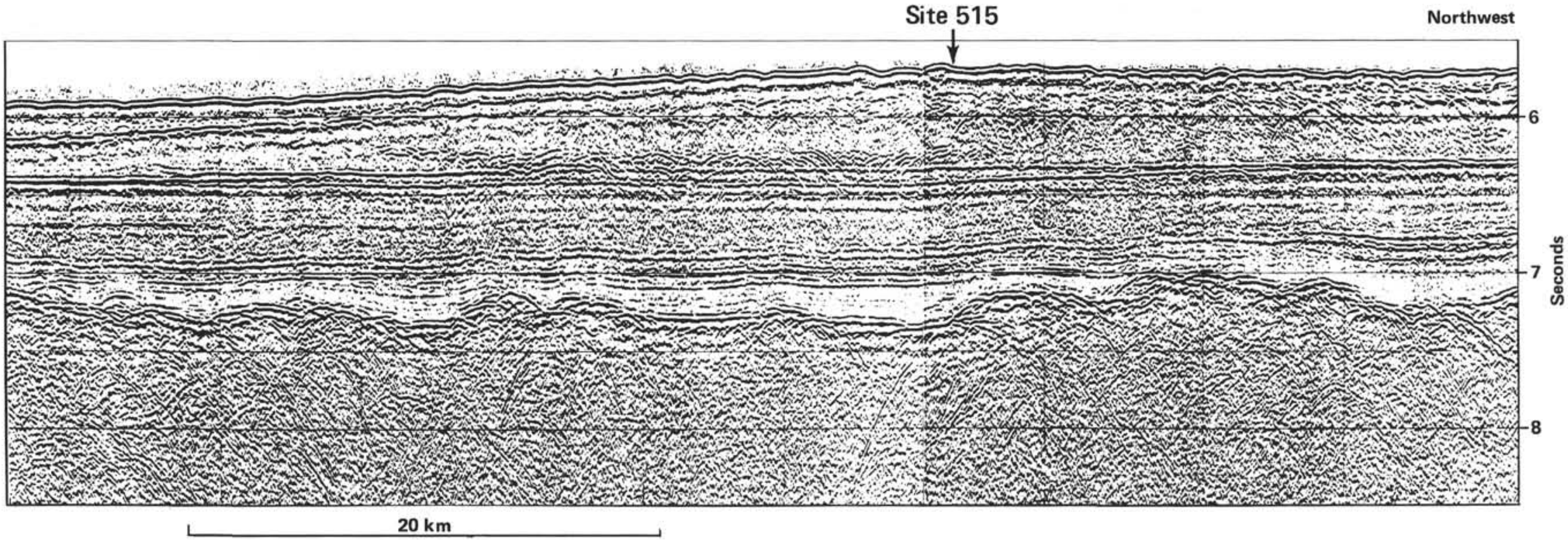

Figure 13. Seismic reflection profile UTMSI WSA20 and the location of Site 515.

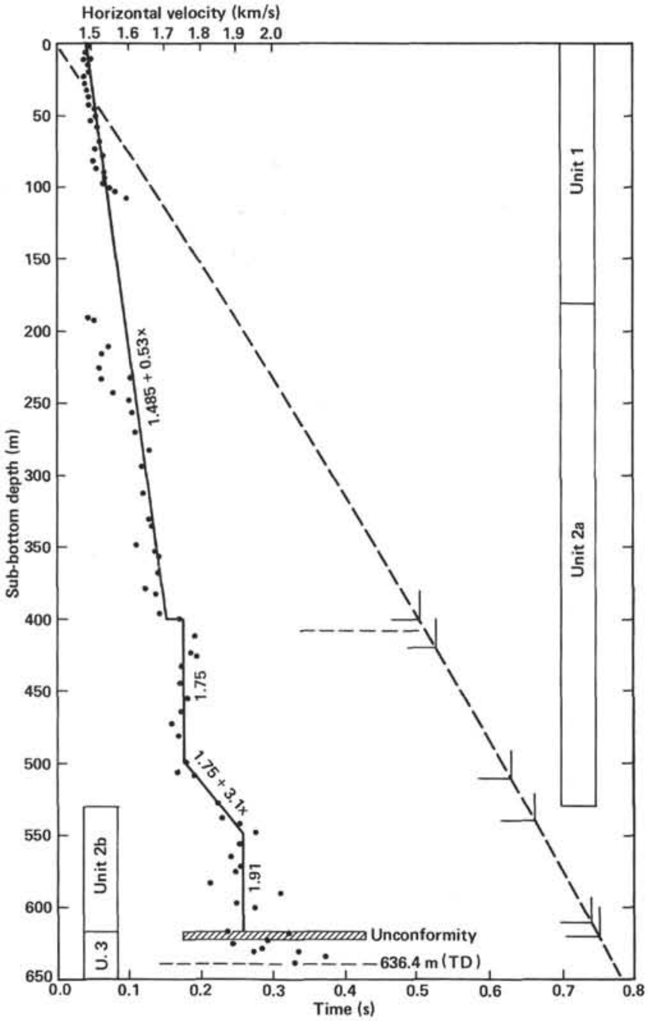

Figure 14. Measured *in situ* horizontal velocities, velocity-depth, (solid line), and time-depth (dashed line) models, Site 515. TD = terminal depth. See text for discussion.

of the basin (Fig. 1). Variations in AABW flow should reflect both short-term ("Milankovich") and long-term climatic variations, the development of the Vema Channel itself, and changes in sill depths at other barriers to bottom water flow farther to the south. In the sediments, these flow variations produce changes in the size and composition of terrigenous detritus and in sediment fabric, sedimentation rate, carbonate content, and the nature and state of preservation of siliceous microfossils (Shor et al., this volume; Johnson, this volume). Cenozoic global cooling had probably proceeded far enough by about 37 Ma (the Eocene/Oligocene boundary) to permit seasonal sea ice production at the Antarctic margin and a sudden initiation of AABW formation (Kennett and Shackleton, 1976). The invigoration of the thermohaline circulation at this time may have produced a widespread hiatus spanning this boundary (Moore et al., 1978).

Recovery was high in both holes (515A, 89%; 515B, 79%), and deformation was low. The only problems were the presence of a 10–50 cm soupy interval at the top of Section 1 of almost all HPC cores, caused by washing the bit down the previously cored interval, and the occasional total core loss because the core catcher dogs had jammed closed in the sticky clay.

The sedimentary section at Site 515 is divided into three principal units. The uppermost 180 m is a Quaternary to early Pliocene or late Miocene grayish brown terrigenous mud deposited at a mean sedimentation rate of between 20 and 35 m/Ma. The first 40 m (about 2 Ma) contain some layers rich in calcareous microfossils (up to 30% $CaCO_3$). Elsewhere, carbonates are rare.

Unit 1 has a gradational contact with Subunit 2a, a dark greenish gray siliceous mud and mudstone, 351 m thick and of mid-Miocene to late Oligocene age. Subunit 2a contains up to 15% of mostly fragmented radiolarians, diatoms, and sponge spicules; rare thin horizons contain up to 10% calcareous material. Bioturbation increases downward, as do small-scale sedimentary structures indicating a more variable and energetic bottom circulation (also inferred from the reflection profiles). The proportion of silt is small, however, and the mean sedimentation rate is a high 40 m/Ma. A small hiatus of about 5 Ma duration may occur within Unit 1, at about 167 m depth.

Subunit 2b is an Oligocene, dark greenish gray terrigenous mudstone, 86 m thick, distinguishable from Subunit 2a by the absence of siliceous microfossils and the more common occurrence of light-colored laminae containing calcareous microfossils. There are again indications in the sediments of fluctuating bottom currents, including an alternation between restricted calcareous and an agglutinated benthic foraminiferal assemblage. The mean sedimentation rate remains high to the base of Unit 2.

Unit 3 is a hard calcareous zeolitic mudstone of early Eocene age (52–55 Ma). The unconformity between Units 2 and 3, which spans approximately 22 Ma, is marked by a lag deposit up to 3 m thick, made up of sand-sized grains of quartz, biotite, assorted heavy minerals, glauconite, and fish teeth. Bioturation is common in this and in the underlying calcareous zeolitic mudstone. Backtracking and isostatic computations give an estimated CCD below 3665 m in the early Eocene, and above 4100 m in the early Oligocene.

The magnetic intensities correlate well with the lithologic units, and seem to be measuring the terrigenous component with some reliability.

The characteristics of Units 1 and 2 are consistent with an origin by redeposition of suspended sediment entrained within AABW that enters the Brazil Basin via the Vema Channel. The accumulation rate of Unit 3 (about 4 m/Ma) is normal for pelagic carbonate sediments, but the much higher rates of Units 1 and 2, despite their essential lack of a calcareous component, are better explained by our picture of bottom-current transport from the south. The fragmented siliceous microfossils of Subunit 2a suggest erosion and redeposition, and the small-scale sedimentary structures and intercalated thin carbonate horizons near the bases of Subunits 2a and 2b suggest redeposition by turbidity currents or deep thermohaline currents.

The hiatus between Units 2 and 3 is extensive over the Vema Channel and southern Brazil Basin. Evidence from Site 515 is consistent with, but does not prove, the original concept of a sudden onset of bottom water production at the Eocene/Oligocene boundary.

The change in accumulation rate across the lower Eocene–middle Oligocene hiatus suggests an initiation of bottom water flow into the Brazil Basin during the period of the hiatus. Such an interpretation would lead one to expect relatively rapid deposition of clay and silt grains transported by a north-flowing current entering the relatively quiet Brazil Basin after transport through and erosion within the narrow abyssal passageways of the Rio Grande Gap and Vema Channel. Low accumulation rates of the Eocene deposits (4 m/Ma compacted) suggest that bottom currents at that time carried little or no sediment from the south, even though sedimentary structures indicate some circulation. Thin zones of black muds in the Eocene deposits suggest that any flow within the basin was an internal circulation of poorly oxygenated waters, waters that were *not* undergoing rapid overturn as in the modern basin.

One puzzling result concerns the differences between Unit 1 and Subunits 2a and 2b. For example, the siliceous microfossils of Subunit 2a are not present in Unit 1 or in Subunit 2b. Diagenesis may account for the deeper transition but not the shallow transition. Why does the sedimentation rate change between Units 1 and 2, and is there a short hiatus? Continuous, although fluctuating, cooling at high latitudes has influenced the production of both AABW and the NADW that lies above it. Tectonic events, such as the subsidence of the Iceland-Faeroes Ridge and the opening of Drake Passage, also influenced bottom water transport and possibly production. The Vema Channel itself subsided to near its present depth during the interval of time represented by the sediments recovered at the base of Site 515 (van Andel et al., 1977). Thus it is unlikely that subsidence of the Vema Channel below a critical threshold depth was the limiting factor in allowing deep thermohaline flow to enter the central and northern Atlantic. When that convection developed in the Paleogene, perhaps in repsonse to the initiation of NADW in the northern Atlantic (Miller et al., in press), the passages in the abyssal western Atlantic were already open, in a configuration not greatly different from that of the modern ocean.

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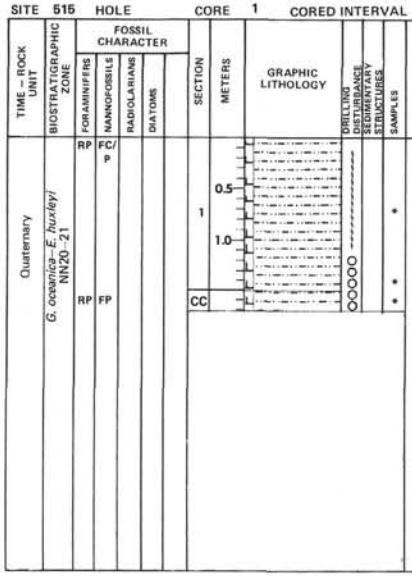
Date of Initial Receipt: November 18, 1982

SITE 515 HOLE CORE 1 CORED INTERVAL 0.0–1.5 m



LITHOLOGIC DESCRIPTION

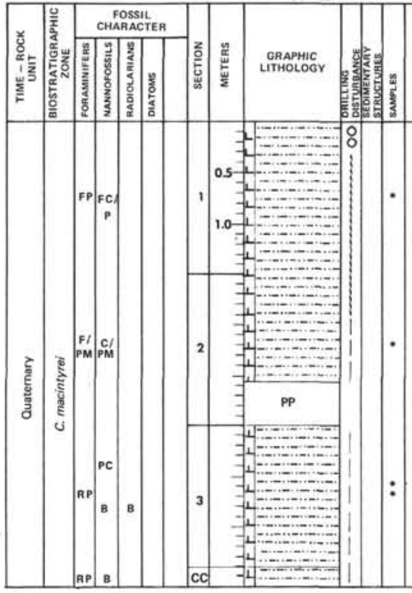
CALCAREOUS and TERRIGENOUS MUD

Color: light brownish gray (2.5Y 6/2) throughout. Uniform color – no mottling or laminations. Slight staining of Mn-oxide 25–60 cm. Carbonate content low at base (dissolved). Soupy and disturbed. Reworked ceratoliths, discoasters at 70 cm; Antarctic diatoms in carbonate-free zone at 145 cm (*Nitzschia kerguelensis*).

SMEAR SLIDE SUMMARY:

	1-70	1-145	CC
	D	D	D
Texture:			
Sand	–	5	–
Silt	25	15	20
Clay	75	80	80
Composition:			
Quartz	3	10	8
Feldspar	2	2	7
Mica	2	5	TR
Heavy minerals	3	2	5
Zeolites	TR	–	–
Other clay minerals	74	66	79
Carbonate unspecified	TR	–	–
Foraminifers	TR	–	–
Nannofossils	15	5	TR
Diatoms	TR	TR	TR
Micronodules	–	10	1
Volcanic glass	TR	TR	TR

SITE 515 HOLE CORE 2 CORED INTERVAL 39.5–49.0 m



LITHOLOGIC DESCRIPTION

Interbedded TERRIGENOUS and CALCAREOUS MUD

Gray (5Y 5/1) with lighter colored calcareous zones, olive gray (5Y 5/2). Structureless. Stiff where undisturbed.

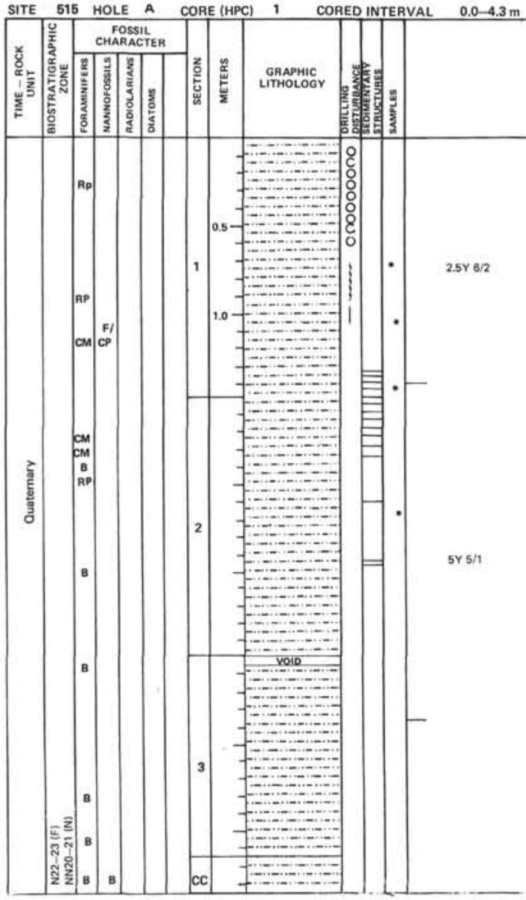
SMEAR SLIDE SUMMARY:

	1-74	2-70	3-70	3-79
	D	M	D	M
Texture:				
Sand	10	5	1	5
Silt	40	15	24	15
Clay	50	80	75	80
Composition:				
Quartz	35	5	9	10
Feldspar	5	1	9	1
Mica	1	1	–	–
Pyrite	1	–	–	TR
Heavy minerals	5	1	–	1
Other clay minerals	46	50	73	78
Carbonate unspecified	1	5	–	5
Nannofossils	–	37	–	–
Diatoms	–	–	TR	–
Volcanic glass	–	–	1	–
Micronodules	5	TR	1	5

NOTE: Core 3: No recovery.

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

SITE 515 HOLE A CORE (HPC) 1 CORED INTERVAL 0.0–4.3 m



LITHOLOGIC DESCRIPTION

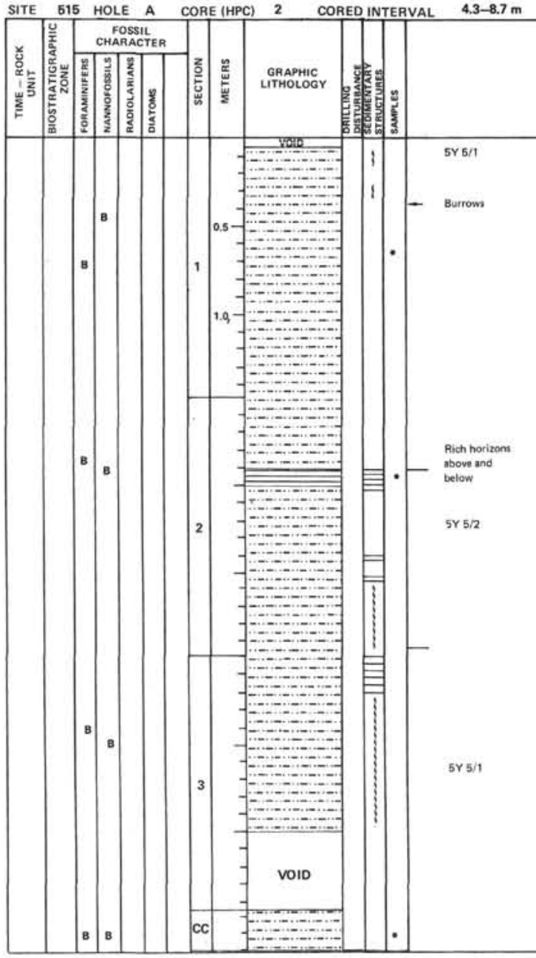
NANNOFOSSIL TERRIGNEOUS MUD

Light brown gray (2.5Y 6/2). Mn staining at 138–150 cm (Section 1).

SMEAR SLIDE SUMMARY:

	1-75 D	1-106 D	1-140 D	2-30 D	2-70 D	3-70 D
Texture:						
Sand	2	5	–	5	3	–
Silt	20	15	25	15	15	25
Clay	78	80	75	80	82	75
Composition:						
Quartz	30	15	5	20	20	10
Feldspar	2	2	5	1	2	10
Mica	2	–	–	1	1	TR
Heavy minerals	3	3	5	3	2	4
Zeolite	–	–	77	–	–	–
Other clay minerals	62	45	72	35	78	75
Carbonate unspecified	TR	–	1	–	–	–
Nannofossils	–	35	4	30	–	TR
Diatoms	TR	TR	1	TR	–	1
Micronodules	–	–	5	10	3	–
Sponge spicules	–	–	TR	TR	TR	–
Glass	–	–	–	–	–	TR

SITE 515 HOLE A CORE (HPC) 2 CORED INTERVAL 4.3–8.7 m



LITHOLOGIC DESCRIPTION

SILICEOUS TERRIGENOUS MUD

Uniform gray (5Y 5/1) throughout section 1.

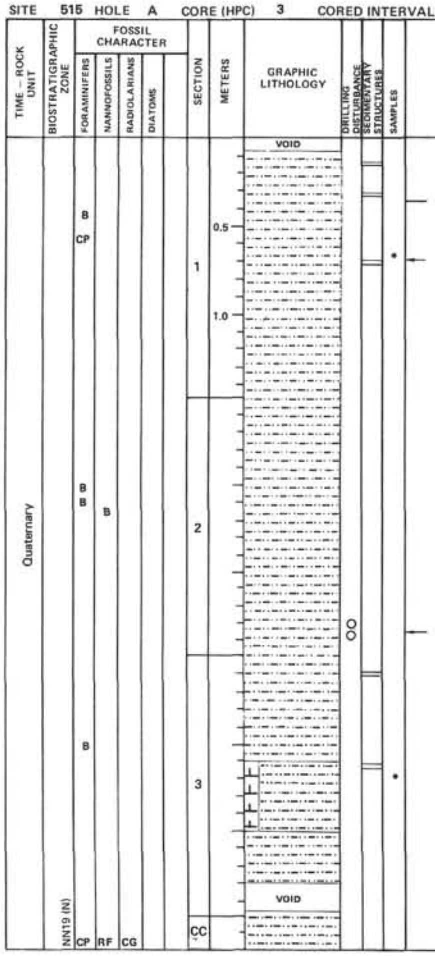
NONFOSSILIFEROUS PELAGIC CLAY

Red brown at Section 2, 40–50 cm.

SMEAR SLIDE SUMMARY:

	1-70 D	2-48 D	CC D
Texture:			
Sand	5	–	1
Silt	15	5	24
Clay	80	95	75
Composition:			
Quartz	–	5	8
Feldspar	–	TR	7
Mica	10	TR	TR
Heavy minerals	5	–	3
Other clay minerals	74	87	76
Carbonate unspecified	5	–	–
Diatoms	1	2	5
Radiolarians	5	–	TR
Silicoflagellates	–	–	TR
Sponge spicules	–	–	TR
Glass	–	–	TR
Micronodules	TR	5	1

SITE 515 HOLE A CORE (HPC) 3 CORED INTERVAL 8.7–13.1 m



5Y 5/1

5Y 5/3 dark laminations gradual contact
Contact darker color below

Contact darker color below

LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Gray (5Y 5/1). Section 3, 60–100 cm: relatively nanno-rich interval with no corresponding color change.

SMEAR SLIDE SUMMARY:

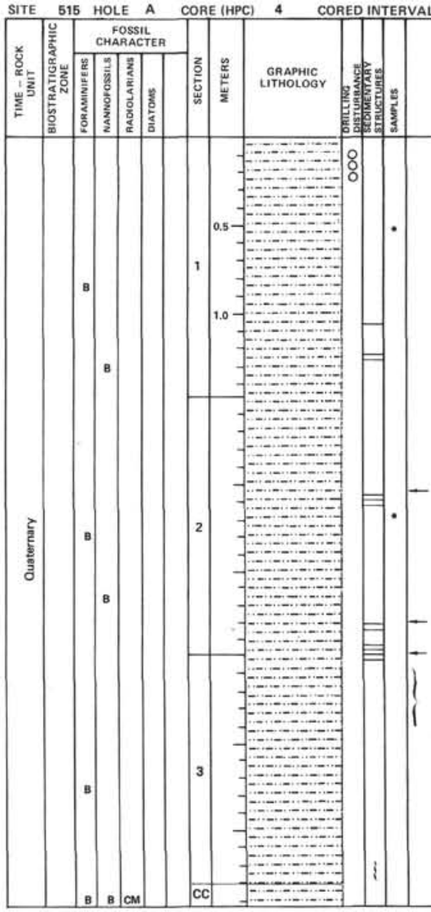
	1-70	3-70
	D	D
Texture:		
Sand	8	TR
Silt	22	15
Clay	70	85
Composition:		
Quartz	5	5
Feldspar	3	3
Mica	3	1
Heavy minerals	5	5
Other clay minerals	70	48
Nannofossils	TR	15
Diatoms	TR	–
Radiolarians	TR	–
Volcanic glass	–	12
Sponge spicules	TR	–
Micronodules	15	1

PHYSICAL PROPERTIES:

	1-100	1-92	2-65	2-63	3-65	3-63
V_v	—	—	—	—	—	—
V_h	1.48	—	1.47	—	1.49	—
Density	—	1.49	—	1.43	—	1.53
Water content	—	53	—	54	—	47

CARBONATE BOMB:
1-20 = 16
1-70 = 9
1-130 = 5
2-20 = 0
2-70 = 5
2-120 = 0

SITE 515 HOLE A CORE (HPC) 4 CORED INTERVAL 13.1–17.5 m



5Y 5/1

5Y 4/2 olive gray laminations

5Y 6/3

5Y 4/2 laminations

Alternations in color ranging from 5Y 5/1–5Y 4/2–5Y 4/1

5 y 5/1

LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

Gray (5Y 5/1).

SMEAR SLIDE SUMMARY:

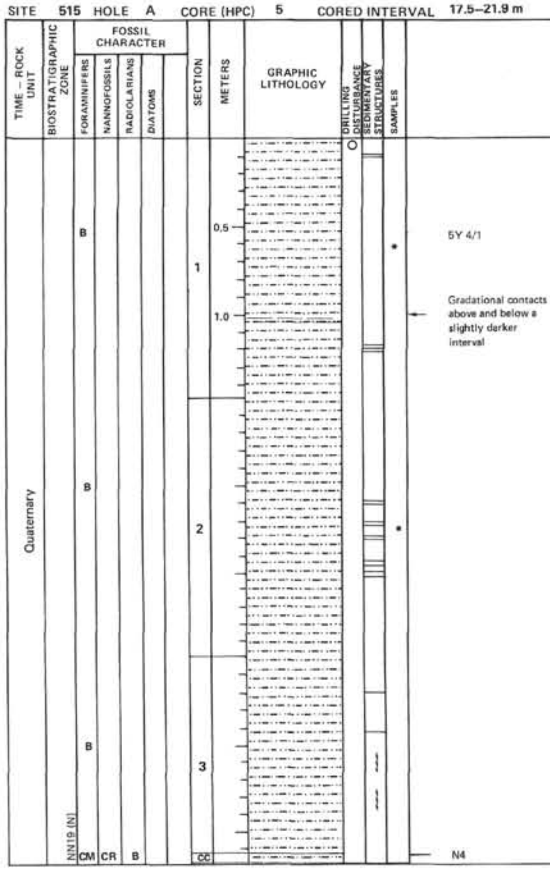
	1-51	2-70
	D	D
Texture:		
Sand	–	20
Silt	20	25
Clay	80	55
Composition:		
Quartz	10	3
Feldspar	2	–
Mica	2	TR
Heavy minerals	–	5
Glauconite	–	3
Other clay minerals	86	77
Diatoms	–	TR
Micronodules	TR	5

PHYSICAL PROPERTIES:

	1-67	1-95	1-103	2-85	2-82	3-65
V_v	—	—	—	—	—	—
V_h	1.49	1.49	—	1.49	—	1.48
Density	—	—	1.50	—	1.52	—
Water content	—	—	49	—	48	—

CARBONATE BOMB:
2-20 = 25
2-70 = 0
2-120 = 11
3-20 = 6
3-70 = 5
3-120 = 5

SITE 515 HOLE A CORE (HPC) 5 CORED INTERVAL 17.5–21.9 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Section 1, 125 cm: distinct, dark green gray (5G 4/1) laminations. Section 2: green (5G 4/1) laminae in 5Y 5/1 groundmass. Section 3: slight mottling – N4 colored spots in gray groundmass.

SMEAR SLIDE SUMMARY:

	1-63	2-70
	D	D
Texture:		
Sand	1	TR
Silt	10	15
Clay	89	85
Composition:		
Quartz	10	5
Glauconite	5	–
Other clay minerals	82	80
Diatoms	TR	5
Radiolarians	–	TR
Sponge spicules	–	1
Micronodules	3	10

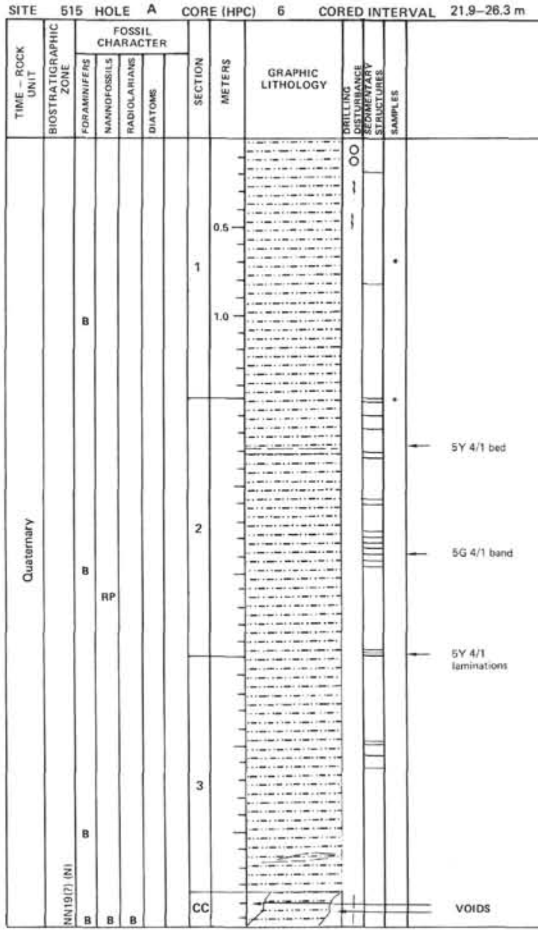
PHYSICAL PROPERTIES:

	1-100	1-98	2-97	2-103	3-65	3-70
V_v	—	—	—	—	—	—
V_h	1.48	—	1.49	—	1.49	—
Density	—	1.46	—	1.50	—	1.53
Water content	—	52	—	49	—	47

CARBONATE BOMB:

1-20 = 5
1-70 = 6
1-120 = 6
2-20 = 5
2-70 = 6
2-120 = 6
3-20 = 6
3-70 = 6

SITE 515 HOLE A CORE (HPC) 6 CORED INTERVAL 21.9–26.3 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

Gray (5Y 5/1) groundmass. Section 3, 115 cm: dark, organic-rich horizon with gradational contacts.

SMEAR SLIDE SUMMARY:

	1-70	2-5
	D	D
Texture:		
Sand	–	5
Silt	50	40
Clay	50	55
Composition:		
Quartz	2	TR
Feldspar	1	TR
Mica	–	TR
Heavy minerals	TR	–
Glauconite	2	–
Other clay minerals	93	72
Carbonate unspecified	–	3
Diatoms	TR	–
Radiolarians	–	57
Micronodules	–	20

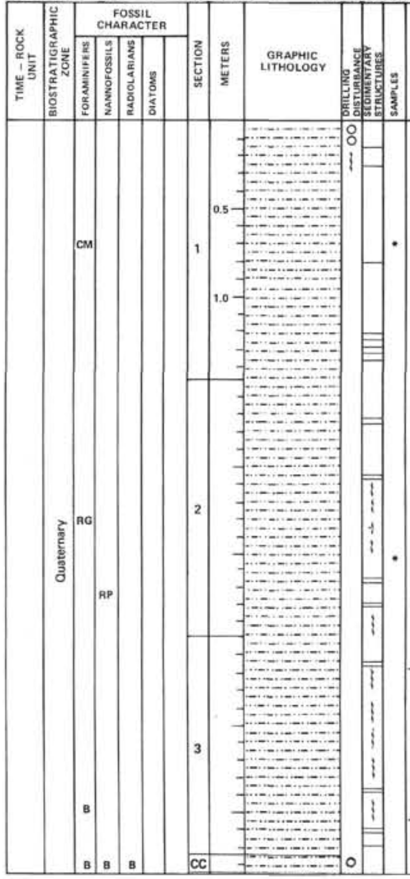
PHYSICAL PROPERTIES:

	1-100	1-102	2-65	2-64	3-73	3-68
V_v	—	—	—	—	—	—
V_h	1.49	—	1.49	—	1.47	—
Density	—	1.46	—	1.52	—	1.50
Water content	—	52	—	47	—	49

CARBONATE BOMB:

1-20 = 5
1-70 = 5
1-130 = 5
2-20 = 5
2-70 = 7
2-120 = 6
3-20 = 8
3-70 = 5
3-120 = 26

SITE 515 HOLE A CORE (HPC) 7 CORED INTERVAL 26.3–30.7 m



Laminations: greenish gray

Laminations: 5Y 2/1

LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Gray (5Y 6/1) groundmass. Groundmass is 5Y 5/3 in Section 2 and laminations are greenish gray (5G 4/1).

SMEAR SLIDE SUMMARY:

	1-70 D	2-104 D
Texture:		
Sand	5	3
Silt	50	30
Clay	45	67
Composition:		
Quartz	2	TR
Feldspar	1	–
Heavy minerals	TR	5
Glauconite	3	8
Other clay minerals	90	77
Nannofossils	1	–
Radiolarians	–	5
Micronodules	–	5
Volcanic glass	2	–

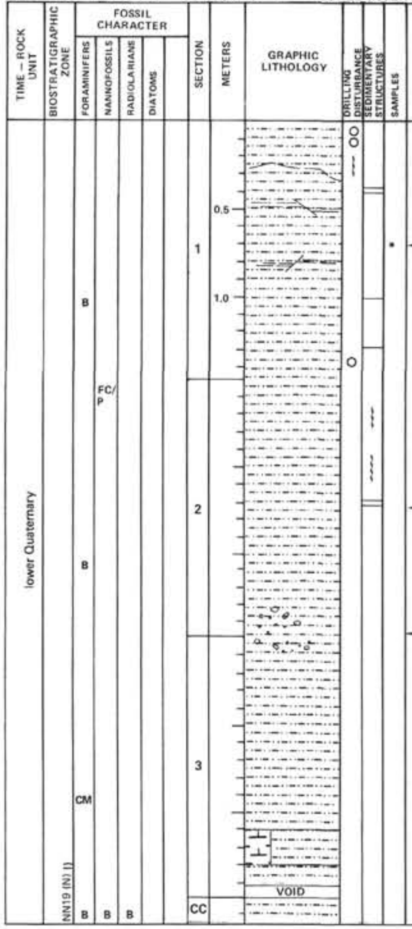
PHYSICAL PROPERTIES:

	1-100	1-102	2-66	2-69	3-64	3-65
V_v	—	—	—	—	—	—
V_h	1.47	—	1.49	—	—	1.50
Density	—	1.55	—	1.47	1.55	—
Water content	—	45	—	51	45	—

CARBONATE BOMB:

1-20 = 4
1-70 = 4
1-120 = 12
2-120 = 4
3-20 = 4
3-70 = 10
3-120 = 6

SITE 515 HOLE A CORE (HPC) 8 CORED INTERVAL 30.7–35.1 m



5 v 5/2

5Y 5/2

Drilling induced(?) offsets

5Y 6/2

Green laminations

5Y 6/3

Black spots

LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Contamination in uppermost part of core. Section 2, 30 cm: 5Y 7/2 layer, with gradual transitions above and below. Section 3 is pale olive (5Y 6/3) groundmass with green laminations. Section 3, 100 cm: light gray (5Y 7/2) layer, with gradual transitions above and below.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	1
Silt	59
Clay	40
Composition:	
Quartz	2
Feldspar	2
Mica	5
Glauconite	3
Other clay minerals	87
Nannofossils	1
Micronodules	TR

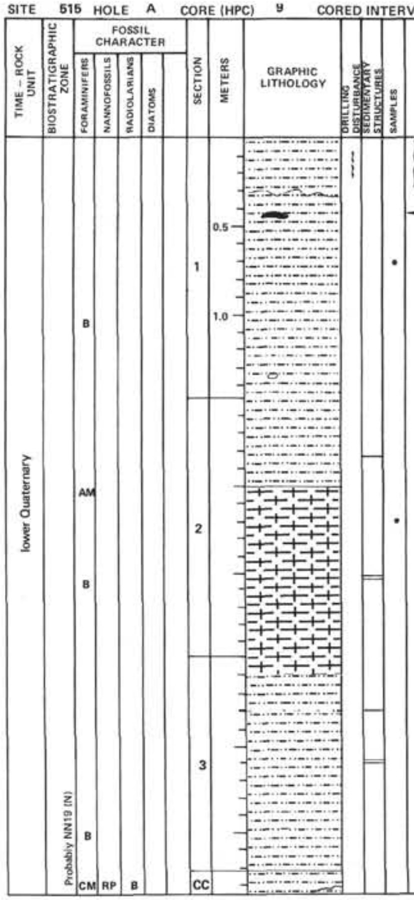
PHYSICAL PROPERTIES:

	1-65	1-104	2-70	2-77	3-68
V_v	—	—	—	—	—
V_h	1.49	—	1.48	—	1.51
Density	—	1.57	—	1.56	1.59
Water content	—	44	—	45	43

CARBONATE BOMB:

1-20 = 6
1-70 = 4
1-120 = 5
2-20 = 4
2-70 = 4
2-120 = 4
3-20 = 4
3-70 = 4
3-120 = 32

SITE 515 HOLE A CORE (HPC) 9 CORED INTERVAL 35.1–39.5 m



LITHOLOGIC DESCRIPTION

Reworked by HPC

Spot (N3)

5Y 4/1

5Y 6/1

TERRIGENOUS MUD WITH NANNO OOZE HORIZONS

Section 1: dark gray (5Y 4/1) with small black spots throughout. Section 2 is gray (5Y 6/1) with little color contrast between nanno-rich and nanno-barren intervals.

SMEAR SLIDE SUMMARY:

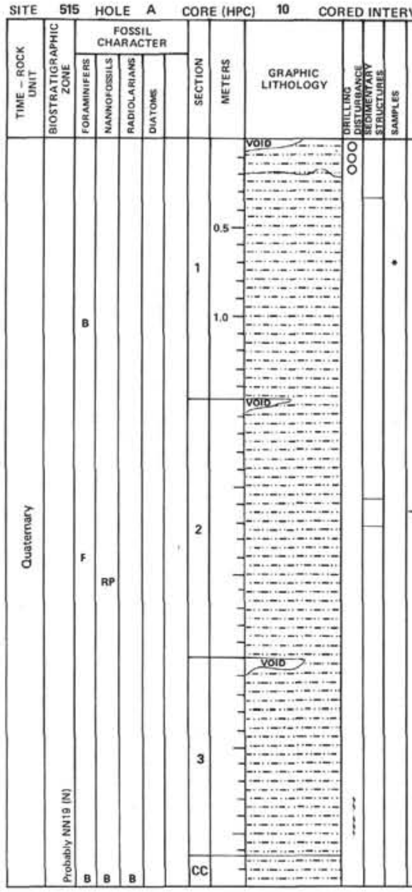
	1-70	2-70
	D	D
Texture:		
Sand	2	8
Silt	15	22
Clay	83	70
Composition:		
Mica	8	–
Heavy minerals	5	–
Other clay minerals	82	–
Carbonate unspecified	5	–
Foraminifers	–	15
Nannofossils	–	85

PHYSICAL PROPERTIES:

	1-100	1-99	2-65	2-66	3-65	3-66
V_v	—	—	—	—	—	—
V_h	1.49	—	1.50	—	1.51	—
Density	—	1.62	—	1.65	—	1.61
Water content	—	41	—	39	—	42

CARBONATE BOMB:
1-20 = 0
1-70 = 4
1-120 = 4
2-20 = 0
2-70 = 18
2-120 = 9
3-20 = 4
3-70 = 1.5
3-120 = 4

SITE 515 HOLE A CORE (HPC) 10 CORED INTERVAL 39.5–43.9 m



LITHOLOGIC DESCRIPTION

5Y 5/1

5Y 5/3

Faint laminations

TERRIGENOUS MUD WITH
NANNO OOZE HORIZONS

Top of Section 1 is disturbed by HPC. Section 3, 40 cm: olive gray (5Y 6/3) gradational contacts above and below.

SMEAR SLIDE SUMMARY:

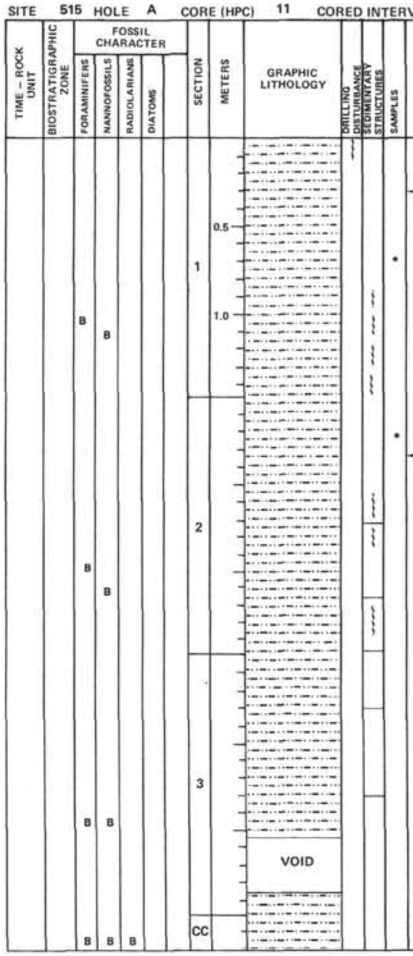
	1-70
	D
Texture:	
Sand	1
Silt	39
Clay	60
Composition:	
Quartz	2
Mica	10
Heavy minerals	5
Glauconite	2
Other clay minerals	60
Carbonate unspecified	5
Nannofossils	TR
Radiolarians	5
Opaque minerals	10
Micronodules	1

PHYSICAL PROPERTIES:

	1-100	1-97	2-100	2-97	3-75	3-58
V_v	—	—	—	—	—	—
V_h	1.50	—	1.49	—	1.50	—
Density	—	1.59	—	1.58	1.63	1.69
Water content	—	43	—	43	40	37

CARBONATE BOMB:
1-30 = 5
1-70 = 4
1-120 = 4
2-20 = 5
2-70 = 4
2-120 = 4
3-20 = 5
3-70 = 22
3-110 = 4

SITE 515 HOLE A CORE (HPC) 11 CORED INTERVAL 43.9–48.3 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD (NONFOSSILIFEROUS)

2.5Y 2/2

SMEAR SLIDE SUMMARY:

	1-70 D	2-22 D
Texture:		
Sand	3	3
Silt	15	15
Clay	82	82
Composition:		
Quartz	15	15
Feldspar	3	3
Mica	1	1
Heavy minerals	2	2
Other clay minerals	78	78

PHYSICAL PROPERTIES:

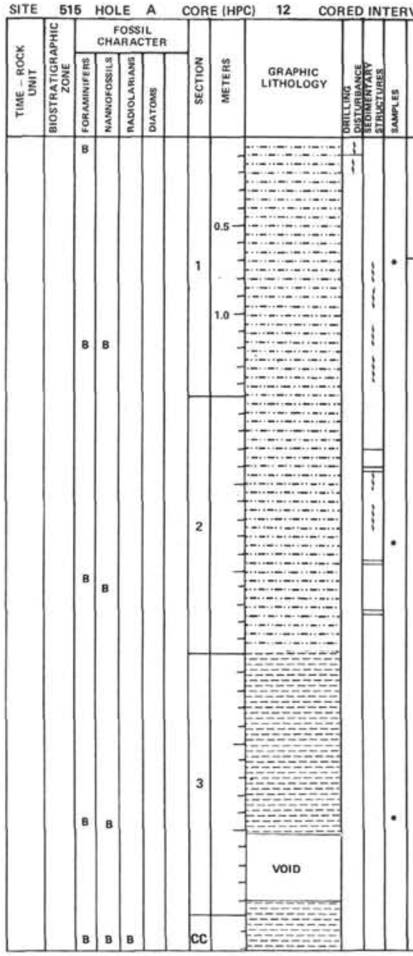
	1-70	2-70	3-70
V_v	—	—	—
V_h	1.50	1.51	1.50
Density	1.63	1.63	1.58
Water content	40	40	44

5Y 5/2

CARBONATE BOMB:
1-20 = 6
1-70 = 5
1-120 = 4
2-20 = 0
2-70 = 4
2-120 = 5
3-20 = 4
3-70 = 4

5Y 5/1

SITE 515 HOLE A CORE (HPC) 12 CORED INTERVAL 48.3–52.7 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS
MUD AND CLAY

Sections 1 and 2: gray (5Y 5/1) mud with Section 3 being olive gray (5Y 4/2) clay.

