6. SITE 590: LORD HOWE RISE, 31°S[1]

Shipboard Scientific Party[2]

HOLE 590

Date occupied: 15 December 1982

Date departed: 15 December 1982

Time on hole: 13 hr.

Position: 31°10.02′S; 163°21.51′E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 26.2

Number of cores: 3

Total length of cored section (m): 26.2

Total core recovered (m): 26.36

Core recovery (%): 100

Oldest sediment cored:
Depth sub-bottom (m): 26.2
Nature: Foraminifer-nannofossil ooze
Age: early Quaternary

Basement: Not reached

HOLE 590A

Date occupied: 15 December 1982

Date departed: 17 December 1982

Time on hole: 51 hr.

Position: 31°10.02′S; 163°21.51′E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 280.8

Number of cores: 27

Total length of cored section (m): 254.6

Total core recovered (m): 224.17

Core recovery (%): 88.1

Oldest sediment cored:
Depth sub-bottom (m): 280.8
Nature: Nannofossil ooze
Age: Middle late Miocene

Basement: Not reached

HOLE 590B

Date occupied: 17 December 1982

Date departed: 19 December 1982

Time on hole: 49 hr.

Position: 31°10.02′S; 163°21.51′E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 499.1

Number of cores: 53

Total length of cored section (m): 499.1

Total core recovered (m): 465.26

Core recovery (%): 93.2

Oldest sediment cored:
Depth sub-bottom (m): 499.1
Nature: Recrystallized nannofossil chalk
Age: Earliest Miocene

Basement: Not reached

Principal results: Site 590 consists of three holes: Hole 590, which was cored continuously with the hydraulic piston corer (HPC) to 26.2 m sub-bottom; Hole 590A, which was cored continuously with the HPC from 26.2–280.8 m sub-bottom; and Hole 590B, which was cored continuously with the HPC from 0–250.7 m sub-bottom and rotary drilled with the extended core barrel (XCB) from 250.7–499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. This represents the first successful use of the XCB and it proves to be a most useful new coring tool.

The section is made up of one lithostratigraphic unit, represented mostly by foraminifer-bearing nannofossil ooze or foraminifer-rich nannofossil ooze. The sequence is divided into three subunits based on changes in color and degree of diagenesis. The upper part of the sequence contains more foraminifer-rich intervals because of increased winnowing that began about 3 m.y. The sequence contains only traces of nonbiogenic components, but volcanic ash is quite persistent. Multiple light green laminae from ear-

[1] Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).

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ly late Miocene to early Miocene are possibly altered volcanic ash layers. Biostratigraphic zonal sequences of transitional type are an important temperate component of the assemblages. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene. A paleomagnetic polarity stratigraphy has been identified down to the middle part of the Gilbert Chron (about 4.2 m.y.).

The Site 590 section provides a superb sequence of pristine foraminifers during the last 15 m.y. and of calcareous nannofossils during the last 10 m.y. The Pliocene/Quaternary and Miocene/Pliocene boundaries are well represented and exhibit clear, gradual, evolutionary sequences within some lineages. The Miocene/Pliocene boundary sequence is missing from the nearby Site 206 sequence.

Remarkably high calcareous biogenic sedimentation rates occur during most of the Pliocene and the middle and late Miocene. Rates (uncorrected for sediment porosity) are as follows for Hole 590B: early Miocene (base NN2–top NN3) 14.4 m/m.y.; middle Miocene (to top NN7) 29.4 m/m.y.; middle late Miocene-early Pliocene (to top NN13) 29.1 m/m.y.; early late Pliocene (to top N18) 52.4 m/m.y.; Quaternary, 17.2 m/m.y.

The seismic profile in the area shows no clear ponding of sediments in much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, which are spectacularly high in the Pliocene, are due to biogenic productivity associated with the Tasman Front.

BACKGROUND AND OBJECTIVES

Site 590 lies to the east of the crest of Lord Howe Rise (Fig. 1). This site was selected as one of several that make up a north–south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites which form a depth traverse for the study of changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m). The seismic reflection profile (Fig. 2) indicates the presence of a relatively thick sequence of pelagic sediments near the site.

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. Site 206 is situated at 32°00′S; 165.27′E. Although Site 206 is a valuable Neogene rotary-cored section, it suffers from a large number of coring gaps, especially in the early Miocene, and contains an unconformity over the Miocene/Pliocene boundary which eliminates important biostratigraphic information. Furthermore, because of the depth of this site (3196 m, below the foraminiferal lysocline), the planktonic foraminiferal assemblage has been altered by dissolution.

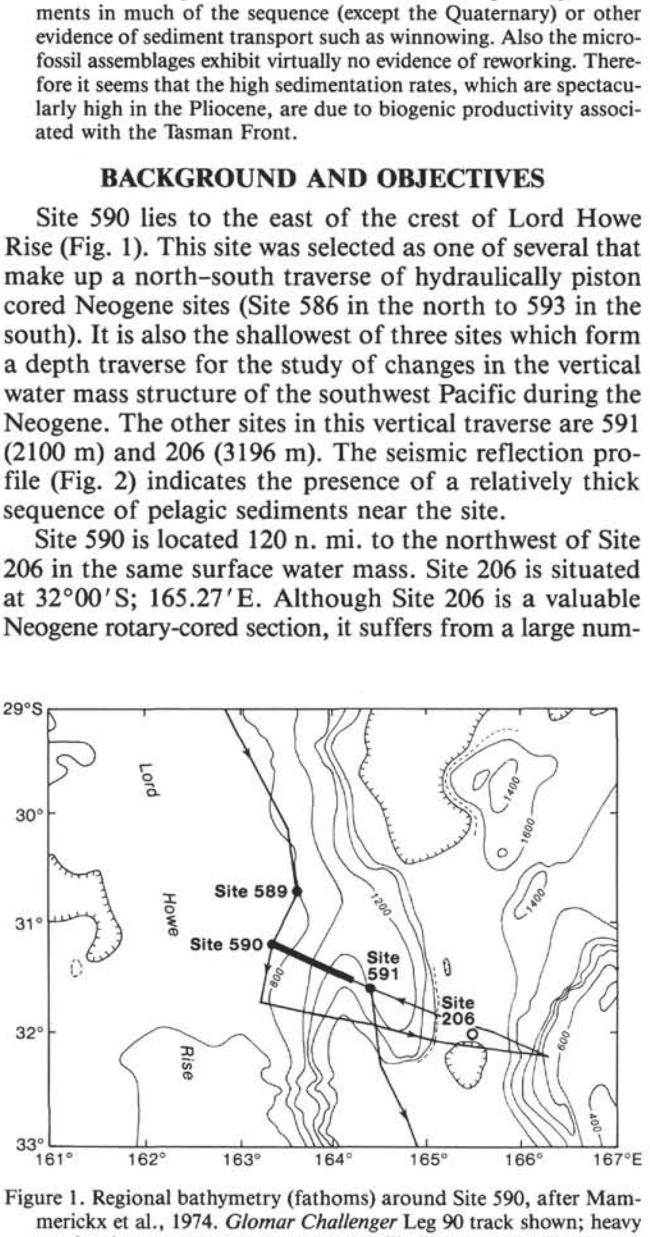

Figure 1. Regional bathymetry (fathoms) around Site 590, after Mammerickx et al., 1974. *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

There are three main reasons why Site 590 was chosen:

1. It is strategically located in waters transitional between the warm subtropical and temperate water masses and is of potential importance in correlating stratigraphic sequences of those areas.
2. It lies at relatively shallow depths near the crest of Lord Howe Rise; and
3. Seismic profile data (Fig. 2) indicate that the area is a quiet pelagic environment and should provide a complete or nearly complete Neogene sequence of carbonate oozes.

Because Site 590 is located in such shallow water, and almost certainly has been located above the foraminiferal lysocline during the entire Neogene, it was expected that foraminiferal and calcareous nannofossil assemblages of this age would be well preserved and would provide an excellent paleoceanographic and paleoclimatic record. An important water mass boundary—the Tropical Convergence—separates the transitional from the warm subtropical water masses. The boundary represents the zone between the eastward flowing East Australian Current and the Trade Wind drift. Its position corresponds fairly closely with the southern limit of the southeast Trade Wind belt, where wind directions change from southwest to southeast, thereby creating convergent flow. The system is quite weak and disappears in summer when the Trade Wind drift turns south. That the tropical convergence is an important surface water mass barrier is suggested by the biogeographic and paleobiogeographic patterns of the planktonic foraminifers (Srinivasan and Kennett, 1981). Faunas at Site 206 have a much more important temperate element than those at Site 208. Paleoreconstructions of this region (Sclater et al., in press) show that Site 590 was about 5–10° of latitude further south in the early Neogene than it is now. This would have placed it well within the zone of westerlies during the early Neogene, with truly temperate planktonic assemblages.

The drilling plan at Site 590 was to core two sites using the hydraulic piston corer to refusal and then to rotary core continuously down to the upper Oligocene.

OPERATIONS

Sites 589 to 590

Following the shipboard computer failure at Site 589, southward transit to an alternate site (1) provided extra time to discover and repair the problem with the positioning computer, (2) if that proved impossible within 8 hr., would have placed the ship closer to New Zealand, where repairs could be made with expert assistance, and (3) would provide time to take seismic profiles in areas of potential new sites (alternates to SW-4 and SW-6) for

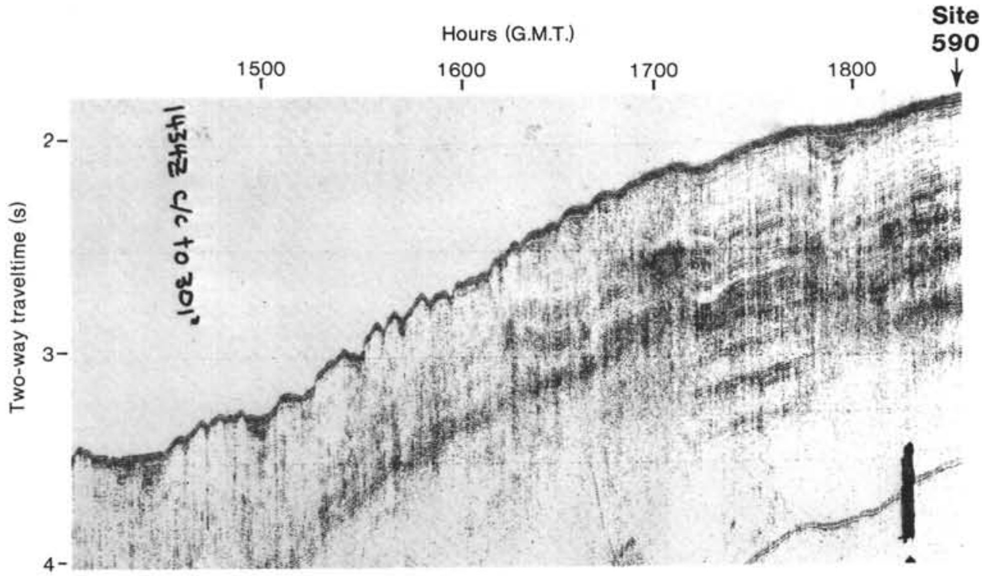

Figure 2. Water gun seismic profile (*Glomar Challenger*) near Site 590; bandpass filter 40–160 Hz.

the same scientific objectives. Further time was also necessary to obtain approval to drill the new sites from the JOIDES Safety Panel.

After possible alternate sites had been surveyed, the problem with the computer had still not been identified, and the ship changed course for Auckland, New Zealand, at 2003 hr., 13 December.

After we had steamed toward Auckland for more than 17 hr., the computer problem was located and repaired, and the vessel immediately returned to the newly chosen Site SW-4, following a track close to the one profiled upon departure from that site. The beacon (13.5 kHz) was dropped at 0533 hr., 15 December 1982. The total distance traveled since departure from Site 589 was 413 mi., at an average speed of 10.09 knots.

Site 590 (new SW-4): Central Lord Howe Rise

Site 590 was located on the Lord Howe Rise, roughly south of and at a water depth equivalent to that of the original SW-4 site specified in the scientific prospectus. Seismic profiling (Fig. 2) showed a sub-bottom character similar to the original SW-4.

Authorization to piston core the new site was received via radio before reaching SW-4, so there was no delay in operations. Once again a dual-purpose bottom-hole assembly (BHA) was lowered to enable piston coring followed by XCB rotary coring. The bit was lowered to 1305 m and a mudline variable-length (VL) HPC core containing 7 m of sediment was taken at 1210 hr., 15 December, after an initial mudline core had been discarded when the core liner shattered.

Three 9.5-m VLHPC cores were taken routinely (Table 1). The fourth attempt was unsuccessful when the coring tool was accidently allowed to fall several feet, so that it hit the lifting clamp violently. This ultimately caused a dislocation of the lower section of the piston core, which was lost through the bit. Unfortunately, the Von Herzen heat-flow package was attached to the lost tool. Because only one Von Herzen heat-flow electronic unit had been available to Leg 90, its scientific value was high; therefore an unsuccessful effort was made to fish for the lost barrel, which was believed to be stuck in the mud only about 3 ft. below the bit. About 2½ hr. were spent making up a special fishing spear and deploying it through the bit. Hole 590 was terminated because of the obstruction.

Hole 590A

The bit was pulled to the mudline and washed back to the point where Core 590-4 was to have been taken. Hole 590A was spudded at 1810 hr., 15 December, and routine piston coring operations were resumed.

At Core 590A-13, the sand line parted at the rope socket on top of the sinker bar assembly. The sinker bars and VLHPC were successfully fished on the first attempt, so little time was lost.

As at the previous sites, full stroke of the piston corer was achieved continuously, generally with only two shear pins. At a depth of 275.8 m BSF, overpulls of 45,000 lb. made it necessary to wash the bit over the protruding corer in order to retrieve the tool. A 5-m VLHPC was then deployed, but it, too, had to be washed over for release. Therefore, piston coring was deemed to be too dangerous to be continued, despite the fact that high-quality full-stroke cores were still being taken.

Hole 590B

Authorization to rotary core this new site had not yet been received, so the repeat piston core sequence was begun by pulling to the mudline and re-establishing water depth with a mudline core after the vessel had been offset 100 ft. The first core was shot with the bit at 1301 m, in order to overlap the piston cores with those from Hole 590A. Hole 590B was officially spudded at 2110 hr., 16 December.

Twenty-seven 9.5-m VLHPC cores were taken without any difficulties in calcareous sediment grading from soupy ooze to firm chalk. Piston coring was terminated at 250.7 m BSF when the familiar pattern of increasing overpull symptoms repeated itself.

Table 1. Coring summary, Site 590.

Core no.	Date (Dec. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 590							
1	15	1235	1307.6–1314.6	0.0–7.0	7.0	6.99	100
2	15	1305	1314.6–1324.2	7.0–16.6	9.6	9.70	100+
3	15	1408	1324.2–1333.8	16.6–26.2	9.6	9.67	100+
		Core barrel broken			26.20	26.36	100
Hole 590A							
1	15	1430	1333.8–1343.4	26.2–35.8	9.6	9.41	98
2	15	2012	1343.4–1353.0	35.8–45.4	9.6	9.39	98
3	15	2115	1353.0–1362.6	45.4–55.0	9.6	8.53	89
4	15	2200	1362.6–1372.2	55.0–64.6	9.6	8.76	91
5	15	2255	1372.2–1381.8	64.6–74.2	9.6	9.22	96
6	15	2343	1381.8–1391.4	74.2–83.8	9.6	9.42	98
7	16	0015	1391.4–1401.0	83.8–93.4	9.6	9.02	94
8	16	0100	1401.0–1410.6	93.4–103.0	9.6	9.50	99
9	16	0150	1410.6–1420.2	103.0–112.6	9.6	0.0	0
10	16	0245	1420.2–1429.8	112.6–122.2	9.6	8.86	92
11	16	0330	1429.8–1439.4	122.2–131.8	9.6	9.71	100
12	16	0445	1439.4–1449.0	131.8–141.4	9.6	9.60	100
132	16	0630	1449.0–1458.6	141.4–151.0	9.6	8.26	86
14	16	0800	1458.6–1468.2	151.0–160.6	9.6	9.29	97
15	16	0850	1468.2–1477.8	160.6–170.2	9.6	9.50	99
16	16	0950	1477.8–1487.4	170.2–179.8	9.6	7.45	78
17	16	1015	1487.4–1497.0	179.8–189.4	9.6	7.85	82
18	16	1105	1497.0–1506.6	189.4–199.0	9.6	9.10	95
19	16	1200	1506.6–1516.2	199.0–208.6	9.6	8.26	86
20	16	1255	1516.2–1525.8	208.6–218.2	9.6	8.75	91
21	16	1345	1525.8–1535.4	218.2–227.8	9.6	9.74	100+
22	16	1420	1535.4–1545.0	227.8–237.4	9.6	2.42	25
23	16	1510	1545.0–1554.6	237.4–247.0	9.6	9.20	96
24	16	1600	1554.6–1564.2	247.0–256.6	9.6	9.71	100+
25	16	1710	1564.2–1573.8	256.6–266.2	9.6	9.11	100+
26	16	1820	1573.8–1583.4	266.2–275.8	9.6	8.91	93
27	16	1915	1583.4–1588.4	275.8–280.8	5.0	5.20	100+
					254.60	224.17	88.1
Hole 590B							
1	16	2135	1308.4–1310.6	0.0–2.2	2.2	2.10	95
2	16	2220	1310.6–1320.2	2.2–11.8	9.6	9.22	96
3	16	2300	1320.2–1329.8	11.8–21.4	9.6	9.65	100+
4	16	2355	1329.8–1339.4	21.4–31.0	9.6	9.58	99.7
5	17	0035	1339.4–1349.0	31.0–40.6	9.6	9.40	97.9
6	17	0100	1349.0–1358.6	40.6–50.2	9.6	9.60	100
7	17	0140	1358.6–1368.2	50.2–59.8	9.6	9.59	99.9
8	17	0300	1368.2–1377.8	59.8–69.4	9.6	9.24	96.2
9	17	0400	1377.8–1387.4	69.4–79.0	9.6	8.05	83.8
10	17	0445	1387.4–1397.0	79.0–88.6	9.6	8.87	92.4
11	17	0535	1397.0–1406.6	88.6–98.2	9.6	9.00	93.7
12	17	0620	1406.6–1416.2	98.2–107.8	9.6	8.52	88.7
13	17	0700	1416.2–1425.8	107.8–117.4	9.6	9.29	96.7
14	17	0740	1425.8–1435.4	117.4–127.0	9.6	9.74	100+
15	17	0830	1435.4–1445.0	127.0–136.6	9.6	9.06	94.4
16	17	0920	1445.0–1454.6	136.6–146.2	9.6	8.76	91.2
17	17	1005	1454.6–1464.2	146.2–155.8	9.6	9.49	98.8
18	17	1045	1464.2–1473.8	155.8–165.4	9.6	8.03	83.6
19	17	1120	1473.8–1483.4	165.4–175.0	9.6	8.33	86.7
20	17	1210	1483.4–1493.0	175.0–184.6	9.6	9.38	98
21	17	1315	1493.0–1502.6	184.6–194.2	9.6	8.44	88
22	17	1410	1502.6–1512.2	194.2–203.8	9.6	6.07	63.2
23	17	1510	1512.2–1521.8	203.8–213.4	9.6	9.47	99
24	17	1550	1521.8–1531.4	213.4–223.0	9.6	8.66	90
25	17	1645	1531.4–1541.0	223.0–232.6	9.6	8.51	89
26	17	1750	1541.0–1550.6	232.6–242.2	9.6	9.73	100+
27	17	1855	1550.6–1559.1	242.2–250.7	8.5	8.49	99
28	17	1950	1559.1–1567.5	250.7–259.1	8.4	9.28	100+
29	17	2055	1567.5–1577.1	259.1–268.7	9.6	8.88	92
30	17	2200	1577.1–1586.7	268.7–278.3	9.6	8.28	86
31	17	2310	1586.7–1596.3	278.3–287.9	9.6	7.84	81.6
32	17	2345	1596.3–1605.9	287.9–297.5	9.6	9.25	96.3
33	18	0043	1605.9–1615.5	297.5–307.1	9.6	9.63	100+
34	18	0200	1615.5–1625.1	307.1–316.7	9.6	8.43	87.8
35	18	0250	1625.1–1634.7	316.7–326.3	9.6	7.60	79.1
36	18	0340	1634.7–1644.3	326.3–335.9	9.6	9.50	98.9
37	18	0432	1644.3–1653.9	335.9–345.5	9.6	9.64	100+
38	18	0520	1653.9–1663.5	345.5–355.1	9.6	9.65	100+
39	18	0610	1663.5–1673.1	355.1–364.7	9.6	9.73	100+
40	18	0700	1673.1–1682.7	364.7–374.3	9.6	9.71	100+
41	18	0745	1682.7–1692.3	374.3–383.9	9.6	9.76	100+
42	18	0830	1692.3–1701.9	383.9–393.5	9.6	9.61	100+
43	18	0915	1701.9–1711.5	393.5–403.1	9.6	7.48	77.9
44	18	1005	1711.5–1721.1	403.1–412.7	9.6	9.65	100+
45	18	1100	1721.1–1730.7	412.7–422.3	9.6	7.72	80.4
46	18	1200	1730.7–1740.3	422.3–431.9	9.6	9.78	100+
47	18	1255	1740.3–1749.6	431.9–441.5	9.6	9.68	100+
48	18	1355	1749.6–1759.2	441.5–451.1	9.6	9.68	100+
49	18	1450	1759.2–1769.1	451.1–460.7	9.6	7.19	75
50	18	1550	1769.1–1778.7	460.7–470.3	9.6	4.31	45
51	18	1650	1778.7–1788.3	470.3–479.9	9.6	9.42	98
52	18	1755	1788.3–1797.9	479.9–489.5	9.6	9.61	100+
53	18	1850	1797.9–1807.5	489.5–499.1	9.6	9.68	100+
					499.10	465.26	93.2

The XCB with its latest modifications was deployed. Excellent cores with high recovery rates were taken. Seven of the first nine cores were retrieved with the liner partially collapsed, but the collapse was always limited to the top 3 ft. or less. This problem was soon eliminated. Twenty-six cores were taken with the XCB to a depth of 499.1 m BSF, where the hole was terminated when the quality of the recovered microfossils deteriorated to the point that useful paleoceanographic work became impossible.

The pipe was tripped and the rig floor was secured for sea. The vessel departed for Site 591 at 2248 hr., 18 December 1982.

LITHOSTRATIGRAPHY

The sequence recovered at Site 590 is dominantly composed of calcareous biogenic sediments which constitute a single lithostratigraphic unit with three subunits (Table 2; Fig. 3). The principal biogenic components are calcareous nannofossils and foraminifers (Fig. 4). The sediments range from an occasional nannofossil–foraminifer ooze through common foraminifer-bearing nannofossil ooze (or chalk) to fairly pure nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, having greatest abundance (1 to 5%) in Cores 590B-32 to 590B-35. The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasionally sponge spicules.

Nonbiogenic components comprise an extremely small proportion of the sediment. Occasional quartz and feldspar grains are present. Trace quantities of clear volcanic glass occur throughout the sequence, and distinct concentrations of volcanic ash were observed in Cores 590A-6, 590B-38, and 590B-51. Zeolites(?) and palagonite occur in Cores 590B-48 to 590B-53. Numerous pale green laminae occur and are most prevalent in Cores 590B-33 to 590B-53. These are possibly related to the presence of increased quantities of volcanic ash. Authigenic iron sulfide occurs within burrows and foraminifer tests, and as finely dispersed medium gray streaks and halos throughout the sequence. Grayish yellow concretions measuring up to 5 cm in diameter were found in Cores 590B-18, 590B-20, and 590B-23. These are composed predominantly of celestite with pyrite crystals occurring on the surface or as a central core.

The sediment becomes more indurated with depth. Sediments above 280 m sub-bottom are ooze that becomes progressively stiffer with depth. Sediments below

Table 2. Lithostratigraphy at Site 590.

Lithostratigraphic unit	Core	Sub-bottom depth (m)	General lithology	Age
IA	590-1 590B-1	0–40 cm 0–30 cm	Yellowish orange foraminifer–nannofossil ooze	late Quaternary
IB	590-1 to 590-3 590A-1 to 590A-27 590B-1 to 590B-30	0.4–26.2 26.2–280.8 0.4–278.3	Very light gray foraminifer-bearing nannofossil ooze to light olive gray foraminifer–nannofossil ooze.	late Miocene
IC	590B-31 to 590B-53	278.1–499.1	Light gray foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk	late Miocene to early Miocene

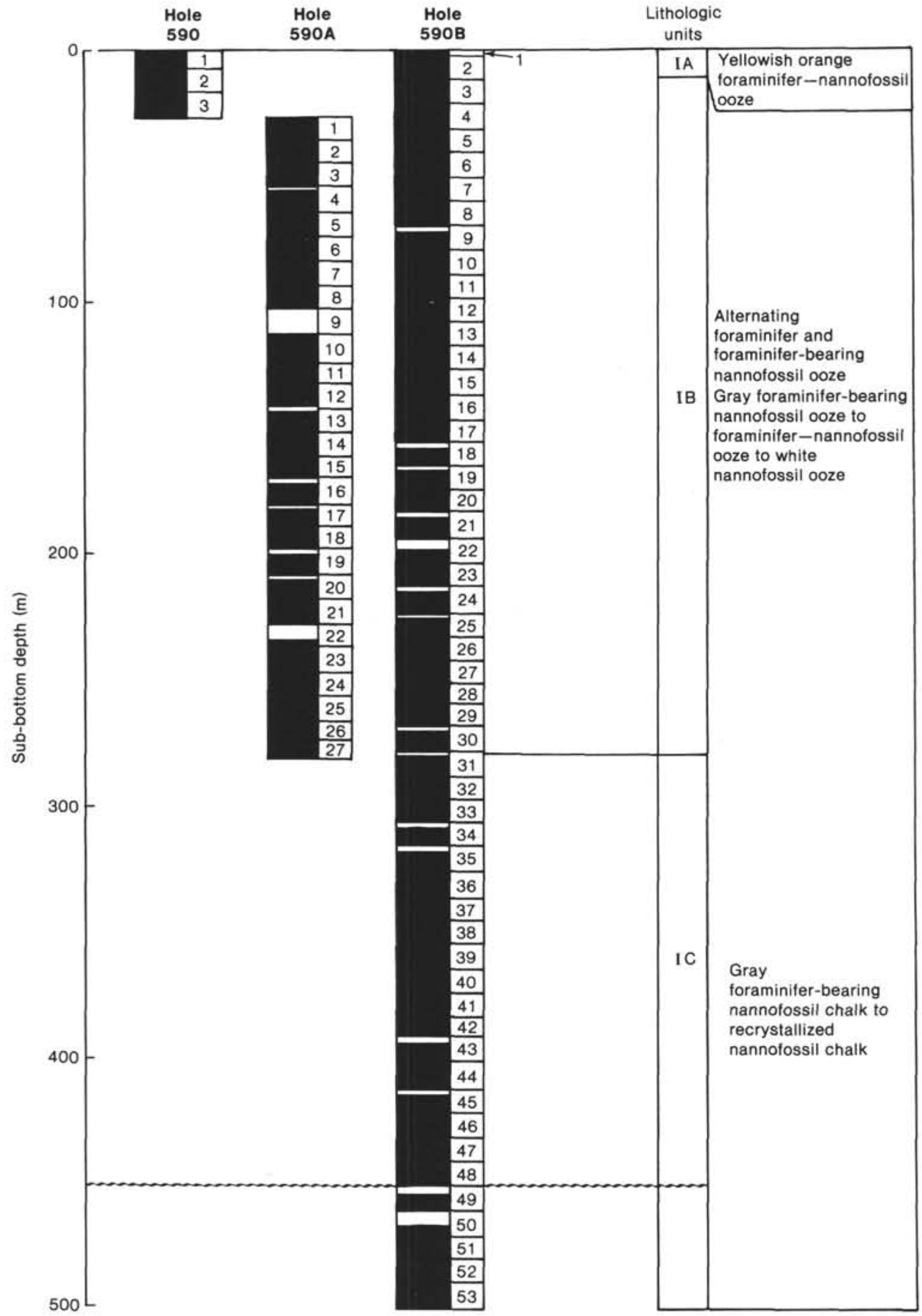

Figure 3. Lithology of Site 590. Recovery in black.

approximately 280 m sub-bottom are chalk with clear recrystallization in Cores 590B-51 to 590B-53.

Sedimentary structures have been created by chemical, physical, and biological effects. Bioturbation is slight in the upper part of the sequence (Cores 590-1 to 590-3, 590A-1 to 590A-16, and 590B-1 to 590B-19), increases to moderate downhole (Cores 590A-17 to 590A-28, and 590B-20 to 590B-31), and becomes intense in Cores 590B-32 to 590B-47. The lowest part of the sequence, Cores 590B-48 to 590B-53, exhibits moderate bioturbation. Various color bands are apparent against the very light gray (N8) to white background of the ooze or chalk. The zones richer in foraminifers tend to be darker gray to light olive gray. Many burrows are yellowish gray (5Y 8/1). Numerous examples of Zoophycos as well as occasional Planolites-like and Chondrites-like burrows are apparent. Several suites of fractures were observed cutting the sediment sequence, but it is not clear whether or not they represent drilling artifacts. One microfault in Core 590B-35 is definitely unrelated to drilling activity, however, because it has clearly been annealed and occurs within a biscuit of hard sediment.

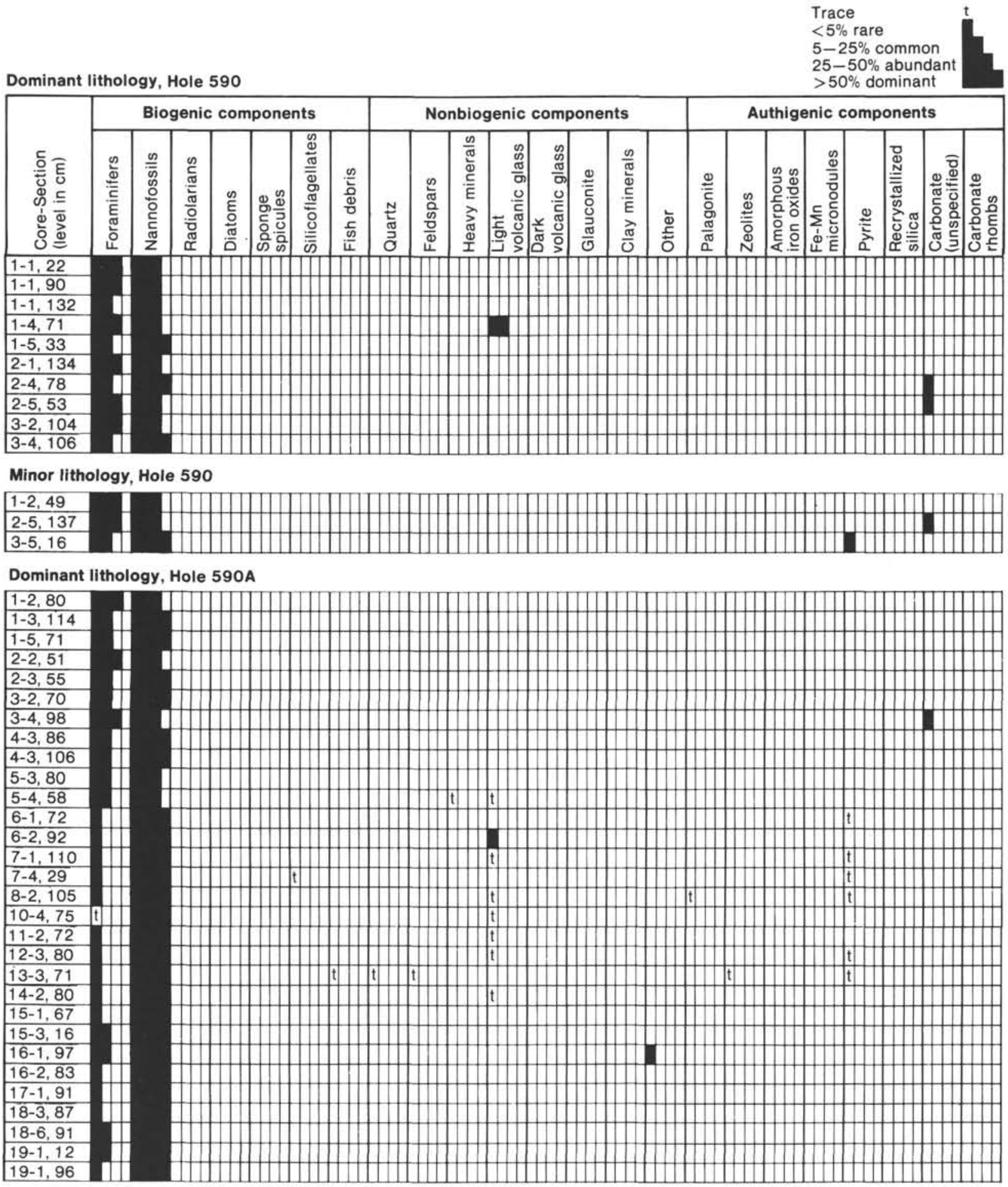

Figure 4. Smear slide summaries, Site 590.

The sequence at Site 590 is divided into three subunits, based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm sub-bottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer-nannofossil ooze. This subunit corresponds to the zone of oxidation and possible current winnowing activity and indicates that the uppermost sediments recovered are from near the sediment/water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing (5 to 10%) nannofossil ooze and layers of light olive gray foraminifer (20 to 50%) nannofossil ooze. The change in

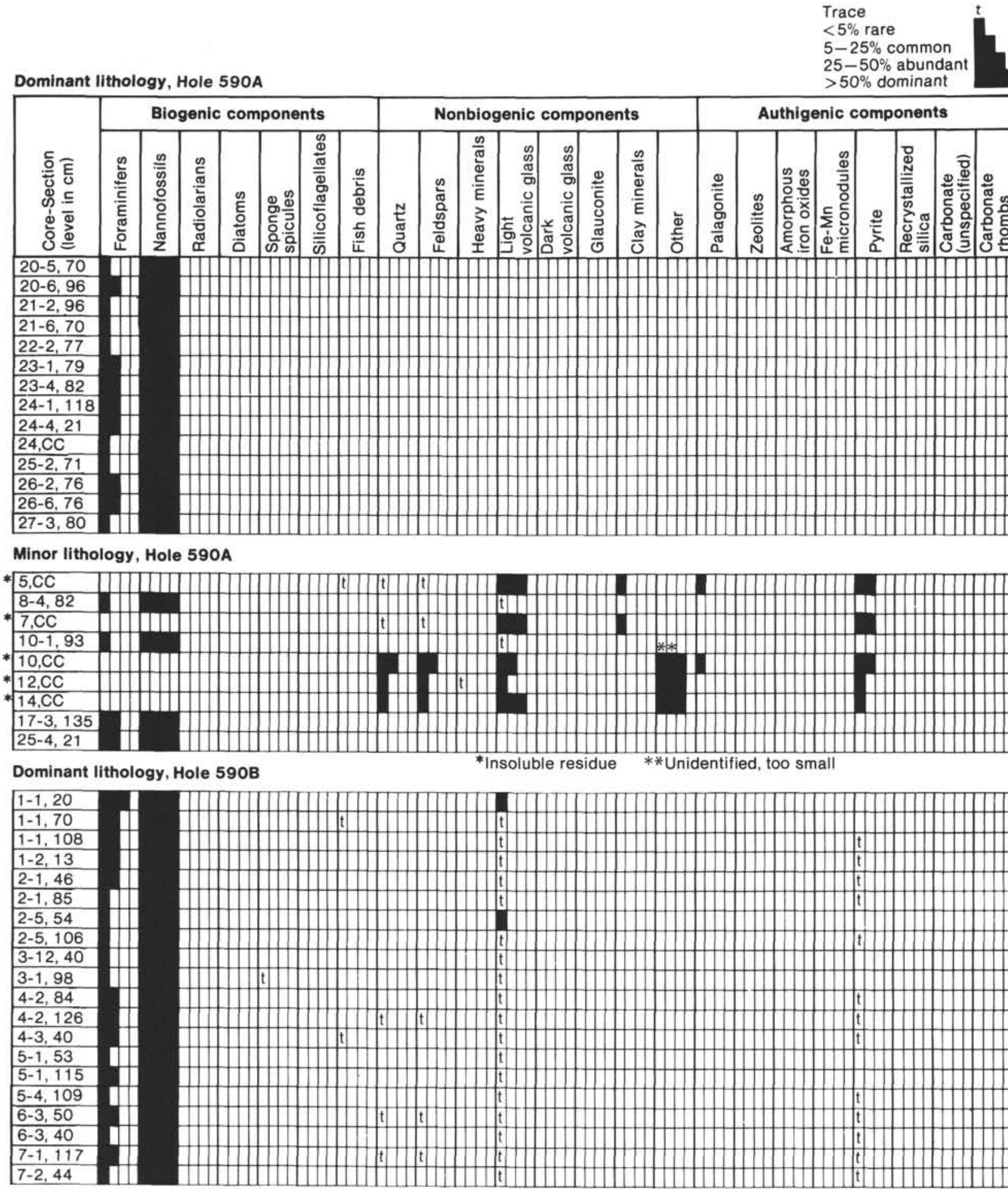

Figure 4. (Continued).

percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional zones of foraminifer-bearing (5 to 10%) nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions compared with the upper part of Subunit IB.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is

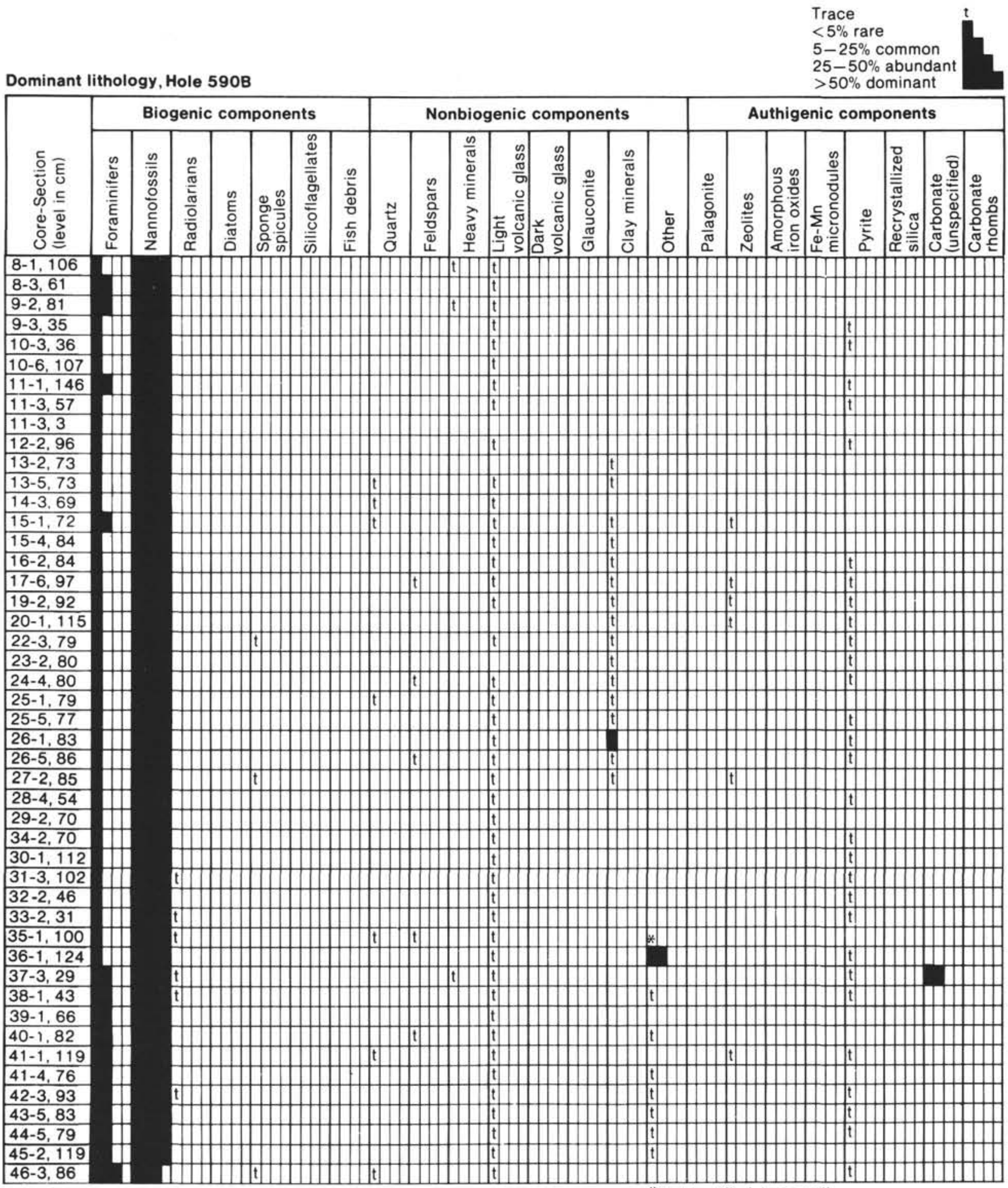

Figure 4. (Continued).

middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this part of the subunit. This subunit resembles the upper part of Subunit IB in consisting of alternating very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to foraminifer-bearing nannofossil chalk and foraminifer-nannofossil chalk, respectively. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450 to 499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk. This part of the subunit lacks the foraminifer-rich layers of the portion above and is

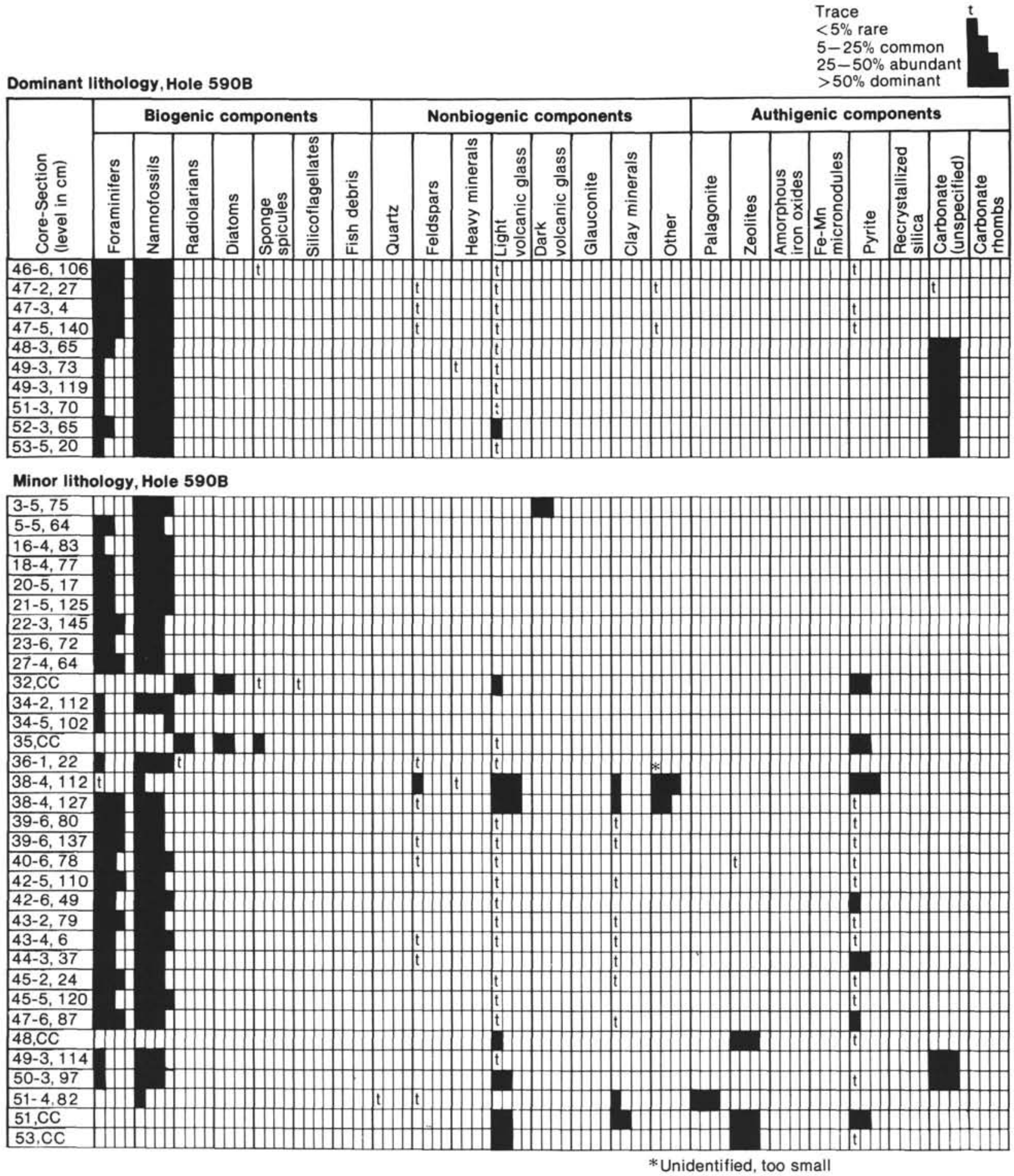

Figure 4. (Continued).

less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

PHYSICAL PROPERTIES

Wet-bulk density, porosity, and grain density were determined throughout the sediment column by using standard gravimetric methods (Boyce, 1976). The HPC cores were also continuously scanned with the GRAPE apparatus to measure wet-bulk density. Sonic velocity and shear strength were determined on each core section as well (see Introduction for specific techniques). A full discussion of the physical properties data for Site 590 is presented by Morin (this volume).

The GRAPE wet-bulk densities (points) for Hole 590B are plotted versus depth in Figure 5A. The results are averaged across each meter and these arithmetic mean values are plotted as the solid line (also relevant for Fig. 5B and 5C). The GRAPE porosities are directly calculated

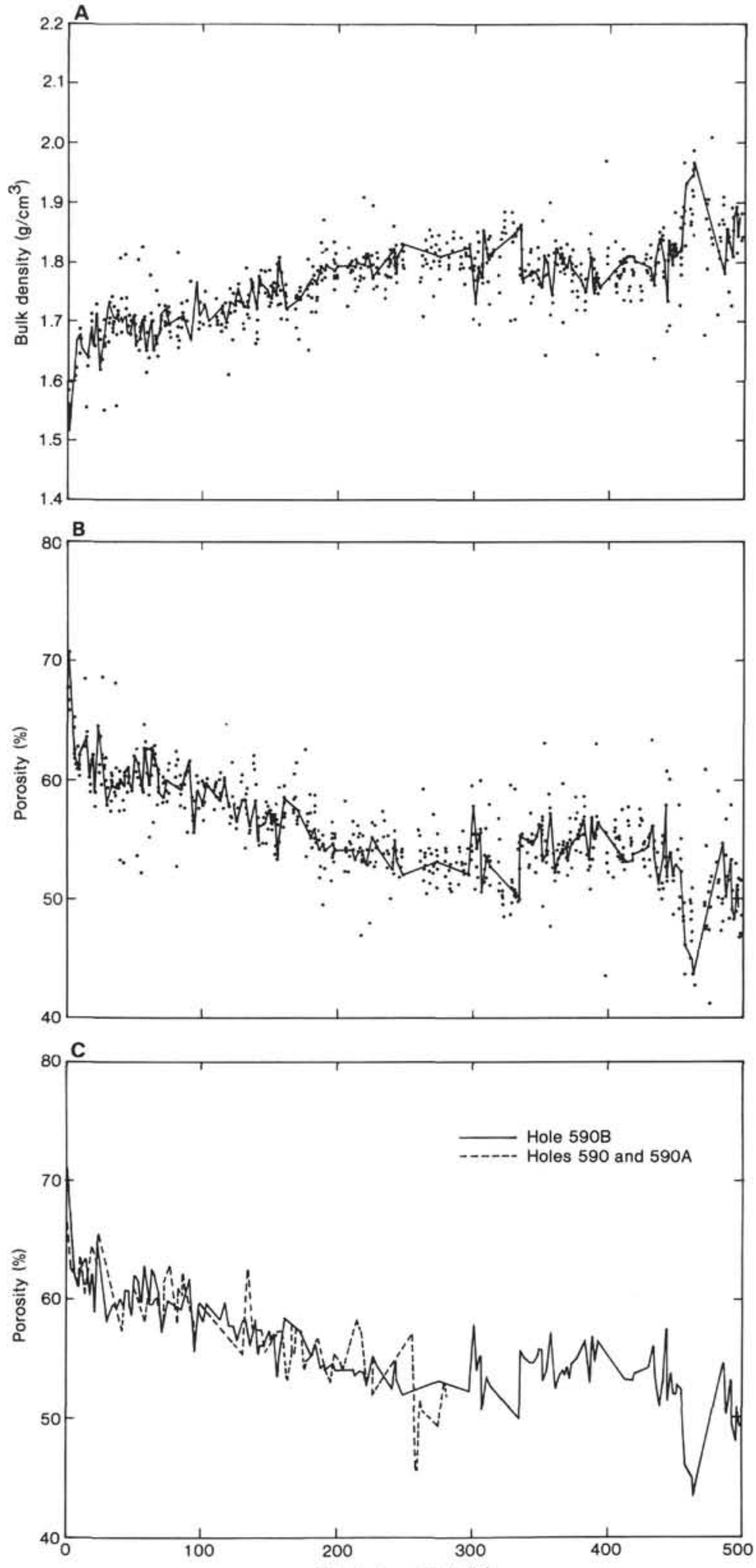

Figure 5. Physical properties, Site 590. A. GRAPE wet-bulk density versus sub-bottom depth for Hole 590B. B. GRAPE porosity versus sub-bottom depth for Hole 590B. C. GRAPE porosity versus sub-bottom depth for Holes 590, 590A, and 590B. D. Compressional velocity versus sub-bottom depth for Hole 590B. E. Porosity versus compressional velocity for Site 590. F. Shear strength versus sub-bottom depth for Hole 590B. G. Porosity versus shear strength for Hole 590B. H. Impedance versus depth for Hole 590B.

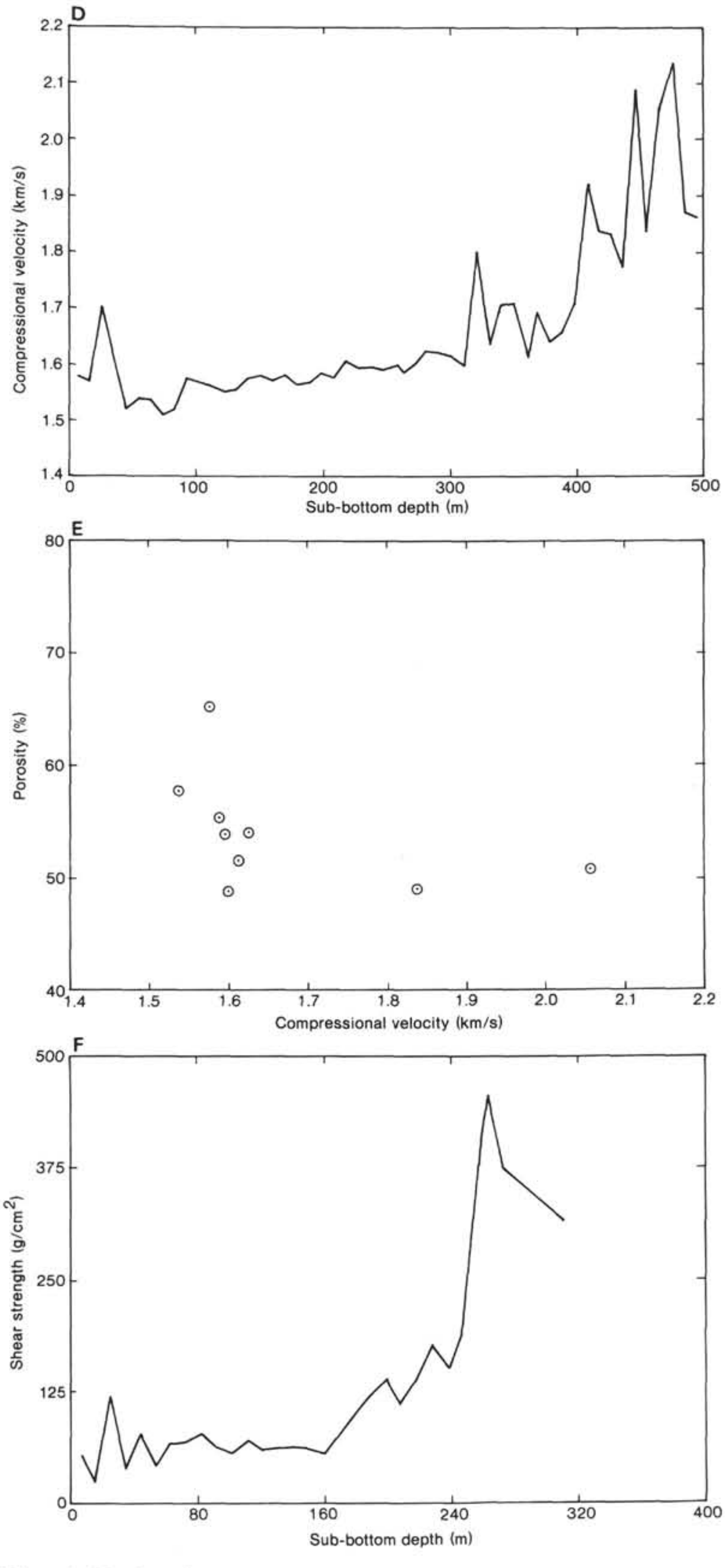

Figure 5. (Continued).

