6. SITE 610[1]

Shipboard Scientific Party[2]

HOLE 610

Date occupied: 28 July 1983

Date departed: 31 July 1983

Time on hole: 3.1 days

Position: 53°13.297′N; 18°53.213′W

Water depth (sea level; corrected m, echo-sounding): 2417

Water depth (rig floor; corrected m, echo-sounding): 2432.8

Bottom felt (m, drill pipe): 2426.7

Penetration (m): 723

Number of cores: 27

Total length of cored section (m): 259.2

Total core recovered (m): 179.32

Core recovery (%): 69

Oldest sediment cored:
Sub-bottom depth (m): 723
Nature: nannofossil chalk
Age: late early Miocene (NN3)
Measured velocity (km/s): 2.304

Basement: not reached

HOLE 610A

Date occupied: 31 July 1983

Date departed: 1 August 1983

Time on hole: 0.9 days

Position: 53°13.297′N; 18°53.213′W

Water depth (sea level; corrected m, echo-sounding): 2417

Water depth (rig floor; corrected m, echo-sounding): 2432.8

Bottom felt (m, drill pipe): 2426.3

Penetration (m): 201

Number of cores: 21

Total length of cored section (m): 201

Total core recovered (m): 191.4

Core recovery (%): 95

Oldest sediment cored:
Sub-bottom depth (m): 201
Nature: nannofossil ooze
Age: early Pliocene (NN15)
Measured velocity (km/s): 1.558

Basement: not reached

HOLE 610B

Date occupied: 1 August 1983

Date departed; 2 August 1983

Time on hole: 0.75 days

Position: 53°13.297′N; 18°53.213′W

Water depth (sea level; corrected m, echo-sounding) 2417

Water depth (rig floor; corrected m, echo-sounding): 2432.8

Bottom felt (m drill pipe): 2427.5

Penetration (m): 146.8

Number of cores: 16

Total length of cored section (m): 146.8

Total core recovered (m): 136.33

Core recovery (%): 93

Oldest sediment cored:
Sub-bottom depth (m): 146.8
Nature: nannofossil ooze
Age: early Pliocene (NN16)

Basement: not reached

HOLE 610C

Date occupied: 2 August 1983

Date departed: 3 August 1983

Time on hole: 0.3 days

Position: 53°13.297′N; 18°53.213′W

Water depth (sea level; corrected m, echo-sounding): 2417

Water depth (rig floor; corrected m, echo-sounding): 2432.8

Bottom felt (m drill pipe): 2427.5

Penetration (m): 118.2

Number of cores: 6

Total length of cored section (m): 48.4

Total core recovered (m): 43.93

Core recovery (%): 91

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[1] Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office).

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Oldest sediment cored:
Sub-bottom depth (m): 118.2
Nature: marly nannofossil ooze
Age: late Pliocene (NN18)

Basement: not reached

HOLE 610D

Date occupied: 3 August 1983

Date departed: 3 August 1983

Time on hole: 0.5 days

Position: 53°13.467′N; 18°53.690′W

Water depth (sea level; corrected m, echo-sounding): 2445

Water depth (rig floor; corrected m, echo-sounding): 2460.8

Bottom felt (m, drill pipe): 2458.7

Penetration (m): 386.8

Number of cores: 7

Total length of cored section (m): 66.0

Total core recovered (m): 54.16

Core recovery (%): 82

Oldest sediment cored:
Sub-bottom depth (m): 336.8
Nature: nannofossil chalk
Age: late Miocene (NN10)

Basement: not reached

HOLE 610E

Date occupied: 3 August 1983

Date departed: 4 August 1983

Time on hole: 0.7 days

Position: 53°13.467′N; 18°53.690′W

Water depth (sea level; corrected m, echo-sounding): 2445

Water depth (rig floor; corrected m, echo-sounding): 2460.8

Bottom felt (m, drill pipe): 2458.7

Penetration (m): 327.2

Number of cores: 7

Total length of cored section (m): 67.2

Total core recovered (m): 53.31

Core recovery (%): 79

Oldest sediment cored:
Sub-bottom depth (m): 327.2
Nature: white nannofossil chalk
Age: late Miocene (NN10)
Measured velocity (km/s): 1.66

Basement: not reached

Principal results: Six holes were drilled near the axis of the Feni Ridge in Rockall Trough. Four holes (610, 610A, 610B, 610C) were located on the crest of a sediment wave and two offset holes (610D, 610E) were drilled in an adjacent trough, 0.7 km to the northwest and in water 28 m deeper.

Two regional seismic reflectors were identified and dated. In Hole 610, which was spot cored beyond the Pliocene–Quaternary to 636.6 m sub-bottom, the regional 0.75-s reflector (two-way traveltime) was identified within a lower Miocene sequence that was continuously cored between 636 and 723 m sub-bottom. The reflector represents a hardness change within a chalk sequence, related to an increased biogenic silica content. Dissolution of the silica may have been caused by a widespread early Miocene oceanographic event. A faint reflector at 0.37 s sub-bottom (two-way traveltime) was continuously cored in Hole 610E and represents rapid lithification from upper Miocene ooze to chalk.

Sediment waves in the vicinity of Site 610 appear generally symmetrical and show no consistent wave migration on 3.5-kHz or airgun profiles. The complexity of their trends and shape is recognizable only from detailed survey lines. Holes 610 and 610A to 610D were located to allow investigation of vertical and lateral facies variations that might be related to the sediment waves.

The lithologies recovered at Site 610 are pelagic with glacial mud to interglacial nannofossil ooze cycles extending to 135 m sub-bottom, and nannofossil oozes and chalks to 723 m sub-bottom. No primary sedimentary structures indicative of bottom-current deposition were observed, but a general reworking of the nannofossil component was apparent. Sediment wave crest-to-trough lithologic differences are apparently slight. Sedimentation rates were remarkably linear at about 51 m/m.y. in the Pliocene–Quaternary and around 46 m/m.y. in the middle and early Miocene. No hiatuses were evident, but there is evidence of marked accumulation-rate changes over the interval of the prominent reflector that was penetrated.

Heave-related core disturbance, as detected by hole-to-hole correlations, resulted in contortion of sections and under-recovery that are severe in the upper 50 m at all holes and only moderate below. Despite this, it was possible to demonstrate that an apparently complete composite section can be pieced together to 2.5 Ma using overlapping cores from five of the six holes.

BACKGROUND AND OBJECTIVES

Site 610 is on the western side of Rockall Trough at the crest of Feni Ridge (Figs. 1 and 2). Feni Ridge is a major sediment drift nearly 600 km in length and up to 700 to 1000 m thick (Fig. 2). It is believed to have been built since Oligocene–Miocene time by the action of intermittent southward flow of Norwegian Sea Overflow Water (NSOW) (Jones et al., 1970; Ellett and Roberts, 1973). The base of the drift at Feni Ridge was originally recognized at the base of a relatively transparent sequence (Roberts, 1975) and tied to a regional seismic reflector, "R-4," west of Rockall Plateau, believed to be Eocene–Oligocene in age (Ruddiman, 1972; Roberts, 1975) (Fig. 3). A number of the large sediment drifts characteristic of the North Atlantic (Hollister et al., 1978) are thought to have originated during the Eocene–Oligocene (Laughton, Berggren, et al., 1972; Vogt, 1972). Indications of more recent base-of-drift ages from drilling results of DSDP Legs 48 (Montadert, Roberts, et al., 1979) and 49 (Luyendyk, Cann, et al., 1979) have led some authors to suggest that the flow of Norwegian Sea Overflow Water did not begin until the early Miocene. The date of initiation and the ages of other prominent reflectors relevant to the accumulation history of major North Atlantic drifts are still unclear (Miller and Tucholke, 1983). Dingle et al. (1982) suggest that, at Feni Ridge, the so-called "R-4" reflector represents a mid-drift horizon and consider that anomalous positive sediment accumulation in the drift began much earlier. Dating of the uppermost regional reflectors at both Feni Ridge and Gardar Ridge during Leg 94 revealed much about changes in Norwegian Sea overflow circulation. The prime objective of variable length hydraulic piston coring (VLHPC) and extended core barrel (XCB) drilling at Site 610 was to investigate the stratigraphic history of Feni Ridge.

The surfaces of large sediment drifts are commonly ornamented with a complex distribution of sediment

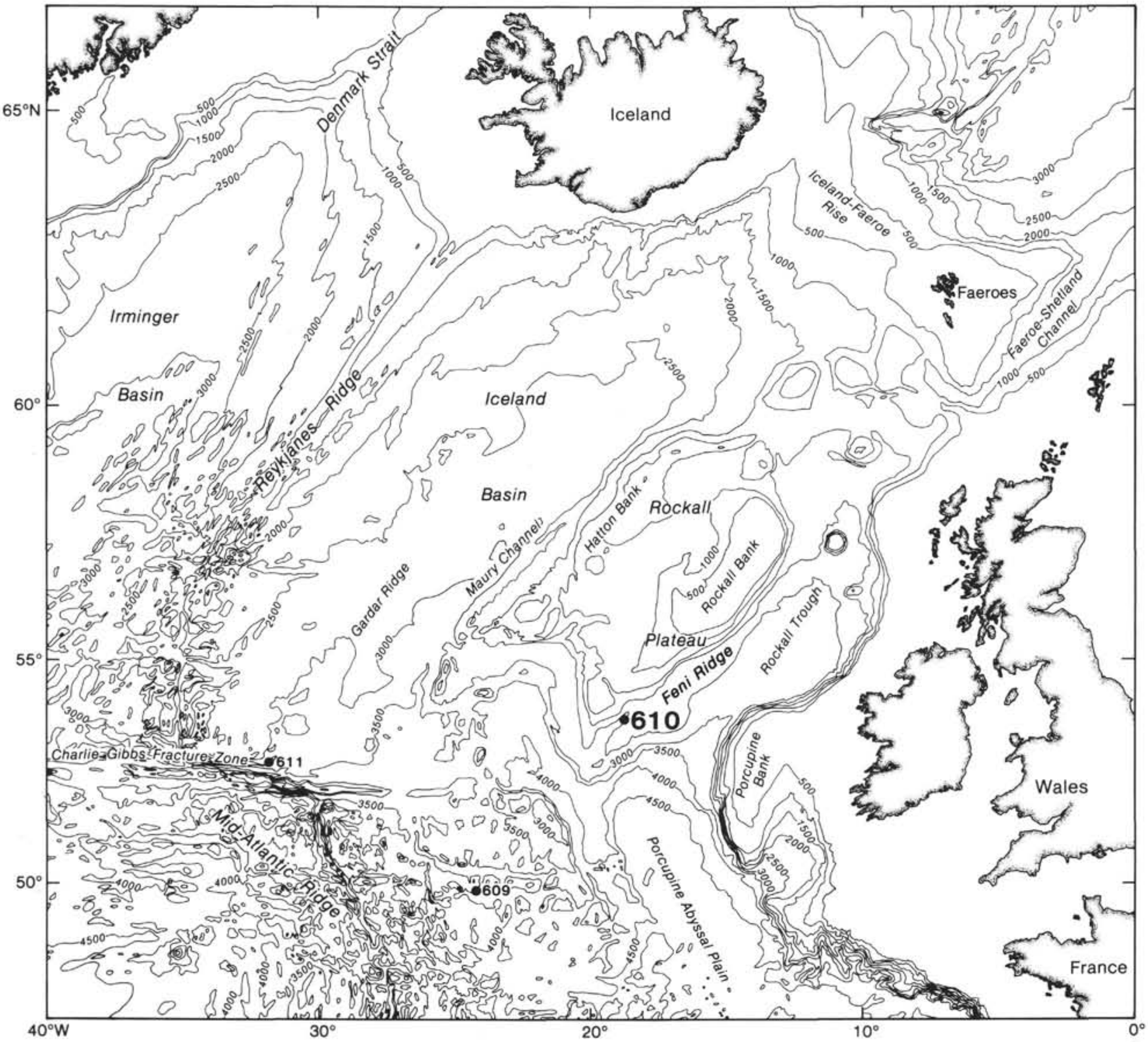


Figure 1. Location of Site 610; bathymetry given in m (after Laughton and Monahan, 1978).

waves. A long-range sidescan sonar survey run in 1977 over Feni Ridge (Fig. 4) showed that the sediment waves there are arranged longitudinally in fields of widely varying trend. On the sonographs, individual sediment wave crests over parts of the ridge flanks can be followed for up to 26 km (Roberts and Kidd, 1979). Simultaneously recorded 3.5-kHz seismic and 12-kHz echo sounder profiles indicated that the sediment waves range in amplitude from 25 to 50 m and are 1 to 4 km in wave length. An ancillary sedimentological objective at Site 610 was to test for lateral variation in the upper parts of offset VLHPC holes that might be due to migration of the sediment waves.

Deep-sea sediments deposited under the influence of bottom currents have been described as "contourites" (Hollister and Heezen, 1972), a generic term inferring that these deposits can be characterized by a sequence of sedimentary structures, grain-size, and composition changes as can "turbidites" (Bouma and Hollister, 1973). "Muddy contourites" and "sandy contourites" have been recognized by Stow and Lovell (1979), but considerable confusion still exists as to whether bottom-current deposits can be characterized solely from sediment characteristics (Stow, 1982).

We planned to document in detail the sedimentary record at Site 610 through the thickest part of a major sediment drift. In particular, we were to look for any vertical or lateral facies changes. In addition, through high-resolution stratigraphy, we wanted to detect local or regional hiatuses that could relate to periods of accelerated bottom water flow.

The sedimentary sequence at Site 610 was expected, because of its high accumulation rates, to provide a very detailed paleoenvironmental history of late Neogene changes in surface-water and deep-water circulation at the northern end of the Leg 94 transect. Additionally it could monitor the effects of warm currents along the European continental margin.