5Y 5/2

SMEAR SLIDE SUMMARY:

	1-70 D	2-84 D	3-96 D
Texture:			
Sand	–	1	–
Silt	10	10	5
Clay	90	89	95
Composition:			
Quartz	6	7	3
Feldspar	1	TR	–
Mica	1	1	–
Heavy minerals	1	1	1
Other clay minerals	90	89	95
Micronodules	1	1	1

5Y 5/1

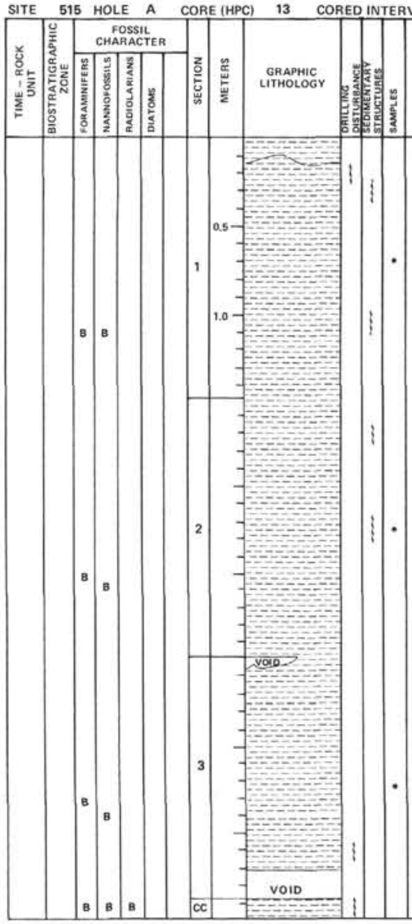
PHYSICAL PROPERTIES:

	1-100	2-70	3-70	3-68
V_v	—	—	—	—
V_h	1.51	1.51	1.52	—
Density	1.62	1.65	—	1.66
Water content	39.3	38.7	—	38.6

CARBONATE BOMB:
1-20 = 4
1-70 = 4
2-20 = 5
2-70 = 4
2-120 = 4
3-20 = 4
3-70 = 4
3-100 = 4

5Y 4/2

SITE 515 HOLE A CORE (HPC) 13 CORED INTERVAL 52.7–57.1 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS TERRIGENOUS CLAY

HPC disturbance at top of Section 1.

10YR 5/1

SMEAR SLIDE SUMMARY:

	1-70 D	2-70 D	3-70 D
Texture:			
Sand	1	–	–
Silt	7	8	5
Clay	92	92	92
Composition:			
Quartz	7	5	8
Mica	–	TR	TR
Heavy minerals	1	1	1
Other clay minerals	90	92	90
Micronodules	2	2	1

PHYSICAL PROPERTIES:

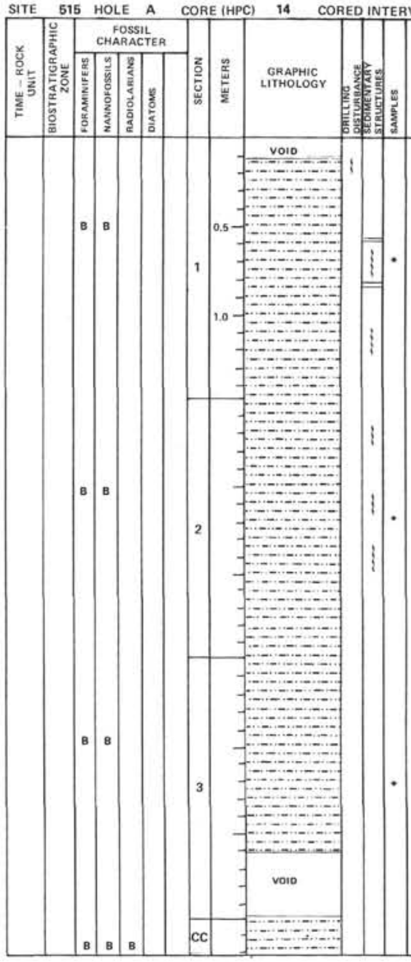
	1-100	1-69	2-70	2-68	3-70	3-68
V_v	—	—	—	—	—	—
V_h	1.52	—	1.50	—	1.52	—
Density	—	1.65	—	1.67	—	1.66
Water content	—	38.7	—	37.9	—	38.5

5Y 5/2

CARBONATE BOMB:
1-20 = 4
1-70 = 5
1-120 = 5
2-20 = 4
2-70 = 5
2-120 = 4
3-20 = 4
3-70 = 4
3-120 = 4

2.5Y 5/2

SITE 515 HOLE A CORE (HPC) 14 CORED INTERVAL 57.1–61.5 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

2.5Y 6/2

Mn-oxide (organic debris?) zones of concentration at 17–37, 42–65, and 114–136 cm of Section 2 and Core-Catcher.

SMEAR SLIDE SUMMARY:

	1-70 D	2-70 D	3-70 D
Texture:			
Sand	–	–	–
Silt	25	20	15
Clay	75	80	85
Composition:			
Quartz Feldspar	15	15	12
Heavy minerals	5	2	1
Other clay minerals	77	81	85
Micronodules	3	1	1

2.5Y 6/4

PHYSICAL PROPERTIES:

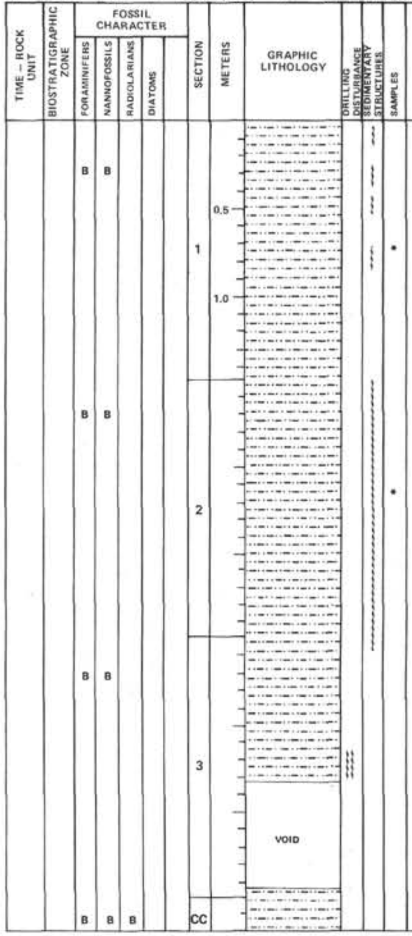
	1-100	1-98	2-70	3-70
V_v	—	—	—	—
V_h	1.52	—	1.52	1.52
Density	—	1.68	1.66	1.68
Water content	—	37.2	38.6	37.2

2.5Y 6/2

CARBONATE BOMB:
1-30 = 4
1-70 = 4
1-120 = 4
2-20 = 4
2-70 = 5
2-120 = 5
3-20 = 5
3-70 = 4

NOTE: Core 15, 61.5–65.9 m: No recovery.

SITE 515 HOLE A CORE (HPC) 16 CORED INTERVAL 65.9–69.9 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Light brownish gray (2.5Y 6/2) with mottling of light bluish gray (5B 7/1) in Sections 2 and 3. Small mottles of Mn-oxide in Section 1. Minor fractures common. Possible flow-in sediments of Section 3 below 35 cm plus Core-Catcher. Not enough color contrast to be certain.

SMEAR SLIDE SUMMARY:

	1-70	2-65
	D	D
Texture:		
Sand	2	3
Silt	15	15
Clay	83	82
Composition:		
Quartz	10	10
Feldspar	3	3
Mica	1	1
Heavy minerals	2	2
Other clay minerals	82	82
Diatoms	TR	–
Micronodules	2	2
Sponge spicules	TR	–

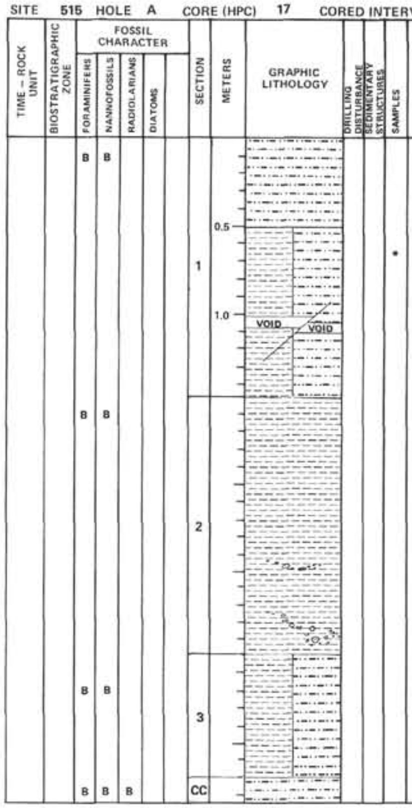
PHYSICAL PROPERTIES:

	1-70	1-68	2-70	2-68
V_v	—	—	—	—
V_h	1.52	—	1.53	—
Density	—	1.69	—	1.67
Water content	—	36.8	—	37.8

CARBONATE BOMB:

1-20 = 4
1-70 = 0.5
1-120 = 5
2-20 = 4
2-70 = 4
2-120 = 4
3-20 = 4

SITE 515 HOLE A CORE (HPC) 17 CORED INTERVAL 69.9–73.9 m



LITHOLOGIC DESCRIPTION

2.5Y 6/2

NONFOSSILIFEROUS TERRIGENOUS CLAY (MANGANIFEROUS)

Light brown gray (2.5Y 6/2) with light bluish gray (5B 7/1) Mn staining. Coring induced offset in Section 1. Mn-rich interval 92–95 cm, Section 2.

SMEAR SLIDE SUMMARY:

	1-70
	D
Texture:	
Sand	1
Silt	7
Clay	92
Composition:	
Quartz	3
Feldspar	2
Mica	1
Heavy minerals	1
Other clay minerals	92
Micronodules	1

PHYSICAL PROPERTIES:

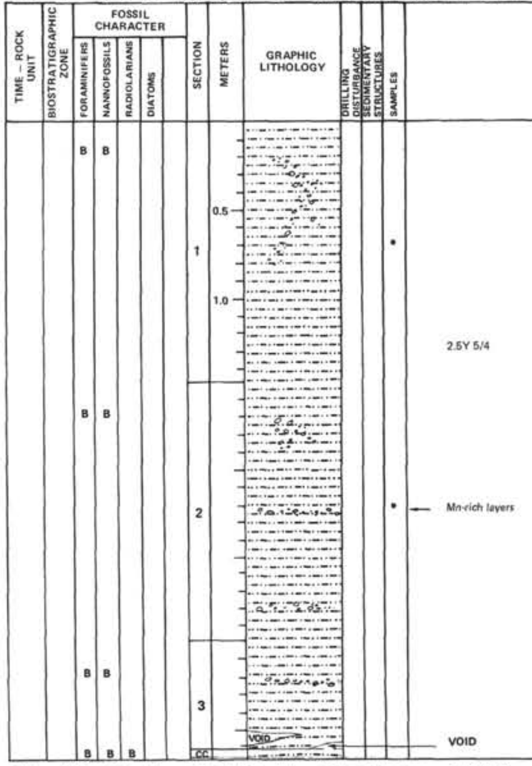
	1-142	2-70	3-52
V_v	—	—	—
V_h	—	1.52	—
Density	1.67	1.68	1.68
Water content	37.9	37.4	37.0

CARBONATE BOMB:

1-20 = 5
1-70 = 4
1-120 = 4
2-20 = 0
2-70 = 4
2-120 = 4
3-20 = 4

2.5Y 5/3

SITE 515 HOLE A CORE (HPC) 18 CORED INTERVAL 73.9–77.9 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

Interval rich in organic debris 20–92 cm (Section 1). Dark grayish brown (2.5Y 4/2) groundmass. Section 2: large clots of organic debris.

SMEAR SLIDE SUMMARY:

	1-70 D	2-70 D
Texture:		
Sand	2	3
Silt	30	15
Clay	68	82
Composition:		
Quartz	2	3
Feldspar	2	2
Mica	2	8
Glauconite	1	–
Other clay minerals	92	85
Radiolarians	–	TR
Micronodules	1	2

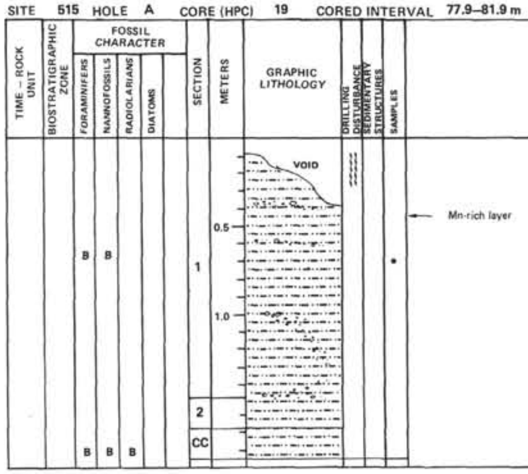
PHYSICAL PROPERTIES:

	1-100	2-65	3-32
V_v	—	—	—
V_h	1.52	1.54	—
Density	1.67	1.70	1.69
Water content	37.8	36.1	36.9

CARBONATE BOMB:

1-20 = 7
1-70 = 4
1-120 = 6
2-20 = 5
2-70 = 4
2-130 = 5
3-20 = 4

SITE 515 HOLE A CORE (HPC) 19 CORED INTERVAL 77.9–81.9 m



LITHOLOGIC DESCRIPTION

MANGANIFEROUS NONFOSSILIFEROUS TERRIGENOUS MUD

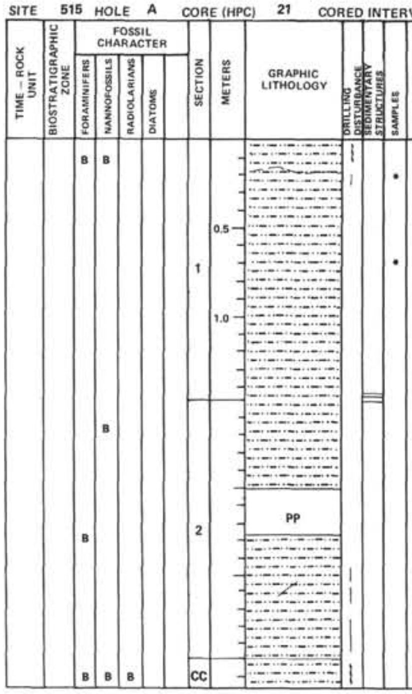
Grayish brown (2.5Y 5/2) groundmass.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	1
Silt	45
Clay	54
Composition:	
Quartz	3
Mica	5
Heavy minerals	5
Other clay minerals	86
Micronodules	1

NOTE: Core 20, 81.9–85.9 m: No recovery.

SITE 515 HOLE A CORE (HPC) 21 CORED INTERVAL 85.9–88.9 m



LITHOLOGIC DESCRIPTION

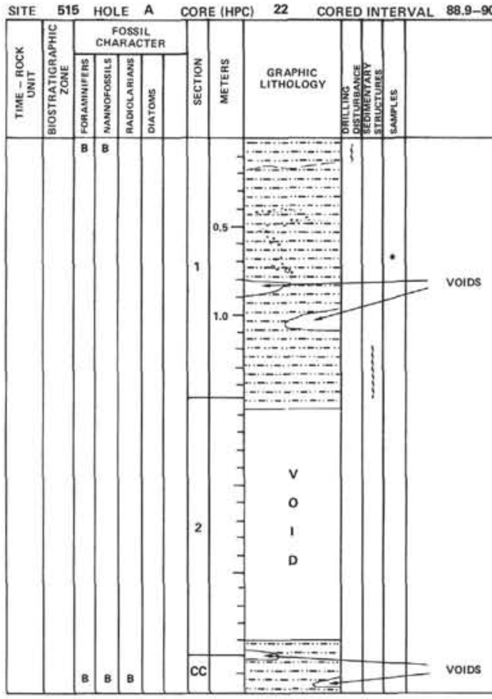
NONFOSSILIFEROUS TERRIGENOUS MUD

Light brownish gray (2.5Y 6/2) groundmass. Section 1, 125–140 cm: disseminated Mn. Offset, HPC induced, olive black (5Y 2/1) manganese bands in Section 2.

SMEAR SLIDE SUMMARY:

	1-21 D	1-70 D
Texture:		
Sand	–	2
Silt	30	43
Clay	70	55
Composition:		
Quartz	5	20 + 5
Feldspar	5	
Mica	5	10
Heavy minerals	5	5
Other clay minerals	78	58
Nannofossils	TR	–
Micronodules	2	2

SITE 515 HOLE A CORE (HPC) 22 CORED INTERVAL 88.9–90.9 m



LITHOLOGIC DESCRIPTION

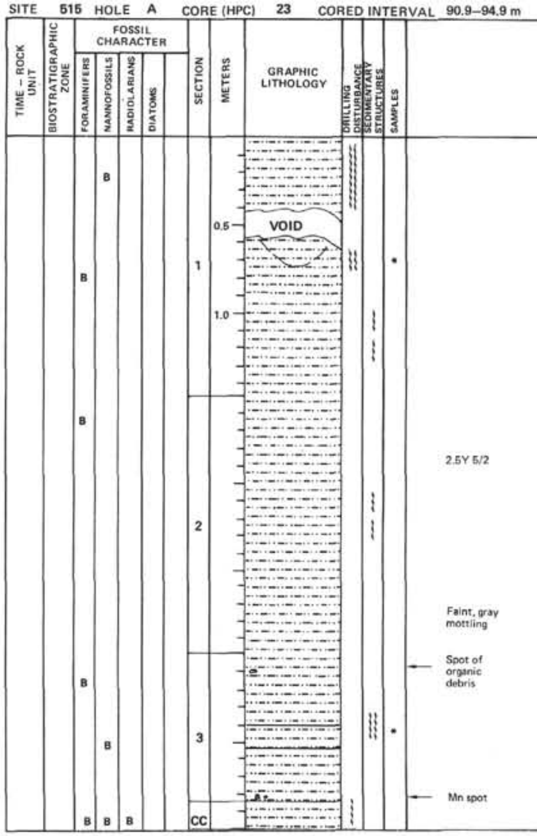
NONFOSSILIFEROUS, TERRIGENOUS MUD

Grayish brown (2.5Y 5/2). Base of Section 1 has mottling and no manganese.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	1
Silt	29
Clay	70
Composition:	
Quartz	1
Feldspar	1
Mica	4
Other clay minerals	93
Micronodules	1

SITE 515 HOLE A CORE (HPC) 23 CORED INTERVAL 90.9–94.9 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

Infilling of coring disturbed sediment in Section 1. Section 3, 40–85 cm: greenish gray (5G 6/1) clay aggregates.

SMEAR SLIDE SUMMARY:

	1-70 D	3-45 D
Texture:		
Sand	TR	3
Silt	15	10
Clay	85	87
Composition:		
Quartz	8	3
Feldspar	3	–
Mica	4	5
Heavy minerals	5	–
Other clay minerals	78	92
Micronodules	2	–

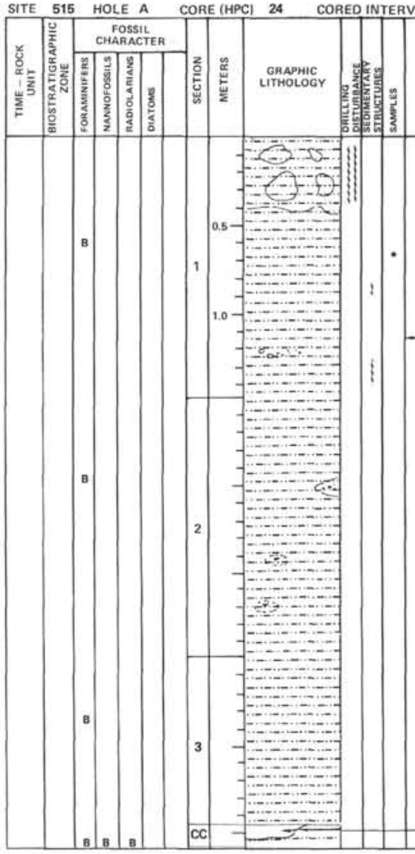
PHYSICAL PROPERTIES:

	1-102	1-110	2-70	3-30	3-29
V_v	—	—	—	—	—
V_h	—	1.52	1.53	1.53	—
Density	1.67	—	1.68	—	1.65
Water content	37.9	—	37.2	—	39.2

CARBONATE BOMB:

1-20 = 4
1-70 = 4
1-120 = 4
2-20 = 4
2-70 = 0
2-120 = 4
3-20 = 6
3-50 = 4

SITE 515 HOLE A CORE (HPC) 24 CORED INTERVAL 94.9–98.9 m



LITHOLOGIC DESCRIPTION

2.5Y 5/2

Faint gray mottles

Spots: *organic* debris

Faint, gray mottling

VOID

NONFOSSILIFEROUS, TERRIGENOUS MUD

Aggregates of greenish sediment worked in during coring. Grayish brown (2.5Y 5/2) groundmass. Section 3: uniform 2.5Y 5/2 with exception of some very faint mottling.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	2
Silt	20
Clay	78
Composition:	
Quartz	8
Feldspar	3
Mica	5
Other clay minerals	70
Green minerals	10
Micronodules	2

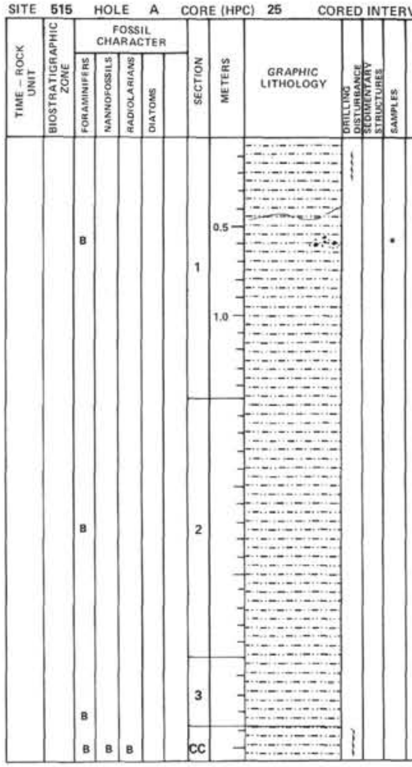
PHYSICAL PROPERTIES:

	1-101	1-110	2-70	3-50
V_v	—	—	—	—
V_h	—	1.52	1.53	1.54
Density	1.67	—	1.72	1.71
Water content	36.8	—	35.2	35.3

CARBONATE BOMB:

1-20 = 4
1-70 = 5
1-120 = 4
2-20 = 4
2-70 = 5
2-120 = 4
3-20 = 4
3-70 = 0

SITE 515 HOLE A CORE (HPC) 25 CORED INTERVAL 98.9–102.4 m



LITHOLOGIC DESCRIPTION

2.5Y 6/2

2.5Y 6/2 and
?.5Y 5/2

NONFOSSILIFEROUS, TERRIGENOUS MUD

Light yellowish brown (2.5Y 6/2) with blebs of opaque grains at 59–64 cm of *Section* 1.

SMEAR SLIDE SUMMARY:

	1-60 M
Texture:	
Sand	10
Silt	50
Clay	40
Composition:	
Other clay minerals	40
Micronodules	60

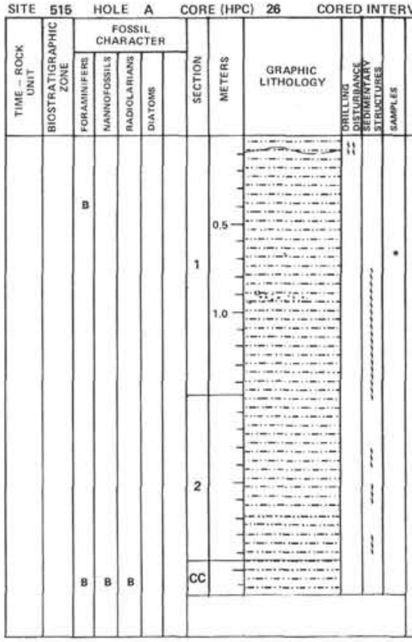
PHYSICAL PROPERTIES:

	1-110
V_v	—
V_h	1.56
Density	1.73
Water content	34.6

CARBONATE BOMB:

1-20 = 4
1-70 = 5
1-120 = 4
2-20 = 4
2-70 = 4
2-120 = 4
3-20 = 4

SITE 515 HOLE A CORE (HPC) 26 CORED INTERVAL 102.4–105.4 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

Light yellow brown (2.5Y 6/2) with mottling of grayish brown (2.5Y 5/2) mottling(?) = burrowing. Top highly disturbed due to core liner implosion and cracking.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	–
Silt	15
Clay	85
Composition:	
Quartz	1
Feldspar	1
Mica	TR
Heavy minerals	2
Micronodules	TR

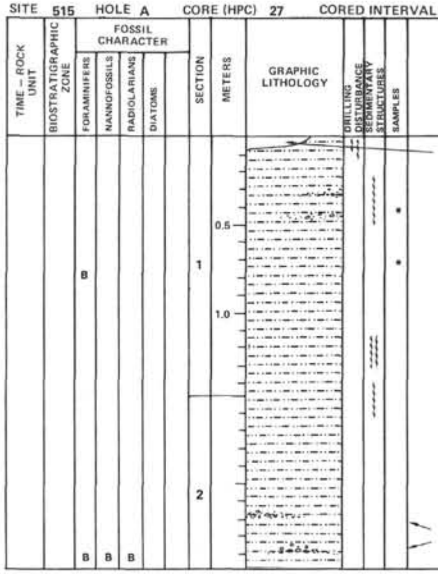
PHYSICAL PROPERTIES:

	1-70	1-68	2-70	2-68
V_v	—	—	—	—
V_h	1.55	—	1.56	—
Density	—	1.76	—	1.73
Water content	—	32.9	—	34.3

CARBONATE BOMB:

1-20 = 4
1-70 = 4
1-120 = 5
2-20 = 5
2-70 = 5

SITE 515 HOLE A CORE (HPC) 27 CORED INTERVAL 105.4–107.9 m



LITHOLOGIC DESCRIPTION

VOID

NONFOSSILIFEROUS, TERRIGENOUS MUD

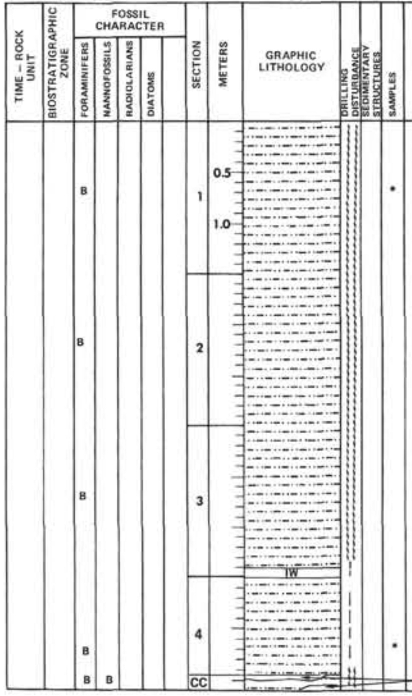
Pale brown (10YR 6/4) terrigenous mud, mottled and with concentrations of dark spots (micronodules?), that sometimes form laminations (35 and 50 cm).

SMEAR SLIDE SUMMARY:

	1-48 M	1-70 D
Texture:		
Sand	10	1
Silt	30	10
Clay	70	89
Composition:		
Quartz	10	5
Feldspar	–	3
Pyrite	–	1
Heavy minerals	–	1
Other clay minerals	40	89
Micronodules	60	1

Mn-rich(?) spots

SITE 515 HOLE B CORE 1 CORED INTERVAL 94.9–104.4 m



LITHOLOGIC DESCRIPTION

5Y 5/3

5Y 5/2

2.5Y 5/2

VOIDS

NONFOSSILIFEROUS, TERRIGENOUS MUD

Color: olive (5Y 5/3) and olive gray (5Y 5/2). Layer of organic debris in Section 1.

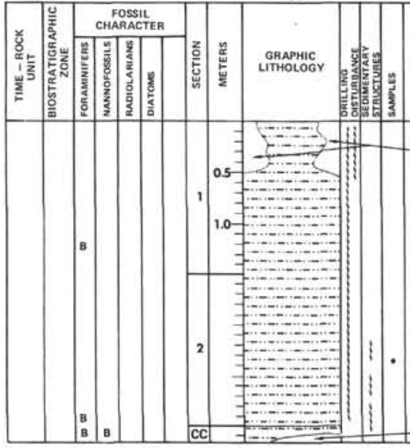
SMEAR SLIDE SUMMARY:

	1-70 D	4-70 D
Texture:		
Sand	3	3
Silt	42	20
Clay	55	77
Composition:		
Quartz	15	30
Feldspar		
Mica	10	5
Heavy minerals	3	3
Other clay minerals	57	59
Micronodules	15	3

PHYSICAL PROPERTIES:

	3-133	3-132	4-70
V_v	—	—	—
V_h	1.51	—	1.54
Density	—	—	—
Water content	—	35.8	35.5

SITE 515 HOLE B CORE 2 CORED INTERVAL 104.4–113.9 m



LITHOLOGIC DESCRIPTION

VOIDS

2.5Y 5/2

VOID

NONFOSSILIFEROUS, TERRIGENOUS MUD

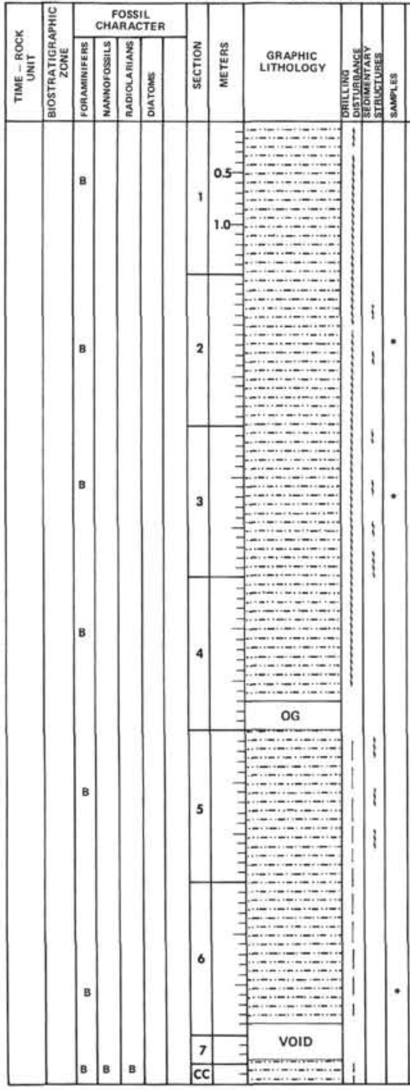
Drilling disturbed. Color: grayish brown (2.5Y 5/2).

SMEAR SLIDE SUMMARY:

	2-85 D
Texture:	
Sand	1
Silt	10
Clay	89
Composition:	
Quartz	5
Feldspar	2
Mica	1
Other clay minerals	89
Micronodules	1

CARBONATE BOMB:
2-100 = 2

SITE 515 HOLE B CORE 3 CORED INTERVAL 113.9–123.4 m



LITHOLOGIC DESCRIPTION

10YR 5/2

10YR 6/1

NONFOSSILIFEROUS, TERRIGENOUS MUD

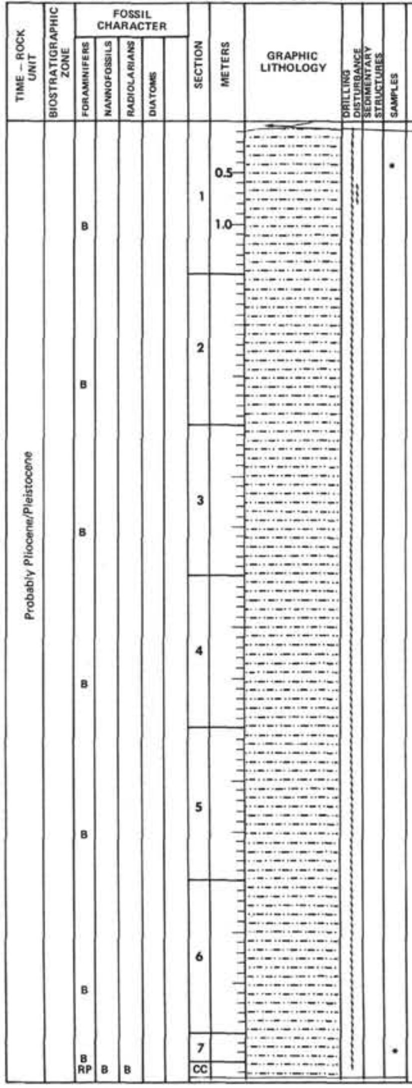
Grayish brown (10YR 5/2) with some mottling in Section 2. Section 4 has some stained spots.

SMEAR SLIDE SUMMARY:

	2-67 D	3-70 D	6-118 D
Texture:			
Sand	1	1	1
Silt	10	10	10
Clay	89	89	89
Composition:			
Quartz	5	5	7
Feldspar	3	3	3
Mica	1	1	1
Heavy minerals	1	1	–
Other clay minerals	89	89	87
Micronodules	1	1	1

CARBONATE BOMB:
2-70 = 2
4-70 = 2
6-70 = 2

SITE 515 HOLE B CORE 4 CORED INTERVAL 123.4–132.9 m



VOID

10YR 5/2

LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

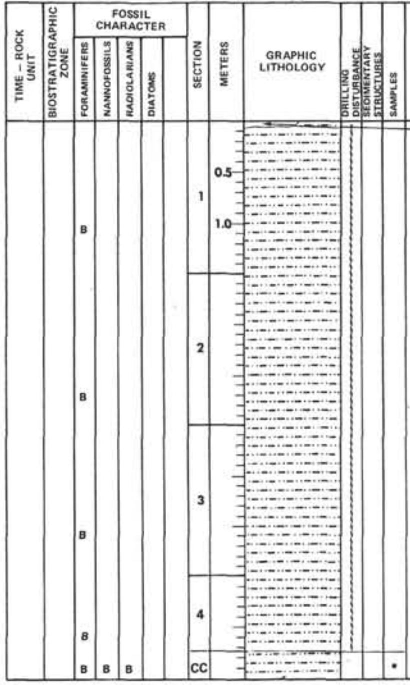
Gray (2.5Y 5/0) mud with bluish mottles.

SMEAR SLIDE SUMMARY:

	1-41 D	7-20 D
Texture:		
Sand	1	TR
Silt	10	10
Clay	89	90
Composition:		
Quartz	4	6
Feldspar	3	3
Mica	2	1
Heavy minerals	1	–
Other clay minerals	89	90
Sponge spicules	1	–
Micronodules	1	1

CARBONATE BOMB:
1-75 = 2
4-70 = 2

SITE 515 HOLE B CORE 5 CORED INTERVAL 132.9–142.4 m



VOID

10YR 5/2

LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

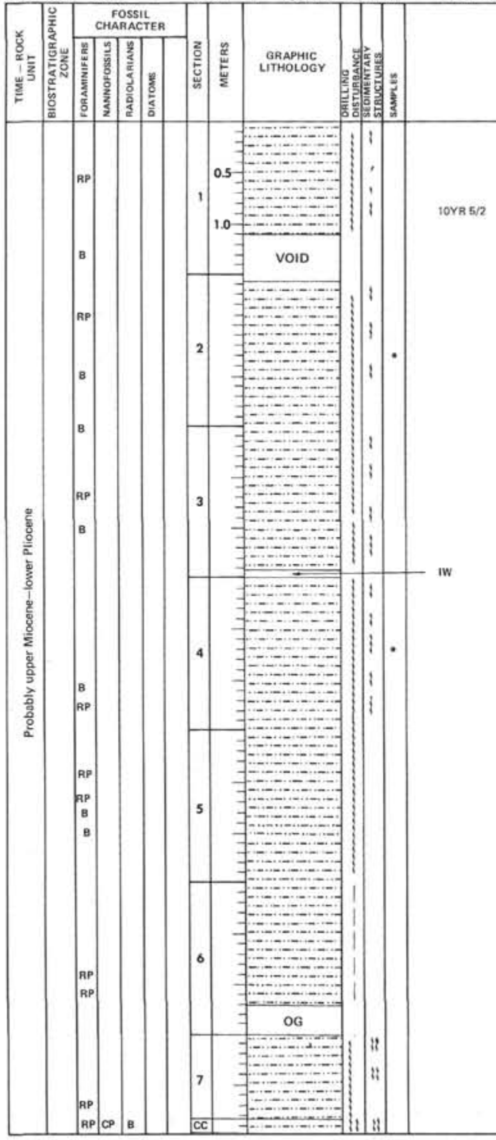
Grayish brown (10YR 5/2) mud. Mn-rich layer at base of Section 1.

SMEAR SLIDE SUMMARY:

	CC, 21 D
Texture:	
Sand	TR
Silt	10
Clay	90
Composition:	
Quartz	4
Feldspar	3
Mica	1
Heavy minerals	1
Other clay minerals	90
Micronodules	1

CARBONATE BOMB:
2-70 = 3
4-70 = 0

SITE 515 HOLE B CORE 6 CORED INTERVAL 142.5–151.9 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

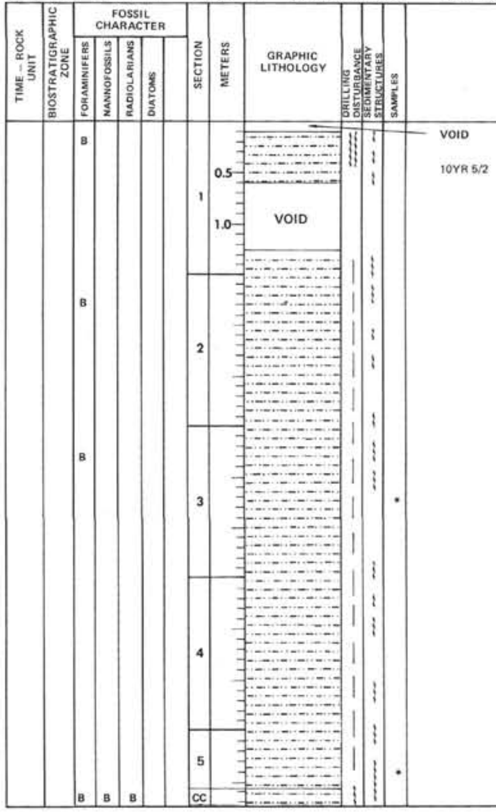
Grayish brown (10YR 5/2) mud, mottled with gray (5Y 5/1). Mottles suggest burrows. Intense burrowing in Section 7.

SMEAR SLIDE SUMMARY:

	2-70 D	4-70 D
Texture:		
Sand	3	1
Silt	32	19
Clay	65	80
Composition:		
Quartz Feldspar	25	15
Mica	TR	–
Heavy minerals	5	4
Other clay minerals	68	80
Carbonate unspecified	TR	TR
Nannofossils	TR	TR
Micronodules	1	TR
Volcanic glass	1	1

CARBONATE BOMB:
2-70 = 0
4-70 = 2
6-70 = 6

SITE 515 HOLE B CORE 7 CORED INTERVAL 151.9–161.4 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

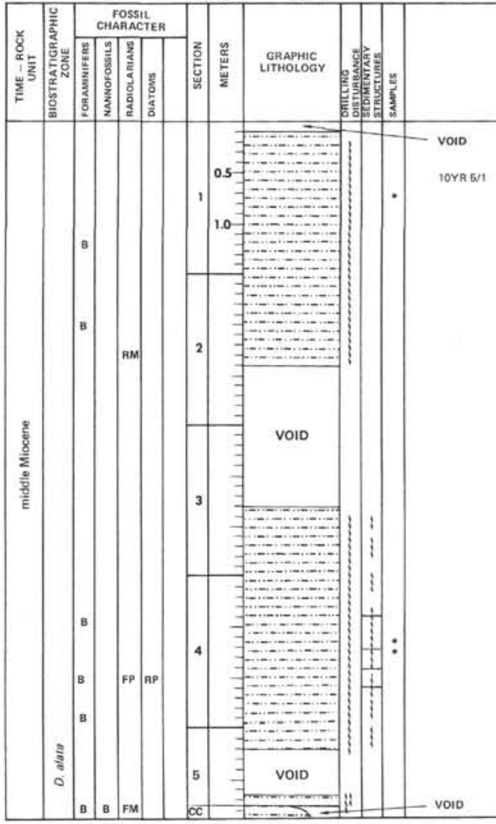
Grayish brown (10YR 5/2) mud mottled by gray (5Y 5/1). Mottles = bioturbation.

SMEAR SLIDE SUMMARY:

	3-70 D	5-40 D
Texture:		
Sand	1	1
Silt	29	15
Clay	70	84
Composition:		
Quartz	25	7
Feldspar		4
Mica	TR	1
Heavy minerals	5	2
Other clay minerals	72	84
Diatoms	TR	–
Silicoflagellates	TR	TR
Volcanic glass	1	–
Micronodules	2	1

CARBONATE BOMB:
2-70 = 1
4-70 = 0

SITE 515 HOLE B CORE 8 CORED INTERVAL 161.4–170.9 m



LITHOLOGIC DESCRIPTION

NONFOSSILIFEROUS, TERRIGENOUS MUD

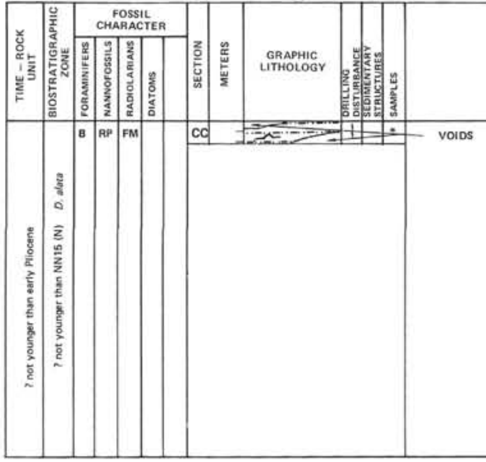
Gray (10YR 5/1) mud mottled by gray (5Y 5/1). Few black spots appear in Section 1. Section 4 is a mottled mixture between gray (10YR 5/1) mud and greenish gray (5G 6/1).

SMEAR SLIDE SUMMARY:

	1-70 D	4-70 D	4-80 D
Texture:			
Sand	TR	–	2
Silt	40	–	10
Clay	60	–	88
Composition:			
Quartz	35	5	–
Feldspar		1	–
Mica	–	1	–
Heavy minerals	TR	TR	–
Other clay minerals	61	75	
Carbonate unspecified	–	3	–
Nannofossils	–	2	–
Diatoms	TR	–	–
Silicoflagellates	–	TR	–
Volcanic glass	1	–	–
Micronodules	1	1	–
Sponge spicules	TR	5	–

CARBONATE BOMB:
2-70 = 2
4-70 = 3

SITE 515 HOLE B CORE 9 CORED INTERVAL 170.9–180.4 m



LITHOLOGIC DESCRIPTION

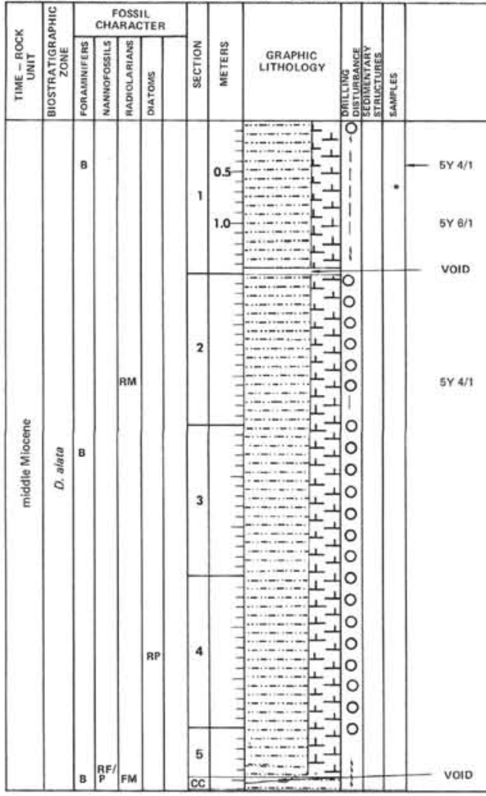
SILICEOUS MUD

Total (approximately 10%) calcareous plus siliceous mud. Greenish gray (5G 6/1) in color and completely disturbed.