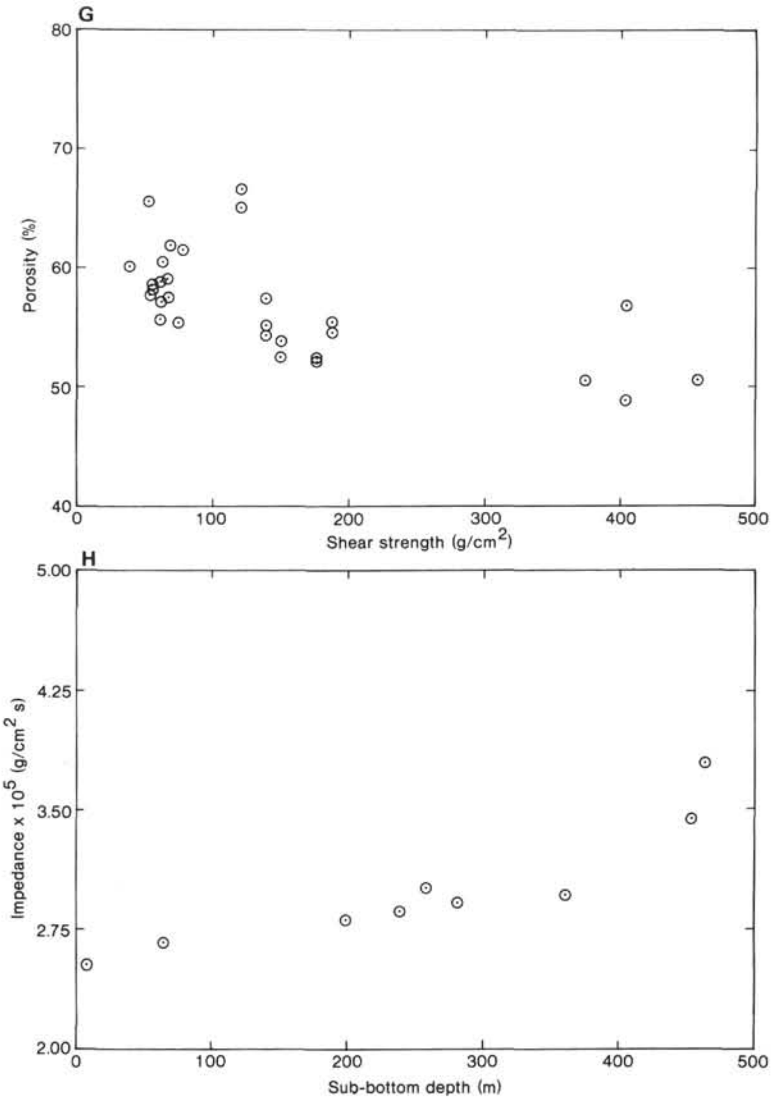

Figure 5. (Continued).

from the density results by assuming a grain density of 2.691 g/cm^3. Since the carbonate content of these sediments is very high ($CaCO_3$ grain density = 2.71 g/cm^3), this assumption provides a reasonable estimate of porosity versus depth (Fig. 5B). The porosity profile for Holes 590 and 590A is compared with that of Hole 590B in Figure 5C.

The results of the compressional velocity measurements performed on the split cores are illustrated in Figure 5D. A sharp increase in this property occurs at approximately 300 m, where the ooze-to-chalk transition is observed. When these data are correlated with the porosity profile, a plot of P-wave velocity versus porosity results (Fig. 5E). This graph illustrates how the acoustic velocity through the sediment at Site 590 increases dramatically as the porosity approaches 50%.

A similar presentation can be made with the shear strength data (Fig. 5F). The shear strength increases rapidly at 250 m. Below a depth of 300 m, the sediment becomes so lithified that its strength measurement is beyond the range of the Wykeham Farrance miniature vane shear device. Again, the sharp rise in the magnitude of this property occurs at the onset of chalk, where the sediment porosity approaches 50% (Fig. 5G).

An estimate of acoustic impedance as a function of depth can be derived by combining the P-wave velocity results with the GRAPE wet-bulk density profile (Fig. 5H). A rapid increase in impedance at a depth of approximately 450 m corresponds to the observed diagenetic recrystallization of the foraminifer-bearing nannofossil chalk.

SEISMIC STRATIGRAPHY

Figure 6 illustrates a portion of the shipboard water gun seismic profile collected during approach to Site 590. Five acoustic units have been identified (A to E), broadly equivalent to the regional acoustic units selected by Willcox et al., 1980. These are correlated in part with the lithology of the site (lithostratigraphic Subunits IA, IB, and IC).

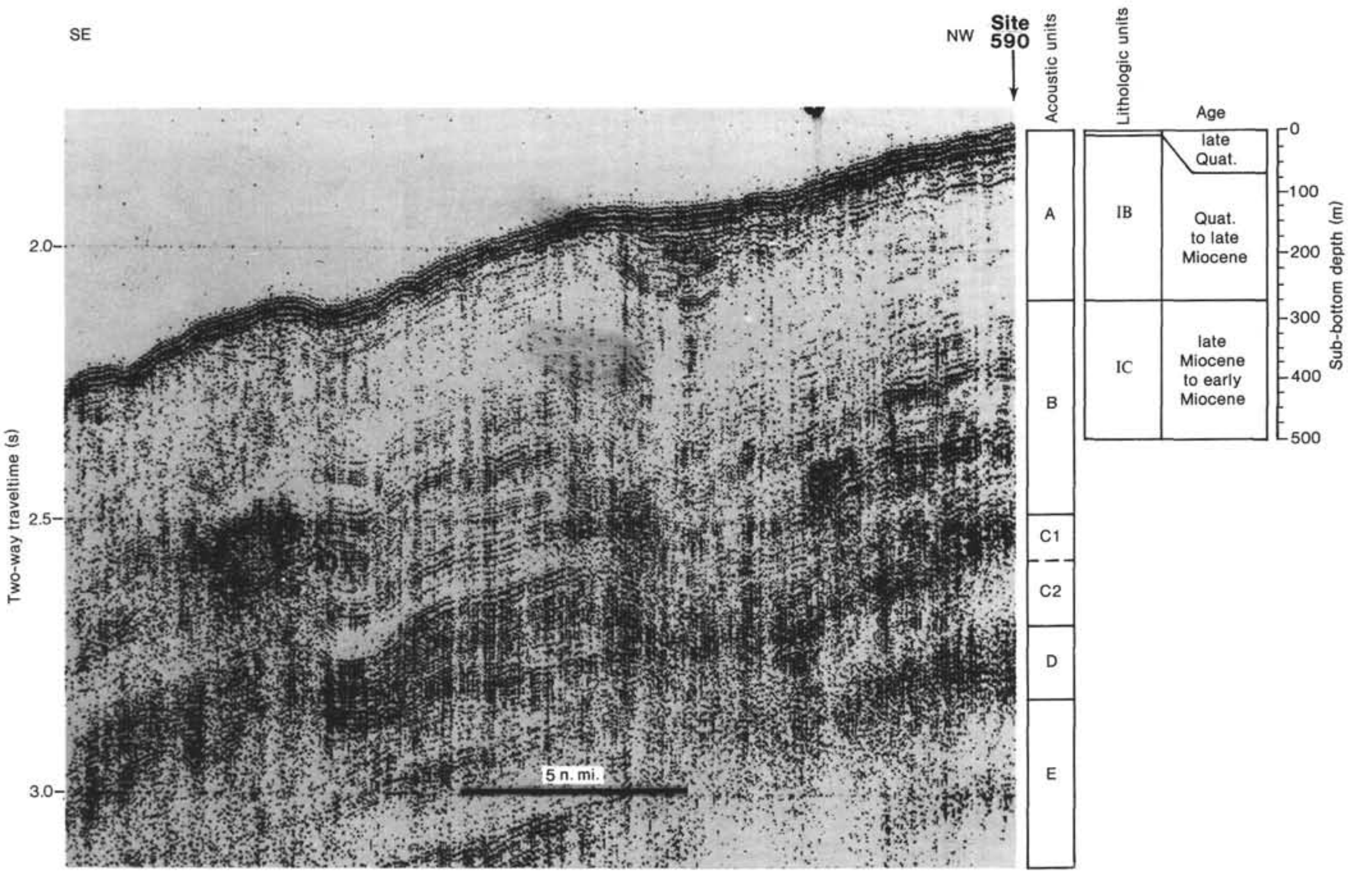

Figure 6. Comparison of acoustic Units A and B with lithologic Unit I Cored at Site 590; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1800 m/s.

Acoustic Unit A is a relatively transparent layer at recorded frequencies. Some relatively coherent reflectors are visible in its uppermost portion, below the reflected wave form. A small basin occurs 7 n. mi. southeast of Site 590, filled with significantly more reflective material. Further down the slope of Lord Howe Rise to the east-southeast (not shown in Fig. 6), additional filled channels or minor basins occur in a similar position with respect to the sediment surface.

Acoustic Unit B is not readily differentiated from A in the water gun record near Site 590. The upper boundary of B has been selected at the top of a slightly more reflective zone which contains layers of coherent reflectors.

Acoustic Unit C can be correlated regionally between drill sites on Lord Howe Rise with a high degree of confidence. It has a well-defined upper limit, and comprises a series of high-amplitude, relatively coherent reflectors (C1) underlain by a transparent zone (C2).[3] This unit has been subdivided in this summary into Subunits C1 and C2, in order to include the transparent zone (C2) which occurs below Site 590 and which occurs typically in grabens between acoustic units C and D. Generally, the highs between grabens are overlain by close juxtaposition of Units C and D, and the transparent Subunit C2 is missing.

Acoustic Unit D comprises a high-amplitude, relatively coherent set of reflectors with an appearance similar to that of Subunit C1.

Acoustic Unit E is a low-amplitude zone which, like C2, is largely confined to basinal areas (e.g., grabens). Its possible occurrence below Site 590 relates to what appears to be a relatively thick sedimentary sequence in this region of the Lord Howe Rise.

Site 590 was drilled to a total depth of 499.1 m, through acoustic Unit A and into B. The sequence has been assigned to three lithostratigraphic subunits. Subunit IA comprises late Quaternary foraminifer-nannofossil ooze, only 40 cm thick, and thus is not represented on Figure 6. Subunit IB comprises mixed foraminifer-bearing nannofossil ooze, foraminifer-nannofossil ooze, and nannofossil ooze, whereas Subunit IC is composed of foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk. Within the sequence, the downward gradation from ooze to chalk begins at a sub-bottom depth of about 275 m.

Comparison of these seismic and lithologic data suggests that the ooze/chalk boundary correlates with the

[3] Acoustic Unit C was not subdivided into C1 and C2 in the summary of Willcox et al., 1980, who may not have recognized Subunit C2 because of the lower frequencies employed during their seismic profiling. However, an effort has been made in this report to adhere to the original units chosen by Willcox et al.; accordingly, the transparent zone has been designated as a subunit.

boundary between acoustic Units A and B. This estimate is based on an interval velocity of 1.8 km/s, averaged from shipboard velocimeter measurements on cores. As described in the preceding section on Physical Properties, a rapid increase in acoustic impedance at a depth of approximately 450 m corresponds to diagenetic recrystallization of the foraminifer-bearing nannofossil chalk. The drilling terminated midway through acoustic Unit B.

BIOSTRATIGRAPHY

The three holes drilled at Site 590 provide a complete calcareous sequence from the early Miocene through Recent, except for an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorotalia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. This gap is not noted in the calcareous nannoplankton zonation, but may be within the *Sphenolithus heteromorphus* Zone (NN5, earliest middle Miocene). The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 was not observed at this site.

Preservation of calcareous nannoplankton is good in the upper part of the sequence and moderate to poor in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the lower Miocene unconformity and very poor below. The benthic foraminifers are well preserved throughout much of the sequence; however, below the upper Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers, perhaps as a result of diagenesis. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

For correlations between different fossil groups see Figure 7.

Planktonic Foraminifers

Zones

The planktonic foraminiferal zones recognized at Site 590 are shown in Figure 7. The zonal boundary marker species are noted in parentheses in the faunal descriptions that follow.

An unconformity exists between Samples 590B-48,CC and 590B-49,CC and the *Orbulina suturalis* Zone and *Praeorbulina glomerosa curva* Zone appear to be missing.

Faunas

***Globorotalia truncatulinoides* Zone (L.A. *Globorotalia tosaensis*)**

The zone fossil is in abundance and exists with *Globorotalia menardii, G. tumida, G. inflata*, and *Pulleniatina obliquiloculata*.

***Globorotalia truncatulinoides–G. tosaensis* Zone (I.A. *G. truncatulinoides*)**

The two zone fossils coexisted together with most species which survived into the *G. truncatulinoides* Zone.

***Globorotalia tosaensis* Zone (I.A. *G. tosaensis*)**

The zone fossil is abundant, with evidence of its evolution from *G. crassaformis* in the lower part of the zone; other important taxa include *Globigerinoides fistulosus, Globorotalia inflata, G. multicamerata, Dentoglobigerina altispira*, and *P. obliquiloculata*.

***Globorotalia inflata* Zone (I.A. *G. inflata*)**

The zone fossil is abundant at this site and occurs with *G. menardii, G. tumida*, and *P. obliquiloculata*.

***Globorotalia crassaformis* Zone (I.A. *G. crassaformis*)**

The zone fossil is abundant in the middle and upper part of the zone but is rarer in the lower part; important markers include *G. margaritae, G. puncticulata*, and *P. primalis*.

***Globorotalia puncticulata* Zone (I.A. G. puncticulata)**

The lower boundary was marked by the evolutionary appearance of the zone fossil with a transition form *G. sphericomiozea;* other important species within the zone include *G. miotumida* and *P. primalis*.

***Globorotalia conomiozea* Zone (I.A. *G. conomiozea*)**

The zone fossil is common within the zone with its typical morphology; thus it differs from Site 588; *G. conomiozea* and *G. margaritae* overlap in the uppermost part of the zone in 590A-18,CC.

***Globigerina nepenthes* Zone (L.A. *Neogloboquadrina continuosa*)**

The upper boundary is well established at this site with the probable evolutionary appearance of *Globorotalia conomiozea;* the lower boundary, based on the extinction of *N. continuosa*, is less securely established because of the scarcity of this species.

***Neogloboquadrina continuosa* Zone (L.A. *G. mayeri*)**

The zonal boundaries are marked by the extinction of the zone fossil at the top and *G. mayeri* at the base; within the zone there is little faunal change.

***Globorotalia mayeri* Zone (L.A. *Fohsella* group)**

The zone fossil was common within the zone; the lower boundary, marked by the extinction of the *Fohsella* lineage, may be stratigraphically low at this site because the keeled members of the *G. fohsi* lineage are absent.

***Globorotalia fohsi* s.l. Zone (I.A. *G. peripheroacuta*)**

The zone fossils, *G. peripheroacuta* and *G. fohsi* s.l., are rare within the zone, and the lower part of the zone may be missing.

***Globorotalia miozea* Zone (L.A. *Catapsydrax dissimilis*)**

Assemblages are poorly preserved within this zone, and identifications were difficult; nevertheless, the absence of *Orbulina* and *Praeorbulina* and the presence of the early Miocene *G. zealandica* confirmed the *G. miozea* Zone.

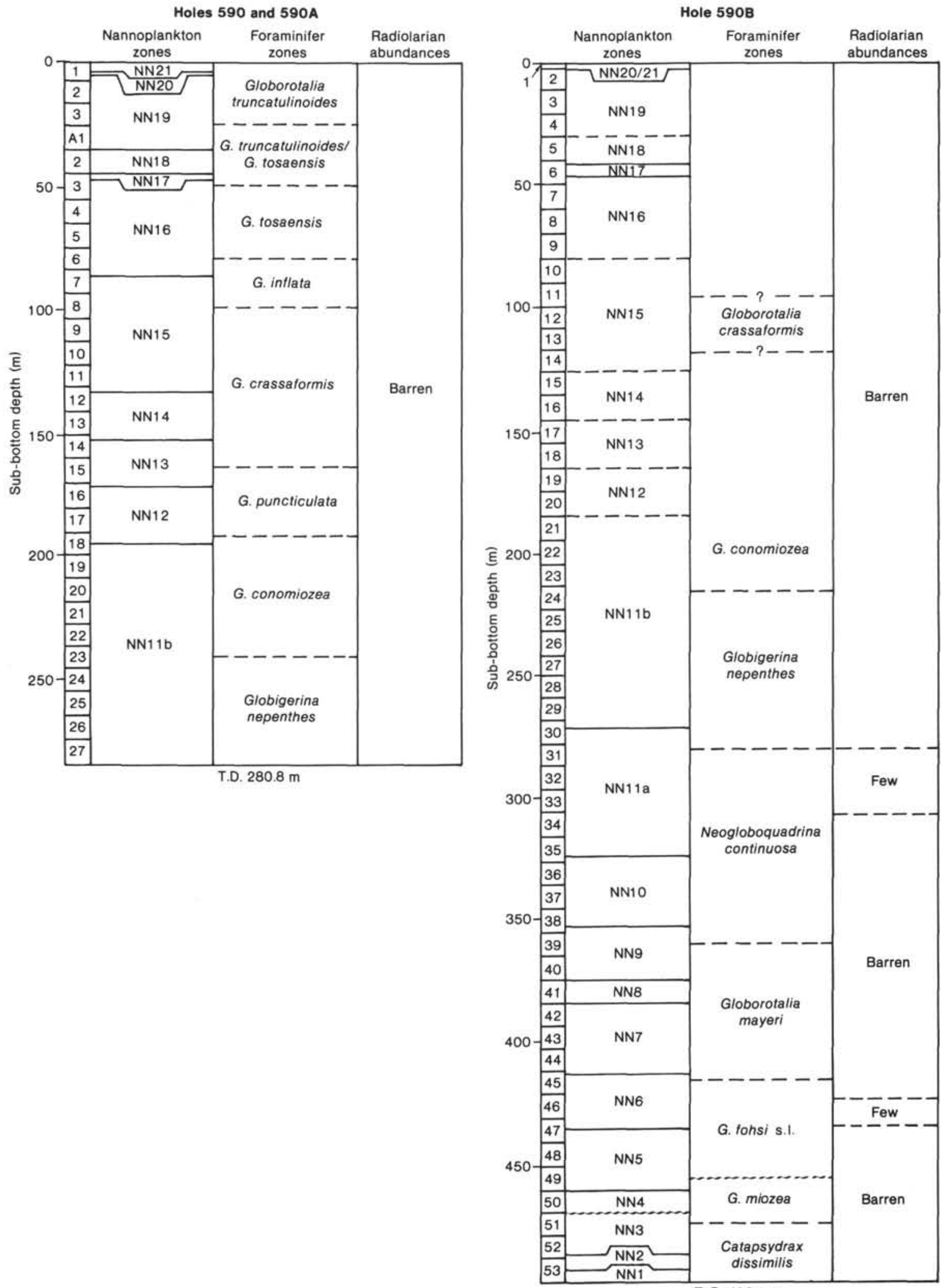

Figure 7. Correlation among calcareous nannoplankton, foraminifer, and radiolarian zones at Site 590.

Catapsydrax dissimilis Zone

There was very poor preservation of the fauna; the presence of the zonal fossil and the absence of *G. kugleri* confirmed the zonal designation.

Paleobiogeography

It is difficult to interpret the early Miocene fauna because of the low diversity caused by bad preservation, but it appears to be a relatively cool water fauna which lacks such tropical species as *Globigerinatella insueta* and *Hastigerinella bermudezi.*

The middle Miocene appears also to be represented by a relatively cool water fauna. The dominant keeled *Globorotalia* is *G. miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are distinctive tropical forms, supports this general observation about the assemblages.

The late Miocene up to and including the early Pliocene *G. puncticulata* Zone fauna is represented by relatively cool water faunas. The younger faunas from the early Pliocene to Pleistocene, indicate sporadically warmer conditions, with the influx of *G. tumida* and *Pulleniatina obliquiloculata.*

Major Boundaries

Pliocene/Pleistocene: well marked by the evolutionary first appearance of *Globorotalia truncatulinoides.*

Miocene/Pliocene: is established at this site at the last appearance of *Globorotalia conomiozea* in Core 590A-18; the first appearance of *G. puncticulata* occurs in Sample 590A-17,CC.

Benthic Foraminifers

Benthic foraminifers were examined in the fraction >63 μm in core-catcher samples from Cores 590-1 to 590-3, 590A-1 to 590A-27, and 590B-30 to 590B-53. The larger part of the Miocene section (590A-24 to 590A-27, 590B-30 to 590B-53) was not well preserved, the foraminiferal faunas are impoverished, and in the middle to lower Miocene (590B-35 to 590B-53) there may be as few as six species remaining in the samples. Pliocene faunas are well preserved, particularly in the upper Pliocene. Fluctuations in faunal abundance through the lower Pliocene are probably a function of variations in the otherwise high sedimentation rates.

The most diagenetically altered faunas occur in the *Globorotalia miozea–G. fohsi* s.l. Zones (590B-53 to 590B-44,CC). Species apparently resistant to diagenetic dissolution include *Oridorsalis umbonatus, Bolivina subaenariensis, Cibicides rugosus, Melonis barleeanum, Heterolepa kullenbergi*, and *Globocassidulina subglobosa.* These species occur most consistently through the remainder of the Miocene section. Although the majority of appearances and disappearances and the fluctuations in specific abundances are considered an artifact of diagenesis, the disappearance of *Cibicidoides tuxpamensis* at the top of the *Globorotalia fohsi* s.l. Zone (590B-45,CC) is considered real, as it occurs at approximately the same level at Site 588.

The one species which may be indicative of upslope benthic migration, *Melonis pompilioides*, was found in only one interval (590B-34,CC) in the mid-*Neogloboquadrina continuosa* Zone of early late Miocene age.

Radiolarians occur throughout the section from the *Globigerina nepenthes* Zone (590A-25 to 590A-27,CC (mid-late Miocene), to 590B-27 to 590B-47,CC (middle Miocene). They are joined by increased amounts of spicules and a large influx of pyritized worm burrows at 590A-27,CC and 590B-28,CC. These samples contain a unique benthic fauna, more than 50% of which consists of *Rectuvigerina multistriata*, accompanied by *Hopkinsina mioindex* in large numbers, a rare *Buliminella* which occurs only at this level (as at Site 588), and a fauna otherwise similar to those above and below.

At the top of the *Globorotalia conomiozea* Zone, preservation improves, benthic diversity increases, the first miliolids appear (or are preserved), and the first hispido-costate uvigerinids, *Uvigerina hispido-costata* and *U. peregrina*, occur in the faunas. Uvigerinids occur in increased abundance in many areas of the world near the top of the Miocene, for example, in the Canary Current (Lutze, 1979). The fact that a new group colonizes the Site 590 area, a group which will dominate the uvigerinid populations from the late Pliocene through the Quaternary, suggests that conditions resembling those during the glacials developed temporarily during the latest Miocene.

Pliocene benthic faunas contain about 20 to 25 species and closely resemble faunas from the Miocene. Only six new species appear throughout the epoch. Benthics are very abundant in the residues and faunal composition appears to be very similar throughout the section. In the top few samples of Hole 590A, preservation favors even delicate species such as *Anomalina semipunctata*, and the very flattened, spinose morphotype of that taxon found at this site.

A pronounced faunal and sedimentation change occurs at the top of the lower Miocene (590A-7 to 590A-8,CC). *U. hispido-costata* rejoins the faunas, and in the sample directly above, *U. peregrina* reappears, joined by *M. pompilioides.* These benthic changes suggest cooling and upward migration of benthics, which then remain in this area through the course of the Pliocene and into the Quaternary.

The three Quaternary samples (590-1 to 590-3,CC) contain benthic samples similar to those of the Pliocene. Glacial–interglacial cycles may be determinable by the alternating abundances of uvigerinids versus cibicidids and cassidulinids.

Calcareous Nannoplankton

Core-catcher samples, along with additional samples sufficient to accurately determine zonal boundaries, were examined for calcareous nannoplankton. All of the zonal indicators are present, with the exception of *Helicosphaera ampliaperta.* The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis.* Calcareous nannoplankton are abundant throughout the section at

Site 590. Preservation is good in the Quaternary and Pliocene. In the Miocene, preservation deteriorates from moderate to poor, and in particular most of the discoasters are heavily overgrown.

Hole 590

Quaternary

Three cores were obtained before the hole terminated at a depth of 26.2 m BSF. Samples 590-1-1, 5-6 cm to 590-3, 5-6 cm contain *Emiliania huxleyi* and belong in the late Pleistocene *Emiliania huxleyi* Zone (NN21). The late Pleistocene *Gephyrocapsa oceanica* Zone (NN20) includes Samples 590-1-4, 5-6 cm and 590-1-5, 5-6 cm. Samples 590-1,CC to 590-3-2, 5-6 cm contain common *Emiliania ovata* and are placed in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The presence of *Calcidiscus macintyrei* in Samples 590-3-3, 5-6 cm to 590-3,CC places these samples in the lower subzone of the early Pleistocene *E. ovata* Zone (NN19a).

Hole 590A

Quaternary

Sample 590A-1-7, 5-6 cm is placed in the lower subzone of the early Pleistocene *E. ovata* Zone (NN19a) based upon the common occurrences of *E. ovata* and *C. macintyrei*.

Pliocene

The presence of *D. brouweri* from Sample 590A-2-1, 5-6 cm to the last occurrence of *D. pentaradiatus* in 590A-3-1, 5-6 cm places Core 590A-1 to Samples 590A-2-1, 5-6 cm to 590A-2,CC in the late Pliocene *Discoaster brouweri* Zone (NN18). Sample 590A-3-2, 5-6 cm, above the last occurrence of *D. surculus* in Sample 590A-3-2, 5-6 cm, is placed in the late Pliocene *D. pentaradiatus* Zone (NN17). The interval from Samples 590A-3-2, 5-6 cm to 590A-7-3, 0-1 cm, above the last occurrence of *Reticulofenestra pseudoumbilica* in Sample 590A-7-4, 0-1 cm, is placed in the late Pliocene *D. surculus* Zone (NN16).

The early Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15) is represented in Samples 590A-7-4, 0-1 cm to 590A-11-7, 0-1 cm, above the last occurrence of *Amaurolithus tricorniculatus* in Sample 590A-11,CC. Samples 590A-11,CC to 590A-14-1, 0-1 cm are placed in the early Pliocene *D. asymmetricus* Zone (NN14), based upon the co-occurrence of *D. asymmetricus* and *A. tricorniculatus*. Sample 590A-14-2, 0-1 cm, below the first occurrence of *D. asymmetricus* to the first occurrence of *Ceratolithus rugosus* in Sample 590A-16-2, 5-6 cm, is placed in the early Pliocene *Ceratolithus rugosus* Zone (NN13). Samples 590A-16-3, 5-6 cm to 590A-18-5, 5-6 cm, are placed in the early Pliocene *Amaurolithus tricorniculatus* Zone (NN12).

Miocene

The co-occurrence of *A. primus* and *D. quinqueramus* in Samples 590A-18-6, 5-6 cm to 590A-27,CC places these samples in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). Hole 590A ended with Core 590A-27 at a depth of 280.8 m BSF.

Hole 590B

Hole 590B begins at the top of the section in Zone NN20; therefore, only core-catcher samples were examined until Zone NN11b was reached.

Miocene

The first occurrence of *A. primus* is in Sample 590B-30-3, 5-6 cm. Therefore the boundary between the upper and lower subzone of the late Miocene *D. quinqueramus* Zone (NN11a/b) is between this sample and Sample 590B-30-4, 5-6 cm. The interval from Sample 590B-30-4, 5-6 cm to the first occurrence of *D. quinqueramus* in Sample 590B-35-5, 5-6 cm is placed in the lower subzone of the late Miocene *D. quinqueramus* Zone (NN11a). The interval between the first occurrence of D. quinqueramus in Sample 590B-35-5, 5-6 cm and the last occurrence of *D. hamatus* in Sample 590B-38,CC is placed in the middle Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus* from Samples 590B-38,CC to 590B-40,CC places these samples in the middle Miocene *D. hamatus* Zone (NN9). Samples 590B-41-5, 5-6 cm and 590B-41,CC, above the first occurrence of *Catinaster coalitus*, are placed in the middle Miocene *Catinaster coalitus* Zone (NN8). The interval from Samples 590B-42-1, 5-6 cm and 590B-45-1, 5-6 cm, above the first occurrence of *D. kugleri*, is placed in middle Miocene *D. kugleri* Zone (NN7). Samples 590B-45-3, 5-6 cm to 590B-47-3, 5-6 cm, above the last occurrence of *Sphenolithus heteromorphus* in Sample 590B-47-5, 5-6 cm, are placed in the middle Miocene *D. exilis* Zone (NN6). The first occurrence of *D. exilis* in Sample 590B-49,CC places Samples 590B-47-5, 5-6 cm to 590B-49,CC in the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). Samples 590B-50-1, 5-6 cm to 590B-50,CC, above the last occurrence of *S. belemnos* in Sample 590B-51-1, 5-6 cm, are placed in the early Miocene *Helicosphaera ampliaperta* Zone (NN4). The interval from the last occurrence of *S. belemnos* in Sample 590B-51-1, 5-6 cm to the last occurrence of *Triquetrorhabdulus carinatus* in Sample 590B-52,CC, is placed in the early Miocene *S. belemnos* Zone (NN3). The co-occurrence of *T. carinatus* and *D. druggii* in Samples 590B-52,CC and 590B-53-1, 5-6 cm places these samples in the early Miocene *D. druggii* Zone (NN2). The absence of *D. druggii* and the presence of *T. carinatus* in Samples 590B-53-3, 5-6 cm to 590B-53,CC places these samples in the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1). Drilling was terminated at a depth of 499.1 m BSF.

PALEOMAGNETISM

The paleomagnetic properties of sediments from this site were generally similar to those of previous Leg 90 sites, except that there is more evidence of viscous overprinting and long-term remagnetization.

Holes 590 and 590A were subsampled at three specimens per section, and 590B was subsampled at two per section of HPC cores and one per section of XCB cores (590A-28 onward). The Kuster orientation tool was deployed in Holes 590A and 590B with success rates of 60 and 48%, respectively. To date, laboratory NRM measurements have been completed on one specimen per section from Holes 590 and 590A (Table 3). The pattern of intensity variation is: (1) high values (1 to 5 μG) in the oxidized surface Subunit IA, Core 590-1, (2) medium intensities (about 0.1 μG) in Subunit IB, Cores 590-2 to 590-5, and (3) very low intensities (0.005 to 0.1 μG) in the remainder of Hole 590A. The last region is characterized by very high accumulation rates during the late Pliocene; they dilute the detrital ferromagnetic component. Depths at which high-intensity spikes were noted are reported in Table 4.

A polarity stratigraphy can be traced back to 4 m.y. (Fig. 8); it is consistent with the microfossil zonations. The Olduvai Event is poorly resolved. Prior to 4 m.y. ago, inclinations are consistently shallower than the expected axial dipole value, and show a definite negative (normal) bias. This must be a consequence of viscous overprinting and/or authigenic growth of magnetic minerals on a time scale which is long compared with the average polarity interval of about 3×10^5 yr. Authigenic iron sulfides are common throughout the section and probably reflect authigenic growth.

SEDIMENTATION RATES

Sedimentation rates are determined by calcareous nannoplankton boundaries and their ages, as discussed in the Introduction.

At Site 590, three holes were drilled in present-day water depths of about 1300 m. The first two holes cover the recent to late Miocene (NN11b) interval down to 280.8 m (Fig. 9). Hole 590B duplicated this interval and was terminated at 499.1 m, after penetrating lower upper Miocene to lower Miocene calcareous sediments. In Hole 590B only core catchers were investigated from 0 to about 280 m sub-bottom, and calculated sedimentation rates are less reliable in this particular interval (dashed line in Fig. 10).

In the early Miocene (Hole 590B, NN1 to top of NN3) the sedimentation rate is 14.4 m/m.y. in indurated calcareous sediments. Between Samples 590B-50,CC and 590B-51-1, the sedimentation rate changes, reaching 29.4 m/m.y. in the middle Miocene (Hole 590B, NN5 to NN7 top) (Fig. 10). The sedimentation rate in the late middle Miocene to early Pliocene interval (Hole 590B, NN7 top to NN13 top) is based on seven datum levels and is 29.1 m/m.y., also in calcareous sediments (Fig. 10). Then a rather remarkable increase to 56.7 m/m.y. was noted in the early to late Pliocene calcareous sequence in Hole 590A (NN13 top to NN18 top), based on five datum levels (Fig. 9). In the Quaternary (Holes 590 and 590A, above NN18 top) the sedimentation rate drops to 19.9 m/m.y. (Fig. 9), probably because of winnowing, as sediments are somewhat coarser than below.

Sedimentation rates in the upper part of Hole 590B, in which only core-catcher samples were investigated, are similar to those of Holes 590 and 590A for the early to late Pliocene (52.4 m/m.y.) and for the Quaternary (17.2 m/m.y.).

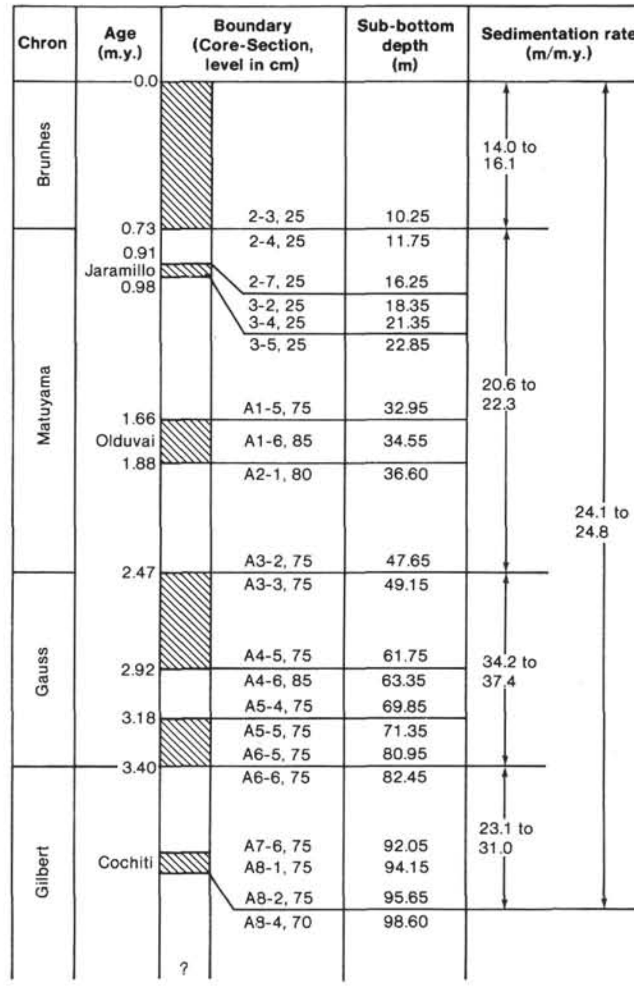

Figure 8. Magnetic polarity stratigraphy and sedimentation rates for Hole 590 and the upper part of Hole 590A. The Olduvai Subchron is poorly resolved.

Table 3. Laboratory NRM measurements, Holes 590 and 590A.

	Hole 590	Hole 590A
Geometric mean intensity (μG)	0.335	0.045
Scalar mean inclination ($\pm$1 s.d.)	$-26.5 \pm 39.0°$	$-12.9 \pm 37.6°$
Axial dipole inclination	-50.9	
Mean angle between repeats		6.1°

Table 4. High intensity magnetization spikes in Holes 590 and 590A.

Sample (level in cm)	Sub-bottom depth (m)	Intensity (μG)
Hole 590		
2-7, 25	16.25	3.375
Hole 590A		
6-5, 75	80.95	0.353
14-6, 75	159.25	0.534
21-6, 75	226.45	0.244
23-6, 75	245.65	0.378
25-5, 75	263.35	0.391

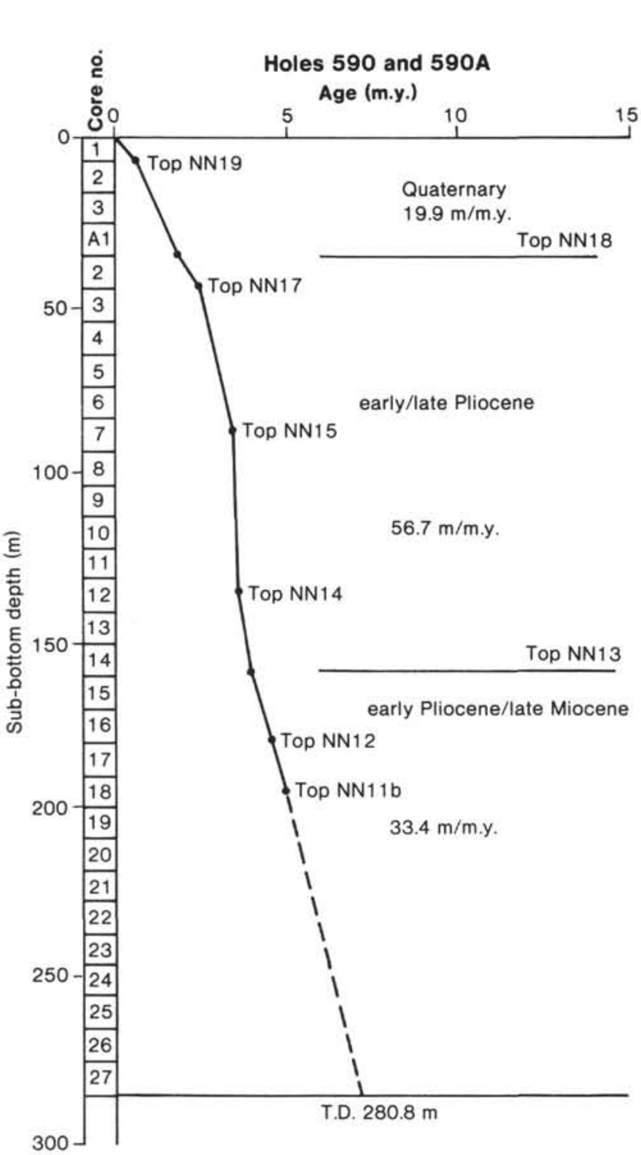

Figure 9. Sedimentation rates in Holes 590 and 590A.

SUMMARY AND CONCLUSIONS

Site 590 lies to the east of the crest of Lord Howe Rise. This site was selected as one of several that make up a north-south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites forming a depth traverse to study changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m).

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. It occupies a shallow-water, transitional position between warm subtropical waters to the north (Site 588) and temperate sites to be drilled further south and provides an important section for correlation between these sites.

Site 590 consists of three holes (Fig. 11): Hole 590, which was continuously cored with the HPC from 0–26.2 m sub-bottom; Hole 590A, which was continuously cored with the HPC from 26.2–280.8 m sub-bottom; and Hole 590B, which was continuously cored with the HPC from 0–250.7 m sub-bottom and rotary drilled with the XCB from 250.7–499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. The primary and persistent disturbance exists as a zone of soupy sediments usually 20–30 cm in thickness, at the top of each core. In a few cores inflow has caused highly disturbed intervals in the upper one or two sections, but a very high percentage of the core lengths are mechanically undisturbed sediments. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. The value of the cores obtained using the extended core barrel is that at most levels the sediment biscuits do not seem to have been moved far from their original stratigraphic positions, in contrast with conventional rotary coring which, in the less consolidated layers, creates clear vertical disturbance within each core.

The three holes drilled at Site 590 provide a complete calcareous sequence from early Miocene through Recent (Fig. 11), with the exception of an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorotalia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 does not occur at this site. A paleomagnetic polarity stratigraphy has been identified down to the middle part of Gilbert Chron (about 4.2 m.y. ago).

The section (Fig. 11) is represented mostly by foraminifer-bearing nannofossil ooze (or chalk) or foraminifer-rich nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, with greatest abundance (1 to 5%) in the early late Miocene (Cores 590B-32 to 590B-35). The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasional sponge spicules.

The sequence contains only traces of nonbiogenic components, but clear volcanic ash is quite persistent. Numerous light green laminae from early late Miocene to early Miocene may be altered volcanic ash layers. Much of the sequence is very light gray to white ooze and chalk. Zones richer in foraminifers are darker gray to light olive gray. Bioturbation is moderate in the early Miocene, intense in the middle to early late Miocene, moderate in the late late Miocene and only slight in the Pliocene and Quaternary.

The sediment becomes more indurated with depth. Sediments above 275 m sub-bottom (middle late Miocene) consist of ooze which becomes progressively stiffer with depth. Sediments below ~275 m sub-bottom are chalk, with clear recrystallization seen in the early Miocene (Cores 590B-51 to 590B-53).

The sequence at Site 590 is divided into three subunits (Fig. 11) based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm sub-bottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer-nannofossil ooze, and repre-

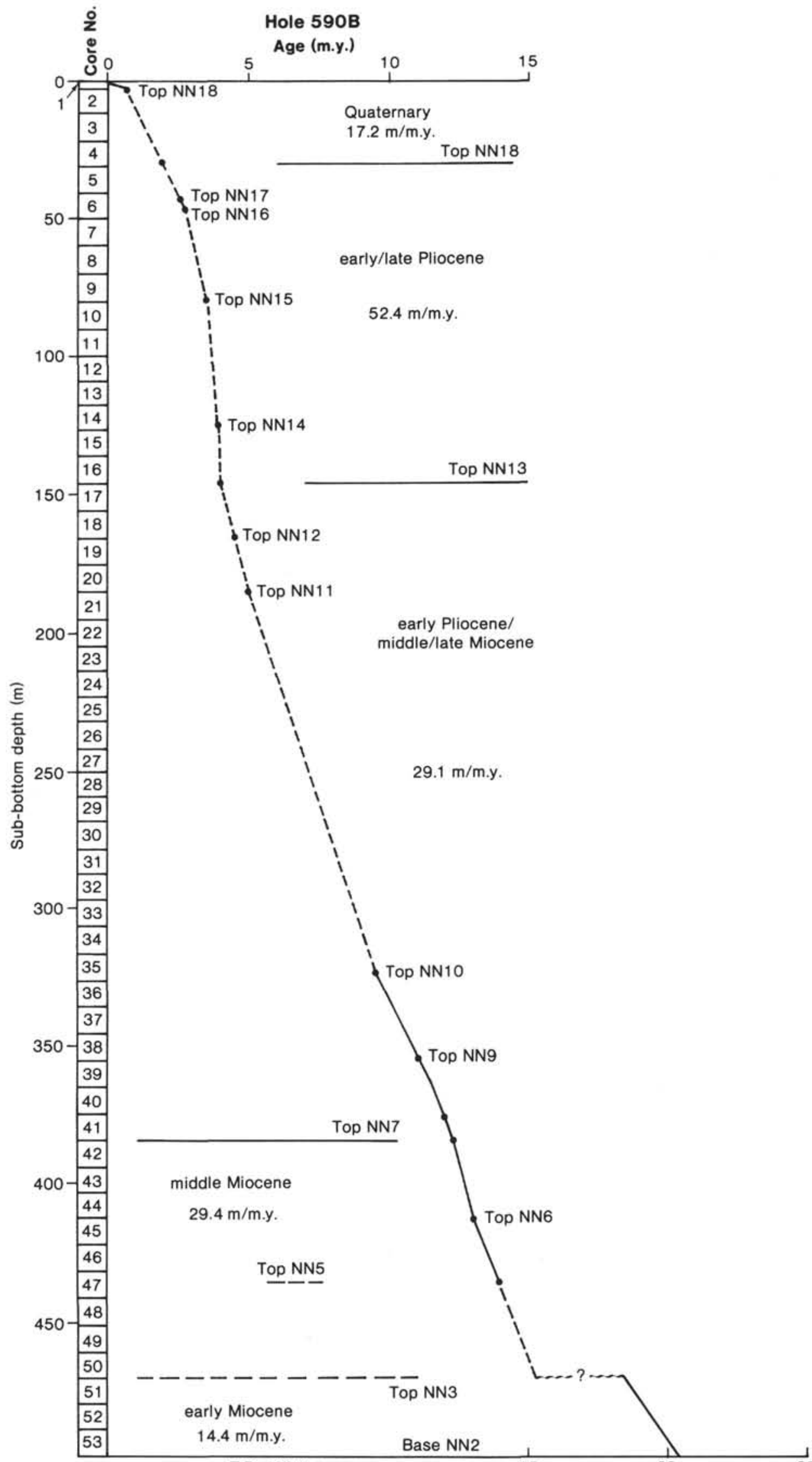

Figure 10. Sedimentation rates in Hole 590B.

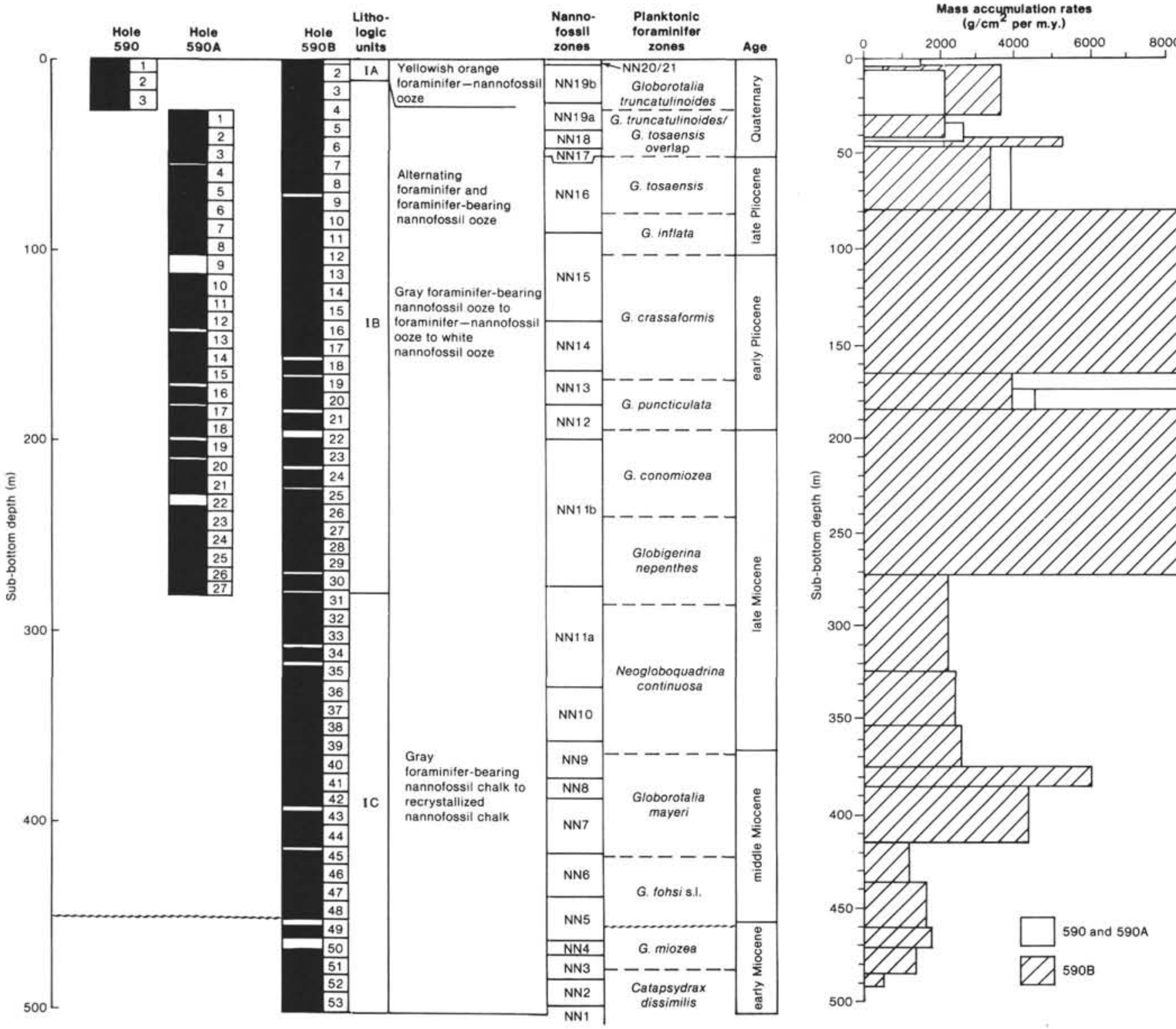

Figure 11. Summary lithology, biostratigraphy, and mass accumulation rates of Site 590. Recovery in black.

sents the zone of oxidation and possible current winnowing activity near the sediment/water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing nannofossil ooze and layers of light olive gray foraminifer–nannofossil ooze. The change in percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom-current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional foraminifer-bearing nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this subunit, which resembles the upper part of Subunit IB in consisting of alternating, very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to chalk. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450–499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk, lacks the foraminifer-rich layers of the portion above, and is less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

Site 590 provides a superb stratigraphic sequence of calcareous microfossils for the middle Miocene and younger. Biostratigraphic zonal sequences of transitional type occur in combination with an important temperate component. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene.

It is difficult to interpret the early Miocene fauna because of the low diversity arising from bad preservation, but it appears to be a temperate fauna lacking tropical species.

The middle Miocene appears also to be represented by a temperate fauna. The dominate keeled globorotaliid is *Globorotalia miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are clear tropical forms, support this general observation of the assemblages.

The fauna of the late Miocene, up to and including the early Pliocene *Globorotalia puncticulata* Zone, is also represented mostly by temperate faunas. The younger faunas from the early Pliocene to Pleistocene were sporadically warmer, with the influx of *G. tumida* and *Pulleniatina obliquiloculata*.

Preservation of calcareous nannoplankton is good in the upper part of the sequence (Quaternary–Pliocene) and moderate (late Miocene) to poor (early middle Miocene) in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the early Miocene unconformity and very poor below. The benthic foraminifers are well-preserved throughout much of the sequence; however, below the late Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

At Site 590 the Pliocene/Quaternary and Miocene/Pliocene boundaries are well represented and the late Neogene exhibits clear, gradual, evolutionary sequences within some lineages. This is particularly noticeable for the *Globorotalia (Globoconella)* lineage, with clear transitions from *G.* (*G.*) *conoidea* (= *G. miotumida*) to *G.* (*G.*) *conomiozea* to *G. puncticulata sphericomiozea* to *G. puncticulata* to *G. inflata*. At nearby Site 206, much of the lineage was missing in the hiatus associated with the Miocene/Pliocene boundary.

Benthic foraminifers occur throughout the sequence but with varying quality of preservation. In the early and middle Miocene, as few as six species remain following diagenetic dissolution. Diversity increases in the early part of the late Miocene and preservation is only moderately good. Preservation improves in the middle late Miocene and assemblages are very well preserved in the Pliocene and Quaternary.

Paleoenvironmental History of Site 590

Neogene sediments at Site 590, near the crest of Lord Howe Rise, were laid down in a pelagic, open-ocean environment at middle bathyal depths that have changed little during the last 23 m.y. Calcareous oozes were deposited in a relatively uncomplicated environment at these shallow depths, and with virtually no terrigenous sedimentary influences other than traces of fine eolian sediments and more common and fluctuating input of volcanic ash. During this time, very little siliceous biogenic material was preserved in the sediment, although almost certainly there was moderate siliceous productivity by plankton in the overlying surface waters. In this region, the Neogene planktonic foraminiferal assemblages are dominated by temperate rather than tropical elements, although the latter exhibit brief incursions of greater abundance.

During the early Miocene, from about 23 to 16 m.y., there were low rates of sedimentation (14 m/m.y.) in this area, and hiatus-forming erosion occurred fairly briefly at about 17.5 and 16.5 m.y. A scarcity of foraminifers in this interval probably resulted from diagenetic dissolution rather than from changes in productivity or dissolution. The earliest Miocene at this site represents an acme of explosive volcanicity in the source regions, judging from a large number of altered volcanic ash layers. Explosive volcanicity of sufficient intensity to form visible ash layers continued through to the early late Miocene, but at lower intensities than during the early late Miocene.

During the middle to early late Miocene (15 to 8 m.y.), sedimentation rates of calcareous biogenic materials increased significantly to about 30 m/m.y. and no hiatus-forming erosion occurred. This situation resulted from decreased bottom-water erosion in the ocean, although deposition of more foraminifer-rich horizons in otherwise foraminifer-bearing nannofossil ooze indicates intervals where bottom-water activity was sufficiently intense to cause winnowing of fine sediments. During this interval, bioturbation was the highest of the entire Neogene, suggesting that organic material was delivered at a higher rate to the ocean floor.

During the late late Miocene (8 m.y.) to the middle Pliocene (3 m.y.) rates of calcareous sediment deposition increased even further to a surprisingly high 57 m/m.y. At this time, rather uniform nannofossil oozes were laid down. Few of the more foraminifer-rich levels were deposited. The lithofacies suggests deposition in a rather uniform environment on the ocean floor, mostly lacking the episodes of increased bottom-water activity that occurred during other times of the Neogene. Bioturbation decreased to moderate levels. The rather uniform depositional conditions were not matched by surface water, which, in contrast, exhibited great paleoceanographic change. For example, during the latest Miocene, from 6 to 5 m.y., the planktonic foraminiferal assemblages became distinctly cooler as temperate waters migrated northward across the area. There were also decreases in faunal diversity and in average specimen size. The latest Miocene cooling is well documented elsewhere, including areas to the south of Site 590 (Kennett and Vella, 1975). At the same time, the first hispido-costate uvigerinids appeared within the benthic foraminifer assemblages. Uvigerinids appeared in increased abundances in many areas of the world's oceans in the latest Miocene in association with the δC^{13} shift (Keigwin, 1979), which reflected important paleoceanographic changes. Since these uvigerinids become more typical on a permanent basis in late Pliocene to Quaternary benthic foraminiferal assemblages, their presence suggests that conditions resembling the glacials developed temporarily during the latest Miocene.

The middle Pliocene (3 m.y.) to Quaternary represents the latest phase of paleoenvironmental evolution at Site 590. About 3 m.y. ago, a pronounced sediment change occurred which is marked by greater winnowing of the fine-grained sediment fraction at certain intervals in alternation with calcareous-nannofossil-rich, foraminifer-poor layers. The succession again indicates episodes of enhanced bottom-water activity alternating with quieter episodes. Sedimentation rates responded by decreasing to 17–20 m/m.y., which is quite low for this area.

The hispido-costate uvigerinids returned on a permanent basis by upward migration from greater depths during a cooling episode. Large-scale oscillations occurred in surface water masses, with brief incursions of relatively warm subtropical assemblages into sequences otherwise dominated by temperate elements.

The youngest part of this interval, which is at and close to the sediment/water interface (upper 40 cm), is winnowed, oxidized, and more foraminifer-rich. This represents the latest of a succession of such layers, which reflect an increase in bottom-water activity. Older such intervals in the section have since undergone chemical reduction and inferred color change from brown to light olive gray.

The changes in sedimentation and in benthic foraminiferal faunas ~3 m.y. ago certainly were related to widespread paleoceanographic changes in the ocean associated with global climatic cooling. At that time bottom waters intensified in activity even at the shallow-water depths of Site 590, and cooler, deeper waters migrated upwards to shallow intermediate depths.

One of the surprises resulting from drilling at Site 590 was the high sedimentation rate (uncorrected for sediment porosity) in largely calcareous biogenic intervals, especially during the Pliocene (50–57 m/m.y.).

The seismic profile in the area shows no clear ponding of sediments for much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, spectacularly high in the Pliocene, are due to high levels of calcareous biogenic productivity.

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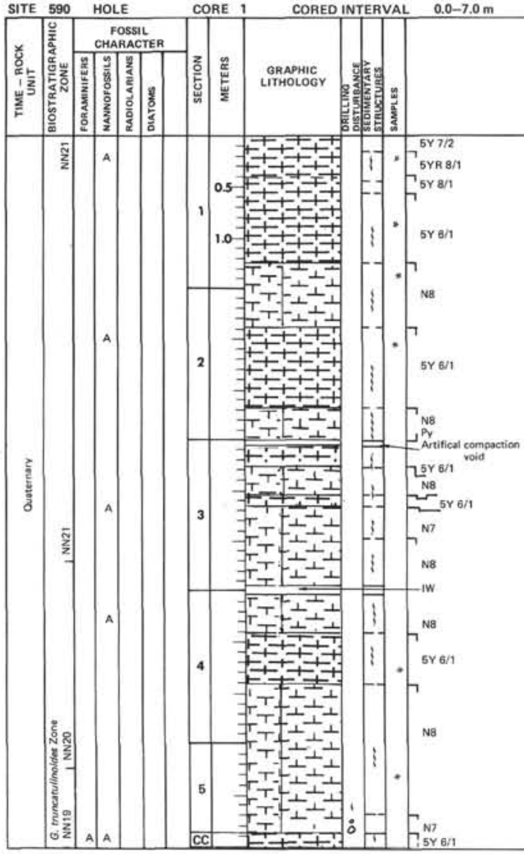
SITE 590 HOLE CORE 1 CORED INTERVAL 0.0–7.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL OOZE, yellowish gray (oxidized) zone, soft. No obvious burrowing, contacts gradational.