During shipboard discussions by the scientific party prior to arriving on site, it became clear that there was

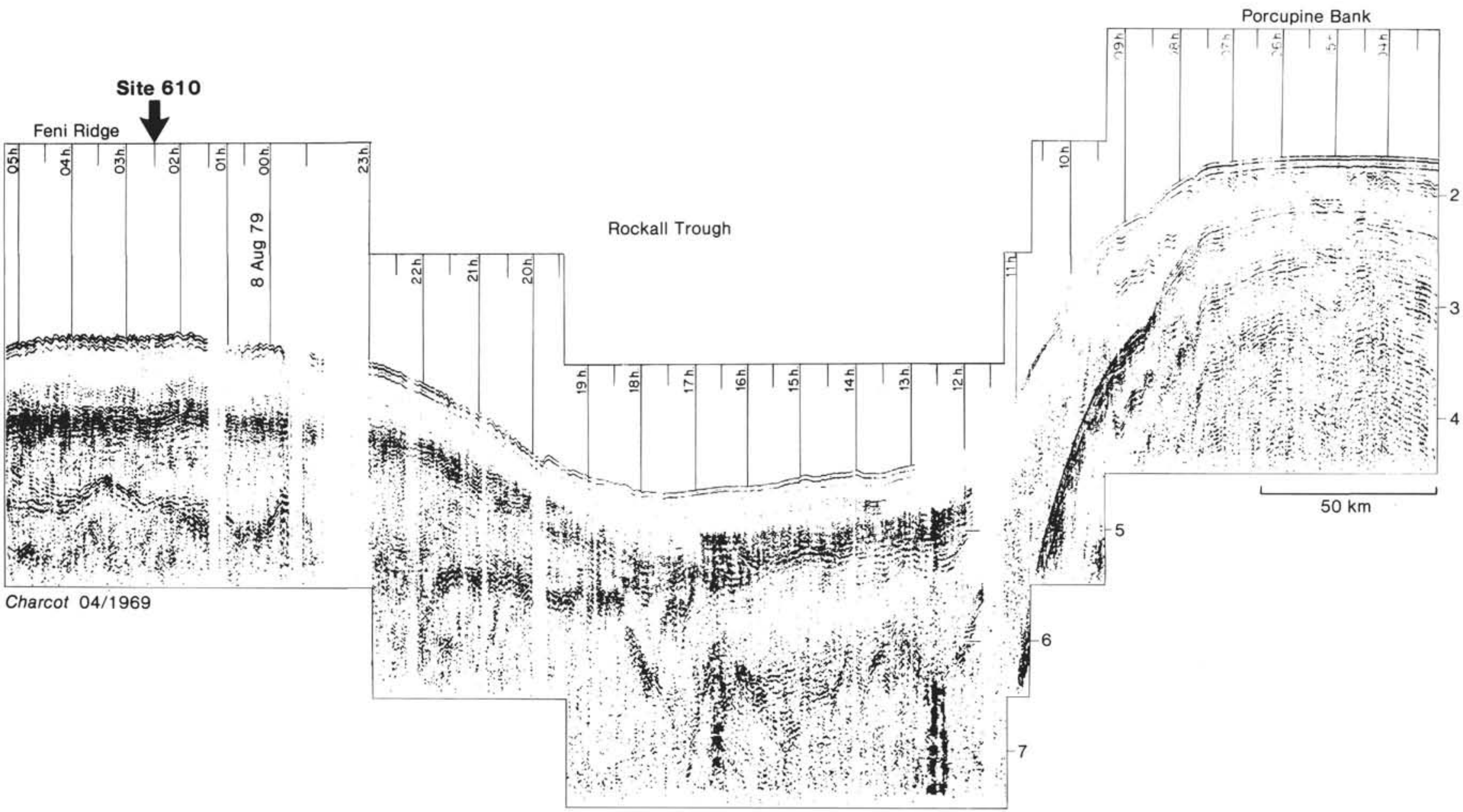


Figure 2. Air-gun profile across Rockall Trough: for location see Figure 3. The location of Site 610 is indicated.

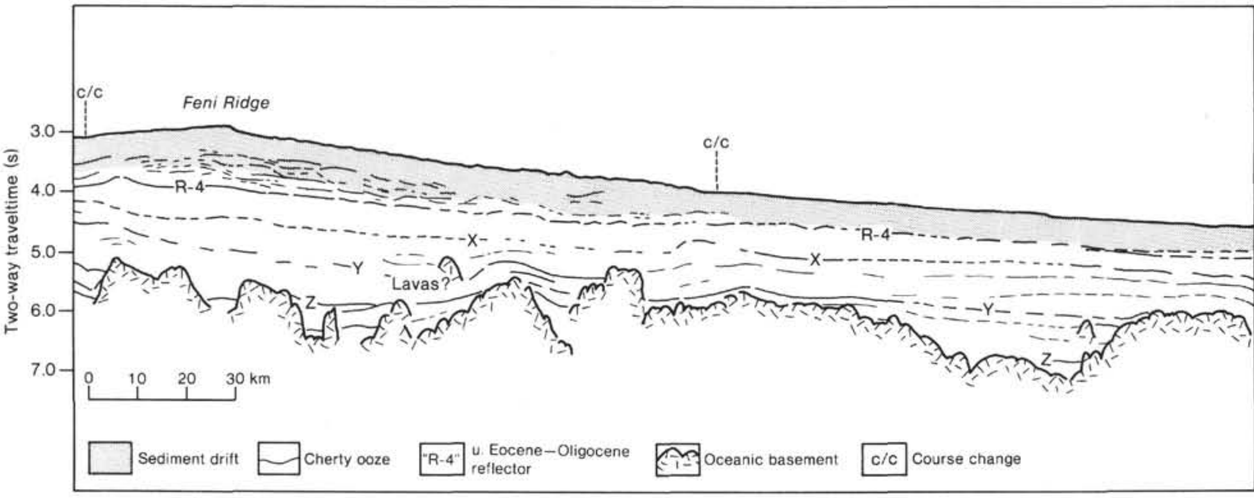


Figure 3. Interpretation of a seismic reflector profile across Feni Ridge and Rockall Trough (from Roberts, 1975; Roberts and Kidd, 1979). "R-4," X, Y, and Z were reflector designations in Roberts (1975). Site 610 drilling revised the age of this "R-4." Note the wave shapes on the surface of Feni Ridge.

considerable interest in our secondary objective, the possible local sediment facies and accumulation rate variation over the sediment waves. Time was sufficient to warrant a slight relocation of the site to tackle this objective on a recognized field of sediment waves. We decided to move the site downslope to an area where long-range sidescan sonar (GLORIA) coverage indicated that there were waves present. The originally proposed Site "7A" (Fig. 4) was located on a course change in the GLORIA survey, and as such we could not interpret the sonographs around this point. The new location (Fig. 5) was controlled by the portion of the *Discovery* cruise 84 air-gun line between 1300 and 1600 hr. and by a crossing *Glomar Challenger* Leg 12 profile, at 0700 to 1000 hr (Fig. 5). Water depths were between 2400 and 2500 m, and the sub-bottom depth to the reflector believed to be "R-4" of Roberts (1975) was picked at 0.75 s (two-way traveltime) on these two profiles. From the sonograph data, the crests of sediment waves at this location just south of the sinuous northeast–southwest trending axis of Feni Ridge appeared to have variable trends but to run roughly east–west and at an angle to the bathymetric contour between the seismic tie-lines (Fig. 5).

We planned to run an extensive survey in the vicinity of the new site with the *Challenger* water gun, PDR, and 3.5-kHz profiling systems in order to locate at least three hole locations. One was to occupy the crest of a prominent mud wave and to be a deep hole drilled to the 0.75-s reflector; the others were to be short VLHPC overlap and/or offset holes to investigate local sedimentologic and stratigraphic variations.

OPERATIONS

Detailed Site Survey

Our approach to the area of Site 610 was on a heading of 045° and speed of 10.8 knots. By about 0500 hr.[3] on 28 July we were detecting the Feni Ridge sediment-wave fields on the profiler records. We were running a course at a slight angle to the *Discovery* Cruise 84 track, slowly converging on it and planning a turn to begin our survey where the two crossed near the axis of Feni Ridge. We slowed to 8 knots at 0644 hr. and slightly adjusted course to 050° at 0708 hr.; satellite fixes were received at 0652 and 0712 hr.

The turn was made at between 0750 and 0754 hr. just over the sinuous axis of the Ridge to begin a survey of its upper southern flank (Fig. 6). The new heading of 172° was run until 1000 hr. away from the axis of the Ridge from water depths of less than 2400 m to around 2600 m (Figs. 6, 7, 8). After a turn to 010°, a further long profile was run, returning to the Ridge axis at 1220 hr. Both long profiles displayed sediment waves (most clearly shown on the precision depth recorder [PDR] and 3.5-kHz records), which varied in apparent amplitude and wave length (Figs. 7, 8). Sediment wave crests were encountered at spacings of 1 to 2 km. Changes in relief on the PDR caused by the waves ranged from 10 to 35 m.

A turn was made at between 1220 and 1225 hr. to follow the *Glomar Challenger* Leg 12 profile on a heading of 163° down the flank (Fig. 5). Only some wave crests could be followed laterally from one major profile to another and a previously favored preliminary site location was found to lie in an interval of no major waves. Thus we determined to run another short south–north line between the first two ridge flank tracks. A turn westward was made from the *Glomar Challenger* Leg 12 track at between 1405 and 1412 hr., and course adjustments were made following satellite fixes at 1420 and 1448 hr. We began to follow a 347° course for the intermediate south–north track at 1530 hr. (Fig. 6). On this line we could apparently correlate at least three major sediment wave crests. We decided to drop the beacon on one of them at the location where our first major ridge flank track had crossed it at 0842 hr. To do this, we made a westward turn between 1617 and 1619 hr. and

[3] All times are local (ship's time).

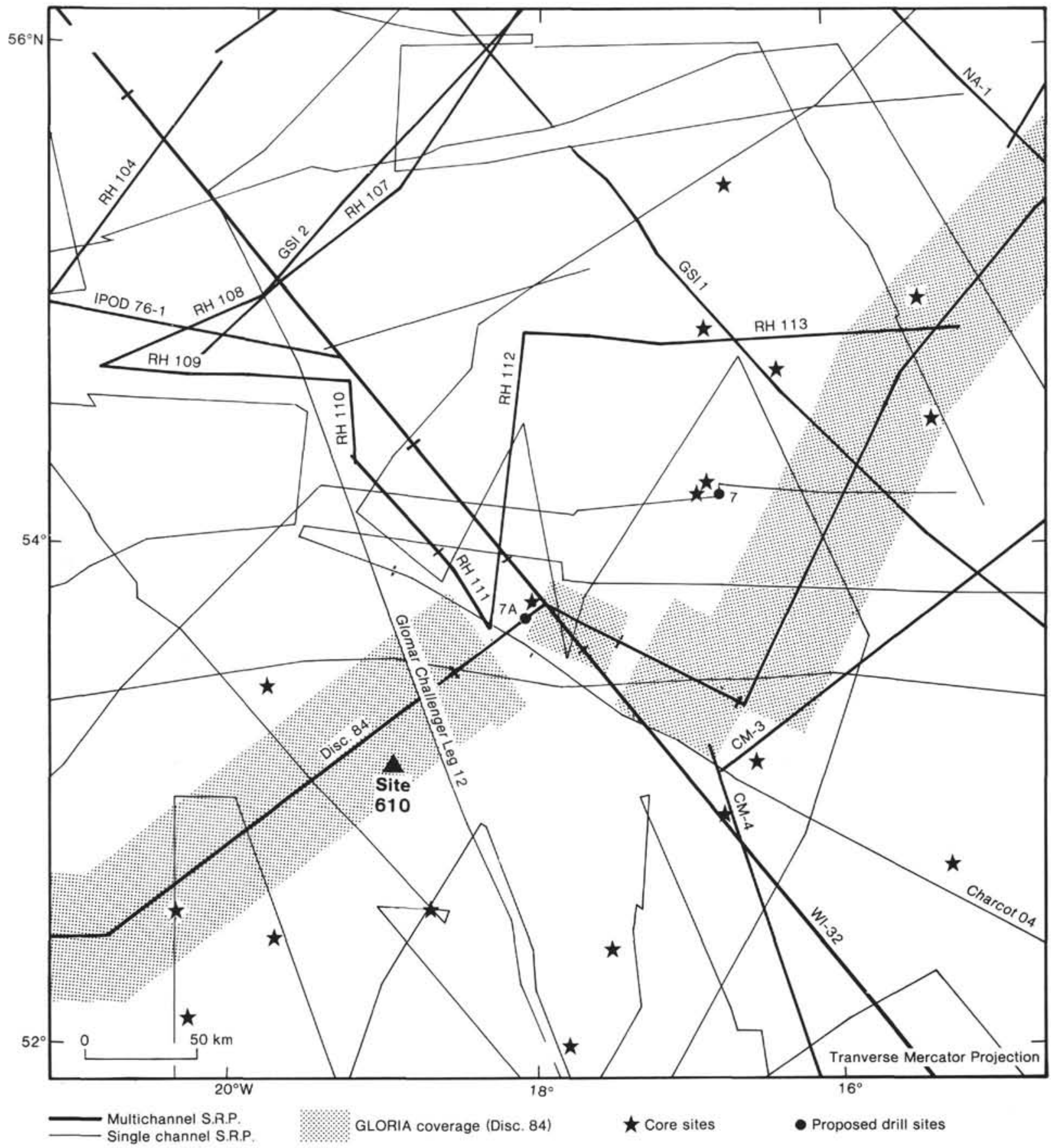


Figure 4. Site survey data for Site 610, showing GLORIA sonograph coverage. (S.R.P. = seismic reflection profile; *Discovery* 84 line was a single channel S.R.P. with simultaneous GLORIA.)

another between 1646 and 1652 hr. to run to the beacon drop on a heading of 160° (Fig. 6).

The drop was made at 1724 hr., after which we made two further passes over the beacon in a "butterfly" pattern that provided approximately northeast-southwest and west-east profiles over the site. The beacon crossings occurred at 1835 hr. on the 300° heading and 1928 hr. on the 90° heading. The tracks were well controlled by two satellite fixes at 1825 and 1900 hr., although most of this tight maneuvering was done on dead reckoning taking into account a strong current and wind from the southwest.

We began to retrieve the seismic gear about 1 n. mi. after the second beacon crossing. Recovery was complete by 1947 hr., and we began positioning over the beacon.