SMEAR SLIDE SUMMARY:

	CC D
Texture:	
Sand	–
Silt	30
Clay	70
Composition:	
Quartz	20
Feldspar	
Other clay minerals	69
Nannofossils	5
Diatoms	5
Volcanic glass	1
Micronodules	TR
Euhedral calcite	TR

SITE 515 HOLE B CORE 10 CORED INTERVAL 180.4–189.9 m



LITHOLOGIC DESCRIPTION

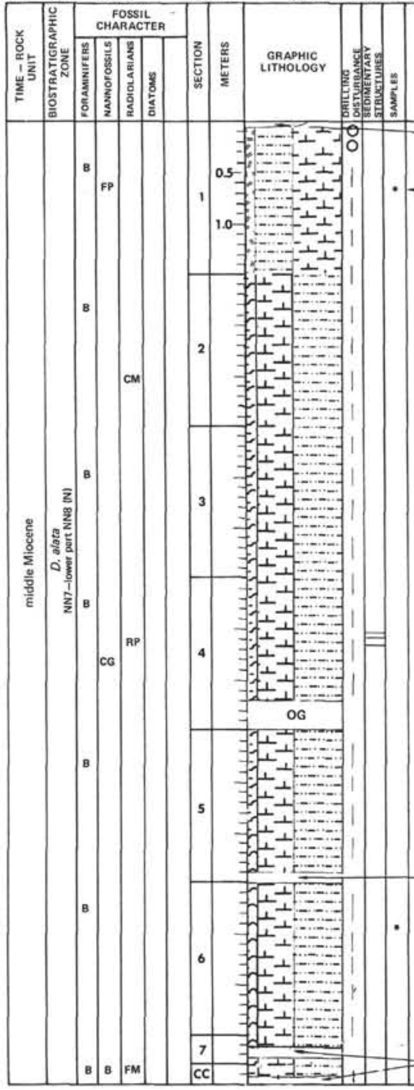
BIOGENIC (TERRIGENOUS) MUD

Black (10YR 2.5/1), organic spots. Large particles (sand-size) are clay aggregates, not fecal pellets, with suggestion of bedding. Section 2 and downcore is very soupy.

SMEAR SLIDE SUMMARY:

	1-70 D
Texture:	
Sand	20
Silt	25
Clay	55
Composition:	
Quartz	3
Other clay minerals	70
Carbonate unspecified	2
Nannofossils	20
Diatoms	3
Radiolarians	1
Sponge spicules	1

SITE 515 HOLE B CORE 11 CORED INTERVAL 189.9–199.4 m



VOID

Includes microspherules

5GY 4/1

IW

VOIDS

LITHOLOGIC DESCRIPTION

TRANSITIONAL BIOGENIC SEDIMENT (NANNOFOSSIL-RICH)

Color: dark greenish gray (5GY 4/1). Spots scattered throughout are black (5Y 2/1).

SMEAR SLIDE SUMMARY:

	1-70 D	6-48 D
Texture:		
Sand	–	–
Silt	20	50
Clay	80	50
Composition:		
Quartz	3	2
Feldspar	2	–
Other clay minerals	30	–
Carbonate unspecified	2	3
Nannofossils	50	80
Diatoms	TR	TR
Radiolarians	1	8
Silicoflagellates	TR	TR
Sponge spicules	1	1
Apatite	1	–
Volcanic glass	10	–

PHYSICAL PROPERTIES:

	1-113	2-50	5-80
V_v	—	—	—
V_h	—	1.50	—
Density	—	—	—
Water content	48.8	—	49.0

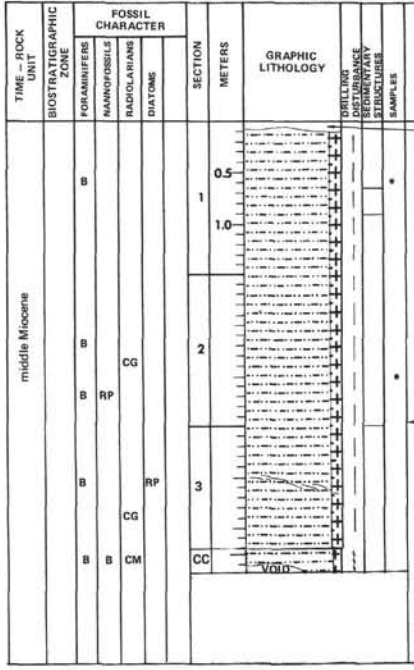
CARBONATE BOMB:

2-70 = 1

4-70 = 0

6-70 = 2

SITE 515 HOLE B CORE 12 CORED INTERVAL 199.4–208.9 m



VOID

5GY 4/1

Green spots lamination

LITHOLOGIC DESCRIPTION

BIOGENIC MUD

Color: dark greenish gray (5GY 4/1). Green laminations (Section 1): clay-rich, fossil poor. Dark (5Y 2/1) deformed layer at 50 cm of Section 3 and also in Core-Catcher.

SMEAR SLIDE SUMMARY:

	1-64 D	2-110 D
Texture:		
Sand	–	10
Silt	30	20
Clay	70	70
Composition:		
Quartz	} 5–10	1
Feldspar		1
Glauconite	–	TR
Other clay minerals	80	69
Foraminifers	–	10
Nannofossils	2	1
Diatoms	–	1
Radiolarians	2	10
Silicoflagellates	–	TR
Volcanic glass	–	15
Sponge spicules	2	2

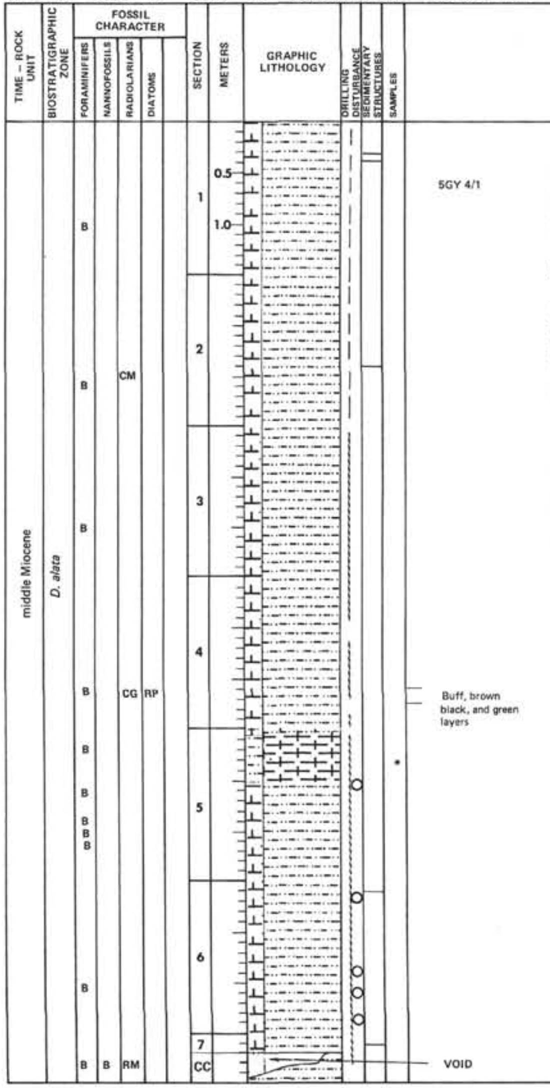
PHYSICAL PROPERTIES:

	2-88	3-96
V_v	—	—
V_h	—	—
Density	—	—
Water content	52.4	48.6

CARBONATE BOMB:

2-70 = 3

SITE 515 HOLE B CORE 13 CORED INTERVAL 208.9–218.4 m



LITHOLOGIC DESCRIPTION

BIOGENIC MUD

Color: dark greenish gray (5GY 4/1) with green lamination staining with black, organic debris. Brown deformed foram-rich beds in Section 4. Foram-rich beds surrounding green bed approximately 1 cm thick in upper part of Section 5.

SMEAR SLIDE SUMMARY:

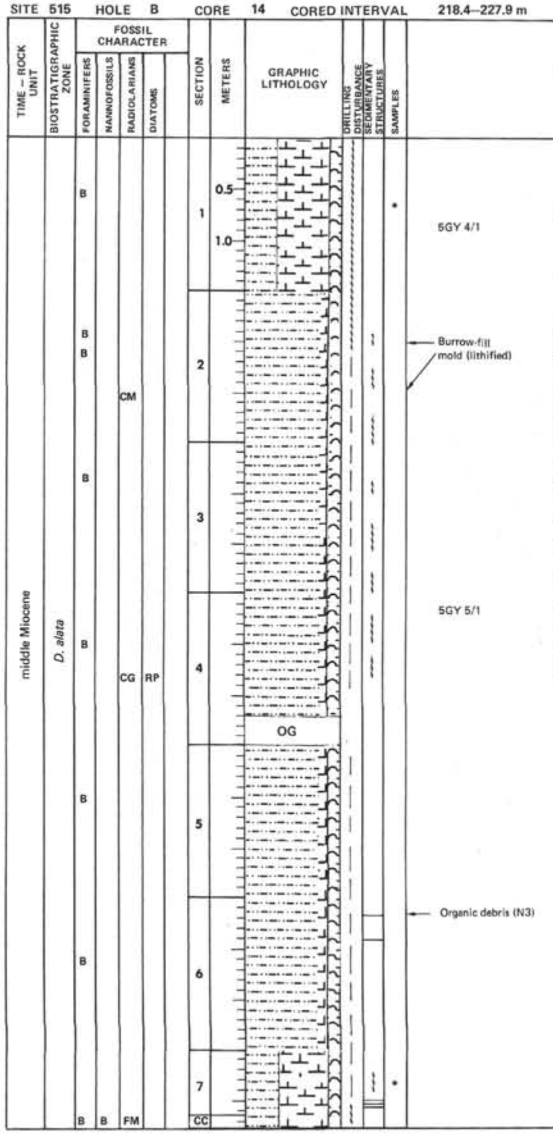
	5-33 M
Texture:	
Sand	10
Silt	40
Clay	50
Composition:	
Other clay minerals	14
Carbonate unspecified	4
Foraminifers	50
Nannofossils	30
Radiolarians	2

PHYSICAL PROPERTIES:

	2-135	2-138	5-92	6-120
V_v	—	—	—	—
V_h	1.54	—	—	1.53
Density	—	—	—	—
Water content	—	50.7	51.7	—

CARBONATE BOMB:
2-70 = 0
4-70 = 2
6-70 = 0

SITE 515 HOLE B CORE 14 CORED INTERVAL 218.4–227.9 m



LITHOLOGIC DESCRIPTION

BIOGENIC MUD
CLAY-RICH NANNO OOZE

Color: dark greenish gray (5GY 4/1 and 5GY 5/1). Section 1, 40 cm: foram-rich, very thin layers.

SMEAR SLIDE SUMMARY:

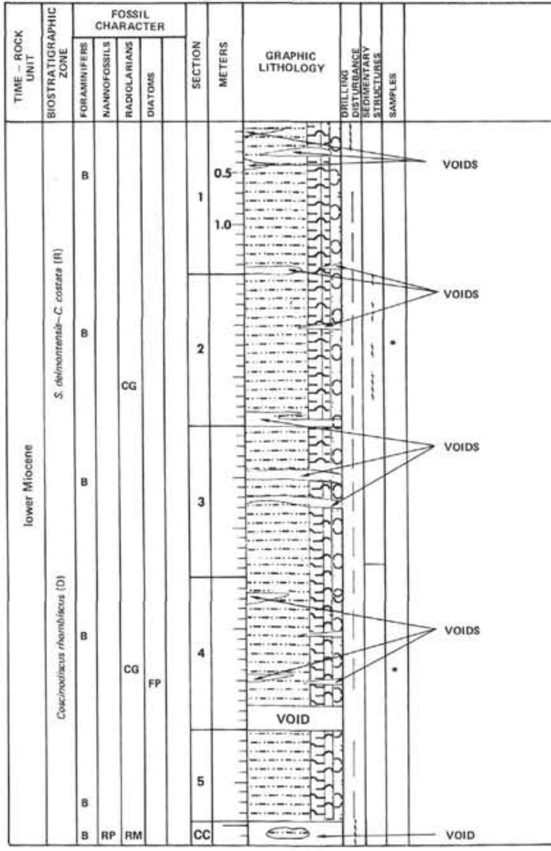
	1-70 D	7-30 D
Texture:		
Sand	20	5
Silt	20	20
Clay	60	75
Composition:		
Quartz	–	TR
Mica	TR	TR
Other clay minerals	25	25
Carbonate unspecified	–	3
Nannofossils	50	50
Diatoms	2	3
Radiolarians	15	10
Sponge spicules	5	–
Volcanic glass	2	–
Sponge spicules	–	8

PHYSICAL PROPERTIES:

	6-100
V_v	—
V_h	1.52
Density	—
Water content	49.0

CARBONATE BOMB:
2-70 = 2
6-70 = 7

SITE 515 HOLE B CORE 15 CORED INTERVAL 227.9–237.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUD

Color dominantly 5GY 4/1 with a greenish black (5GY 2/1) layer at base of Section 3 (140–150 cm).

SMEAR SLIDE SUMMARY:

	2-70 D	4-90 D
Texture:		
Sand	8	15
Silt	35	30
Clay	57	55
Composition:		
Quartz	–	2
Mica	–	3
Heavy minerals	–	TR
Other clay minerals	53	54
Nannofossils	1	–
Diatoms	3	–
Radiolarians	25	25
Micronodules	–	3
Sponge spicules	18	10

PHYSICAL PROPERTIES:

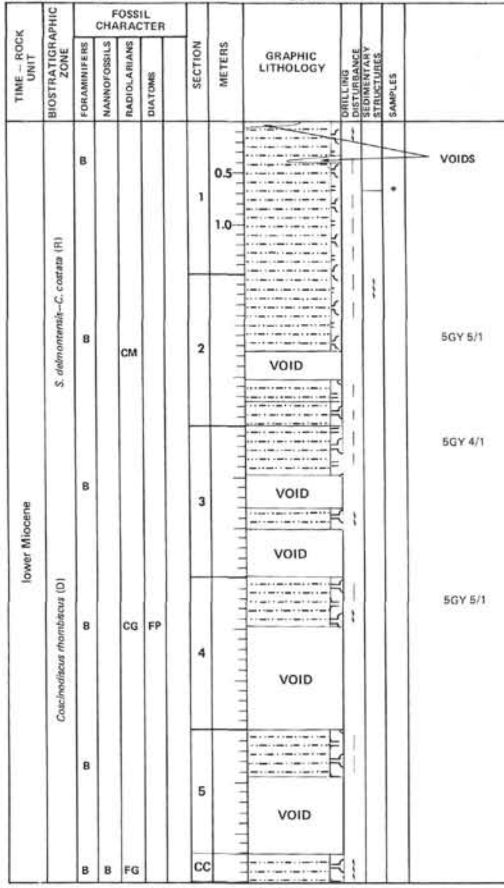
	3-109	4-76
V_v	—	—
V_h	1.60	1.53
Density	—	—
Water content	43.1	—

CARBONATE BOMB:

2-70 = 0

4-70 = 1

SITE 515 HOLE B CORE 16 CORED INTERVAL 237.4–246.9 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUD

Section 1 is greenish gray (5G 6/1) with mottling dark gray (N4).

SMEAR SLIDE SUMMARY:

	1-70[a] D
Texture:	
Sand	–
Silt	–
Clay	–
Composition:	
Quartz	1
Feldspar	1
Mica	TR
Other clay minerals	80
Foraminifers	TR
Nannofossils	TR
Diatoms	TR
Radiolarians	10
Silicoflagellates	1
Micronodules	TR
Volcanic glass	7

[a] Size analysis doesn't apply, because the particles are aggregates of clay as large as sand grains.

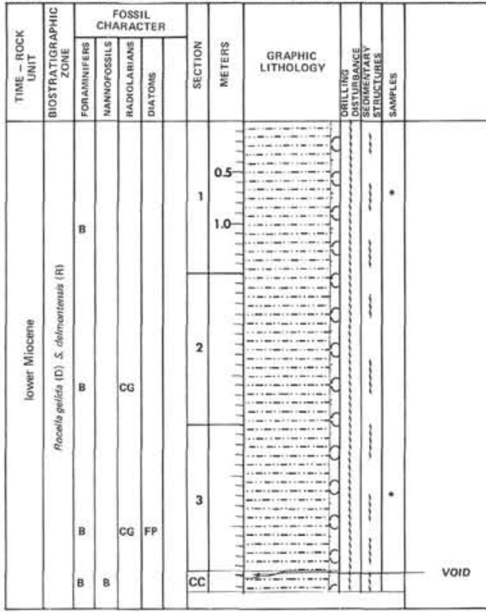
PHYSICAL PROPERTIES:

	5-10
V_v	—
V_h	—
Density	—
Water content	51.0

CARBONATE BOMB:

2-70 = 4

SITE 515 HOLE B CORE 17 CORED INTERVAL 246.9–256.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUD

Dark greenish gray (5G 4/1) with faint laminations throughout Section 1.

SMEAR SLIDE SUMMARY:

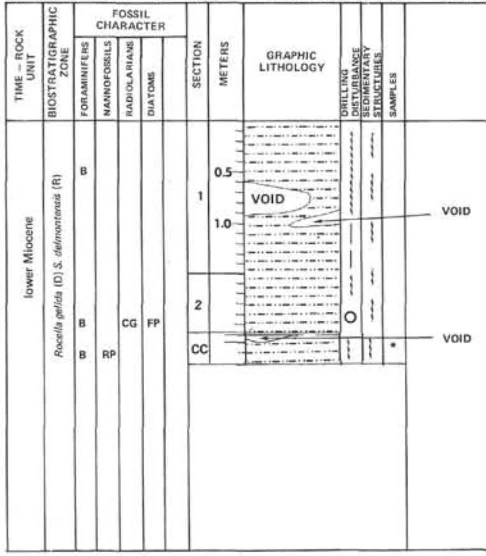
	1-70 D	3-76 D
Texture:		
Sand	10	10
Silt	–	15
Clay	–	75
Composition:		
Quartz	3	5
Mica	TR	TR
Other clay minerals	85	75
Nannofossils	–	5
Diatoms	5	–
Radiolarians	1	3
Silicoflagellates	TR	TR
Micronodules	TR	–
Sponge spicules	10	10

PHYSICAL PROPERTIES:

	1-113	1-120	3-6	3-12
V_v	—	—	—	—
V_h	1.60	—	—	1.61
Density	—	—	—	—
Water content	—	47.5	47.9	—

CARBONATE BOMB:
2-70 = 6

SITE 515 HOLE B CORE 18 CORED INTERVAL 256.4–265.9 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS MUD

Dark greenish gray (5G 4/1) mud.

SMEAR SLIDE SUMMARY:

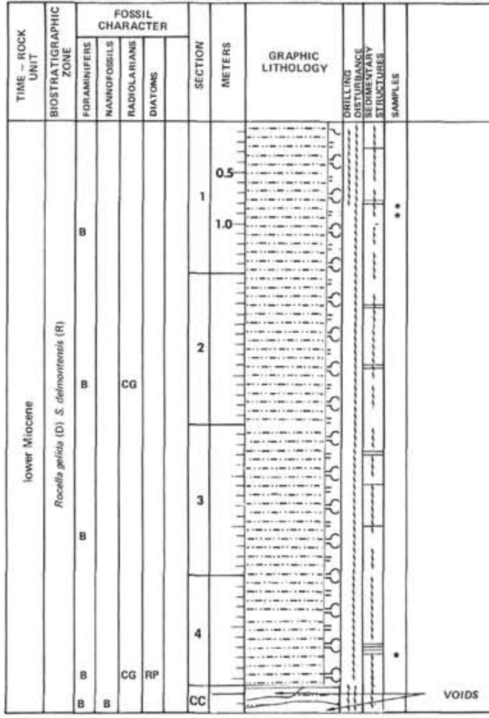
	CC, 18 D
Texture:	
Sand	5
Silt	15
Clay	80
Composition:	
Quartz	10
Mica	TR
Heavy minerals	TR
Other clay minerals	80
Nannofossils	2
Diatoms	TR
Sponge spicules	3

PHYSICAL PROPERTIES:

V_v	1.58
V_h	1.61
Density	1.50
Water content	47.2

CARBONATE BOMB:
1-70 = 0

SITE 515 HOLE B CORE 19 CORED INTERVAL 265.9–275.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS BIOGENIC MUDSTONE

Dark greenish gray (5G 4/1) siliceous mudstones, with few burrows and some faint laminations. Drill biscuits throughout.

SMEAR SLIDE SUMMARY:

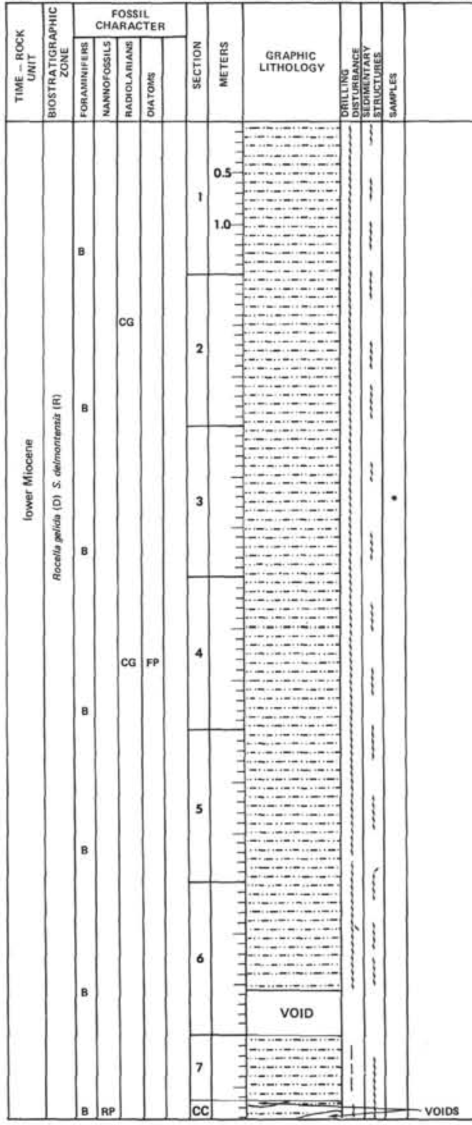
	1-88 D	1-91 D	4-84 D
Texture:			
Sand	5	3	2
Silt	15	50	15
Clay	80	47	83
Composition:			
Quartz	3	2	2
Mica	TR	–	TR
Heavy minerals	–	–	TR
Other clay minerals	78	47	83
Carbonate unspecified	2	–	–
Nannofossils	–	1	2
Diatoms	5	3	2
Radiolarians	2	2	TR
Silicoflagellates	TR	TR	TR
Micronodules	TR	–	TR
Sponge spicules	10	2	8
Unidentified mineral	–	30	–

PHYSICAL PROPERTIES:

	3-108
V_v	1.58
V_h	1.62
Density	1.49
Water content	47.5

CARBONATE BOMB:
2-70 = 2
4-70 = 3

SITE 515 HOLE B CORE 20 CORED INTERVAL 275.4–284.9 m



LITHOLOGIC DESCRIPTION

MUDSTONE

Dark greenish gray (5G 4/1) siliceous mudstone, burrowed. Faint laminations from Section 4 through Section 6.

SMEAR SLIDE SUMMARY:

	3-70
	D
Texture:	
Sand	3
Silt	10
Clay	87
Composition:	
Quartz	TR
Mica	TR
Other clay minerals	87
Nannofossils	2
Silicoflagellates	TR
Micronodules	TR
Sponge spicules	10

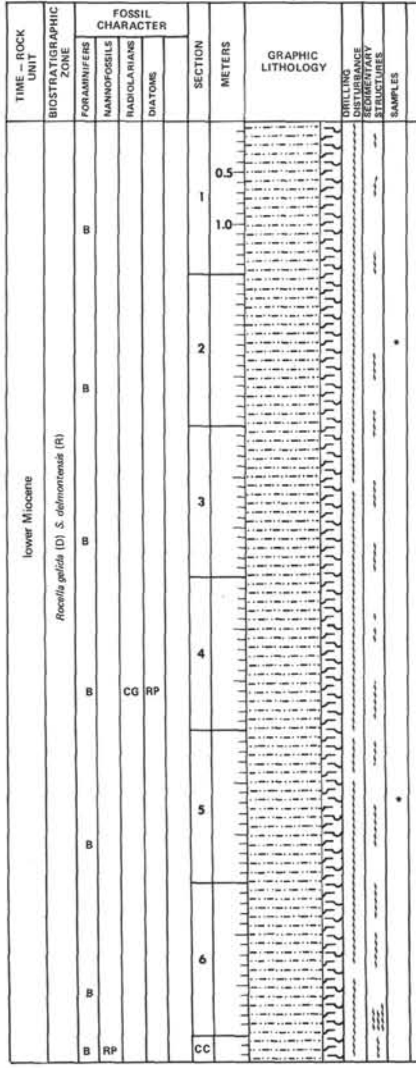
PHYSICAL PROPERTIES:

	6-34
V_v	1.64
V_h	1.66
Density	1.51
Water content	47.0

CARBONATE BOMB:

2-90 = 2
4-70 = 0
6-70 = 0

SITE 515 HOLE B CORE 21 CORED INTERVAL 284.9–294.4 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Greenish gray (5G 4/1 and 5G 6/1). Dark gray (N3) burrows common – typically a few mm to 1 cm diameter. Coring biscuits separated by soft, disturbed intervals. Very little carbonate – only a few poorly preserved coccoliths.

SMEAR SLIDE SUMMARY:

	2-70	5-70
	D	D
Texture:		
Sand	1	1
Silt	34	34
Clay	65	65
Composition:		
Quartz Feldspar	} 10	} 10
Heavy minerals	3	2
Glauconite	–	TR
Other clay minerals	65	67
Nannofossils	TR	–
Diatoms	20	20
Radiolarians	1	1
Micronodules	1	TR
Sponge spicules	TR	TR

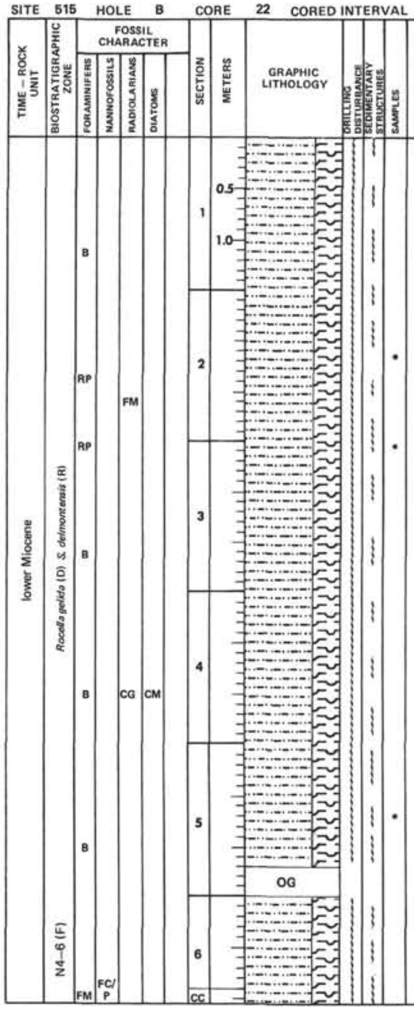
PHYSICAL PROPERTIES:

	6-95
V_v	—
V_h	—
Density	1.61
Water content	41.2

CARBONATE BOMB:

2-70 = 0
4-70 = 2
6-70 = 2

SITE 515 HOLE B CORE 22 CORED INTERVAL 294.4–303.9 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Biscuited throughout. Greenish gray (5G 4/1–5G 6/1) siliceous mudstone with small burrows. Grayish brown (10YR 7/4) streaks and burrows scattered from 60 cm of Section 1 to 20 cm of Section 3.

SMEAR SLIDE SUMMARY:

	2-70 D	3-14[a] M	5-70 D
Texture:			
Sand	3	2	3
Silt	42	60	32
Clay	60	38	65
Composition:			
Quartz	} 10	2	} 5
Feldspar		–	
Heavy minerals	2	TR	1
Other clay minerals	55	47	64
Nannofossils	7	–	3
Diatoms	25	2	25
Radiolarians	1	TR	1
Silicoflagellates	TR	–	–
Volcanic glass	1	–	TR
Apatite	–	60	–
Sponge spicules	TR	3	1

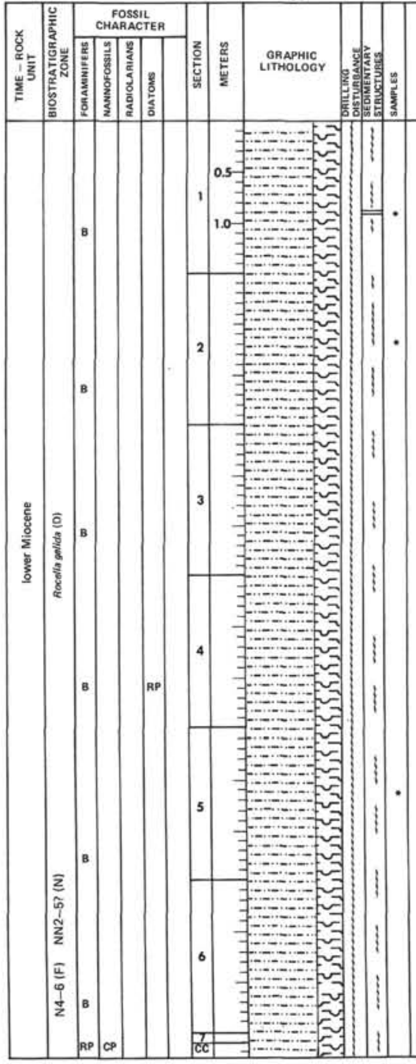
[a] Sample from a burrow

PHYSICAL PROPERTIES:

	1-51
V_v	1.65
V_h	1.63
Density	1.53
Water content	44.4

CARBONATE BOMB:
2-70 = 8
4-70 = 2
6-70 = 8

SITE 515 HOLE B CORE 23 CORED INTERVAL 303.9–313.4 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

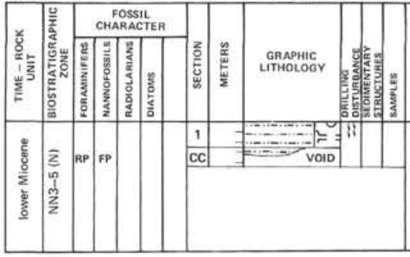
Greenish gray (5G 4/1–5G 6/1) with dark gray (N3) burrows (1–20 mm diameter) common throughout. Several light-colored burrows and laminae (horizontal burrows?) contain apatite. Best-developed layer at Section 1, 95 cm. Biscuited.

SMEAR SLIDE SUMMARY:

	1-95 M	2-70 D	5-70 D
Texture:			
Sand	–	–	2
Silt	–	40	38
Clay	–	60	60
Composition:			
Quartz	} 2	} 5	} 5
Feldspar			
Heavy minerals	–	1	1
Other clay minerals	32	66	64
Nannofossils	2	5	2
Diatoms	1	20	25
Radiolarians	–	2	2
Silicoflagellates	–	TR	TR
Apatite(?)	60	–	–
Sponge spicules	3	1	1

CARBONATE BOMB:
2-70 = 8
4-70 = 9
6-70 = 4

SITE 515 HOLE B CORE 24 CORED INTERVAL 313.4–322.9 m

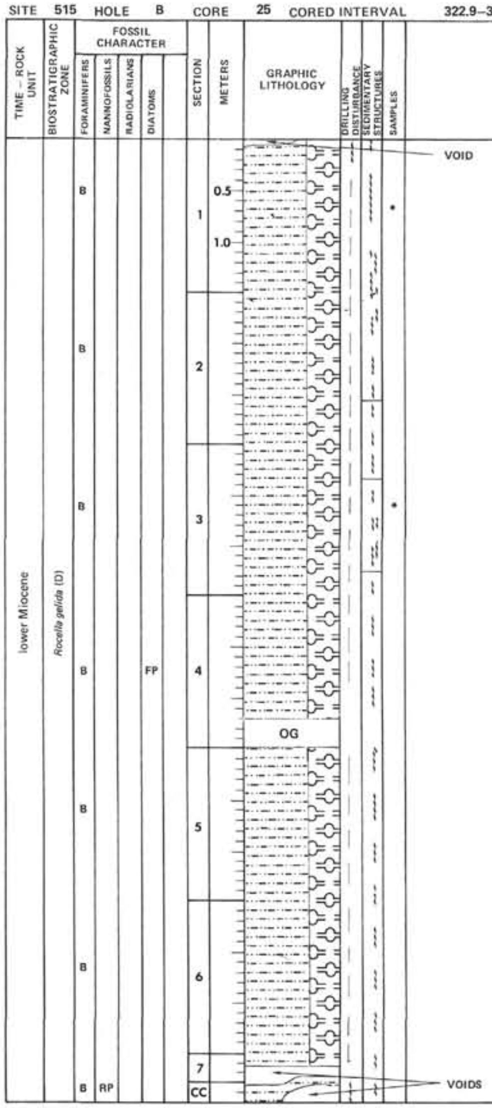


LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

CARBONATE BOMB:
1-15 = 2

SITE 515 HOLE B CORE 25 CORED INTERVAL 322.9–332.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE (RADIOLARIAN)
Color: Olive gray (5Y 4/1). Section 2, 20 cm–Section 4, 80 cm: 10YR 6/3 deformed burrow-fill.

SMEAR SLIDE SUMMARY:

	1-70[a]	3-70
	D	M
Texture:		
Sand	5	–
Silt	30	50
Clay	65	50
Composition:		
Quartz	2	–
Other clay minerals	63	28
Carbonate unspecified	2	–
Nannofossils	1	3
Diatoms	–	1
Radiolarians	20	3
Sponge spicules	12	5
Micronodules	TR	–
Apatite spherules	–	30
Reworked microfossils	–	30

[a] Siliceous components reworked and recrystallized.

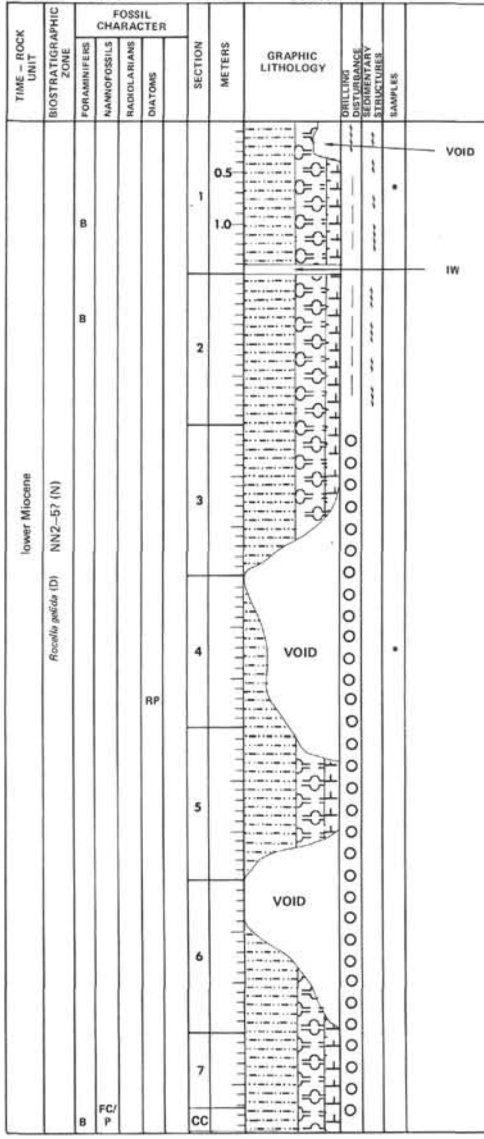
PHYSICAL PROPERTIES:

	6-82
V_v	1.81
V_h	1.66
Density	1.86
Water content	43.2

CARBONATE BOMB:
2-70 = 0
4-70 = 2
6-70 = 2

ORGANIC CARBON
1, 113–123 = 0.16

SITE 515 HOLE B CORE 26 CORED INTERVAL 332.4–341.9 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE AND SOUP

Medium gray (5B 5/1) throughout with mottles of olive gray (5Y 4/1) in first two sections.

SMEAR SLIDE SUMMARY:

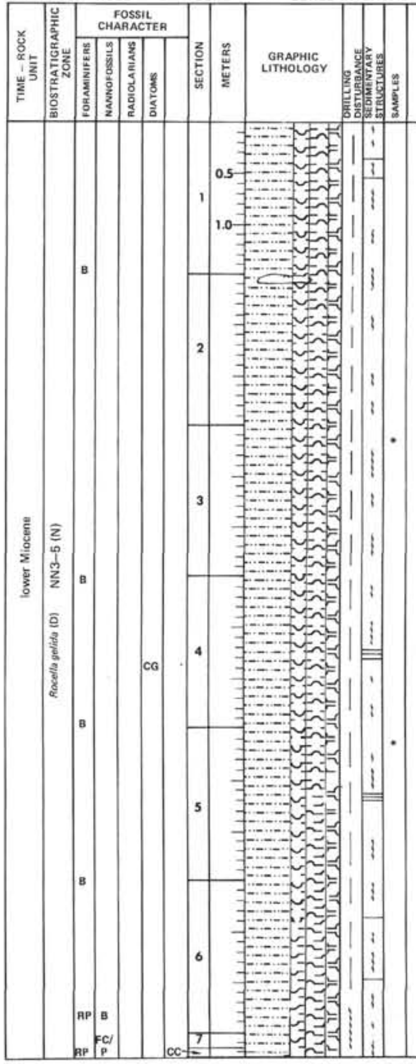
	1-70	4-80
	D	D
Texture:		
Sand	1	–
Silt	40	35
Clay	59	65
Composition:		
Quartz	4	–
Other clay minerals	39	45
Carbonate unspecified	–	3
Nannofossils	5	30
Diatoms	20	3
Radiolarians	20	8
Micronodules	–	1
Sponge spicules	8	8
Volcanic glass	4	2

PHYSICAL PROPERTIES:

	2-82
V_v	1.61
V_h	1.66
Density	1.52
Water content	45.7

CARBONATE BOMB:
2-70 = 1

SITE 515 HOLE B CORE 27 CORED INTERVAL 341.9–351.4 m



LITHOLOGIC DESCRIPTION

5Y 6/1 spot

SILICEOUS MUDSTONE

Biscuited and burrowed throughout. Fill is dark gray (N3). Laminations are black. Section 2: light olive gray (5Y 6/1) spot. Section 3, 120 cm: micro-burrows filled with pale brown (10YR 6/3) sediment.

SMEAR SLIDE SUMMARY:

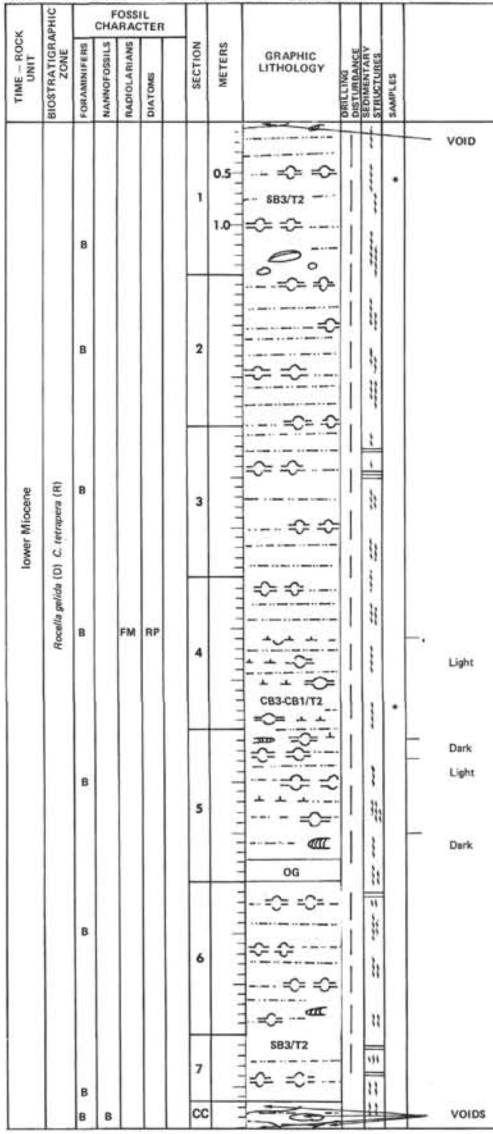
	3-27	5-21
	D	D
Texture:		
Sand	5	5
Silt	35	25
Clay	60	70
Composition:		
Quartz	2	2
Feldspar	–	2
Other clay minerals	60	59
Nannofossils	–	TR
Diatoms	15	8
Radiolarians	5	15
Sponge spicules	15	10
Micronodules	–	2
Volcanic glass	3	2

PHYSICAL PROPERTIES:

	5-108
V_v	1.58
V_h	1.62
Density	1.49
Water content	46.8

CARBONATE BOMB:
2-70 = 2
4-70 = 3
6-70 = 1

SITE 515 HOLE B CORE 28 CORED INTERVAL 351.4–360.9 m



LITHOLOGIC DESCRIPTION

BIOGENIC MUD (CALCAREOUS AND SILICEOUS)

Biscuited throughout. Medium bluish gray (5B 5/1) in color. Hard round pieces of 10YR 6/3 claystone. Subtle color alternations begin at Section 4, 60 cm and end at base of Section 5. Lighter color (5G 6/1) in Section 4 is associated with fewer burrows. Dark laminations and dark burrow fill at 104 cm of Section 6.

SMEAR SLIDE SUMMARY:

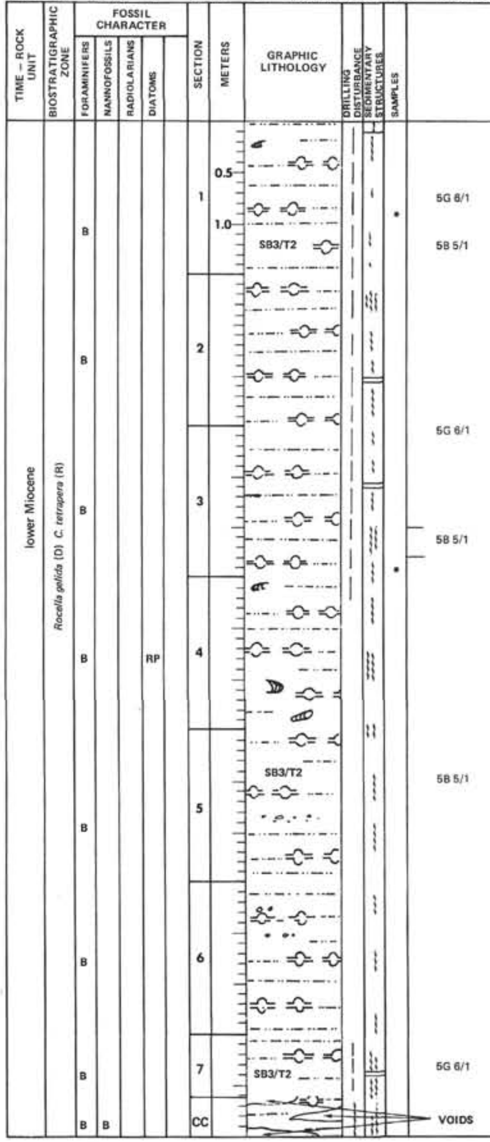
	1-68	4-130
	D	D
Texture:		
Sand	6	2
Silt	40	15
Clay	54	83
Composition:		
Quartz	5	–
Other clay minerals	50	40
Nannofossils	1	35
Diatoms	10	8
Radiolarians	10	5
Sponge spicules	20	10
Micronodules	3	–
Volcanic glass	1	2

PHYSICAL PROPERTIES:

	4-93
V_v	1.68
V_h	1.68
Density	1.54
Water content	44.4

CARBONATE BOMB:
2-65 = 0
4-65 = 0
6-65 = 5

SITE 515 HOLE B CORE 29 CORED INTERVAL 360.9–370.4 m



LITHOLOGIC DESCRIPTION

BIOGENIC MUDSTONE

Biscuited throughout. Dominant color: Greenish gray (5G 6/1) and medium bluish gray (5B 5/1). Sections 5 and 6: light olive gray burrow fill.