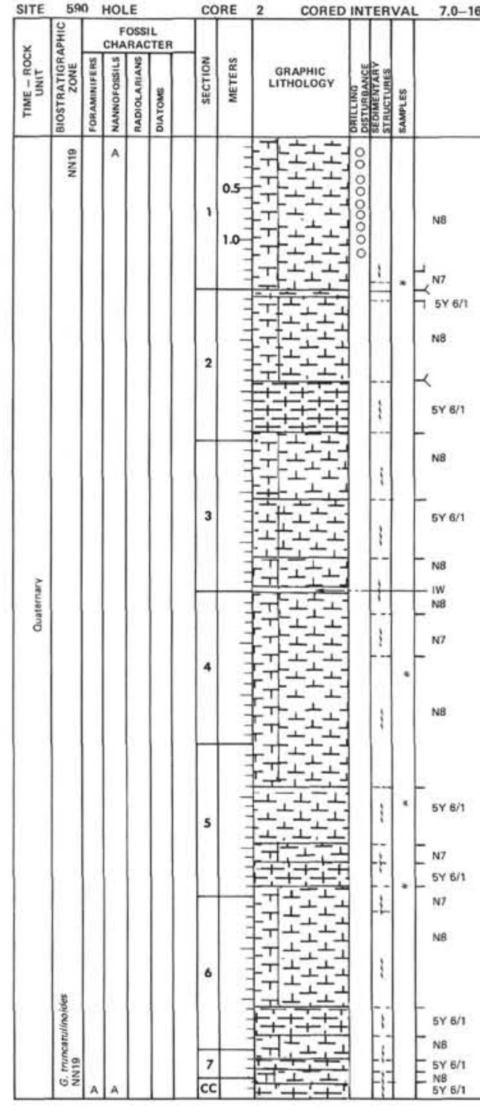
FORAMINIFER-NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N8), soft, no obvious burrowing, occasional blebs of iron sulfide, contacts gradational.

SMEAR SLIDE SUMMARY:

	1, 22	1, 90	1, 132	4, 71	5, 33	2, 49
	D	D	D	D	D	M
Texture:						
Sand	C	C	C	C	R	C
Silt	A	A	C	C	C	A
Clay	A	A	A	A	D	A
Composition:						
Volcanic glass	–	–	–	C	–	–
Foraminifers	A	A	C	A	C	A
Calc. nannofossils	A	A	A	A	D	A

SITE 590 HOLE CORE 2 CORED INTERVAL 7.0–16.3 m



LITHOLOGIC DESCRIPTION

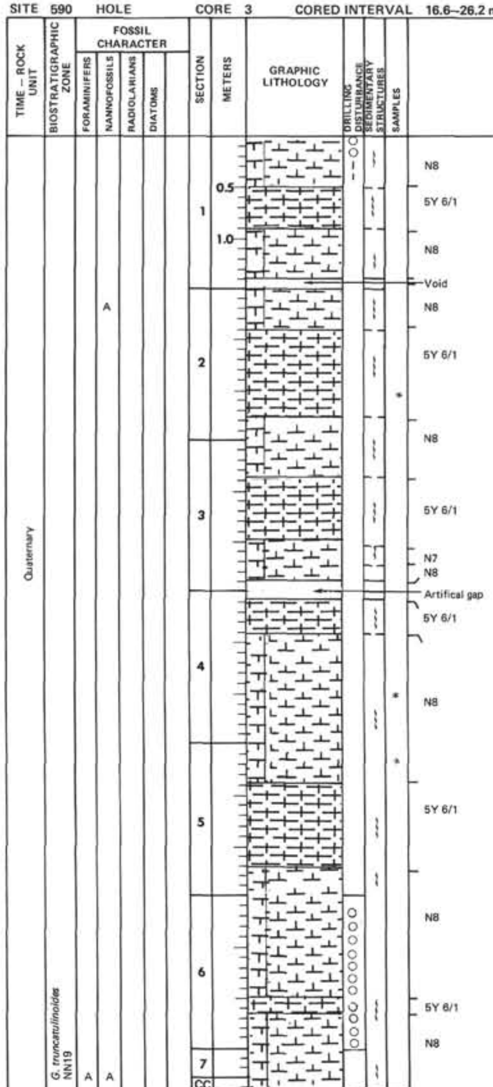
FORAMINIFER-BEARING, NANNOFOSSIL OOZE, light gray (N8), soft, occasional burrows and iron sulfide blebs and streaks.

FORAMINIFER-NANNOFOSSIL OOZE, soft, light olive gray (5Y 6/1), occasional burrows and iron sulfide blebs and streaks.

SMEAR SLIDE SUMMARY:

	1, 134	4, 78	5, 53	5, 150
	D	D	D	M
Texture:				
Sand	C	–	R	C
Silt	A	C	C	A
Clay	A	D	A	A
Composition:				
Carbonate unspec.	–	R	R	R
Foraminifers	A	C	A	A
Calc. nannofossils	A	D	A	A

SITE 590 HOLE CORE 3 CORED INTERVAL 16.6–26.2 m



LITHOLOGIC DESCRIPTION

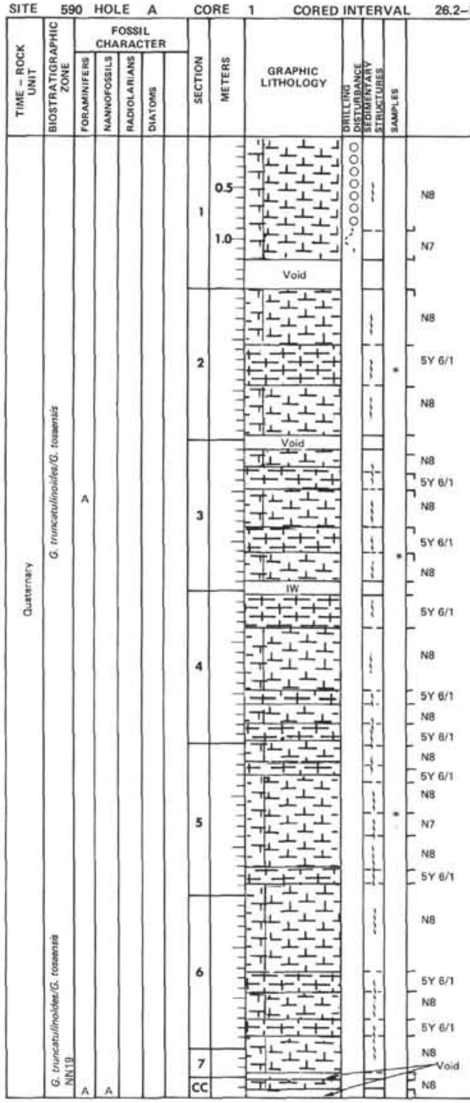
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, periodic burrows.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft, occasional blebs and streaks of pyrite and burrowing activity.

SMEAR SLIDE SUMMARY:

	2, 104	4, 106	5, 16
	D	D	M
Texture:			
Sand	C	R	R
Silt	A	C	C
Clay	A	D	D
Composition:			
Pyrite	–	–	R
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE A CORE 1 CORED INTERVAL 26.2–35.8



LITHOLOGIC DESCRIPTION

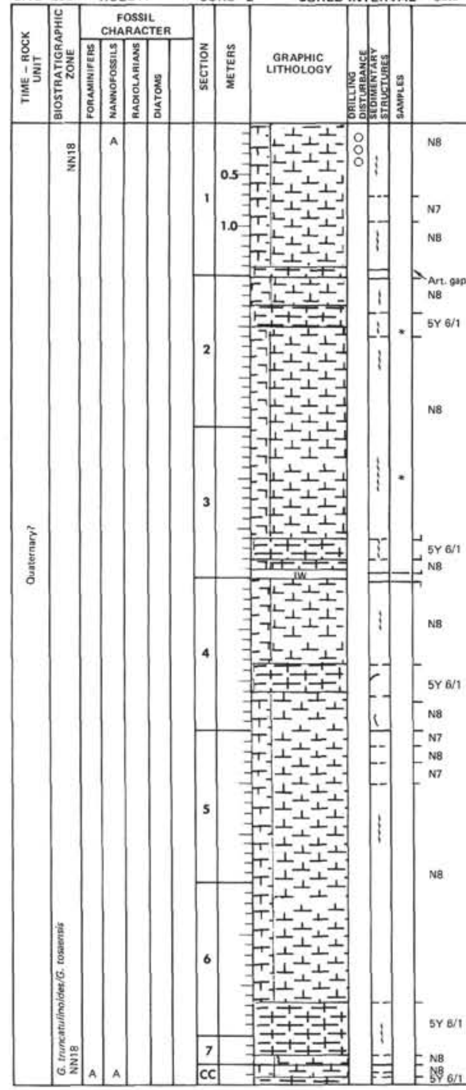
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, occasional burrows.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), higher percentage of forams, soft, occasional blebs and streaks of pyrite and burrows.

SMEAR SLIDE SUMMARY:

	2, 80	3, 114	5, 71
	D	D	D
Texture:			
Sand	C	R	R
Silt	A	C	C
Clay	A	D	D
Composition:			
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE A CORE 2 CORED INTERVAL 35.8–45.5 m



LITHOLOGIC DESCRIPTION

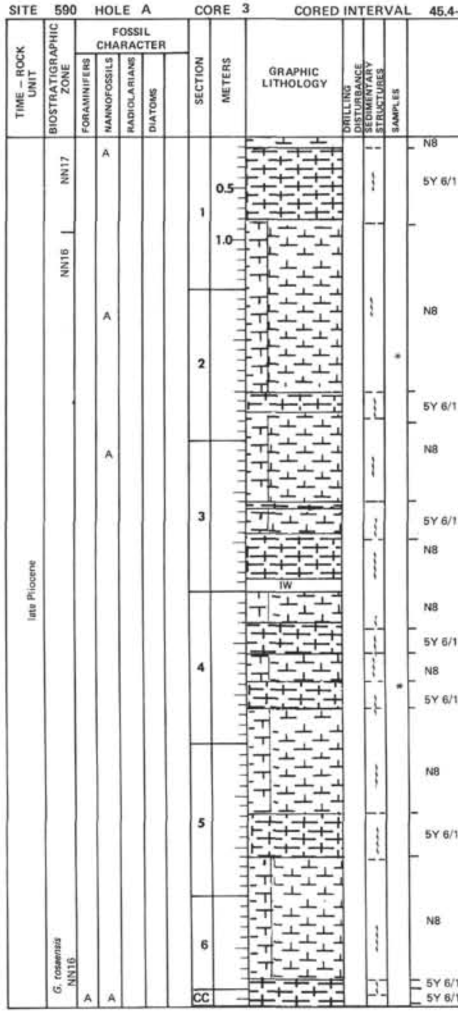
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7), soft, occasional burrows and streaks and blebs of pyrite.

NANNOFOSSIL FORAMINIFER OOZE, light olive gray (5Y 6/1), soft, occasional burrows and streaks and blebs of pyrite.

SMEAR SLIDE SUMMARY:

	2, 51	3, 95
	D	D
Texture:		
Sand	C	R
Silt	A	C
Clay	A	D
Composition:		
Foraminifers	A	C
Calc. nannofossils	A	D

SITE 590 HOLE A CORE 3 CORED INTERVAL 45.4–55.0 m



LITHOLOGIC DESCRIPTION

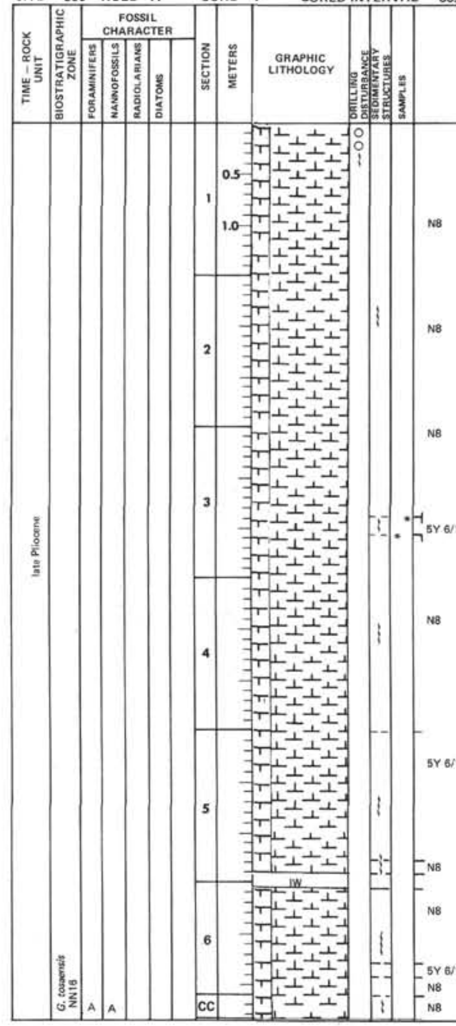
FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, occasional blebs and streaks of pyrite, burrows common.

FORAMINIFER NANNOFOSSIL OOZE, light olive gray (5Y 6/1), soft, occasional burrows and blebs and streaks of pyrite.

SMEAR SLIDE SUMMARY:

	2, 70	4, 98
	D	D
Texture:		
Sand	R	C
Silt	C	C
Clay	D	A
Composition:		
Carbonate unspec.	–	R
Foraminifers	C	A
Calc. nannofossils	D	A

SITE 590 HOLE A CORE 4 CORED INTERVAL 55.0–64.6 m



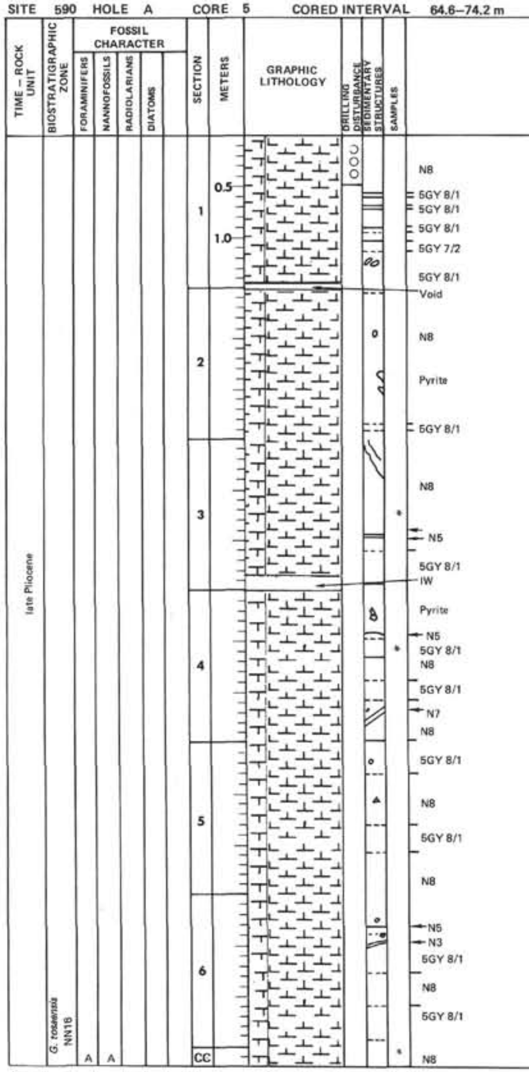
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) to light olive gray (5Y 6/1), soft, occasional blebs of pyrite and burrows.

SMEAR SLIDE SUMMARY:

	3, 86	3, 106
	D	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 5 CORED INTERVAL 64.6–74.2 m



LITHOLOGIC DESCRIPTION

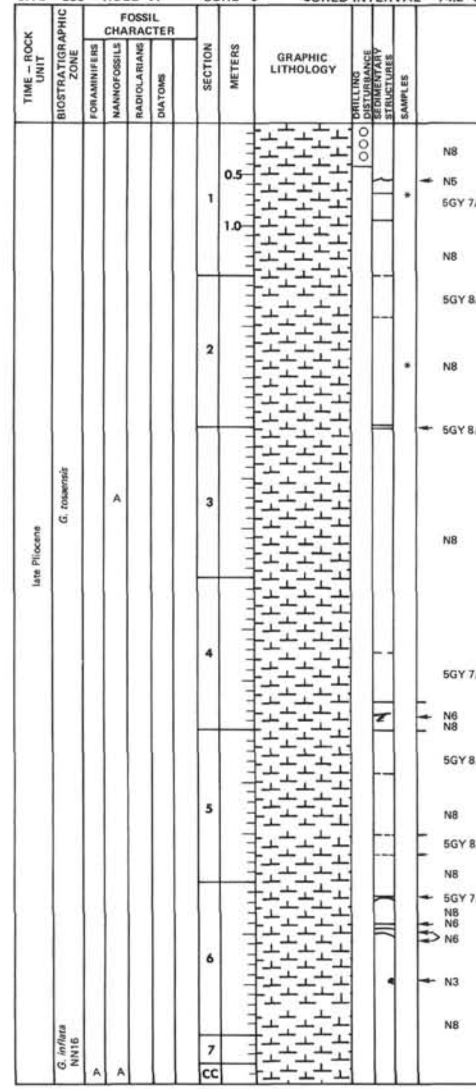
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1), dark (N5) spots and streaks throughout the entire core (↦ iron sulfide minerals), undefined burrows, near 30–40 cm (Section 6) *Planolites.*

SMEAR SLIDE SUMMARY:

	3, 80	4, 58	CC[1]
	D	D	M
Composition:			
Quartz	–	–	T
Feldspar	–	–	T
Heavy minerals	–	T	–
Clay	–	–	R
Volcanic glass	–	T	A
Palagonite	–	–	R
Pyrite	–	–	C
Foraminifers	C	C	–
Calc. nannofossils	A	A	–
Fish remains	–	–	T

[1] Insol. residue

SITE 590 HOLE A CORE 6 CORED INTERVAL 74.2–83.8 m



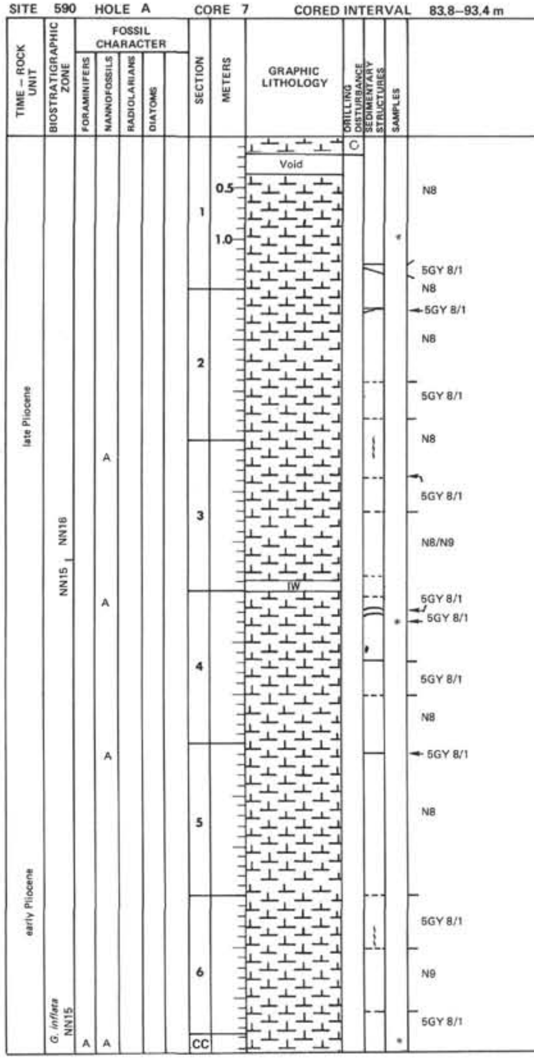
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to grayish yellow green (5GY 7/2), dark (N4–N5) spots and streaks throughout the entire core (↪ iron sulfide) undefined burrows.

SMEAR SLIDE SUMMARY:

	1, 72	2, 92
	D	D
Composition:		
Volcanic glass	R	R
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 7 CORED INTERVAL 83.8–93.4 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1) dark (N5) spots throughout the core.

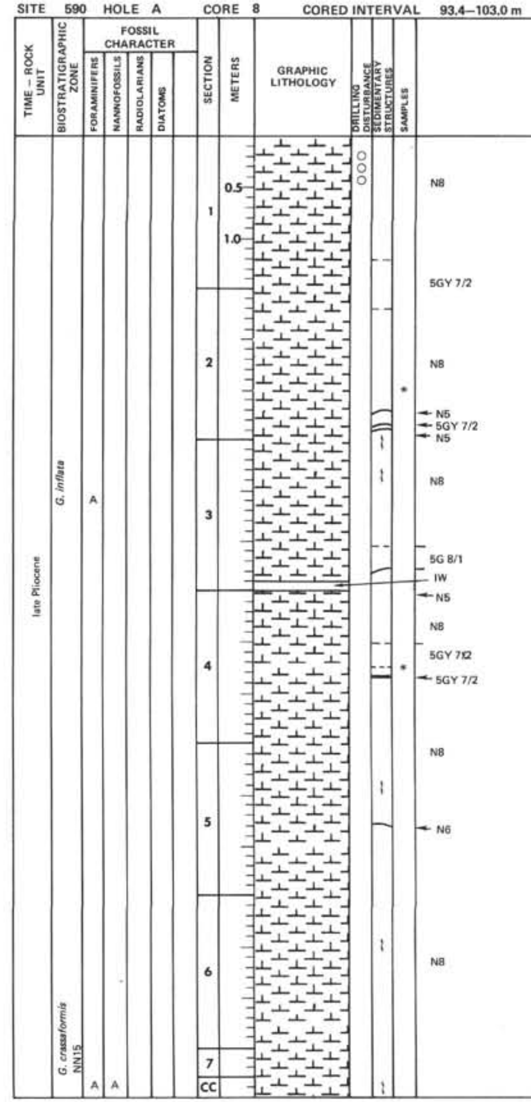
Note: H_2S odor when splitting Section 4.

SMEAR SLIDE SUMMARY:

	1, 110	4, 29	CC[1]
	D	D	M
Composition:			
Quartz	–	–	T
Feldspar	–	–	T
Clay	–	–	R
Volcanic glass	T	–	A
Pyrite	T	T	C
Foraminifers	R	R	–
Calc. nannofossils	D	D	–
Sponge spicules	–	T	–

[1] Insol. residue

SITE 590 HOLE A CORE 8 CORED INTERVAL 93.4–103.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to light greenish gray (5GY 8/1) and grayish yellow green (5GY 7/2) iron sulfide spots (N5) throughout the entire core; gradational color changes; bioturbation rare.

SMEAR SLIDE SUMMARY:

	2, 105	4, 82
	D	M
Composition:		
Volcanic glass	T	T
Palagonite	T	–
Pyrite	T	T
Foraminifers	R	R
Calc. nannofossils	D	D

Core 9, 103.0–112.6 m: no recovery.

SITE 590 HOLE A CORE 10 CORED INTERVAL 112.6–122.2 m

TIME – ROCK UNIT: early Pliocene

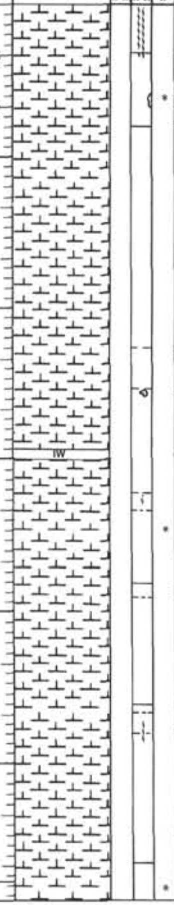
BIOSTRATIGRAPHIC ZONE: *G. crassaformis* NN15

FOSSIL CHARACTER: FORAMINIFERS A; NANNOFOSSILS A; RADIOLARIANS; DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, light greenish gray (5GY 8/1) to very light gray (N8); dark (N5) spots throughout the entire core (iron sulfide); top of the core intensively bioturbated.

SMEAR SLIDE SUMMARY:

	1, 93	4, 75	CC[1]
	M	D	M
Composition:			
Quartz	–	–	C
Feldspar	–	–	C
Volcanic glass	T	T	C
Palagonite	–	–	T
Pyrite	T	–	C
Foraminifers	R	T	–
Calc. nannofossils	D	D	–
Other	–	–	A

[1] Insol. residue

SITE 590 HOLE A CORE 11 CORED INTERVAL 122.2–131.8 m

TIME – ROCK UNIT: early Pliocene

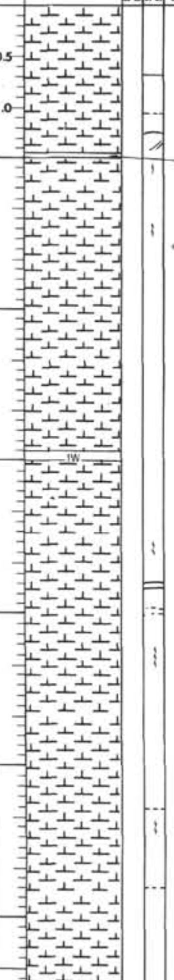
BIOSTRATIGRAPHIC ZONE: *G. crassaformis* NN14/NN15

FOSSIL CHARACTER: FORAMINIFERS A; NANNOFOSSILS A, A; RADIOLARIANS; DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots and streaks throughout the entire core (→iron sulfide), some unidentified burrows.

SMEAR SLIDE SUMMARY:

	2, 72
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 12 CORED INTERVAL 131.8–141.4 m

TIME–ROCK UNIT: early Pliocene

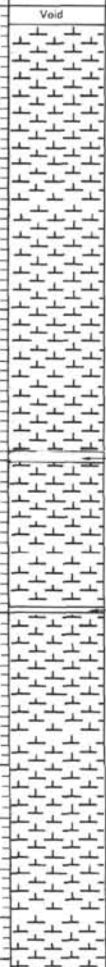
BIOSTRATIGRAPHIC ZONE: NN15; NN14; *G. crassaformis* NN14

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): A; A; A A

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

N8
5GY 8/1
N8
IW
N5
Void
N8
N7
N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots and streaks throughout the entire core, some unidentified burrows.

SMEAR SLIDE SUMMARY:

	3, 80	CC[1]
	D	M
Composition:		
Quartz	–	R
Feldspar	–	R
Heavy minerals	–	T
Volcanic glass	T	R
Pyrite	T	R
Foraminifers	R	–
Calc. nannofossils	D	–
Other	–	A

[1] Insol. residue

SITE 590 HOLE A CORE 13 CORED INTERVAL 141.4–151.0 m

TIME–ROCK UNIT: early Pliocene

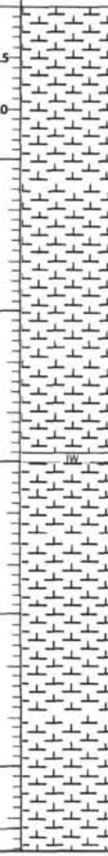
BIOSTRATIGRAPHIC ZONE: *G. crassaformis* NN14

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): A A

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

N8
5GY 8/1
N8
N8–N9
5GY 8/1
N9
5GY 8/1
N8–9
N8

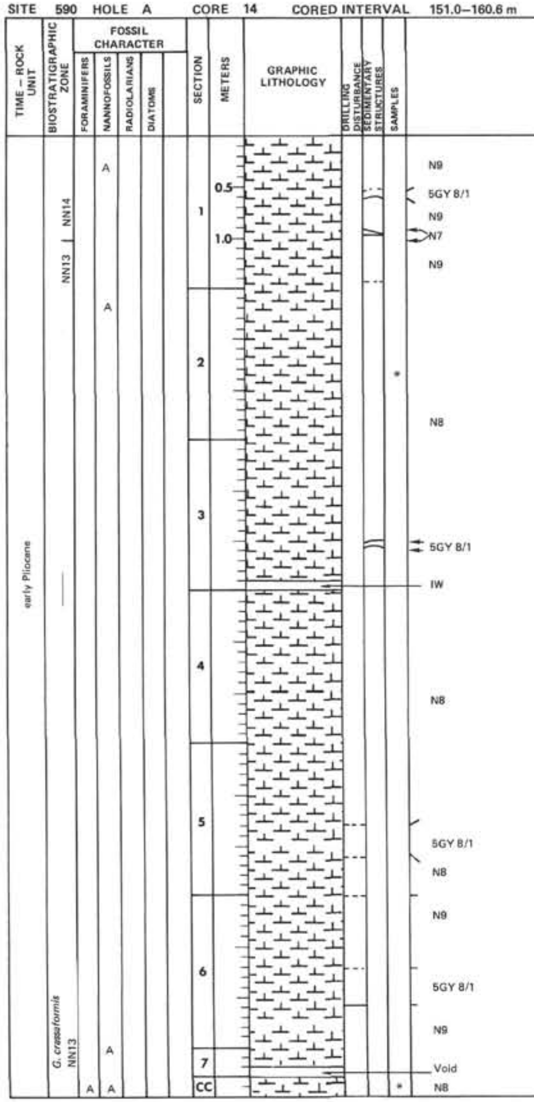
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8), homogeneous, dark (N5) spots rare, core slightly to very deformed.

SMEAR SLIDE SUMMARY:

	3, 71
	D
Composition:	
Quartz	T
Feldspar	T
Palagonite	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 14 CORED INTERVAL 151.0–160.6 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to light greenish gray (5GY 8/1), dark (N5) spots and streaks throughout the entire core, bioturbation rare.

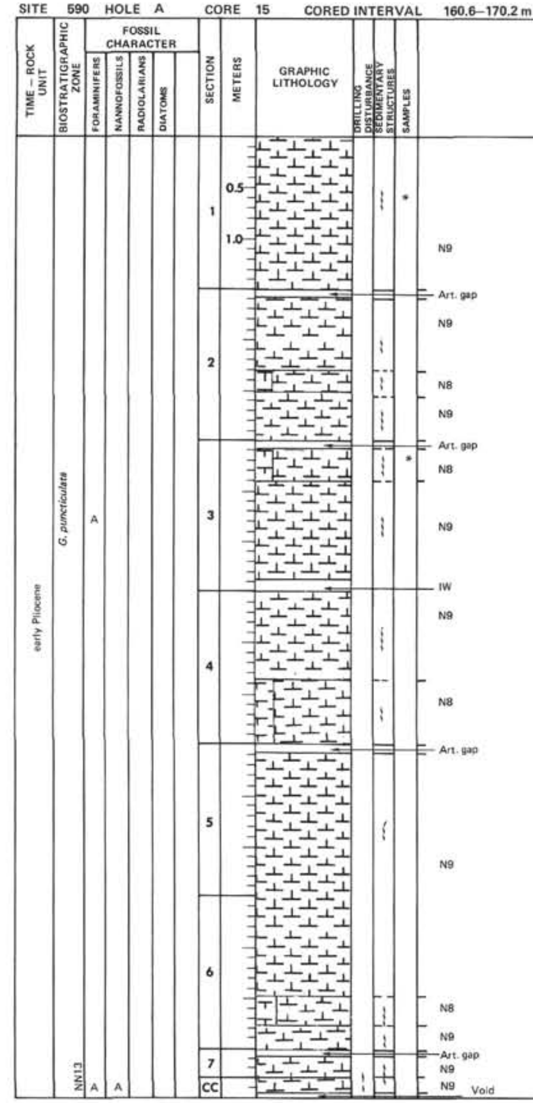
Note: H_2S odor when splitting Sections 2 and 3.

SMEAR SLIDE SUMMARY:

	2, 80	CC[1]
Composition:	D	M
Quartz	–	R
Feldspar	–	R
Volcanic glass	T	A
Pyrite	–	R
Foraminifers	R	–
Calc. nannofossils	D	–
Fish remains	T	–
Other	–	A

[1] Insolub. residue

SITE 590 HOLE A CORE 15 CORED INTERVAL 160.6–170.2 m



LITHOLOGIC DESCRIPTION

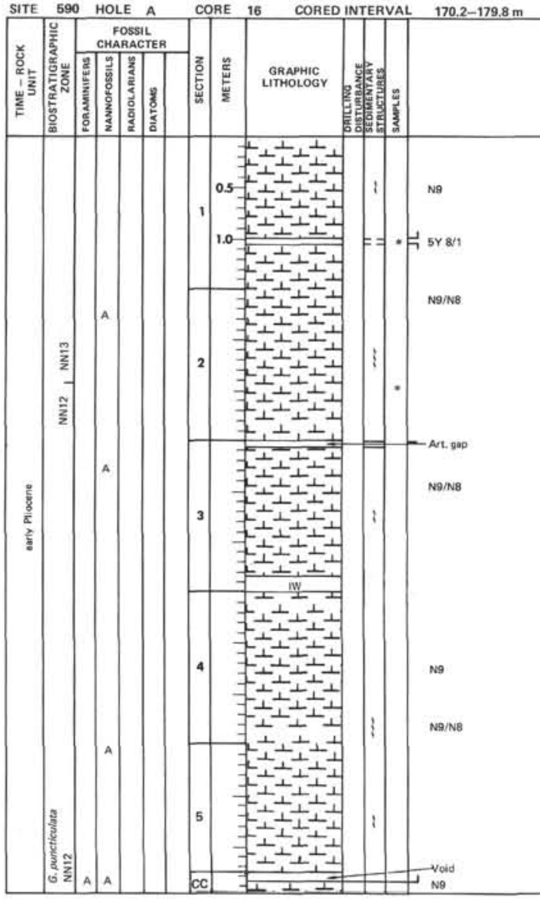
NANNOFOSSIL OOZE, white (N9), soft, moderately burrowed throughout, occasional streaks and halos of pyrite.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, moderate to heavy burrowing, occasional streaks or halos of pyrite.

SMEAR SLIDE SUMMARY:

	1, 67	3, 16
	D	D
Texture:		
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 16 CORED INTERVAL 170.2–179.8 m



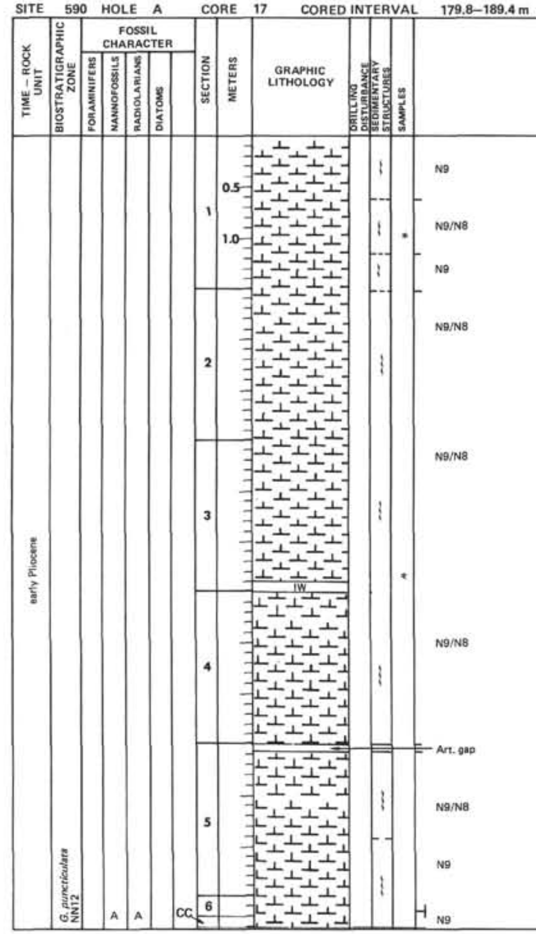
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray/white (N8/N9), soft, occasional burrows and pyrite halos. Burrows are yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	1, 97	2, 83
	M	D
Texture:		
Sand	R	–
Silt	C	C
Clay	D	D
Composition:		
Mica	R	–
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 17 CORED INTERVAL 179.8–189.4 m



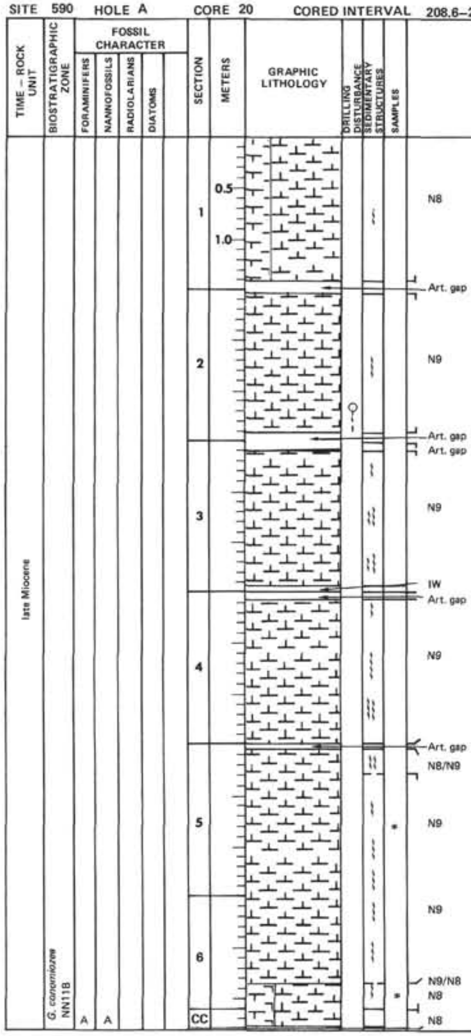
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8) throughout, soft, yellowish gray (5Y 8/1) burrows and pyrite streaks periodically throughout.

SMEAR SLIDE SUMMARY:

	3, 135	1, 91
	M	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 20 CORED INTERVAL 208.6–218.2 m



LITHOLOGIC DESCRIPTION

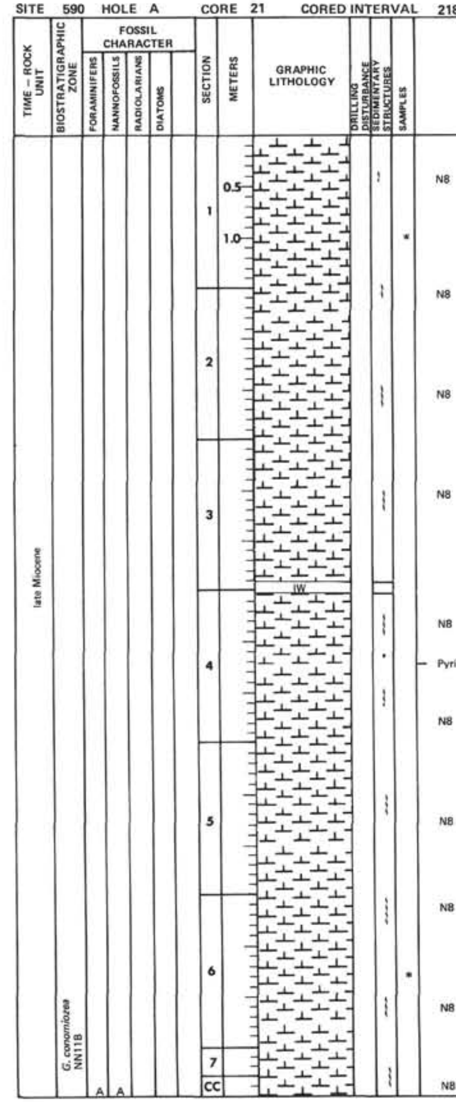
NANNOFOSSIL OOZE, white (N9), soft, pyrite streaks and burrows, yellowish gray (5Y 8/1).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray zones (N7), soft, burrows and pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	5, 70	6, 96
	D	D
Texture:		
Sand	–	R
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 21 CORED INTERVAL 218.2–227.8 m



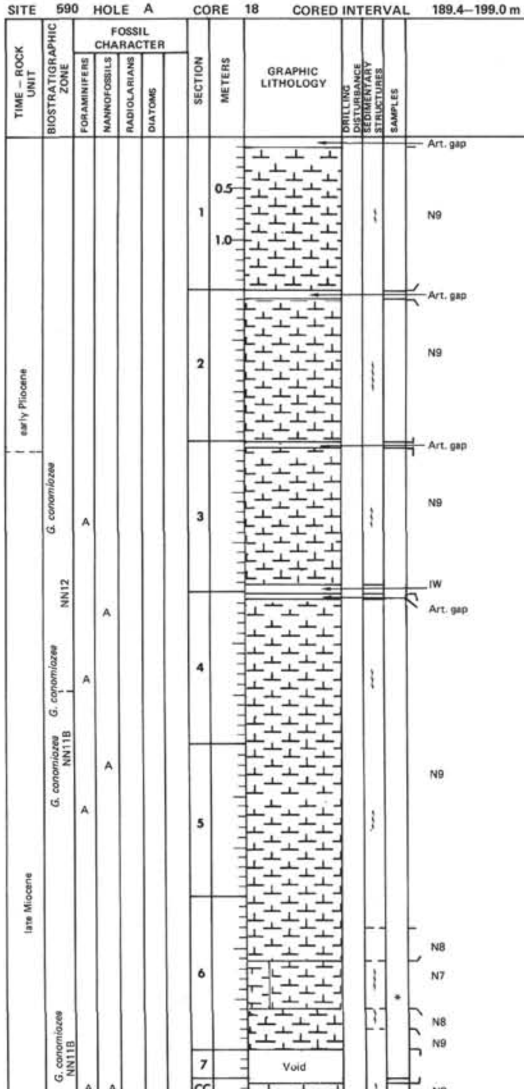
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed, burrows yellowish gray (5Y 8/1), pyrite streaks throughout, one pyrite concretion.

SMEAR SLIDE SUMMARY:

	1, 96	6, 70
	D	D
Texture:		
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 18 CORED INTERVAL 189.4–199.0 m



LITHOLOGIC DESCRIPTION

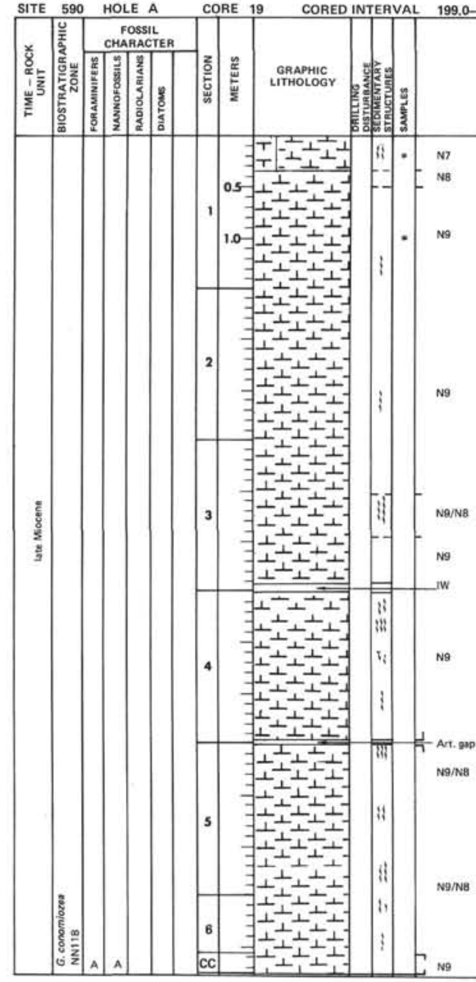
NANNOFOSSIL OOZE, white (N9), soft, with periodic burrows yellowish gray (5Y 8/1), pyrite streaks and burrows throughout.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N7), soft, occasional burrows and pyrite streaks.

SMEAR SLIDE SUMMARY:

	3, 87	6, 91
	D	D
Texture:		
Sand	–	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 19 CORED INTERVAL 199.0–208.6 m



LITHOLOGIC DESCRIPTION

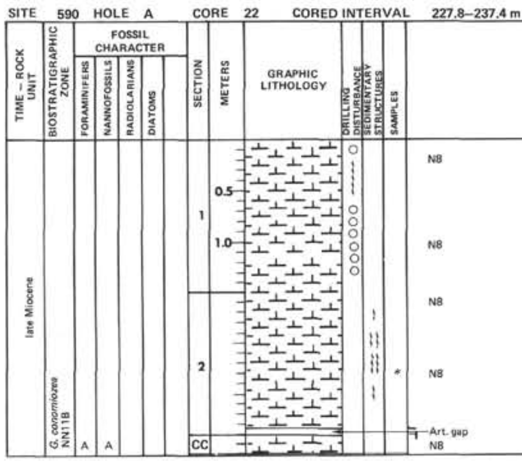
FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gray (N7), soft, burrows and pyrite streaks common.

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), soft, moderate to heavy burrowing, pyrite streaks common.

SMEAR SLIDE SUMMARY:

	1, 12	1, 96
	D	D
Texture:		
Sand	R	–
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 22 CORED INTERVAL 227.8–237.4 m



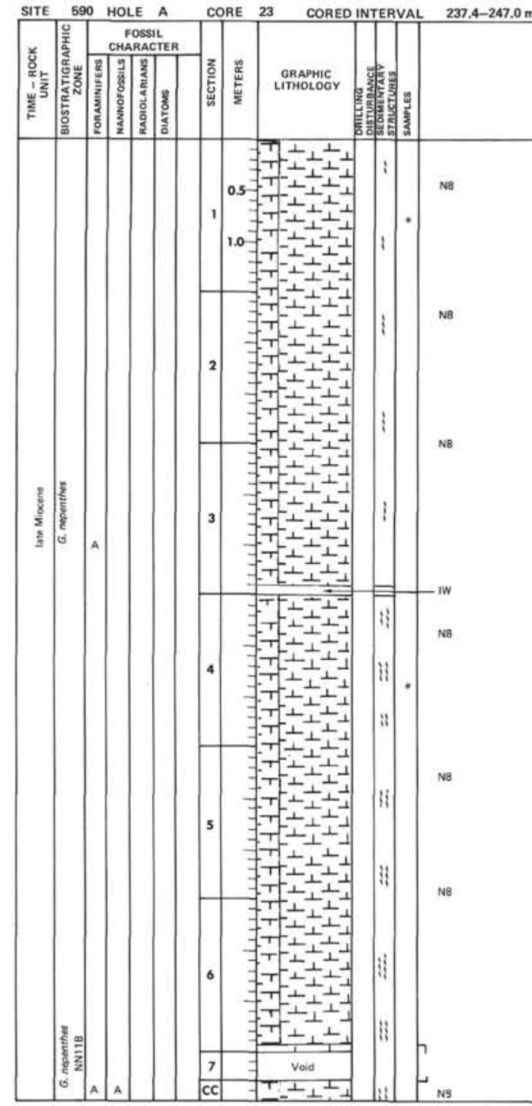
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), moderately burrowed, burrows yellowish gray (5Y 8/1), faint streaks of pyrite throughout.

SMEAR SLIDE SUMMARY:

	2, 77
	D
Texture:	
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE A CORE 23 CORED INTERVAL 237.4–247.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, burrows and faint pyrite streaks throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	1, 79	4, 82
	D	D
Texture:		
Sand	R	T
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 24 CORED INTERVAL 247.0–256.6 m

TIME-ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: *G. nepenthes* NN11B

FOSSIL CHARACTER: FORAMINIFERS A; NANNOFOSSILS A; RADIOLARIANS; DIATOMS

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

METERS: 0.5, 1.0

Section 1: N8
Section 2: N8
Section 3: N8
IW
Section 4: N8
Section 5: N8
Section 6: N8
Section 7: N8
Art. gap
CC: N8

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft to stiff, moderate to light burrowing throughout, burrows yellowish gray (5Y 8/1), faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	1, 118	4, 21
	D	D
Texture:		
Sand	T	T
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 25 CORED INTERVAL 256.6–266.2 m

TIME-ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: *G. nepenthes* NN11B

FOSSIL CHARACTER: FORAMINIFERS A; NANNOFOSSILS A; RADIOLARIANS; DIATOMS

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

METERS: 0.5, 1.0

Section 1: N8
Art. gap
Section 2: N8
? Slickensided joint with
? mineralization along joint[1] or coring artifact!
? ? 1
Section 3: N8
IW
Section 4: N8
Section 5: N8
Section 6: N8
CC: N8

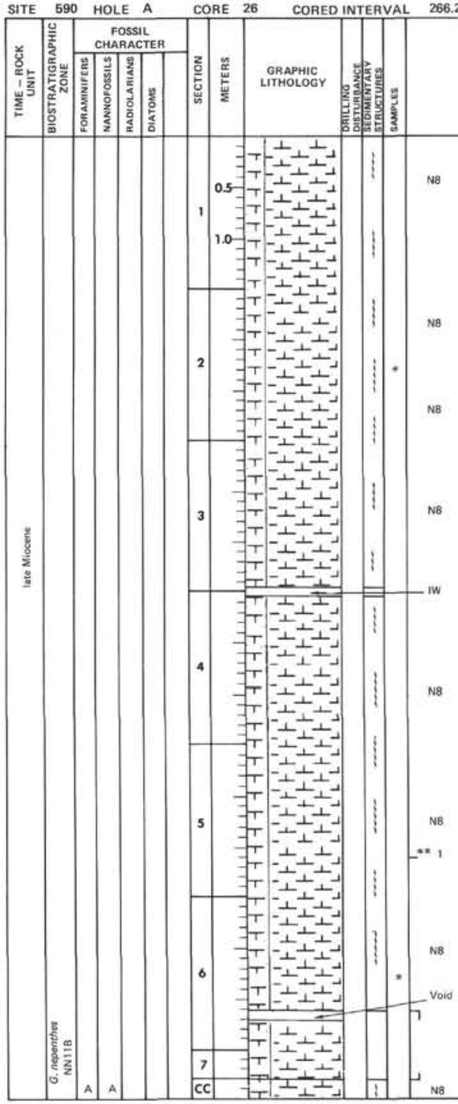
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed, faint streaks of pyrite, burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 71	4, 21
	D	M
Texture:		
Sand	T	R
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 26 CORED INTERVAL 266.2–275.8 m



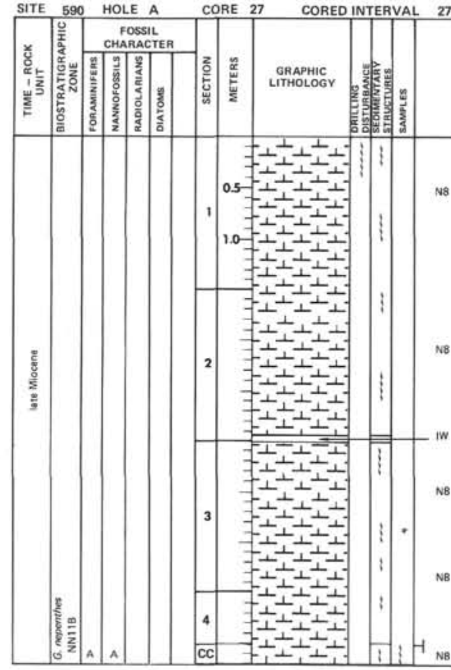
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed and faint pyrite streaks throughout, occasional silicified burrows[1]. Burrow mottling yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 76	6, 76
	D	D
Texture:		
Sand	R	R
Silt	C	C
Clay	D	D
Composition:		
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE A CORE 27 CORED INTERVAL 275.8–280.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff) faint pyrite streaks throughout, moderate burrowing, burrowing yellowish gray (5Y 8/1).

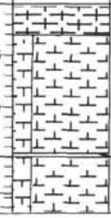
SMEAR SLIDE SUMMARY:

	3, 80
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 1 CORED INTERVAL 0.0–2.2 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Quaternary	*G. truncatulinoides* NN20	A	A			1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY



10YR 7/4
10YR 8/6
5Y 6/4
10Y 6/2
N8
5GY 7/2
N8
10Y 6/2
5G 6/1
Void
5GY 7/2
5GY 8/1 and
5GY 7/2

LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL OOZE, soft, orange gray (10YR 7/4) to pale yellowish orange (10YR 8/6); coarser than section below.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, pale olive (10Y 6/2) to very light gray (N8) colors, in the light (N8) parts some dark (N5) spots (iron sulfide). Core Catcher—sediment mottled.

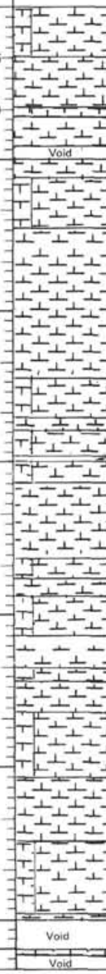
SMEAR SLIDE SUMMARY:

	1, 20	1, 70	1, 108	2, 13
	D	D	D	D
Composition:				
Volcanic glass	R	T	T	T
Pyrite	–	–	T	T
Foraminifers	A	C	C	C
Calc. nannofossils	D	D	D	D
Fish remains	–	T	–	–

SITE 590 HOLE B CORE 2 CORED INTERVAL 2.2–11.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Quaternary	NN19		A			1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0

GRAPHIC LITHOLOGY



5GY 6/1
5G 8/1
5GY 7/2
5GY 8/1
N7
N8
N7
N8
5GY 8/1
N8
N8
5GY 8/1
5GY 7/2
N8
5Y 7/2
N8
N9
N8
5G 8/1
N8
Void
5G 8/1
N9
N8
5G 8/1
N8
5G 8/1
N8
5G 8/1
N8
5GY 7/2
5G 8/1
5GY 7/2
N8
5G 8/1
N9
5G 8/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), some darker (N5) spots (⊥—iron sulfide).

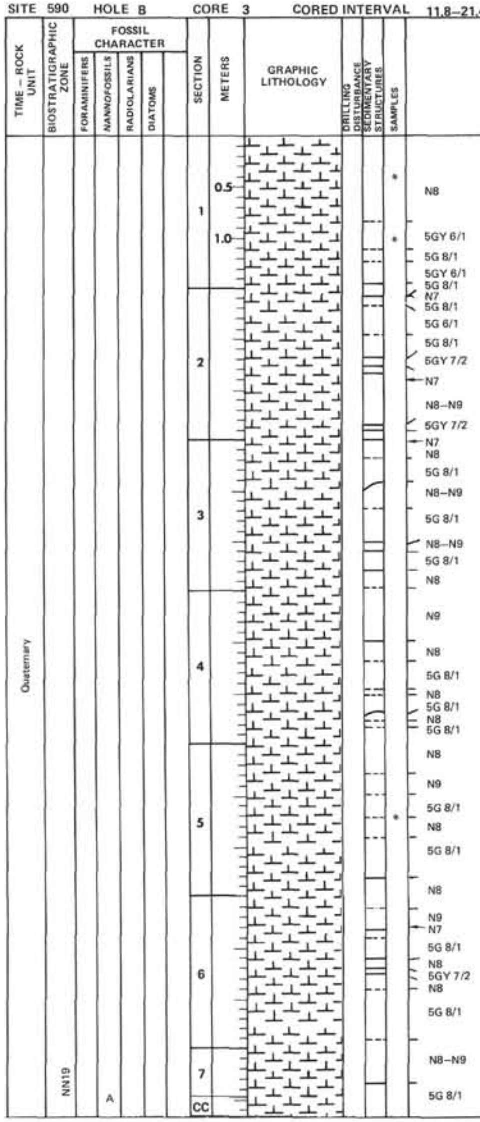
FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, greenish gray (5GY 6/1), grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N5) spots, coarser than the lighter parts of the core.