Later averaging of satellite fixes placed the site at latitude 53°13.297′N, longitude 18°53.213′W, and the first hole on the wave crest was in a water depth of 2417 m (corrected). An offset hole in a trough to one side (northwest) of this mud wave crest required that we move the vessel at least 0.75 km from the beacon (Fig. 8B).

Our water gun profiles during this survey unfortunately did not identify a clear "R-4" reflector as shown on the *Discovery* 84 and *Glomar Challenger* Leg 12 pro-

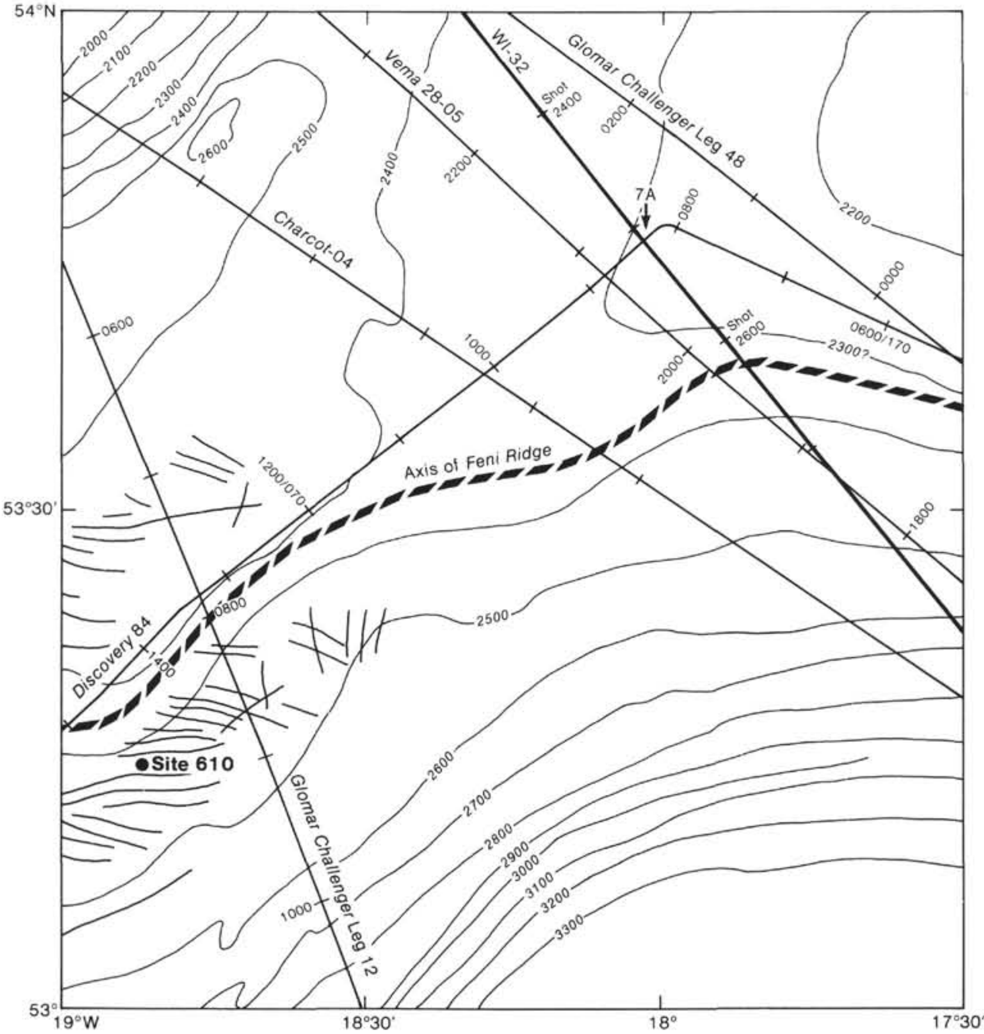


Figure 5. Relocation of the drill site from proposed site "7A" to sediment wave field at Site 610. Bathymetry is in meters, hour marks are indicated along seismic profiles (except multichannel line WI-32). Sediment-wave trends from *Discovery*-84 GLORIA survey (Roberts and Kidd, 1979).

files at 0.75 and 0.7 s sub-bottom depth, respectively. Instead a relatively coherent mixed acoustic return begins at between 0.55 to 0.57 s below the main transparent seismic unit and continues as far as penetration is detectable (0.85 s). From earlier profiles around this location we took 0.75 s as the most likely depth at which we would encounter "R-4" of Roberts (1975) and calculated that it would be located around 690 m sub-bottom.

Drilling Operations

We began running in Hole 610 at 2115 hr. on 28 July. While feeling for bottom one water core was recovered, and the first, almost full, VLHPC was recorded aboard at 0440 hr. on 29 July. This contained a good mudline and was followed by four continuous VLHPC cores to 48 m sub-bottom (Table 1). Cores 610-3, 610-4, and 610-5 showed considerable coring disturbance, mostly confined to their upper halves (top 5 m), which we decided might have been caused by sea swell that was causing the ship to heave about 10 ft. and to pitch at 3- to 5°-angles. We decided to wash down to the extended core barrel (XCB) level, and began with our first XCB core at 147 m sub-bottom. This came aboard at 1145 hr. and was followed by three continuous XCB cores extending to 185.4 m sub-bottom. All were typically pelagic nannofossil oozes with no trace of structural, compositional, or stratigraphical evidence of current deposition. We concluded that there was little point in trying to characterize these sediments further for our sedimentological "drift" objectives and determined in this hole we should now concentrate on our prime objective of obtaining the ages of significant deep reflectors.

We continued with a program of washing down four core intervals and then coring 9.6 m, such that the cores were spaced at approximately 50-m intervals. The first core in this succession, Core 610-10 (233.4–243.0 m sub-bottom), was recovered at 1710 hr. on 29 July, and the lowermost Core 610-18 came aboard at 1847 hr. on 30 July. Rates of recovery had slowed from 2.5 to 5.5 hr. over the 25.5-hr. period.

Each wash-down interval, of necessity, recovered a wash core that was discarded. Between Cores 610-18 and

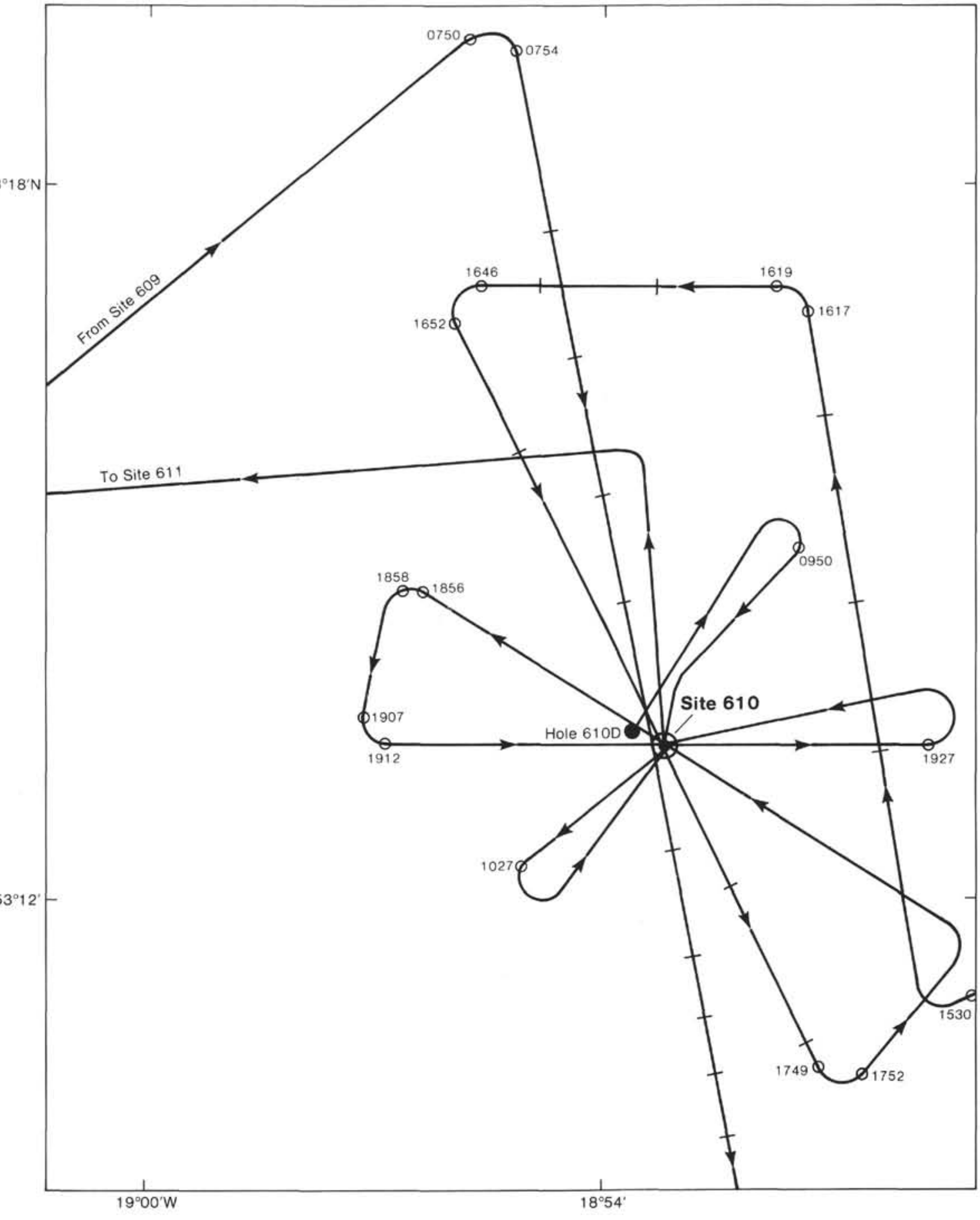


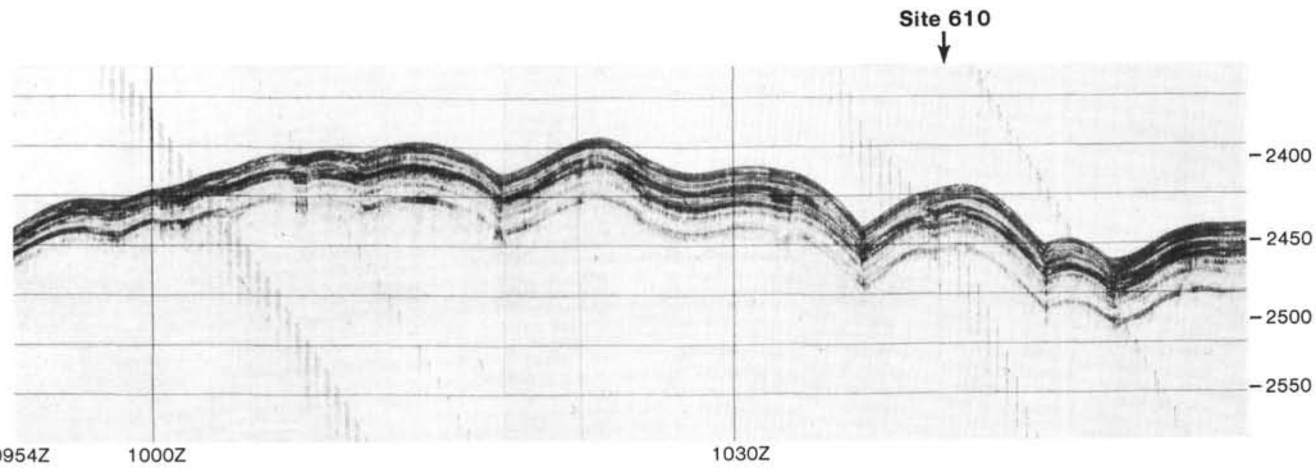
Figure 6. Pre-site surveys and departure from Site 610. Tracks in solid lines with local times and crossings of sediment wave crests (ticks) indicated.

610-19, we took the opportunity to run the core barrel pressure tool (CBPT) and obtained good data in the three-core interval between 607.8 and 636.6 m sub-bottom.

We began continuous XCB coring at 636.6 m sub-bottom with Core 610-19 and took a further eight cores over the estimated interval of the so-called "R-4" reflector to a terminal depth of 723 m sub-bottom. Core 610-19 was recovered at 0122 hr. on 31 July and the last core (610-27) came aboard at 2030 hr.

Figure 9 shows a plot of penetration rate over the interval of Cores 610-16 to 610-27 constructed from drillers' records. A major increase in cutting time occurred at Core 610-19, and this gradually decreased through Core 610-24.