SMEAR SLIDE SUMMARY:

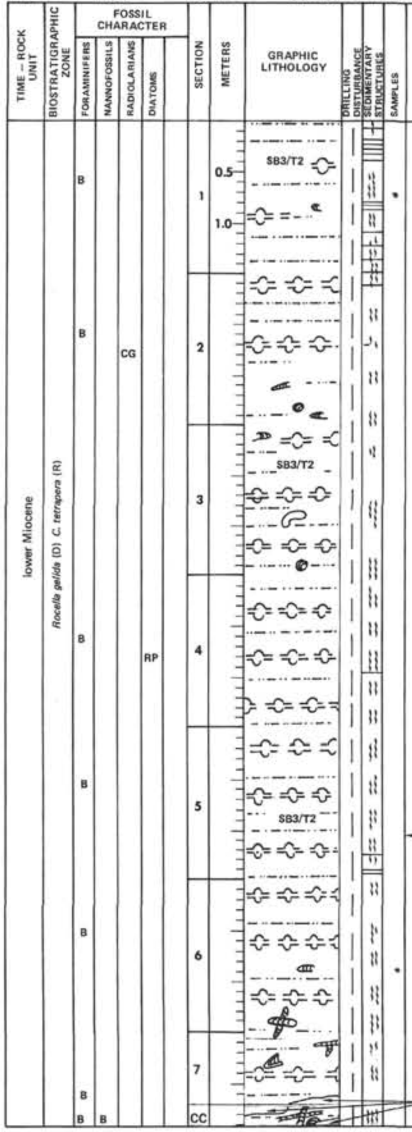
	1-90	3-147
	D	D
Texture:		
Sand	–	2
Silt	50	35
Clay	50	65
Composition:		
Quartz	3	–
Feldspar	2	–
Mica	TR	TR
Other clay minerals	59	66
Nannofossils	1	–
Diatoms	10	10
Radiolarians	10	10
Micronodules	1	–
Sponge spicules	10	10
Volcanic glass	5	3

PHYSICAL PROPERTIES:

	5-136
V_v	1.63
V_h	1.68
Density	1.54
Water content	44.5

CARBONATE BOMB:
2-70 = 2
4-70 = 2
6-70 = 2

SITE 515 HOLE B CORE 30 CORED INTERVAL 370.4–379.9 m



5B 5/1

5G 6/1

5B 5/1

10YR 6/3 layer associated with lamination

VOIDS

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Biscuited and bioturbated throughout. Section 3 is light olive gray (5Y 6/1) fill (concretion? or very large burrow).

SMEAR SLIDE SUMMARY:

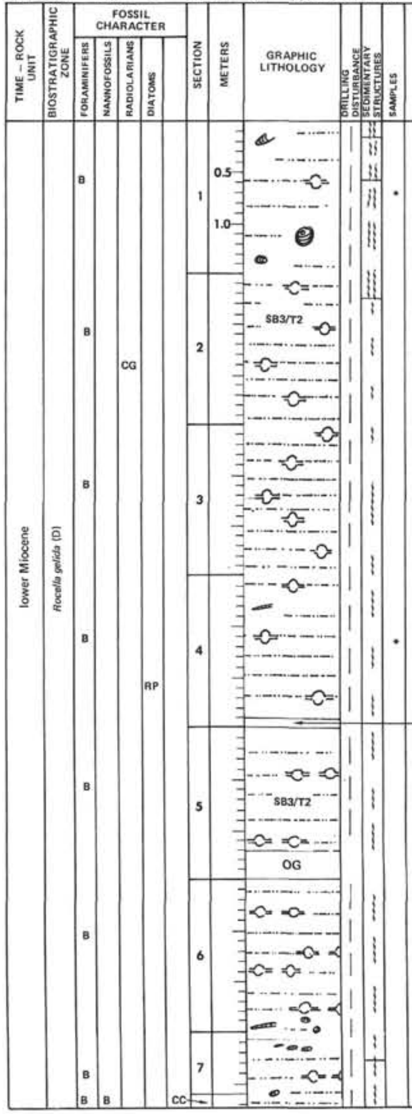
	1-70 D	6-90 D
Texture:		
Sand	2	3
Silt	38	43
Clay	60	54
Composition:		
Quartz	3	4
Mica	1	2
Heavy minerals	–	1
Other clay minerals	60	53
Nannofossils	–	TR
Diatoms	8	10
Radiolarians	12	15
Silicoflagellates	–	15
Sponge spicules	15	–
Micronodules	2	–

PHYSICAL PROPERTIES:

	6-125
V_v	1.65
V_h	1.64
Density	1.52
Water content	45.3

CARBONATE BOMB:
1-70 = 0
4-70 = 0
6-70 = 1

SITE 515 HOLE B CORE 31 CORED INTERVAL 379.9–389.4 m



5B 5/1

IW

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Biscuited throughout and color being medium bluish gray (5B 5/1). Light olive gray (5Y 6/1) tube filling (Section 4).

SMEAR SLIDE SUMMARY:

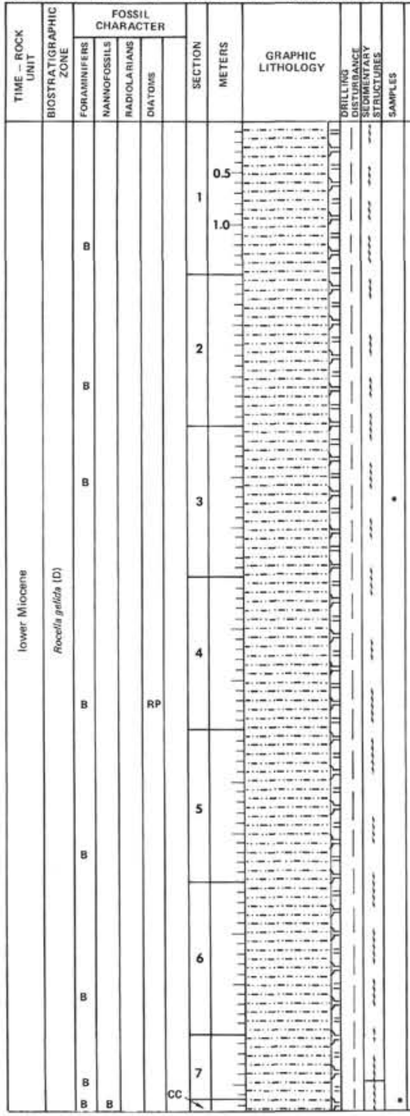
	1-70 D	4-70 D
Texture:		
Sand	6	1
Silt	40	39
Clay	54	60
Composition:		
Quartz	1	2
Mica	TR	2
Other clay minerals	56	38
Carbonate unspecified	–	2
Nannofossils	–	3
Diatoms	10	2
Radiolarians	10	5
Silicoflagellates	10	2
Micronodules	4	1
Sponge spicules	4	40
Volcanic glass	5	3

PHYSICAL PROPERTIES:

	2-120
V_v	1.64
V_h	1.67
Density	1.52
Water content	44.4

CARBONATE BOMB:
2-70 = 1
4-70 = 9
6-70 = 8

SITE 515 HOLE B CORE 32 CORED INTERVAL 389.4–398.9 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Between greenish gray (5G 6/1) and medium bluish gray (5B 5/1) siliceous mudstone burrowed throughout and with faint laminations.

SMEAR SLIDE SUMMARY:

	3-68 D	CC, 10 (crack) D
Texture:		
Sand	5	5
Silt	15	15
Clay	80	80
Composition:		
Quartz	10	4
Mica	TR	TR
Pyrite	TR	TR
Heavy minerals	2	1
Other clay minerals	80	80
Carbonate unspecified	1	–
Diatoms	3	4
Radiolarians	TR	1
Silicoflagellates	–	TR
Sponge spicules	5	–
Micronodules	1	–

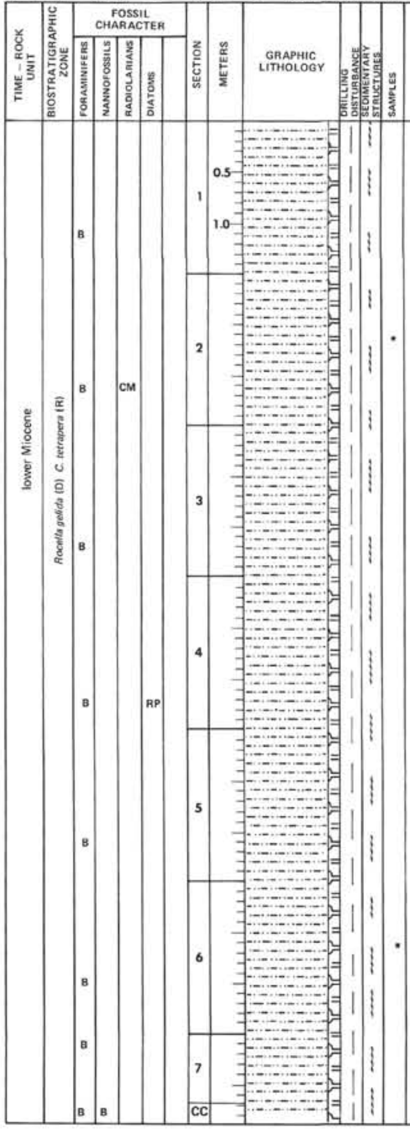
PHYSICAL PROPERTIES:

	5-34
V_v	1.68
V_h	1.68
Density	1.56
Water content	42.1

CARBONATE BOMB:

2-70 = 0
4-70 = 0
6-70 = 2

SITE 515 HOLE B CORE 33 CORED INTERVAL 398.9–408.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Between greenish gray (5G 6/1) and dark greenish gray (5G 4/1), siliceous mudstone with faint layering, burrows (brown color) and small (3 mm) dark spots throughout the section.

SMEAR SLIDE SUMMARY:

	2-70 D	6-70 D
Texture:		
Sand	2	3
Silt	50	15
Clay	48	82
Composition:		
Quartz	3	3
Mica	TR	–
Pyrite	1	2
Heavy minerals	1	1
Zeolites	–	TR
Other clay minerals	48	82
Diatoms	2	2
Radiolarians	TR	TR
Silicoflagellates	TR	–
Apatite	35	–
Sponge spicules	5	3
Micronodules	–	5

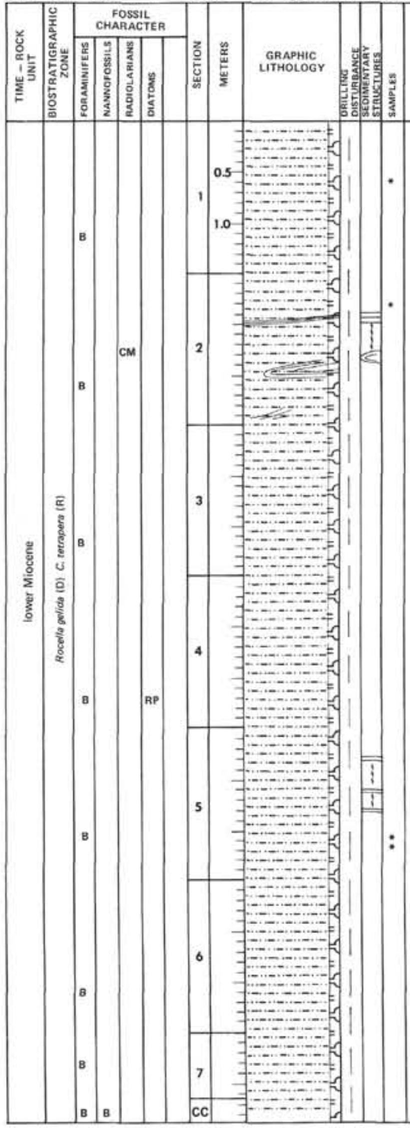
PHYSICAL PROPERTIES:

	2-20
V_v	1.69
V_h	1.74
Density	1.58
Water content	41.8

CARBONATE BOMB:

2-70 = 2
4-70 = 2
6-70 = 2

SITE 515 HOLE B CORE 34 CORED INTERVAL 408.4–417.9 m



5G 4/1

5Y 4/1 and 5Y 6/1

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Dark greenish gray (5G 4/1) with small (1–2 mm) green spots and faint laminations throughout. Section 2 having a possible fold (sedimentary) and burrows throughout. Some laminations are wavy (ripples?). Section 7 and Core-Catcher: between olive gray (5Y 4/1) and light olive gray (5Y 6/1) with faint laminations and burrows throughout.

SMEAR SLIDE SUMMARY:

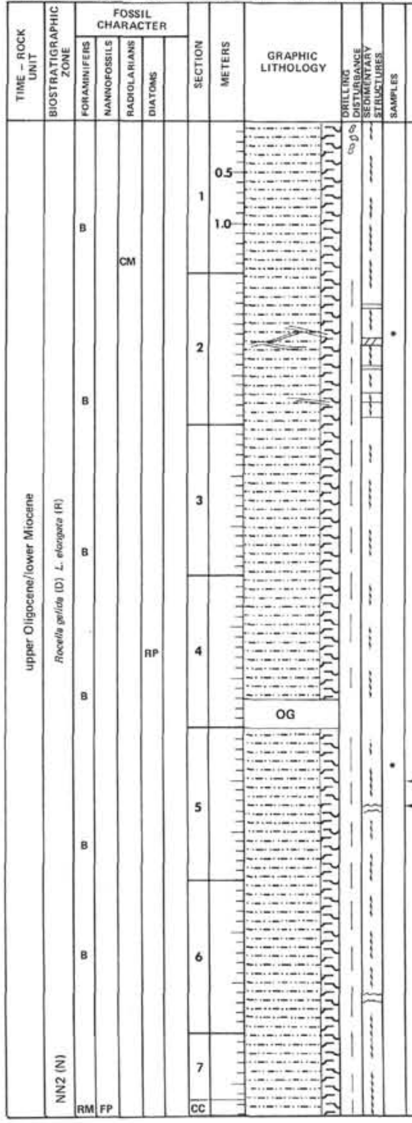
	1-65 D	2-31 D	5-125 D	5-110 D
Texture:				
Sand	1	10	5	7
Silt	34	20	15	20
Clay	65	70	80	73
Composition:				
Quartz	10	10	5	5
Feldspar	–	3	2	3
Mica	TR	–	TR	1
Pyrite	1	3	1	–
Heavy minerals	2	1	1	–
Other clay minerals	67	70	80	70
Diatoms	17	3	4	3
Radiolarians	2	2	1	3
Silicoflagellates	–	TR	TR	–
Sponge spicules	1	3	3	5
Fecal pellets	–	–	–	20
Chamosite	5	–	–	–

PHYSICAL PROPERTIES:

	3-87	6-4	6-9
V_v	1.73	1.78	–
V_h	1.78	1.83	1.82
Density	1.60	1.63	—
Water content	40.6	38.7	—

CARBONATE BOMB:
2-70 = 1
4-70 = 1
6-70 = 3

SITE 515 HOLE B CORE 35 CORED INTERVAL 417.9–427.4 m



Winnowing?

Ripples?, wavy bedding

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Greenish gray (5G 4/1–5G 6/1). Extensive burrowing, with parallel and inclined laminations. Minor silty zones, occasional soft mud deformation and microfaulting and folding. Coring deformation – biscuits interbedded with drill breccia.

SMEAR SLIDE SUMMARY:

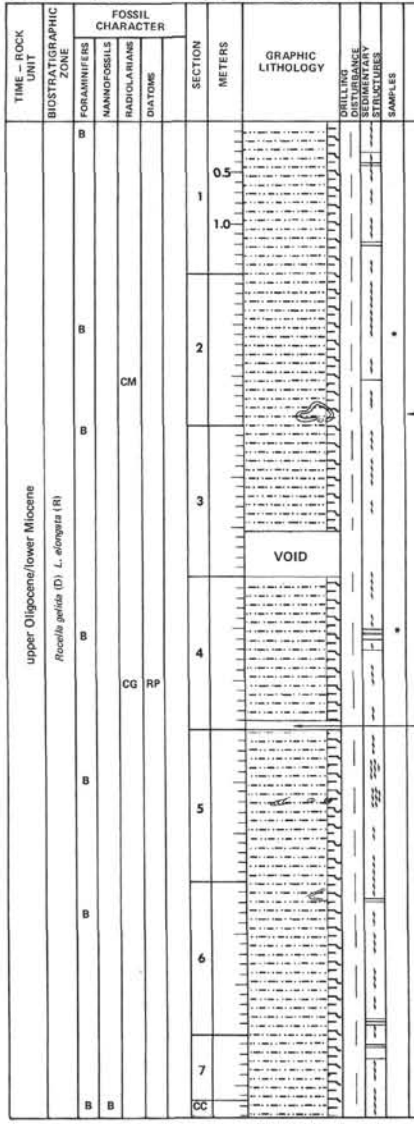
	2-70 D	5-36 (silty zone) D
Texture:		
Sand	2	2
Silt	28	43
Clay	70	55
Composition:		
Quartz Feldspar	5	5
Pyrite	TR	TR
Heavy minerals	1	TR
Other clay minerals	70	56
Carbonate unspecified	TR	–
Diatoms	15	30
Radiolarians	2	5
Volcanic glass	TR	1
Chamosite	5	1
Sponge spicules	1	2

PHYSICAL PROPERTIES:

	4-42	6-106
V_v	1.72	—
V_h	1.77	1.78
Density	1.60	—
Water content	41.4	—

CARBONATE BOMB:
2-70 = 0
4-70 = 1
6-70 = 5

SITE 515 HOLE B CORE 36 CORED INTERVAL 427.4–436.9 m



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Greenish gray (5G 4/1–5G 6/1) in color. Very similar to Core 35. Contains phosphatic(?) zones. Burrowing, laminations, deformation structures common. Drill biscuits common.

SMEAR SLIDE SUMMARY:

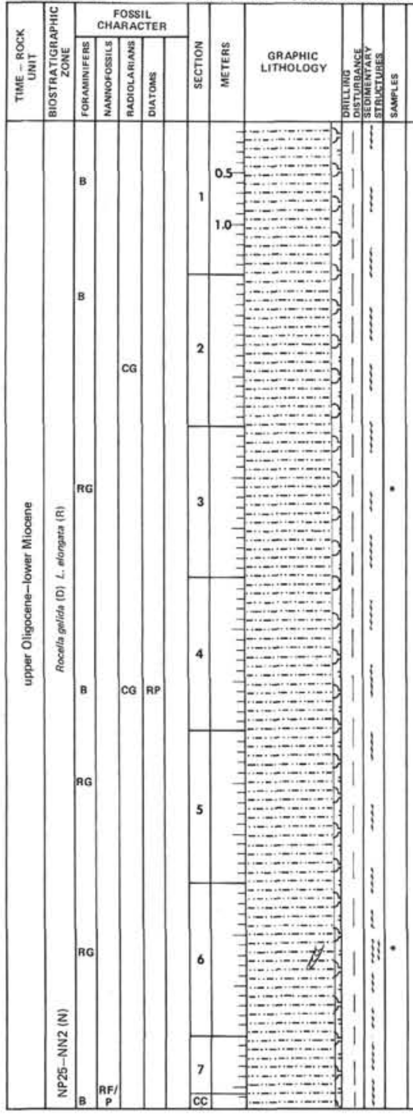
	2-70	4-53
	D	D
Texture:		
Sand	TR	TR
Silt	35	50
Clay	65	50
Composition:		
Quartz Feldspar	} 5	} 2
Mica	TR	–
Pyrite	1	–
Heavy minerals	1	TR
Other clay minerals	69	53
Diatoms	15	15
Radiolarians	3	4
Volcanic glass	TR	–
Chamosite	5	25
Sponge spicules	1	1

PHYSICAL PROPERTIES:

	3-100
V_v	1.67
V_h	1.74
Density	1.58
Water content	44.7

CARBONATE BOMB:
4-70 = 0
6-70 = 1

SITE 515 HOLE B CORE 37 CORED INTERVAL 436.9–446.4 m



LITHOLOGIC DESCRIPTION

5G 4/1–5G 6/1

SILICEOUS MUDSTONE

Greenish gray (5G 4/1–5G 6/1) and heavily burrowed with both dark gray (N3) and yellowish gray (5Y 8/1). Biscuited more than previous core. Large phosphatic(?) burrow in Section 6. Biscuited throughout.

SMEAR SLIDE SUMMARY:

	3-70	6-70
	D	M
Texture:		
Sand	5	5
Silt	15	25
Clay	80	70
Composition:		
Quartz Feldspar	} 10	} 3
Pyrite	TR	2
Heavy minerals	1	1
Other clay minerals	80	74
Nannofossils	–	10
Diatoms	3	3
Radiolarians	2	2
Silicoflagellates	TR	–
Sponge spicules	5	5
Micronodules	TR	TR

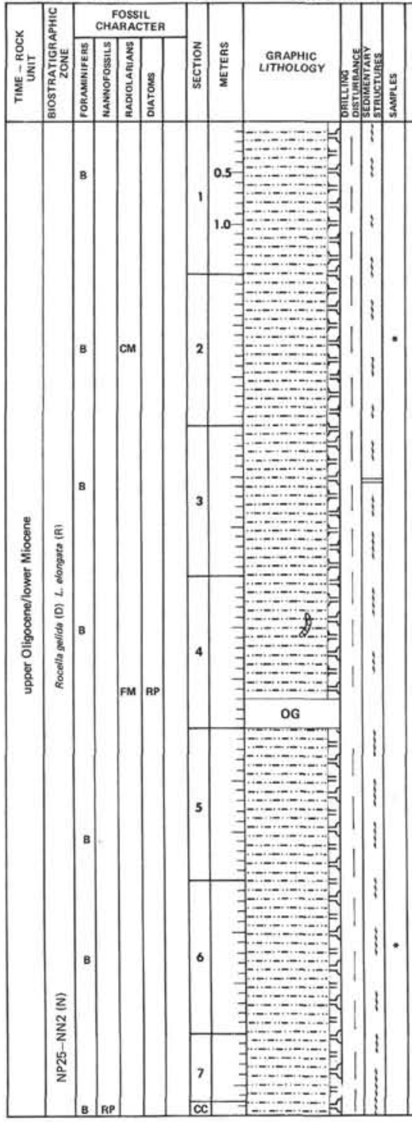
PHYSICAL PROPERTIES:

	6-43
V_v	1.72
V_h	1.74
Density	1.59
Water content	40.9

CARBONATE BOMB:
2-70 = 1
4-70 = 1
6-70 = 4

5Y 8/1

SITE 515 HOLE B CORE 38 CORED INTERVAL 446.4–455.9 m



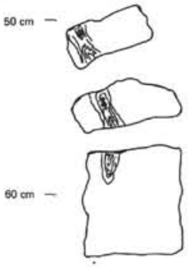
LITHOLOGIC DESCRIPTION

5G 4/1–5G 6/1

SILICEOUS MUDSTONE

Color: greenish gray (5G 4/1–5G 6/1). Burrowed with dark gray (N3) and minor light yellowish gray (5Y 8/1). Biscuited throughout. Yellowish (5Y 8/1) zone at 56–57 cm (Section 3).

Section 4:



SMEAR SLIDE SUMMARY:

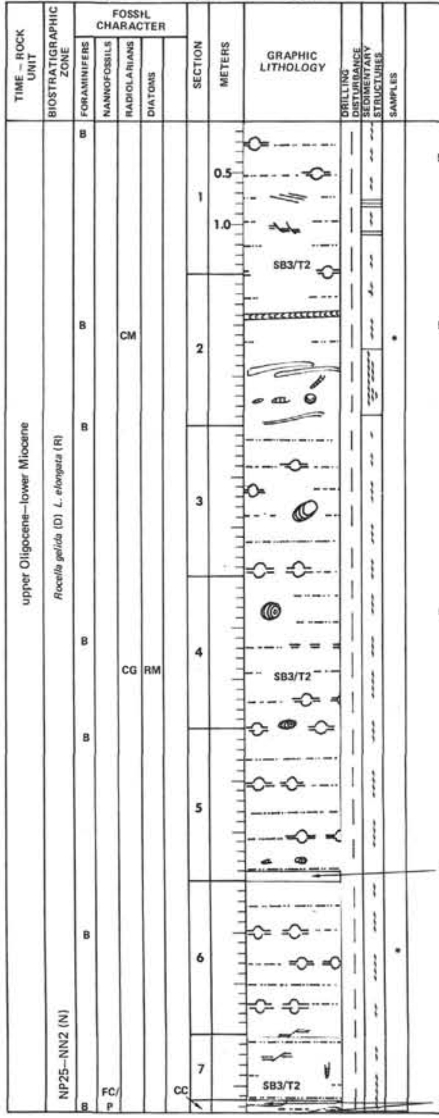
	2-68	6-71
	D	D
Texture:		
Sand	3	3
Silt	17	17
Clay	80	80
Composition:		
Quartz	5	5
Feldspar		
Pyrite	2	1
Heavy minerals	1	–
Other clay minerals	80	70
Nannofossils	TR	–
Diatoms	5	5
Radiolarians	2	3
Silicoflagellates	–	TR
Chamosite	–	10
Sponge spicules	5	5

PHYSICAL PROPERTIES:

	1-10	6-138
V_v	1.66	1.70
V_h	1.73	1.76
Density	—	1.59
Water content	—	41.8

CARBONATE BOMB:
2-70 = 3
4-70 = 2
6-70 = 1

SITE 515 HOLE B CORE 39 CORED INTERVAL 455.9–465.4 m



LITHOLOGIC DESCRIPTION

5G 5/1

5G 4/1

5G 6/1

SILICEOUS BIOGENIC MUDSTONE

Biscuited throughout. Bioturbated (N3 color). Inclined laminations within biscuits. Small-scale offsets of laminations. Light gray (10YR 7/2) deformed beds (Section 2) also small burrows and deformed laminations. Burrow fill (Section 4): dark gray (N3).

SMEAR SLIDE SUMMARY:

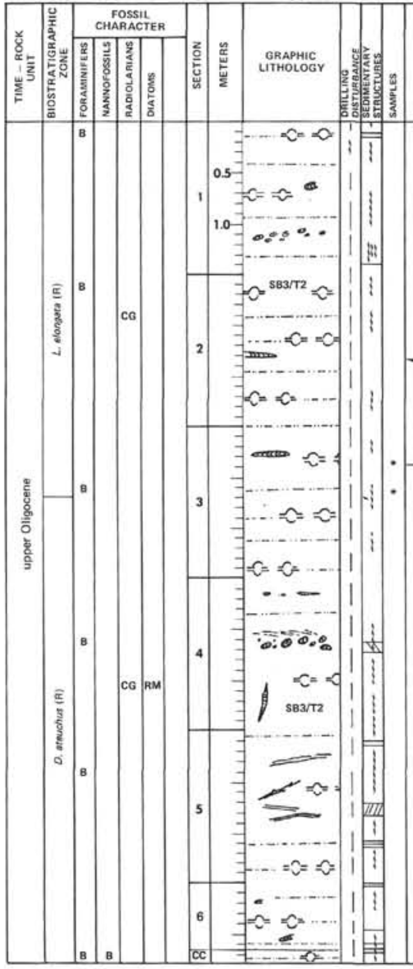
	2-70	6-70
	D	D
Texture:		
Sand	10	5
Silt	40	30
Clay	50	65
Composition:		
Quartz	10	5
Mica	1	1
Heavy minerals	1	–
Other clay minerals	50	40
Nannofossils	–	30
Diatoms	10	6
Radiolarians	10	10
Sponge spicules	15	8
Volcanic glass	3	–

PHYSICAL PROPERTIES:

	6-98
V_v	1.67
V_h	1.74
Density	1.61
Water content	41.2

CARBONATE BOMB:
2-70 = 1
4-70 = 4
6-70 = 2

SITE 515 HOLE B CORE 40 CORED INTERVAL 465.4–474.9 m



LITHOLOGIC DESCRIPTION

5Y 6/1 burrow-fill

5B 5/1 with
N3 mottles

Slight color change

5G 4/1 with
N3 burrows

SILICEOUS MUDSTONE

Biscuited throughout. Dominant color: dark greenish gray (5G 4/1).

SMEAR SLIDE SUMMARY

	3-36[a]	3-75
	M	D
Texture:		
Sand	–	3
Silt	–	30
Clay	–	67
Composition:		
Quartz	–	5
Mica	–	2
Other clay minerals	22	60
Nannofossils	50	–
Diatoms	5	10
Radiolarians	5	10
Silicoflagellates	–	10
Sponge spicules	3	–
Micronodules	15	–
Volcanic glass	–	2

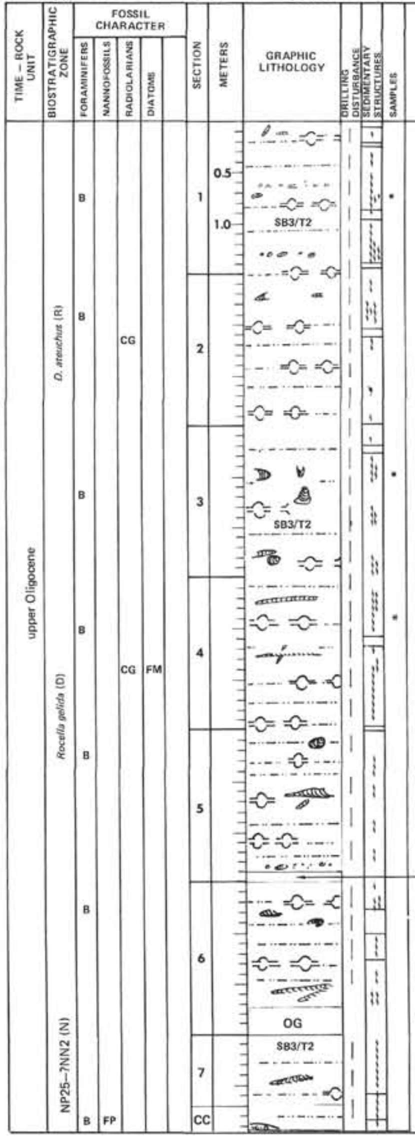
[a] From burrow-fill

PHYSICAL PROPERTIES:

	1-53	5-48
V_v	—	1.66
V_h	1.73	1.71
Density	—	1.54
Water content	—	43.4

CARBONATE BOMB:
2-70 = 2
4-70 = 2
6-50 = 2

SITE 515 HOLE B CORE 41 CORED INTERVAL 474.9–484.4 m



IW

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Biscuited and bioturbated throughout. Intensively burrowed with 10YR 7/2 calcareous sediment. Color: dark greenish gray (5G 4/1). Microspherules are chamosite oolites, fecal debris. Micronodules are black and noncrystalline.

SMEAR SLIDE SUMMARY:

	1-71	3-49
	M	D
Texture:		
Sand	6	TR
Silt	30	50
Clay	64	50
Composition:		
Quartz	–	5
Other clay minerals	40	22
Nannofossils	20	20
Diatoms	15	5
Radiolarians	10	5
Silicoflagellates	10	–
Sponge spicules	–	2
Micronodules and spherules	35	40
Volcanic glass	1	1

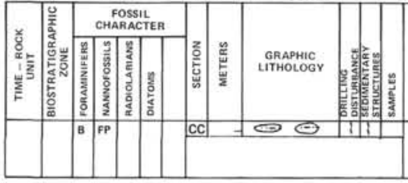
PHYSICAL PROPERTIES:

	6-92
V_v	1.68
V_h	1.73
Density	1.52
Water content	42.9

CARBONATE BOMB:
2-70 = 2
4-70 = 4
6-70 = 0

ORGANIC CARBON:
4, 32–38 = 0.13

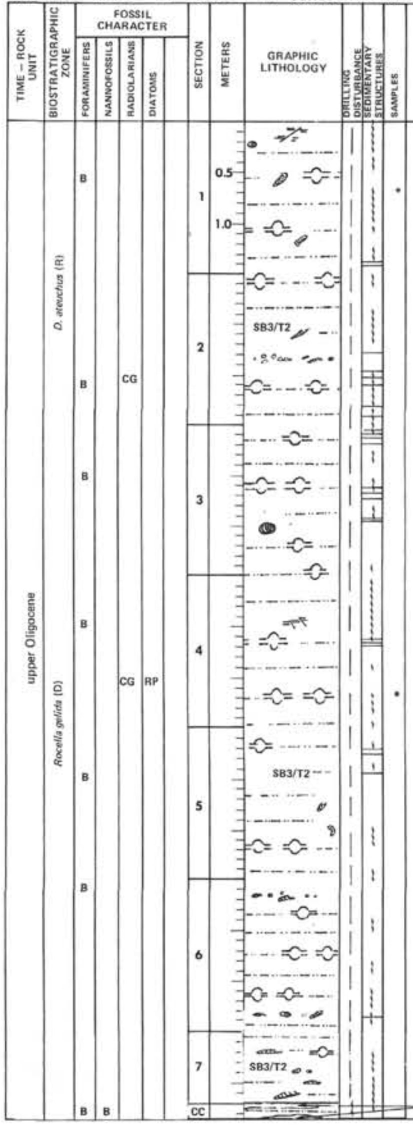
SITE 515 HOLE B CORE 42 CORED INTERVAL 484.4–493.9 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE
Color: 5G 4/1.

SITE 515 HOLE B CORE 43 CORED INTERVAL 493.9–503.4 m



VOIDS

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE
Biscuited and bioturbated throughout. Greenish gray (5G 6/1) with N3 burrow-fill. Burrowing disrupting parallel laminations.

SMEAR SLIDE SUMMARY:

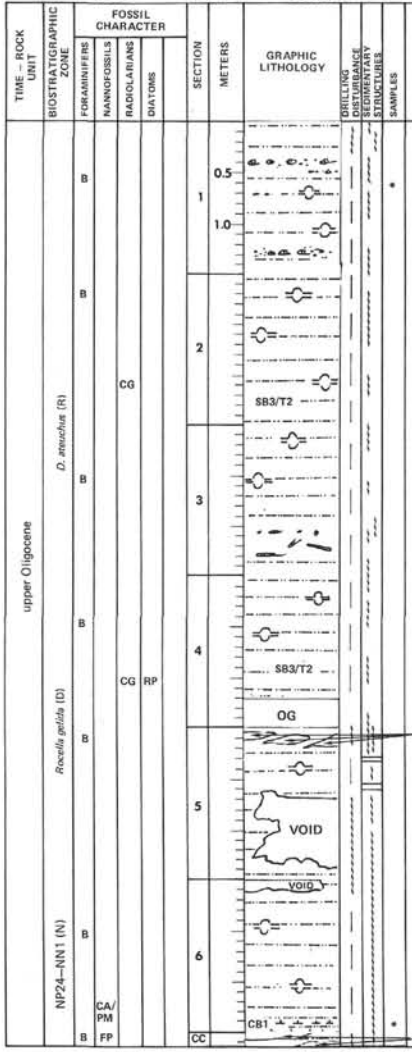
	1-70	4-120
	D	D
Texture:		
Sand	5	1
Silt	60	30
Clay	35	69
Composition:		
Quartz	2	} 10
Feldspar	2	
Other clay minerals	62	67
Foraminifers	TR	–
Diatoms	7	8
Radiolarians	5	8
Sponge spicules	10	5
Microspherules	1	–
Micronodules	1	2
Volcanic glass	10	–

PHYSICAL PROPERTIES:

	6-121
V_v	1.69
V_h	1.75
Density	1.57
Water content	41.6

CARBONATE BOMB:
2-70 = 0
4-70 = 1
6-70 = 3

SITE 515 HOLE B CORE 44 CORED INTERVAL 503.4–512.9 m



LITHOLOGIC DESCRIPTION

5G 6/1

5G 4/1

VOIDS

5YR 8/1 nanno layer

VOIDS

SILICEOUS MUDSTONE
Bioturbated and biscuited throughout.

SMEAR SLIDE SUMMARY:

	1-70[a]	6-140
	D	M
Texture:		
Sand	–	–
Silt	–	80
Clay	–	20
Composition:		
Quartz	3	–
Mica	–	TR
Other clay minerals	76	2
Nannofossils	–	90
Diatoms	2	–
Radiolarians	5	3
Sponge spicules	2	5
Microspherules	12	–

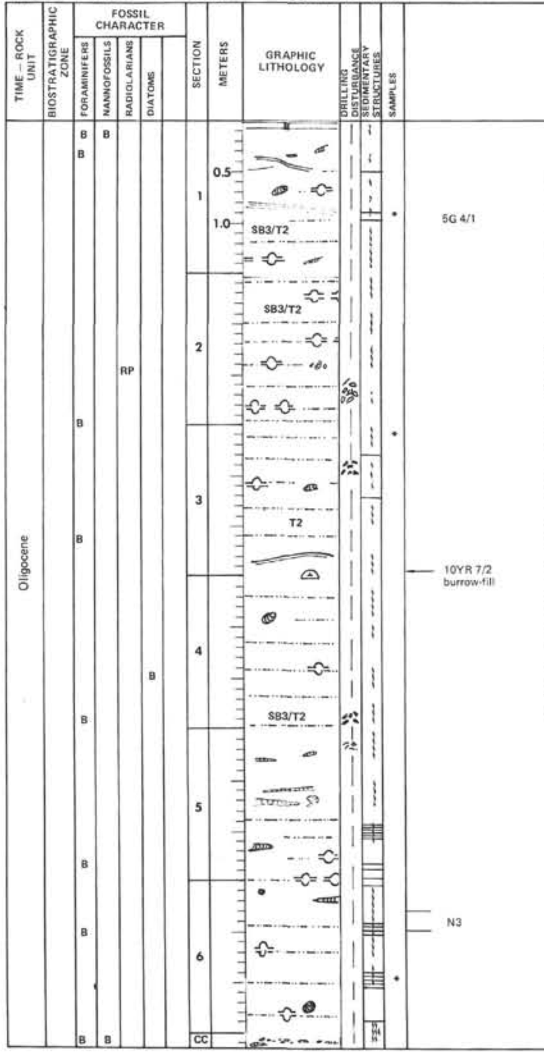
[a] No size analysis because clay is aggregates.

PHYSICAL PROPERTIES:

	1-0	3-138
V_v	—	1.70
V_h	1.74	1.78
Density	—	1.56
Water content	—	42.9

CARBONATE BOMB:
2-70 = 1
4-70 = 0
6-70 = 5

SITE 515 HOLE B CORE 45 CORED INTERVAL 512.9–522.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE

Burrowed and biscuited throughout. Pale brown (10YR 7/2) layer cut by burrow (Section 1, 10 cm). Bedding change within one biscuit. Burrows filled with pale brown (10YR 7/2) sediment. Microsheared from Section 2, 120 cm–Section 4, 140 cm. Beautifully preserved 10YR 8/4 laminations at Section 6, 110 cm.

SMEAR SLIDE SUMMARY:

	1-98	3-17	6-108
	D	D	D
Texture:			
Sand	8	1	–
Silt	22	30	10
Clay	70	69	90
Composition:			
Microspherules (apatite)	–	–	80
Quartz	10	12	–
Mica	2	–	–
Glauconite	TR	–	–
Other clay minerals	60	80	7
Diatoms	10	–	–
Radiolarians	10	2	2
Volcanic glass	–	3	3
Sponge spicules	5	TR	–
Micronodules	2	2	8

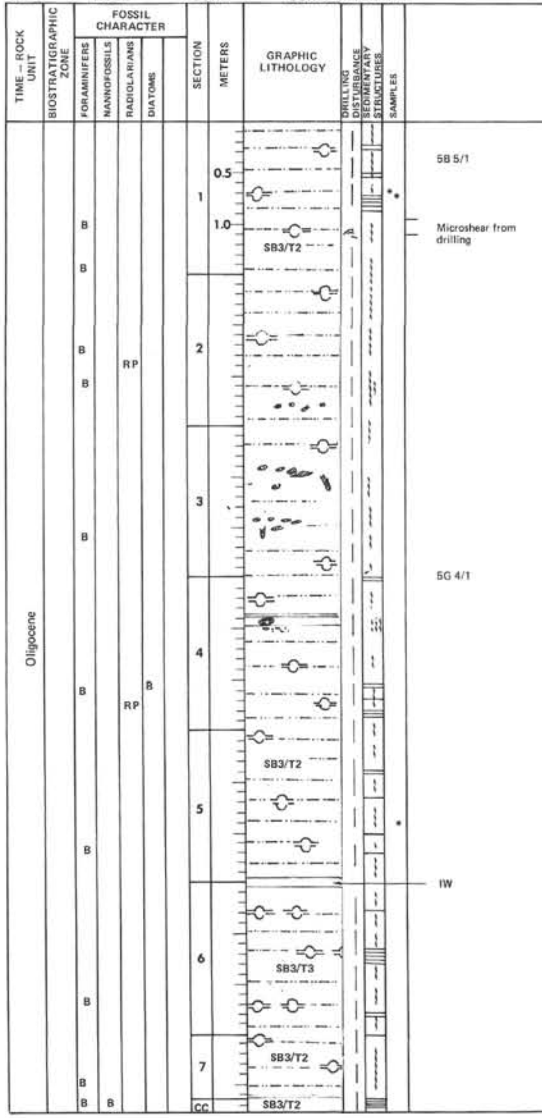
PHYSICAL PROPERTIES:

	3-88
V_v	1.73
V_h	1.81
Density	1.83
Water content	30.5

CARBONATE BOMB:

2-70 = 1
4-70 = 0
6-70 = 0

SITE 515 HOLE B CORE 46 CORED INTERVAL 522.4–531.9 m



LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE (QUARTZ-RICH)

Bioturbated and biscuited throughout. Color: medium bluish gray (5B 5/1). Yellow gray (5Y 8/1) laminations, rip-up structures above the laminations. Light olive gray (5Y 6/1) burrows. Medium dark gray (N4) layer with large burrow.

SMEAR SLIDE SUMMARY:

	1-70	1-76	5-90
	D	M	D
Texture:			
Sand	10	–	2
Silt	30	35	30
Clay	60	65	68
Composition:			
Quartz	2	4	14
Feldspar	–	–	2
Mica	TR	–	2
Other clay minerals	72	33	80
Foraminifers	TR	–	–
Nannofossils	1	60	–
Radiolarians	2	3	TR
Sponge spicules	5	–	TR
Micronodules	4	–	2
Microspherules	2	–	–
Volcanic glass	10	–	–

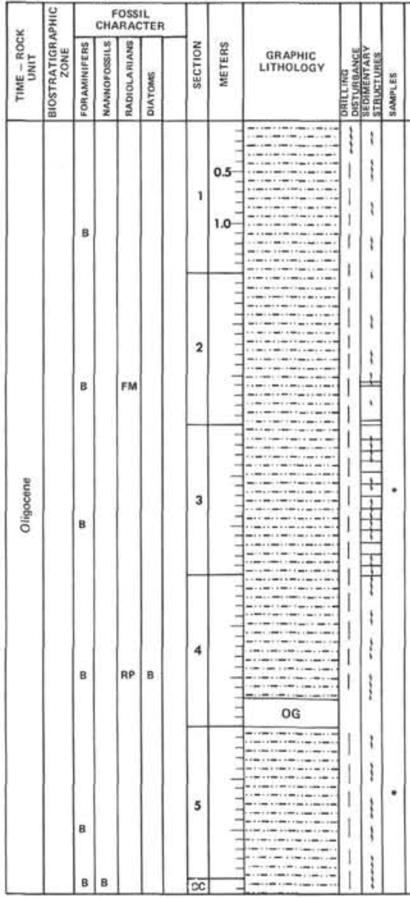
PHYSICAL PROPERTIES:

	5-10
V_v	1.74
V_h	1.84
Density	1.81
Water content	29.2

CARBONATE BOMB:

2-70 = 0
4-70 = 3
6-70 = 0

SITE 515 HOLE B CORE 47 CORED INTERVAL 531.9–541.4 m



LITHOLOGIC DESCRIPTION

QUARTZ-RICH, TERRIGENOUS MUDSTONE

Dark greenish (5G 4/1) mudstone with laminations and burrows throughout. Sediments show faulting (primary, not due to drilling).