Sharp contacts near 10 and 145 cm of Section 6.

SMEAR SLIDE SUMMARY:

	1, 46	1, 85	5, 54	5, 106
	D	D	D	D
Composition:				
Volcanic glass	T	T	R	T
Pyrite	T	T	–	T
Foraminifers	C	R	R	R
Calc. nannofossils	D	D	D	D

SITE 590 HOLE B CORE 3 CORED INTERVAL 11.8–21.4 m



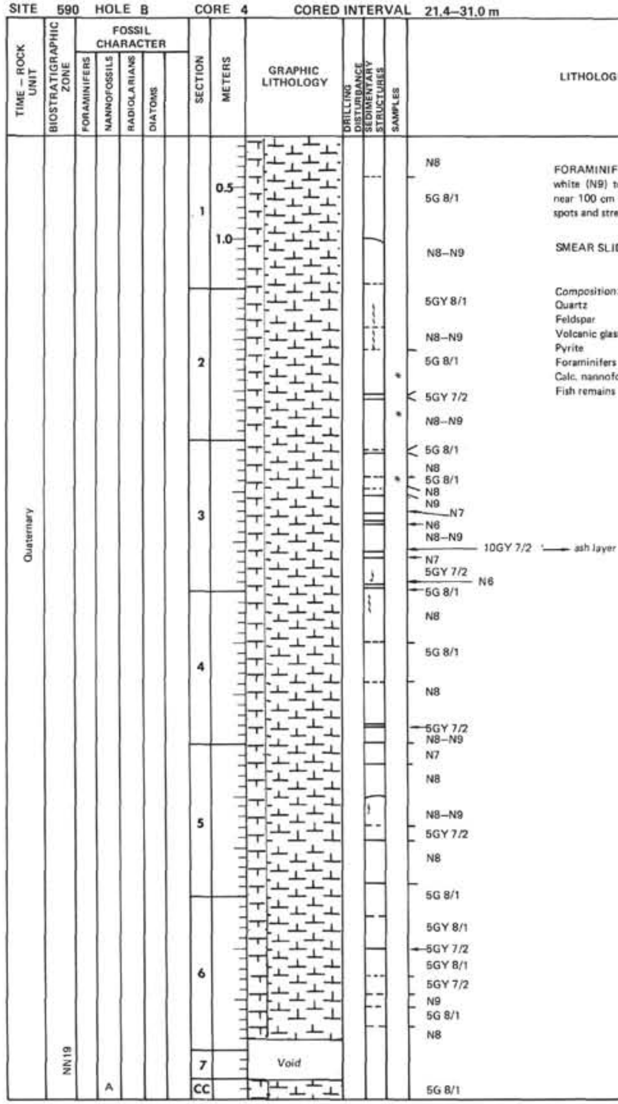
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to greenish gray (5GY 6/1), dark (N5–N4) spots and streaks throughout the entire core (L←iron-sulfide).

SMEAR SLIDE SUMMARY:

	1, 40	1, 98	5, 75
	D	D	M
Composition:			
Volcanic glass	T	T	–
Pyrite	–	–	A
Foraminifers	R	R	–
Calc. nannofossils	D	D	D
Sponge spicules	–	T	–

SITE 590 HOLE B CORE 4 CORED INTERVAL 21.4–31.0 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to light greenish gray (5G 8/1), sharp contacts near 100 cm (Section 1) and 110 cm (Section 2), dark (N5) spots and streaks throughout the entire core.

SMEAR SLIDE SUMMARY:

	2, 84	2, 126	3, 40
	D	D	D
Composition:			
Quartz	–	T	–
Feldspar	–	T	–
Volcanic glass	T	T	T
Pyrite	T	T	T
Foraminifers	C	C	C
Calc. nannofossils	D	D	D
Fish remains	–	–	T

SITE 590 HOLE B CORE 5 CORED INTERVAL 31.0–40.6 m

TIME–ROCK UNIT: late Pliocene

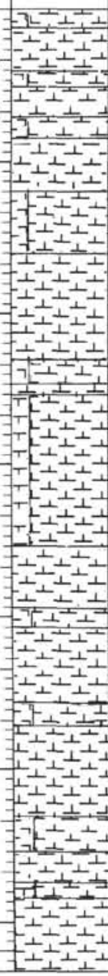
BIOSTRATIGRAPHIC ZONE: NN18

FOSSIL CHARACTER: Foraminifers A

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



Colors (top to bottom): 5GY 7/2, N8, N7, N8, 5G 8/1, N8, N6, 5GY 7/2, N8–N9, 5G 8/1, 5GY 6/1, N8, 10GY 7/2 (ash layer), N8, N9, 5G 8/1, N9, 5G 8/1, 5GY 6/1, 5GY 7/2, 5G 8/1, 5GY 7/2, N9, 5G 8/1, N8–N9, 10GY 7/2 (ash layer), 5GY 7/2, N8–N9, 5G 8/1, N9, 5G 8/1, N6, N8, N7, N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5–N4) spots and streaks (iron sulfide).

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, greenish yellow green (5GY 7/2) to light greenish gray (5G 8/1), dark spots and streaks throughout the entire core (iron sulfide), coarser than the whitish parts.

Some bioturbation (*Planolites*).

Sharp contacts near 20 and 123 cm in Section 1.

SMEAR SLIDE SUMMARY:

	1, 53	1, 115	5, 64	4, 109
	D	D	M	D
Composition:				
Volcanic glass	T	T	C	T
Pyrite	–	–	–	T
Foraminifers	R	C	C	R
Calc. nannofossils	D	D	A	D
Sponge spicules	–	–	T	–

SITE 590 HOLE B CORE 6 CORED INTERVAL 40.6–50.2 m

TIME–ROCK UNIT: late Pliocene

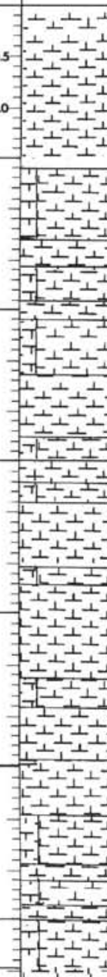
BIOSTRATIGRAPHIC ZONE: NN18, NN17, NN16

FOSSIL CHARACTER: Foraminifers A, A, A, A

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



Colors (top to bottom): N8, 5GY 7/2, N8, 5G 8/1, N8–N9, 5GY 7/2, N8, 5GY 7/2, N7, N9, 5G 8/1, N8, 5G 8/1, N8–N9, 5GY 7/2, N8, N7, N8, N7, N9, 5GY 7/2, N9, 5G 8/1, N8–N9, 5GY 7/2, N8, 5GY 7/2, N8, 5G 8/1, N9, 5G 8/1, N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5) spots and streaks.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N5) spots and streaks, coarser than white parts.

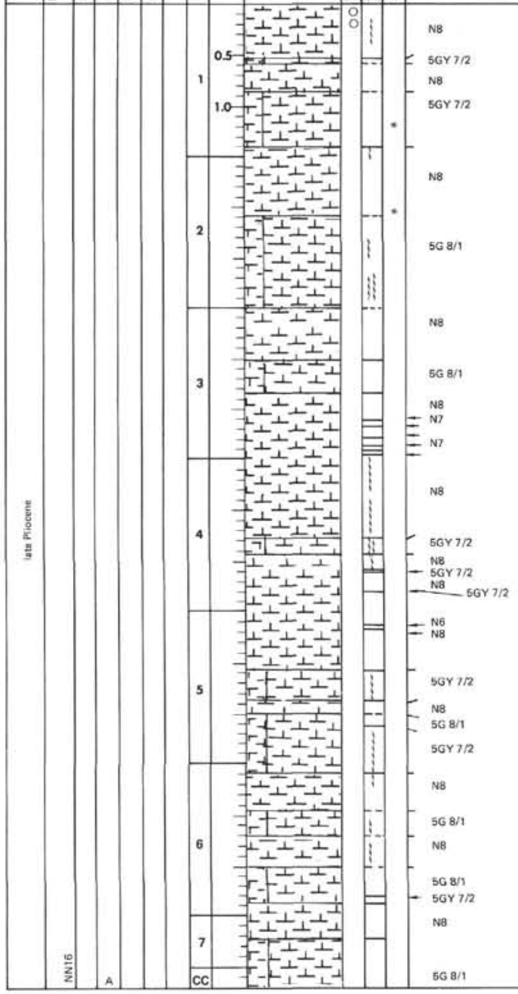
Sharp contacts near 140 cm (Section 2), 65 cm (Section 3), and 94 and 135 cm (Section 6).

SMEAR SLIDE SUMMARY:

	3, 50	5, 40
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 7 CORED INTERVAL 50.2–59.8 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



NANNOFOSSIL OOZE, soft, very light gray (N8), dark spots and streaks.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark (N5) spots and streaks; coarser than white parts of the core.

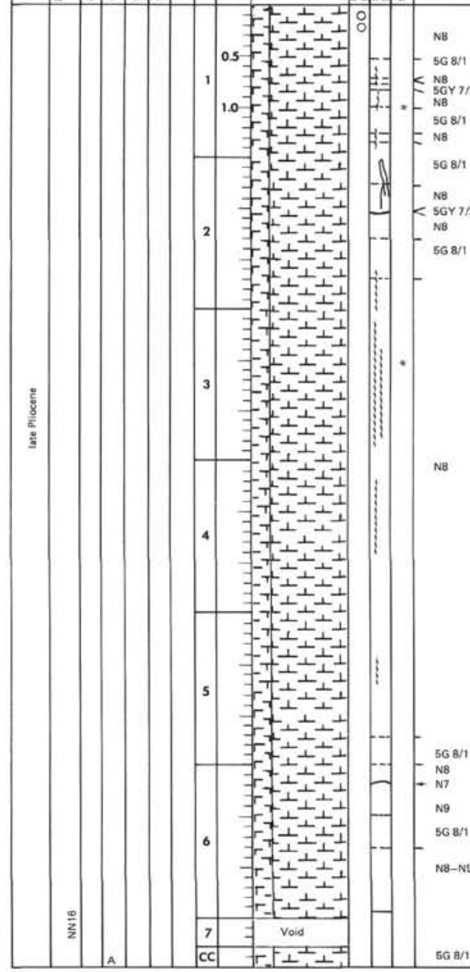
Intensive bioturbation throughout the entire core.

SMEAR SLIDE SUMMARY:

	1, 117	2, 44
	D	D
Composition:		
Quartz	T	–
Feldspar	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 8 CORED INTERVAL 59.8–69.4 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



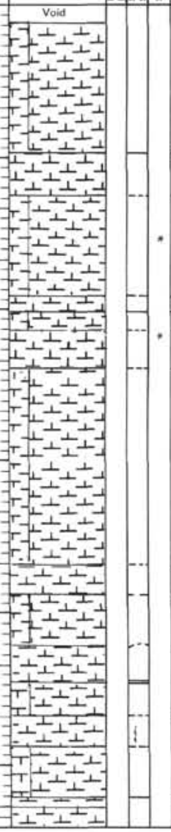
NANNOFOSSIL TO FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, very light gray (N8) to grayish yellow green (5GY 7/2) and light greenish gray (5G 8/1) dark (N5) spots and streaks. Bioturbation *Planolites* + undefined) throughout the entire core.

SMEAR SLIDE SUMMARY:

	1, 106	3, 61
	D	D
Composition:		
Heavy minerals	T	–
Volcanic glass	T	T
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 9 CORED INTERVAL 69.4–79.0 m

TIME – ROCK UNIT: late Pliocene
BIOSTRATIGRAPHIC ZONE: NN16
FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS: A | RADIOLARIANS | DIATOMS
SECTION: 1, 2, 3, 4, 5, 6, CC
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



N8–N9
5G 8/1
N8–N9
5GY 7/2
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
5GY 7/2
N9
5G 8/1
N9
5G 8/1

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8).

Greenish parts fewer foraminifers └→NANNOFOSSIL OOZE.

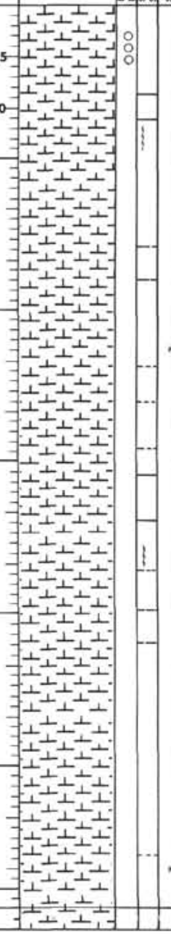
Dark (N5) spots and streaks throughout the entire core.

SMEAR SLIDE SUMMARY:

	2, 81	3, 35
	D	D
Composition:		
Heavy minerals	T	–
Volcanic glass	T	T
Pyrite	–	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 10 CORED INTERVAL 79.0–88.6 m

TIME – ROCK UNIT: early Pliocene
BIOSTRATIGRAPHIC ZONE: NN15
FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS: A | RADIOLARIANS | DIATOMS
SECTION: 1, 2, 3, 4, 5, 6, 7, CC
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



N9
N8
N9
N8
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
N9
5G 8/1
N8–N9
5G 8/1
5G 8/1

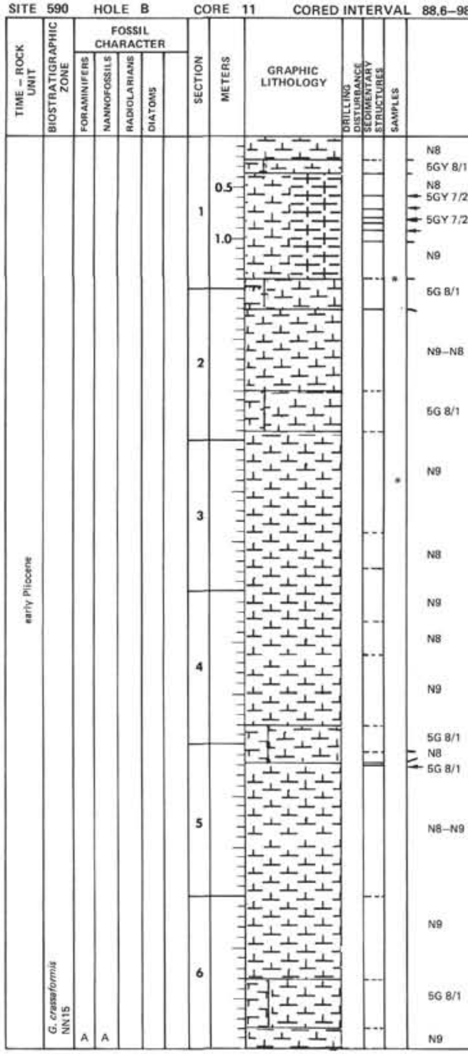
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark (N5) spots (└→iron sulfide). Bioturbation in Sections 1 and 4.

SMEAR SLIDE SUMMARY:

	3, 36	6, 107
	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	–
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 11 CORED INTERVAL 88.6–98.2 m



LITHOLOGIC DESCRIPTION

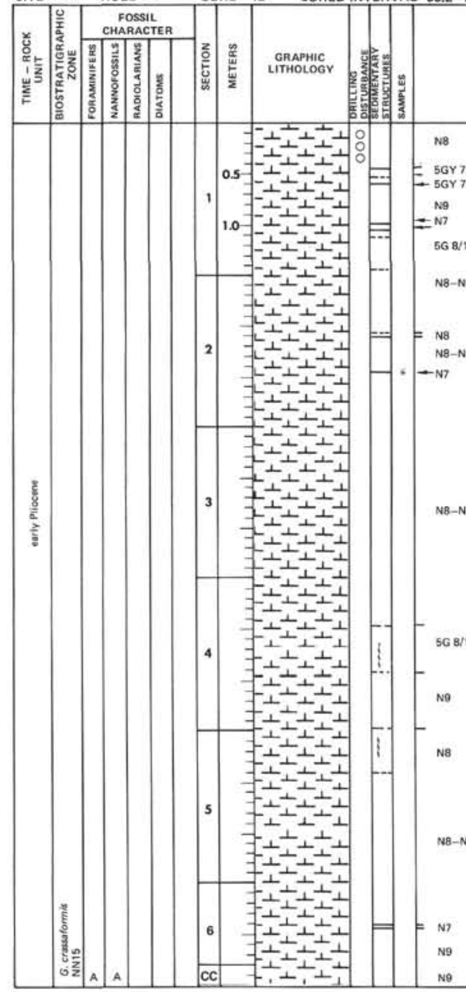
NANNOFOSSIL OOZE, soft, white (N9) to very light gray (N8), dark spots and streaks.

FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish yellow green (5GY 7/2) to light greenish gray (5G 8/1) dark spots and streaks, coarser than the white parts of the core.

SMEAR SLIDE SUMMARY:

	1, 146	3, 37
	D	D
Composition:		
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 12 CORED INTERVAL 98.2–107.8 m



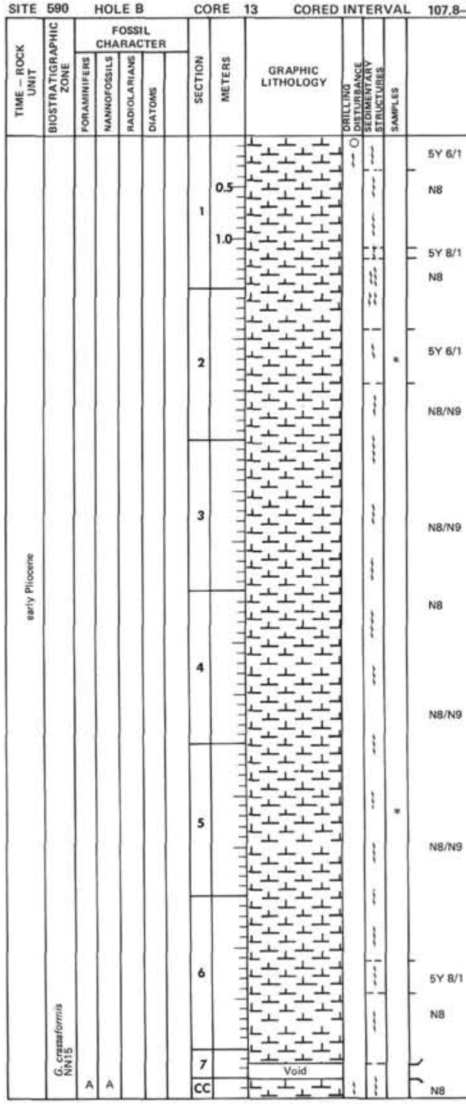
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, white (N9) to grayish yellow green (5GY 7/2). Some dark spots and streaks (←iron sulfide). Gradational color changes.

SMEAR SLIDE SUMMARY:

	2, 96
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 13 CORED INTERVAL 107.8–117.4 m



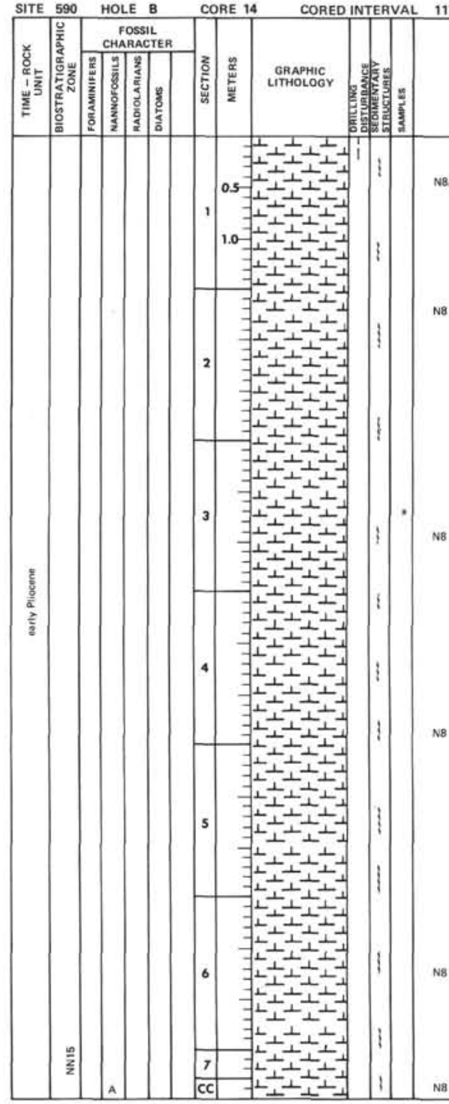
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), with layers of light olive gray (5Y 6/1), moderately burrowed, burrows yellowish gray (5Y 8/1), occasional pyrite blebs and concretions, faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	2, 73 D	5, 73 D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 14 CORED INTERVAL 117.4–127.0 m



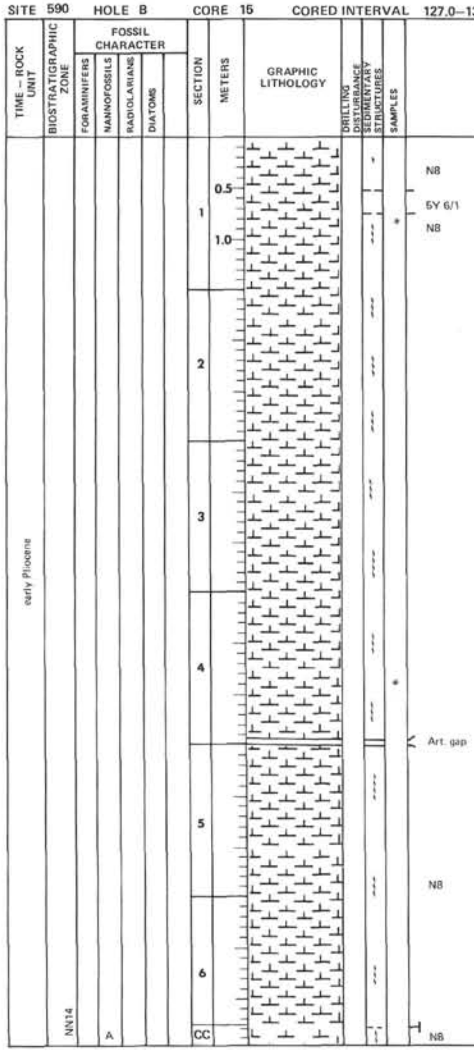
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), light to moderately burrowed, faint pyrite streaks throughout, occasional pyrite blebs.

SMEAR SLIDE SUMMARY:

	3, 69 D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 15 CORED INTERVAL 127.0–136.6 m



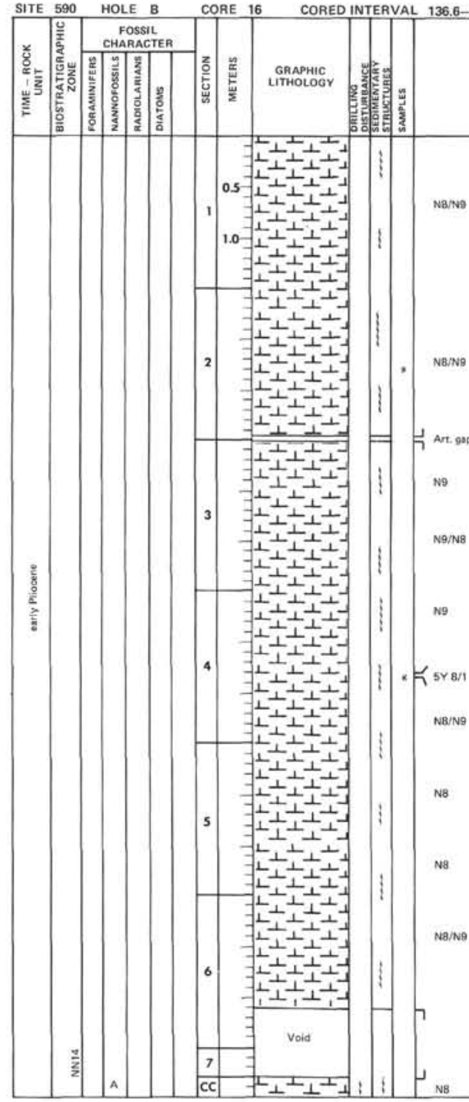
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE TO FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8) with interlayer of light olive gray (5Y 6/1), soft, light to moderately burrowed and faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	1, 72	4, 84
	D	D
Texture:		
Sand	R	T
Silt	C	R
Clay	D	D
Composition:		
Foraminifers	C	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 16 CORED INTERVAL 136.6–146.2 m



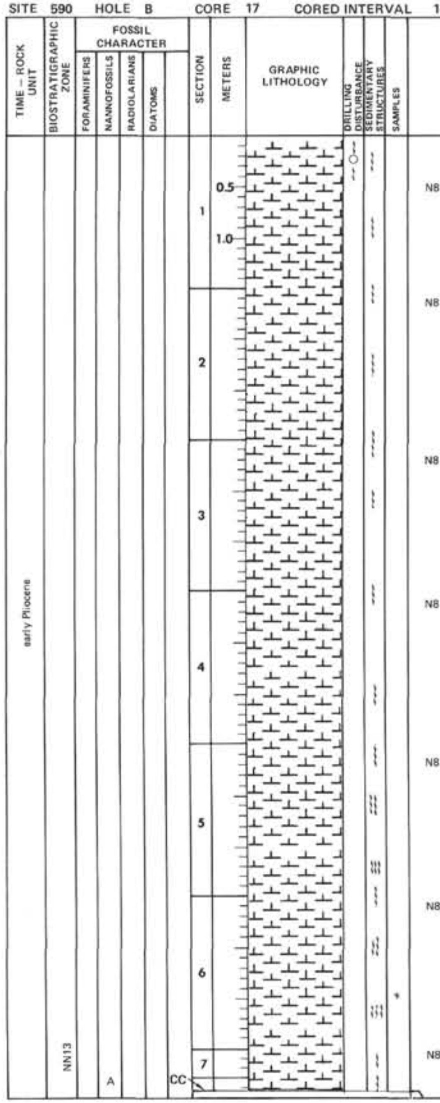
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8) to white (N9), soft, light to moderately burrowed, faint pyrite streaks throughout, burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 84	4, 83
	D	M
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 17 CORED INTERVAL 146.2–155.8 m



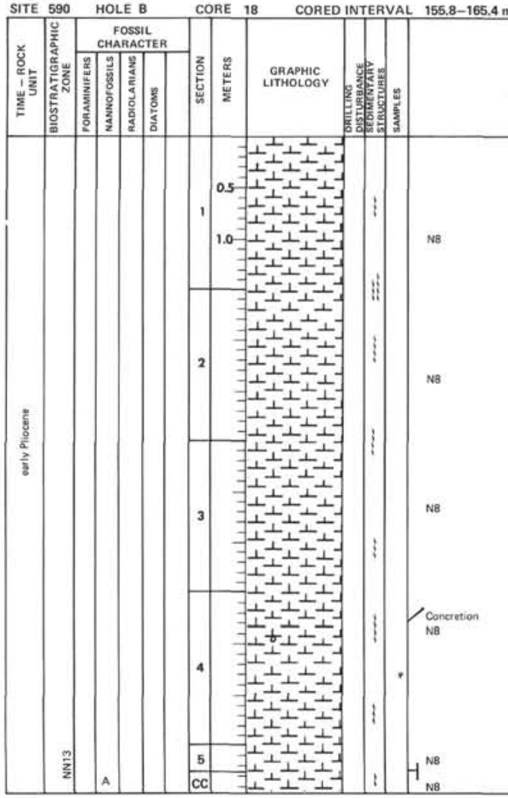
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, light to heavy burrowing with faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	6, 97
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 18 CORED INTERVAL 155.8–165.4 m



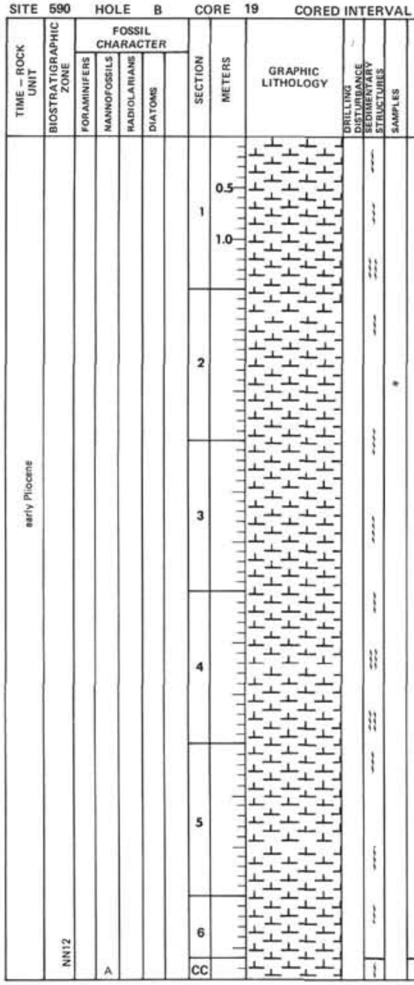
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, light to moderately burrowed with faint pyrite streaks throughout, burrows yellowish gray (5Y 8/1). Rare mineral concretions present.

SMEAR SLIDE SUMMARY:

	4, 77
	M
Texture:	
Sand	T
Silt	C
Clay	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 590 HOLE B CORE 19 CORED INTERVAL 165.4–175.0 m



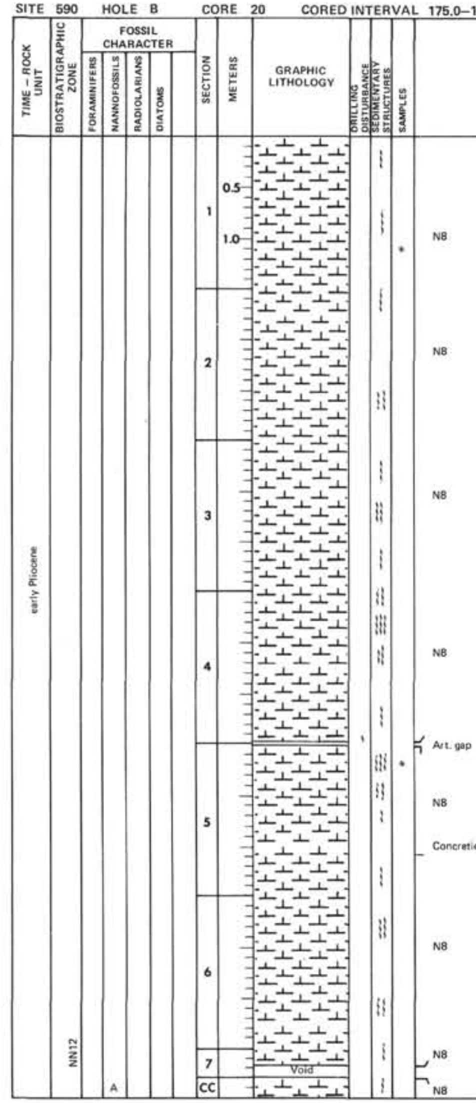
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed with faint pyrite streaks and halos throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	2, 92
	D
Texture:	
Sand	T
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 20 CORED INTERVAL 175.0–184.6 m



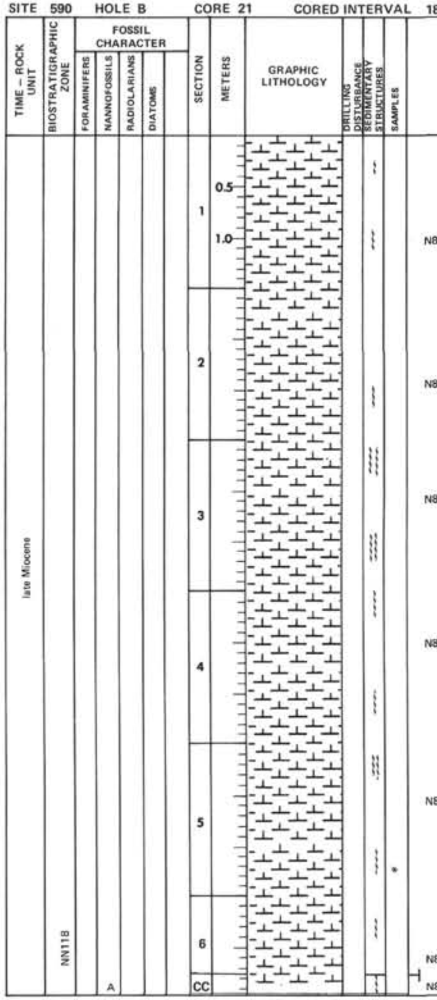
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, light to heavily mottled yellowish gray (5Y 8/1) by burrowing, faint pyrite streaks throughout. Mineralized burrow[1] at 5, 110 cm.

SMEAR SLIDE SUMMARY:

	1, 115	5, 17
	D	M
Texture:		
Sand	T	T
Silt	R	C
Clay	D	D
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 21 CORED INTERVAL 184.6–194.2 m



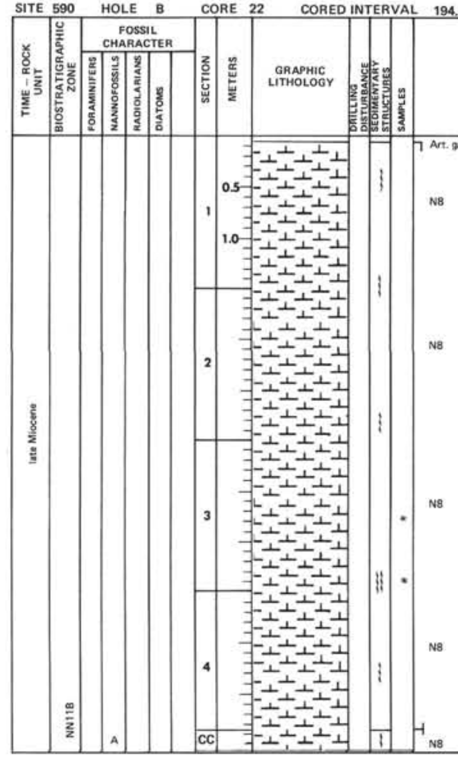
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed and faint pyrite streaks throughout.

SMEAR SLIDE SUMMARY:

	5, 125
	M
Texture:	
Sand	R
Silt	C
Clay	D
Composition:	
Foraminifers	C
Calc. nannofossils	D

SITE 590 HOLE B CORE 22 CORED INTERVAL 194.2–203.8 m



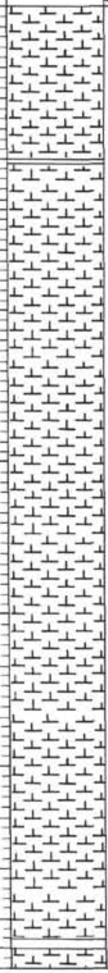
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderate burrowing with pyrite streaks throughout. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	3, 79	3, 145
	D	M
Texture:		
Sand	T	C
Silt	R	A
Clay	D	A
Composition:		
Pyrite	T	–
Foraminifers	R	A
Calc. nannofossils	D	A
Sponge spicules	T	–
Volcanic glass	T	–
Clay minerals	T	–

SITE 590 HOLE B CORE 23 CORED INTERVAL 203.8–213.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
late Miocene	NN11B		A			1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0				*	

N8

Art. gap

N8

N8

N8

N8

N8

Concretion[1]
5Y 8/1

N8

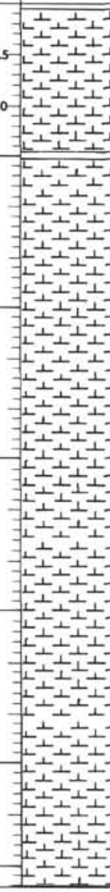
N8

NANNOFOSSIL OOZE, very light gray (N8) with heavily burrowed portions yellowish gray (5Y 8/1), soft, moderate to heavily burrowed, large concretion present.[1]

SMEAR SLIDE SUMMARY:

	2, 80	6, 72
	D	M
Texture:		
Sand	T	C
Silt	R	C
Clay	C	A
Composition:		
Foraminifers	R	C
Calc. nannofossils	D	A
Clay minerals	T	–
Pyrite	T	–

SITE 590 HOLE B CORE 24 CORED INTERVAL 213.4–223.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
late Miocene	NN11B	A				1, 2, 3, 4, 5, 6, CC	0.5, 1.0				*	

Art. gap

N8

Art. gap

N8

N8

N8

N8

N8

N8

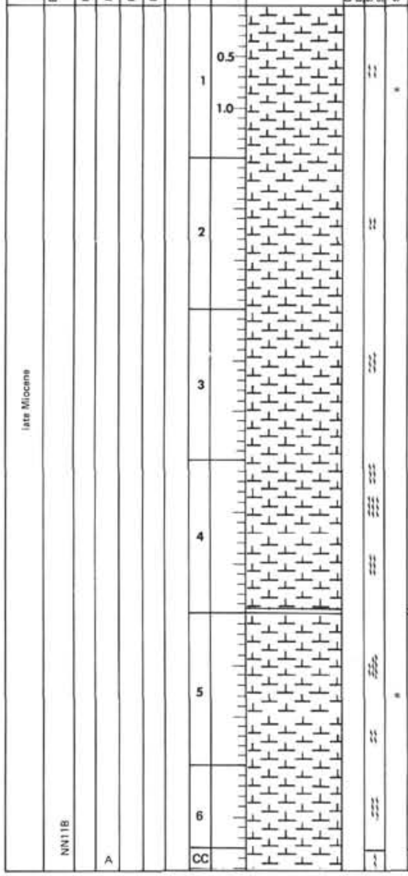
NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed with light streaks of pyrite. Burrows yellowish gray (5Y 8/1).

SMEAR SLIDE SUMMARY:

	4, 80
	D
Texture:	
Sand	R
Silt	R
Clay	D
Composition:	
Foraminifers	R
Calc. nannofossils	D
Feldspar	T
Volcanic glass	T
Clay minerals	T
Pyrite	T

SITE 590 HOLE B CORE 25 CORED INTERVAL 223.0–232.6 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION



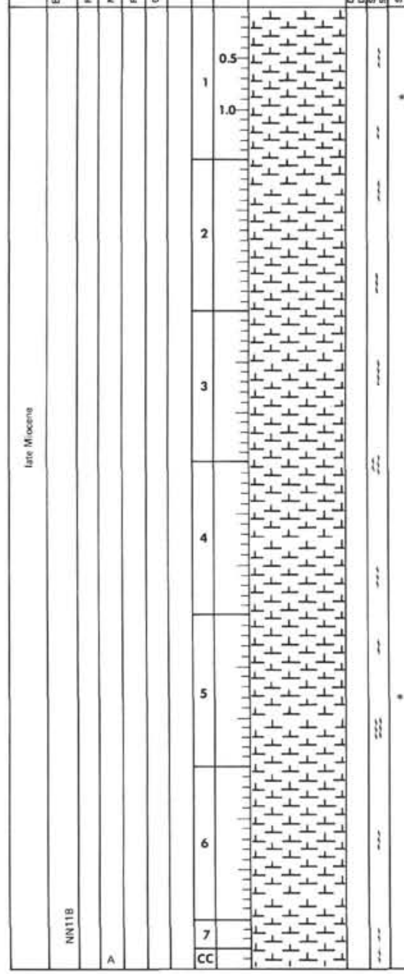
NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderate to heavily burrowed, burrows yellowish gray (5Y 8/1), pyrite streaks and halos medium light gray (N6).

SMEAR SLIDE SUMMARY:

	1, 79	5, 77
	D	D
Texture:		
Sand	T	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D
Quartz	T	–
Volcanic glass	T	T
Clay minerals	T	T
Pyrite	–	T

SITE 590 HOLE B CORE 26 CORED INTERVAL 232.6–242.2 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION

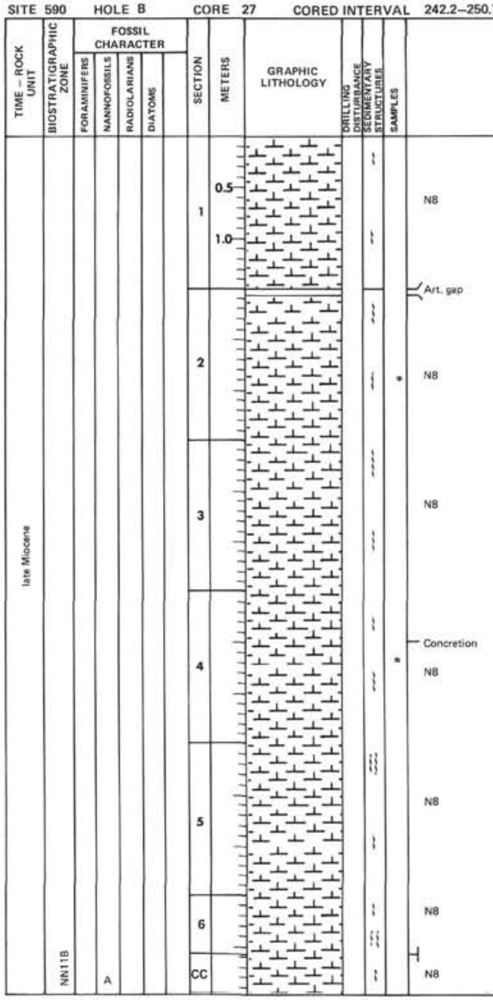


NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed throughout, burrows yellowish gray (5Y 8/1), faint pyrite streaks medium gray (N6) frequent.

SMEAR SLIDE SUMMARY:

	1, 83	5, 86
	D	D
Texture:		
Sand	R	T
Silt	R	R
Clay	D	D
Composition:		
Foraminifers	R	R
Calc. nannofossils	D	D
Volcanic glass	T	T
Clay minerals	R	T
Pyrite	T	T
Feldspar	–	T

SITE 590 HOLE B CORE 27 CORED INTERVAL 242.2–250.7 m



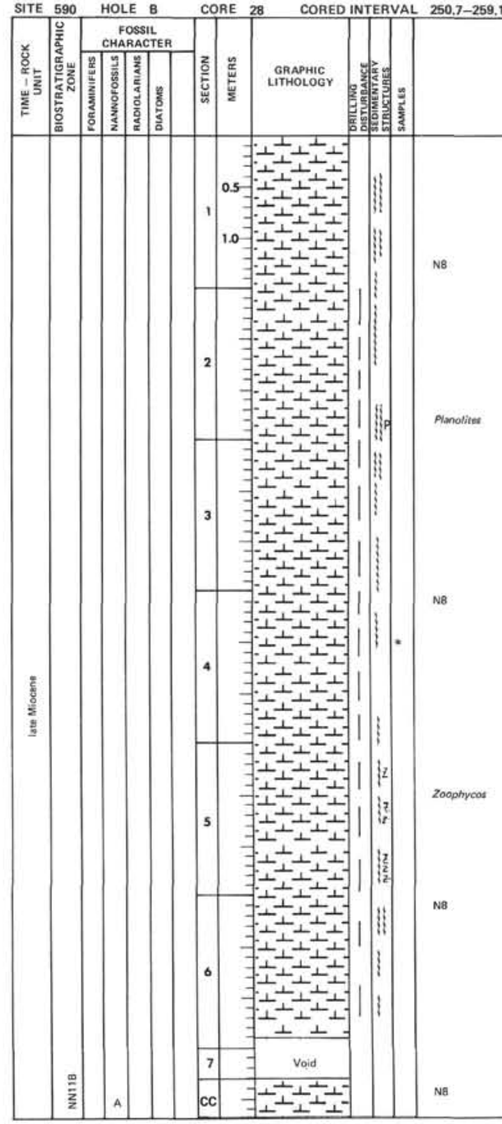
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft (stiff), moderately burrowed, burrows yellowish gray (5Y 8/1), faint pyrite streaks medium gray (N6) throughout.

SMEAR SLIDE SUMMARY:

	2, 85	4, 64
	D	M
Texture:		
Sand	T	C
Silt	R	C
Clay	D	A
Composition:		
Foraminifers	R	A
Calc. nannofossils	D	A
Sponge spicules	T	–
Volcanic glass	T	–
Clay minerals	T	–
Zeolites	T	–

SITE 590 HOLE B CORE 28 CORED INTERVAL 250.7–259.1 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, moderately burrowed, burrows (*Planolites, Zoophycos*) grayish yellow green (5GY 7/2) to yellowish gray (5Y 8/1), gray (N6–N5) streaks rare.

Drilling disturbance:

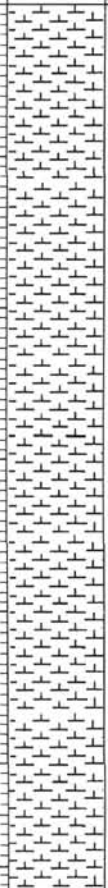
SMEAR SLIDE SUMMARY:

	4, 54
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 29 CORED INTERVAL 259.1–268.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	COLOR / REMARKS
late Miocene						1	0.5, 1.0	N8; 5GY 8/1
						2		N8; *Planolites*
						3		N8
						4		5GY 8/1; N8; 5G 8/1
						5		N8
						6		N8
	NN11B		A			CC		N8

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), soft, slightly bioturbated, burrows yellowish gray (5Y 8/1) (*Planolites*, undefined). Gray (N6–N5) spots throughout the core (rare).

Drilling disturbance:

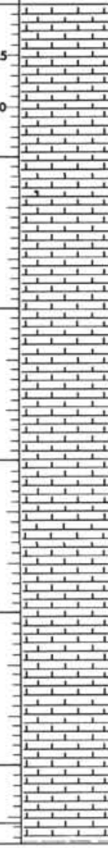
SMEAR SLIDE SUMMARY:

	2, 70
	D
Composition:	
Volcanic glass	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 30 CORED INTERVAL 268.7–278.3 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	COLOR / REMARKS
late Miocene	NN11B					1	0.5, 1.0	N8; 5G 7/2 (pale green ash layer?); N8
			A			2		N8
			A			3		N8
	NN11A		A			4		5G 8/1
			A			5		N8; 5G 8/1
						6		N8
	G. nepenthes NN11A	A	A			CC		N8

GRAPHIC LITHOLOGY



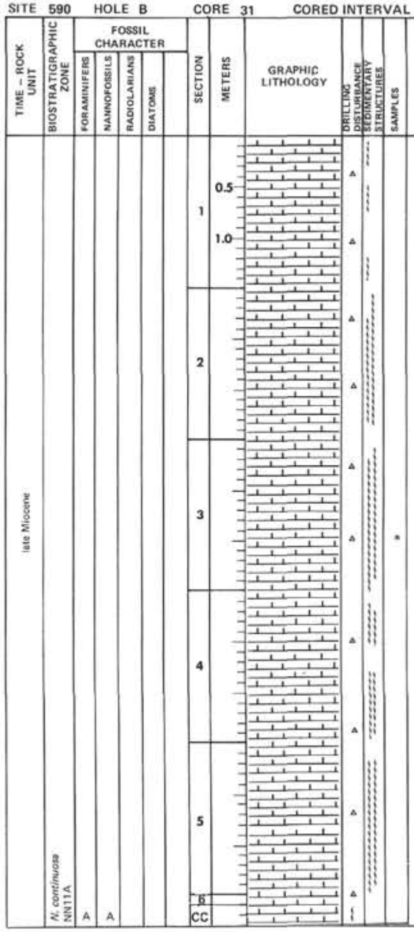
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8); intensively bioturbated. Burrows (*Zoophycos*, *Planolites*) yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2). Dark (N6) spots throughout the core (rare).

SMEAR SLIDE SUMMARY:

	1, 112
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D

SITE 590 HOLE B CORE 31 CORED INTERVAL 278.3–287.9 m



LITHOLOGIC DESCRIPTION

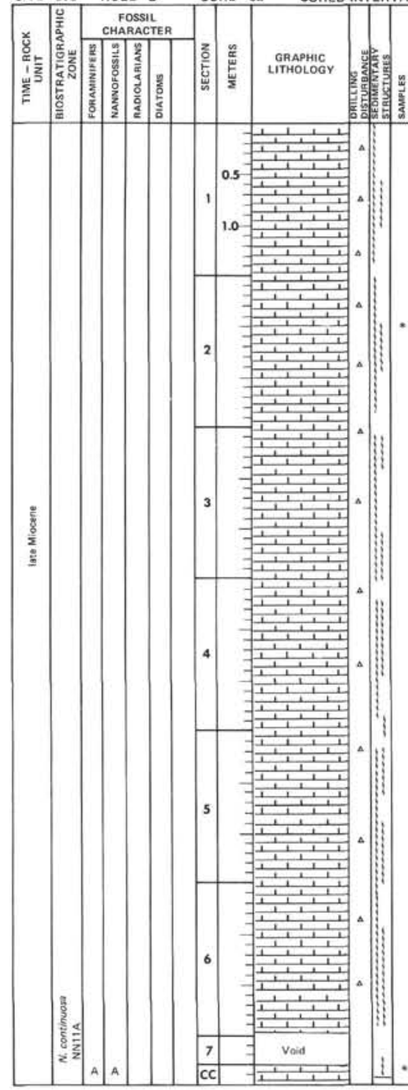
N8
N8
N8
N8
N8
N8

NANNOFOSSIL CHALK, firm, very light gray (N8), moderately to intensively bioturbated. Burrow (*Zoophycos, Planolites*) yellowish gray (5Y 8/1) and light gray (N7). Dark (N6–N7) spots throughout the entire core (rare).

SMEAR SLIDE SUMMARY:

	3, 102
Composition:	D
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 590 HOLE B CORE 32 CORED INTERVAL 287.9–297.5 m



LITHOLOGIC DESCRIPTION

N8
N8
N8
N8
N8
N8
5G 7/2 ash layer(?)

NANNOFOSSIL CHALK, firm, very light gray (N8), intensively bioturbated burrows (*Zoophycos, Planolites*) yellow gray (5Y 8/1) and light gray (N7). Dark (N6–N7)

SMEAR SLIDE SUMMARY:

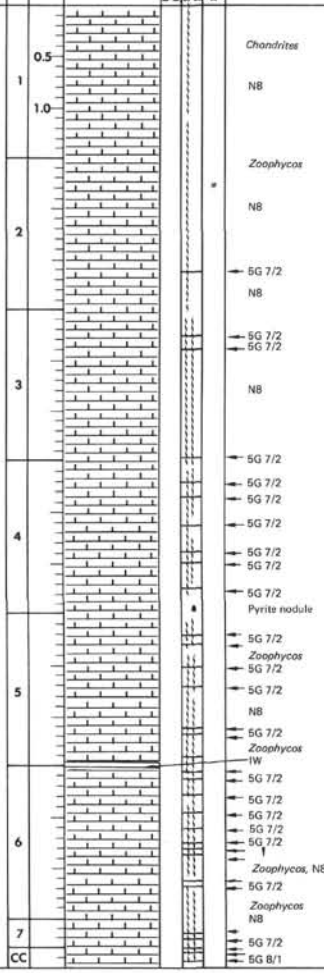
	2, 46	CC[1]
	D	M
Composition:		
Volcanic glass	T	R
Pyrite	T	C
Foraminifers	R	–
Calc. nannofossils	D	–
Diatoms	–	C
Radiolarians(?)	–	C
Sponge spicules	–	T
Silicoflagellates	–	T

[1]Insol. residue

SITE 590 HOLE B CORE 33 CORED INTERVAL 297.5–307.1 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
late Miocene	*N. continuosa* NN11A	A	A		

FOSSIL CHARACTER; SECTION; METERS; GRAPHIC LITHOLOGY; DRILLING DISTURBANCE; SEDIMENTARY STRUCTURES; SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8), moderately to intensively bioturbated. Burrows (*Zoophycos, Planolites, Chondrites*) yellowish gray (5Y 8/1) to light gray (N7). Increased bioturbation Sections 3–7, fine pale green (5G 7/2) layers ⟶ ash layers(?).

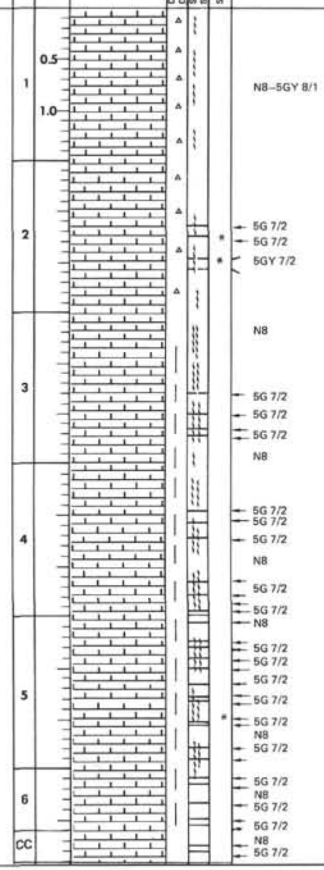
SMEAR SLIDE SUMMARY:

	2, 31
	D
Composition:	
Volcanic glass	T
Pyrite	T
Foraminifers	R
Calc. nannofossils	D
Radiolarians	T

SITE 590 HOLE B CORE 34 CORED INTERVAL 307.1–316.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
late Miocene	*N. continuosa* NN11A	A	A		

FOSSIL CHARACTER; SECTION; METERS; GRAPHIC LITHOLOGY; DRILLING DISTURBANCE; SEDIMENTARY STRUCTURES; SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5GY 8/1); moderately to heavily bioturbated. Burrows (*Zoophycos, Planolites*) yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2). Dark spots throughout the core. Pale green (5G 7/2) thin layers (⟶ ash layer?).

SMEAR SLIDE SUMMARY:

	2, 70	2, 112	5, 102
	D	M	M
Composition:			
Volcanic glass	T	–	–
Pyrite	T	–	–
Foraminifers	R	R	R
Calc. nannofossils	D	D	D

SITE 590 HOLE B CORE 35 CORED INTERVAL 316.7–326.3 m

TIME-ROCK UNIT: late Miocene

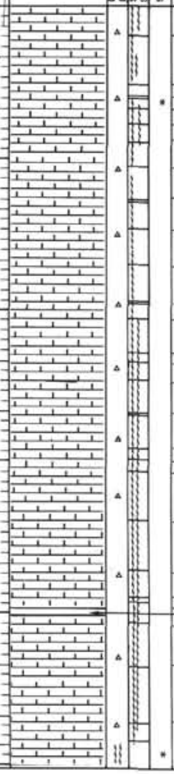
BIOSTRATIGRAPHIC ZONE: NN11A; *N. continuosa* NN10

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



Section 1: 5G 7/2, N8, 5G 7/2, 5G 7/2, 5G 7/2, 5G 7/2
Section 2: 5G 7/2, N8, 5G 7/2, N8, 5G 7/2, N8, 5G 7/2, N8
Section 3: 5G 7/2, 5G 7/2, N8, 5G 7/2, 5G 7/2, N8, 5G 7/2, N8
Section 4: 5G 7/2, 5G 7/2, N8, 5G 7/2, N8, 5G 7/2, 5G 7/2
Section 5: IW, 5G 7/2, N8, 5G 7/2, N8, 5G 7/2
CC: N8

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8), intensively bioturbated (*Zoophycos, Planolites, Chondrites*) yellow gray (5Y 8/1). Dark (N6–N7) spots. Thin pale green (5G 7/2) laminae └→ ash layers(?).