By the time Core 610-27 was recovered, weather and sea conditions had improved somewhat, with the prospect of getting considerably better. We began VLHPC coring again, making only a nominal offset for Hole 610A. The spud-in was made at 2340 hr., and we re-



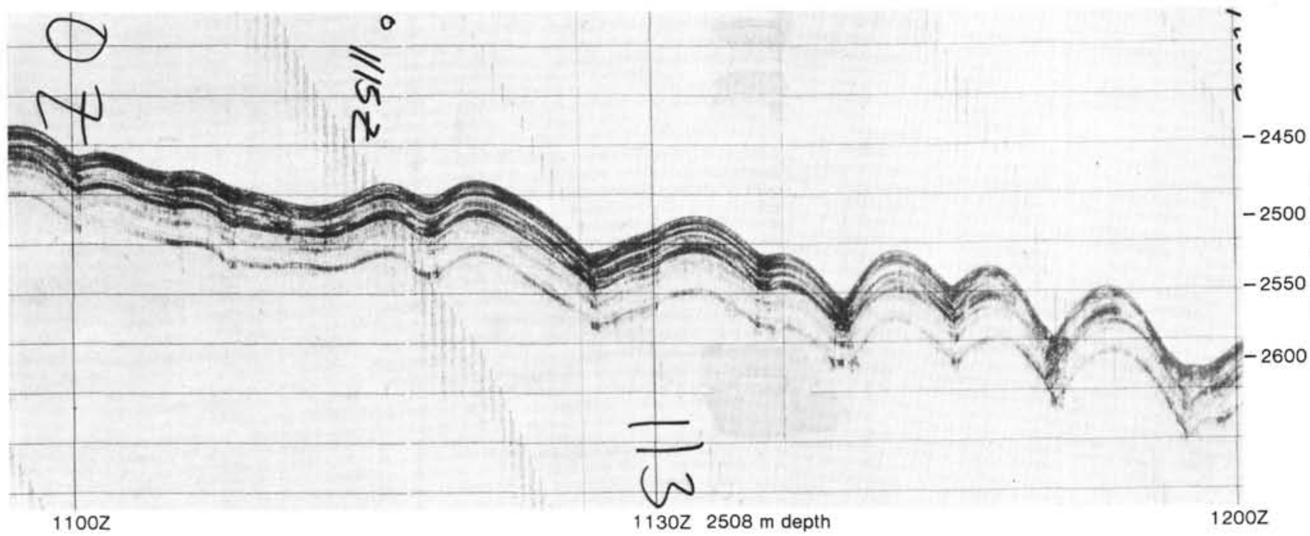


Figure 7. North-south 3.5-kHz profile from the axis of Feni Ridge at about 2400- to 2570-m water depth, through the sediment wave drilled at Site 610.

trieved a good mudline in an 8.83-m core recovered at 0010 hr. on 1 August. Core 610A-1 was undisturbed, Core 610A-2 was disturbed in Sections 2, 3 and 4, and Core 610A-3 was again undisturbed. Cores 610A-4 and -5 were disturbed, but only in the upper part of Section 1; below this level (approximately 47 m sub-bottom) the disturbance, now presumed to be due to swell, did not occur. Hole 610A was continuously VLHPC cored to 201 m sub-bottom with good recovery (95%) through the interval of the glacial-interglacial carbonate cycles. During retrieval of the cores over-pulls of between 10,000 and 40,000 lbf. were experienced beginning at only 47 m sub-bottom. Maxima of 40,000 lbf. occurred twice on recovering Core 610A-17 (153-162 m sub-bottom). We were nevertheless able to continue with the VLHPC to 201 m total depth without resorting to overcoring.

We had planned a second overlapping VLHPC hole on this sediment wave crest, but had been concerned that a third might be necessary to ensure a complete stratigraphic section over the VLHPC interval. This was partly because of the core disturbances that we attributed to swell. The breakaway piston head of the APC corer had, in the meantime, been modified to fit the VLHPC, and this was to be tried in Hole 610B. We pulled out of Hole 610A and cleared the mudline by 2120 hr.

Again a nominal offset was made, and we spudded in for Hole 610B at 2200 hr. on 1 August. Only slightly better initial core recovery ensued. Both Cores 610B-1 and -2 were undisturbed, whereas Cores 610B-3, 610B-4 and 610B-5 were disturbed in part or in whole. Sea conditions had improved as predicted, so it was not clear whether the slight improvement was due to the breakaway piston head being used or to the now calmer sea conditions and rather gentle swell.

VLHPC coring was continued in Hole 610B to a terminal depth of 146.8 m, but we recognized that the lack of some critical stratigraphic intervals necessitated another hole on the sediment wave crest.

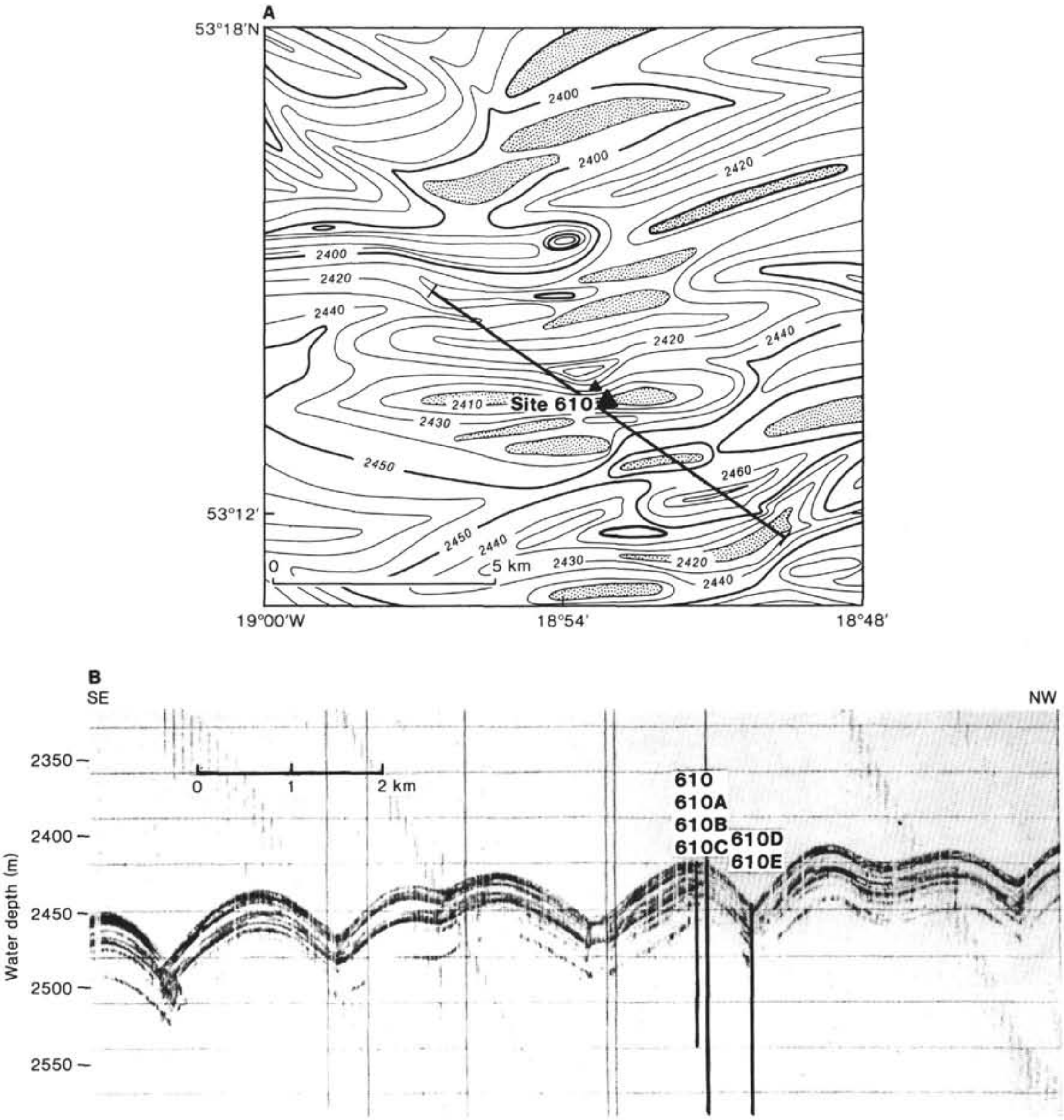


Figure 8. A. Sediment-wave directions on Feni Ridge wave crests are stippled. Trough offset holes are at position of the small triangle. Water depths in corrected meters. The position of Figure 8B is indicated. B. High-resolution seismic profile (3.5-kHz) of the sediment waves on Feni Ridge, illustrating the location of the crest and trough drilling at Site 610.

Hole 610C was spudded in at 1607 hr. on 2 August with a wash-down to 8 m sub-bottom. Two cores were taken with the 5-m VLHPC in the interval 8 to 18 m sub-bottom before a further wash-down to 26 m sub-bottom for Cores 610C-3 and 610C-4. Another wash-down was made to recover the interval 99 to 118.2 m with Cores 610C-5 and 610C-6. At this point we pulled out of Hole 610C. The last two cores in this hole underwent 20,000-lbf. over-pulls on retrieval.

Hole 610D was to be an offset hole in the trough adjacent to the sediment wave on which we had set the beacon (Fig. 8B). The mudline was cleared at 0018 hr. on 3 August. The major offset from the beacon was followed on the PDR record over an interval of 2.5 hr. We crossed the trough axis in a direction heading 300° and then returned to it. The relative relief of the wave trough versus the crest was 32 m at this point. The eventual offset position was 850 ft. north and 1520 ft. west of the beacon. Averaging of satellite fixes later gave its position (and that of Hole 610E) as latitude: 53°13.467′N, longitude: 18°53.690′W in a water depth of 2445 m compared with 2417 m at Holes 610, and 610A through 610C (28 m deeper).

We spudded in Hole 610D at 0300 hr. and the first VLHPC core came aboard at 0329 hr. with a good mudline recovered. Five VLHPC cores were taken in this hole to a depth of 56.4 m sub-bottom to look for facies and accumulation rate variations from the sediment wave crest to this adjacent trough. One core interval was washed between 8.4 and 18 m sub-bottom where no good stratigraphic datum was expected. Core disturbance was found to a maximum of 70 cm downsection in Cores 610D-1 to

Table 1. Coring summary, Site 610.

Core No.	Date (July–August, 1983)	Time (hr.)	Depth from drill floor (m) Top–Bottom	Depth below seafloor (m) Top–Bottom	Length cored (m)	Length recovered (m)	Recovery (%)
Hole 610							
1	29	0440	2427.7–2437.3	0.0–9.6	9.6	9.52	99.2
2	29	0543	2437.3–2446.9	9.6–19.2	9.6	7.97	83.0
3	29	0655	2446.9–2456.5	19.2–28.8	9.6	4.77	49.7
4	29	0758	2456.5–2466.1	28.8–38.4	.6	8.91	92.8
5	29	0903	2466.1–2475.7	38.4–48.0	9.6	9.35	97.4
Wash	29		2475.7–2574.7	48.0–147.0	99.0	0.00	0.0
6	29	1145	2574.7–2584.3	147.0–156.6	9.6	8.08	8.4
7	29	1300	2584.3–2593.9	156.5–166.2	9.6	9.88	102.9
8	29	1345	2593.9–2603.5	166.2–175.8	9.6	9.59	99.9
9	29	1453	2603.5–2613.1	175.8–185.4	9.6	9.73	101.3
Wash	29		2613.1–2661.1	185.4–233.4	48.0	0.00	0.0
10	29	1710	2661.1–2670.7	233.4–243.0	9.6	5.78	60.2
Wash	29		2670.7–2728.3	243.0–300.6	57.6	0.00	0.0
11	29	1937	2728.3–2737.9	300.6–310.2	9.6	3.57	37.2
Wash	29		2737.9–2776.3	310.2–348.6	38.4	0.00	0.0
12	29	2210	2776.3–2785.9	348.6–358.2	9.6	0.54	5.6
13	30	0015	2785.9–2795.5	358.2–367.8	9.6	3.61	37.6
Wash	30		2795.5–2833.9	367.8–406.2	38.4	0.00	0.0
14	30	0305	2833.9–2843.5	406.2–415.8	9.6	4.84	50.4
Wash	30		2843.5–2881.9	415.8–454.2	38.4	0.00	0.0
15	30	0600	2881.9–2891.5	454.2–463.8	9.6	8.89	92.6
Wash	30		2891.5–2929.9	463.8–502.2	38.4	0.00	0.0
16	30	0900	2929.9–2939.5	502.2–511.8	9.6	9.71	101.1
Wash	30		2939.5–2977.9	511.8–550.2	38.4	0.00	0.0
17	30	1310	2977.9–2987.5	550.2–559.8	9.6	8.82	91.9
Wash	30		2987.5–3025.9	559.8–598.2	38.4	0.00	0.0
18	30	1847	3205.9–3035.5	598.2–607.8	9.6	7.61	79.3
Wash	30		3035.5–3064.3	607.8–636.6	28.8	0.00	0.0
19	31	0122	3064.3–3073.9	636.6–646.2	9.6	4.18	43.5
20	31	0415	3073.9–3083.5	646.2–655.8	9.6	3.37	35.1
21	31	0650	3083.5–3093.1	655.8–665.4	9.6	2.64	27.5
22	31	0935	3093.1–3102.7	665.4–675.0	9.6	9.87	102.7
23	31	1155	3102.7–3112.3	675.0–684.6	9.6	2.42	25.2
24	31	1455	3112.3–3121.9	684.6–694.2	9.6	4.52	47.1
25	31	1634	3121.9–3131.5	694.2–703.8	9.6	6.16	64.2
26	31	1832	3131.5–3141.1	703.8–713.4	9.6	5.68	59.2
27	31	2030	3141.1–3150.7	713.4–723.0	9.6	9.31	97.0
					259.2[a]	179.32	69.2
Hole 610A							
1	1	0010	2426.3–2435.3	0.0–9.0	9.0	8.83	98.1
2	1	0115	2435.3–2444.9	9.0–18.6	9.6	9.56	99.6
3	1	0220	2444.9–2454.5	18.6–28.2	9.6	9.52	99.2
4	1	0300	2454.5–2464.1	28.2–37.8	9.6	9.22	96.0
5	1	0410	2464.1–2473.7	37.8–47.4	9.6	9.57	99.7
6	1	0510	2473.7–2483.3	47.4–57.0	9.6	9.45	98.4
7	1	0615	2483.3–2492.9	57.0–66.6	9.6	9.35	97.4
8	1	0720	2492.9–2502.5	66.6–76.2	9.6	9.34	97.3
9	1	0815	2502.5–2512.1	76.2–85.8	9.6	9.44	98.3
10	1	0919	2512.1–2521.7	85.8–95.4	9.6	9.18	95.6
11	1	1016	2521.7–2531.3	95.4–105.0	9.6	8.90	92.7
12	1	1118	2531.3–2540.9	105.0–114.6	9.6	9.28	96.7
13	1	1227	2540.9–2550.5	114.6–124.2	9.6	9.43	98.2
14	1	1321	2550.5–2560.1	124.2–133.8	9.6	9.04	94.2
15	1	1423	2560.1–2569.7	133.8–143.4	9.6	9.30	96.9
16	1	1505	2569.7–2579.3	143.4–153.0	9.6	9.11	94.9
17	1	1605	2579.3–2588.9	153.0–162.6	9.6	9.08	94.6
18	1	1655	2588.9–2598.5	162.6–172.2	9.6	8.00	83.3
19	1	1755	2598.5–2608.1	172.2–181.8	9.6	8.33	86.7
20	1	1850	2608.1–2617.7	181.8–191.4	9.6	9.14	95.2
21	1	2000	2617.7–2627.3	191.4–201.0	9.6	8.41	87.6
					201.0	191.48	95.3
Hole 610B							
1	1	2227	2427.5–2432.3	0.0–4.8	4.8	4.80	100.0
2	1	2330	2432.3–2441.9	4.8–14.4	9.6	6.34	66.0
3	2	0040	2441.9–2451.5	14.4–24.0	9.6	9.60	100.0
4	2	0151	2451.5–2461.1	24.0–33.6	9.6	8.38	87.3
5	2	0255	2461.1–2470.7	33.6–43.2	9.6	8.73	90.9

Table 1 (continued).