SMEAR SLIDE SUMMARY:

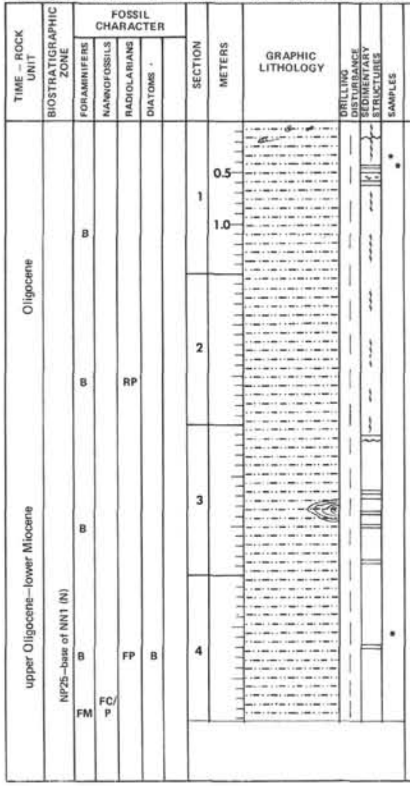
	3-70	5-70
	D	D
Texture:		
Sand	2	2
Silt	13	13
Clay	85	85
Composition:		
Quartz Feldspar	} 10	} 10
Mica	TR	TR
Heavy minerals	1	1
Other clay minerals	78	78
Fecal pellets	5	5
Micronodules	5	5
Sponge spicules	1	1

PHYSICAL PROPERTIES:

	4-109
V_v	1.77
V_h	1.85
Density	1.87
Water content	28.2

CARBONATE BOMB:
2-70 = 2
4-70 = 3

SITE 515 HOLE B CORE 48 CORED INTERVAL 541.4–550.9 m



LITHOLOGIC DESCRIPTION

5G 4/1

QUARTZ-RICH TERRIGENOUS MUDSTONE

Color: dark greenish gray (5G 4/1). Burrowed with dark gray (N3) and various shades of greenish gray. Laminated band of phosphatic light yellowish gray (5Y 8/1) mudstone altered from nannofossil ooze. Biogenic silica in trace quantities only; carbonate also rare except in light colored interval. Sedimentary structures include parallel laminations and rip-up clasts. Suggestion of small ripple marks in Section 1 (15 cm). Section 1, 70 cm: lithologic contact. Biscuited throughout.

SMEAR SLIDE SUMMARY:

	1-31	1-138	4-68
	D	D	M
Texture:			
Sand	15	10	TR
Silt	35	20	50
Clay	50	70	50
Composition:			
Quartz Feldspar	} 20	} 20	} 5
Mica	TR	TR	–
Pyrite	3	3	1
Heavy minerals	1	2	TR
Other clay minerals	50	68	38
Carbonate unspecified	–	–	TR
Nannofossils	–	–	5
Diatoms	1	–	–
Volcanic glass	–	–	1
Micronodules	1	–	–
Apatite	20	10	50
Sponge spicules	1	–	TR

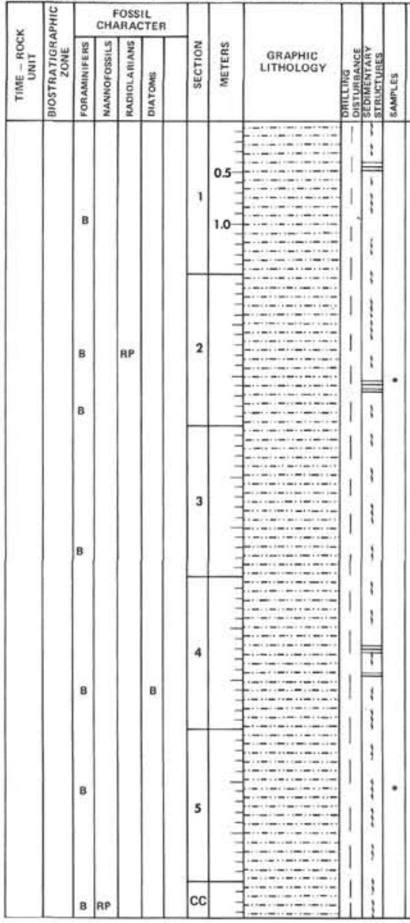
5Y 8/1

PHYSICAL PROPERTIES:

	1-30	4-75
V_v	1.78	—
V_h	1.90	1.95
Density	2.04	—
Water content	25.4	—

CARBONATE BOMB:
2-70 = 1
4-70 = 3

SITE 515 HOLE B CORE 49 CORED INTERVAL 550.9–560.4 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS MUDSTONE

Mudstone dark greenish gray (5G 4/1), burrowed and laminated with dark gray (N3). Chert and associated carbonate are nannofossil-rich, light colored layers ranging from light greenish gray (5G 8/1) at base to greenish gray (5G 6/1) in upper portion. Basal contacts sharp. sharp.

SMEAR SLIDE SUMMARY:

	2-102	5-64
	M	D
Texture:		
Sand	5	10
Silt	15	20
Clay	80	70
Composition:		
Quartz	} 5	7
Feldspar		3
Mica	–	TR
Pyrite	–	3
Heavy minerals	–	1
Micronodules	–	2
Fecal pellets	–	20
Other clay minerals	85[a]	65
Nannofossils	10	–

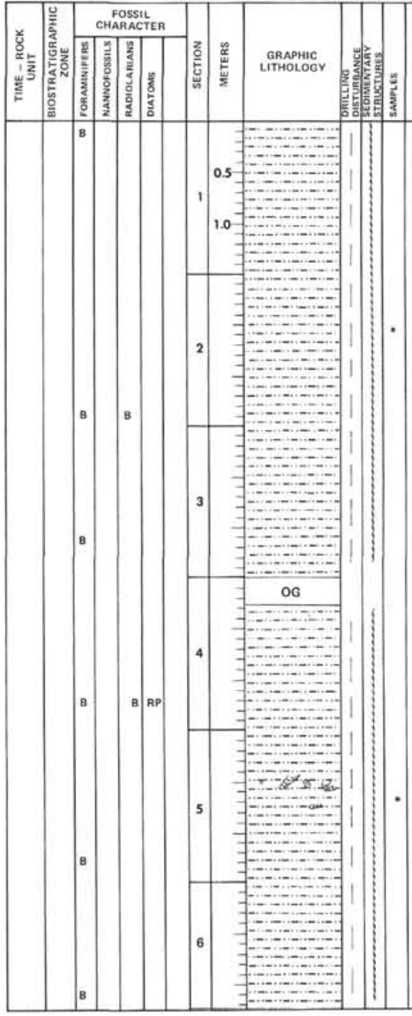
[a] Includes silica seen in acidified sample.

PHYSICAL PROPERTIES:

	4-50
V_v	1.80
V_h	1.90
Density	1.93
Water content	26.2

CARBONATE BOMB:
2-70 = 5
4-70 = 8

SITE 515 HOLE B CORE 50 CORED INTERVAL 560.4–569.9 m



LITHOLOGIC DESCRIPTION

QUARTZ-RICH TERRIGENOUS MUDSTONE

Color: dark greenish gray (5G 4/1). Burrowed and laminated with dark gray (N3). Two thin light greenish gray (5G 6/1) intervals as in Core 49. Biscuited throughout.

SMEAR SLIDE SUMMARY:

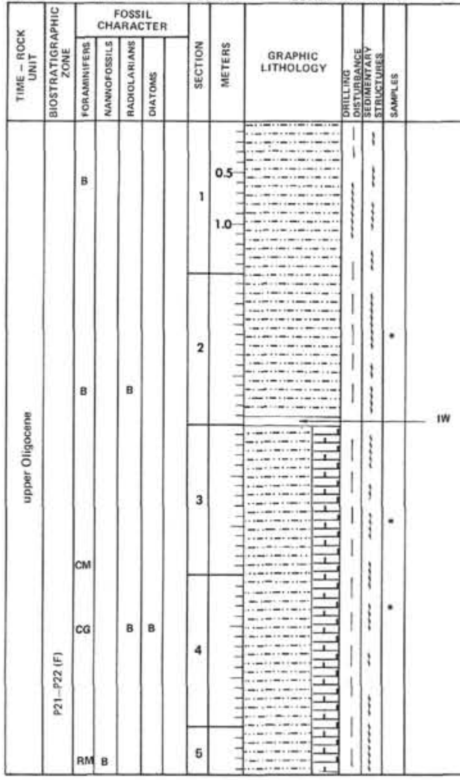
	2-65	5-70
	D	D
Texture:		
Sand	10	10
Silt	30	30
Clay	60	60
Composition:		
Quartz	25	25
Feldspar	5	5
Mica	TR	TR
Pyrite	3	3
Heavy minerals	2	3
Other clay minerals	60	60
Diatoms	TR	–
Fecal pellets	5	–
Micronodules	2	2
Sponge spicules	TR	TR

PHYSICAL PROPERTIES:

	3-79
V_v	1.77
V_h	1.88
Density	1.90
Water content	26.5

CARBONATE BOMB:
2-70 = 3
4-70 = 3
6-70 = 0

SITE 515 HOLE B CORE 51 CORED INTERVAL 569.9–579.4 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS to CALCAREOUS MUDSTONE

Dark greenish gray (5G 4/1). Burrowed and laminated with dark gray (N3). Microfaulting, silty laminae. Nannofossils 10–20% in Sections 3 and 4 – no color change. One thin cherty carbonate layer in Section 2, similar to those in preceding cores.

SMEAR SLIDE SUMMARY:

	2-70	3-103	4-40
	D	D	D
Texture:			
Sand	15	7	5
Silt	35	23	30
Clay	50	70	65
Composition:			
Quartz	25	5	3
Feldspar	5	3	2
Mica	TR	TR	–
Pyrite	3	3	TR
Heavy minerals	3	2	TR
Other clay minerals	50	65	64
Nannofossils	–	20	30
Diatoms	TR	TR	TR
Fecal pellets	5	–	–
Micronodules	2	2	TR
Sponge spicules	TR	–	TR

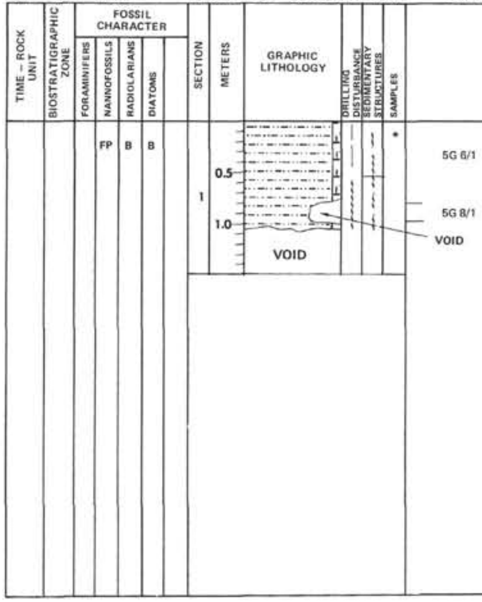
PHYSICAL PROPERTIES:

	1-7	4-2
V_v	—	—
V_h	1.90	1.89
Density	—	1.91
Water content	—	26.1

CARBONATE BOMB:

2-70 = 1
4-70 = 11

SITE 515 HOLE B CORE 52 CORED INTERVAL 579.4–588.9 m



LITHOLOGIC DESCRIPTION

QUARTZ MUDSTONE

Bioturbated and biscuited. Color: dark greenish gray (5G 6/1).

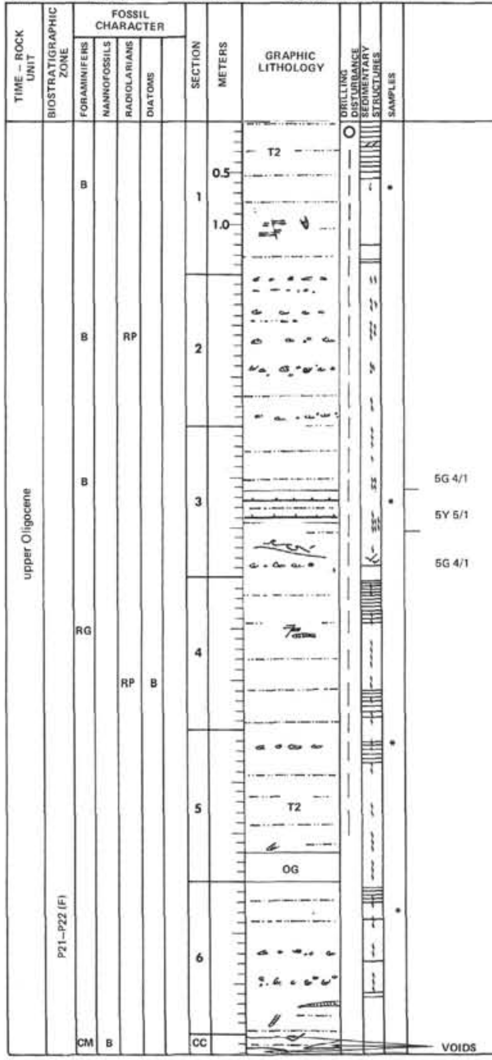
SMEAR SLIDE SUMMARY:

	1-20
	D
Texture:	
Sand	5
Silt	30
Clay	65
Composition:	
Quartz	30
Feldspar	2
Mica	2
Glauconite	TR
Other clay minerals	53
Nannofossils	10
Diatoms	TR
Radiolarians	TR

PHYSICAL PROPERTIES:

	1-10
V_v	1.77
V_h	1.82
Density	1.89
Water content	26.5

SITE 515 HOLE B CORE 53 CORED INTERVAL 588.9–598.4 m

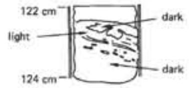


LITHOLOGIC DESCRIPTION

QUARTZ-RICH MUDSTONE

Biscuited throughout except for laminated 25 cm of Section 1. Dark greenish gray (5GY 4/1) with burrows generally gray (N3). Cyclicity throughout Sections 2 and 6. Alteration of brown (5GY 4/1) intervals with grayer (5G 4/1) – brown intervals are strongly burrowed.

Section 3 – Thin Section:



SMEAR SLIDE SUMMARY:

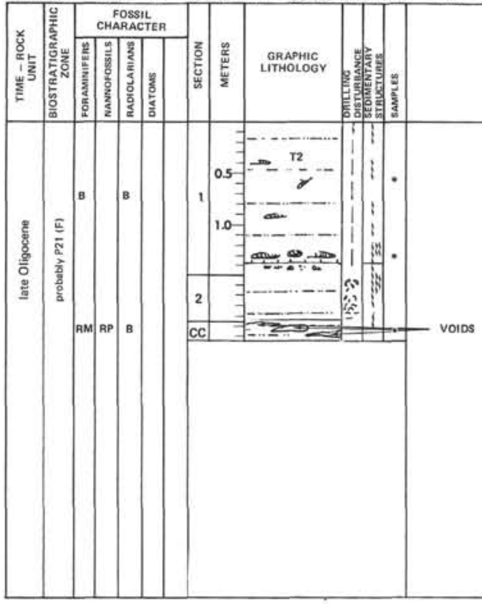
	1-70	3-72	5-15	6-35
	D	D	M	D
Texture:				
Sand	20	–	–	–
Silt	30	30	80	30
Clay	50	70	20	70
Composition:				
Quartz	15	4	2	20
Feldspar	–	2	2	5
Heavy minerals	–	–	16	–
Glauconite	1	TR	–	–
Other clay minerals	78	40	–	65
Carbonate unspecified	–	2	–	–
Nannofossils	–	50	–	3
Diatoms	–	TR	–	–
Radiolarians	–	–	TR	–
Microspherules (apatite)	–	–	80	–
Micronodules	1	–	2	5
Volcanic glass	5	–	–	–

PHYSICAL PROPERTIES:

	1-12	6-130
V_v	—	1.78
V_h	2.02	1.89
Density	—	1.88
Water content	—	26.6

CARBONATE BOMB:
4-70 = 2
6-70 = 2

SITE 515 HOLE B CORE 54 CORED INTERVAL 598.4–607.9 m



LITHOLOGIC DESCRIPTION

QUARTZ-RICH MUDSTONE

Biscuited throughout. Gray (N3) burrow-fill in dark greenish gray matrix. Dark burrows in light gray (10YR 7/2) matrix. Microsheared by drilling.

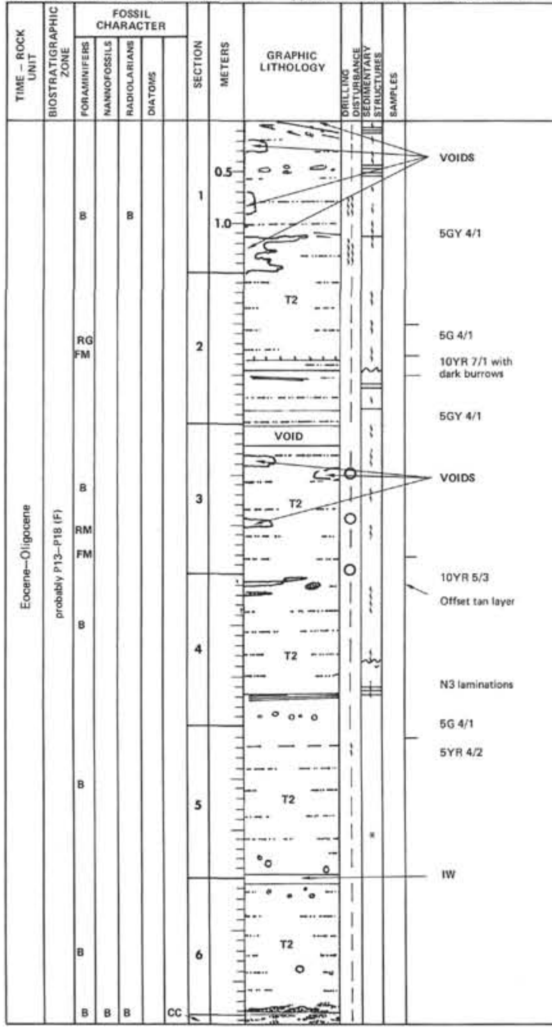
SMEAR SLIDE SUMMARY:

	1-60	1-145	CC, 20
	D	D	D
Texture:			
Sand	–	–	–
Silt	20	15	30
Clay	80	85	70
Composition:			
Quartz	20	–	15
Glauconite	–	–	1
Other clay minerals	70	20	77
Carbonate unspecified	–	–	1
Nannofossils	2	80	–
Diatoms	TR	–	–
Radiolarians	TR	–	–
Opaque minerals	5	–	6
Micronodules	3	–	–

PHYSICAL PROPERTIES:

	1-120
V_v	1.83
V_h	1.95
Density	1.84
Water content	27.0

SITE 515 HOLE B CORE 55 CORED INTERVAL 607.9–617.4 m



LITHOLOGIC DESCRIPTION

QUARTZ-RICH MUDSTONE

Section 1, 50 cm: intraformational conglomerate/mottles are light gray (10YR 7/1). Voids are markers for drilling deformed layers perhaps micro-conglomerates. Color: 5G 4/1 contrasts with surrounding dark greenish gray. Brown (10YR 5/3) becomes more prominent towards base of the core. Brownish gray (5Y 4/1) with 5B 6/1 sediment within at areas: Section 4, 135 cm, Section 5, 135 cm, and Section 6, 20 and 90 cm. Section 6: sand and heavy mineral intercalations, microconglomerate

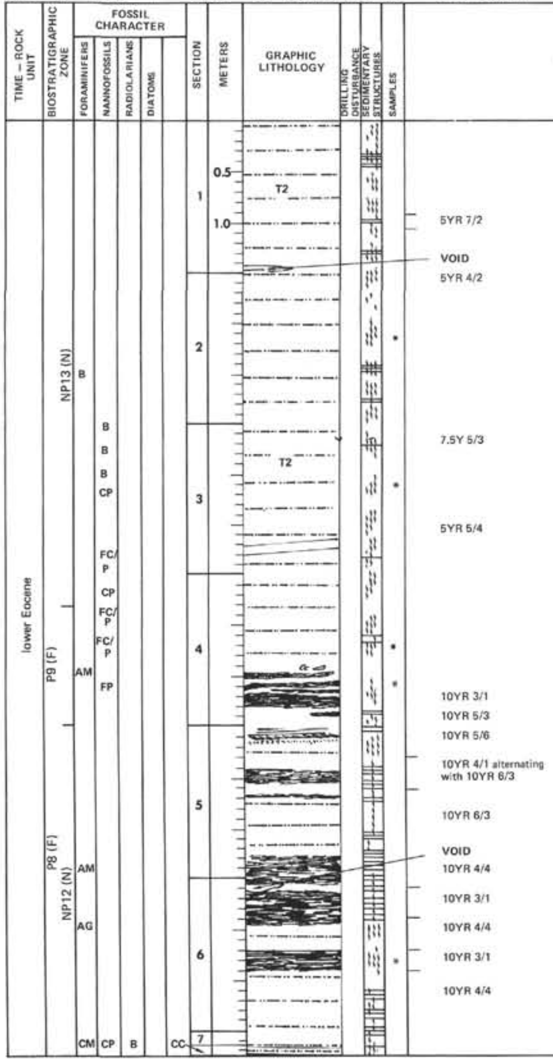
PHYSICAL PROPERTIES:

	CC	4-15
V_v	—	1.88
V_h	2.04	1.87
Density	—	1.94
Water content	—	24.7

CARBONATE BOMB:
2-70 = 5
4-80 = 8
6-70 = 2

ORGANIC CARBON:
5, 118–126 = 0.02

SITE 515 HOLE B CORE 56 CORED INTERVAL 617.4–626.9 m



LITHOLOGIC DESCRIPTION

BIOTURBATED extensive ZEOLITIC MUDSTONE increasing calcareous component downcore. No deformation. Rose colored (5YR 5/4) bed with bioturbation at base of Section 3.

SMEAR SLIDE SUMMARY:

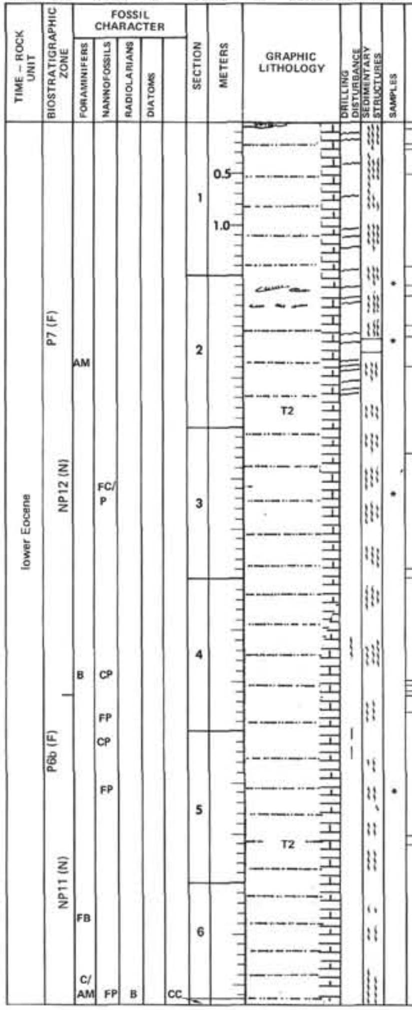
	4-70
	D
Texture:	
Sand	2
Silt	38
Clay	60
Composition:	
Quartz Feldspar	} 5
Pyrite	1
Heavy minerals	1
Zeolites	5
Other clay minerals	62
Nannofossils	25
Iron-oxide	TR
Volcanic glass	1

PHYSICAL PROPERTIES:

	2-81	2-90	3-127	4-128	5-105	6-131
V_v	—	1.92	—	—	—	—
V_h	1.91	—	1.98	1.89	1.96	1.94
Density	—	2.03	—	—	—	—
Water content	—	20.2	—	—	—	—

ORGANIC CARBON:
4, 120–125 = 0.02
6, 70–78 = 0.05

SITE 515 HOLE B CORE 57 CORED INTERVAL 626.9–636.4 m



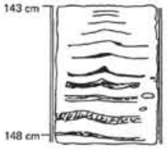
LITHOLOGIC DESCRIPTION

10YR 5/4
5Y 6/1
10YR 5/4
5Y 6/1
10YR 5/4
5Y 6/1
5YR 3/4
5Y 6/1
10YR 5/4
5GY 6/1
10YR 5/4
5Y 6/1
10YR 5/4
5Y 6/1
Mottled with 5GY 8/1
5G 6/1
5Y 6/1
5G 6/1
5Y 6/1
5G 6/1
5Y 4/1
5G 6/1

BIOTURBATED, QUARTZ-RICH, ZEOLITIC MUDSTONE

Flattened burrows difficult to distinguish from laminations. Section 4, 102 cm: dark layer contains lots of biotite (washed sample).

Section 3:

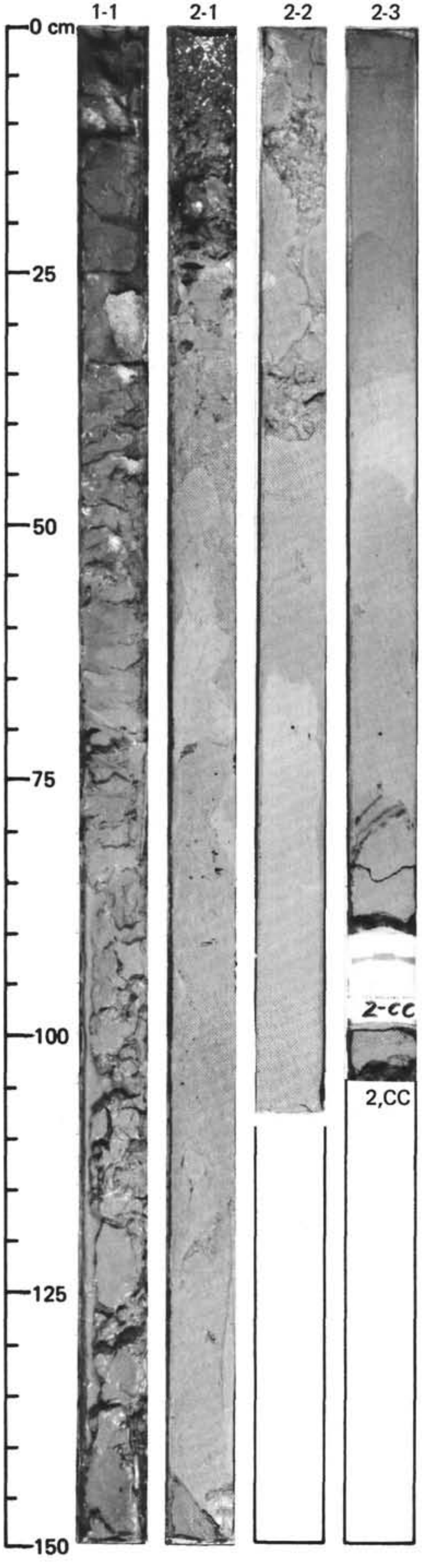


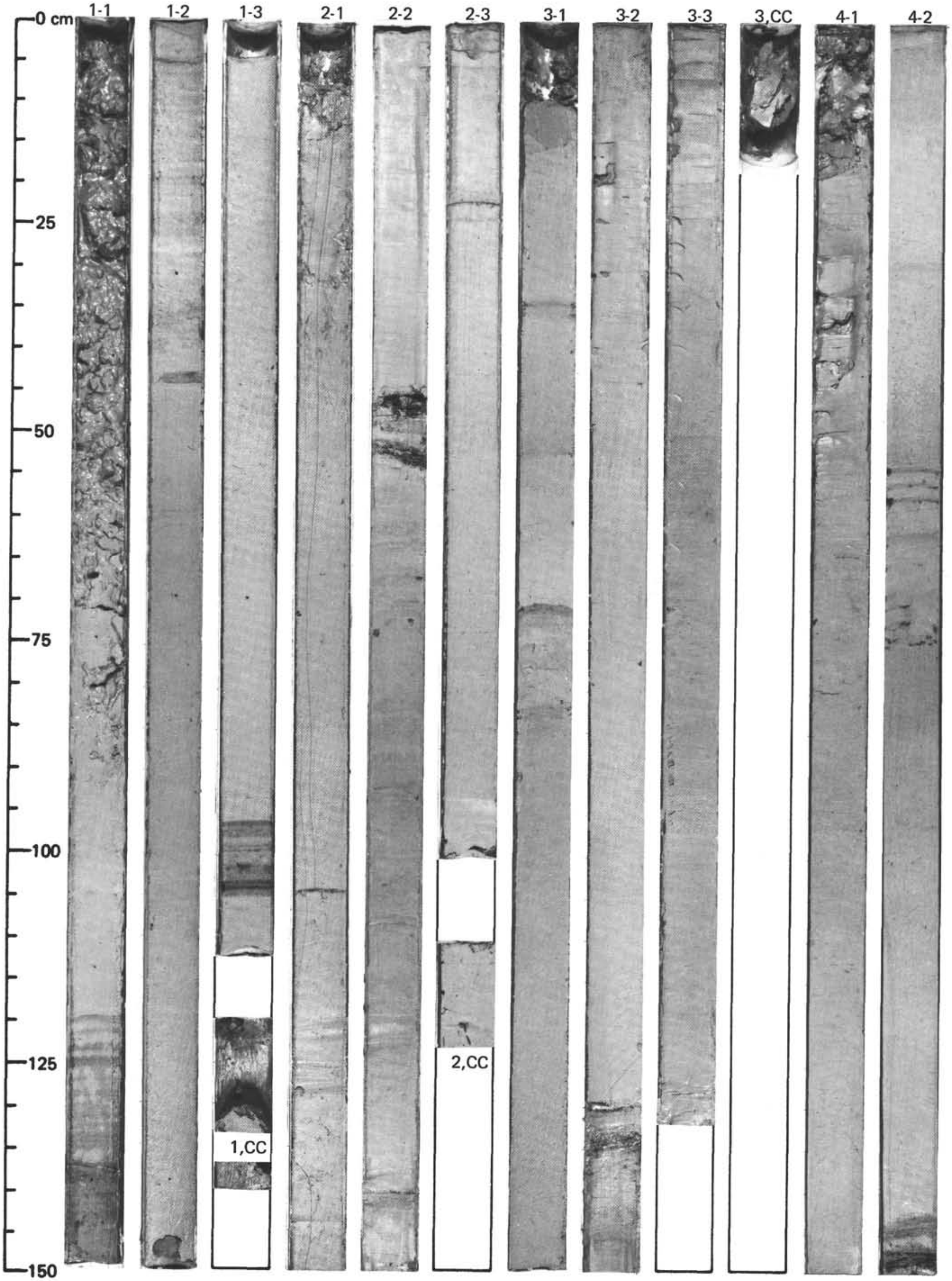
SMEAR SLIDE SUMMARY:

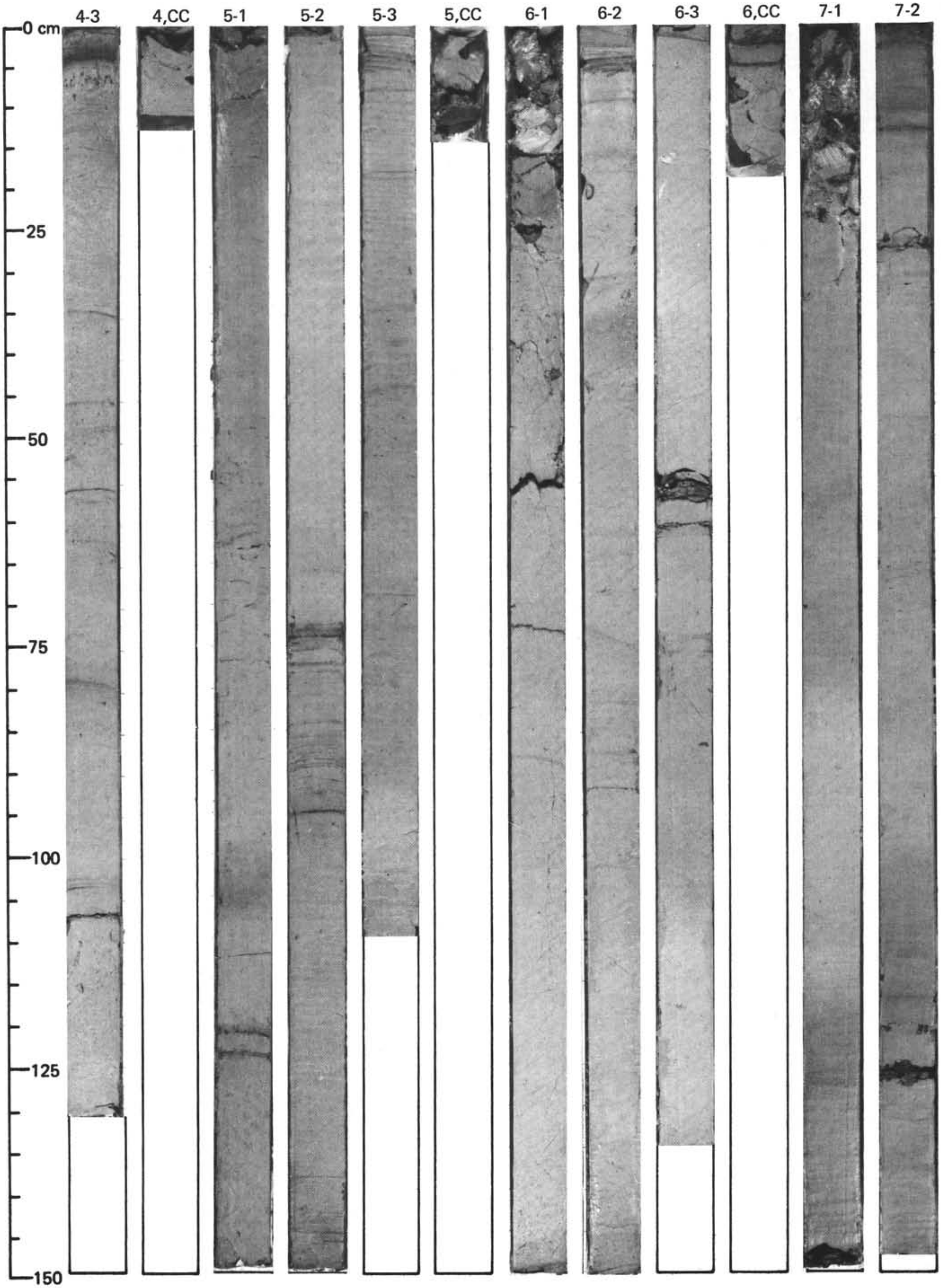
	2-14	2-65	5-61
	D	D	D
Texture:			
Sand	TR	3	1
Silt	50	37	45
Clay	50	60	54
Composition:			
Quartz Feldspar	5	3	3
Mica	TR	–	–
Pyrite	–	1	1
Heavy minerals	1	TR	1
Zeolites	40	5	25
Other clay minerals	49	60	54
Carbonate unspecified	TR	2	–
Foraminifers	–	TR	–
Nannofossils	3	22	15
Fecal pellets	–	5	–
Volcanic glass	1	TR	1
Iron-oxide	1	1	–

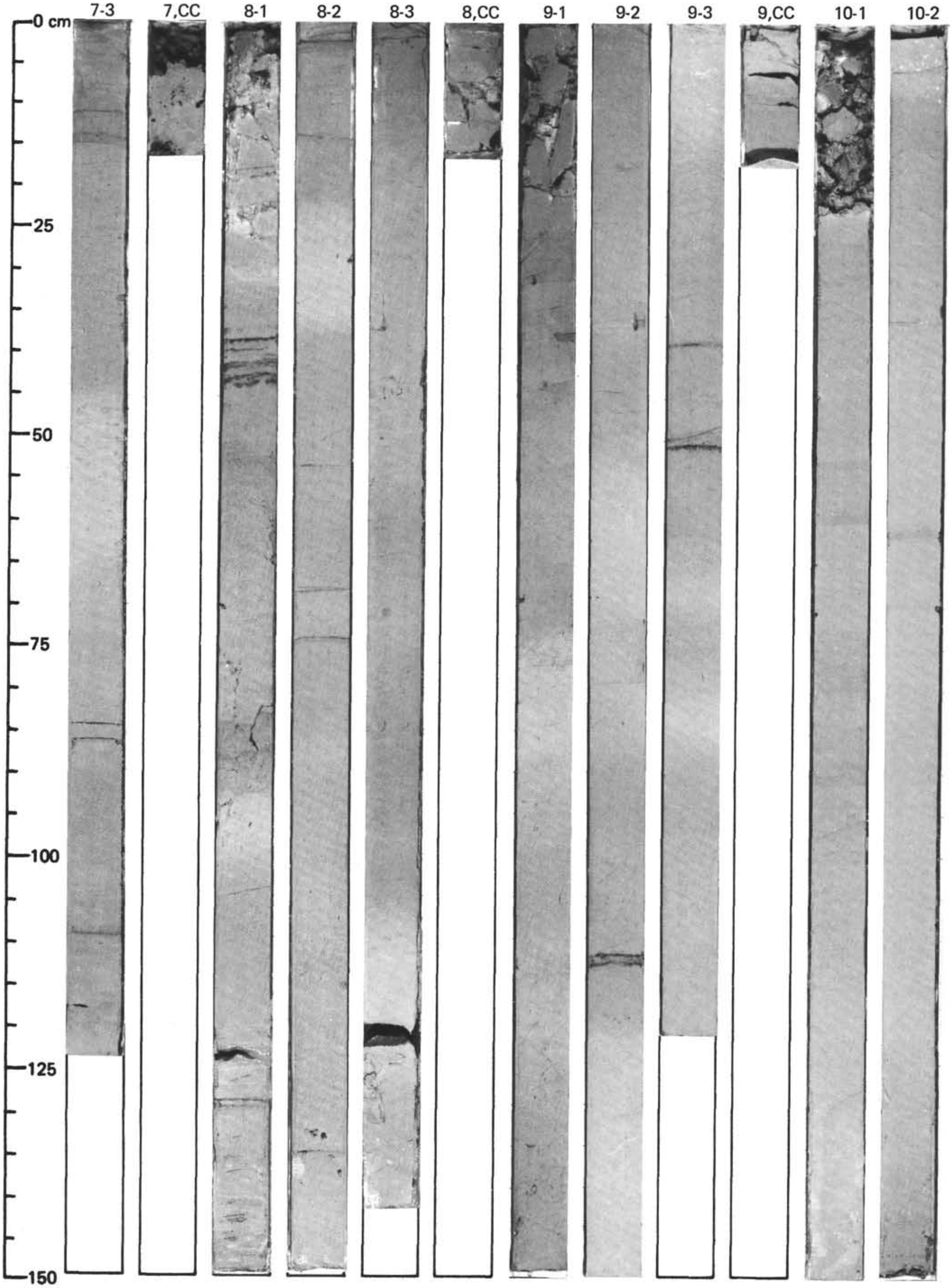
PHYSICAL PROPERTIES:

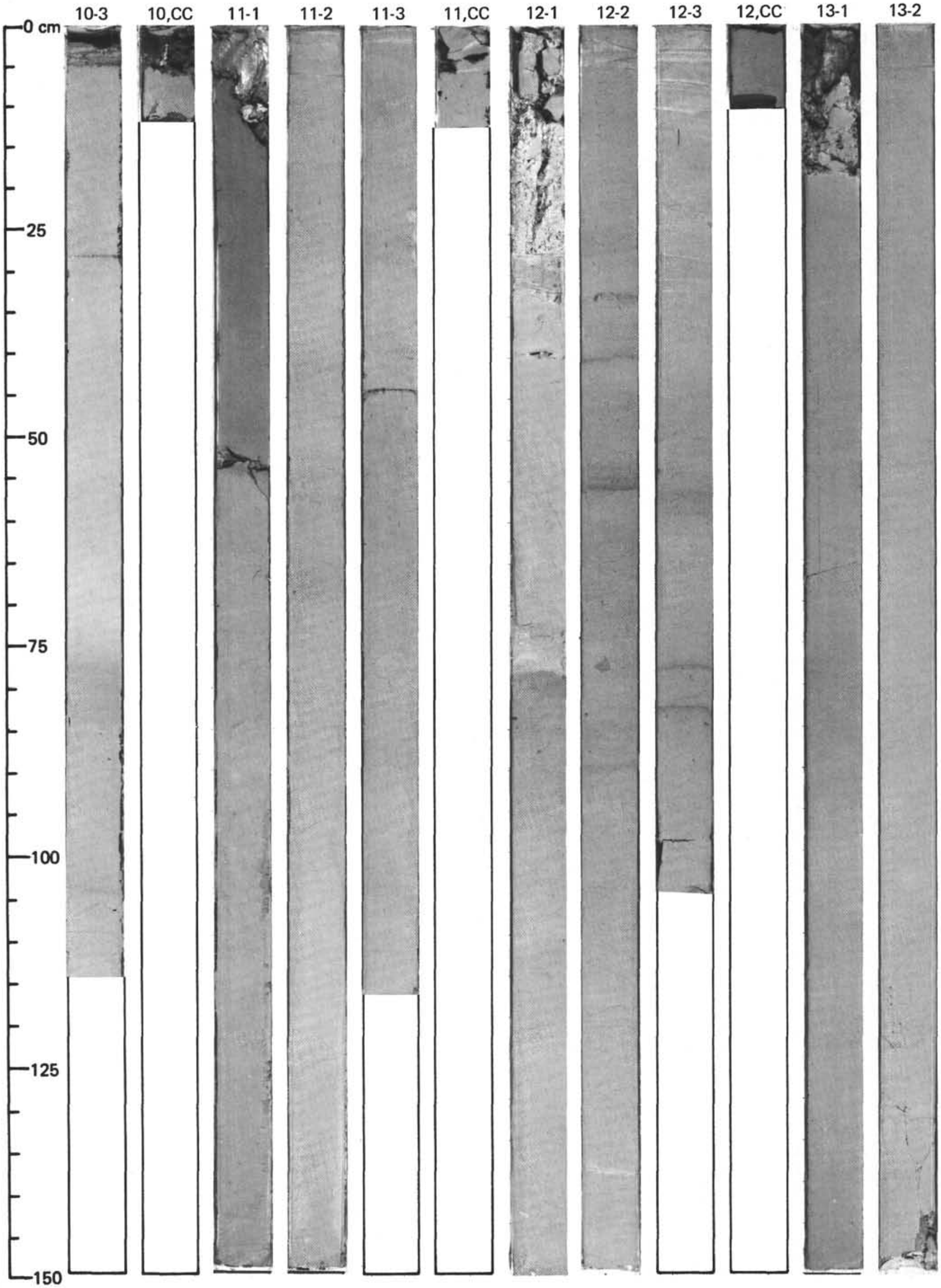
	1-116	3-95	5-125
V_v	1.99	—	—
V_h	2.06	2.14	2.06
Density	2.01	—	—
Water content	20.5	—	—