Microfault near 75 cm Section 3.

SMEAR SLIDE SUMMARY:

	1, 100	CC[1]
	D	M
Composition:		
Quartz	T	–
Feldspar	T	T
Volcanic glass	T	T
Pyrite	–	C
Foraminifers	R	–
Calc. nannofossils	D	–
Diatoms	–	C
Radiolarians	T	C
Sponge spicules	–	R
Unident.	–	A

[1] Insol. residue

SITE 590 HOLE B CORE 36 CORED INTERVAL 326.3–335.9 m

TIME-ROCK UNIT: late Miocene

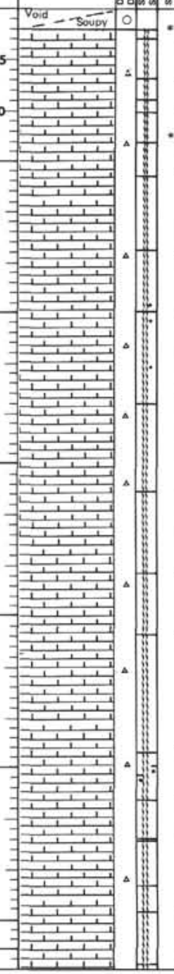
BIOSTRATIGRAPHIC ZONE: *N. continuosa* NN10

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



Section 1: 5GY 7/2, 5G 7/2, 5G 7/2, 5G 7/2, 5G 7/2
Section 2: 5G 7/2, N8, 5G 7/2, 5G 7/2 Pyrite nodules, Pyrite nodule
Section 3: Pyrite nodule, 5G 7/2, N8
Section 4: 5G 7/2, N8, 5G 7/2
Section 5: 5G 7/2, N8, 5G 7/2 Pyrite nodules
Section 6: 5G 7/2, 5G 7/2, 5G 7/2, 5G 7/2
Section 7: N8
CC: 5G 7/2

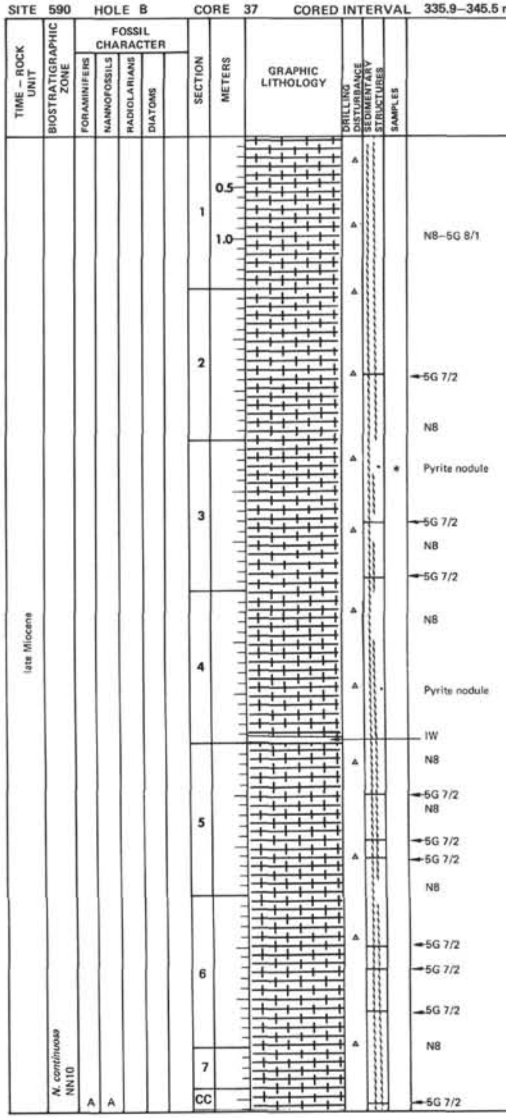
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5GY 8/1), intensively bioturbated (*Zoophycos, Planolites*). Burrows grayish yellow green (5GY 7/2) and yellowish gray (5Y 8/1). Dark (N6) spots. Thin pale green (5G 7/2) layers └→ ash layers?.

SMEAR SLIDE SUMMARY:

	1, 22	1, 124
	M	D
Composition:		
Feldspar	T	–
Clay	C	–
Volcanic glass	T	T
Pyrite	–	T
Foraminifers	R	R
Calc. nannofossils	D	D
Radiolarians	T	–
Unident.		C
(degrad. ash?)	C	–

SITE 590 HOLE B CORE 37 CORED INTERVAL 335.9–345.5 m



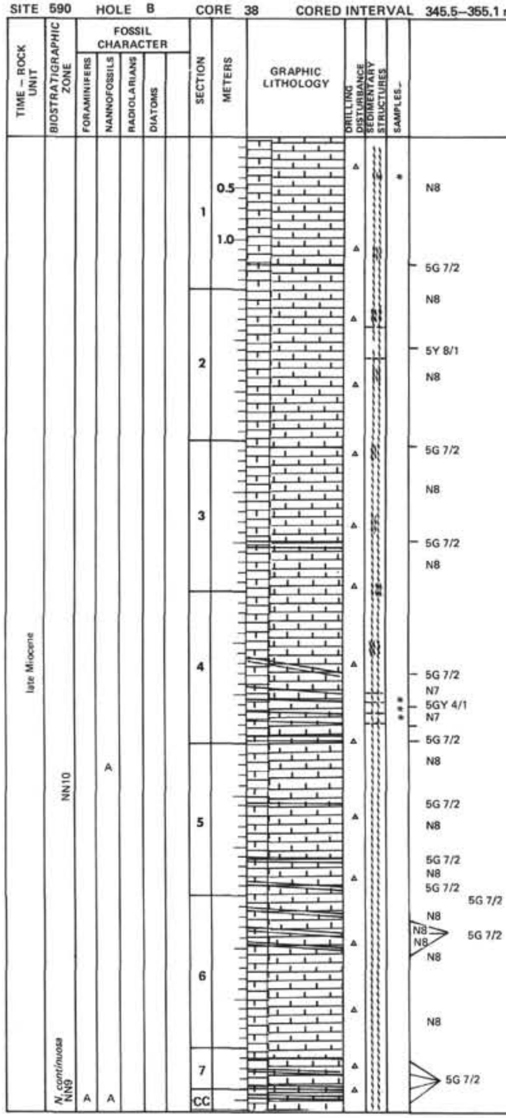
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1); intensively bioturbated (*Planolites, Zoophycos, Chondrites*). Burrows yellowish gray (5Y 8/1), grayish yellow green (5GY 7/2), and light gray (N7); dark spots (N6). Thin pale green (5G 7/2) laminae └→ash layers(?).

SMEAR SLIDE SUMMARY:

	3, 29
	D
Composition:	
Heavy minerals	T
Volcanic glass	T
Carbonate unspec.	C
Foraminifers	C
Calc. nannofossils	A
Radiolarians	T
Pyrite	T

SITE 590 HOLE B CORE 38 CORED INTERVAL 345.5–355.1 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated with burrows yellowish gray (5Y 8/1) to grayish yellow green (5GY 7/2), light gray (N6) pyrite streaks. Pale green (5G 7/2) ash(?) layers periodically.

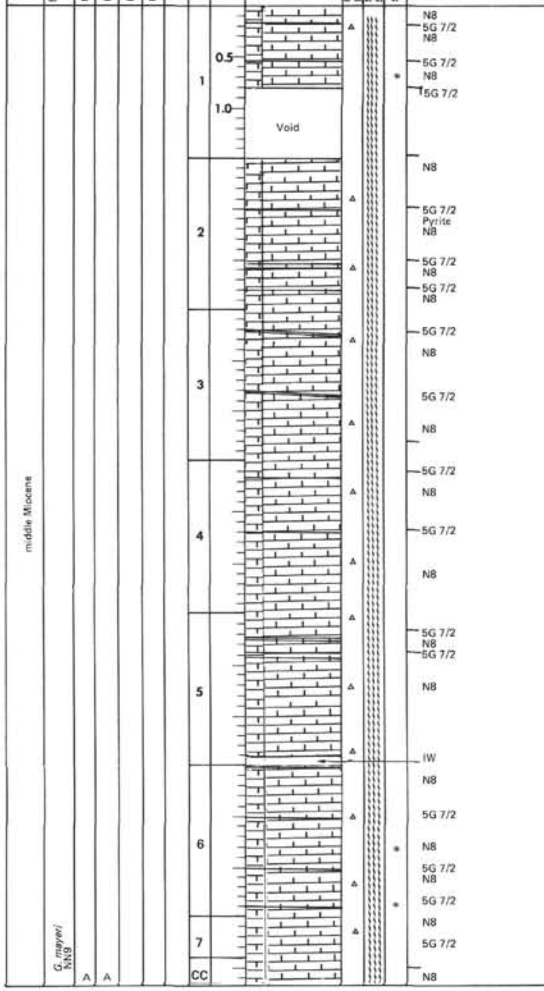
PYRITIFEROUS VITRIC ASH in Section 4 at 105–115 cm, dark greenish gray (5GY 4/1), VITRIC ASH FORAMINIFER NANNOFOSSIL CHALK, below to ~ 130 cm, medium light gray to light gray (N7). *Zoophycos* burrows obvious.

SMEAR SLIDE SUMMARY:

	1, 43	4, 112	4, 127
	D	M	M
Texture:			
Sand	R	R	A
Silt	C	D	A
Clay	D	R	A
Composition:			
Feldspar	–	R	T
Clay minerals (incl. mica)	T	R	R
Heavy minerals	–	T	–
Volcanic glass	T	A	A
Pyrite	T	A	T
Foraminifers	C	T	A
Calc. nannofossils	D	R	A
Radiolarians	T	–	–

SITE 590 HOLE B CORE 39 CORED INTERVAL 355.1–364.7 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



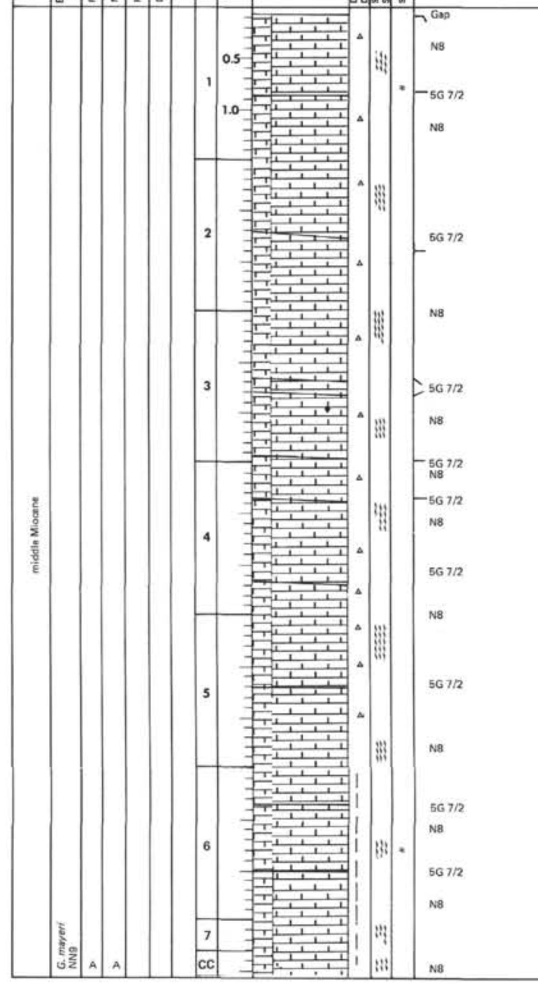
FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated. Burrows yellowish gray (5Y 8/1). *Zoophycos* burrows common. Pale green (5G 7/2) layers common. Medium dark gray (N4) streaks throughtout — pyrite?.

SMEAR SLIDE SUMMARY:

	1, 66	6, 80	6, 137
	D	M	M
Texture:			
Sand	C	C	C
Silt	C	C	C
Clay	D	A	A
Composition:			
Feldspar	–	–	T
Clay minerals (incl. mica)	–	T	T
Volcanic glass	T	T	T
Pyrite	–	T	T
Foraminifers	C	A	A
Calc. nannofossils	D	A	A

SITE 590 HOLE B CORE 40 CORED INTERVAL 364.7–374.3 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

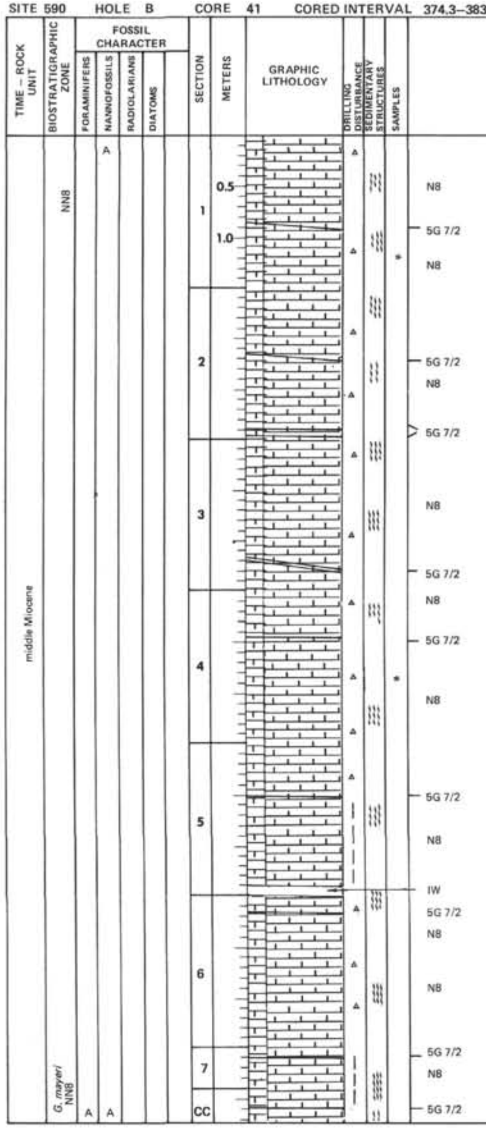


FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated. Burrows light gray (N7) to yellowish gray (5Y 8/1). *Zoophycos* apparent, pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	1, 82	6, 78
	D	M
Texture:		
Sand	C	C
Silt	C	C
Clay	D	D
Composition:		
Feldspar	T	T
Mica	T	–
Volcanic glass	T	T
Pyrite	–	T
Zeolite	–	T
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 41 CORED INTERVAL 374.3–383.9 m



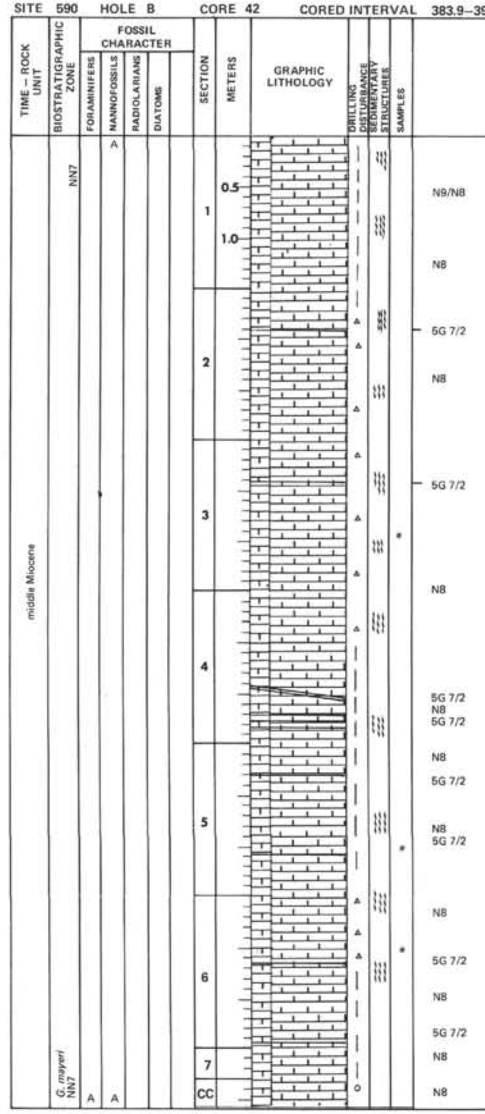
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated, burrows light gray (N7) to yellowish gray (5Y 8/1). Pale green (5G 7/2) layers common. Medium dark gray (N4) streaks throughout.

SMEAR SLIDE SUMMARY:

	1, 119	4, 76
	D	D
Texture:		
Sand	C	C
Silt	C	C
Clay	D	D
Composition:		
Quartz	T	–
Mica	–	T
Volcanic glass	T	T
Pyrite	T	–
Zeolite	T	–
Foraminifers	C	C
Calc. nannofossils	D	D

SITE 590 HOLE B CORE 42 CORED INTERVAL 383.9–393.5 m



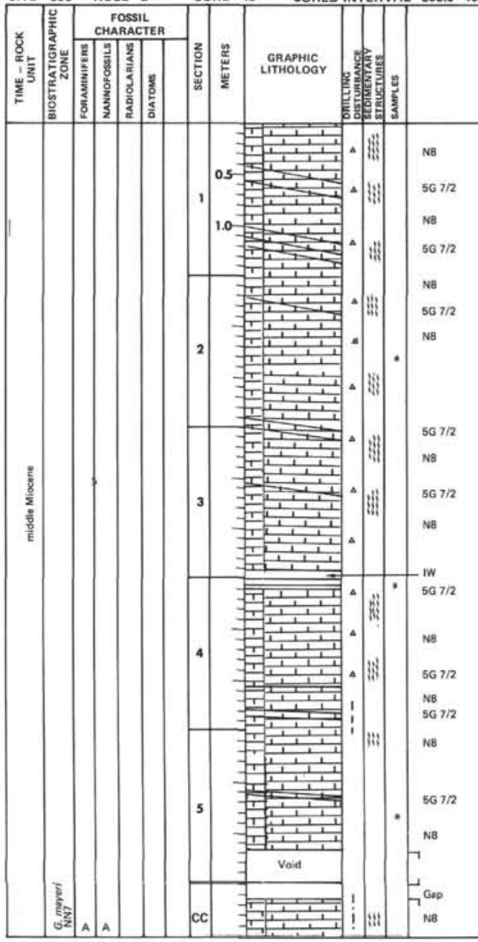
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to white (N9). Moderate to intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers occur. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	3, 93	5,110	6, 49
	D	M	M
Texture:			
Sand	C	C	C
Silt	C	C	C
Clay	D	A	D
Composition:			
Clay minerals (incl. mica)	T	T	–
Volcanic glass	T	T	T
Pyrite	T	T	R
Foraminifers	C	A	C
Calc. nannofossils	D	A	D
Radiolarians	T	–	–

SITE 590 HOLE B CORE 43 CORED INTERVAL 393.5–403.1 m



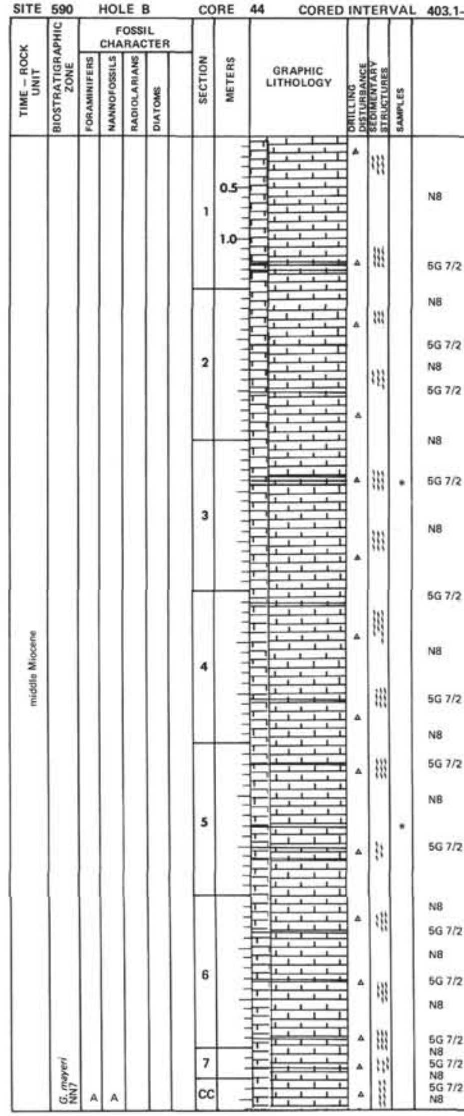
LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely bioturbated, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	2, 79	4, 6	5, 83
	M	M	D
Texture:			
Sand	C	C	R
Silt	C	C	C
Clay	A	D	D
Composition:			
Clay minerals (incl. mica)	T	T	T
Volcanic glass	T	T	T
Pyrite	T	T	T
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE B CORE 44 CORED INTERVAL 403.1–412.7 m



LITHOLOGIC DESCRIPTION

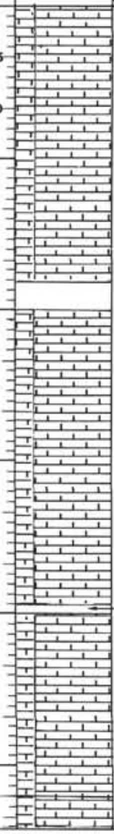
FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1). Pale green (5G 7/2) layers. Medium dark gray (N4) streaks common.

SMEAR SLIDE SUMMARY:

	5, 79	3, 37
	D	M
Texture:		
Sand	R	R
Silt	C	A
Clay	D	A
Composition:		
Feldspar	–	T
Mica	T	T
Volcanic glass	T	–
Pyrite	T	C
Foraminifers	C	C
Calc. nannofossils	D	A

SITE 590 HOLE B CORE 45 CORED INTERVAL 412.7–422.3 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
middle Miocene	NN7		A			1	0.5 1.0				
	NN6		A			2, 3, 4, 5					* * *
	G. fohsi s. l. NN6	A	A			6, CC					



N8

Void

N8

IW

N8

N8

N8

LITHOLOGIC DESCRIPTION

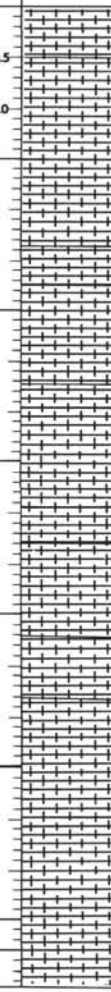
FORAM-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8), intensely burrowed, burrows light gray (N7) to light olive gray (5Y 6/1).

SMEAR SLIDE SUMMARY:

	2, 24	2, 119	5, 120
	M	D	M
Texture:			
Sand	R	C	R
Silt	C	C	C
Clay	A	D	D
Composition:			
Mica	T	T	–
Volcanic glass	T	T	T
Pyrite	T	–	T
Foraminifers	A	C	C
Calc. nannofossils	A	D	D

SITE 590 HOLE B CORE 46 CORED INTERVAL 422.3–431.9 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
middle Miocene						1, 2, 3, 4, 5, 6, 7	0.5 1.0				* *
	G. fohsi s. l. NN6	A	A			CC					



N8

5G 7/2

N7

N8

5G 7/2

N8

N7

5Y 8/1

N7

N8

N7

5GY 7/2

N7

N8

5G 7/2

5Y 8/1

N7

N8

5G 7/2

N8

5G 7/2

N8

N8

N8

N8

N8

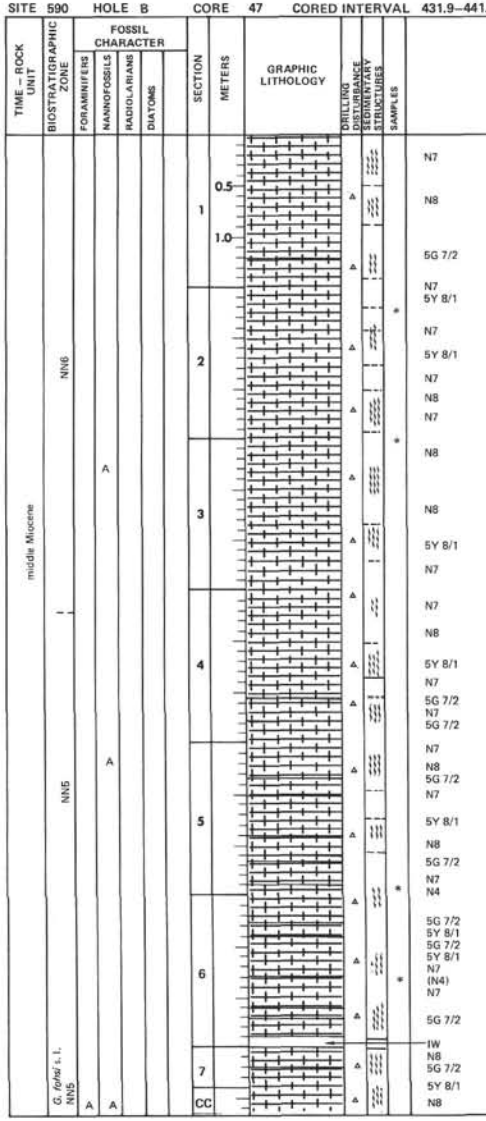
LITHOLOGIC DESCRIPTION

FORAMINIFER NANNOFOSSIL CHALK, firm, very light gray (N8), heavily burrowed, burrows light gray (N7) to light olive gray (5Y 8/1). Pale green (5G 7/2) alteration layers. Medium gray (N4) streaks.

SMEAR SLIDE SUMMARY:

	3, 86	6, 106
	D	D
Texture:		
Sand	C	C
Silt	C	C
Clay	A	A
Composition:		
Quartz	T	–
Volcanic glass	T	T
Pyrite	T	T
Foraminifers	A	A
Calc. nannofossils	A	A
Sponge spicules	T	T

SITE 590 HOLE B CORE 47 CORED INTERVAL 431.9–441.5 m



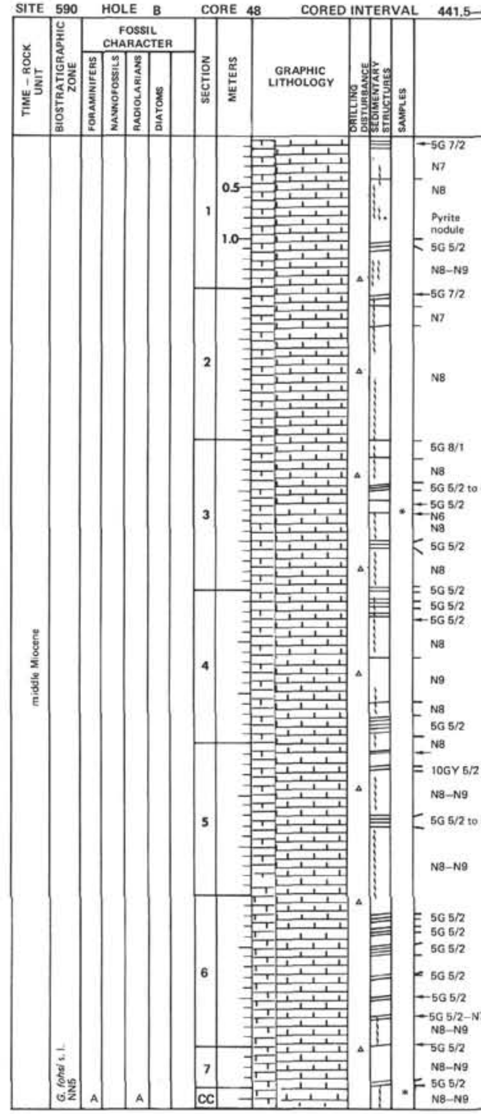
LITHOLOGIC DESCRIPTION

NANNOFOSSIL FORAMINIFER CHALK, firm, very light gray (N8) to light gray (N7) to light olive gray (5Y 8/1) with pale green (5G 7/2) and medium dark gray (N4) streaks. Intensely bioturbated. Burrows concentrated in light (N7–N8) zones. Contacts gradational. Light (N8) zones lower in foraminifers becoming a foraminifer nannofossil chalk.

SMEAR SLIDE SUMMARY:

	2, 27	3, 4	5, 140	6, 87
	D	D	D	M
Texture:				
Sand	C	C	C	C
Silt	A	A	C	A
Clay	A	A	A	A
Composition:				
Feldspar	T	T	T	–
Mica	T	–	T	T
Volcanic glass	T	T	T	T
Pyrite	–	T	T	R
Carbonate unspec.	T	–	–	–
Foraminifers	A	A	A	A
Calc. nannofossils	A	A	A	A

SITE 590 HOLE B CORE 48 CORED INTERVAL 441.5–451.1 m



LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light gray (N7). Moderately bioturbated (*Planolites*, beautiful *Zoophycos*) burrows grayish yellow green (5GY 7/2). Thin pale green (5G 7/2) to grayish green (5G 5/2) laminae → (compressed) ash layers(?).

SMEAR SLIDE SUMMARY:

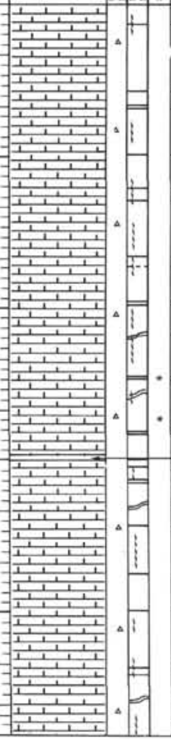
	3, 65	CC[1]
	D	M
Composition:		
Volcanic glass	T	R
Pyrite	–	T
Zeolite	–	A
Carbonate unspec.	A	–
Foraminifers	C	–
Calc. nannofossils	A	–

[1] Insoluble residue

SITE 590 HOLE B CORE 49 CORED INTERVAL 451.1–460.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Miocene	G. miozea NN5	A	A			1, 2, 3, 4, 5, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



5G 8/1
N8
5G 5/2
5G 8/1
N8
5G 8/1
N8
N7
N8–N9
5G 5/2
5G 8/1
N8–N9
5G 5/2
N8–N9
5G 5/2
5G 8/1
IW
5G 5/2
N9
5G 8/1
N7
N9
5G 8/1
5G 7/2
N8
5G 8/1
N9
5G 8/1
5G 5/2
N7
5G 8/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1), less bioturbated greenish gray (5G 5/2) to light gray (N7) laminae → (compressed) ash layers(?). Greenish gray parts recrystallized. Some flaser type bedding( ).

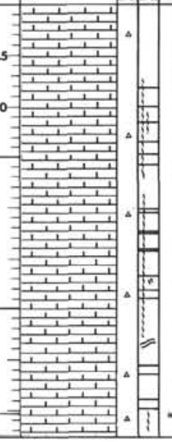
SMEAR SLIDE SUMMARY:

	3, 73	3, 114
	D	D
Composition:		
Heavy minerals	T	–
Volcanic glass	T	T
Carbonate unspec.	A	A
Foraminifers	R	R
Calc. nannofossils	A	A

SITE 590 HOLE B CORE 50 CORED INTERVAL 460.7–470.3 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Miocene	NN4 … G. miozea NN4	A	A, A, A			1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



5GY 8/1
N8
5GY 6/1
N8
5G 3/2
5GY 6/1
N8
5G 6/1
5G 6/1
N8
N9
5G 7/1
N8
5G 7/1
Stylolites(?)
5G 8/1
N9
5G 8/1
5G 3/2
5G 6/1
5G 8/1

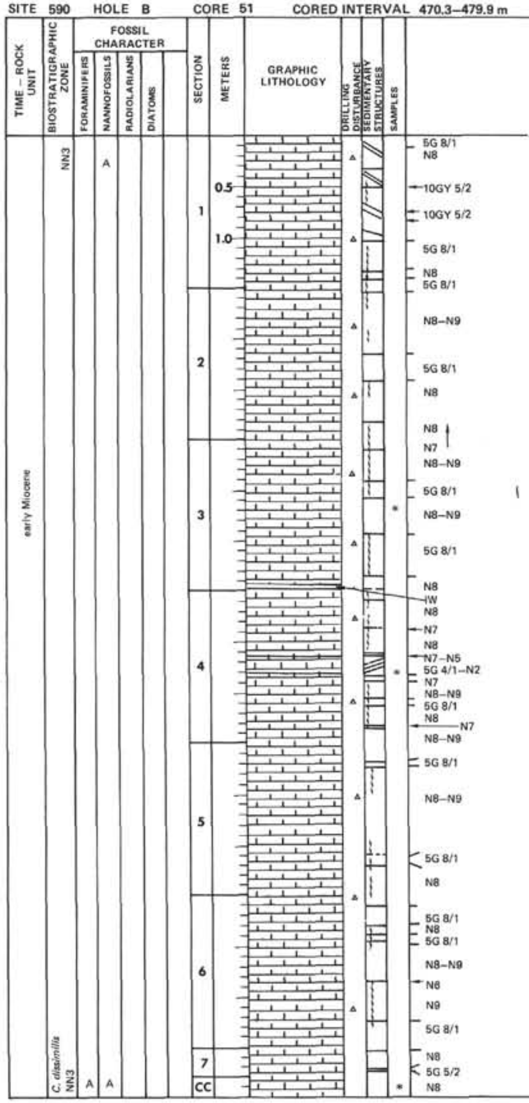
LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, firm, light greenish gray (5GY 8/1) to greenish gray (5GY 6/1), bioturbation rare (*Zoophycos*, *Planolites*, undefined). Some greenish (5G 3/2) layers → volcanic ash? Some flaser bedding ( ). Section 3, 90–100 cm breccia (bx).

SMEAR SLIDE SUMMARY:

	3, 97
	M
Composition:	
Volcanic glass	C
Pyrite	T
Carbonate unspec.	A
Foraminifers	R
Calc. nannofossils	A

SITE 590 HOLE B CORE 51 CORED INTERVAL 470.3–479.9 m



LITHOLOGIC DESCRIPTION

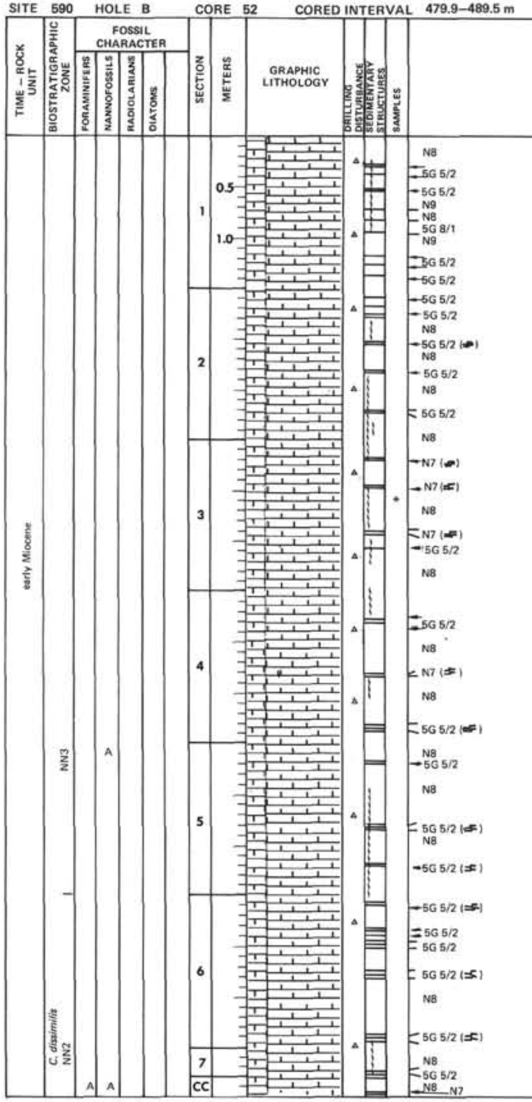
RECRYSTALLIZED NANNOFOSSIL CHALK, firm, very light gray (N8) and white (N9) to greenish gray (5GY 6/1), bioturbation moderate (*Planolites, Zoophycos, Chondrites*). Section 1: thin, angular (~ 30°) laminae (greenish gray [10GY 5/2]) in the upper part of the section, near 50 cm flaser bedding. Section 4: 66–82 cm interval dark greenish gray (5G 4/1) to grayish black (N2) part, fine laminae, *Chondrites*. Smear slide → ALTERED VOLCANIC GLASS (palagonite).

SMEAR SLIDE SUMMARY:

	3, 70 D	4, 82 M	CC[1] M
Composition:			
Quartz	–	T	–
Feldspar	–	T	–
Clay (smectite?)	–	R	C
Volcanic glass	T	–	C
Palagonite	–	A	–
Pyrite	–	–	C
Carbonate unspec.	A	–	–
Foraminifers	R	–	–
Calc. nannofossils	A	R	–

[1] Insol. residue

SITE 590 HOLE B CORE 52 CORED INTERVAL 479.9–489.5 m



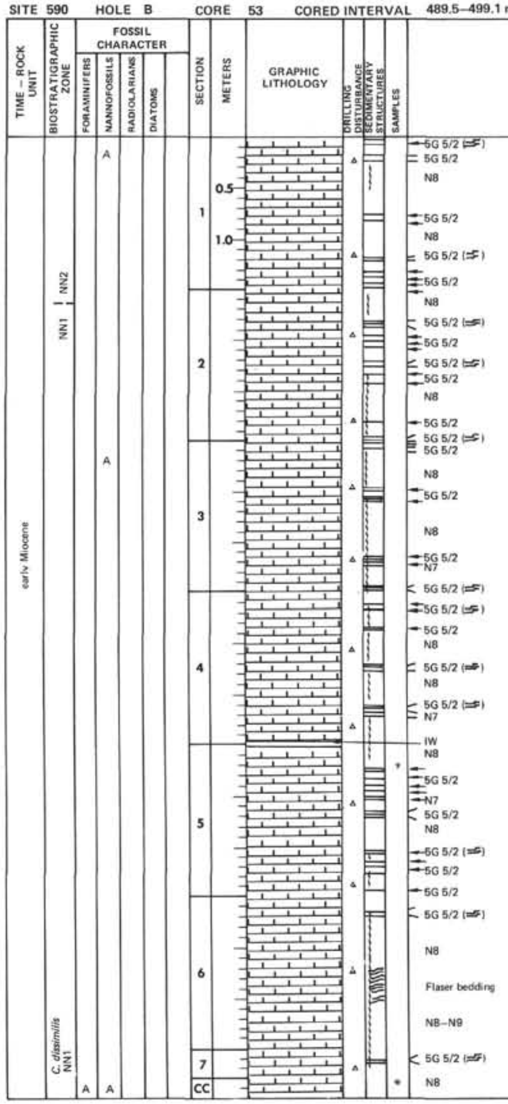
LITHOLOGIC DESCRIPTION

RECRYSTALLIZED FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very light gray (N8) to light greenish gray (5G 8/1), moderately bioturbated (*Planolites, Zoophycos*). Thin, grayish green (5G 5/2) laminae → volcanic ash layers(?), flaser bedding ( ).

SMEAR SLIDE SUMMARY:

	3, 65 D
Composition:	
Volcanic glass	R
Carbonate unspec.	A
Foraminifers	C
Calc. nannofossils	A

SITE 590 HOLE B CORE 53 CORED INTERVAL 489.5–499.1 m

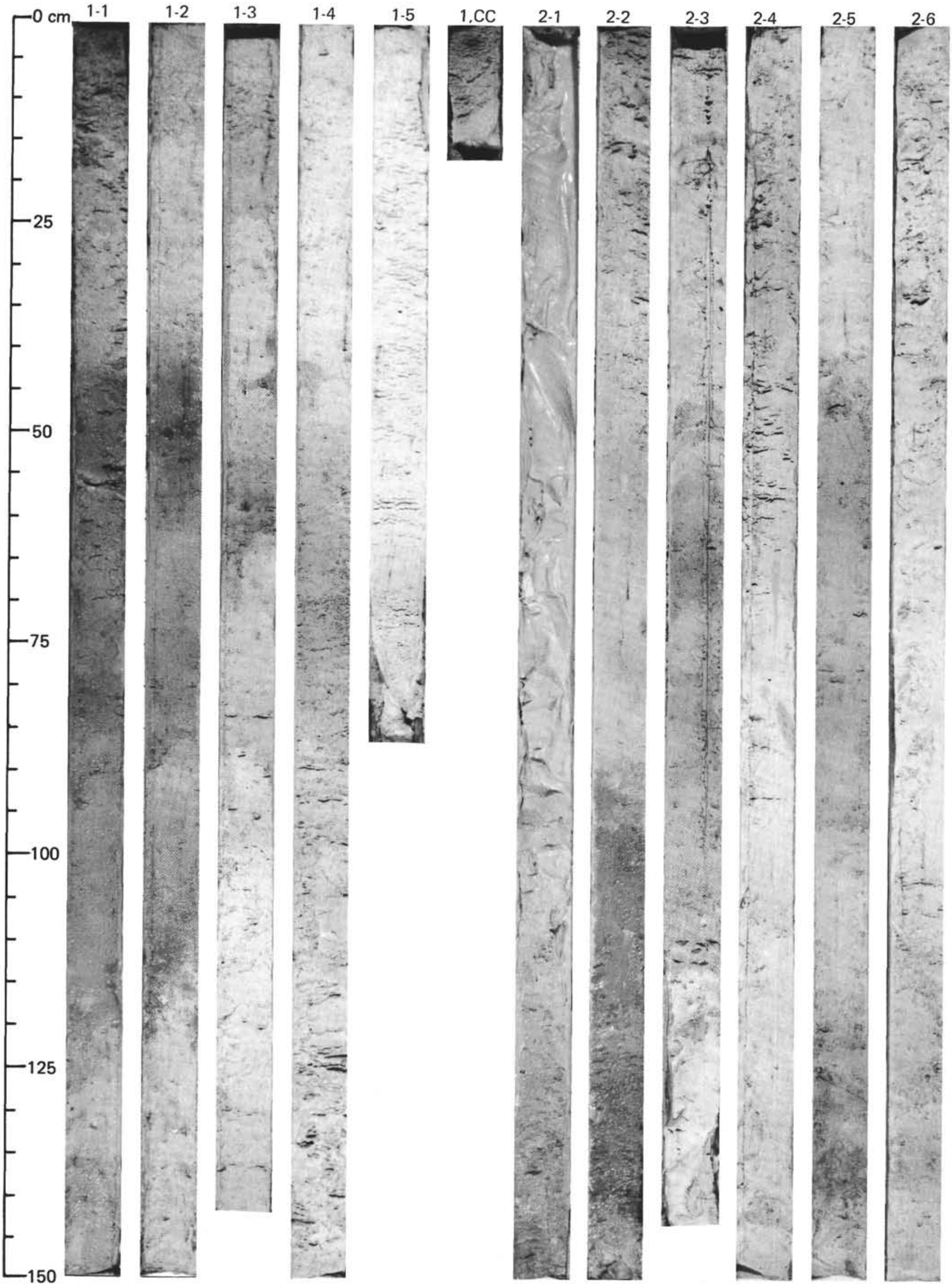


LITHOLOGIC DESCRIPTION

RECRYSTALLIZED NANNOFOSSIL CHALK, firm, very light gray (N8). Some bioturbation. Thin, greenish gray (5G 5/2) laminae → (compressed) ash layers?. Some dark (N6) spots → iron sulfide, flaser bedding ( ).

SMEAR SLIDE SUMMARY:

	5, 20	CC[1]
	D	M
Composition:		
Volcanic glass	T	C
Zeolites	–	A
Pyrite	–	T
Foraminifers	R	–
Calc. nannofossils	A	–
Carbonate unspec.	A	–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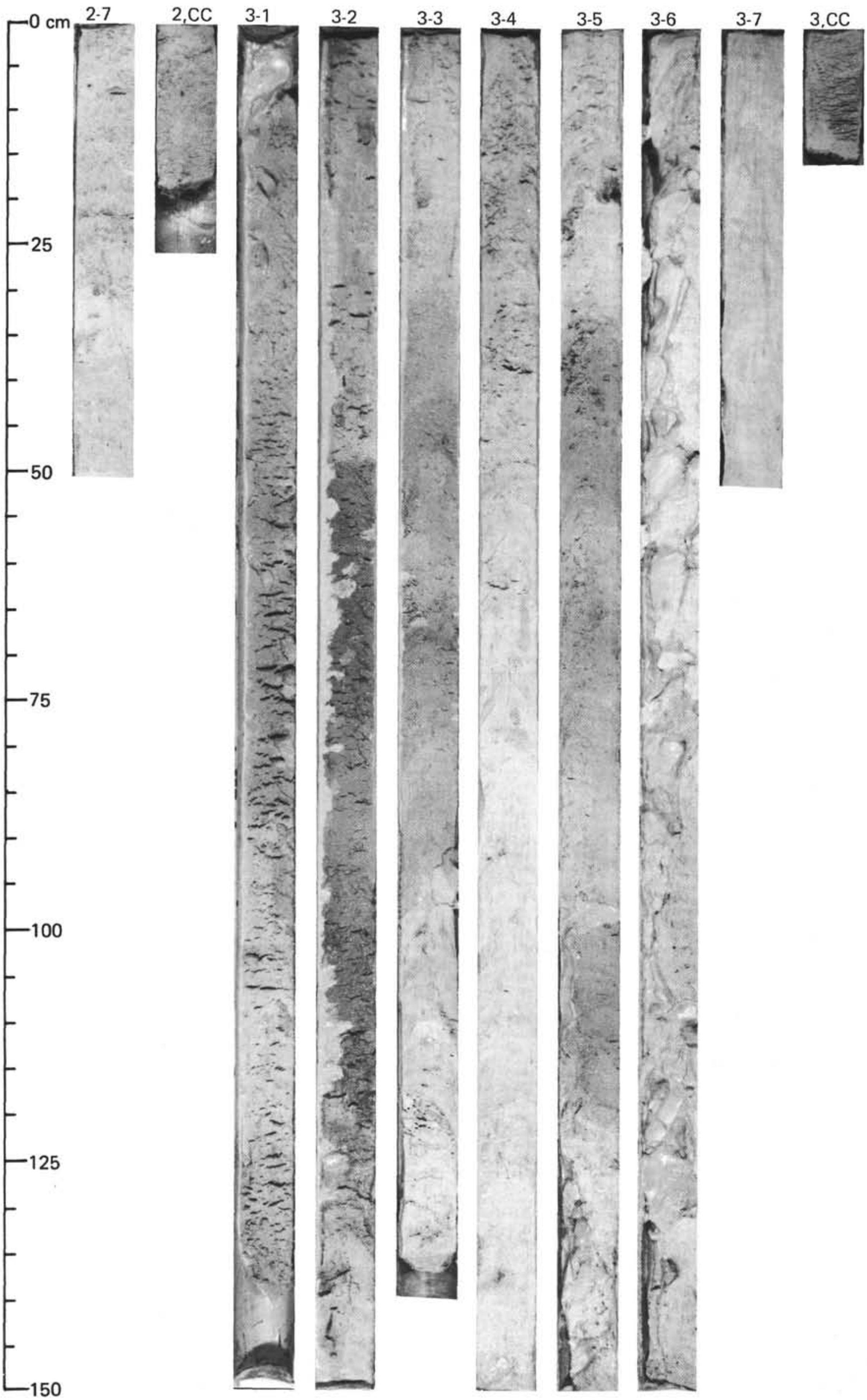
2-6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3-6
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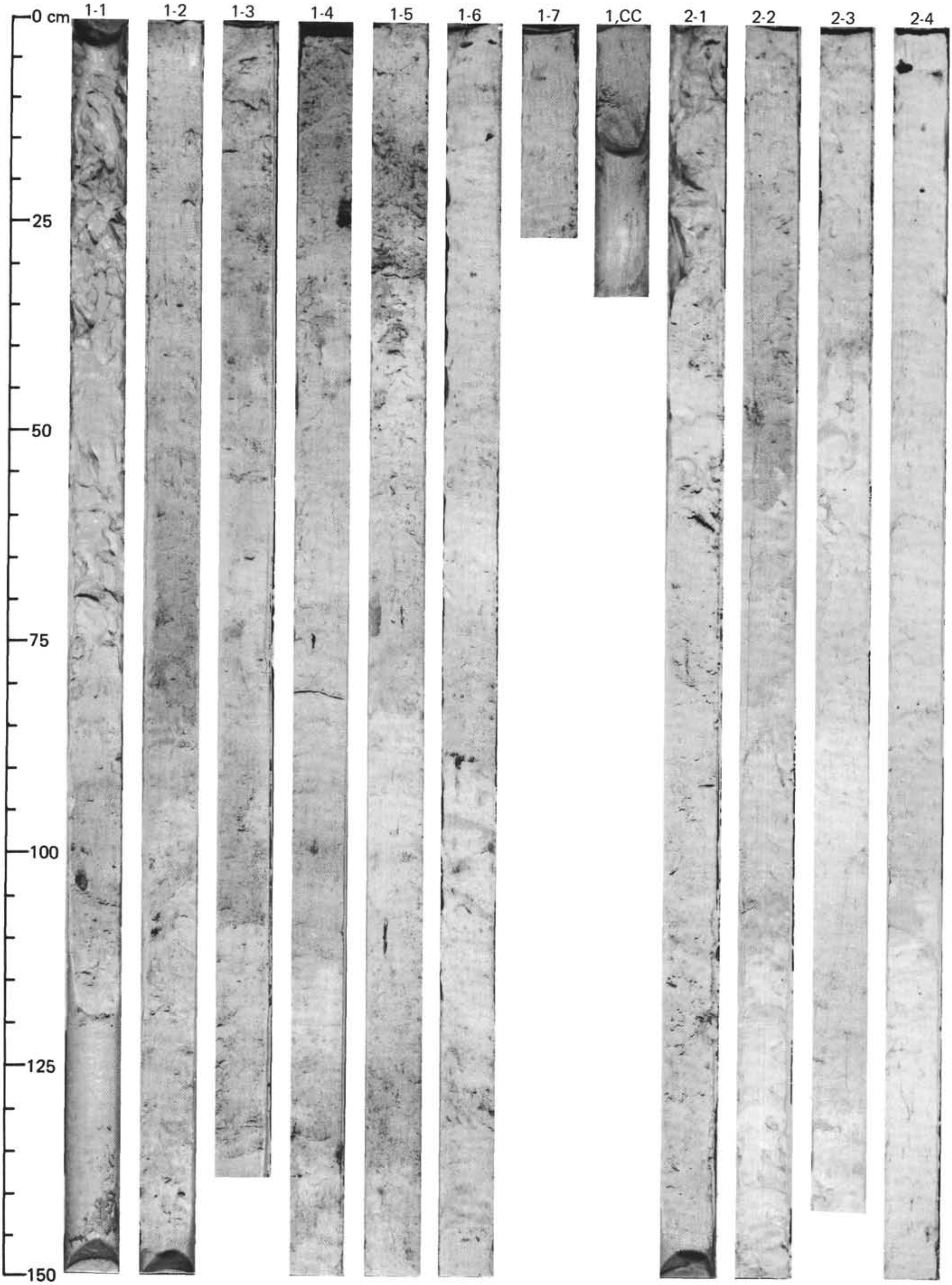
3,CC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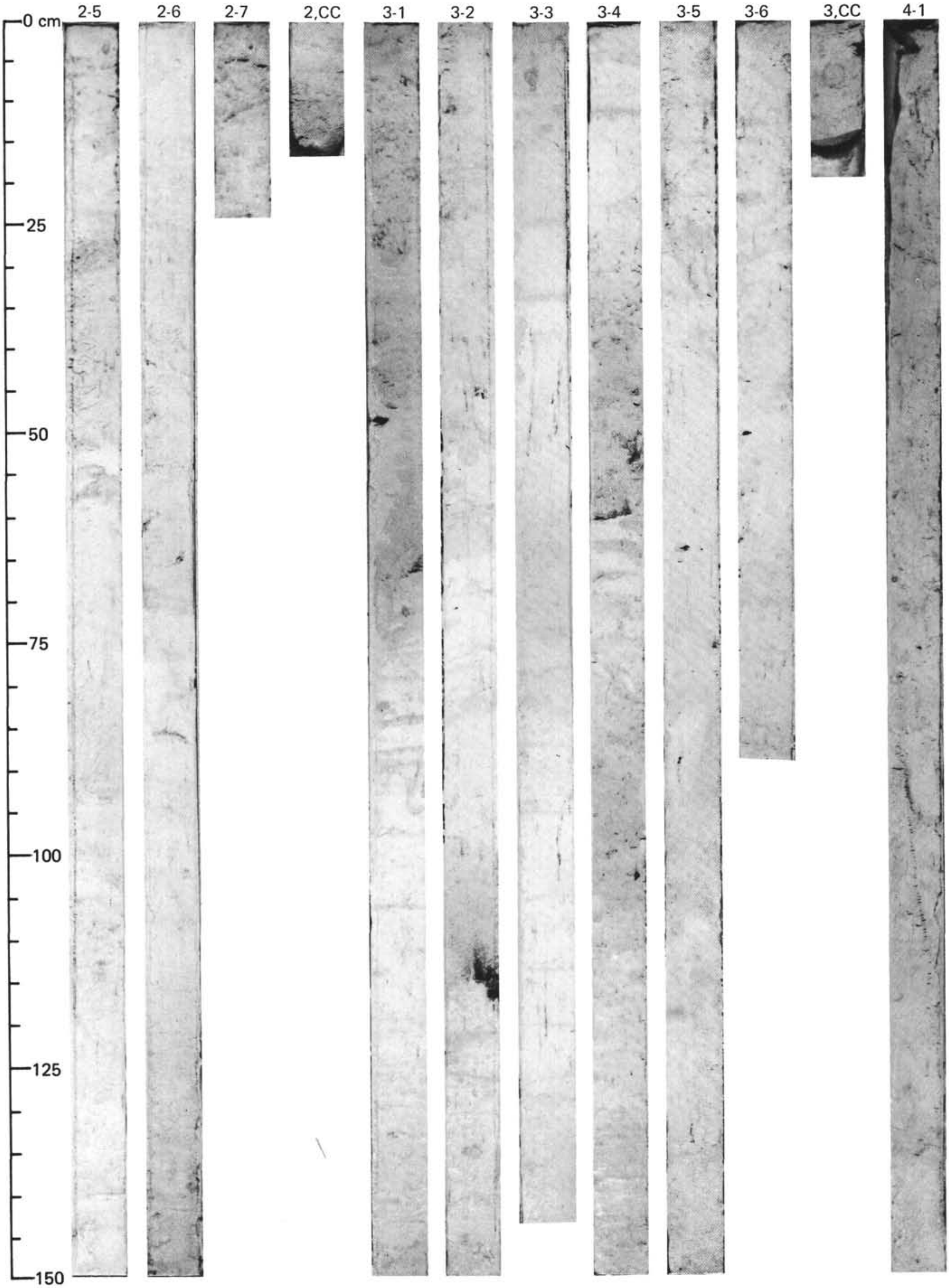
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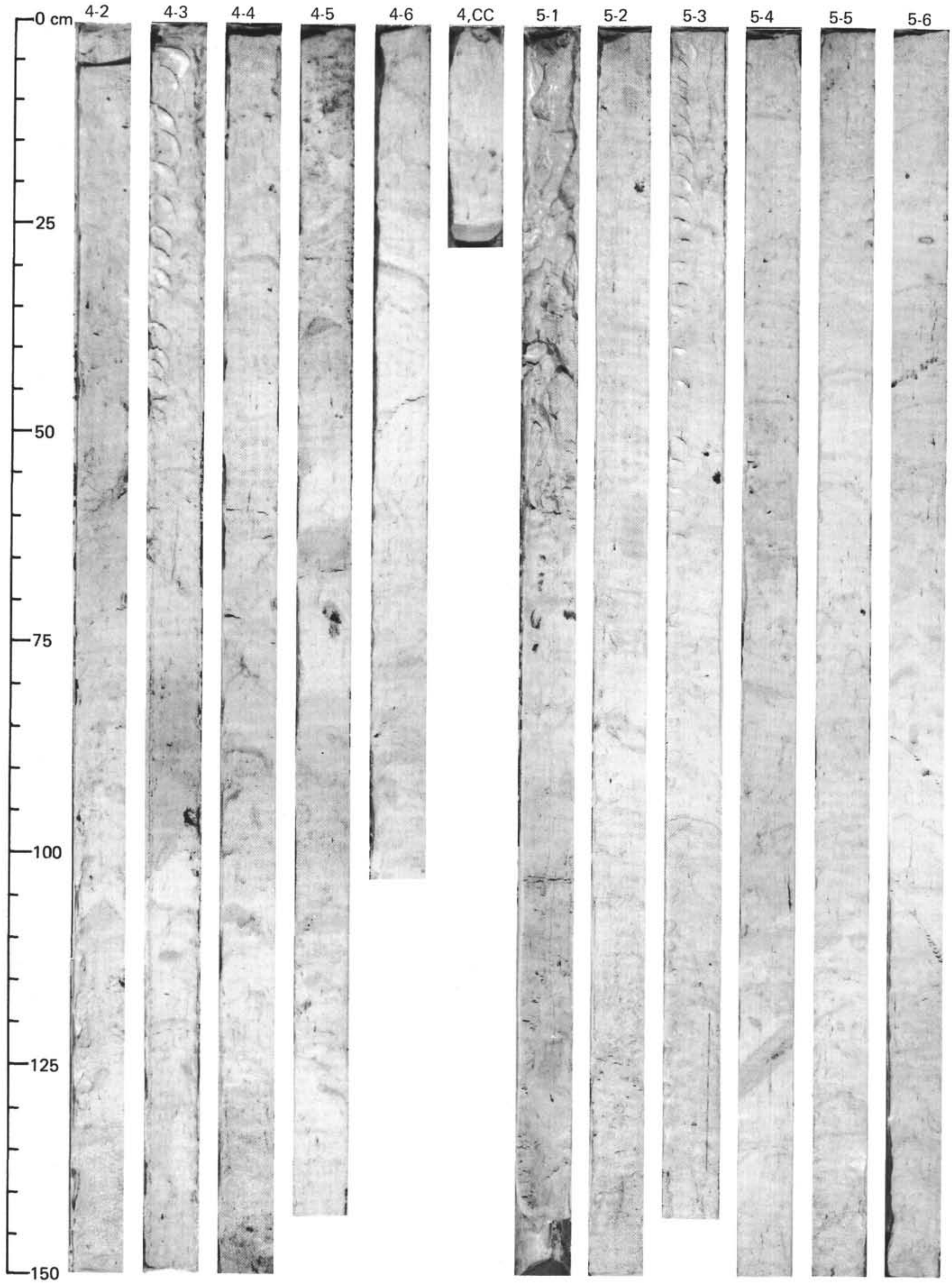
4-1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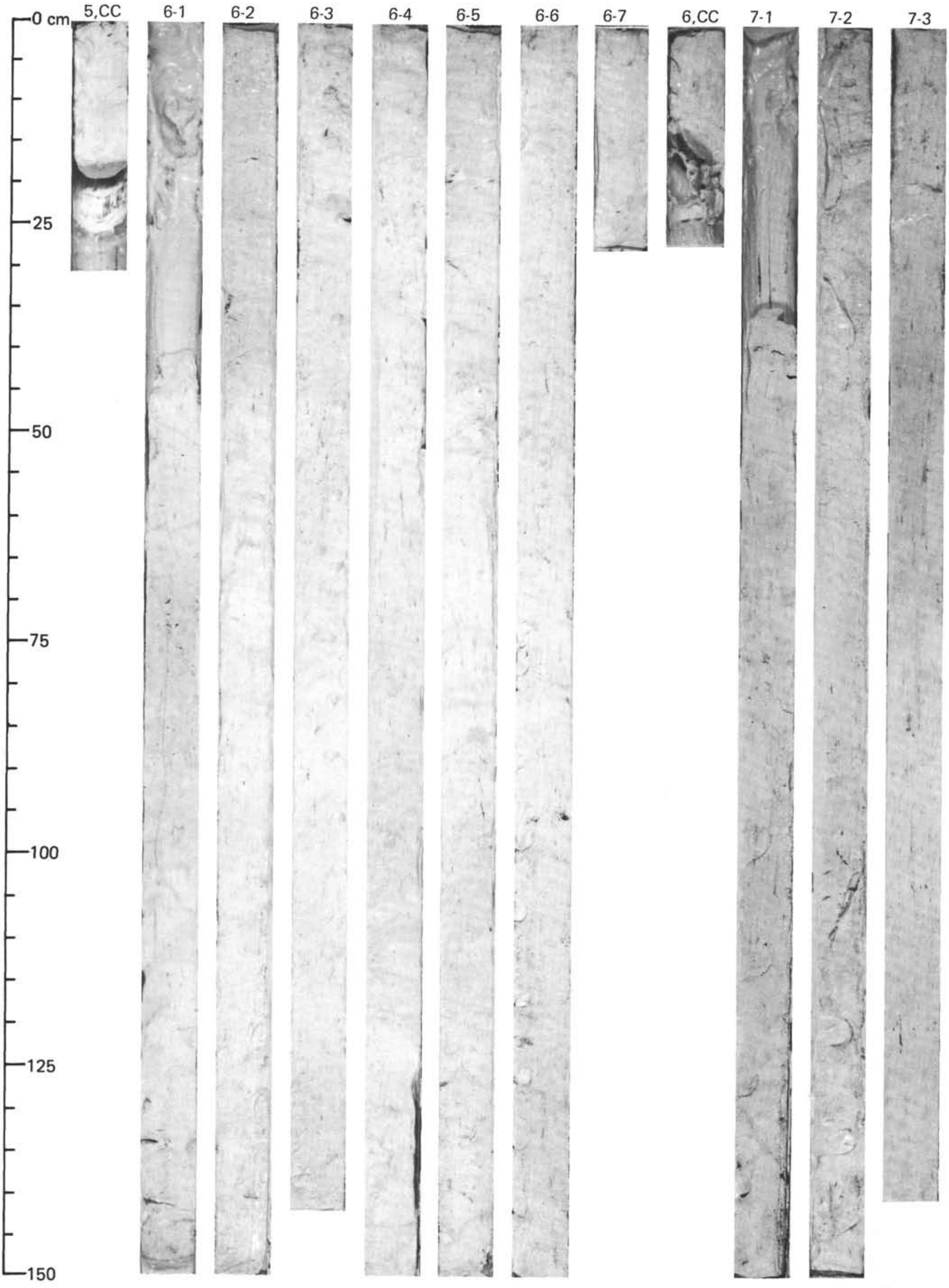
5-5
5-6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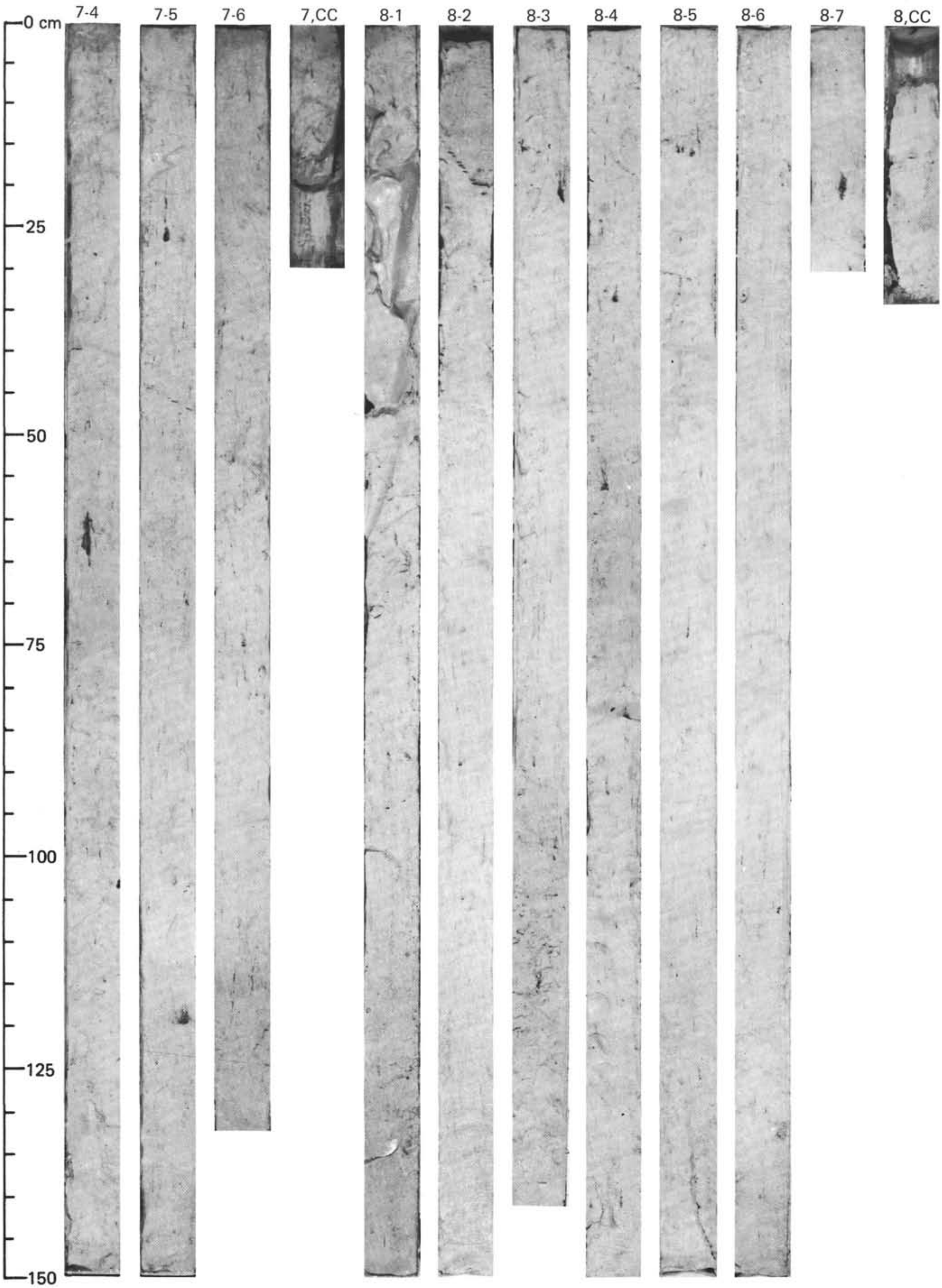
7-2
7-3