Core No.	Date (July–August, 1983)	Time (hr.)	Depth from drill floor (m) Top–Bottom	Depth below seafloor (m) Top–Bottom	Length cored (m)	Length recovered (m)	Recovery (%)
Hole 610B (Cont.)							
6	2	0410	2470.7–2480.3	43.2–52.8	9.6	9.18	95.6
7	2	0520	2480.3–2489.9	52.8–62.4	9.6	9.41	98.0
8	2	0609	2489.9–2499.5	62.4–72.0	9.6	9.26	96.5
9	2	0712	2499.5–2509.1	72.0–81.6	9.6	9.12	95.0
10	2	0815	2509.1–2518.7	81.6–91.2	9.6	9.24	96.3
11	2	0922	2518.7–2528.3	91.2–100.8	9.6	8.46	88.1
12	2	1100	2528.3–2537.9	100.8–110.4	9.6	8.92	92.9
13	2	1158	2537.9–2545.5	110.4–118.0	7.6	8.27	108.8
14	2	1300	2545.5–2555.1	118.0–127.6	9.6	9.25	96.4
15	2	1346	2555.1–2564.7	127.6–137.2	9.6	8.27	86.2
16	2	1440	2564.7–2574.3	137.2–146.8	9.6	9.10	94.8
					146.8	136.33	92.9
Hole 610C							
Wash	2		2427.5–2435.5	0.0–8.0			
1	2	1648	2435.5–2440.5	8.0–13.0	5.0	4.17	83.4
2	2	1742	2440.5–2445.5	13.0–18.0	5.0	3.69	73.8
Wash	2		2445.5–2453.5	18.0–26.0			
3	2	1907	2453.3–2463.1	26.0–35.6	9.6	8.79	91.3
4	2	1958	2463.1–2472.7	35.6–45.2	9.6	8.66	90.2
Wash	2		2472.7–2526.5	45.2–99.0			
5	2	2034	2526.5–2536.1	99.0–108.6	9.6	9.50	99.0
6	2	2330	2536.1–2545.7	108.6–118.2	9.6	9.12	95.0
					48.4[a]	43.93	90.8
Hole 610D							
1	3	0329	2458.7–2467.1	0.0–8.4	8.4	8.36	99.5
2	4	0436	2467.1–2476.7	8.4–18.0	9.6	8.95	93.2
Wash			2476.7–2486.3	18.0–27.6			
3	3	0537	2486.3–2495.9	27.6–37.2	9.6	8.66	90.2
4	3	0632	2495.9–2505.5	37.2–46.8	9.6	8.99	93.6
5	3	0731	2505.5–2515.1	46.8–56.4	9.6	8.72	90.8
Wash	3		2515.1–2776.3	56.4–317.6			
6	3	1238	2776.3–2785.9	317.6–327.2	9.6	5.12	53.3
7	3	1400	2785.9–2795.5	327.2–336.8	9.6	5.36	55.8
					66.0[a]	54.16	82.1
Hole 610E							
Wash	3		2458.7–2718.7	0.0–260.0			
1	3	2021	2718.7–2728.3	260.0–269.6	9.6	5.03	52.4
2	3	2124	2728.3–2737.9	269.6–279.2	9.6	6.35	66.1
3	3	2220	2737.9–2747.5	279.2–288.8	9.6	9.56	99.6
4	3	2325	2747.5–2757.1	288.8–298.4	9.6	8.61	89.7
5	4	0034	2757.1–2766.7	298.4–308.0	9.6	9.60	100.0
6	4	0150	2766.7–2776.3	308.0–317.6	9.6	5.89	61.3
7	4	0250	2776.3–2785.9	317.6–327.2	9.6	8.27	86.1
					67.2[a]	53.31	79.3

[a] Excluding washed intervals.

610D-4, but in 610D-5 it was extended into Section 2. We then washed down to 317.6 m sub-bottom. Here we were aiming to take continuous cores over a possible upper Miocene stratigraphic hiatus that had been identified tentatively in Hole 610 close to the level predicted for a mid-drift reflector. Dating of the two cores recovered revealed that we had missed the critical interval and were already approximately 40 m lower in the sequence than was Core 610-11, our target level. At this point, we decided to pull out of Hole 610D from a terminal depth of 386.8 m and to attempt a second wash-down to this required interval.

We spudded in for Hole 610E at 1543 hr. on 3 August after only a nominal offset and began a wash-down to 260 m sub-bottom. At this level we began continuous XCB coring and recovered seven cores to a terminal depth of 327.2 m. We were satisfied that we had successfully recovered the stratigraphic interval missed in the previous holes and pulled out of the hole.

Postdrilling Survey

When all rig operations were complete at 0930 hr. and we were ready to leave the site, a last crossing of the sediment wave was planned to determine more finely the

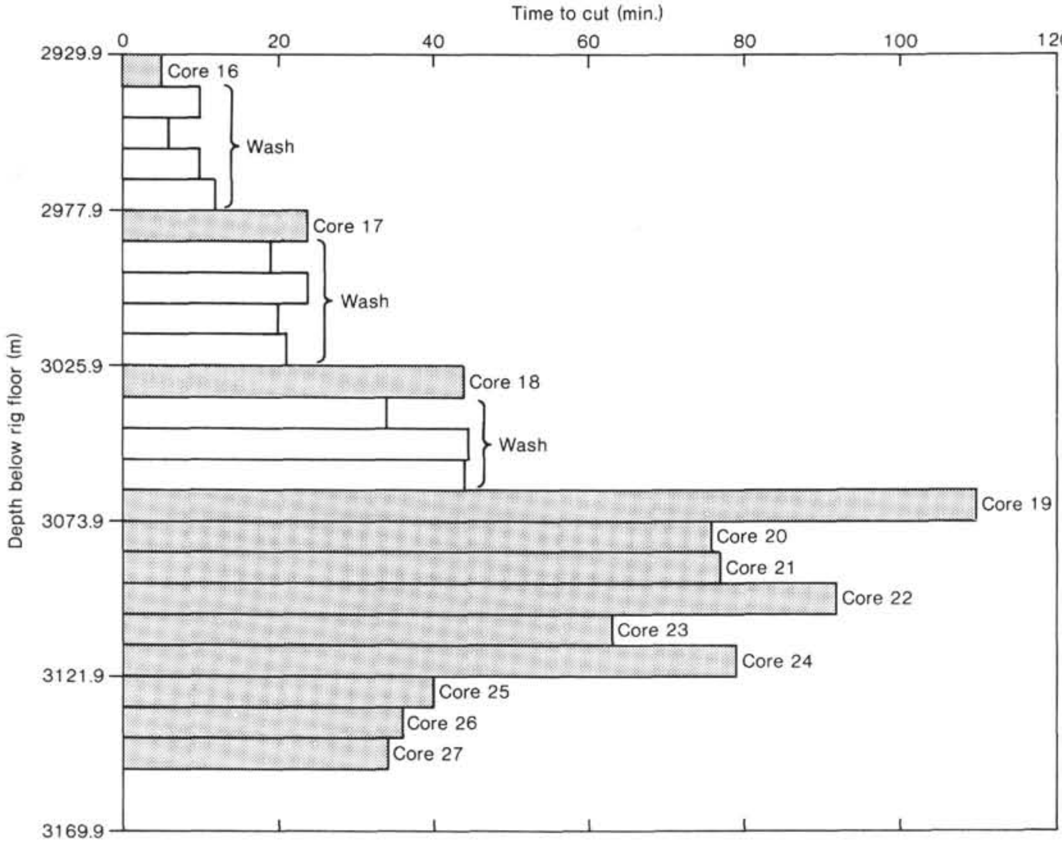


Figure 9. Penetration rate in Hole 610 over the interval 502.2 to 723.0 m sub-bottom (2929.2-3150.7 m below rig floor) as constructed from drillers' records. Cored intervals are shaded, washed intervals unshaded.

orientation of its axis. We began with a run at 4 knots while streaming the seismic gear on a heading of 045° until a turn was made at 0950 hr. (Fig. 6). Gaining speed to 8 knots and on the new heading of 225°, we determined by eventual detection of the beacon that we were on course to cross the position of Hole 610D rather than the beacon itself. Although we made a course change and crossed the beacon, the crossing was not in the required direction. Thus we made another turn at 1027 hr. to make a return crossing on a heading of 038°. The crossing was made, again only after a course change when the beacon came in range, but we were satisfied with the orientation of our approach and so a turn was made to a heading of 266° and we departed for Site 611.

SEDIMENT LITHOLOGY

The recovery of sediment from the six holes is summarized in Figure 10. Although a continuous sequence was obtained in the upper 200 m of the sediment column only, the recovered cores can be divided into two main lithologic units (Fig. 10A, B).

Unit I consists of interbedded calcareous mud and foraminiferal-nannofossil ooze of Quaternary and late Pliocene age and includes the interval 0 to 135 m in Hole 610A and 0 to 140 m in Hole 610B. Incomplete sections of the unit were recovered in all holes except 610E. The cycles are thought to be related to glacial-interglacial oscillations. Calcareous mud intervals consist of predominantly olive gray and light brown clayey silts that may contain up to 15% sand. The silt and clay fractions are made up of quartz and feldspar, with a relatively low content of clay minerals. Minor constituents include opaque and ferromagnesian heavy minerals, volcanic glass and shell fragments. Foraminifers and nannofossils are present in variable amounts. The interbedded white to very light gray oozes range from very pure carbonate with less than 5% terrigenous content to marly ooze with 30 to 60% terrigenous material. Foraminifers make up more than 10% of the sediment. Occasional diffuse pale green gray and gray laminae (pyrite-rich) are characteristic of the ooze beds.

Lithologic contacts are generally gradational, which results in the range of intermediate compositions. The sediments lack obvious primary sedimentary structures that might relate to current deposition. Intense bioturbation is clearly seen at the lithological boundaries and the trace fossils Zoophycos, Chondrites, and Planolites are common. The calcareous mud beds vary in thickness from 20 to 30 cm near the base of the unit to a maximum of 3 m at the top. The ooze layers are generally between 0.5 and 1.0 m thick throughout the section. Gravel-sized dropstones are a common constituent of the calcareous mud beds. A range of clast lithologies were seen (Fig. 11) including basalt, pumice, gneiss, amphibolite, and various sedimentary rocks. The volcanic clasts make up 36% of the dropstones logged.

Dark gray to black volcanic-ash-rich beds compose a minor lithology in Unit I. The ash occurs as thin (1–4 cm),

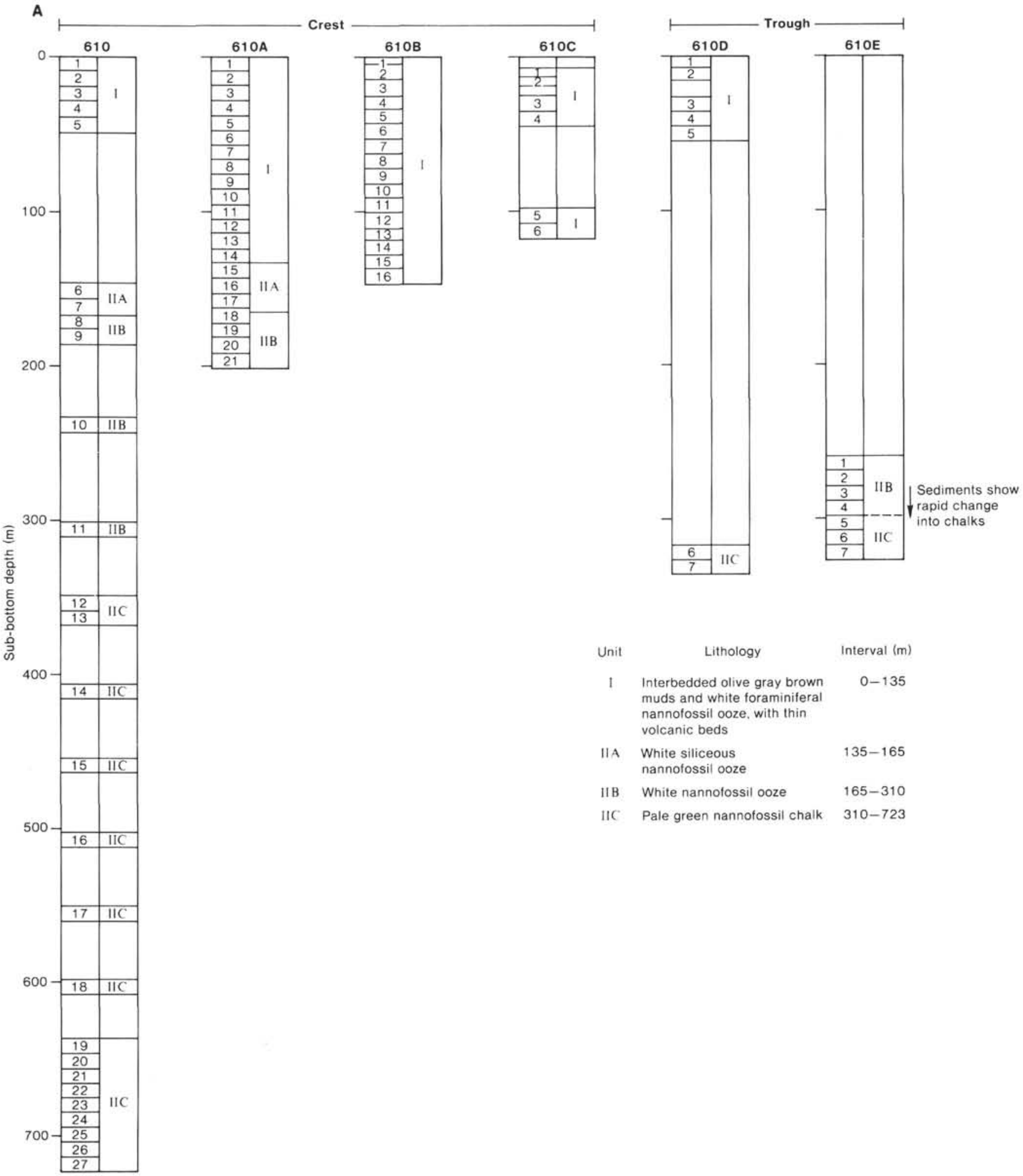


Figure 10. A. Core recovery and lithologic units sampled at Site 610 (crest and trough holes). B. Core recovery and lithologic units summarized for Site 610 crest holes.