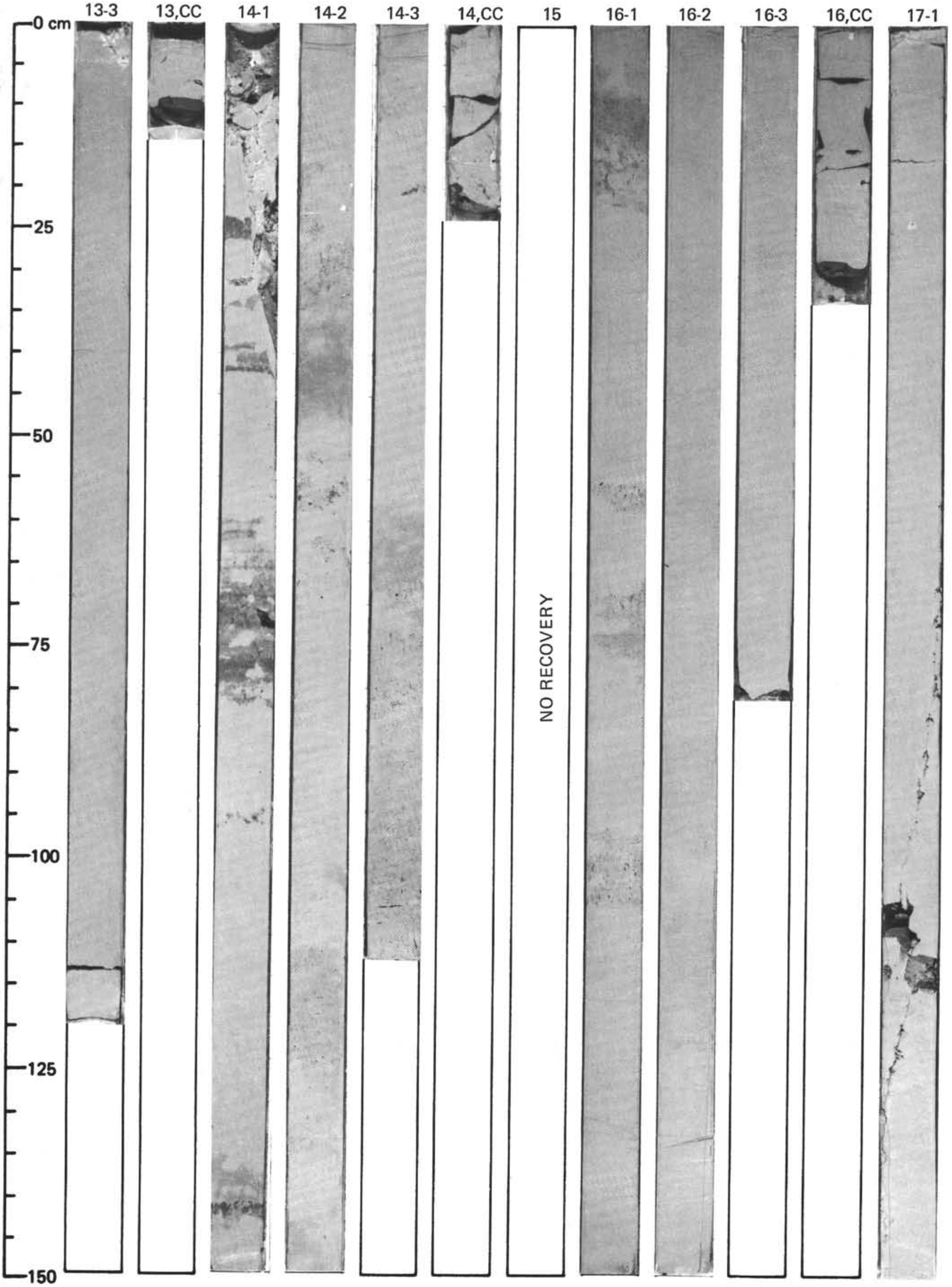

1-1
2-1
2-2
2-3
0 cm
25
50
75
100
125
150
2-cc
2,CC

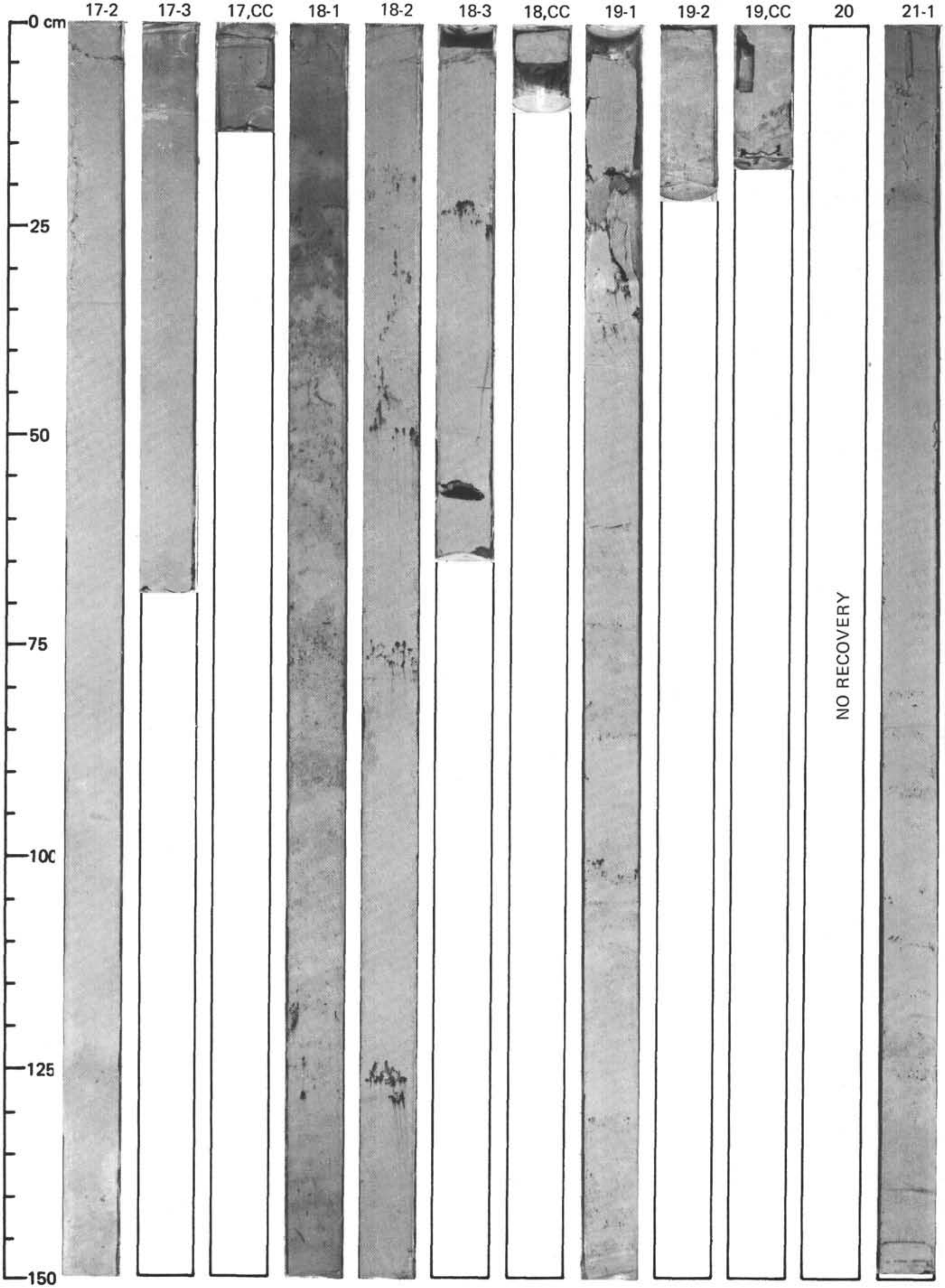

0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1,CC
2-1
2-2
2-3
2,CC
3-1
3-2
3-3
3,CC
4-1
4-2

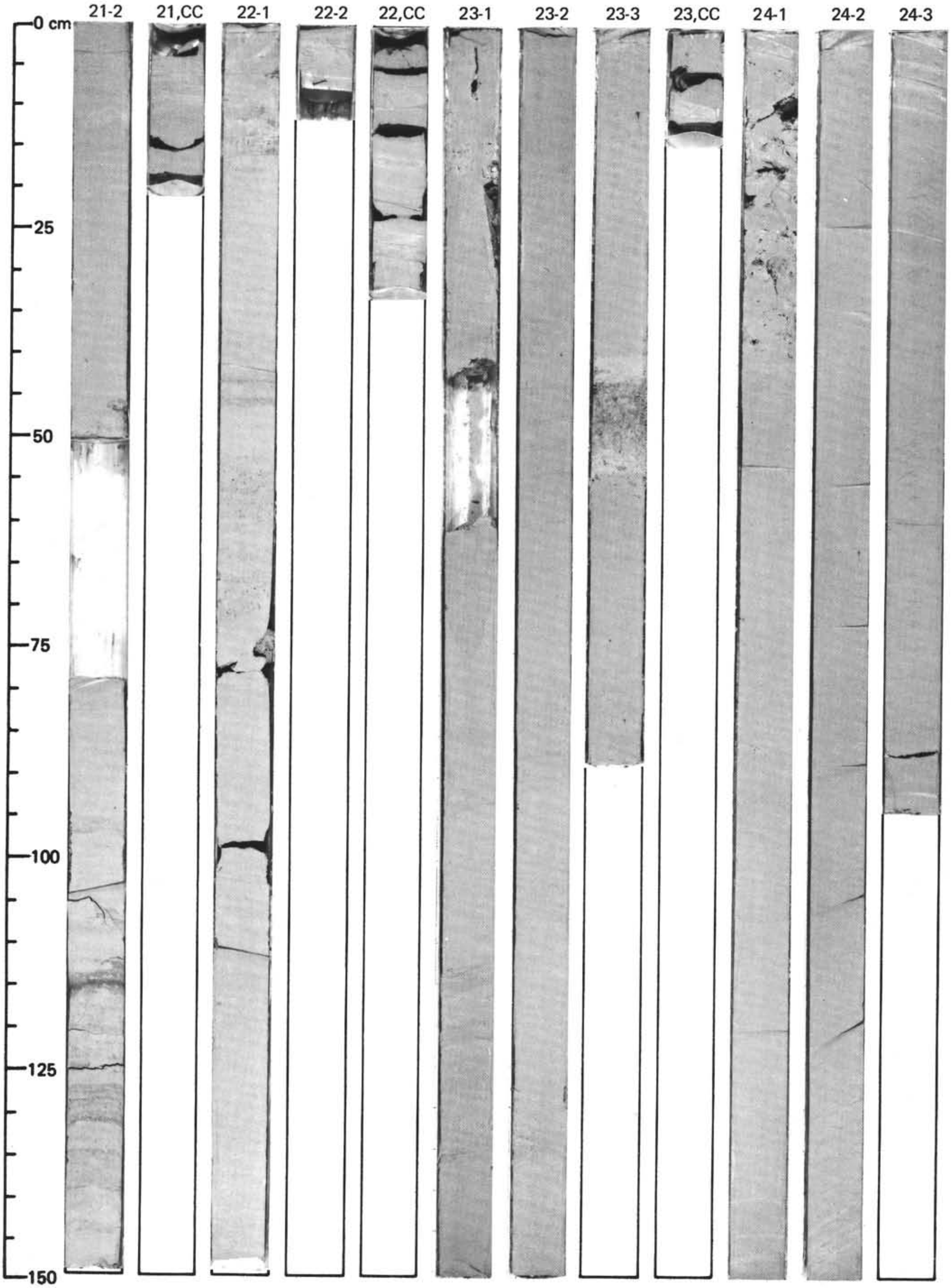

4-3
4,CC
5-1
5-2
5-3
5,CC
6-1
6-2
6-3
6,CC
7-1
7-2
0 cm
25
50
75
100
125
150


7-3
7,CC
8-1
8-2
8-3
8,CC
9-1
9-2
9-3
9,CC
10-1
10-2
0 cm
25
50
75
100
125
150


10-3
10,CC
11-1
11-2
11-3
11,CC
12-1
12-2
12-3
12,CC
13-1
13-2
0 cm
25
50
75
100
125
150


13-3
13,CC
14-1
14-2
14-3
14,CC
15
16-1
16-2
16-3
16,CC
17-1
0 cm
25
50
75
100
125
150
NO RECOVERY


17-2
17-3
17,CC
18-1
18-2
18-3
18,CC
19-1
19-2
19,CC
20
21-1
0 cm
25
50
75
100
125
150
NO RECOVERY


0 cm
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125
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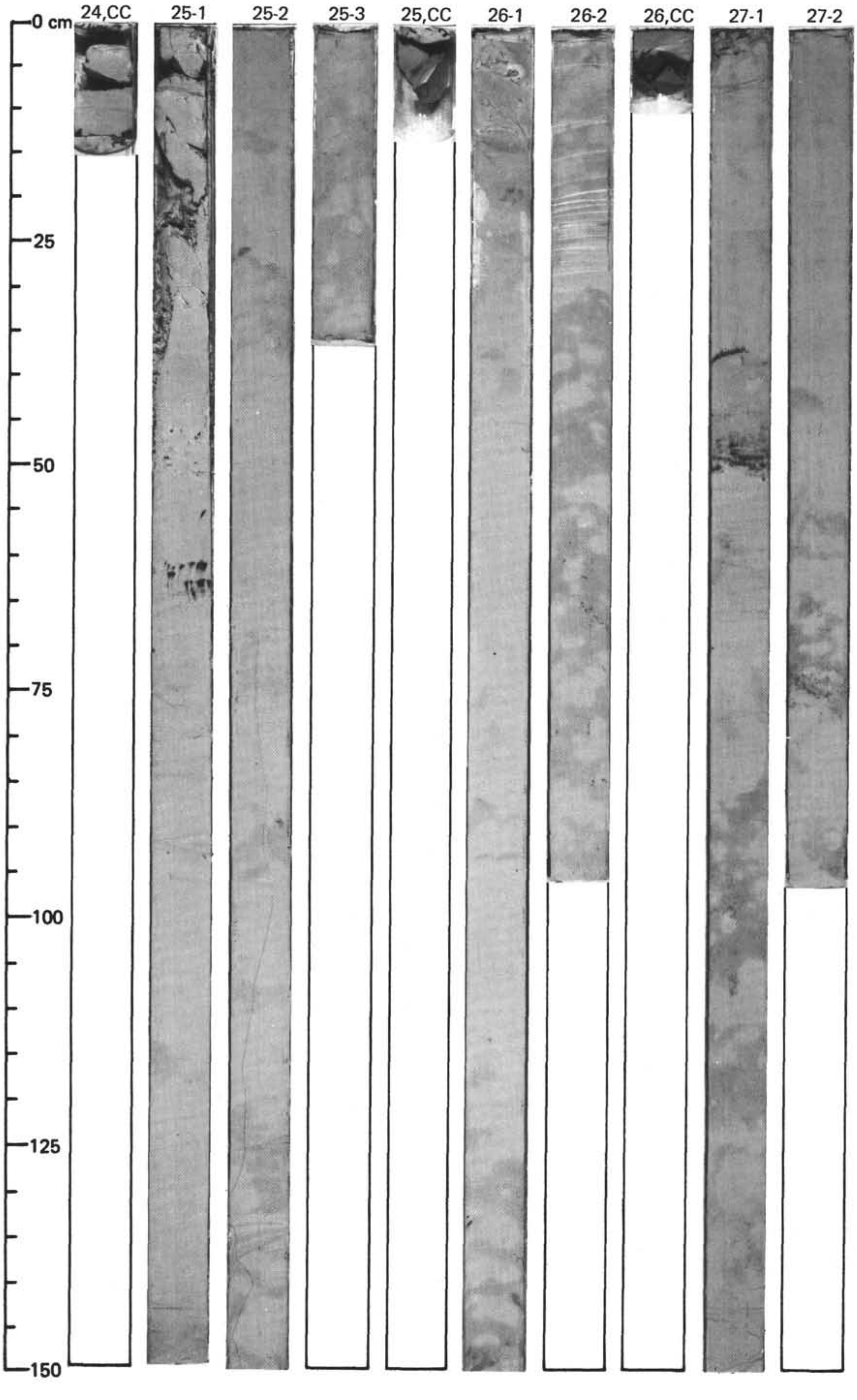
21,CC
22-1
22-2
22,CC
23-1
23-2
23-3
23,CC
24-1
24-2
24-3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24,CC
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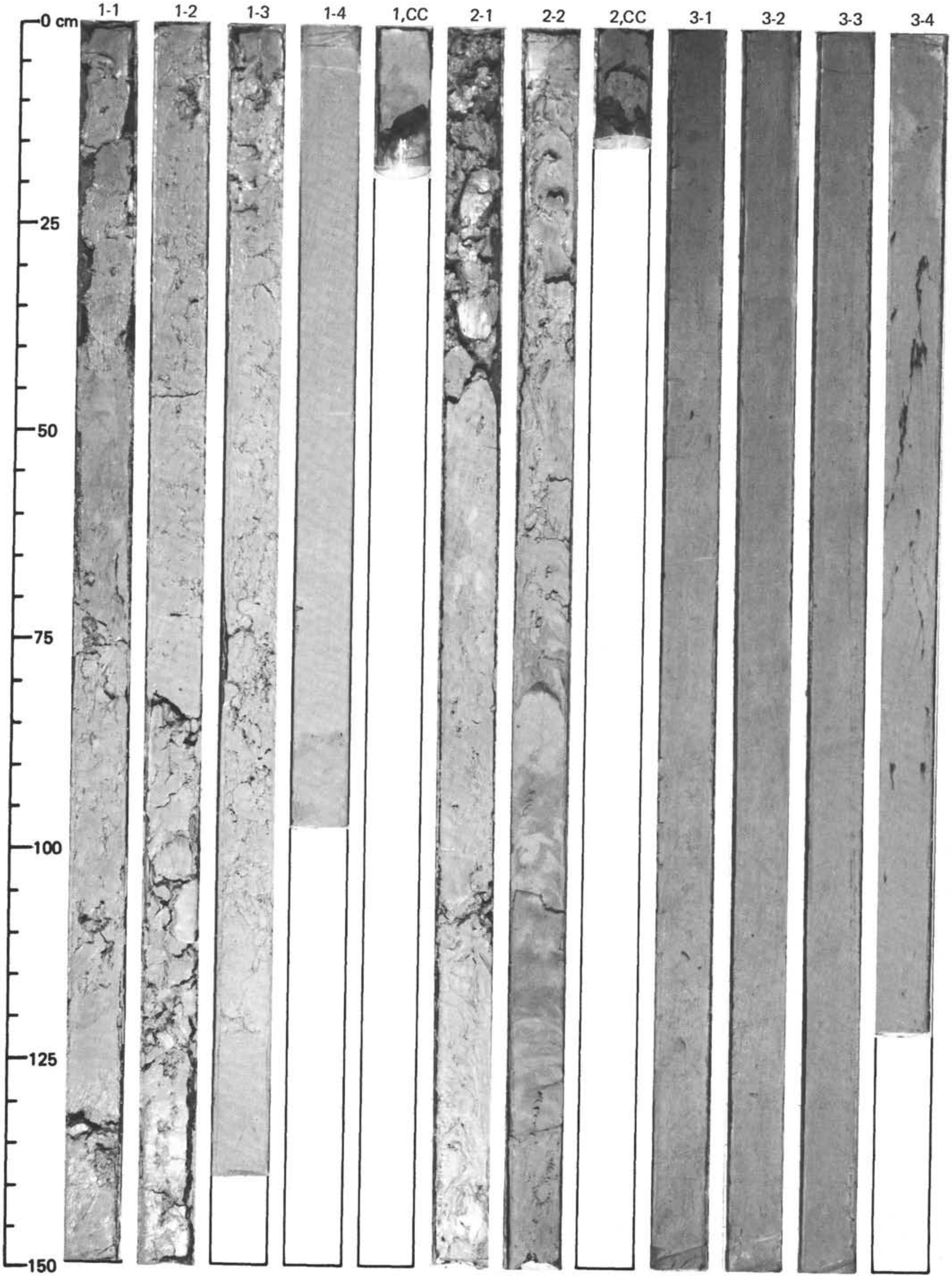
25-3
25,CC
26-1
26-2
26,CC
27-1
27-2


1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2,CC
3-1
3-2
3-3
3-4
0 cm
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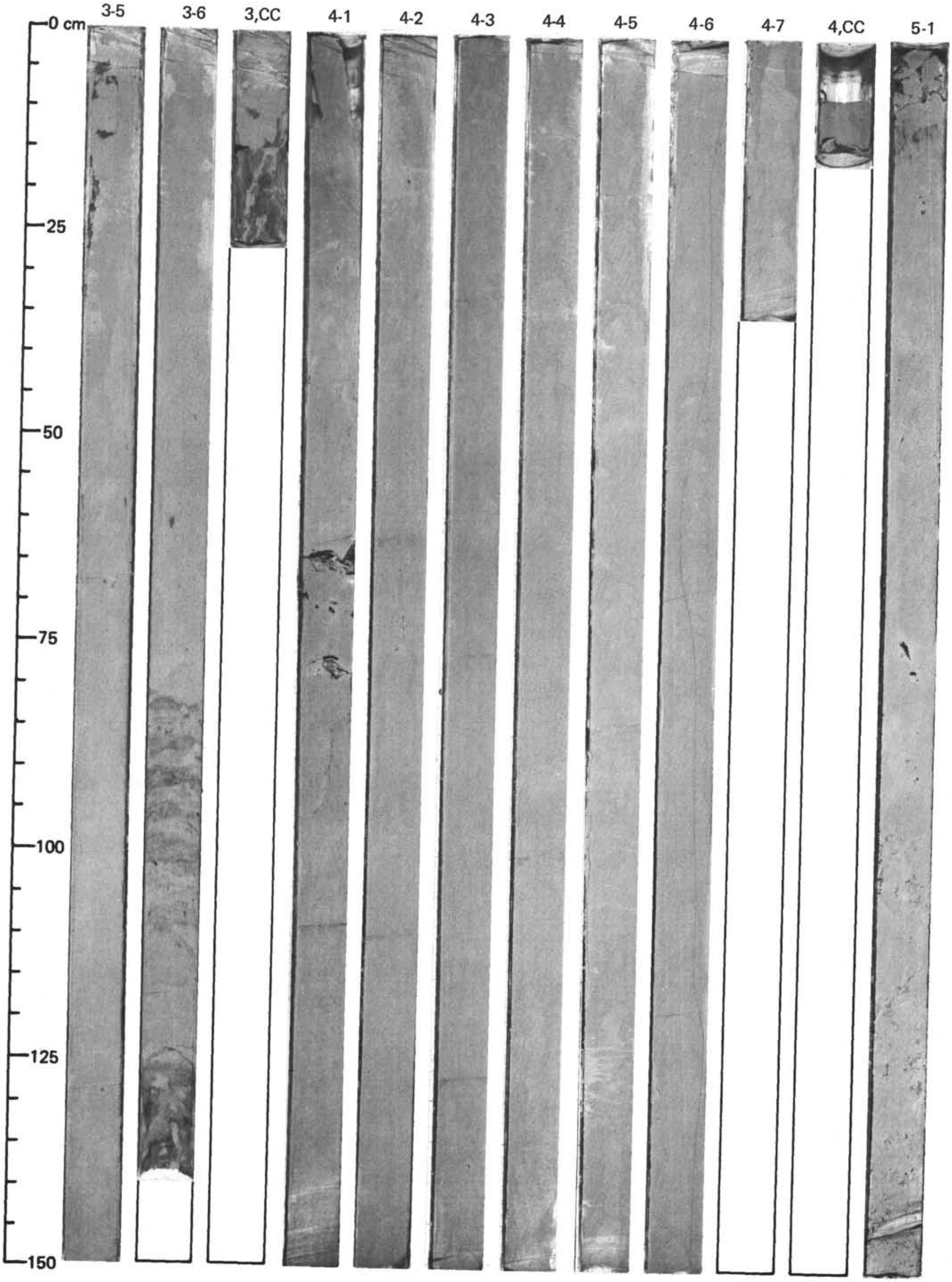
150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3-6
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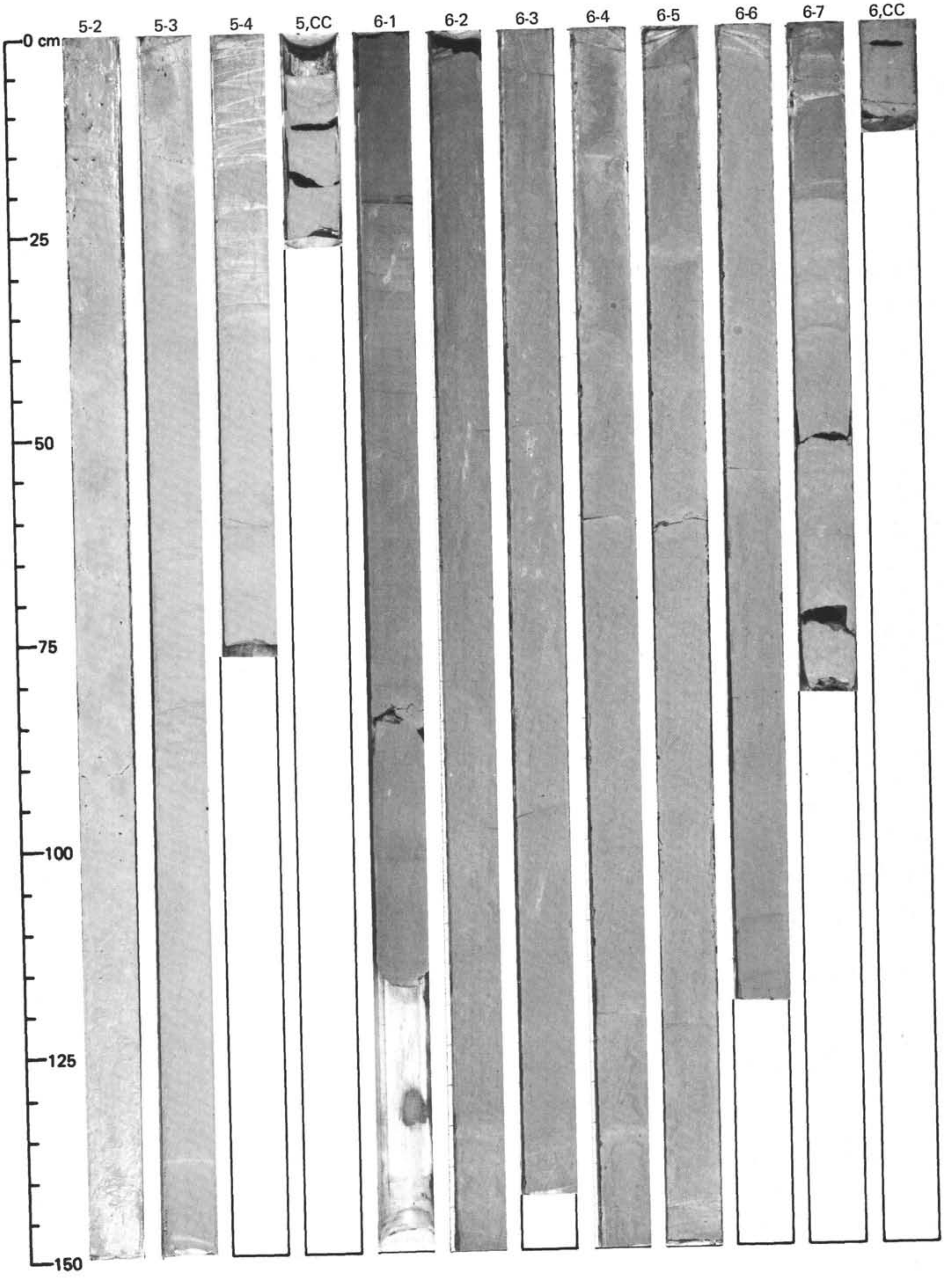
4-1
4-2
4-3
4-4
4-5
4-6
4-7
4,CC
5-1


5-2
5-3
5-4
5,CC
6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
0 cm
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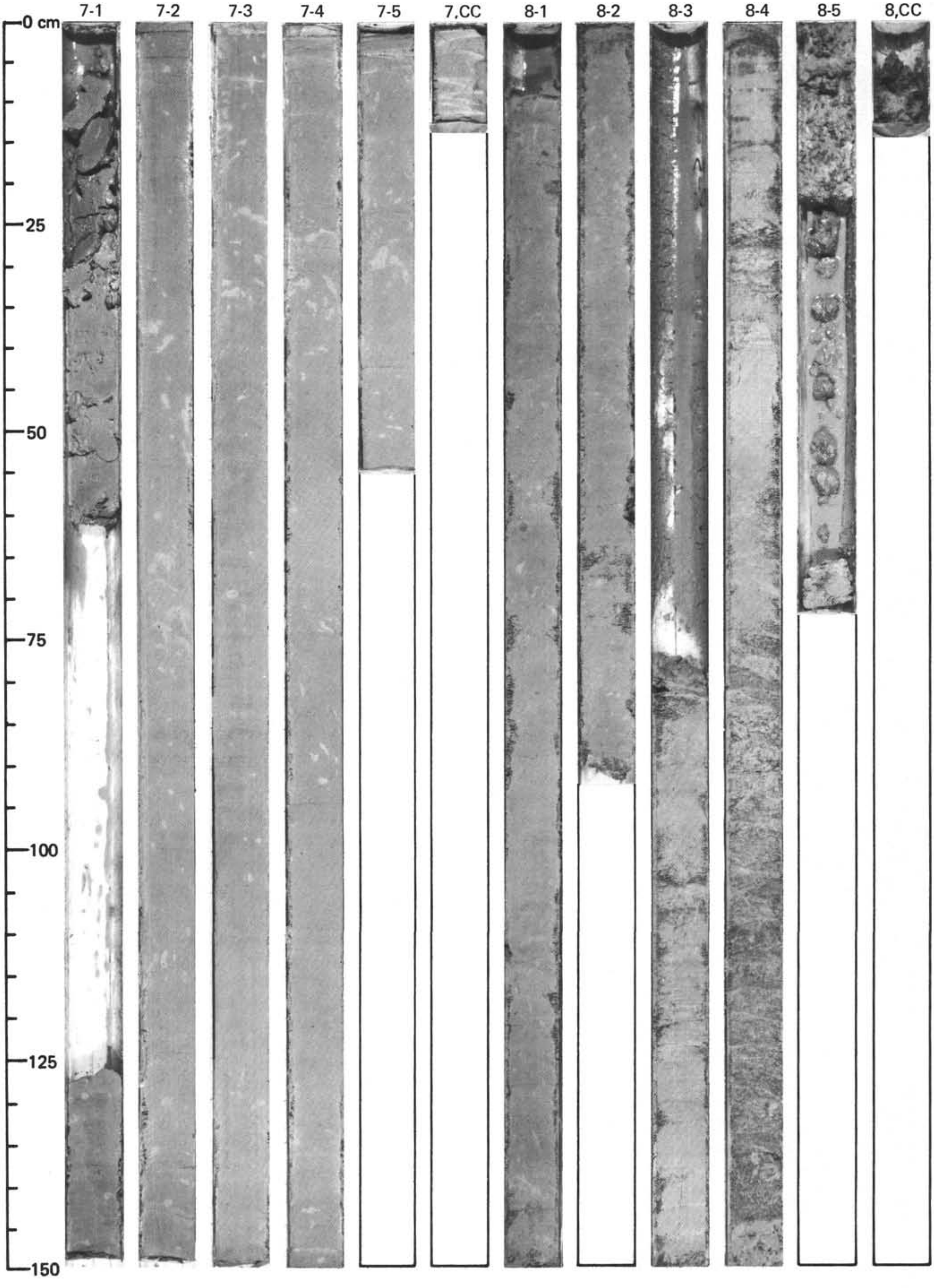
7-1
7-2
7-3
7-4
7-5
7,CC
8-1
8-2
8-3
8-4
8-5
8,CC
0 cm
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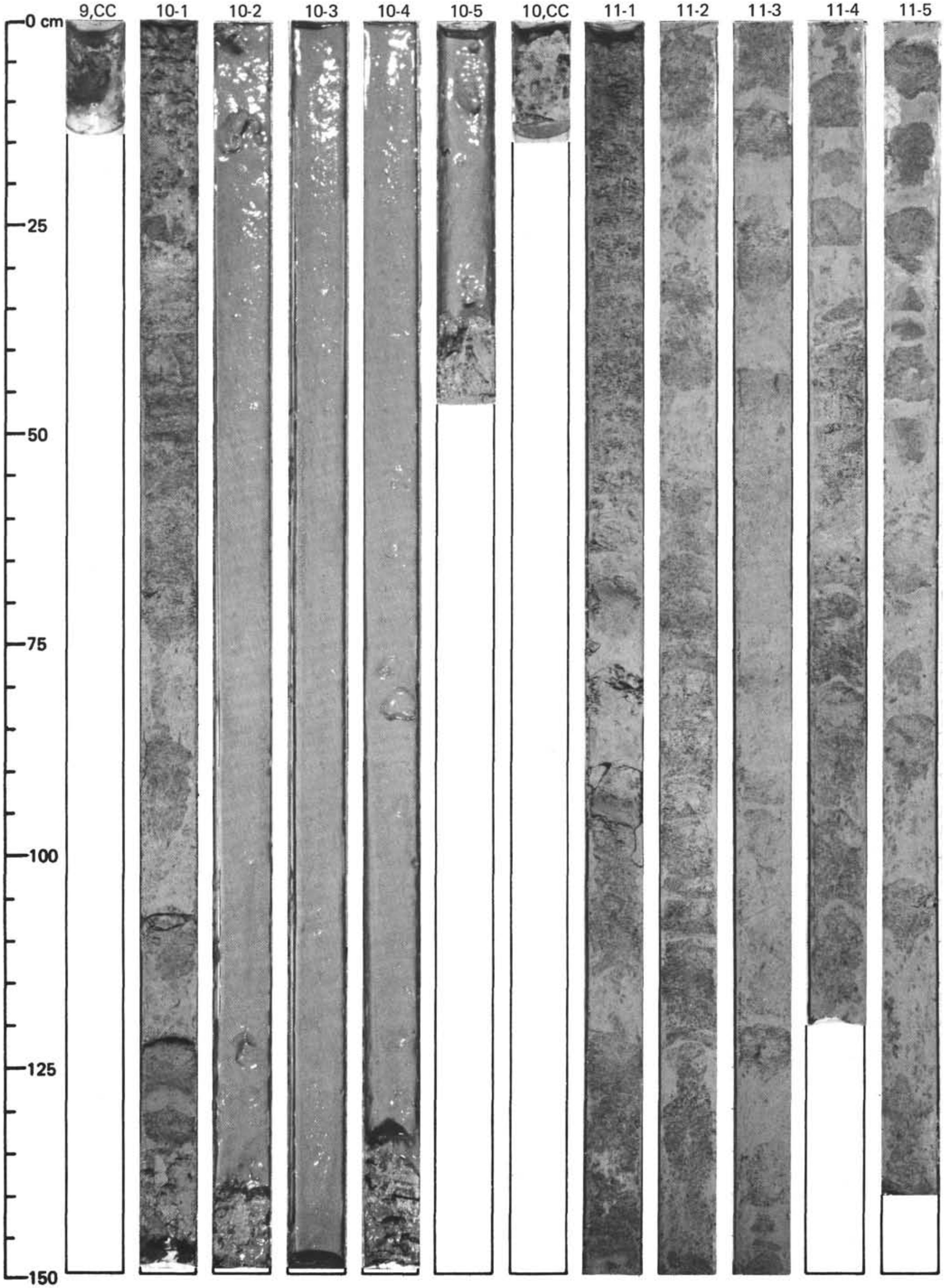
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125
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9,CC
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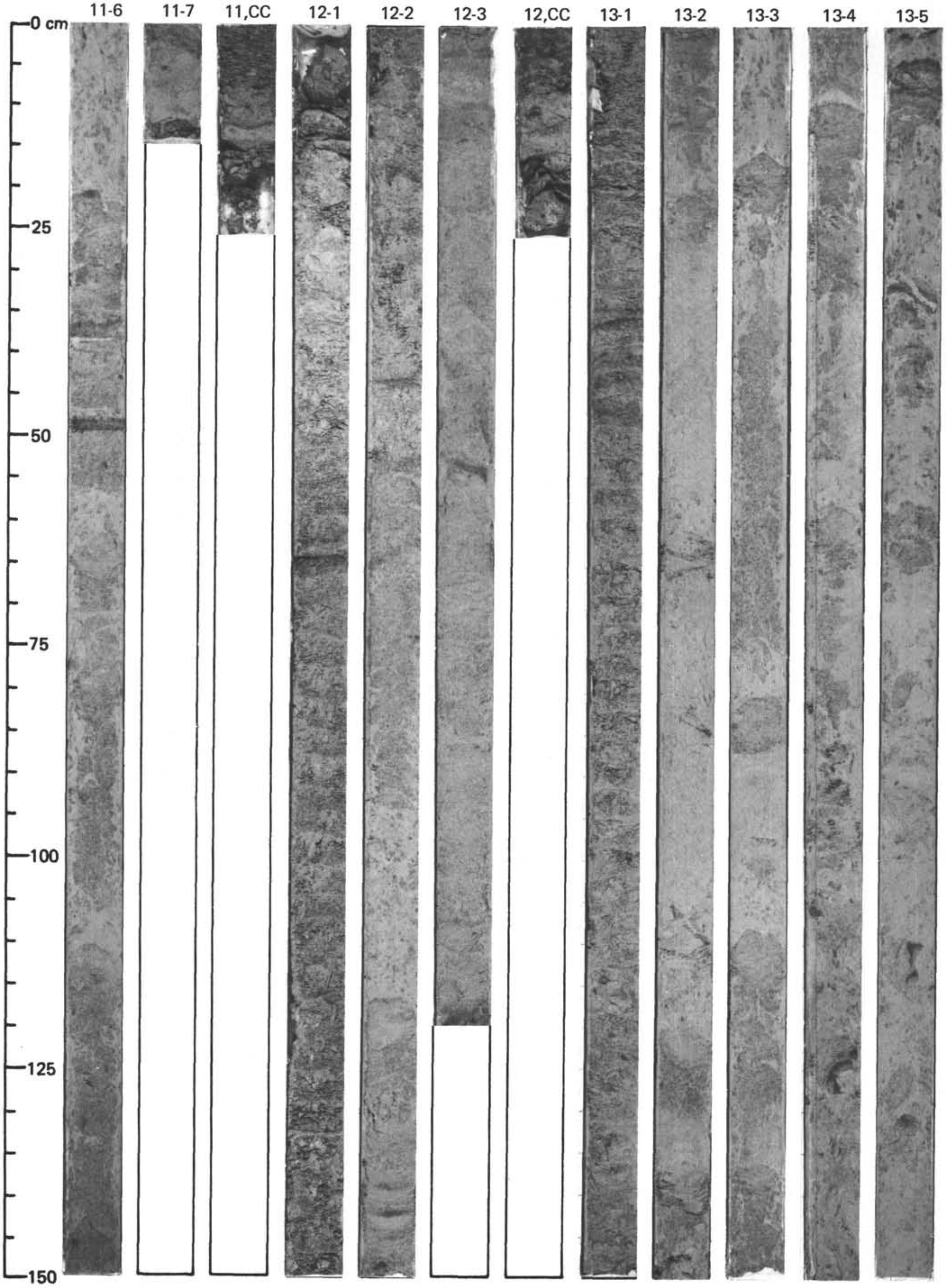
10-4
10-5
10,CC
11-1
11-2
11-3
11-4
11-5


11-6
11-7
11,CC
12-1
12-2
12-3
12,CC
13-1
13-2
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13-4
13-5
0 cm
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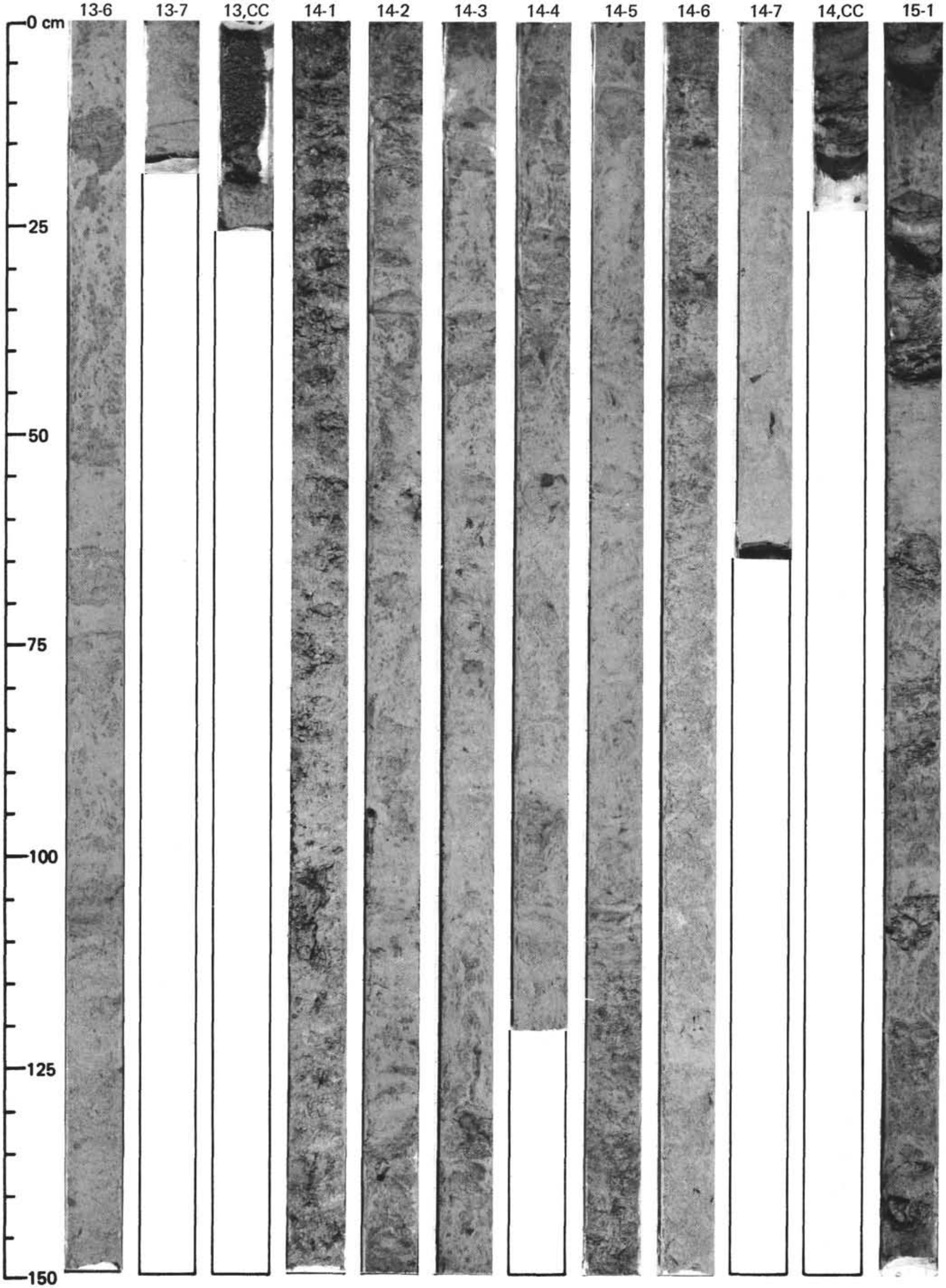

0 cm
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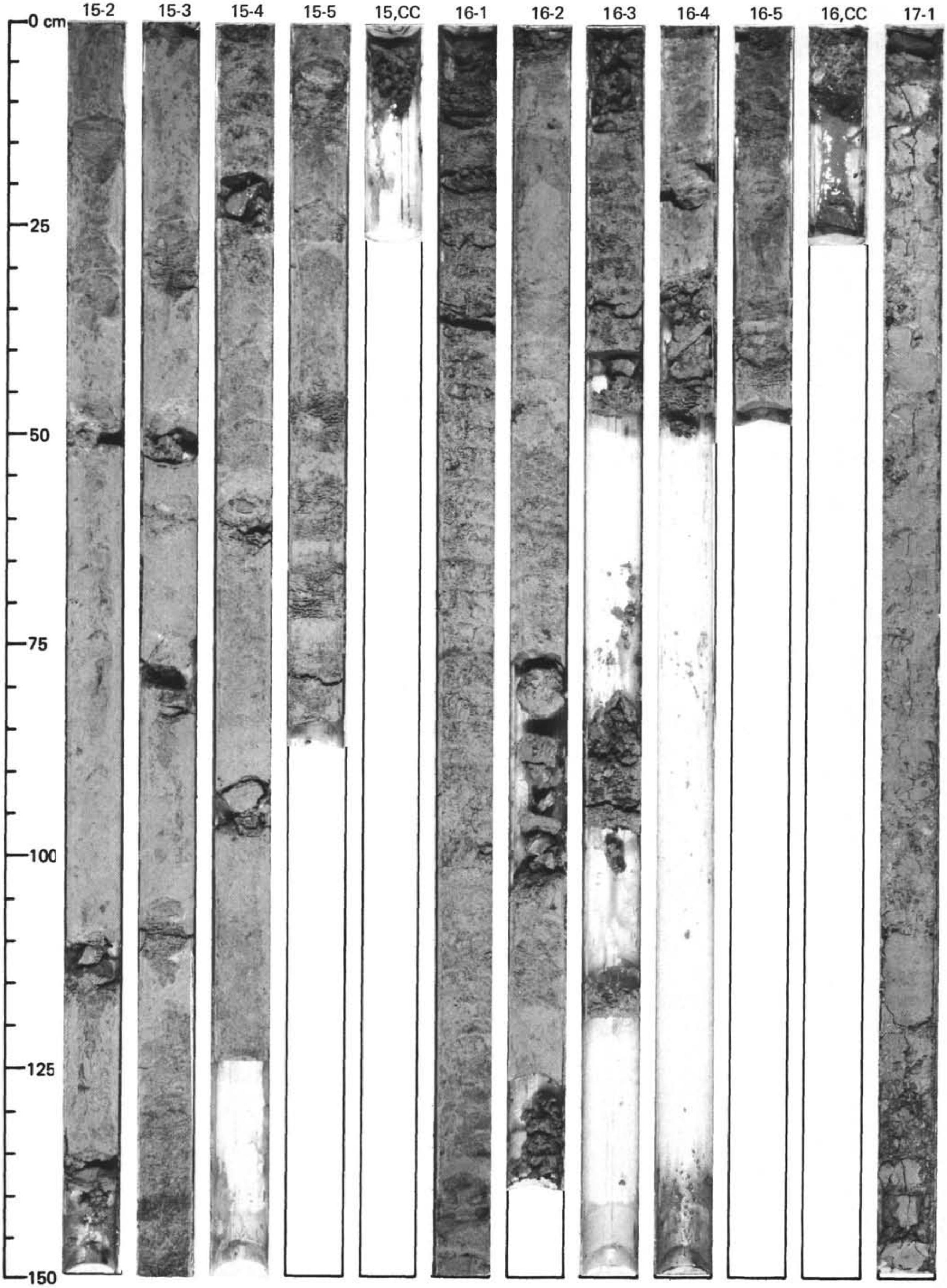
14-5
14-6
14-7
14,CC
15-1