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8-6
8-7
8,CC

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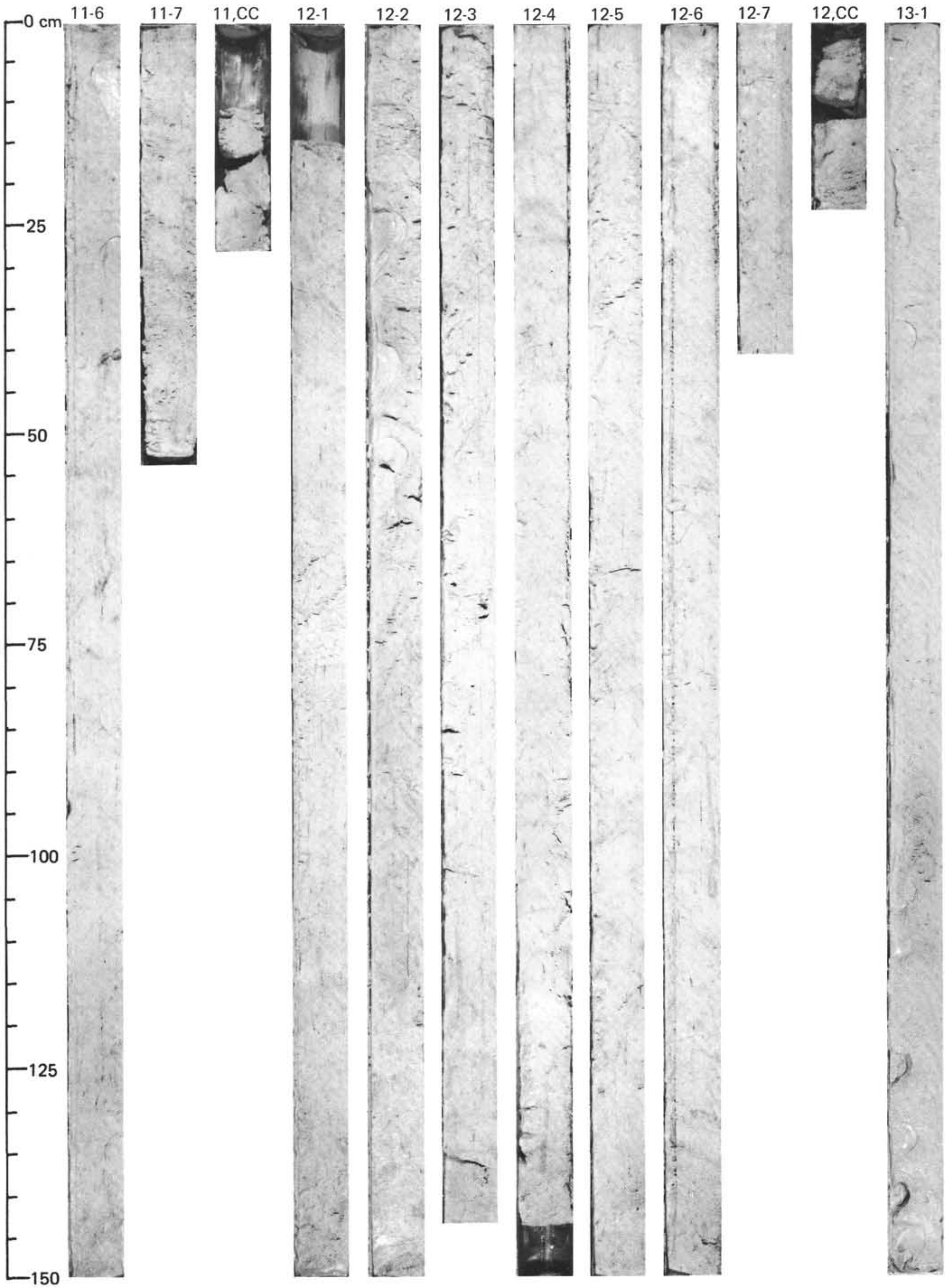

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11,CC
12-1
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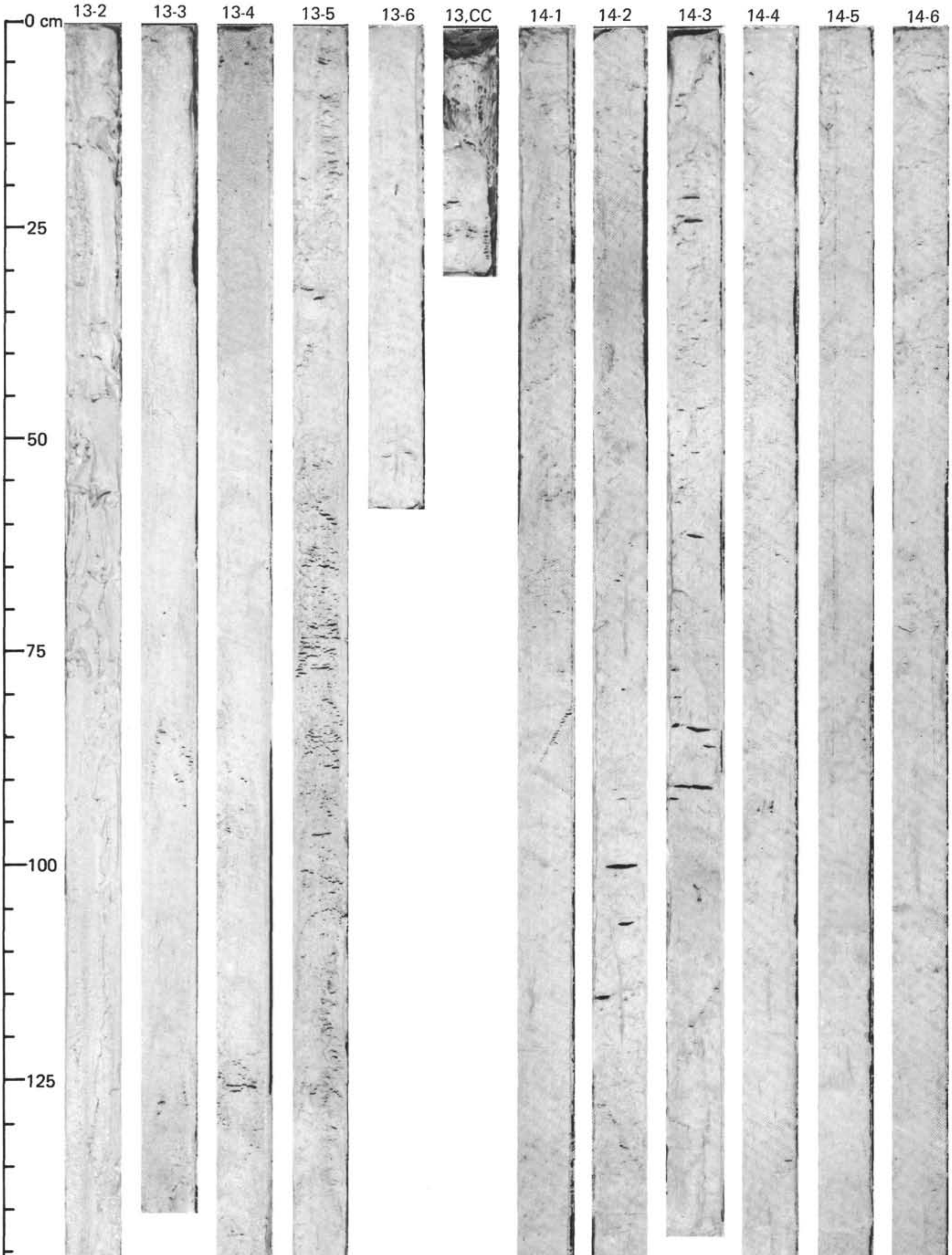
12,CC
13-1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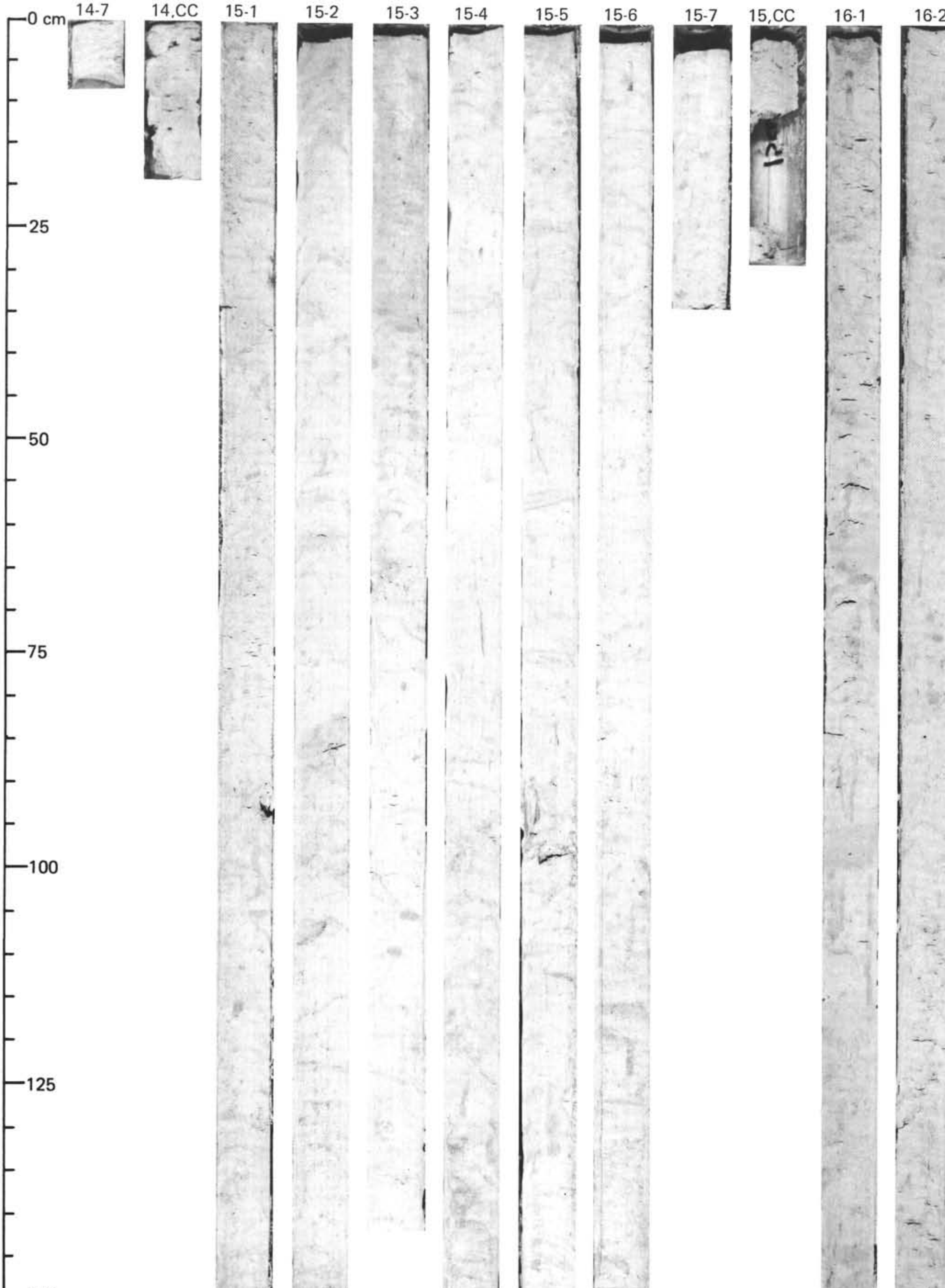
14-6



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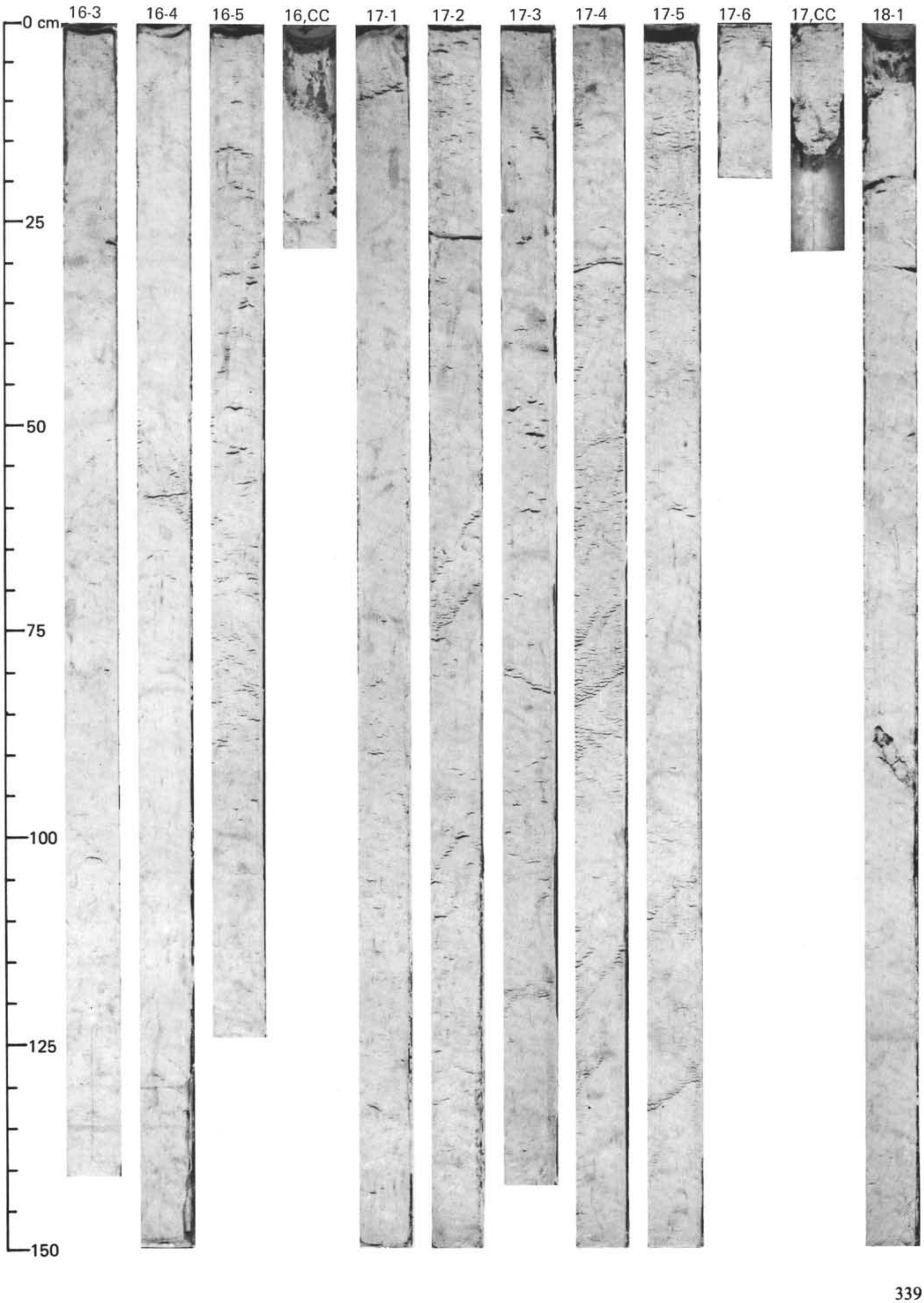
15,CC
16-1
16-2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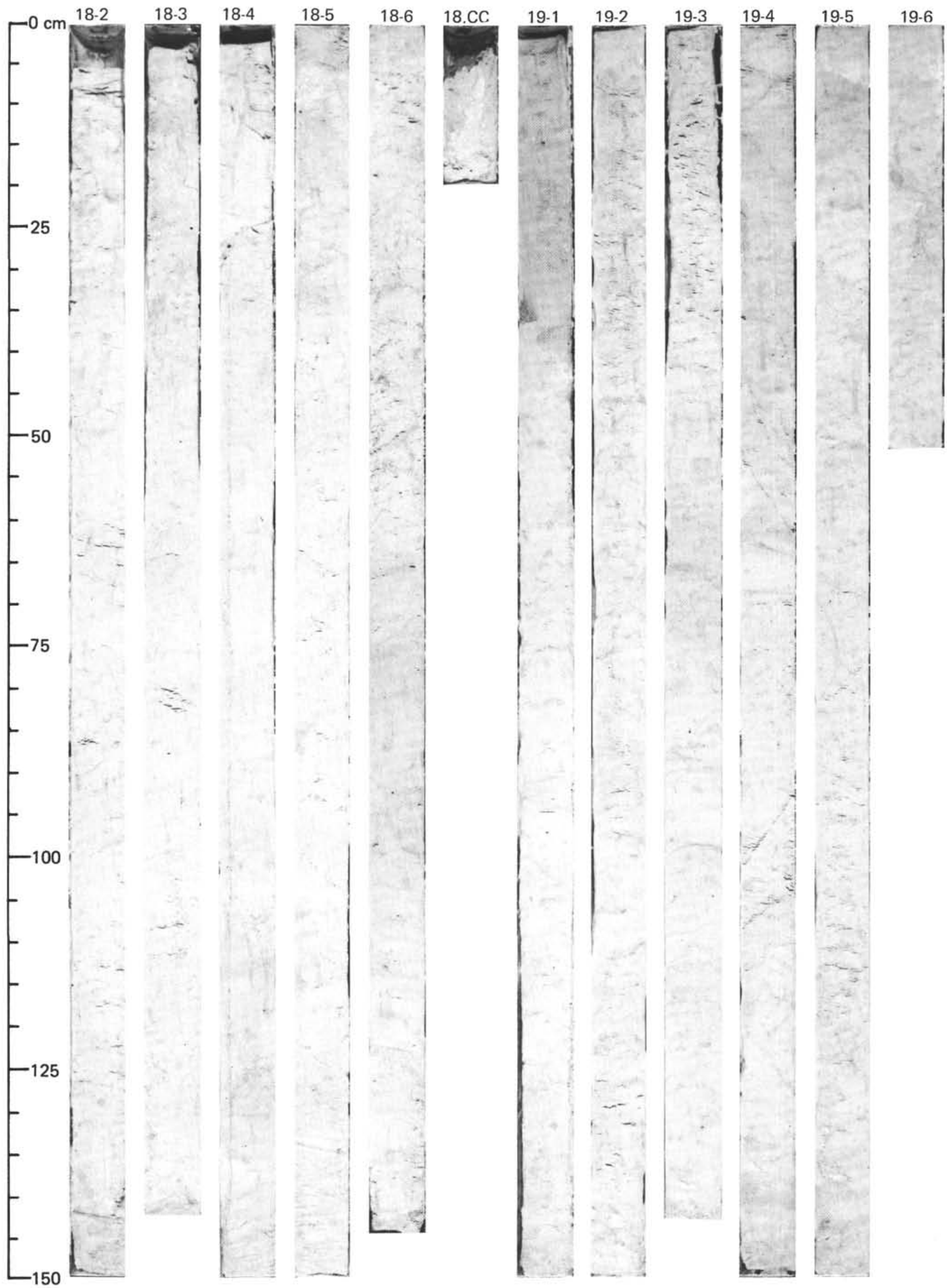
18-1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18,CC
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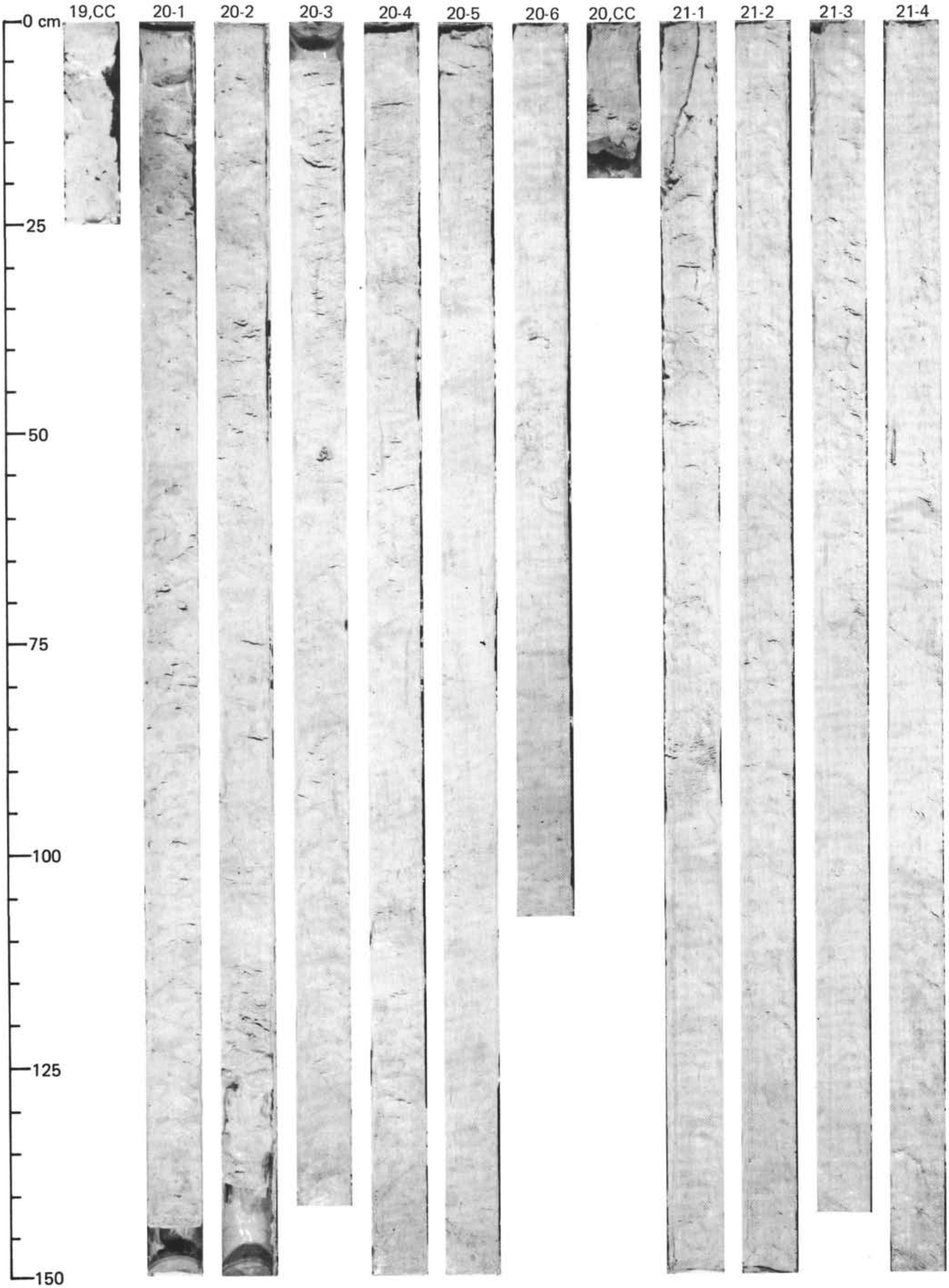
19-5
19-6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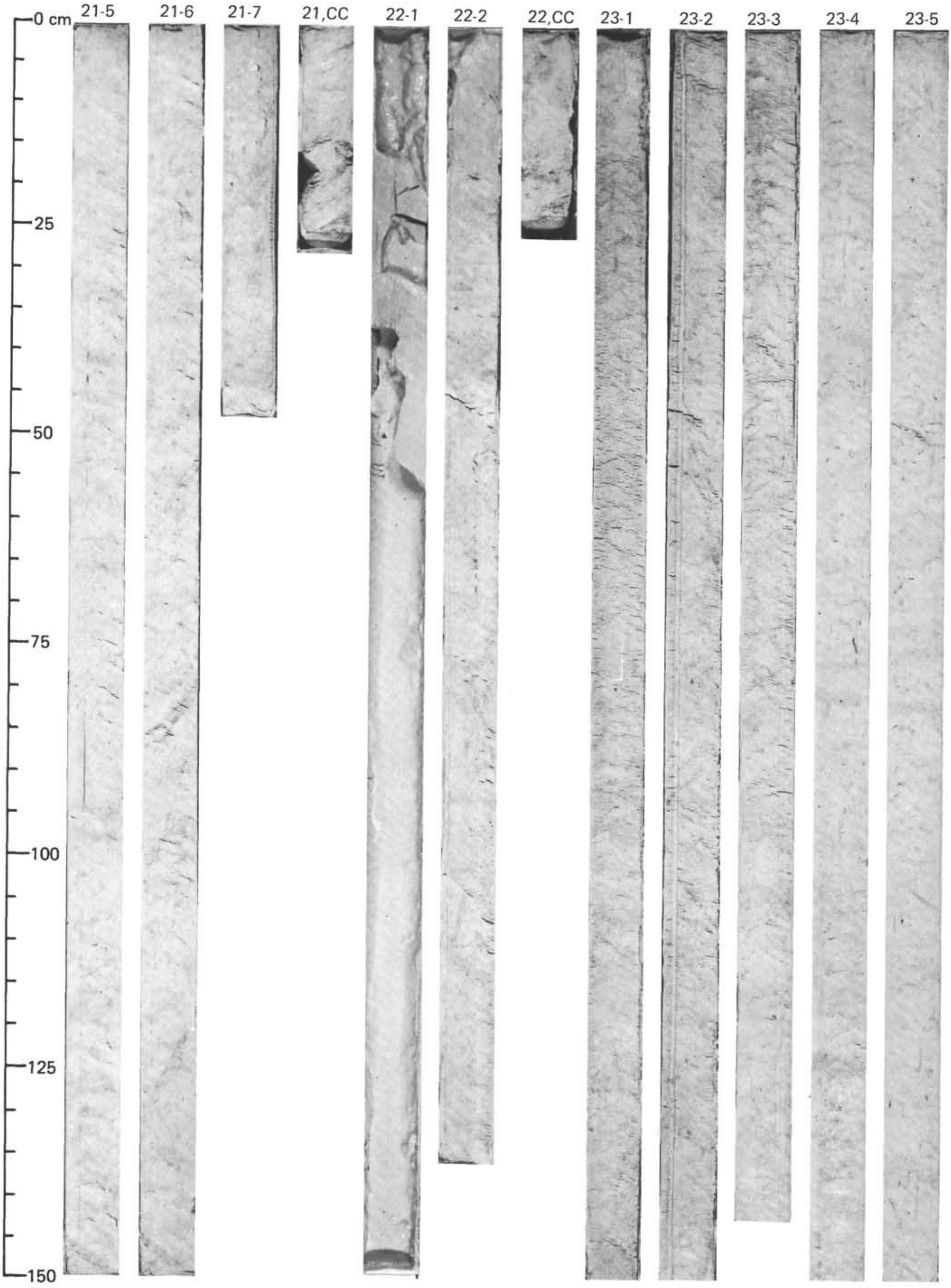
21-4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21,CC
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22,CC
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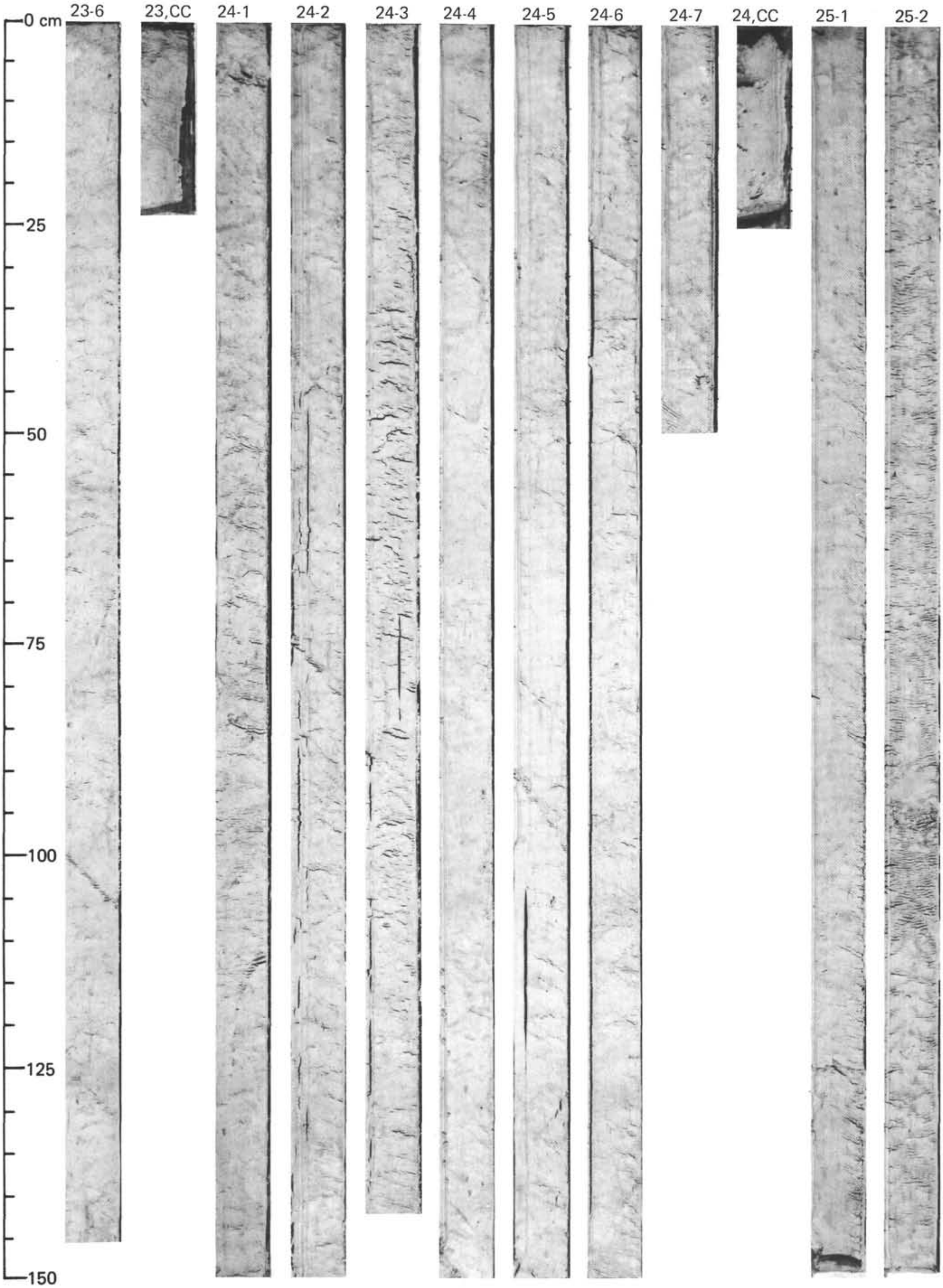
23-3
23-4
23-5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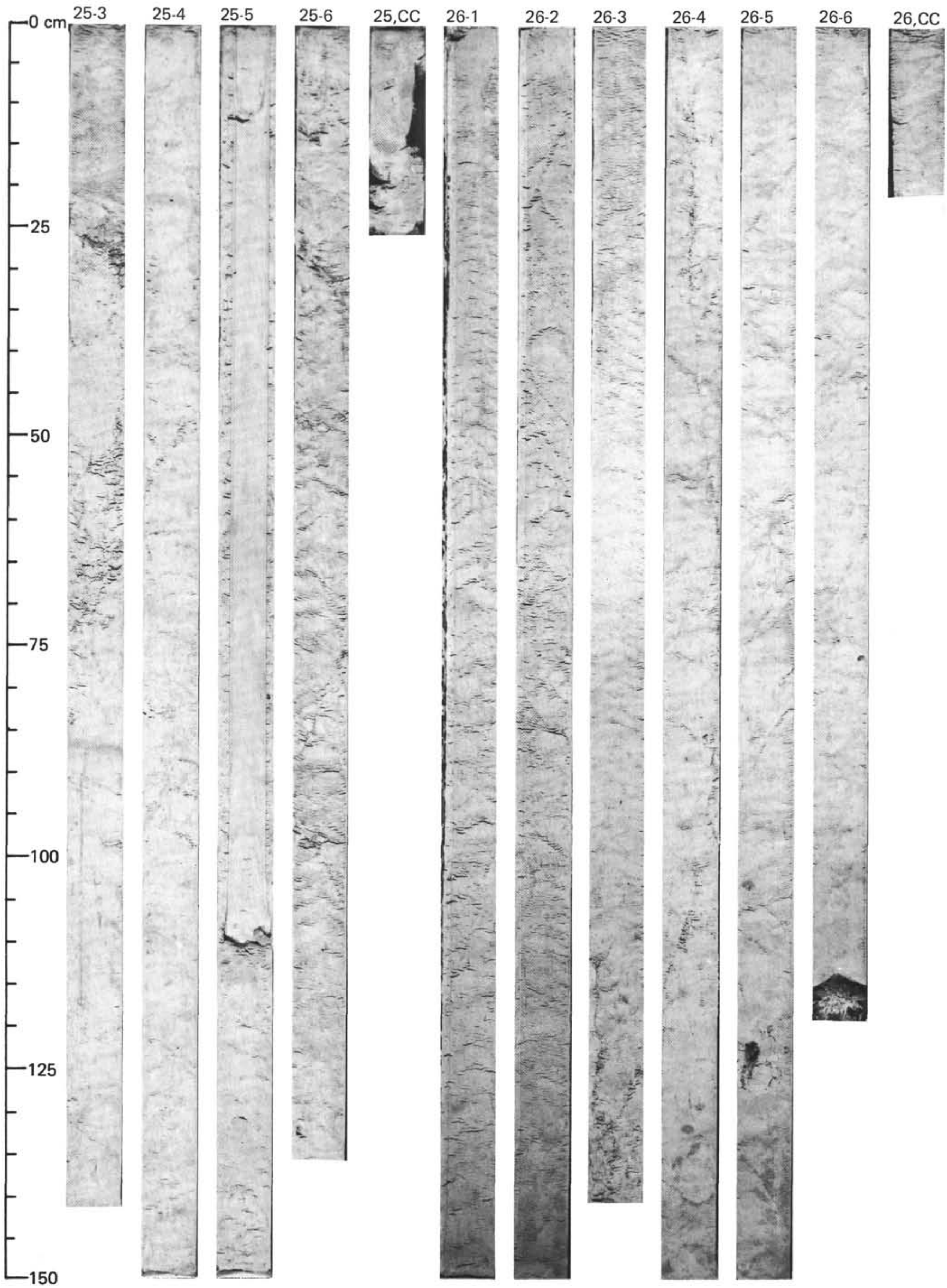
24,CC
25-1
25-2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25-6
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26-1
26-2
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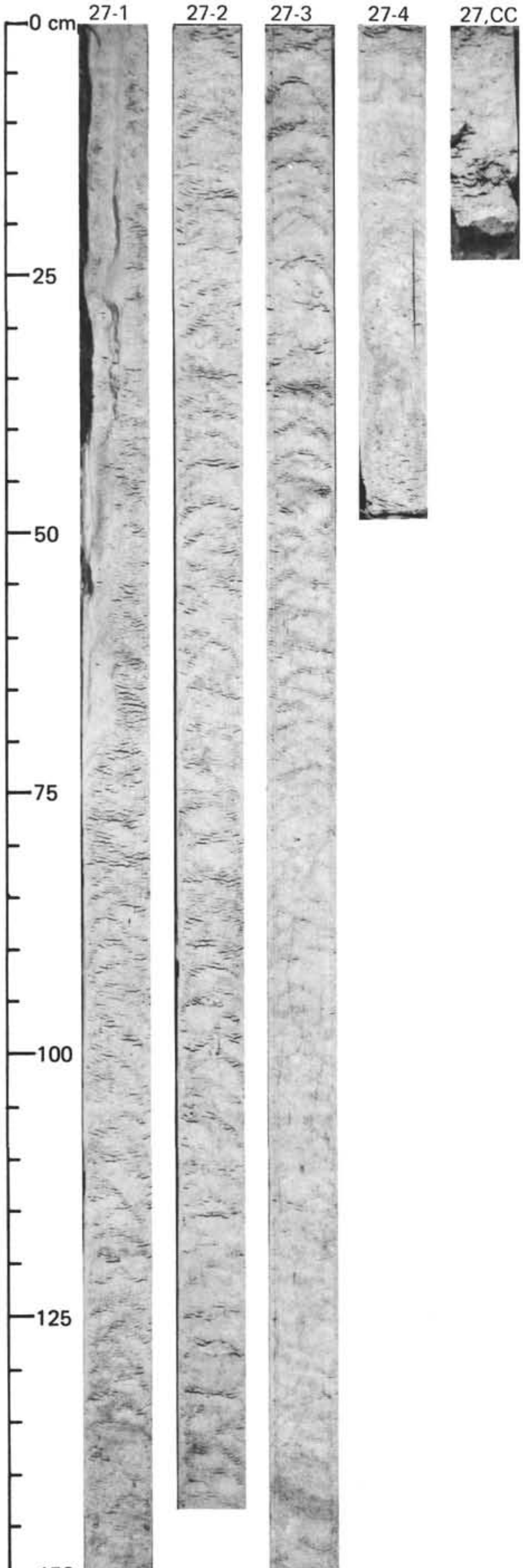
26-5
26-6
26,CC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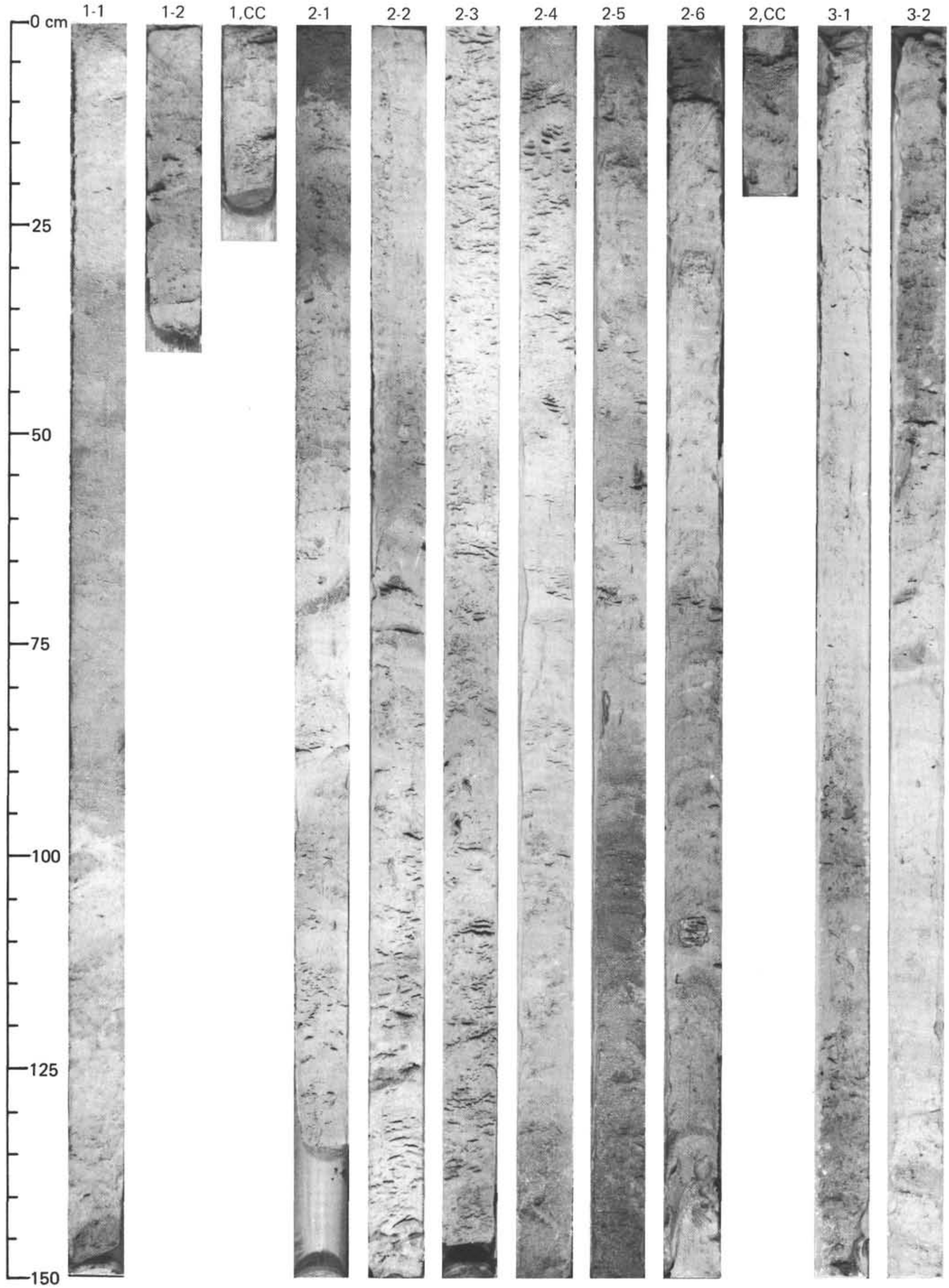
27-1
27-2
27-3
27-4
27,CC