sharp-based beds of sand-sized volcanic glass shards, with feldspars, pyroxenes, and secondary pyrite (Type 1), or dark gray calcareous mud units, which commonly have relatively sharp bases and a significant content of non-volcanic material, principally of detrital quartz and carbonate (Type 2). Both types of ash-rich layers are associated with gravel-sized clasts of volcanic composition; their size and surficial features suggest an ice-rafted glacial origin. One incongruous sharp-based Type 1 sandy bed with an associated "volcanic dropstone" occurs in

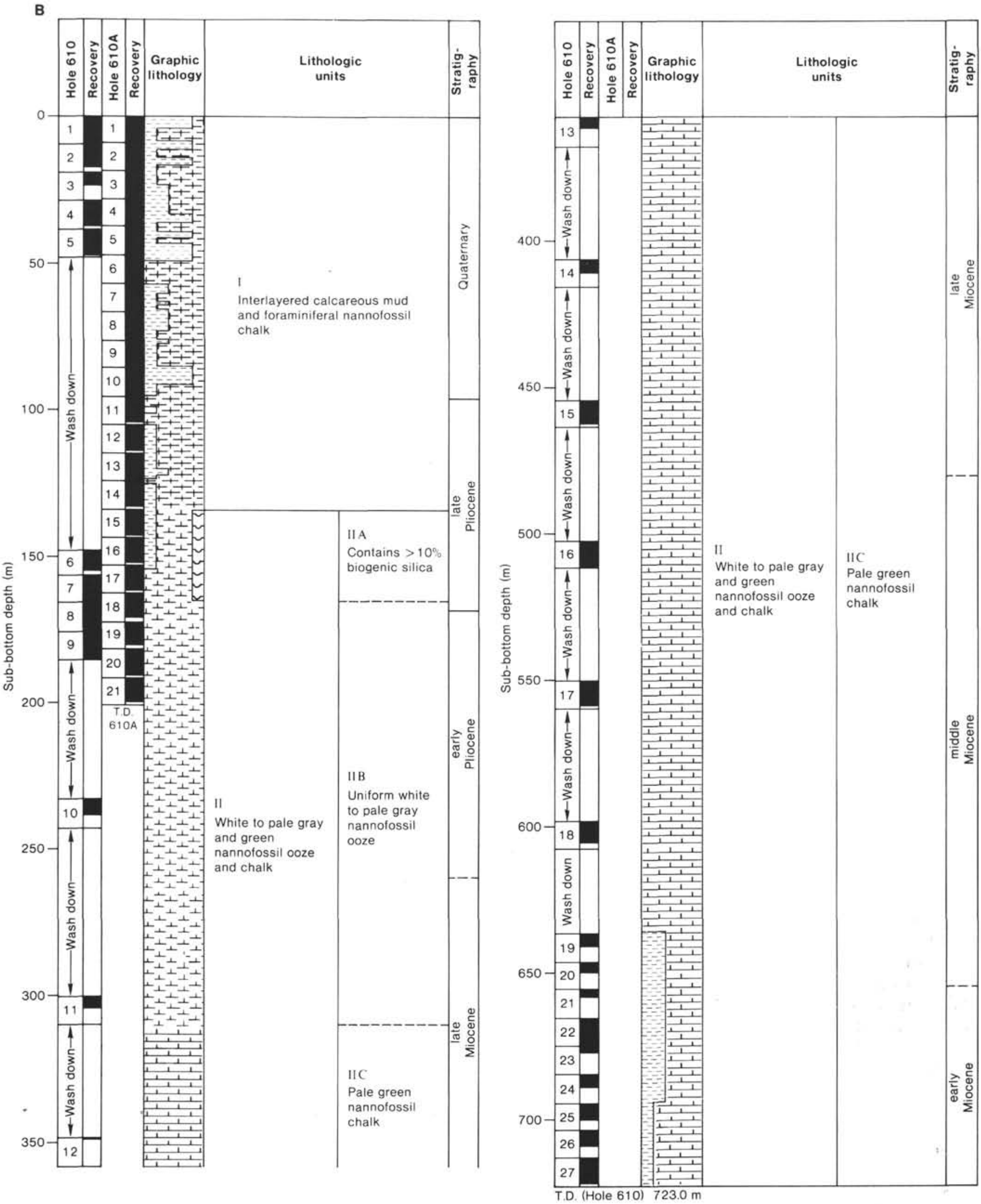


Figure 10 (continued).

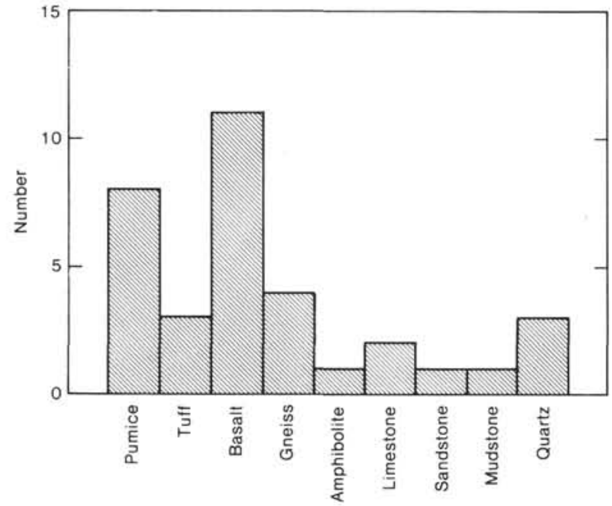


Figure 11. Composition of glacial erratics ("dropstones"), Site 610 (total number = 34; an additional 26 were unidentified).

both Sections 610A-11-5 and 610B-12-5, within a thick ooze interval that is presumed to have been deposited during an interglacial period.

The typically sharp bases of these units suggest that the ash may have been redeposited, perhaps from turbidity currents or bottom currents. Type 2 beds can generally be explained as material that first was ice-rafted and later underwent local redeposition. Type 1 beds, with their lack of quartz, suggest a more direct volcanic input, but no obvious source or transport path is clear at present.

At the base of Unit I, the calcareous mud beds become thinner and more marly, finally passing gradually into the relatively pure ooze of Unit II (Fig. 10). This lower unit includes all sediment recovered below Unit I and consists of nannofossil oozes and chalks. Unit II ranges in color from white to pale shades of gray or green and contains less than 5% terrigenous material. Three subunits have been defined within Unit II.

The topmost 20 m of Unit II (Subunit IIA, 135–165 m) contains more than 10% biogenic silica, predominantly diatoms and sponge spicules. This upper Pliocene homogeneous lithology may reflect an oceanographic change just prior to the onset of glaciation.

From 165 to about 310 m, the sequence consists of uniform white to very light gray nannofossil ooze (Subunit IIB) of early Pliocene and latest Miocene age. Occasional pyrite mottling and pale green gray laminae similar to those in the ooze layers of Unit I barely break the monotony of this subunit.

Between 280 and 310 m (in Hole 610E), a rapid change in the degree of lithification of the upper Miocene sediments is observed, from firm white ooze to the hard pale green chalk of Subunit IIC. The ooze and chalk are compositionally very similar, but slightly darker green intervals within the chalk represent slightly marlier compositions. Bioturbation structures are more clearly seen in the pale green chalk, and Zoophycos becomes common in Subunit IIC.

Toward the base of Subunit IIC (Hole 610), diagenetic features become more abundant (Fig. 12). Various

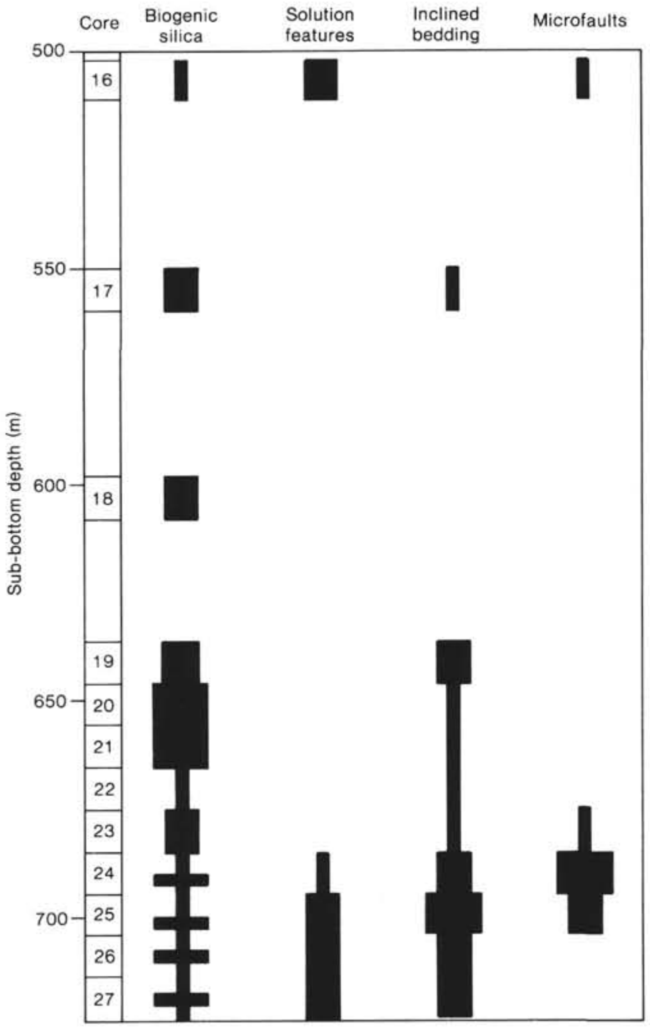


Figure 12. Qualitative importance of various diagenetic and tectonic features in lithologic Subunit IIC, Hole 610.

pressure solution features are initially observed in Core 610-13 and become very common in 610-16 (Figs. 13–16). Simple stylolites (Fig. 13) are relatively uncommon, but are found at the base of Core 610-16. More commonly, green wispy laminae are observed that apparently result from the merging of several simple stylolites (Fig. 14) (see also Hill, this volume).

Thicker green laminae containing lenses of chalk (Fig. 15) may represent a further stage of solution. This third type of solution feature is commonly observed in association with Zoophycos burrows, which may have provided a favorable geochemical environment for dissolution of $CaCO_3$. The green laminae become as thick as 0.5 cm. XRD analyses indicate that these laminae contain much higher proportions of quartz and smectite clay than the surrounding chalk. Dissolution of the chalk by HCl leaves a residue of similar composition. Thick intervals (up to 3 or 4 cm) of wispy solution laminae are common (Fig. 16) and contain lenses of chalk. These intervals bear some similarity to flaser chalk lithologies described at Site 608 (Hill, this volume), where undeformed Zoophycos burrows indicate the shearing to be a soft sediment process. The relationships between slow, soft sediment

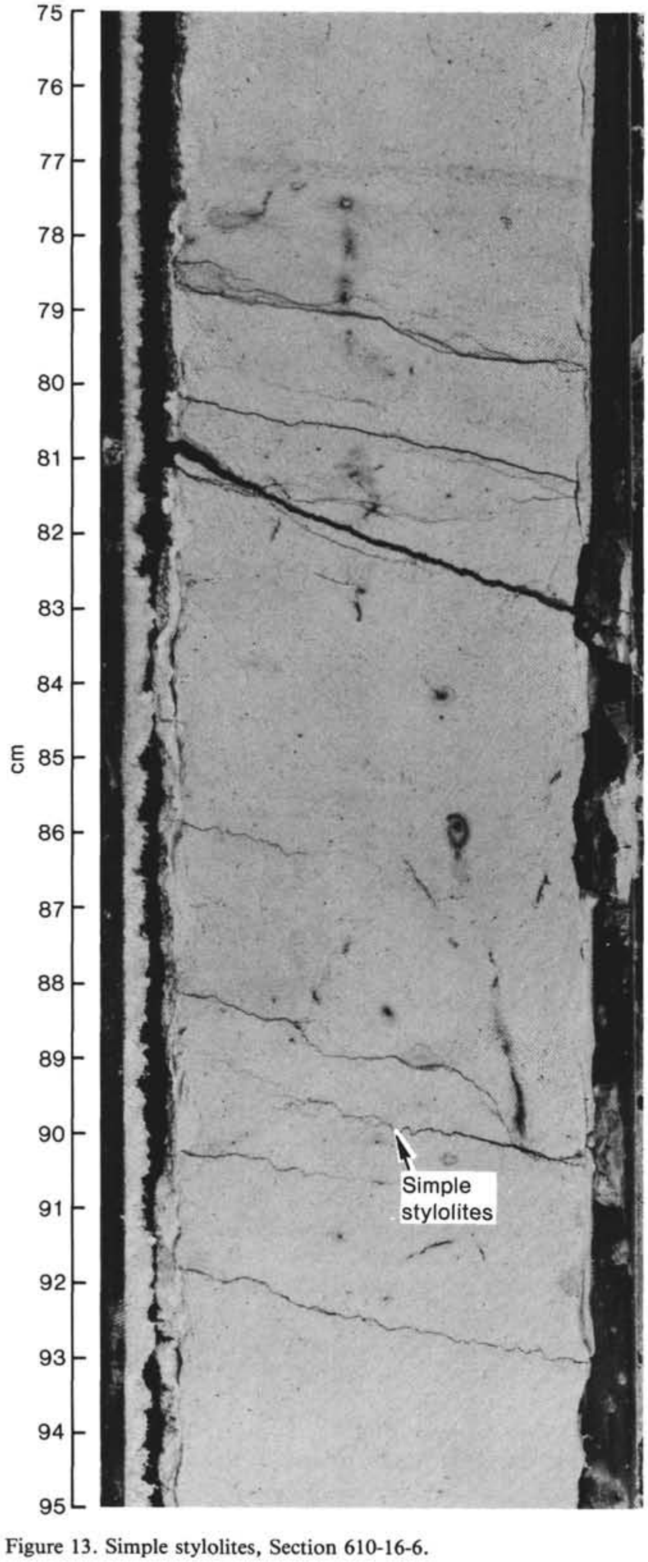


Figure 13. Simple stylolites, Section 610-16-6.