15-2
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15-5
15,CC
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16-3
16-4
16-5
16,CC
17-1
0 cm
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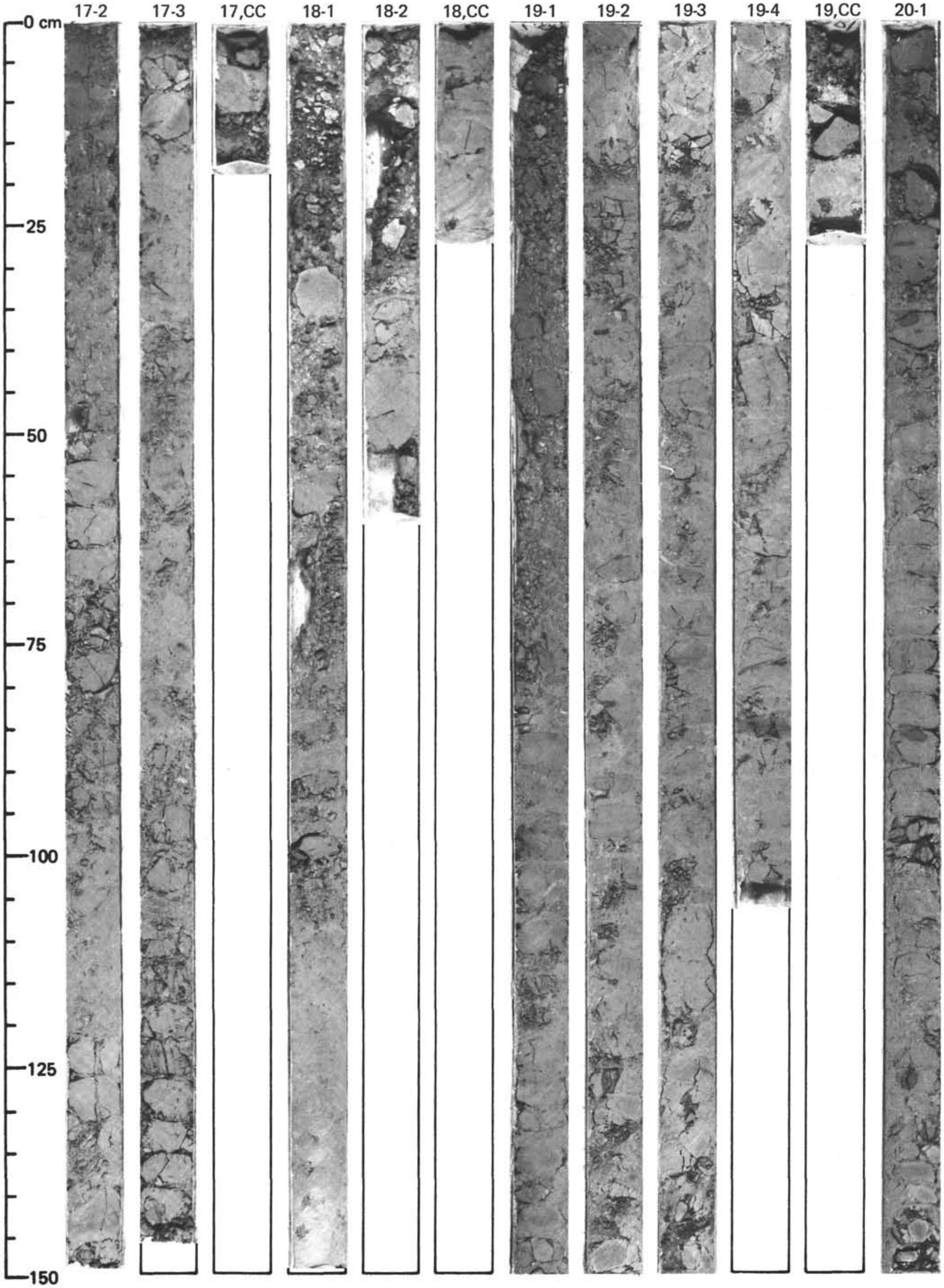
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17,CC
18-1
18-2
18,CC
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19-2
19-3
19-4
19,CC
20-1
0 cm
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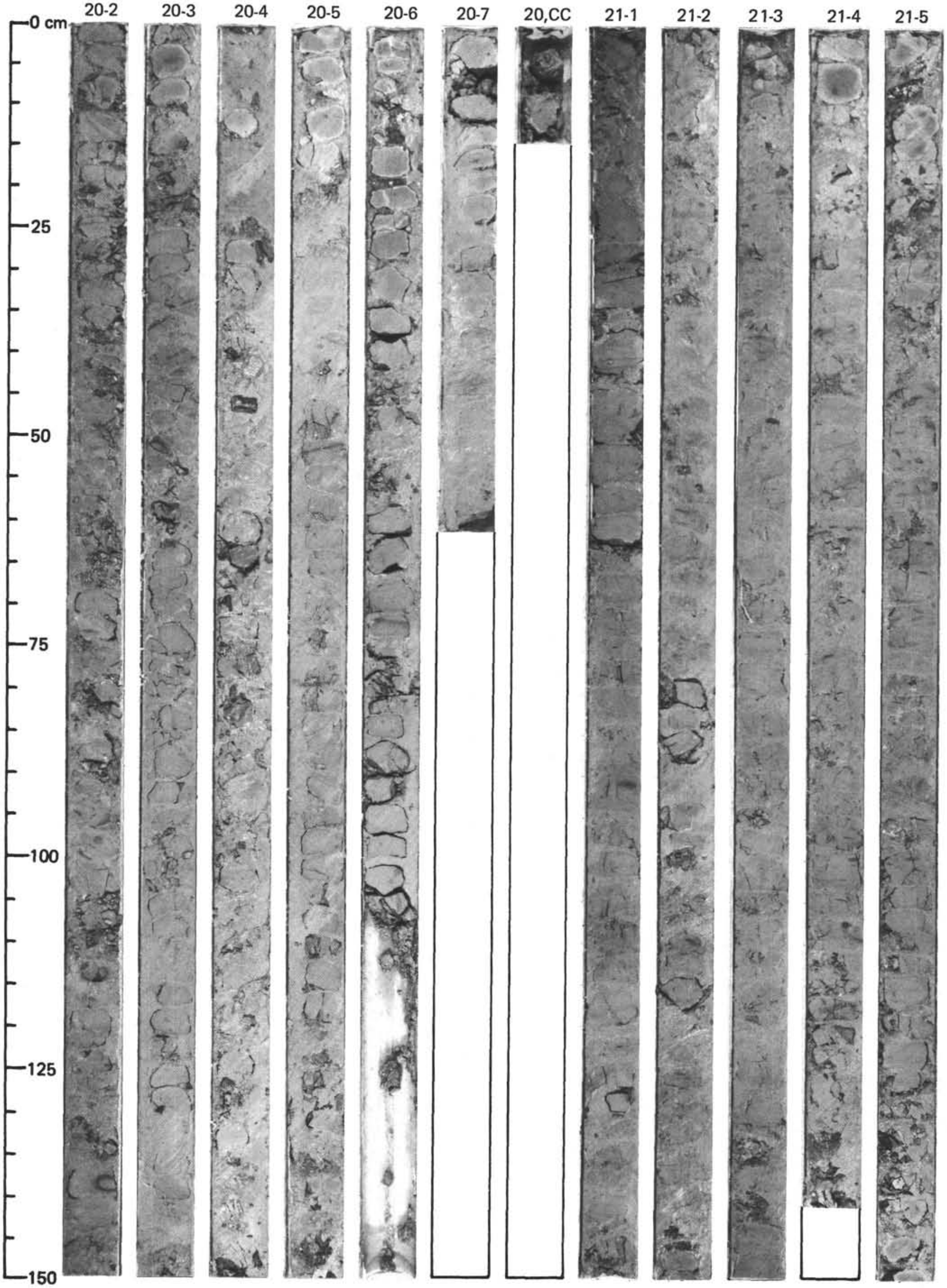

20-2
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21-1
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0 cm
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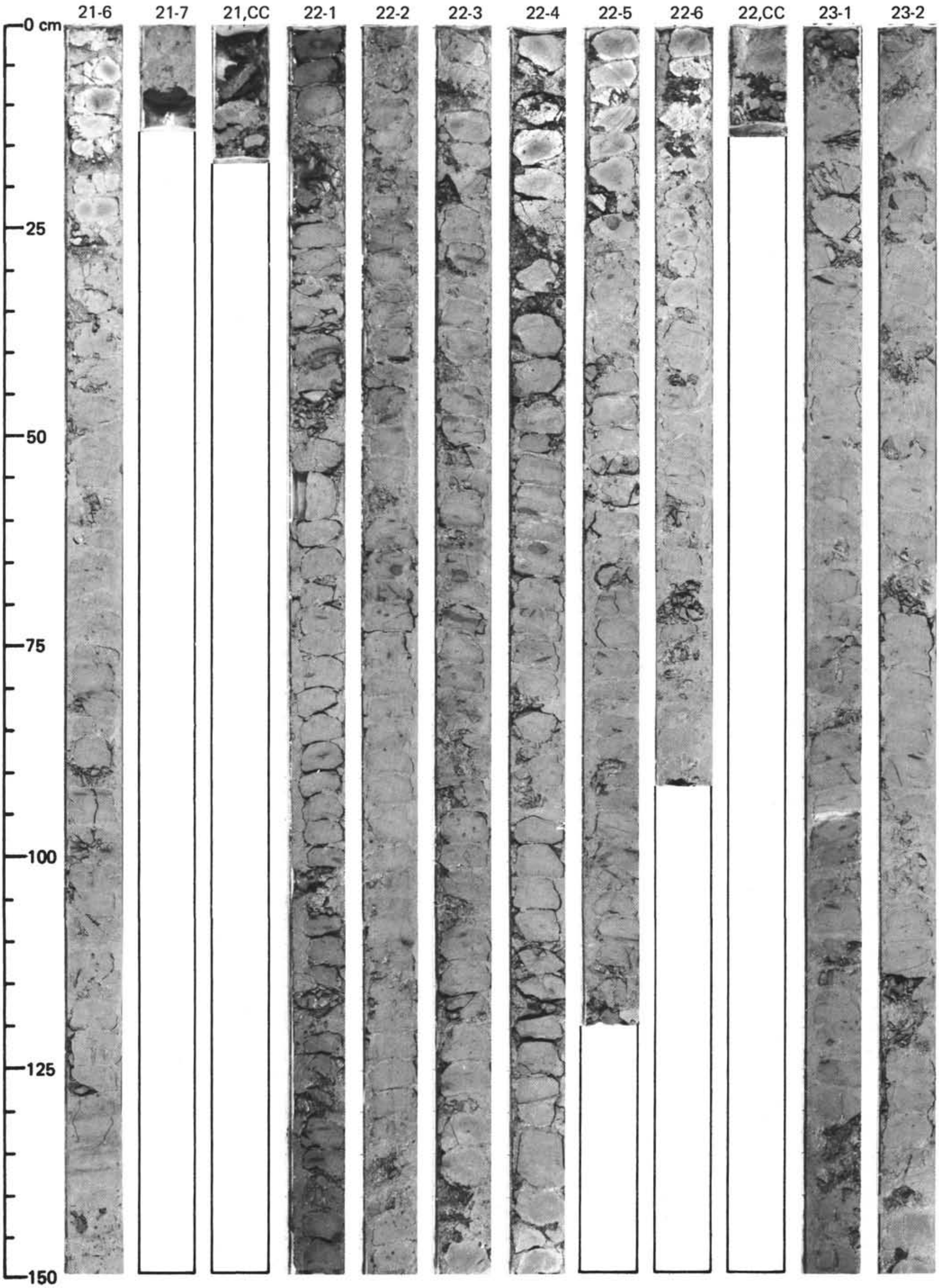
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21-7
21,CC
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0 cm
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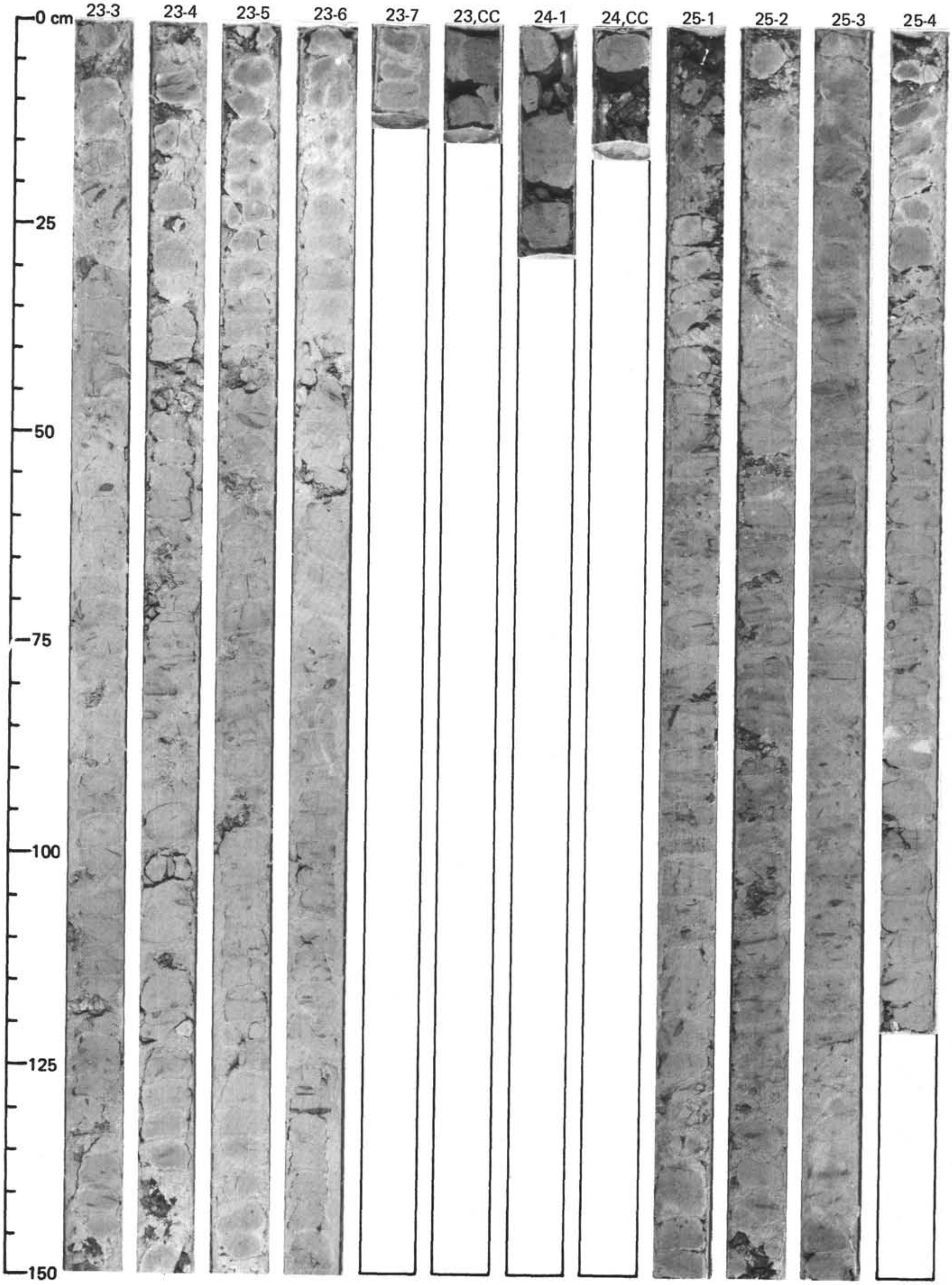
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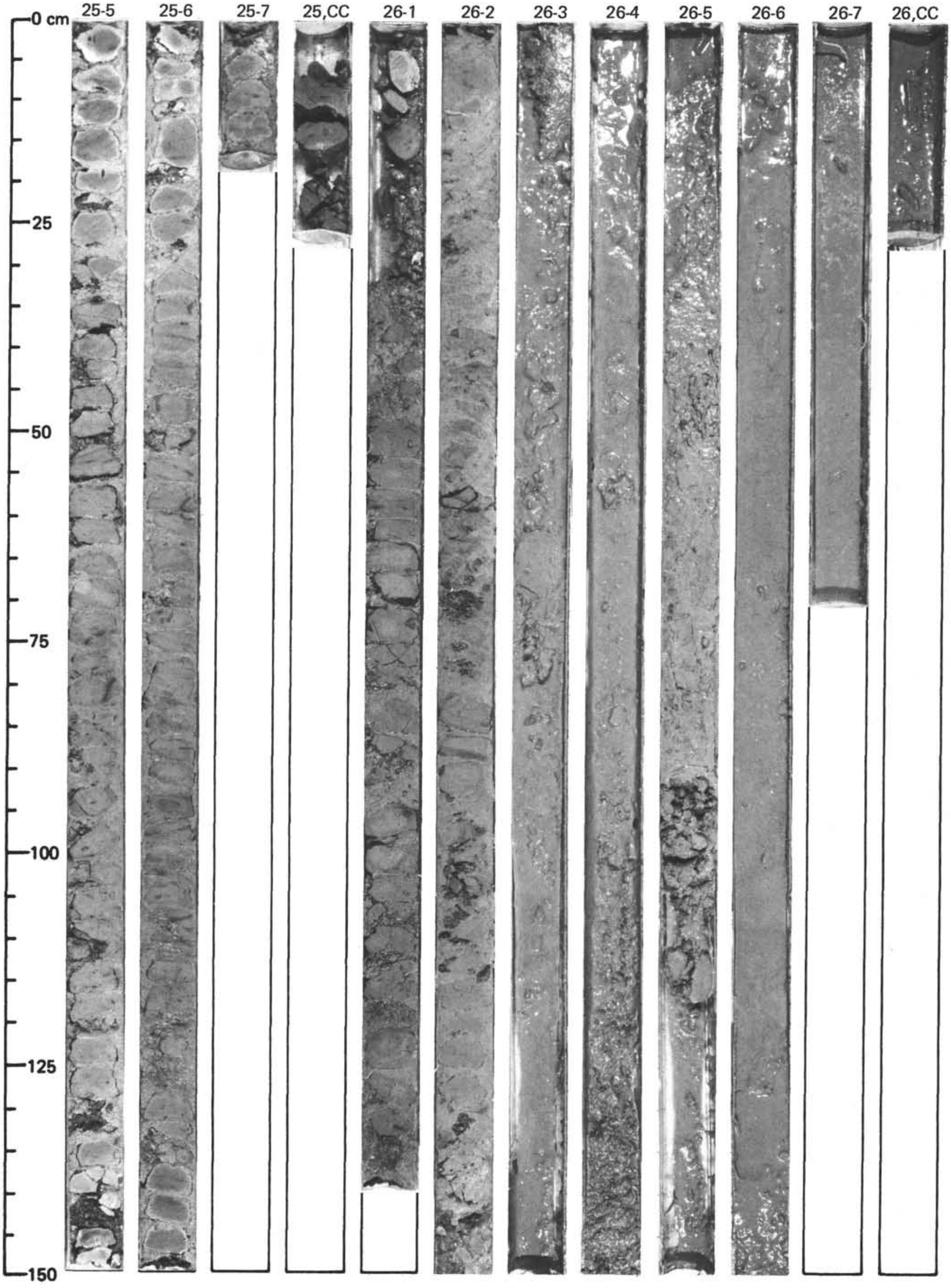
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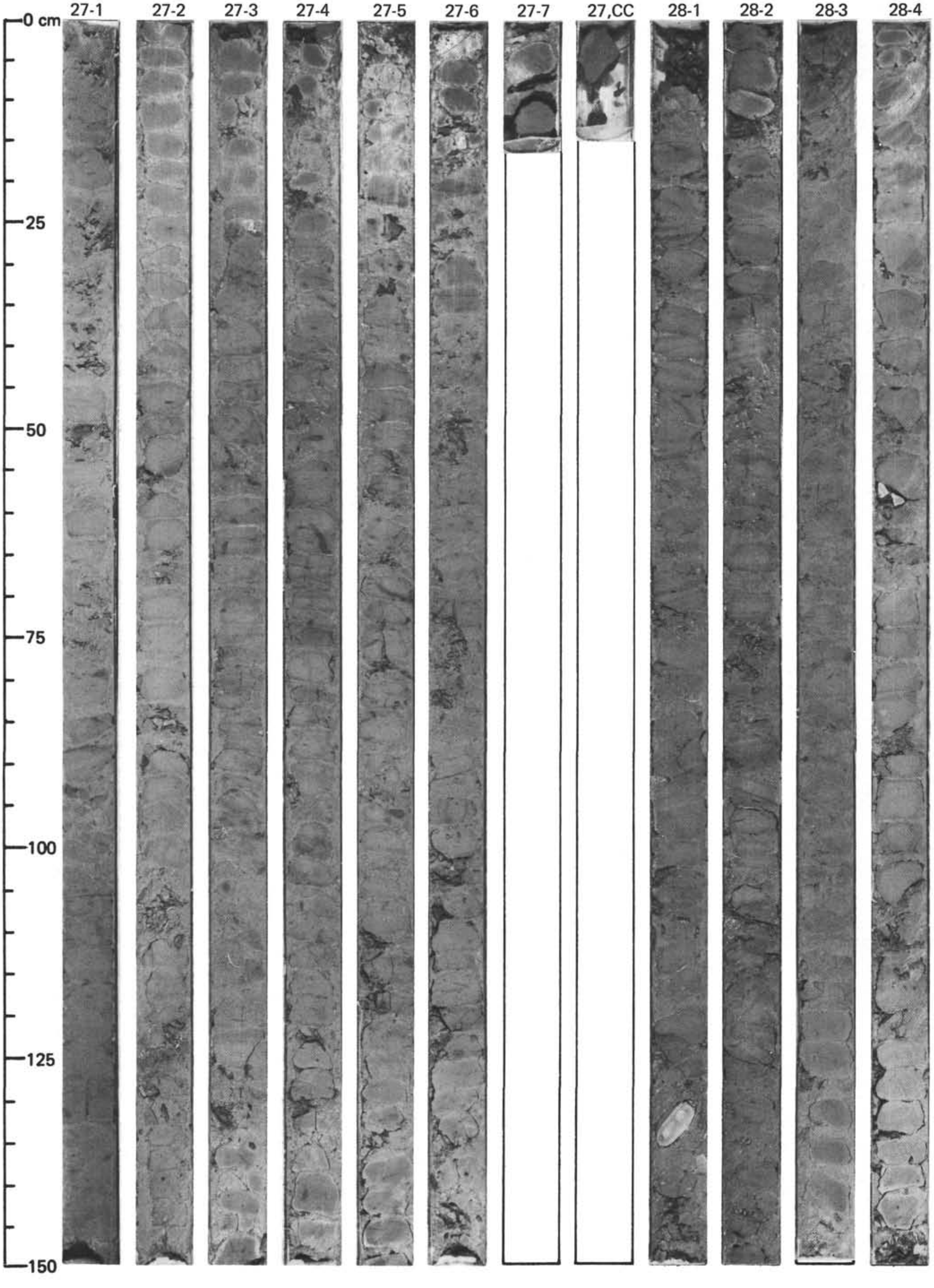
26-6
26-7
26,CC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27,CC
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0 cm
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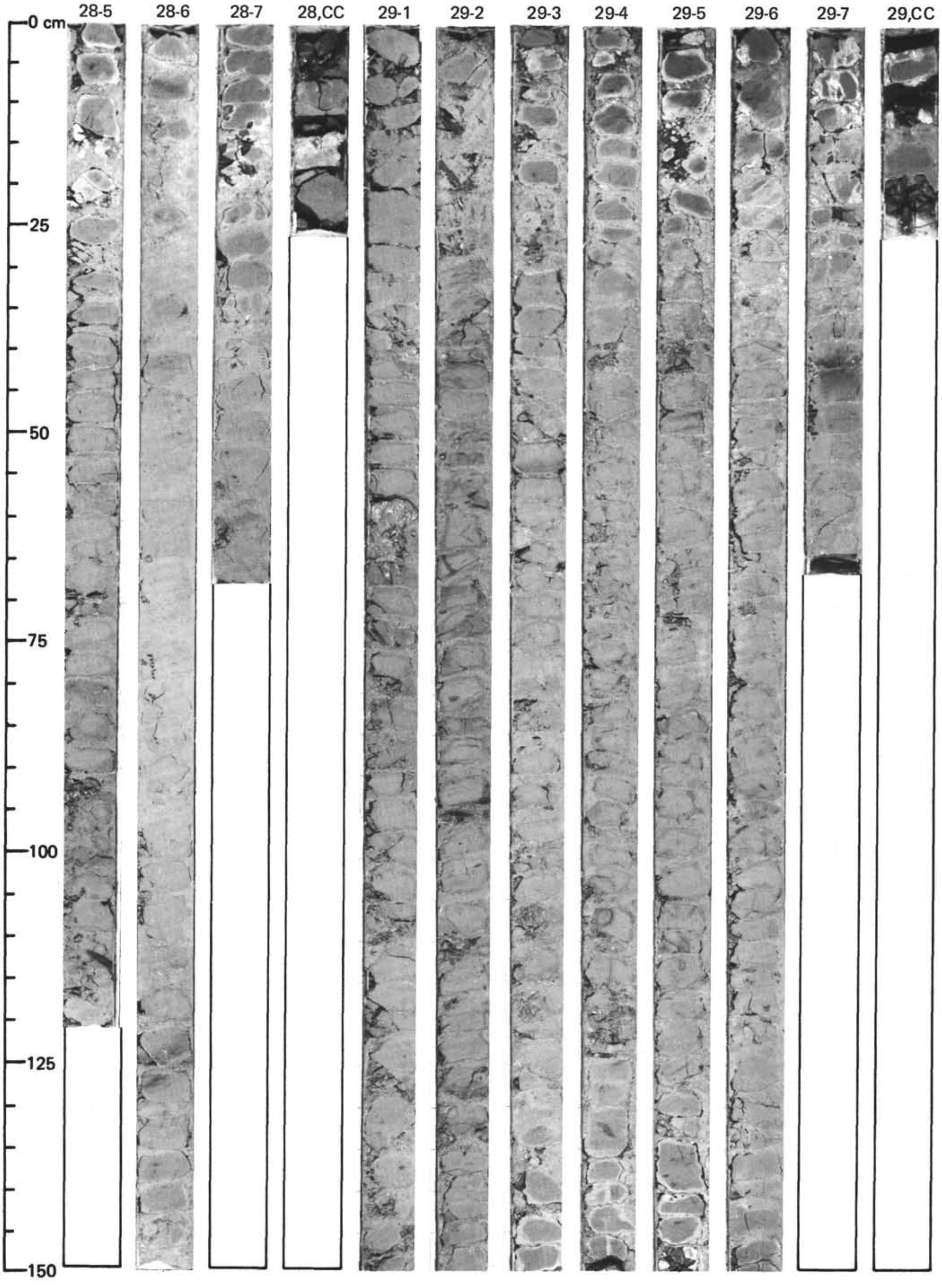
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29,CC
0 cm
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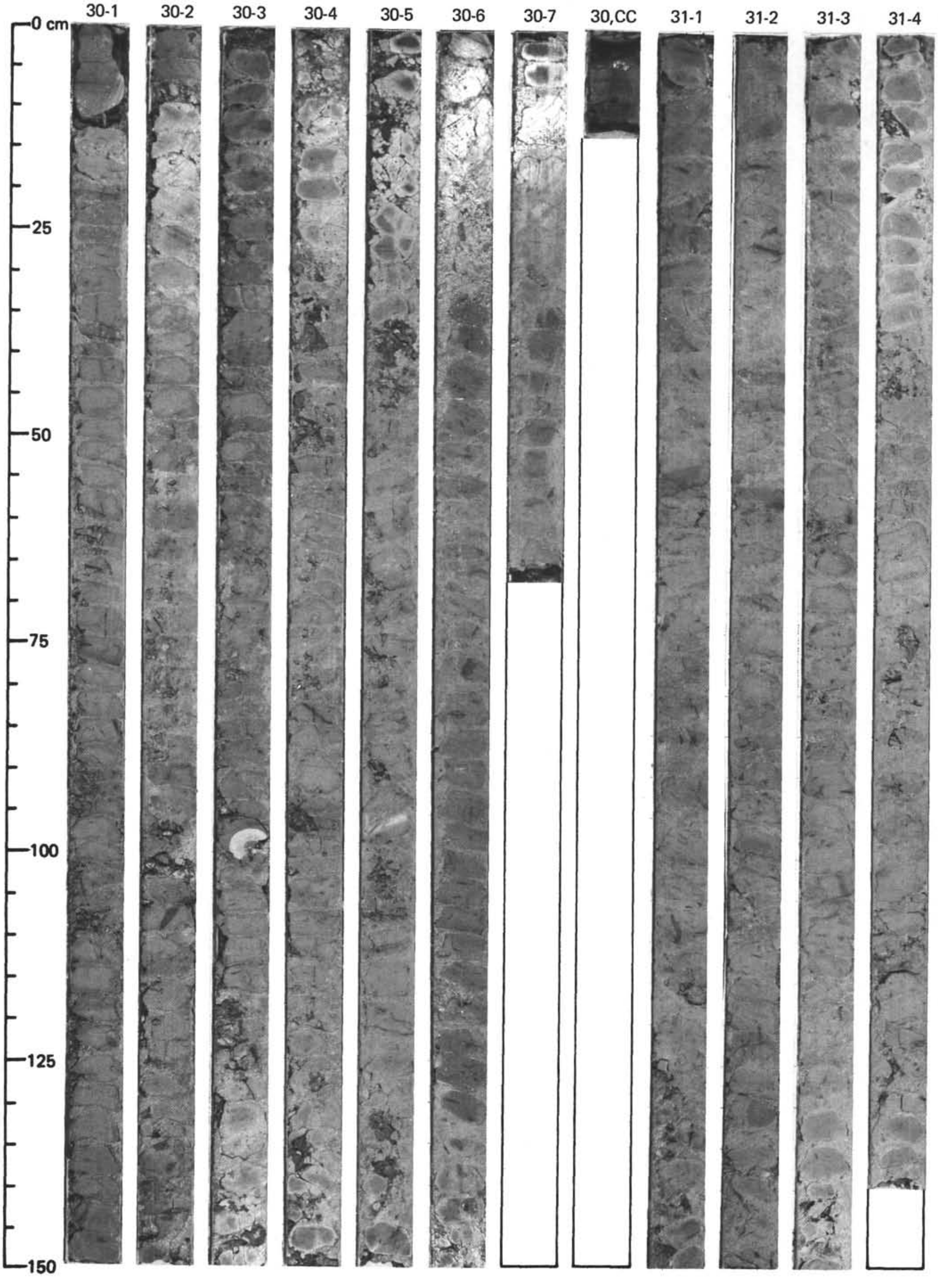
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30,CC
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0 cm
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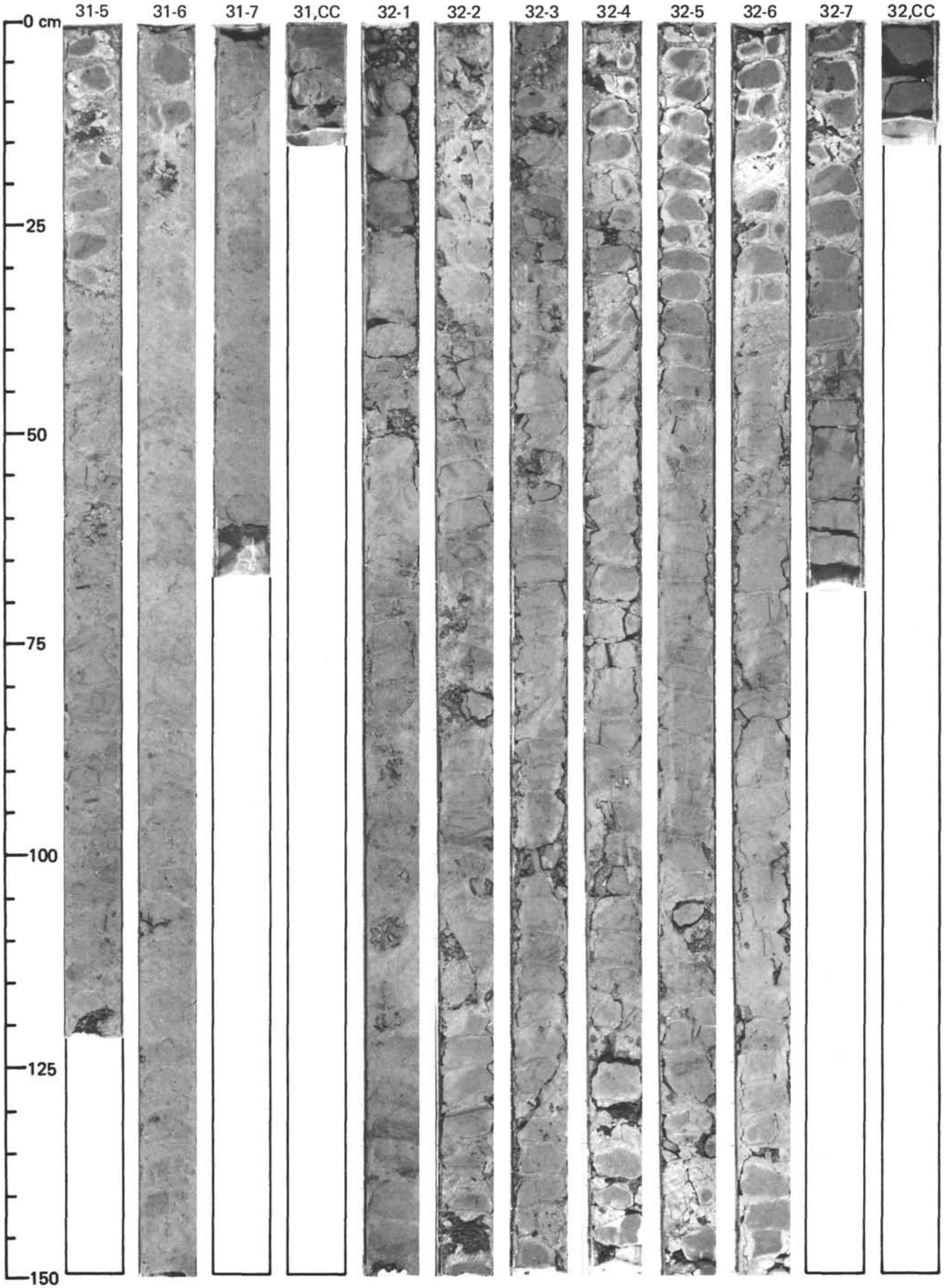
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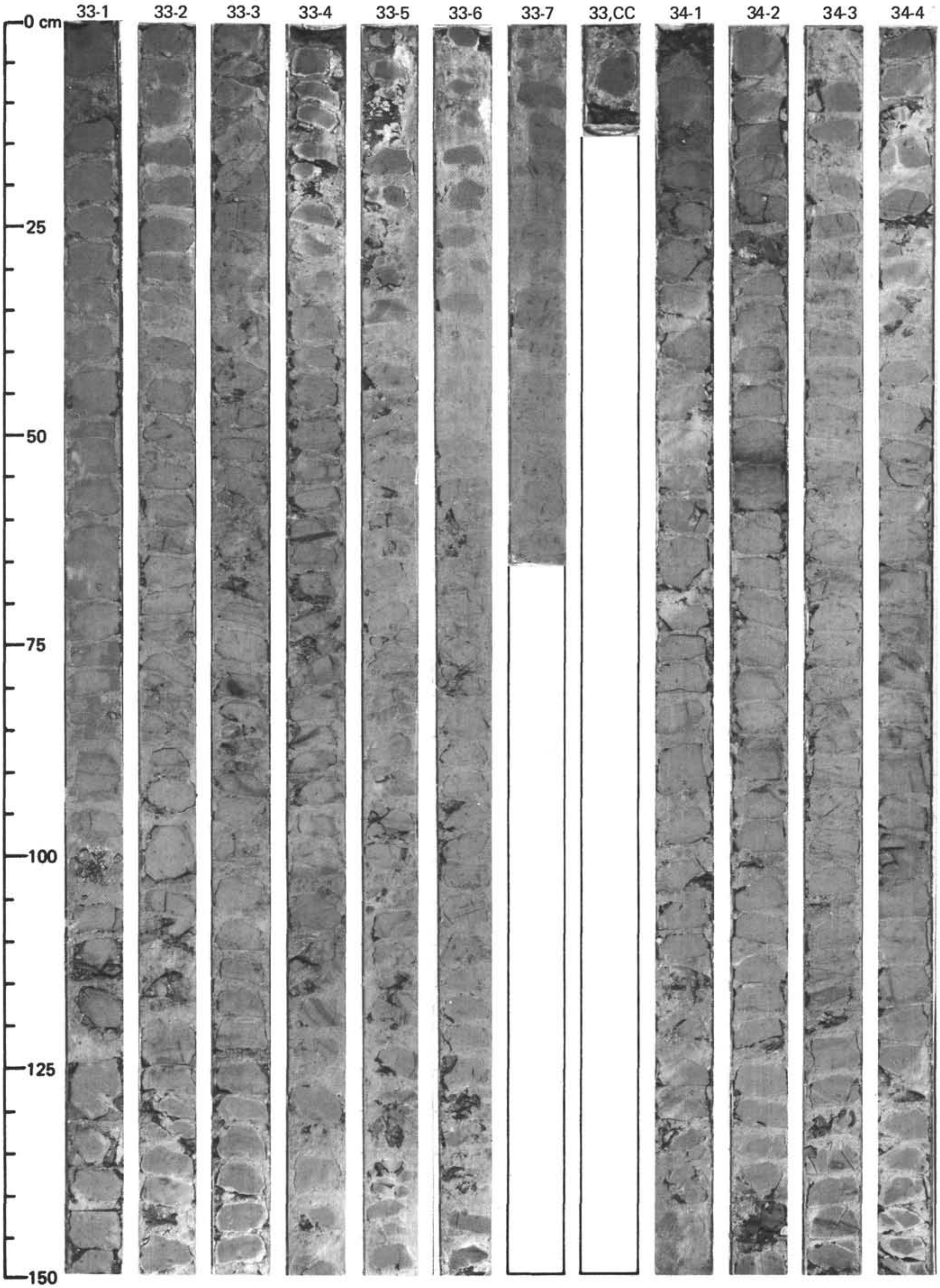
32-6
32-7
32,CC