1-1
1-2
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2,CC
3-1
3-2
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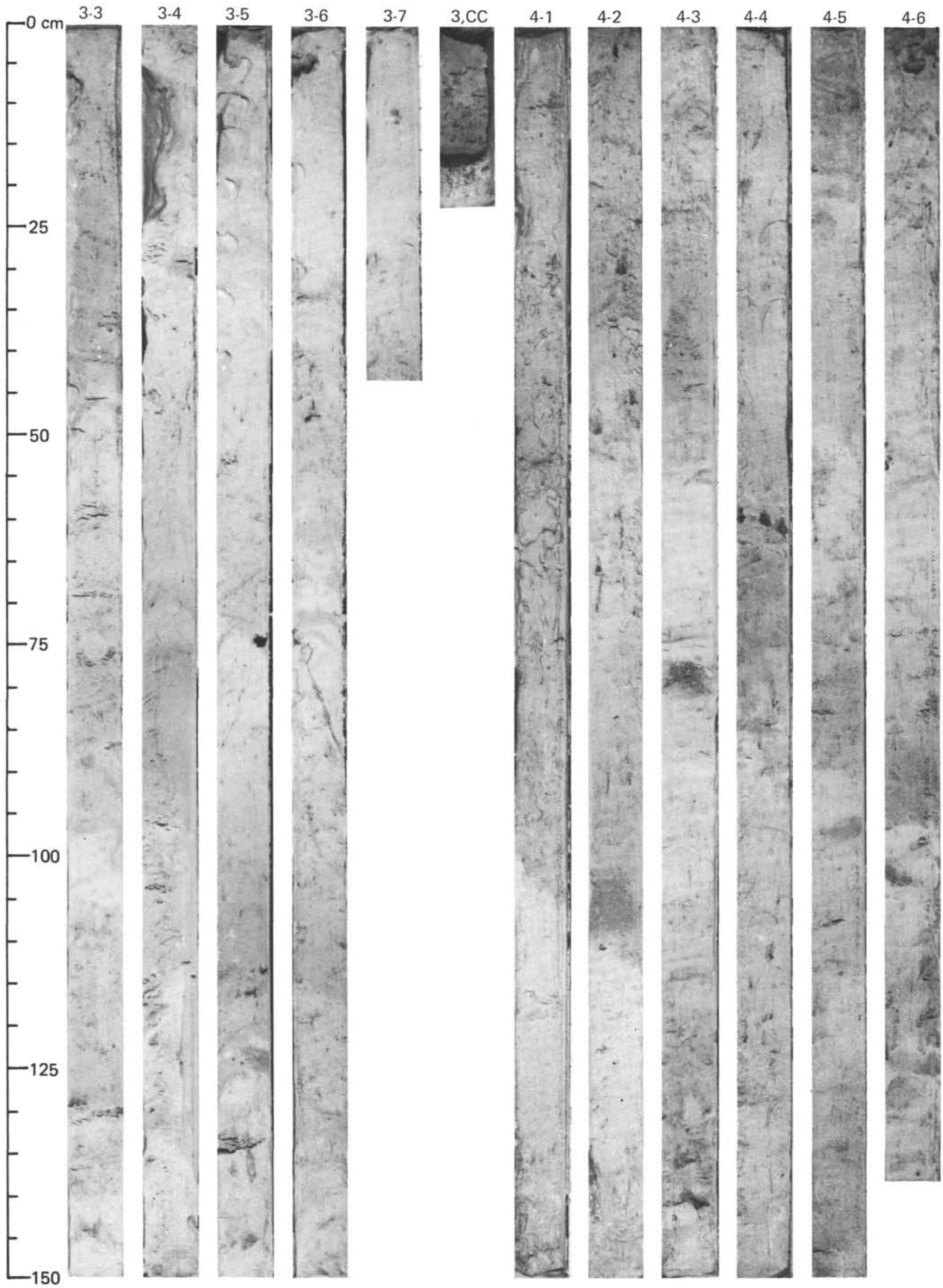
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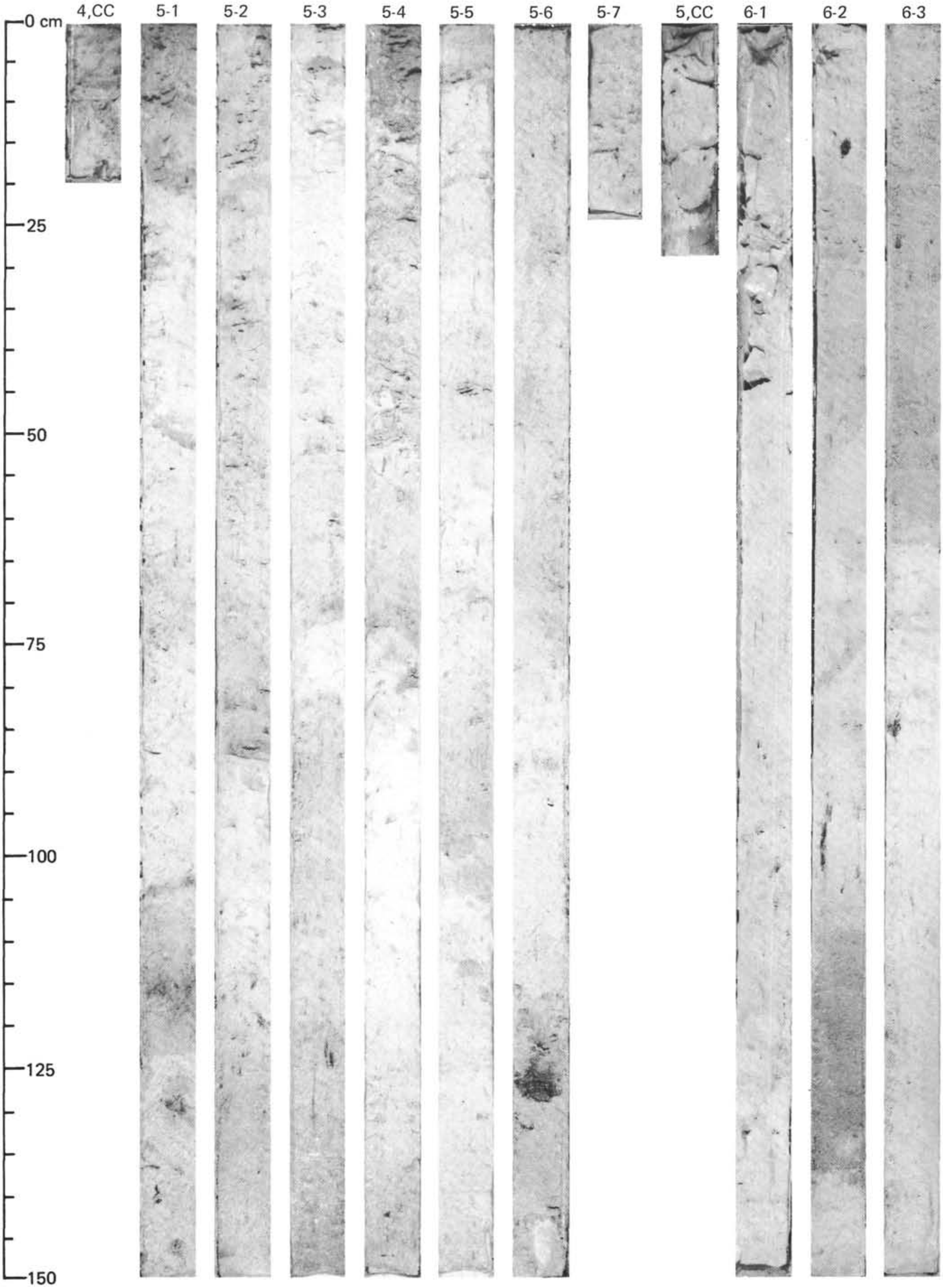
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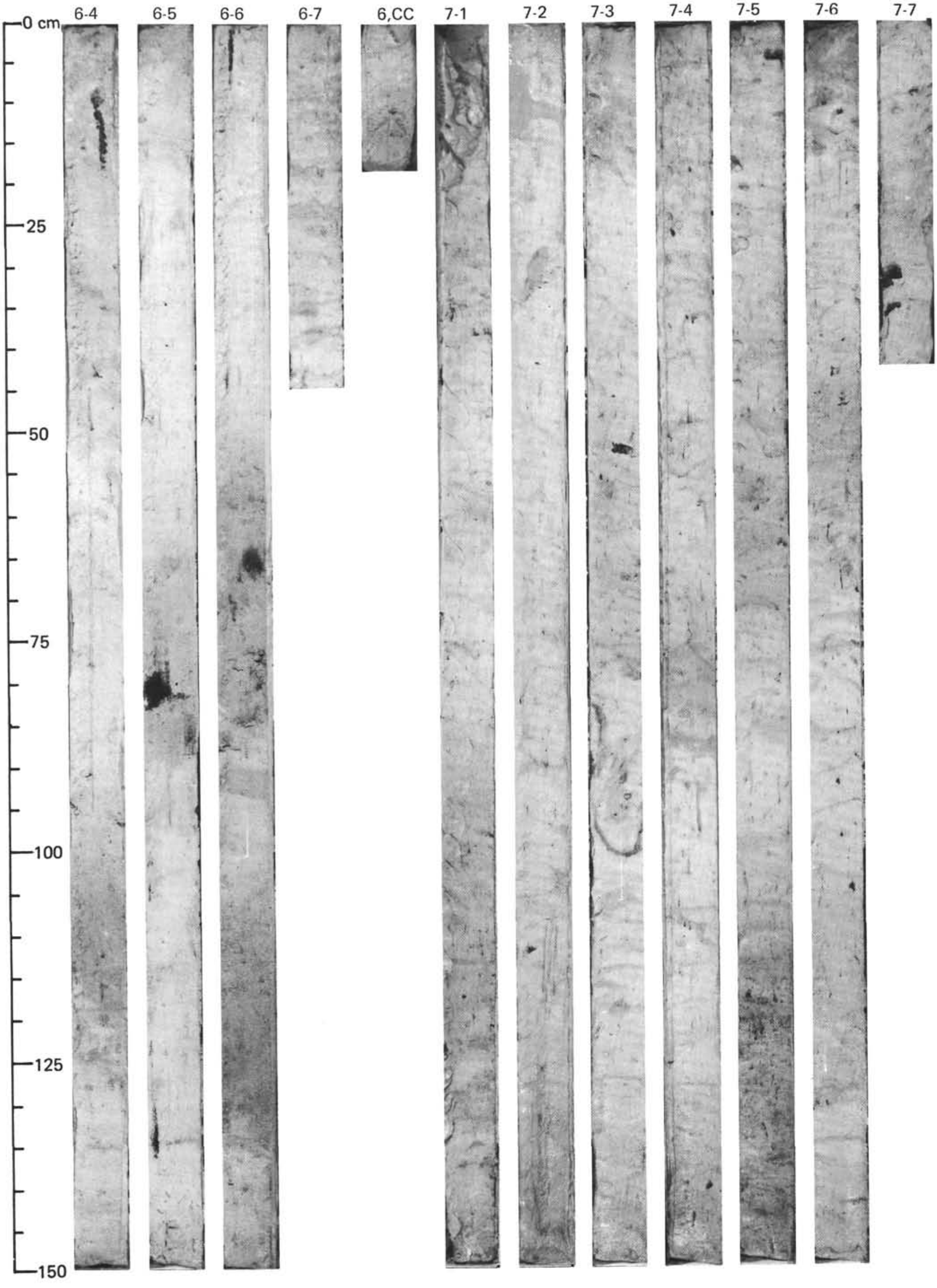

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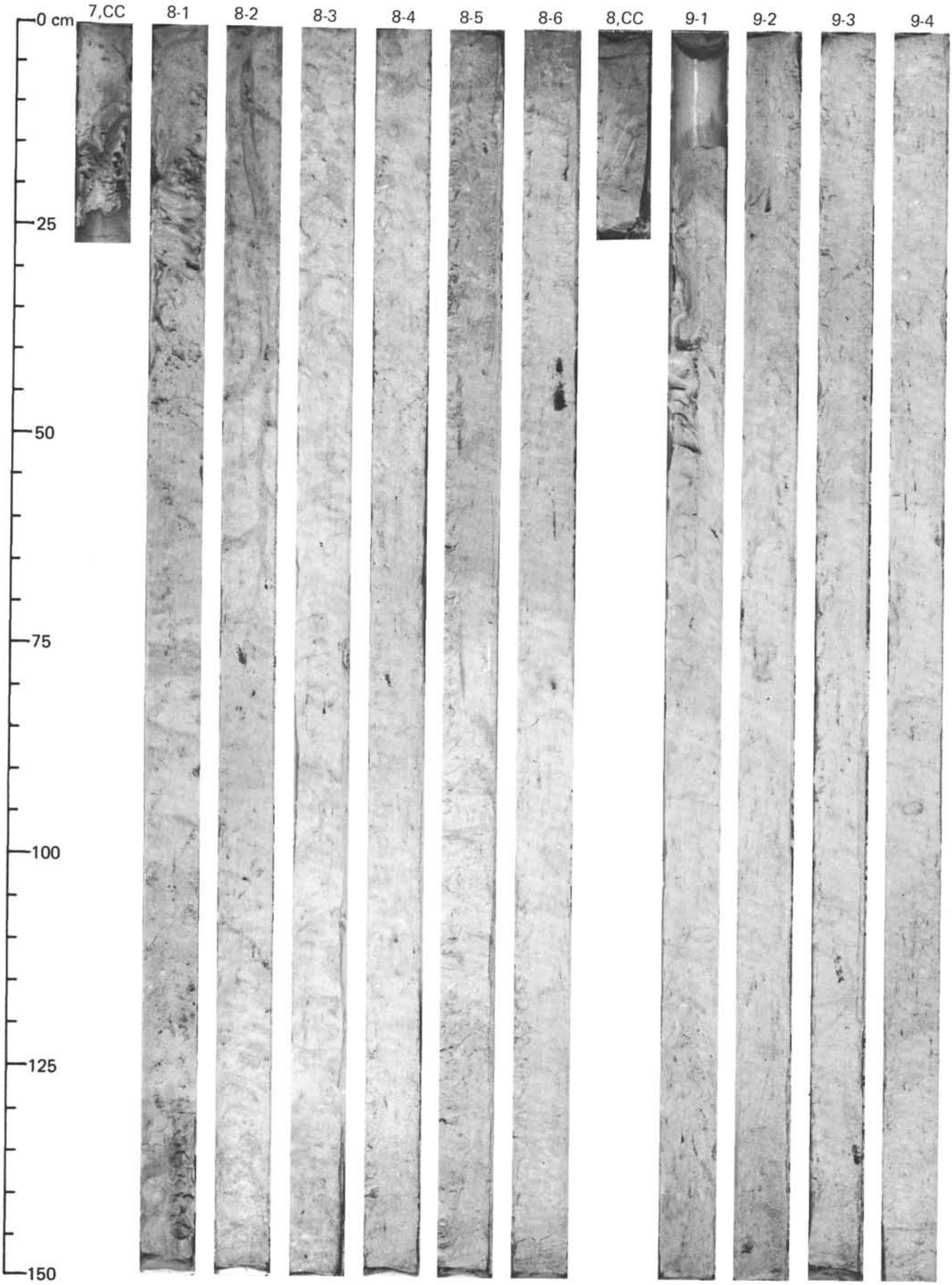
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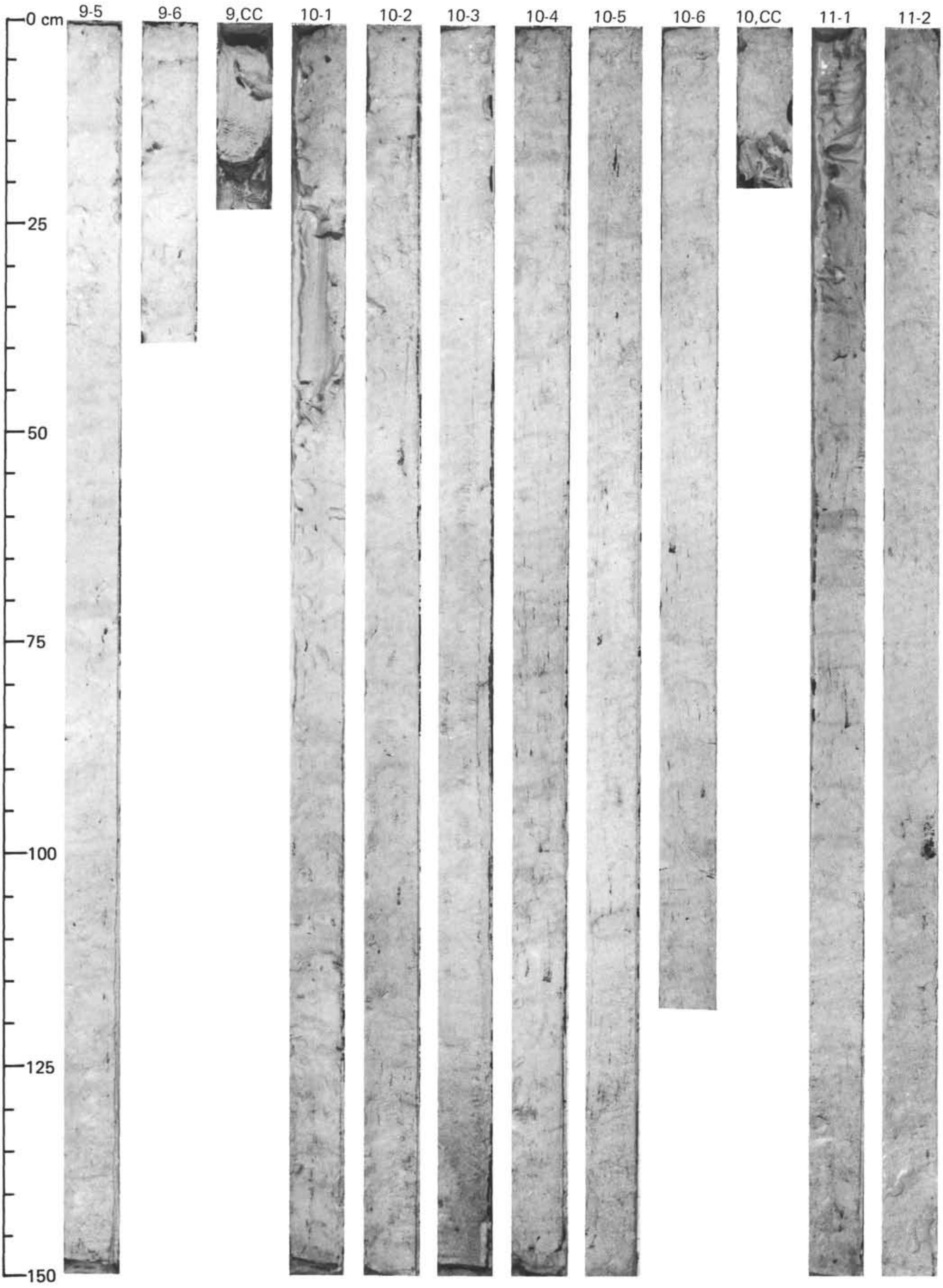
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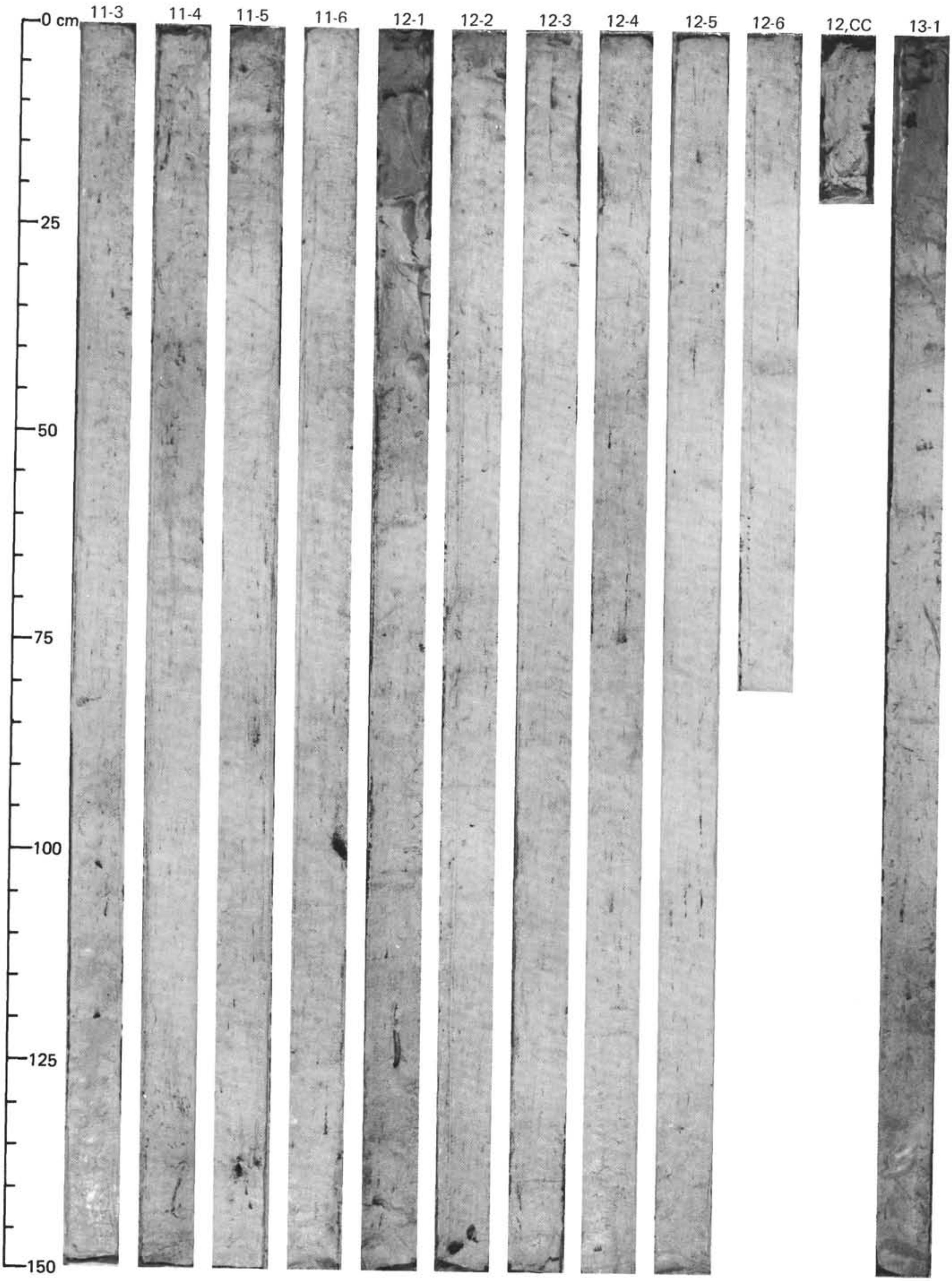
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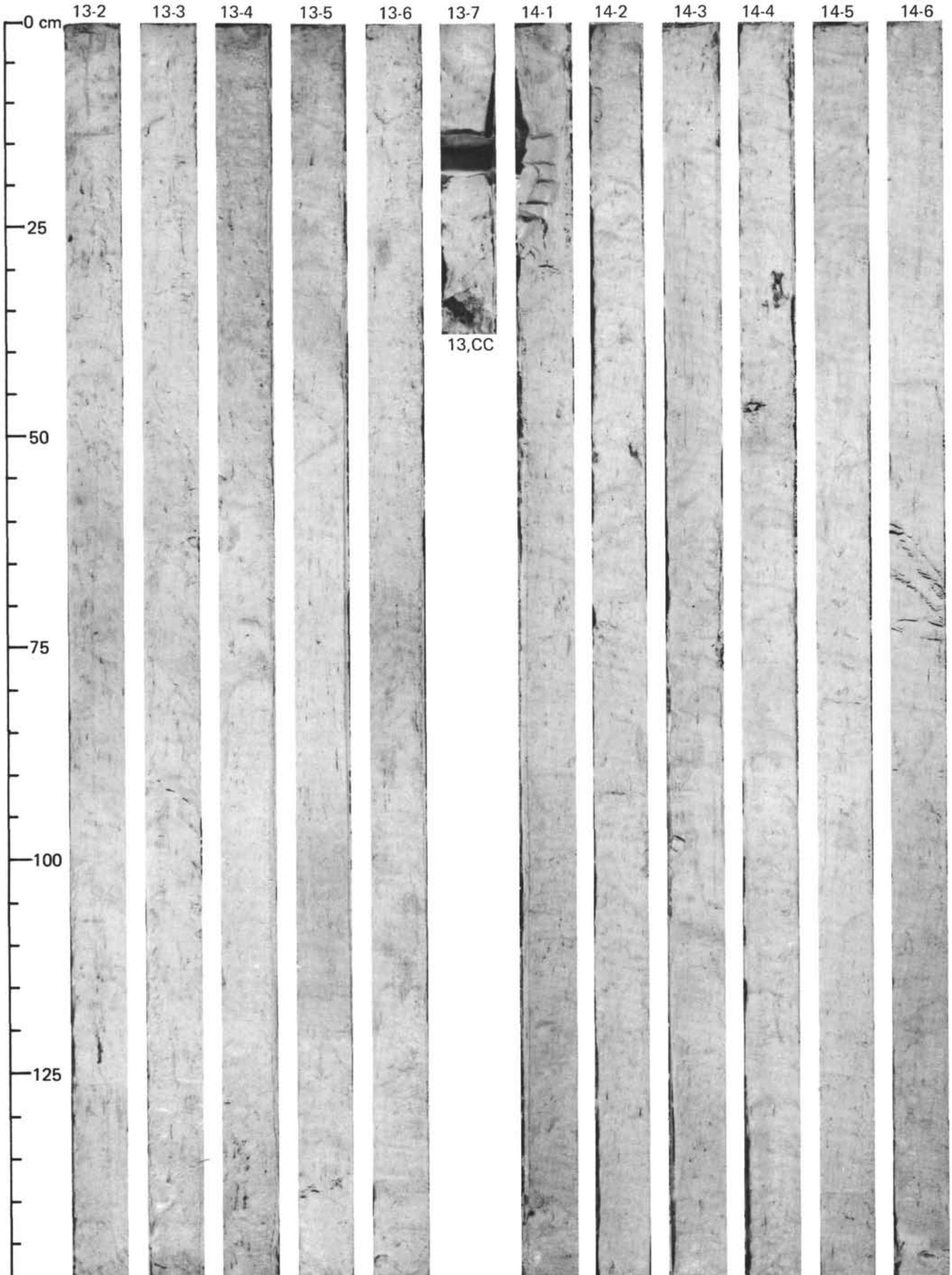
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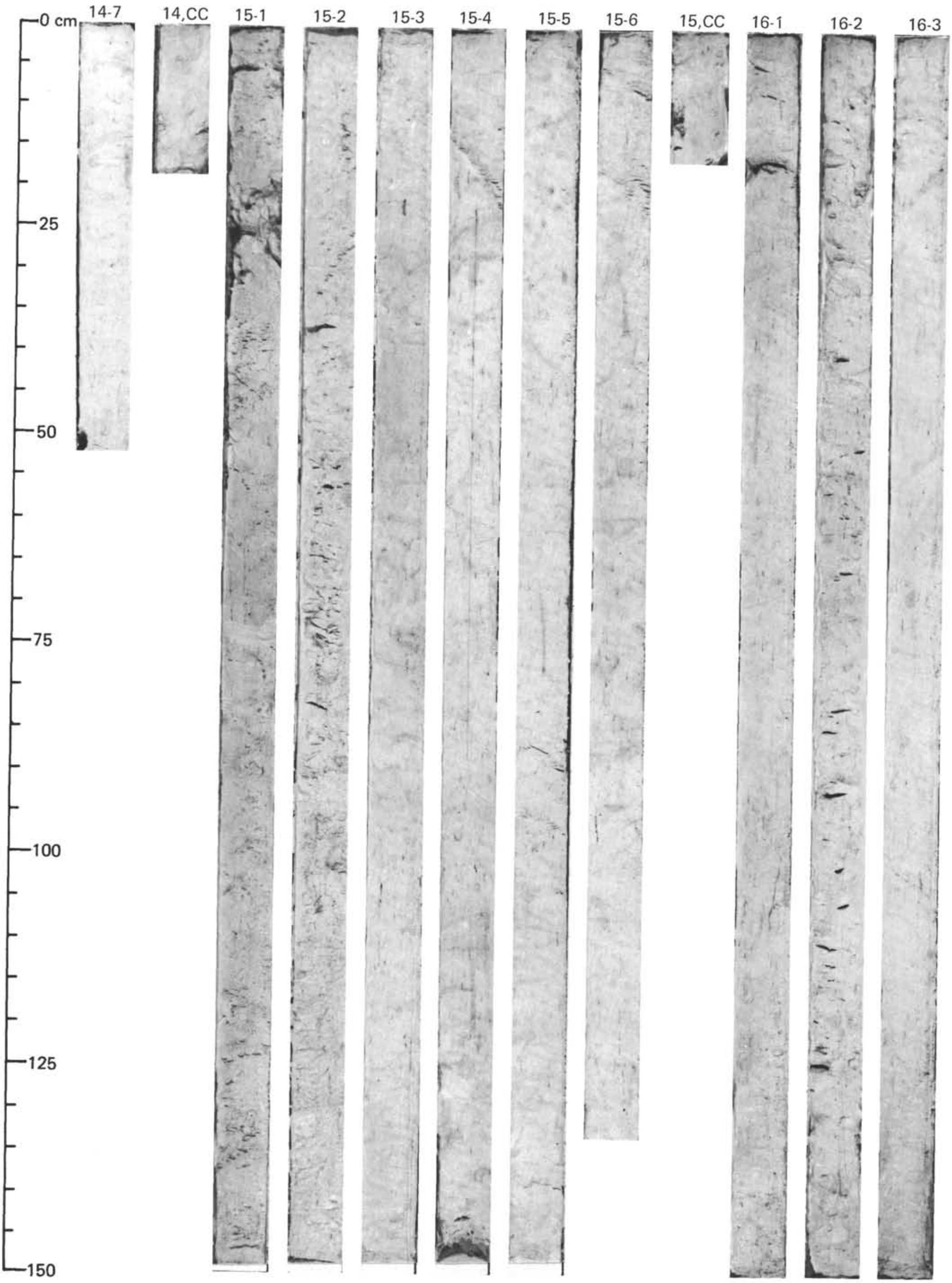
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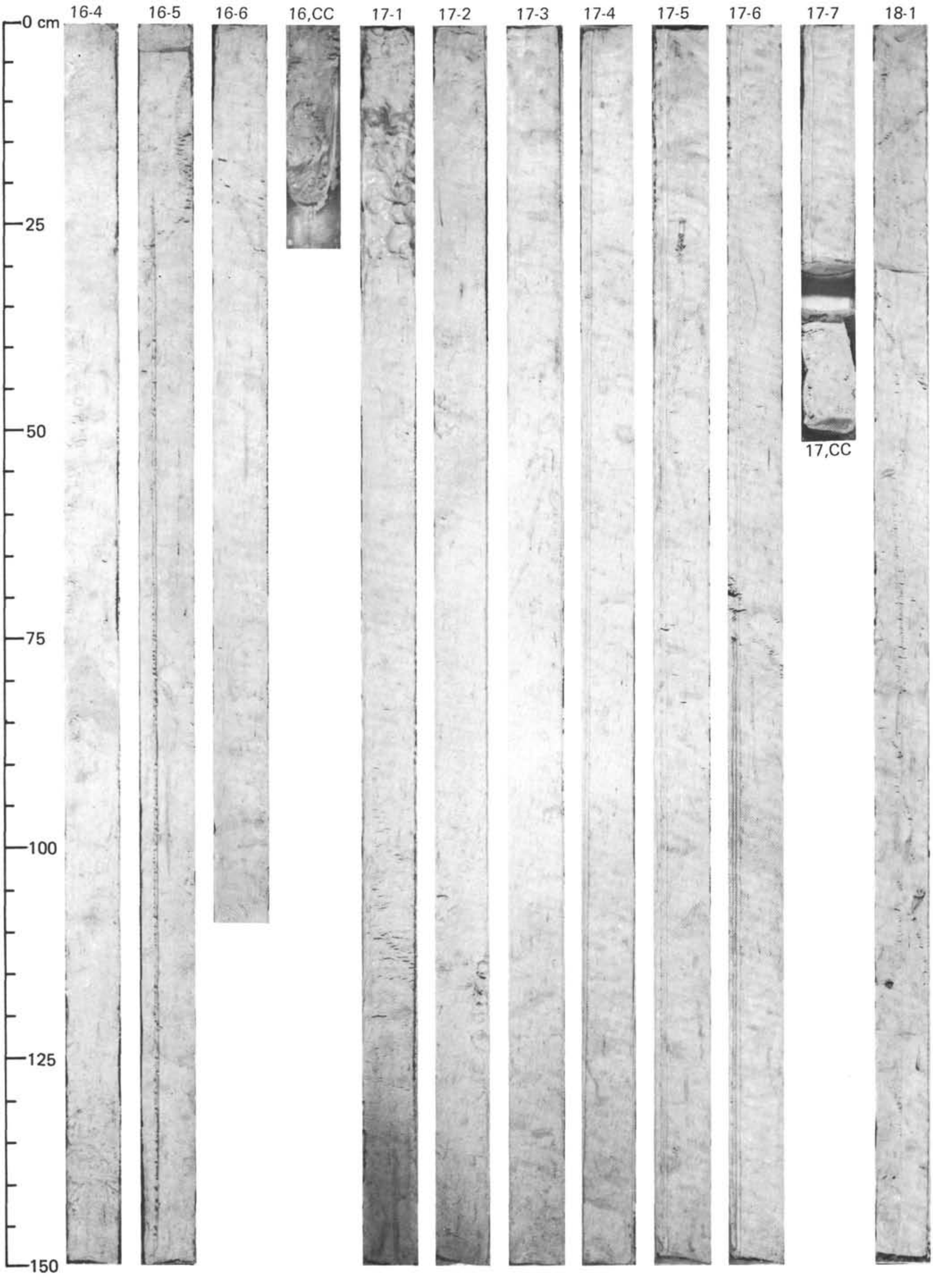
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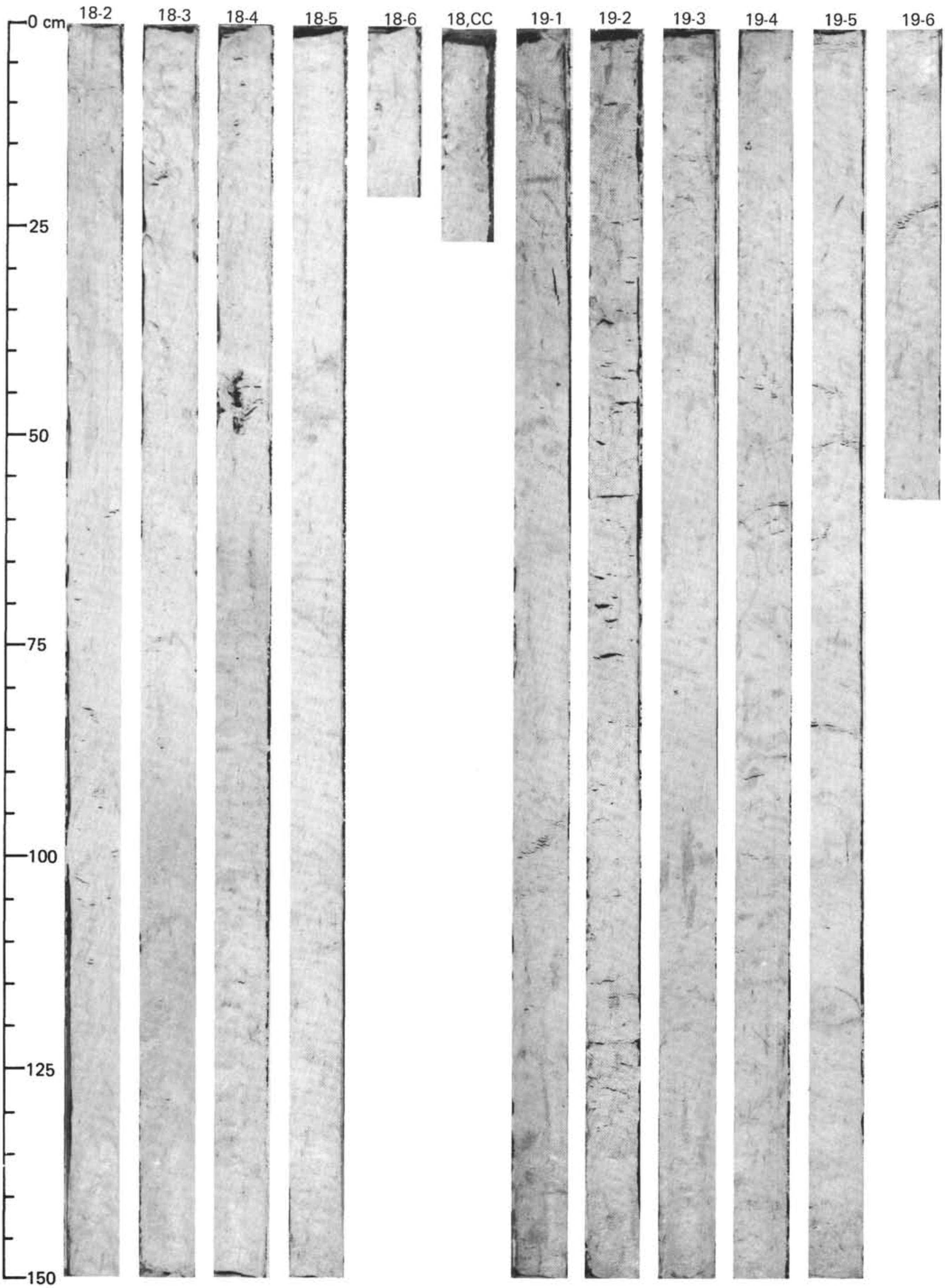
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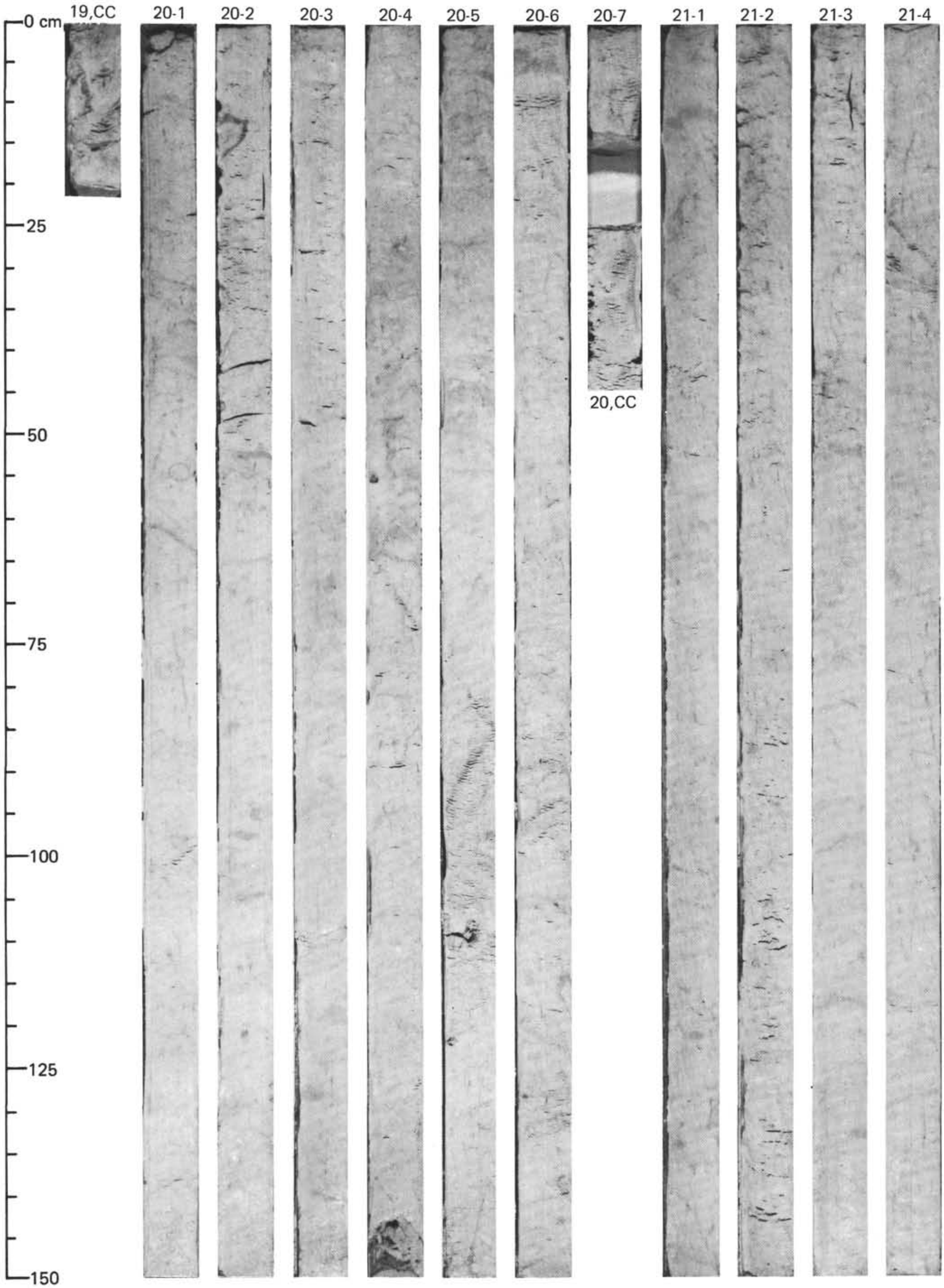
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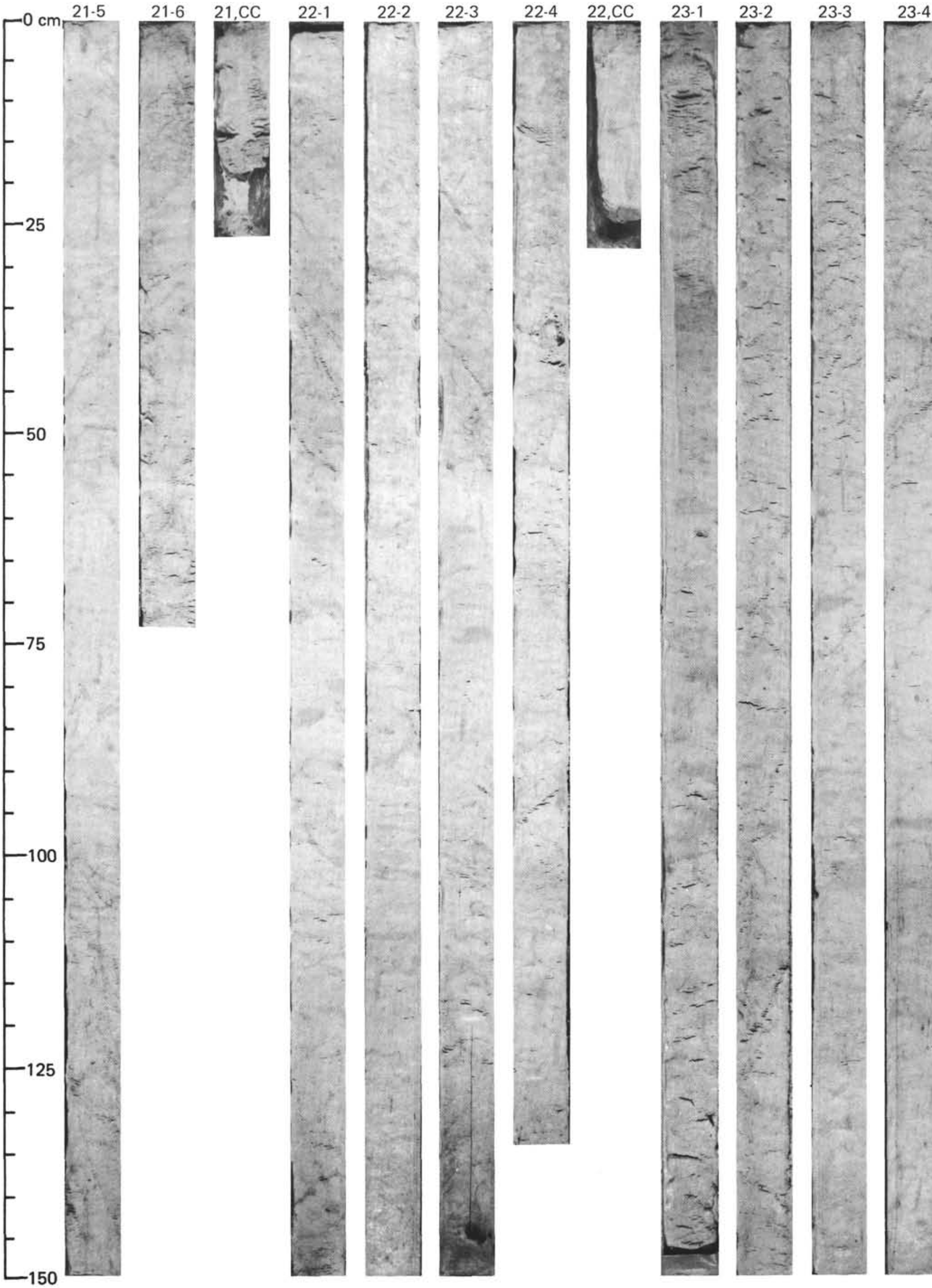
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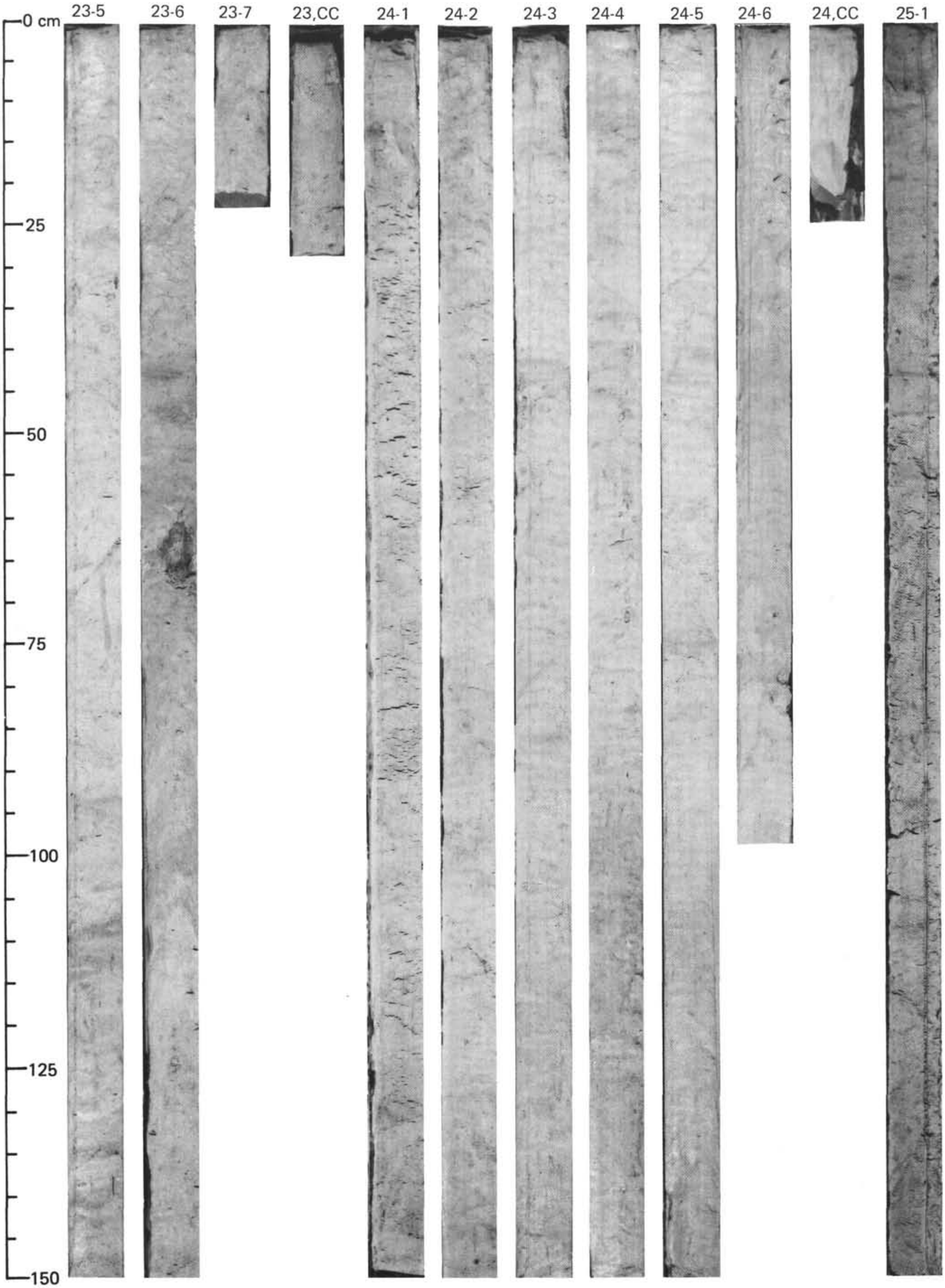
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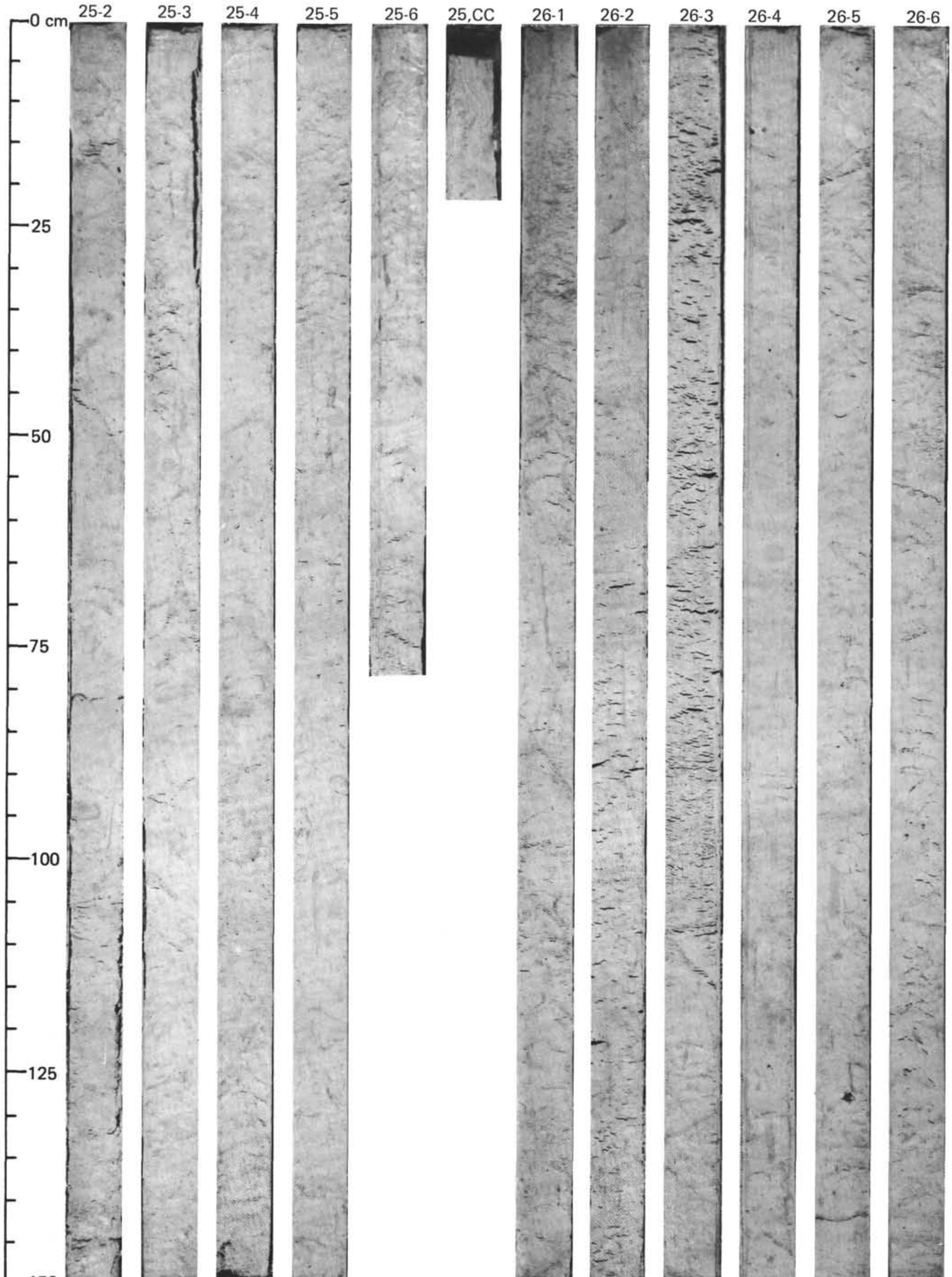
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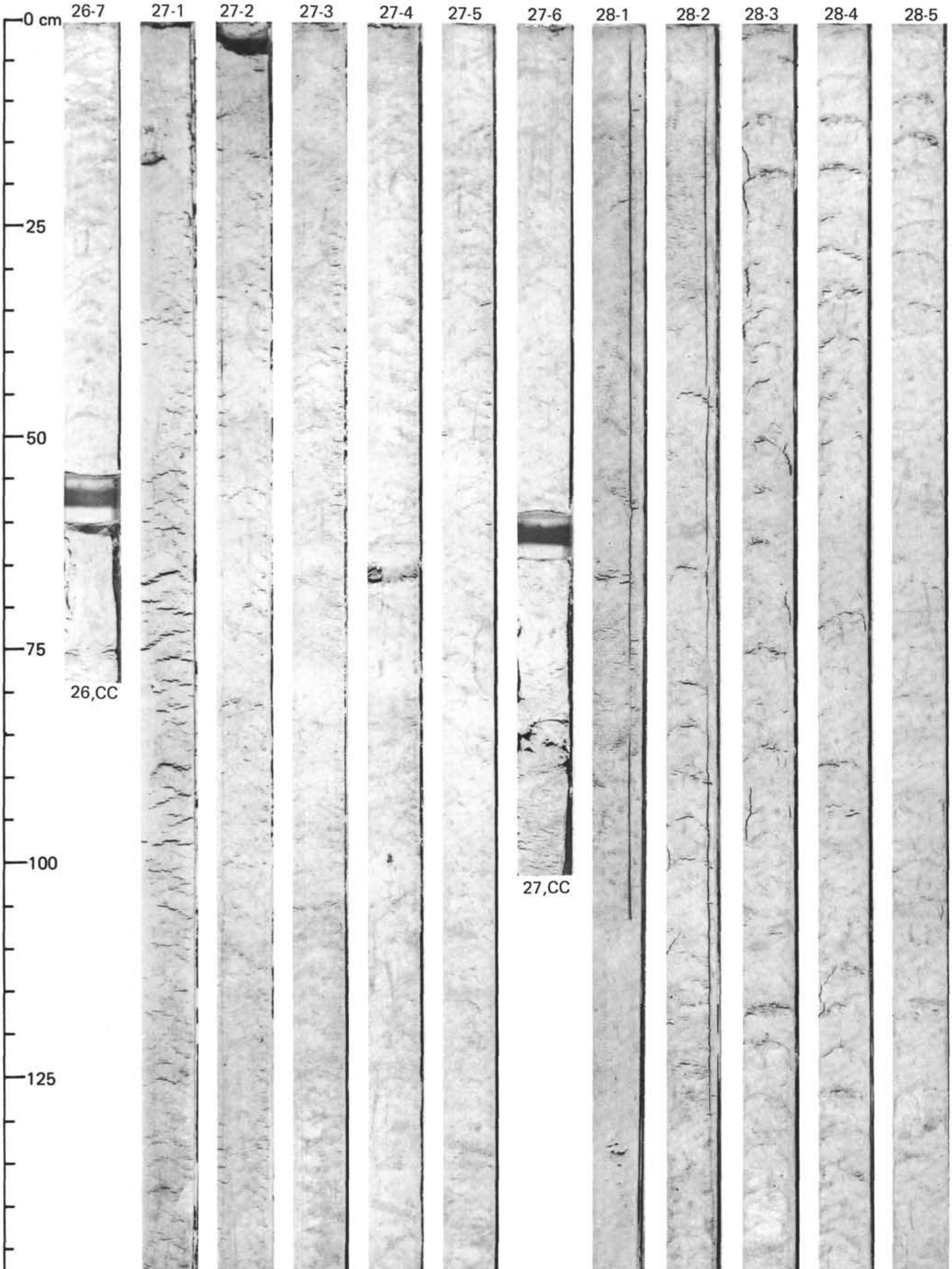
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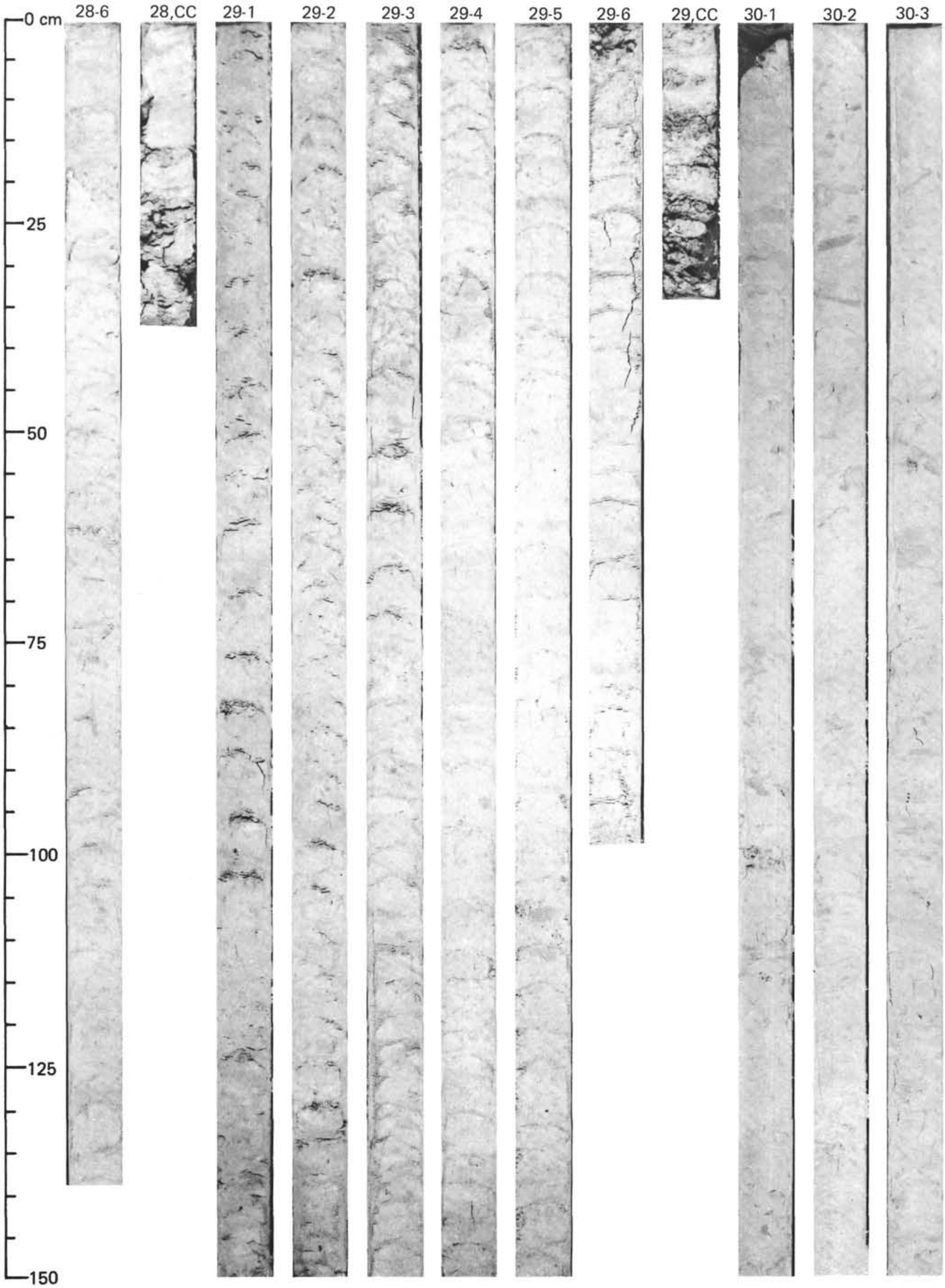
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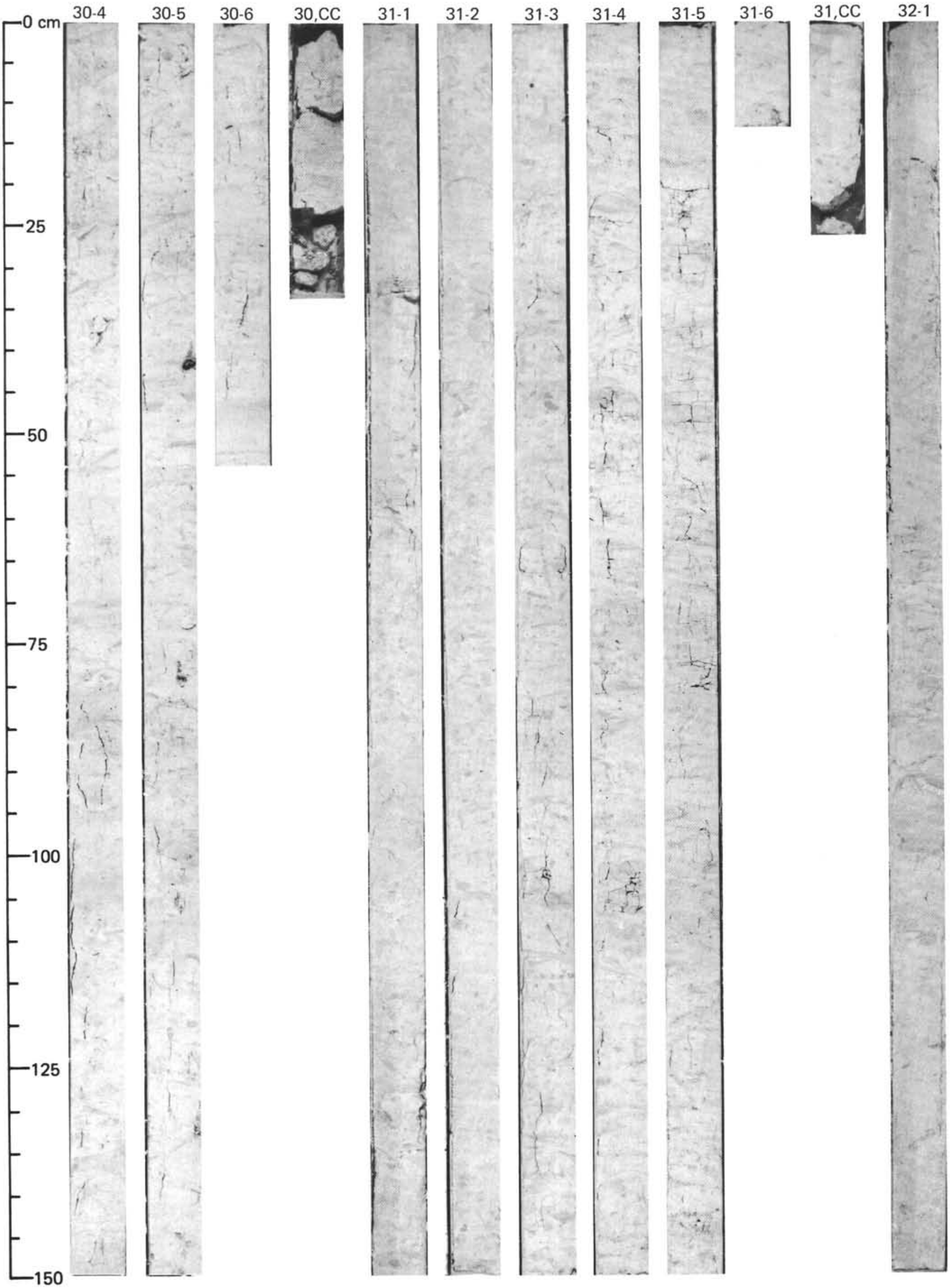
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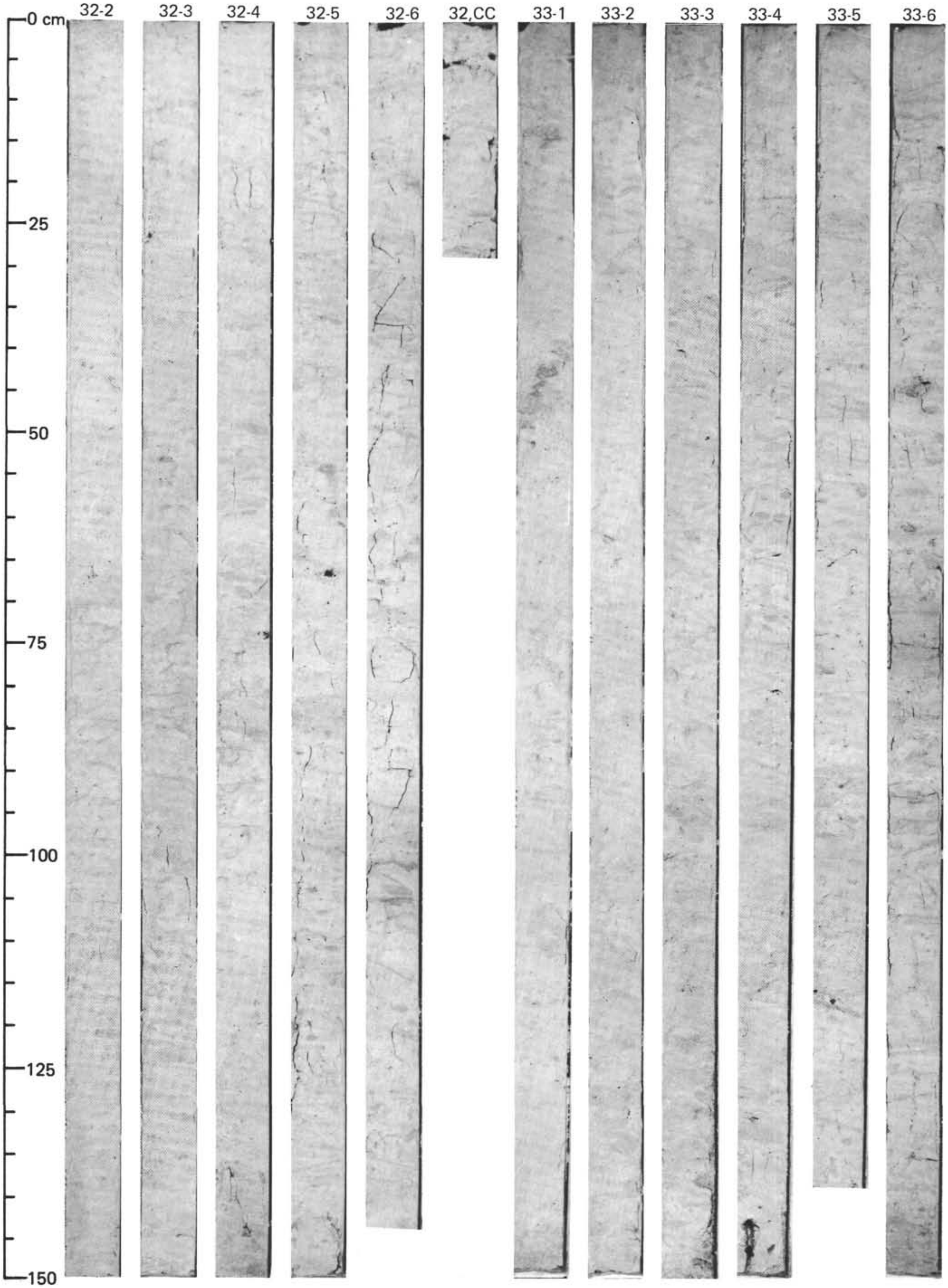
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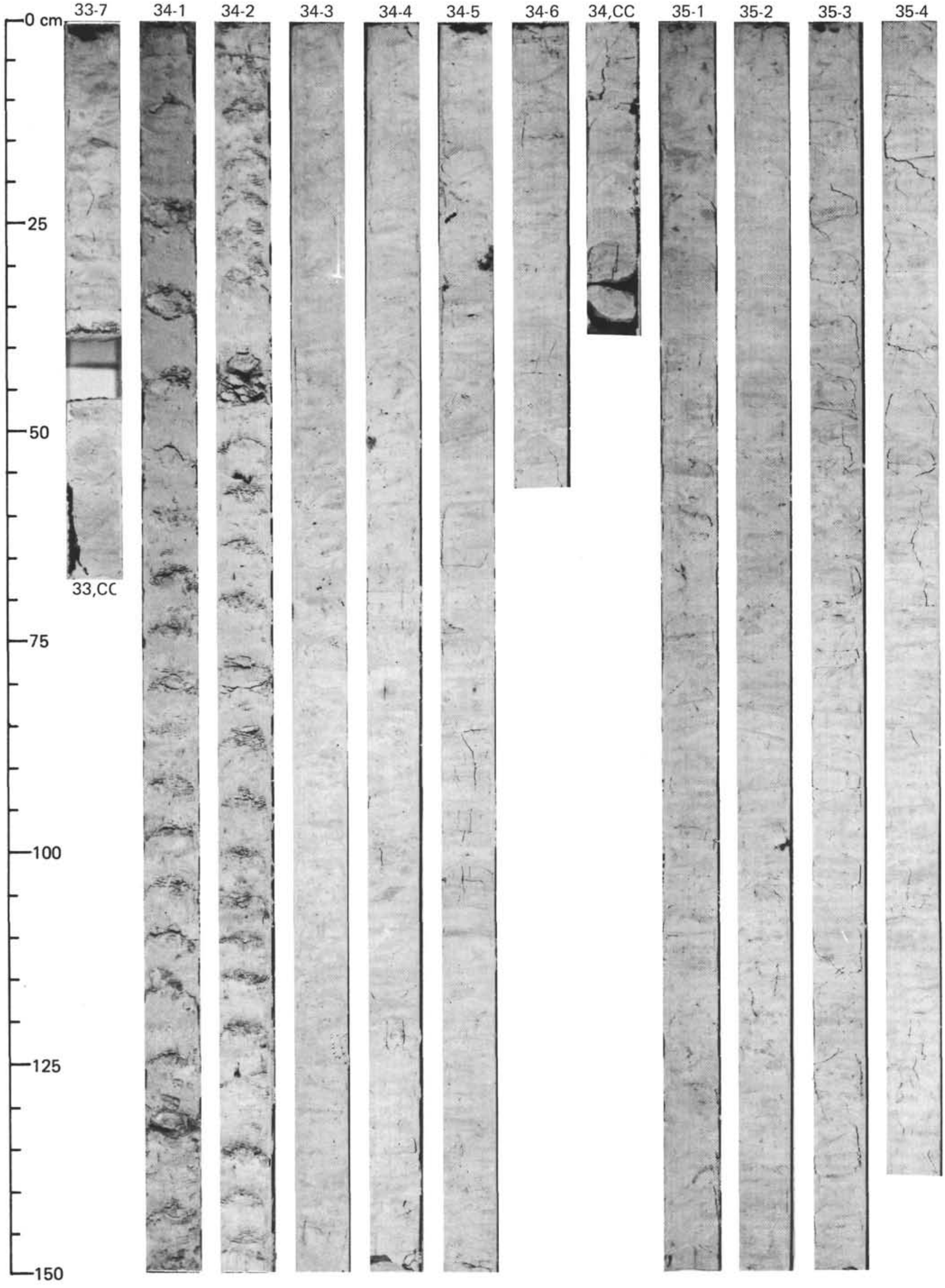
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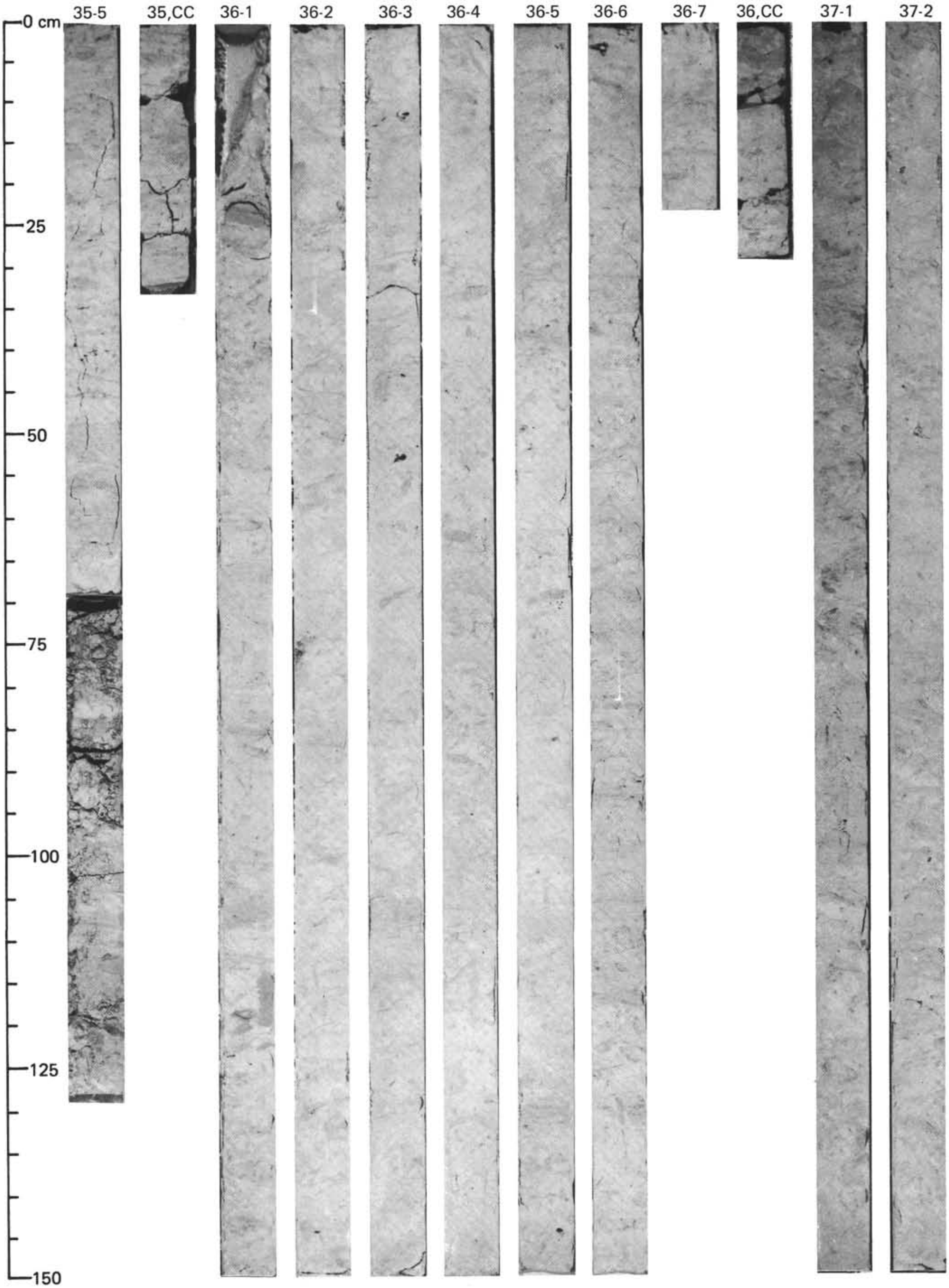
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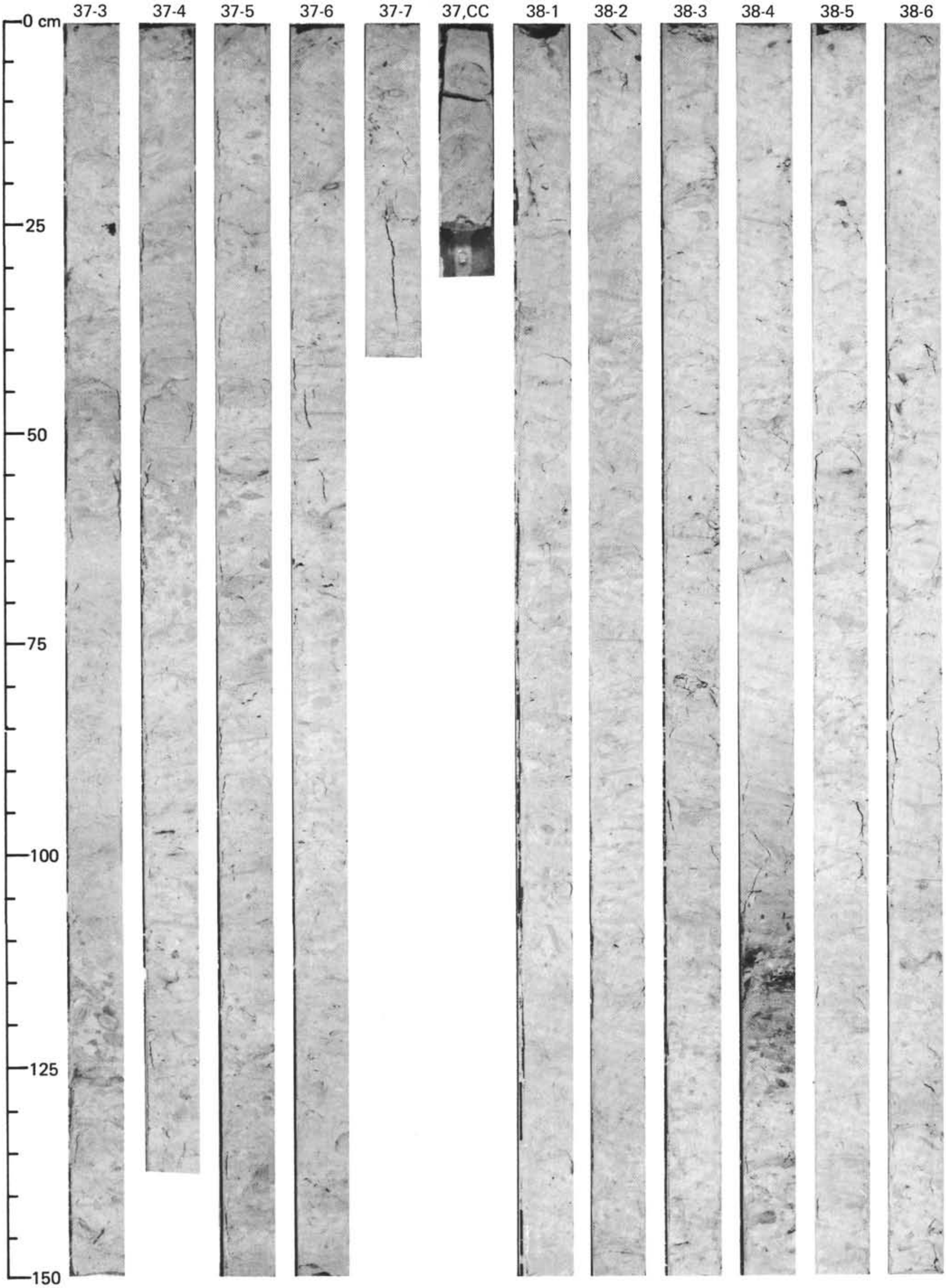