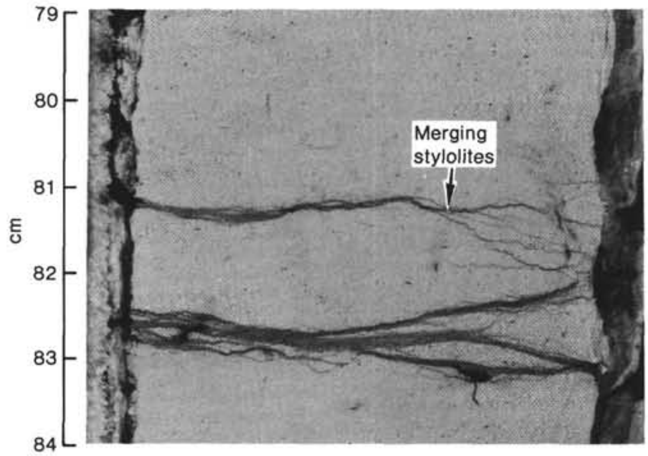


Figure 14. Merging stylolites and wispy solution laminae. Section 610-16-3.

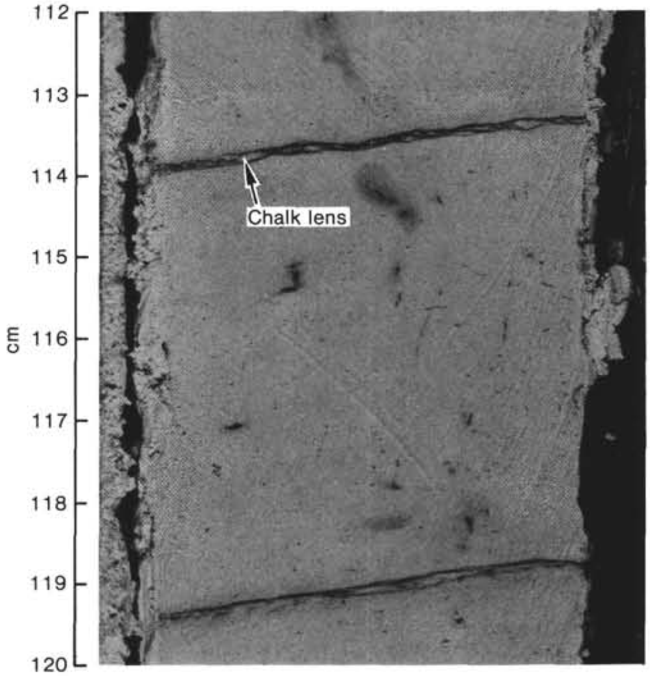


Figure 15. Thin green zones produced by carbonate solution, containing chalk lens, Section 610-16-4.

deformation (creep?), carbonate dissolution, and diagenesis present an interesting problem for further study.

Below Core 610-16, pressure solution features in Hole 610 are rare until Cores 24 to 27 (Fig. 17), where a similar range of features is observed. In these cores, the concentration of biogenic silica (diatoms and sponge spicules) is high within green solution laminae, but the surrounding chalk contains normal proportions of siliceous microfossils (Fig. 12). An increased proportion of biogenic silica is apparent from smear slides in Cores 610-17 to 610-21, particularly in 610-20 and 610-21.

The lower basal part of the lower and middle Miocene section in Hole 610 is characterized by numerous tectonic features. Cores 610-17 and 610-19 to 610-27 contain 0.5 to 6-m-thick intervals of inclined bedding. Generally, the dip lies between 10 and 20°, but within one section of Core 610-24 is as high as 45° (see also Hill; Dolan; and Baldauf, all this volume). This zone of steeply inclined bedding underlies a fine breccia bed (Fig. 17) and overlies nearly horizontal white chalk. Similar white

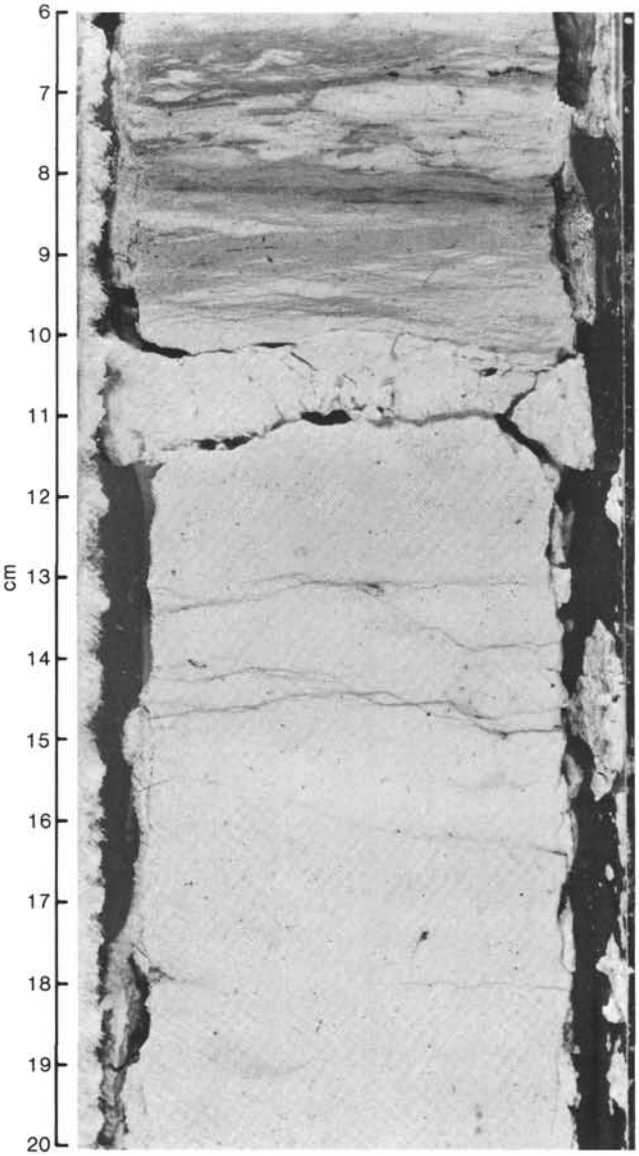


Figure 16. Thick zone of wispy solution laminae, Section 610-16-4.

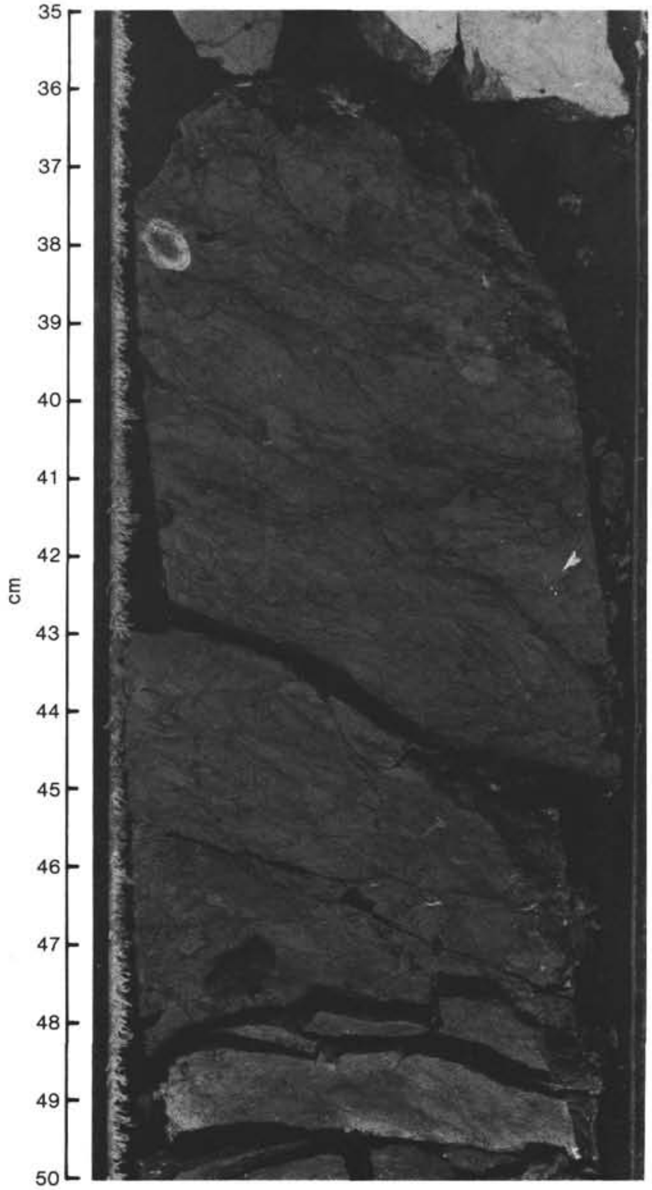


Figure 17. Fractured breccia bed in Section 610-24-2.

chalk also overlies the breccia bed. The whole of Core 610-24 is fractured by cross-cutting microfaults showing slickensides. Cores 610-23 and 610-25 also contain numerous microfaults (Fig. 12). A similar sequence consisting of a breccia bed overlying an interval of inclined bedding occurs in Core 610-19, although the dip remains below 20°.

In the absence of supporting evidence for soft-sediment deformation, the inclined bedding, the highly fractured nature of the rock in Cores 610-23 to 610-25, and the breccias might be related to tectonic faulting. One interpretation could be that Hole 610 penetrated through a high-angle fault zone centered on Core 610-24 (around 690 m sub-bottom) where the greatest degree of tilting and fracturing has taken place. This was the level at which drilling rates significantly decreased (Fig. 9).

PHYSICAL PROPERTIES

The physical properties measured on samples from Holes 610, 610A, and 610E are shown in Figure 18 (A–J). The values of dry water content, wet water content, porosity, and void ratio (Fig. 18A–D) decrease with depth. The dry water content of 100% at the surface decreases to about 65% at 50 m sub-bottom. Measured values for dry water content decrease roughly linearly with depth, from 65% at 50 m to 45% at 300 m sub-bottom. Wet water content decreases linearly with depth from values of 45 to 50% at the surface to 30% at 300 m sub-bottom.

Porosity decreases linearly with depth from values around 65% at the surface to 53% at 300 m sub-bottom (Fig. 18C). The void ratio follows the same pattern. The

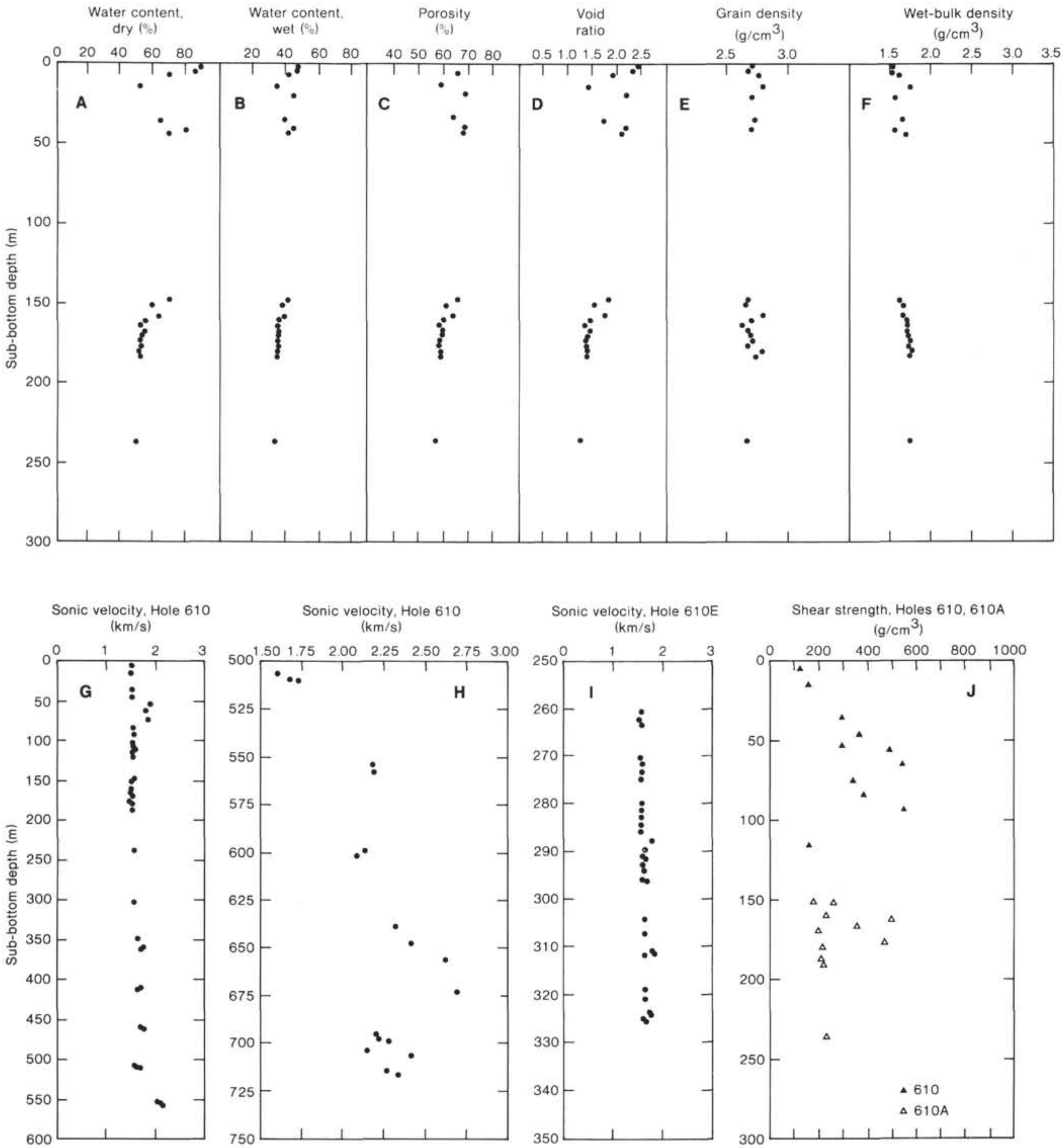


Figure 18. A–J. Physical properties at Site 610.

void ratio of 2.5 in the surface sediments diminishes to around 1.25 at the bottom of the hole (Fig. 18D).