0 cm
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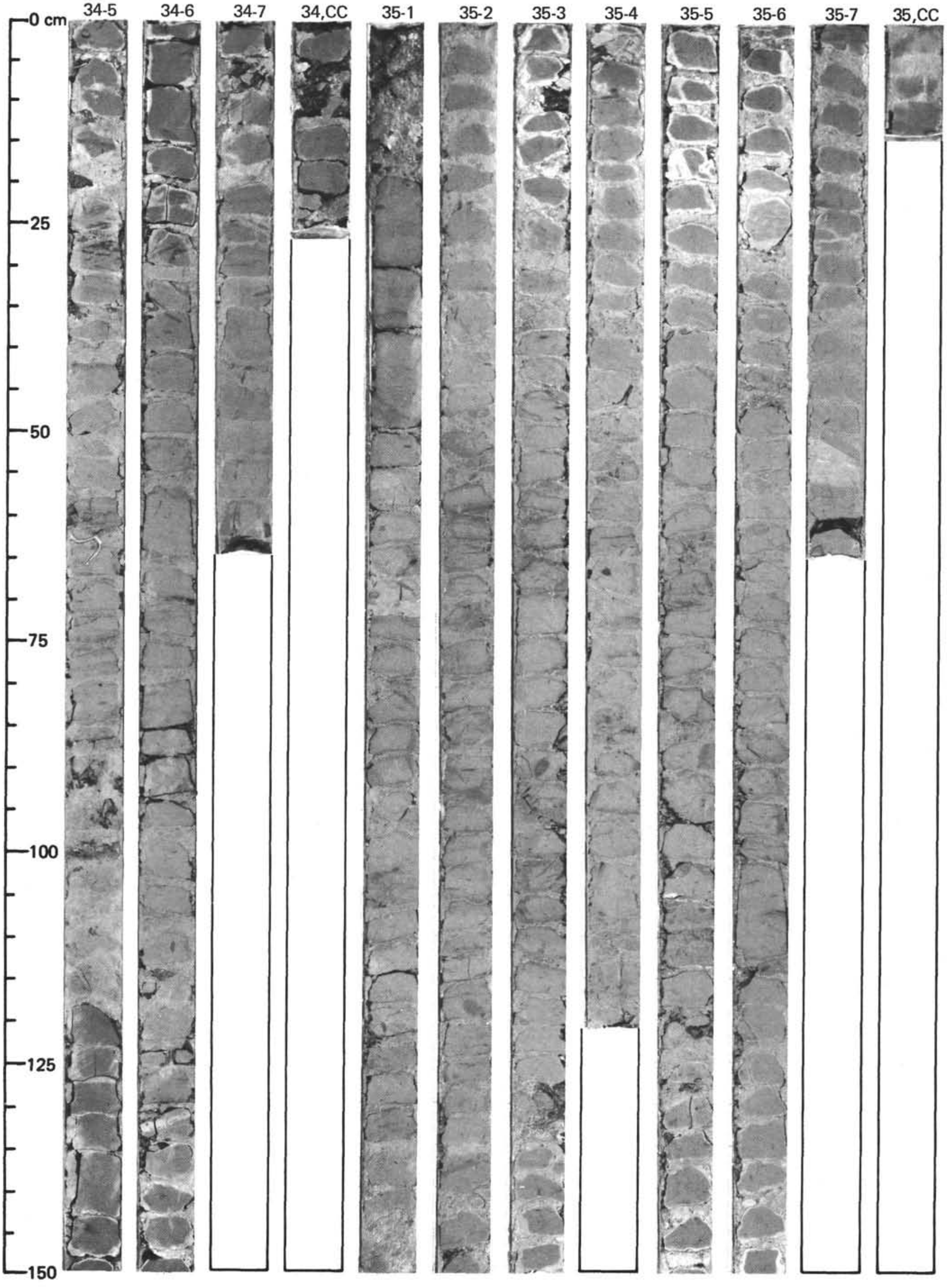
0 cm
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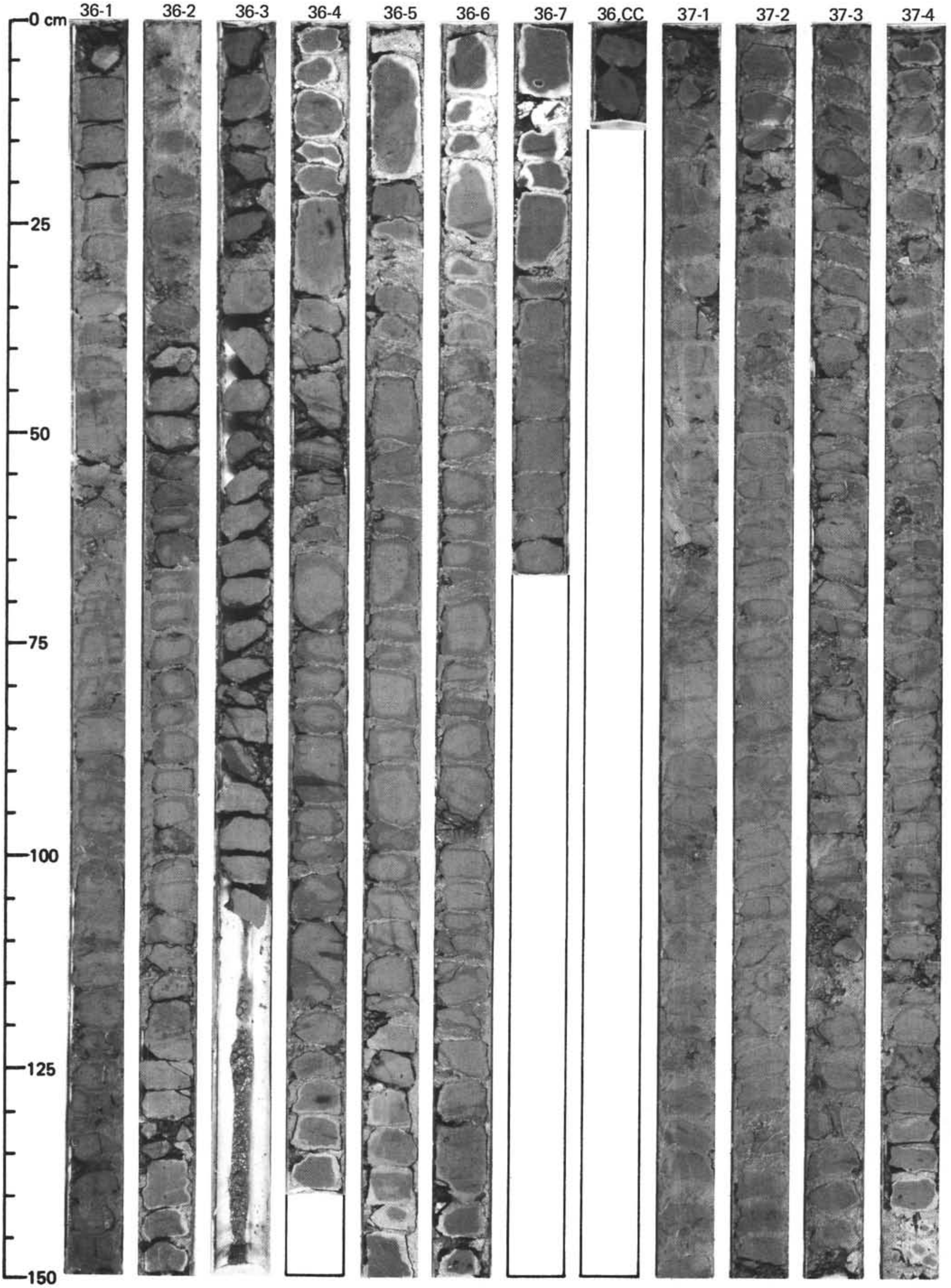
35,CC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36,CC
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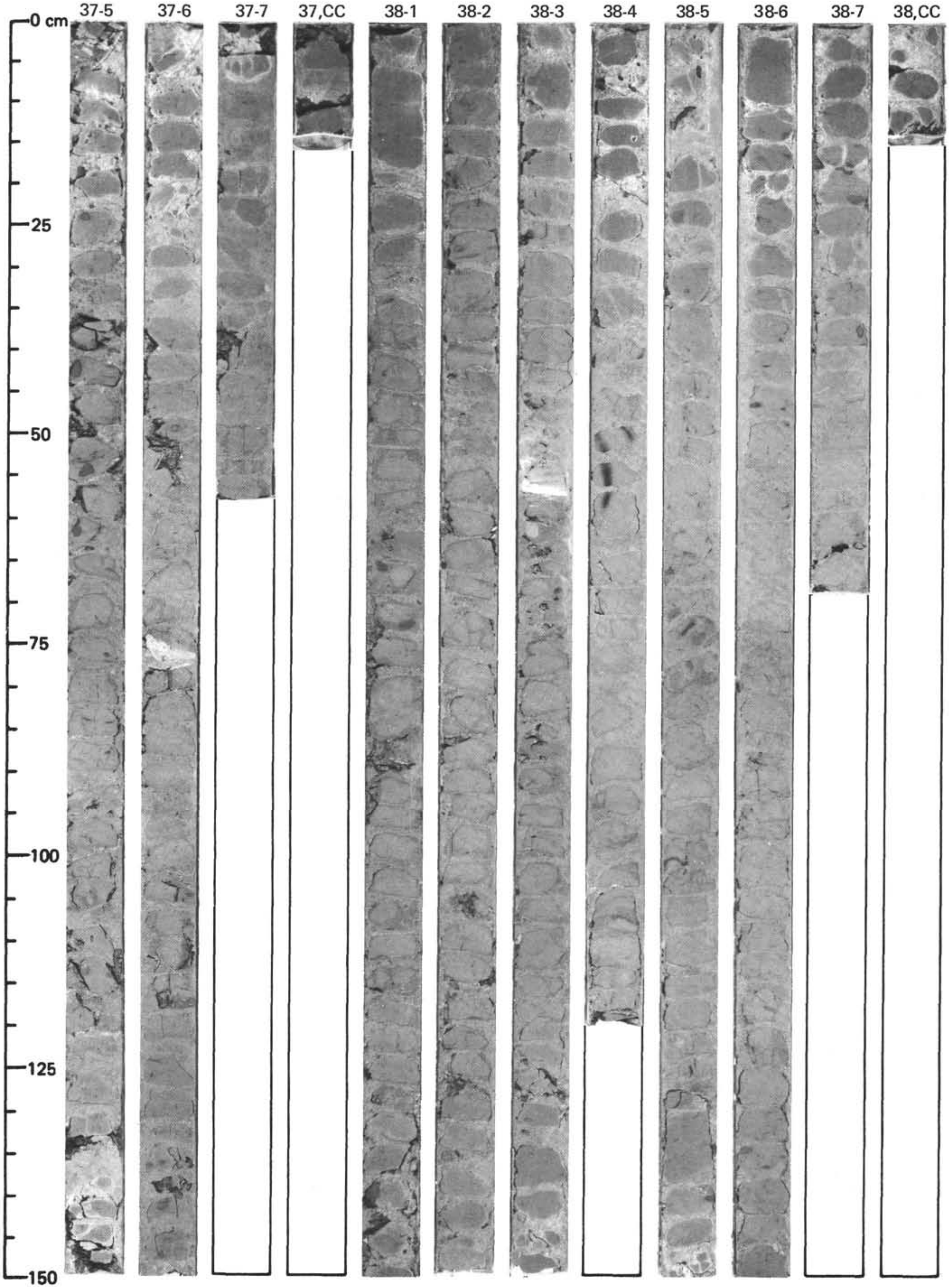
37-2
37-3
37-4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37-6
37-7
37,CC
38-1
38-2
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38-4
38-5
38-6
38-7
38,CC
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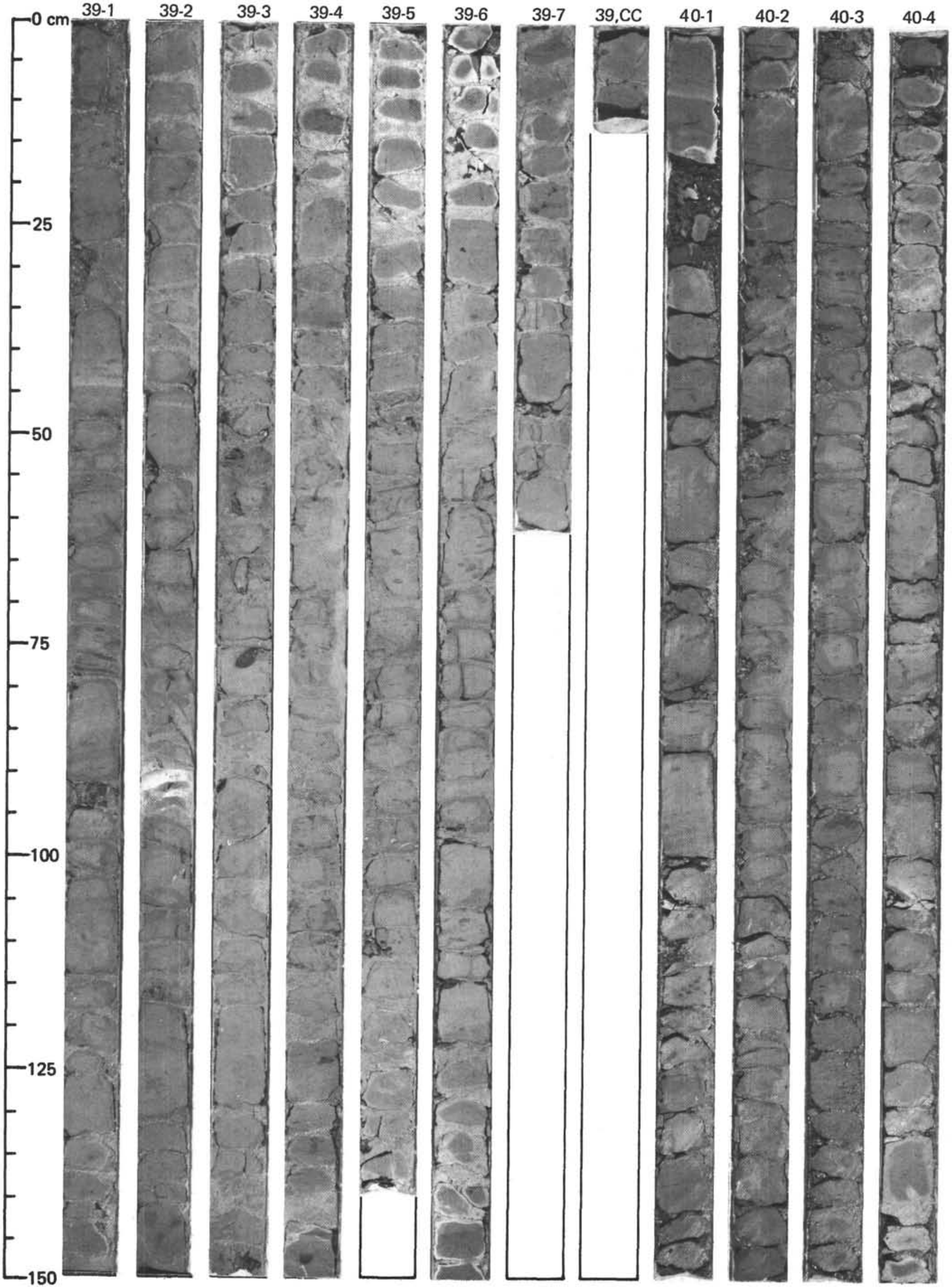
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39-6
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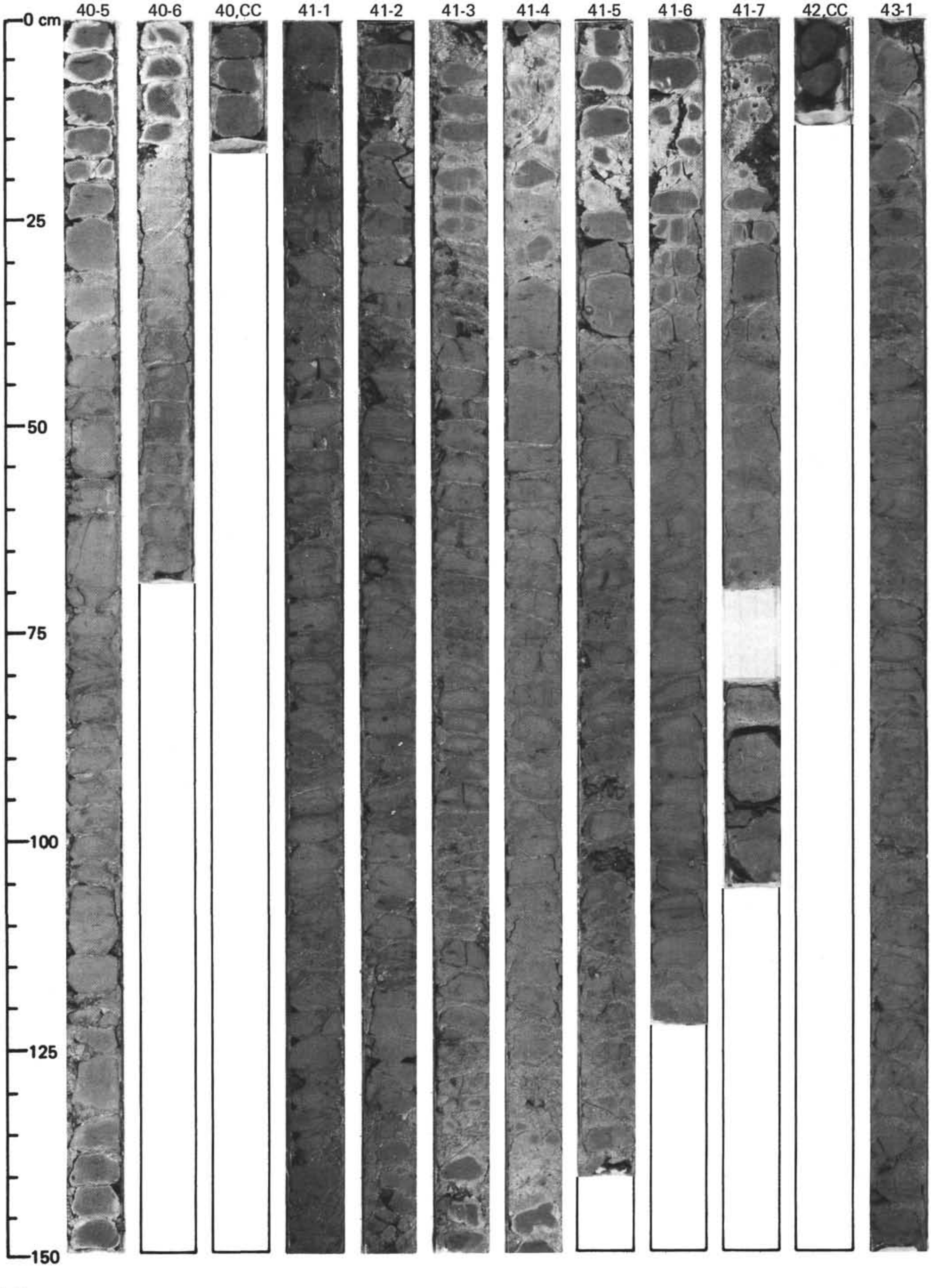
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41-7
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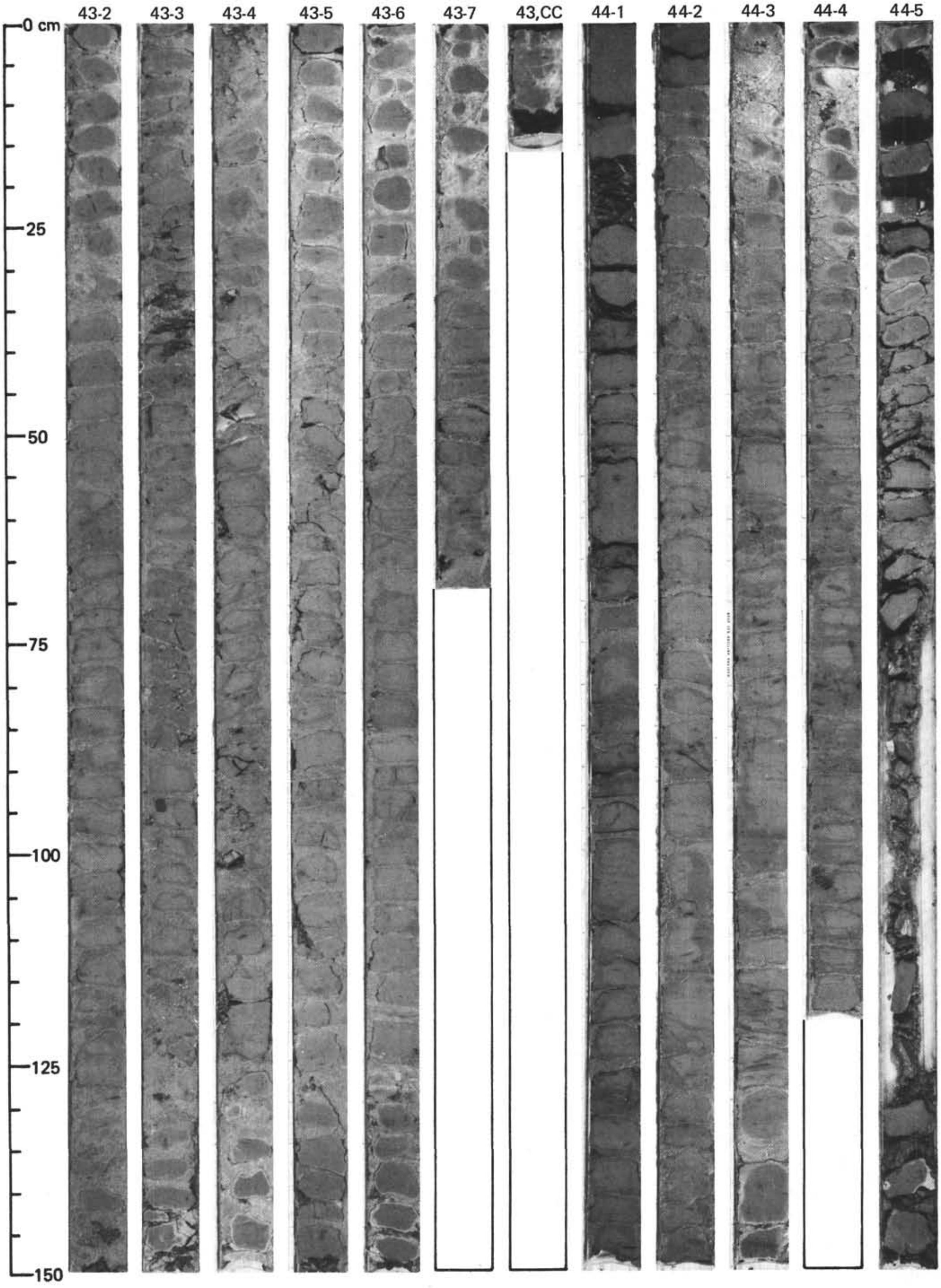
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43-5
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44-5
0 cm
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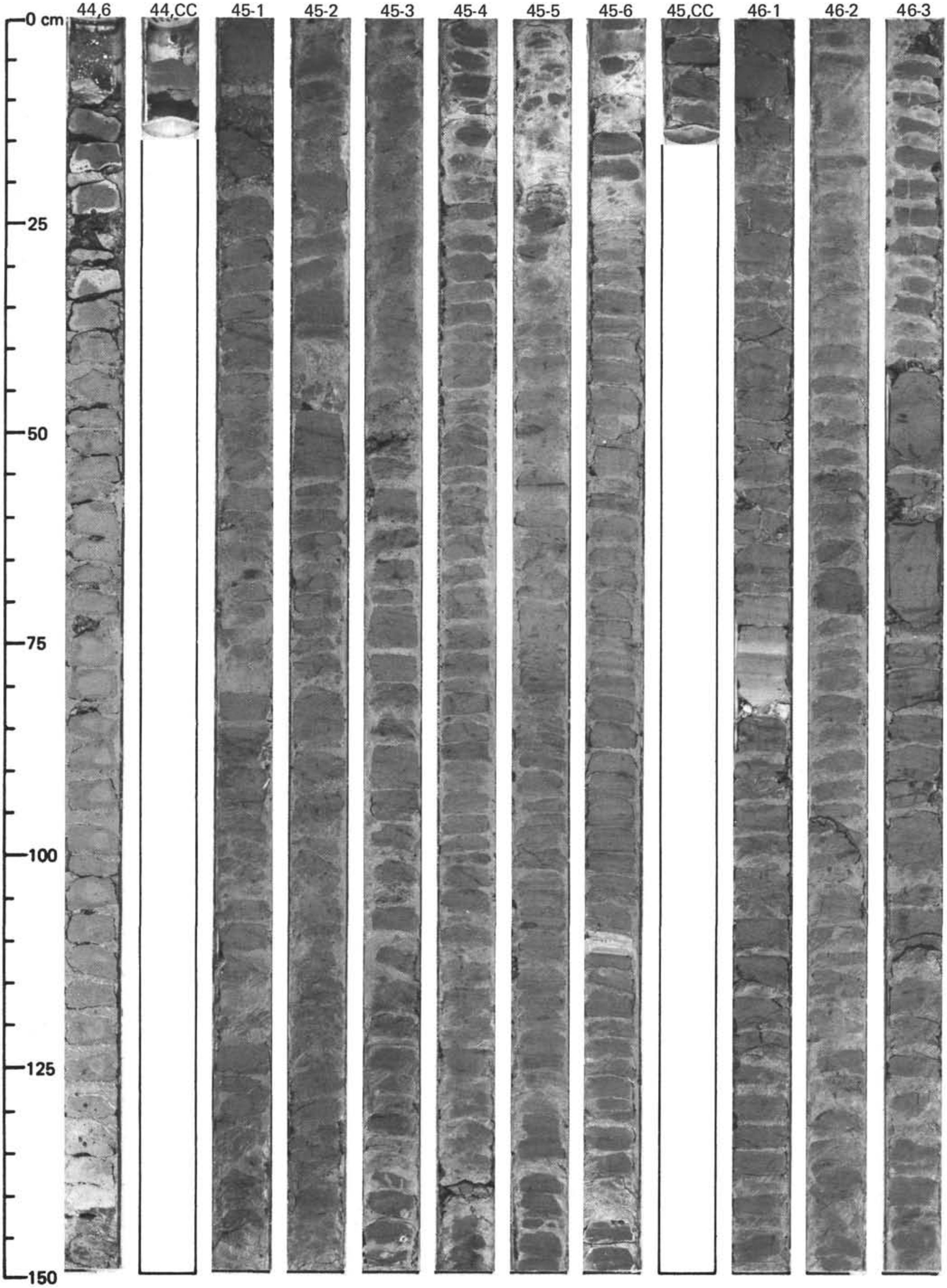
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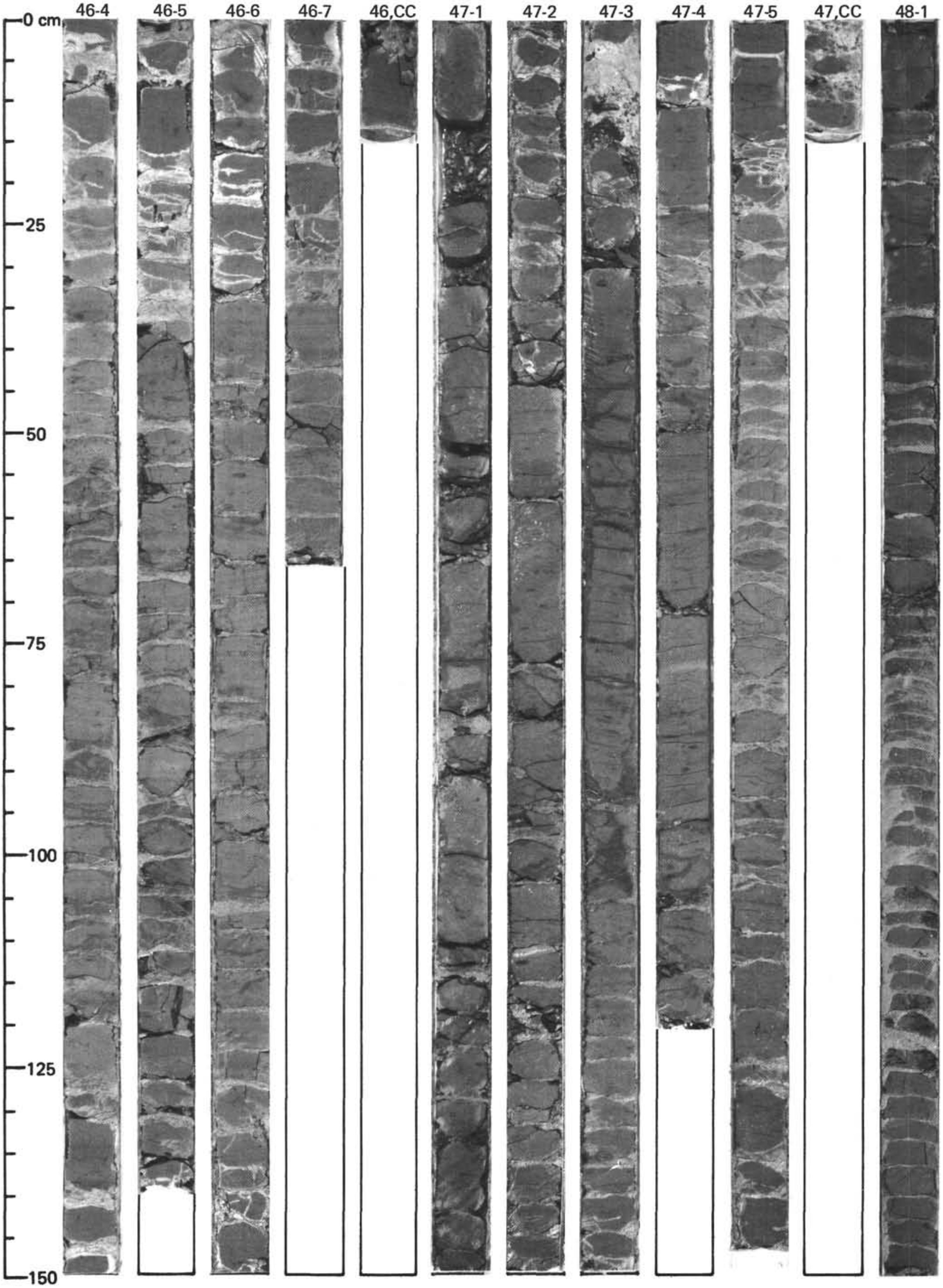
45-6
45,CC
46-1
46-2
46-3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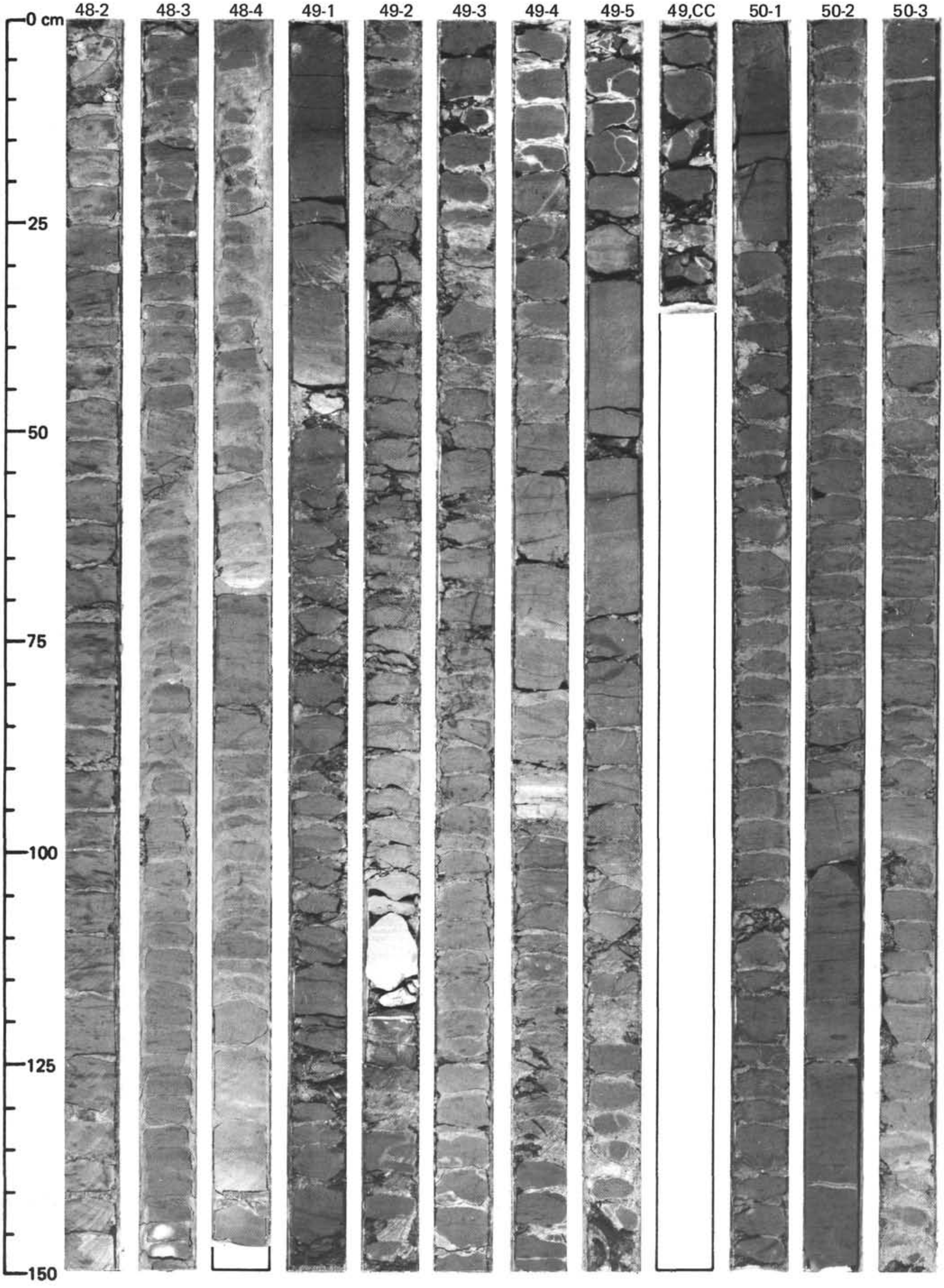
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49-1
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0 cm
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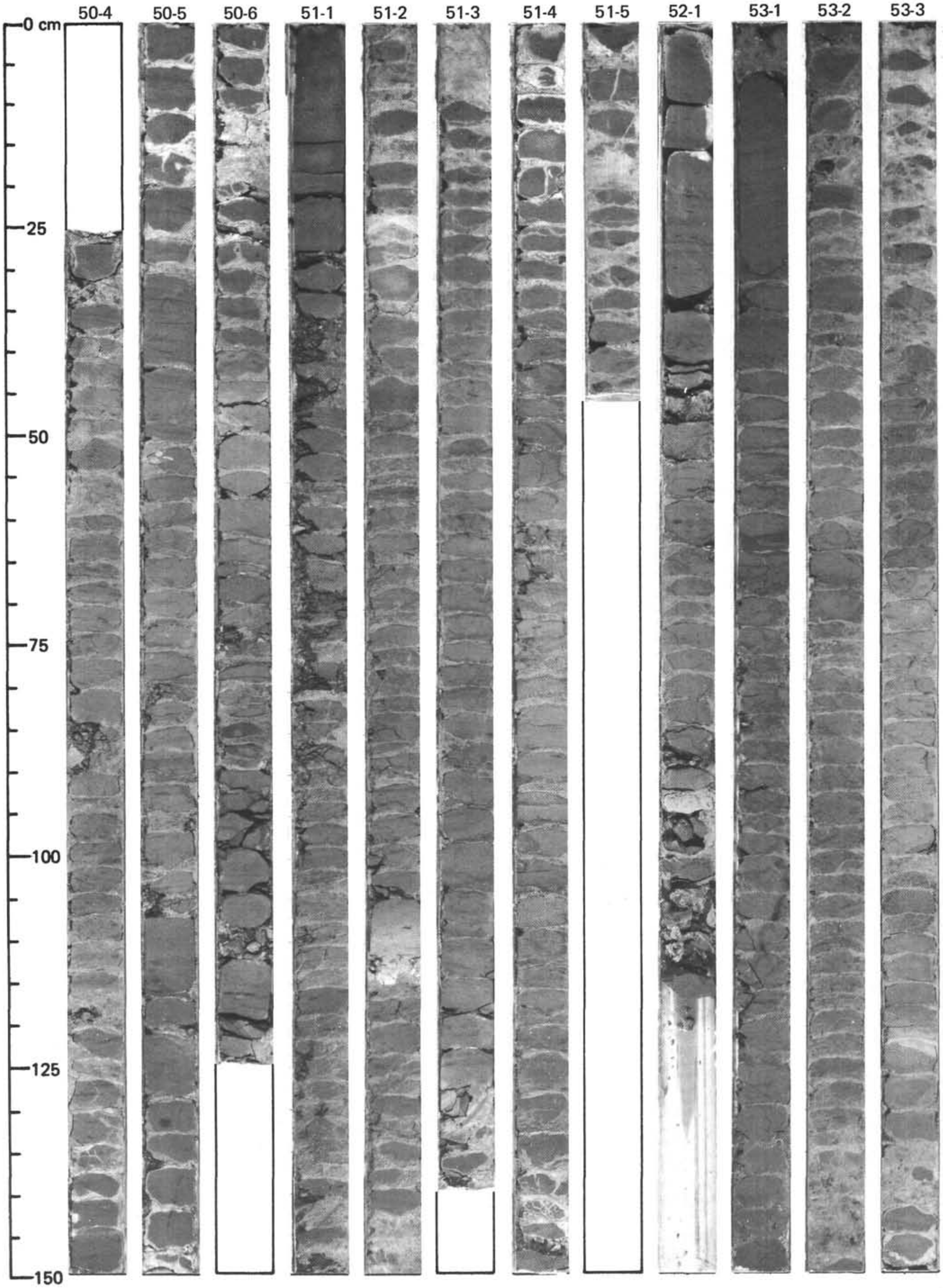

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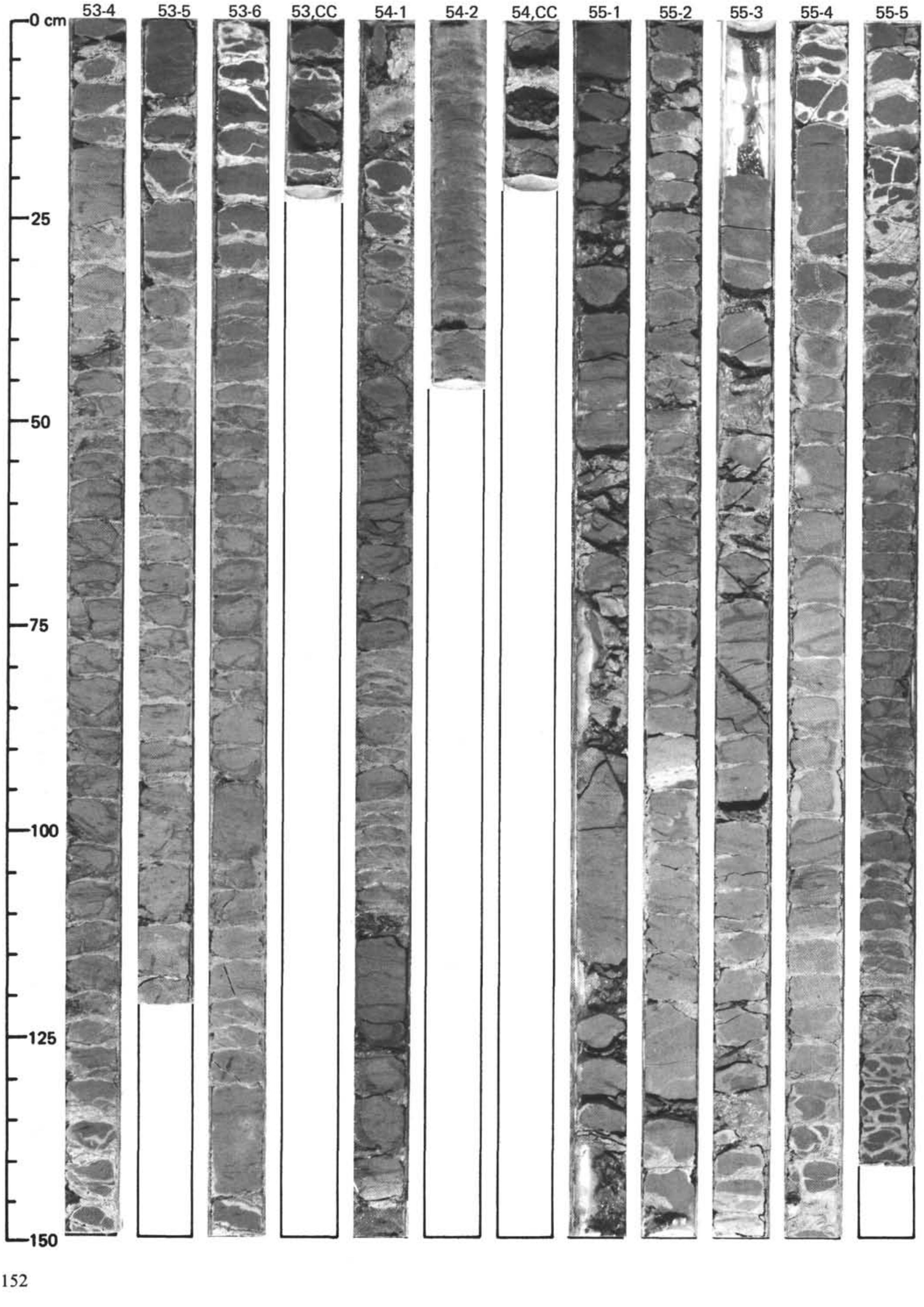
53-3


53-4
53-5
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53,CC
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54,CC
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0 cm
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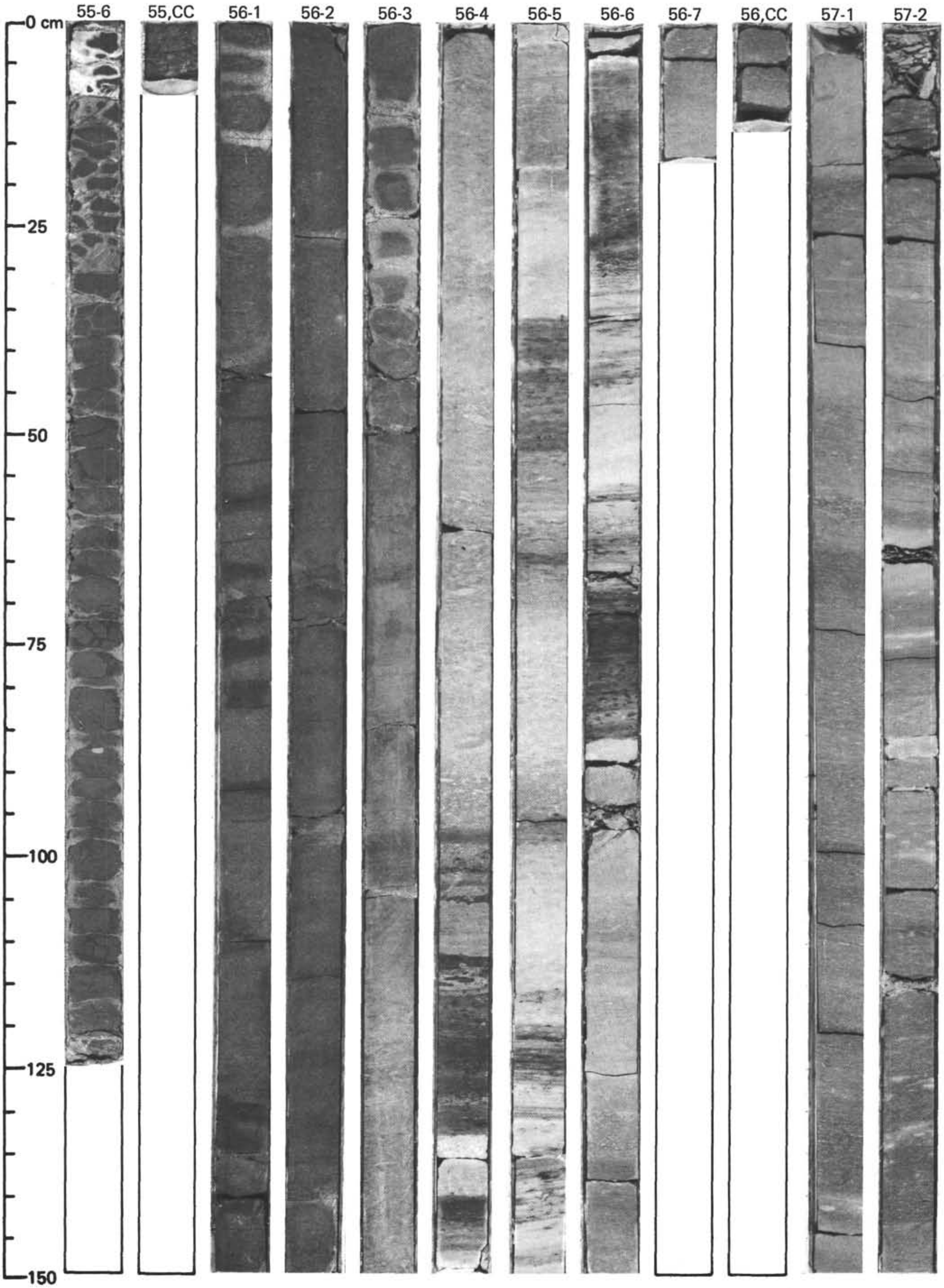
0 cm
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56-4
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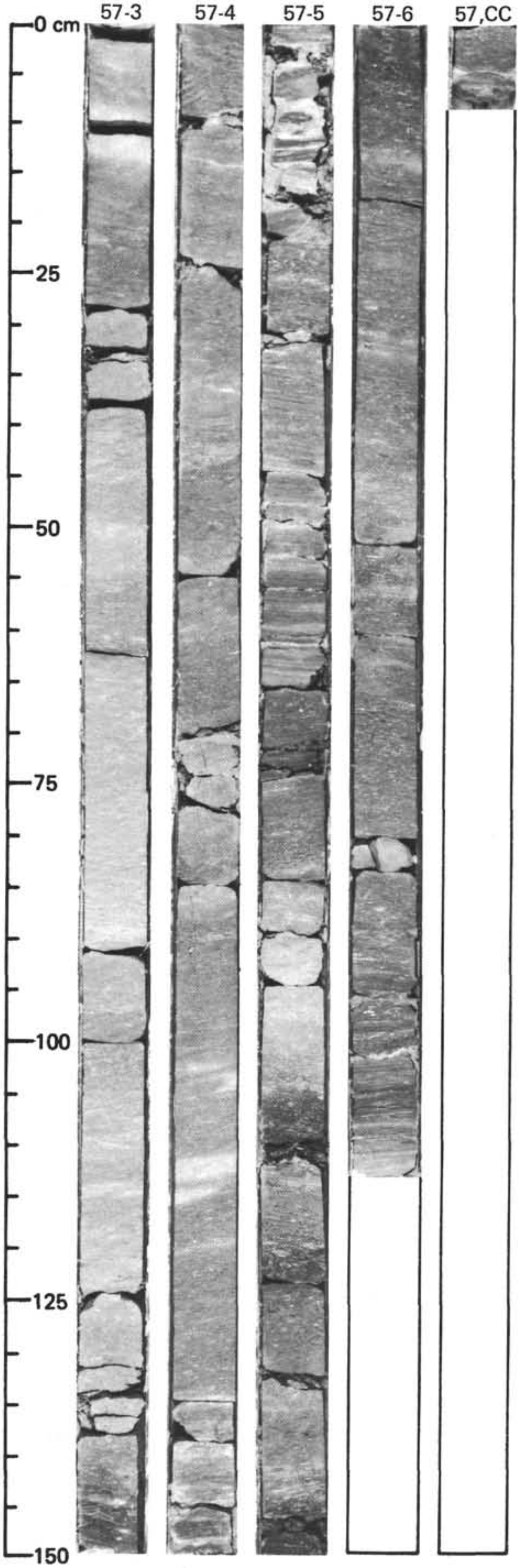
56,CC
57-1
57-2


57-3
57-4
57-5
57-6
57,CC
0 cm
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