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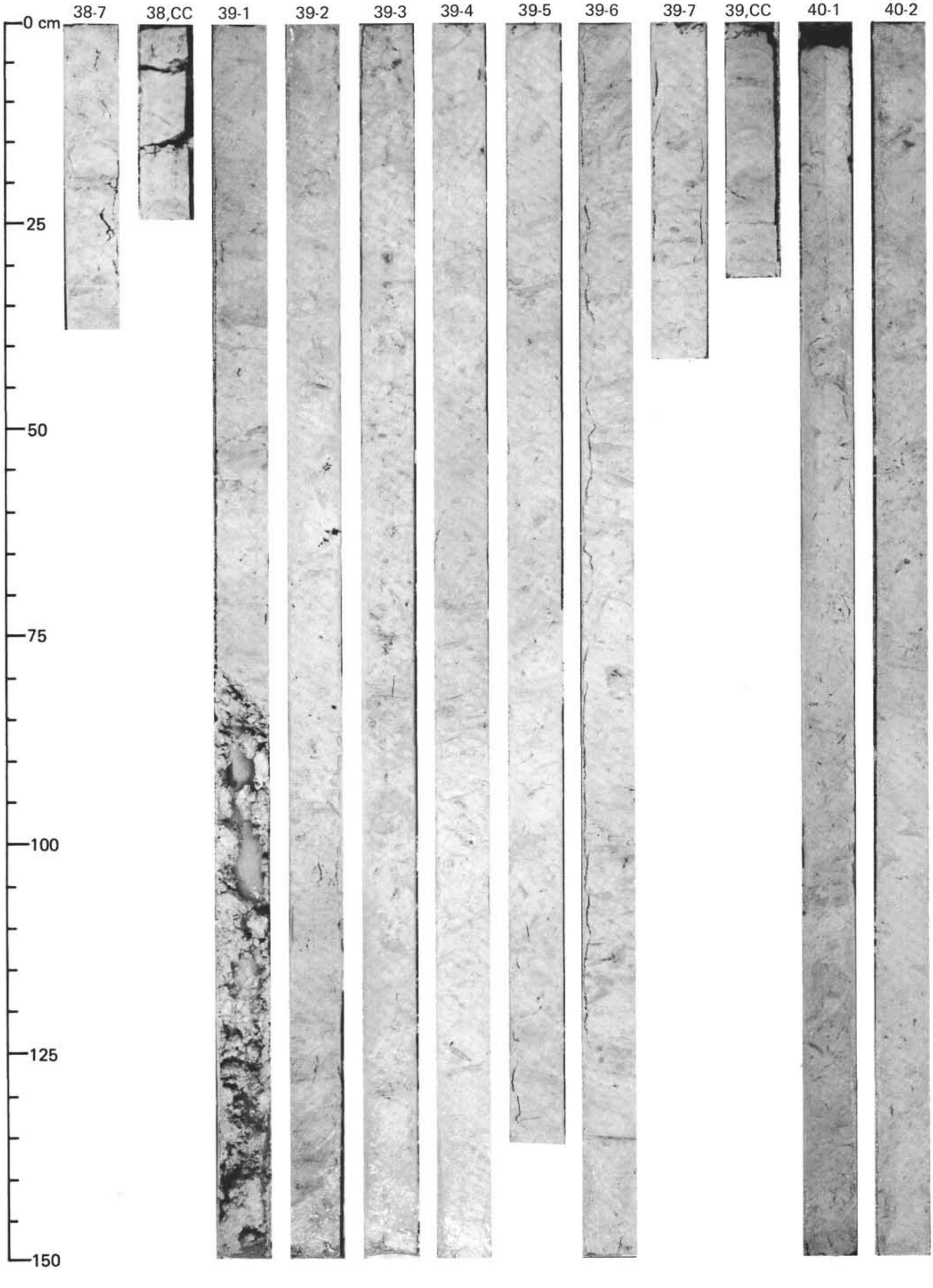

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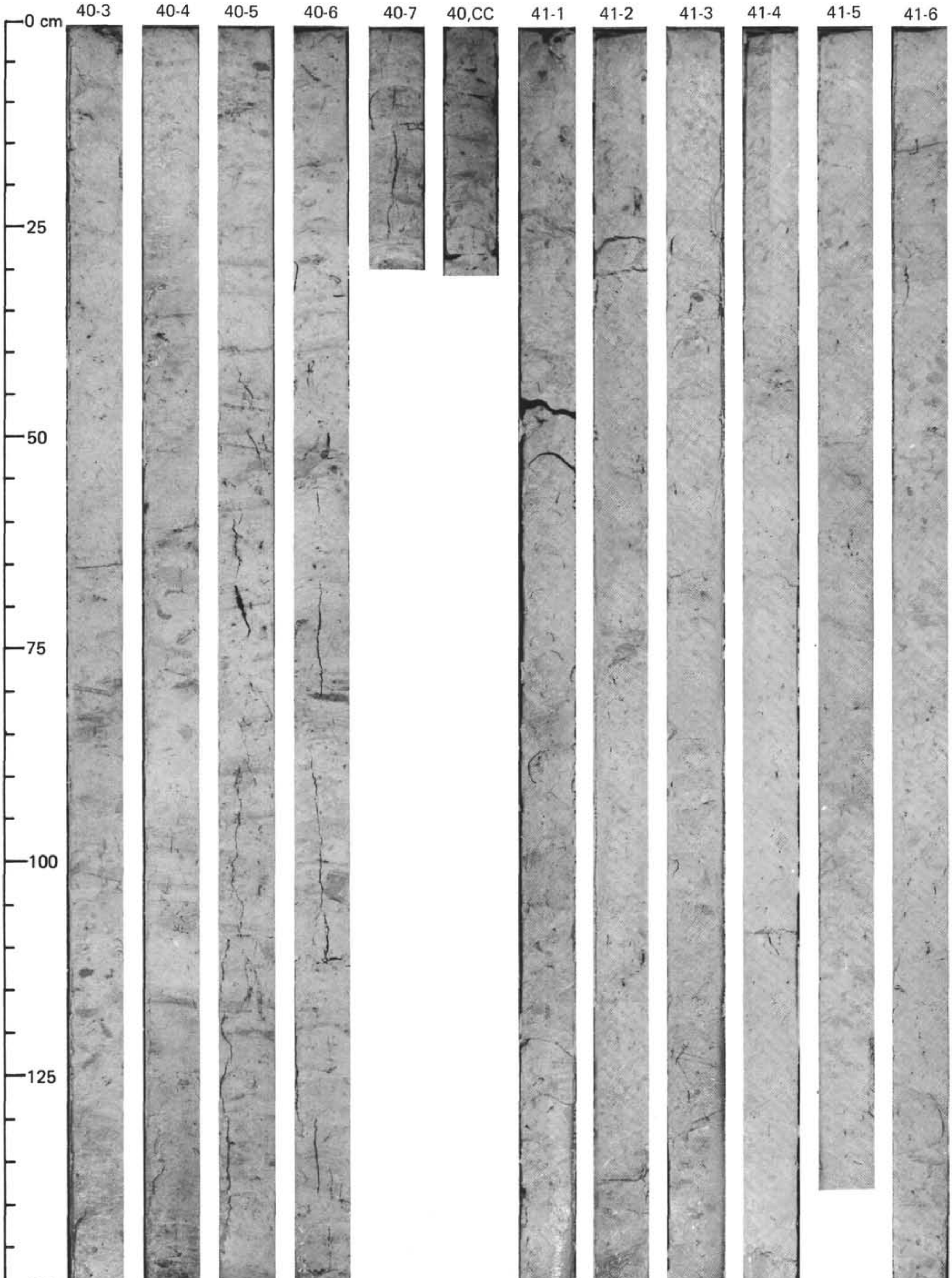
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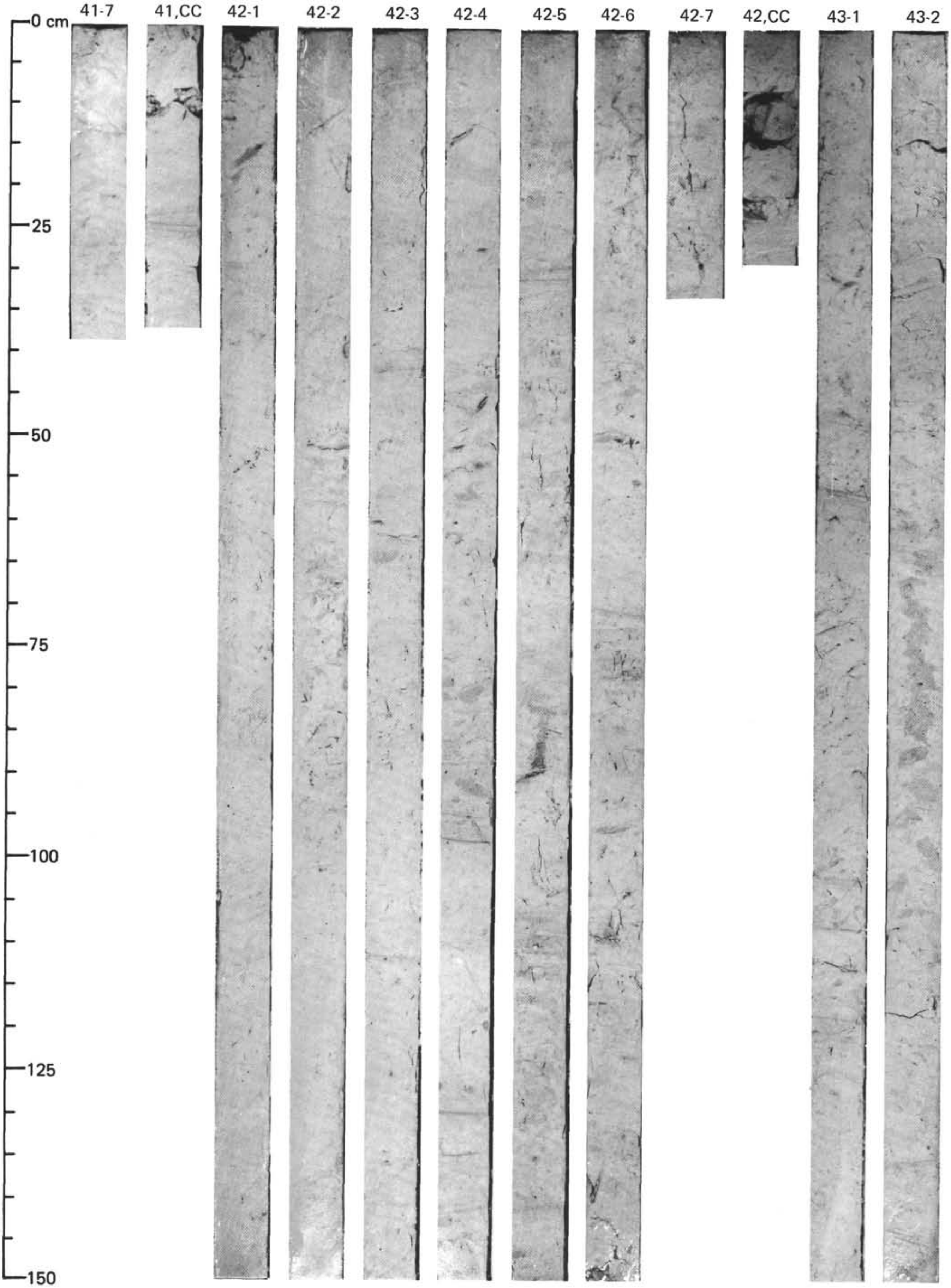
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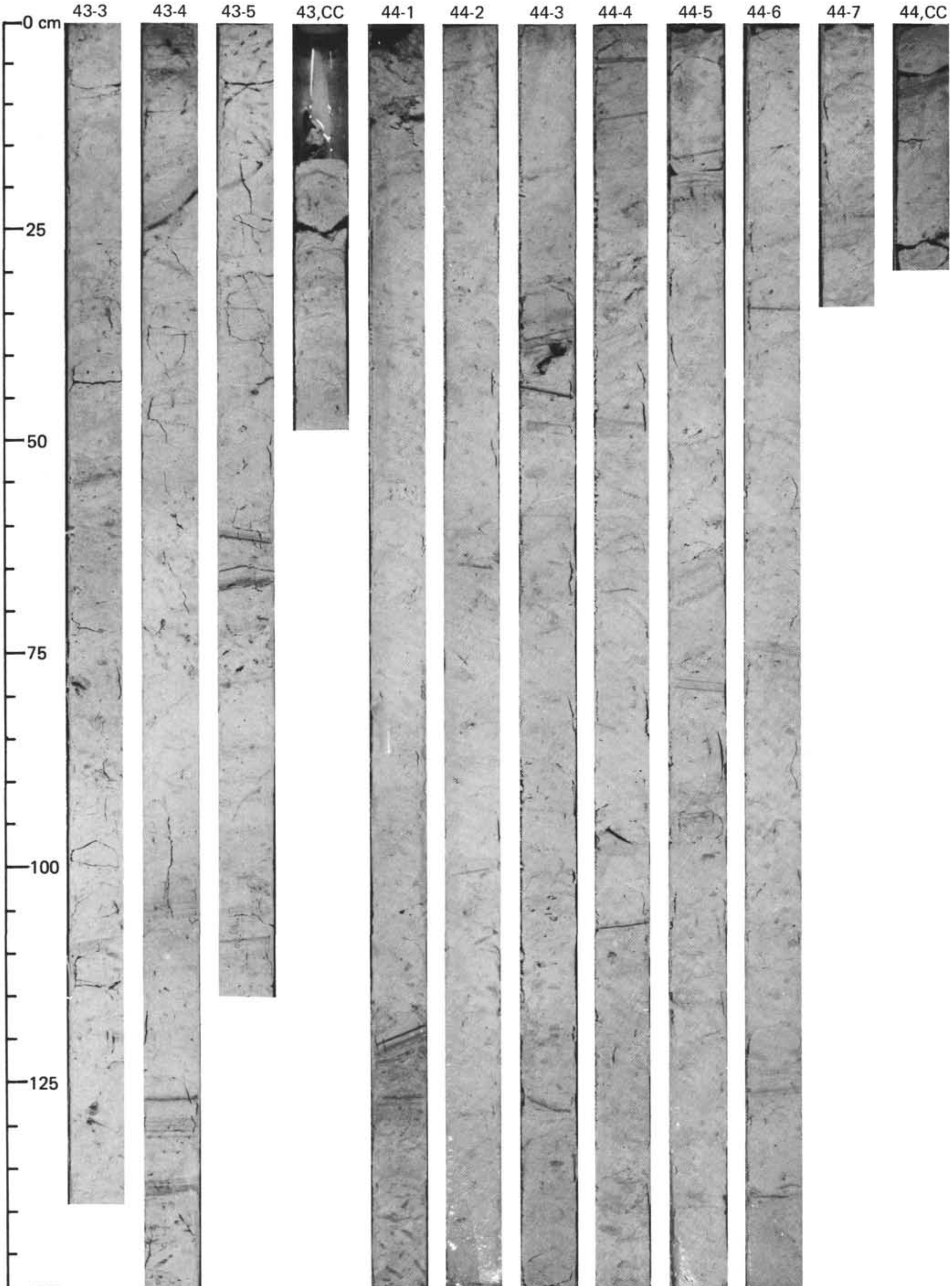

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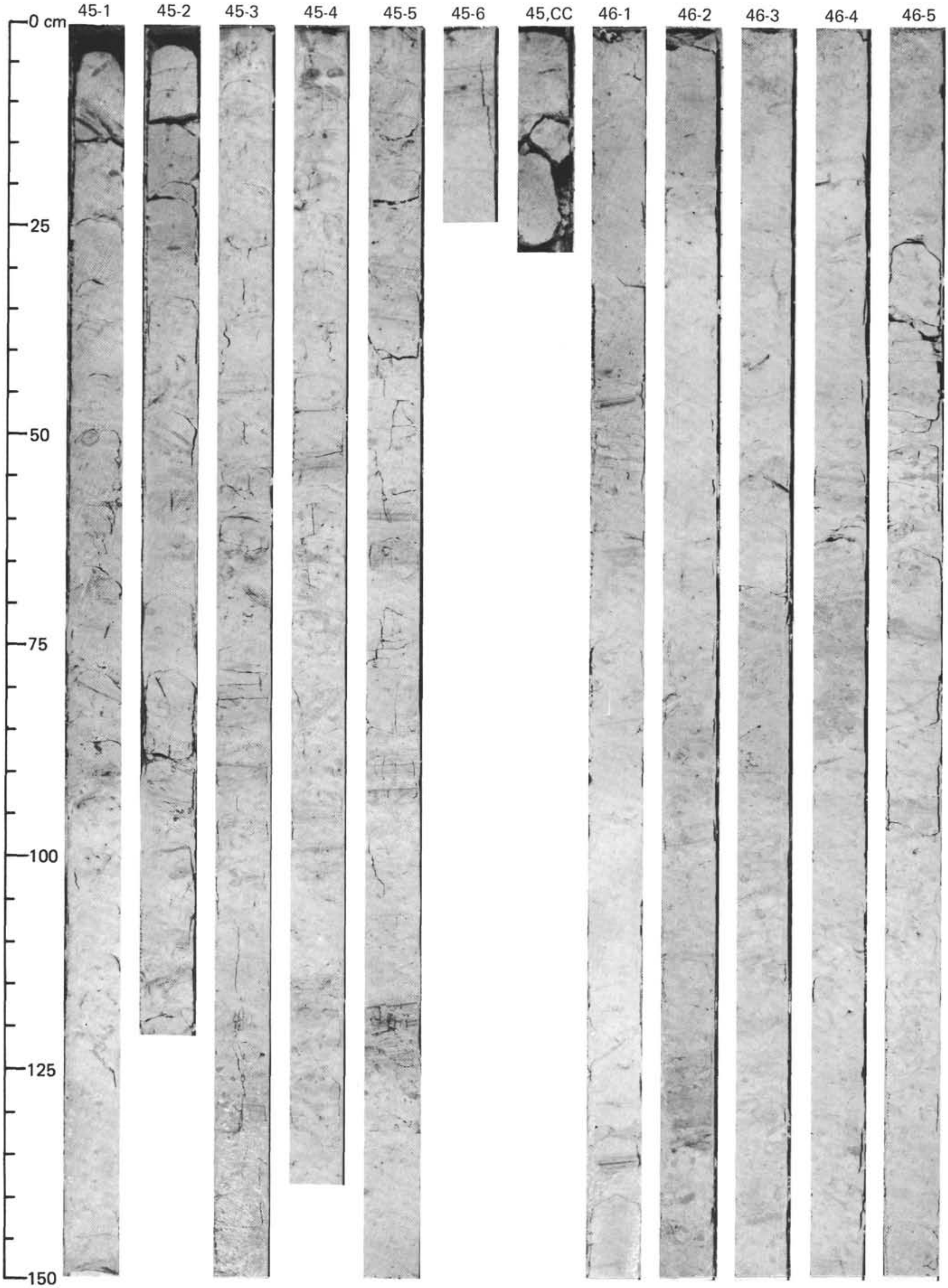

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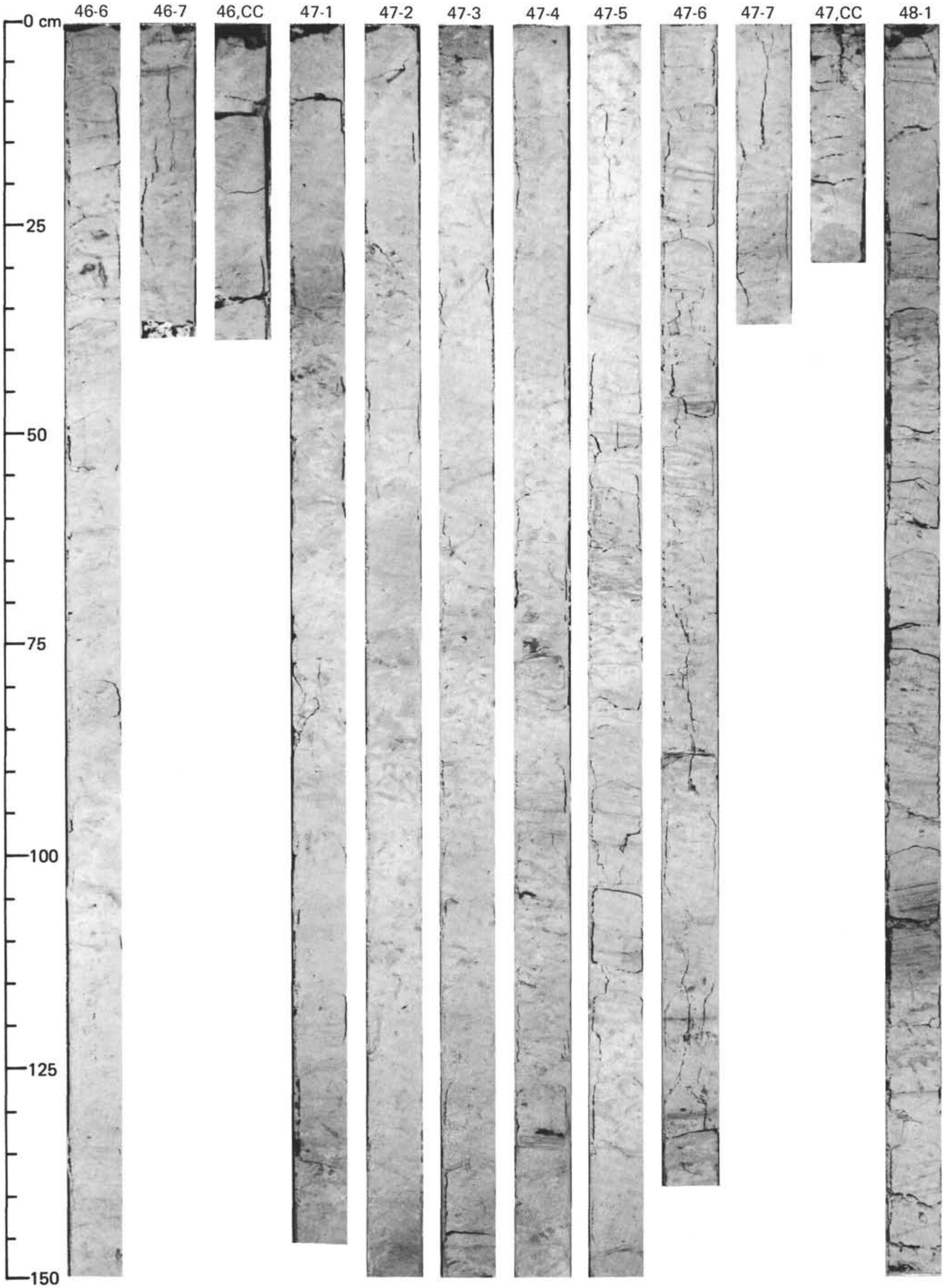
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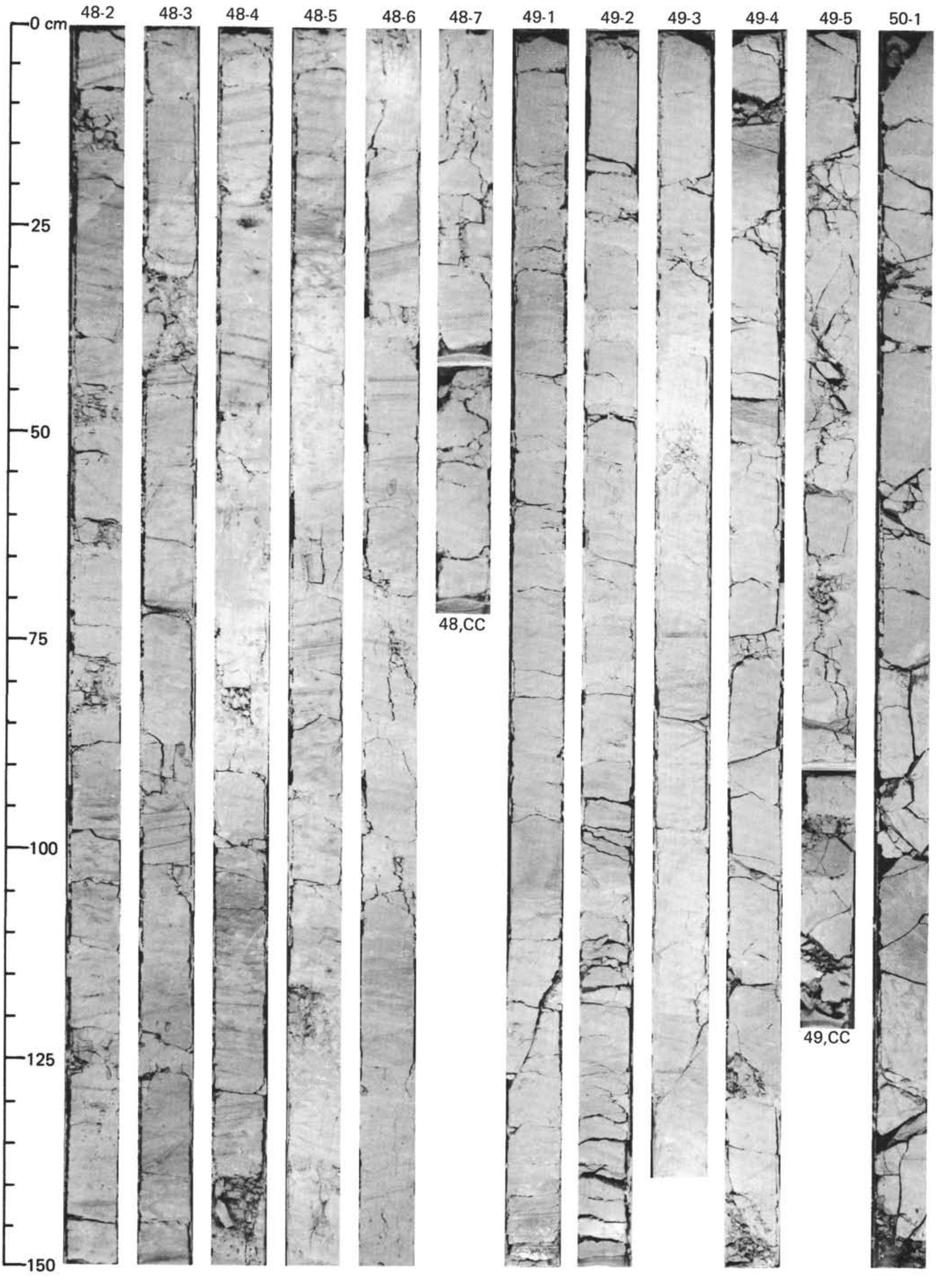

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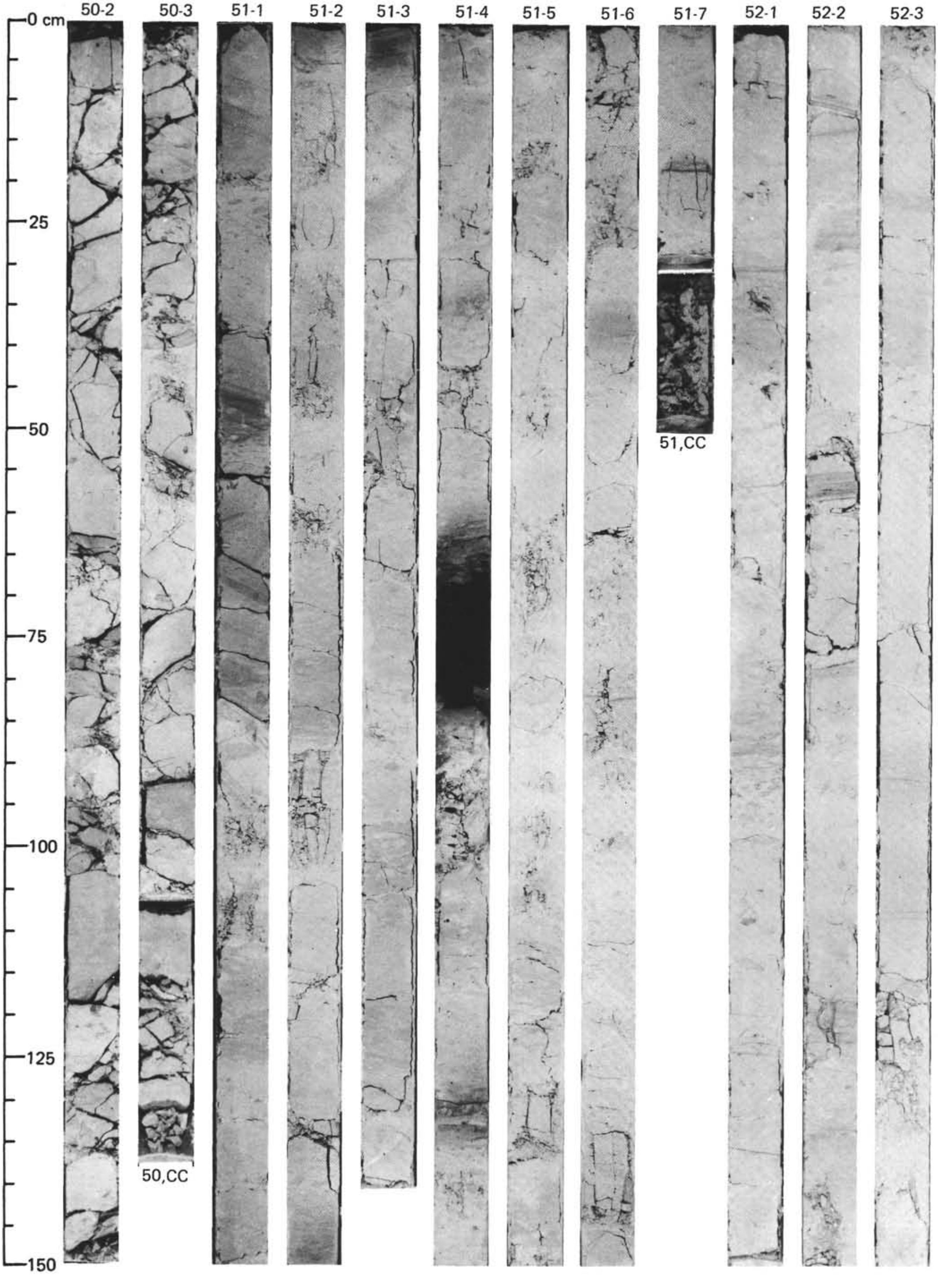
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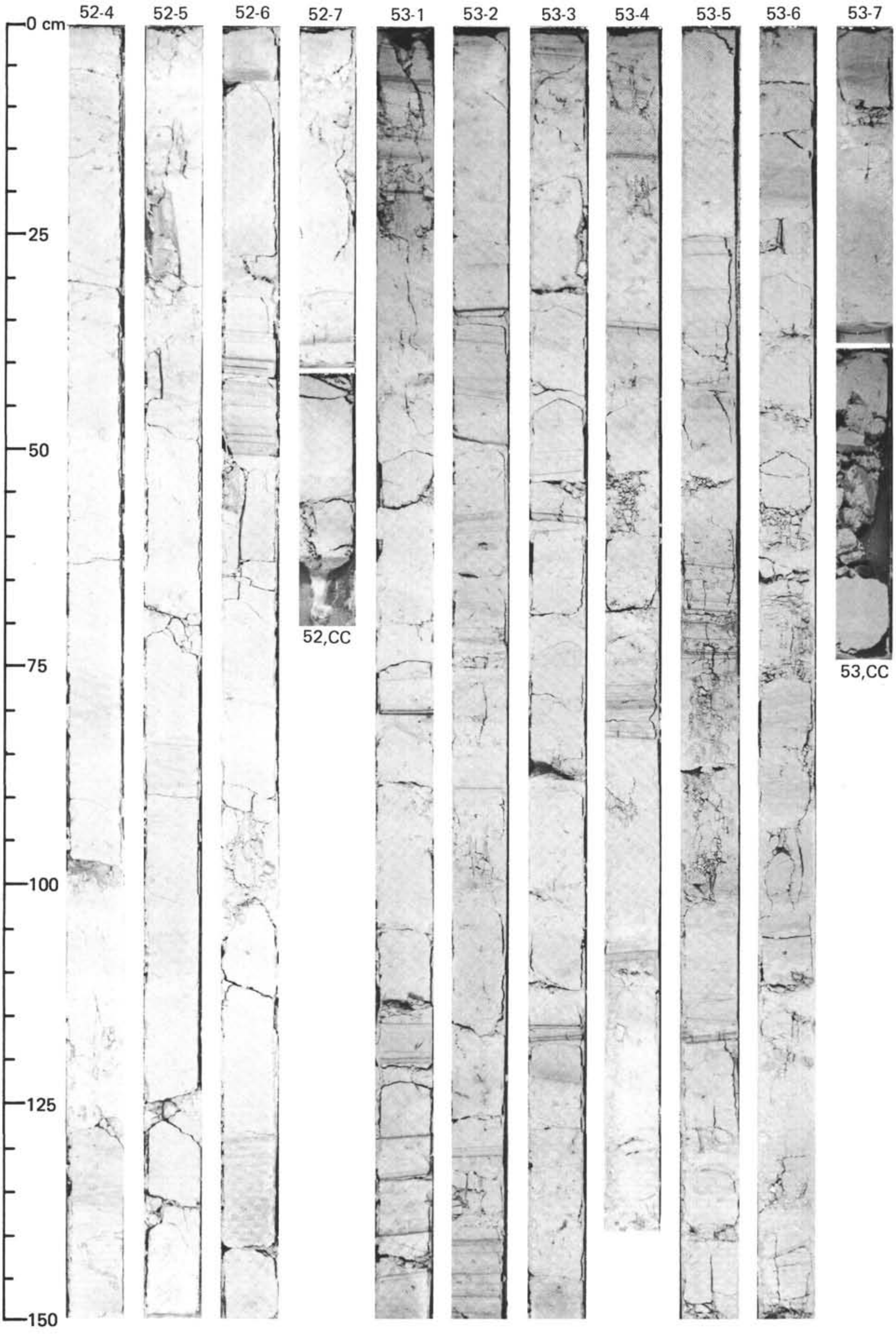
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