Values measured for grain density fall between 2.65 and 2.8 g/cm^3 (Fig. 18E).

Wet-bulk density values increase with depth. A value of 1.6 was measured for bulk density at the surface; this increases to 1.8 g/cm^3 at 300 m depth (Fig. 18F).

Sonic velocities stay around 1.52 km/s over the first 250 m of the sediment column, except for a short interval between 50 and 75 m in which the sonic velocity is around 1.9 km/s. Sonic velocity values increase linearly with depth from 1.55 km/s at 250 m sub-bottom to 1.9 km/s at 520 m sub-bottom (Fig. 18G). Measured values for sonic velocity in the interval between 520 and

720 m are highly variable (Fig. 18H). A very high value was observed at a depth of 675 m.

Sonic velocities measured at Hole 610E show a linear increase from 1.5 to 1.75 km/s over the continuously cored interval from 250 to 350 m sub-bottom (Fig. 18I).

Shear strength values increase with depth. The change in coring technique from VLHPC to XCB coring causes a major shift in the curve toward lower values at a depth of 110 m sub-bottom (Fig. 18J).

SEISMIC STRATIGRAPHY

As noted in the section on Operations, the water gun profiles during our detailed survey in the vicinity of Site 610 did not detect the reflector that occurs at 0.75 s on the *Discovery* 84 and *Glomar Challenger* Leg 12 reference air gun profiles and on other profiles in the area (see Jacobs, this volume). Neither did it appear when we towed a 120-in.^{3} air gun and crossed the beacon twice before departing the site. The Leg 94 profiles show instead an interval of relatively coherent mixed returns that begins at 0.6 s sub-bottom (two-way traveltime) below a thick acoustically transparent unit. The interval continues downward as far as 0.85 s, which is the lowest level at which returns are detected on the records (Fig. 19). We suspect that this characteristic of our profiles might be due to the filter settings of the *Challenger* seismic system. However, generally we find that track-to-track correlation of reflectors in the upper 1 s of penetration is difficult for single channel records taken in this region (Masson and Kidd, this volume).

Above 0.62 s, the *Glomar Challenger* seismic section displays two main acoustic units (Fig. 19). From the sediment/water interface to 0.25 s sub-bottom, the records are characterized by a wavy stratified signature that appears in phase with the sediment wave morphology at the surface (acoustic Unit A). No wave migration is apparent at this scale, although the amplitude of the wave-like forms seems to increase upward. It is not clear whether this waviness represents draping of sediments or a focusing effect caused by the surface wave relief.

Between 0.25 and 0.62 s sub-bottom occurs a relatively transparent acoustic interval, acoustic Unit B. Within this interval, a faint reflector is detected at 0.37 s, and this is traceable throughout our Leg 94 survey tracks. Acoustic Unit C is the zone described above between 0.62 and 0.85 s sub-bottom, and Unit D is defined as the interval below this interval of coherent returns that may simply be the limit of our acoustic penetration (Fig. 19).

Table 2 lists calculations of two-way traveltime, made during the drilling of Hole 610, taking selected sub-bottom intervals and using seismic velocities measured on sediment core material as it was worked on in the laboratory. The resulting cumulative sub-bottom traveltimes can be compared with two-way traveltimes to the reflectors on the seismic records.

The two lithologic units described from the holes drilled at this site are divided at 135 m sub-bottom where the glacial-interglacial carbonate cycles begin (Fig. 19). This level has no clear correspondence with the seismic records, in contrast to similar reverberant stratified units that did seem to correlate with the cycles at previously drilled Leg 94 sites.

The base of the wavy stratified acoustic Unit A at 0.25 s lies between Cores 610-9 (175.8–185.0 m sub-bottom) and 610-10 (233.4–243.0 m sub-bottom) in an uncored interval in the white siliceous nannofossil oozes of lithologic Unit IIB.

The faint reflector at 0.37 s sub-bottom lies between Cores 610-10 and Cores 610-11, probably at around 300 m. It corresponds to the boundary of lithologic Subunits IIB and IIC, which was identified where white nannofossil oozes gives way downward to pale green nannofossil chalks.

The only indication of a noticeable change in the sediment column between Cores 610-15 and 610-16 that might correspond to the top of acoustic Unit C at 0.62 s is a short interval with pressure solution features and microfaulting in Core 16 (Fig. 12).

A marked increase in sonic velocities measured from the sediment occurs *below* the boundary of acoustic Units B and C and reaches a maximum in Core 610-23 in average values of 2.7 km/s (Fig. 18H). The regional seismic reflector picked from survey profiles in the area at 0.75 s sub-bottom (two-way traveltime) would correspond to the interval of Core 610-19, using Table 2 data. However, it is more likely that the reflector results from the integrated effect of this relatively sudden increase in seismic velocity over the entire interval between 625 and 675 m sub-bottom. Lithologically the cause of the rise in seismic velocity would appear to be an increase in content of biogenic silica in the chalks (Fig. 12). The hardness of the chalks obviously increased dramatically over this interval, as evidenced by the drillers' log of penetration rate (Fig. 9). This plot shows that Core 610-19 took about two hours to cut. The geologic significance of this reflector will be discussed in a later section.

It is difficult to comment on whether the boundary of acoustic Units C and D at 0.85 s two-way traveltime is real or is simply due to a lack of acoustic penetration. Certainly by the lowermost Core 610-27, cutting rates for the drilling had increased (Fig. 9) and seismic velocities had decreased as rapidly as they had risen (Fig. 18H), so we infer that we had already penetrated the level of the reflector. The decrease in seismic velocity relates to an increase in microfaulting in the cores (Fig. 12). Pressure solution features also increase below Core 610-24 (684.6–694.2 m sub-bottom). We speculate that the zone defined as acoustic Unit C is bounded by intervals with a general increase in reflectivity caused by microfaulting and localized pressure solution. Characteristics of our seismic system may have emphasized these zones in the records, thus situating the regional reflector at 0.75 s sub-bottom.

BIOSTRATIGRAPHY

Holes 610A, 610B, 610C, and the upper nine cores of Hole 610, on the crest of a sediment wave, give a complete record to 201 m sub-bottom (0–4.3 Ma). The lower part of Hole 610 was spot cored every 50 m to 636 m sub-bottom and then continuously cored to 723 m sub-bottom (lower Miocene). Holes 610D and 610E, in the

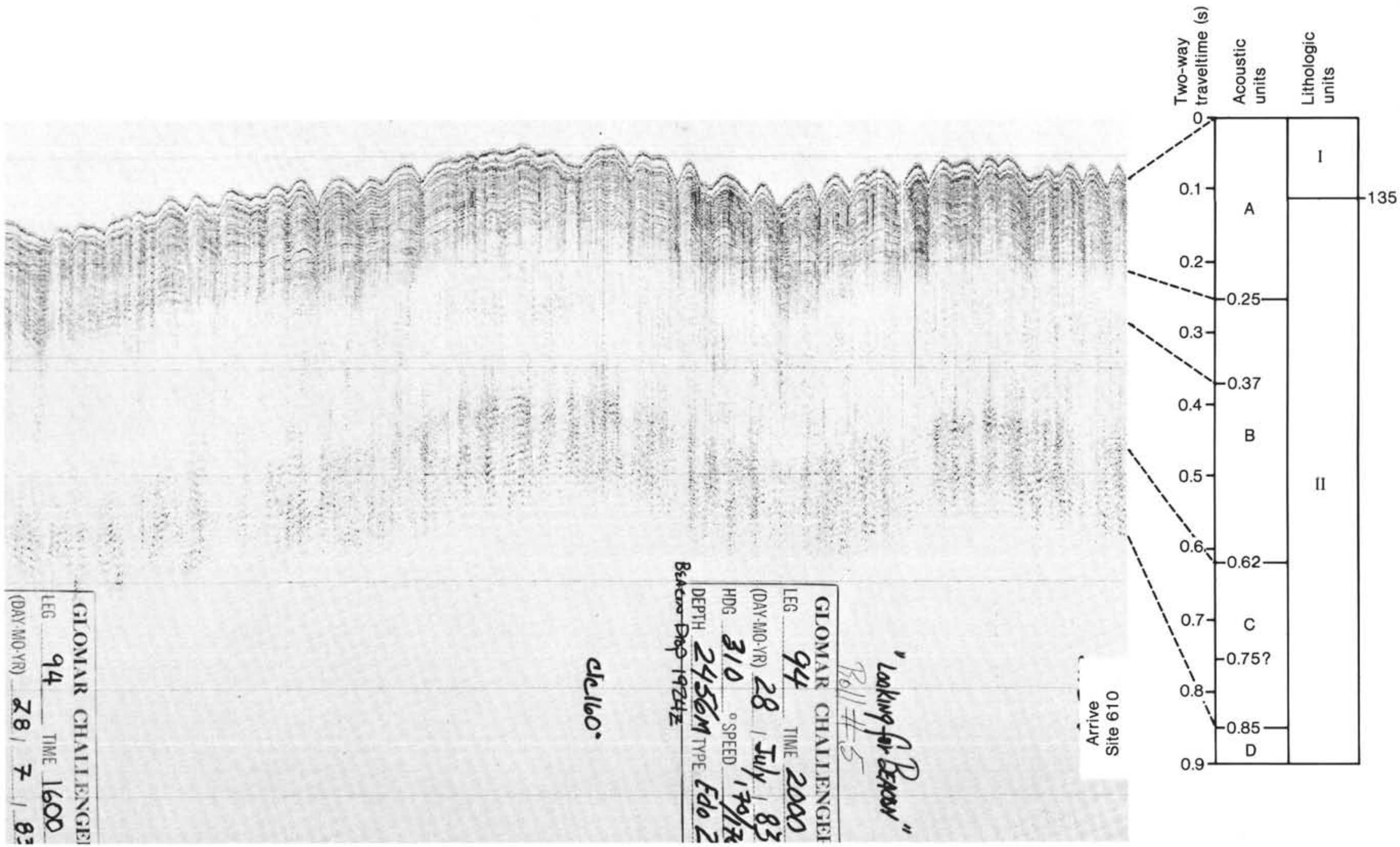


Figure 19. Seismic stratigraphy and correlation with lithologic units, Site 610.

Table 2. Two-way traveltimes measured during the drilling of Hole 610.

Core no.	Sub-bottom depth to base of interval (m)	Interval used in calculation (m)	Averaged seismic velocity (km/s)	Calculated two-way traveltime for interval (s)	Cumulative sub-bottom two-way traveltime (s)	Sequence of reflectors two-way traveltime (s)
5	38.4	38.4	1.542	0.050	0.050	
7	166.2	127.8	1.536	0.166	0.216	
9	185.4	19.2	1.547	0.025	0.241	
						0.25
10	243.0	57.6	1.591	0.072	0.313	
						0.37
11	310.2	67.2	1.602	0.084	0.397	
12	358.2	48.0	1.708	0.056	0.453	
14	415.8	57.6	1.727	0.065	0.520	
15	463.8	48.0	1.768	0.054	0.574	
						0.62
16	511.8	48.0	1.730	0.055	0.629	
17	559.8	48.0	2.168	0.044	0.673	
18	607.8	48.0	2.132	0.045	0.718	
19	646.2	38.4	2.283	0.034	0.752	
20	655.8	9.6	2.300	0.008	0.760	
22	675.0	19.2	2.697	0.014	0.774	
24	694.2	19.2	2.515	0.015	0.789	
27	723.0	28.8	2.308	0.025	0.814	

trough of a sediment wave, give a composite record to 56.4 m sub-bottom (mid-Quaternary) and from 260 to 337 m sub-bottom (upper part of the upper Miocene). The stratigraphy of all holes can be seen in Figure 20 (A and B)[4].

The more northerly location of this site is reflected in the cooler-water assemblages of both planktonic foraminifers and calcareous nannofossils. Several of the foraminiferal zonal species are rare or absent at this site, and discoasters are also much less common. Reworking is evident, particularly of nannofossils, with Cretaceous specimens common during many of the Quaternary glacial periods and fairly abundant Eocene–Oligocene nannofossils common in the upper Miocene.

The cores provide a complete sequence back to about 4.3 Ma (early Pliocene) and a discontinuous record to about 18 Ma (early Miocene). The Quaternary consists of alternating glacial and interglacial intervals reflected by strong changes in the planktonic foraminiferal assemblages. Preservation of all groups except diatoms is good throughout this interval. Diatoms are generally rare or absent in glacial intervals. Some glacial samples contain so much detrital material that the abundance of foraminifers and nannofossils is severely reduced. Pliocene and upper Miocene samples generally contain well preserved benthic and planktonic foraminifers, although diatoms are rare or absent through the lower part of the Pliocene and upper Miocene. Preservation of benthic and planktonic foraminifers through the middle Miocene is generally moderate to good, whereas the lower Miocene Samples 610-19,CC through 610-27,CC show moderate to poor preservation, with numerous flattened foraminifers in some samples, and common recrystallization.

Stratigraphic control at this site is limited because of the reduced numbers of nannofossil zonal species (particularly discoasters and ceratoliths) and the unreliable published ages of some planktonic foraminiferal datums. In the continuously cored sequences reliable ages were obtained by a sequential method using paleontological data for rough stratigraphic placement, and then paleomagnetic data for refinement. In the spot-cored interval of Hole 610, individual cores were not sufficient to provide a recognizable paleomagnetic sequence. Thus the ages within this interval are very broadly defined (Fig. 21, Table 3).

Calcareous Nannofossils

At Site 610, sediments yielded abundant calcareous nannofossils in various states of preservation and moderate to high diversity at all six holes. An almost complete sequence was identified from the upper Pleistocene *Emiliania huxleyi* Zone (NN21) to the lower Miocene *Sphenolithus belemnos* Zone (NN3). The calcareous nannoflora assemblages at this site contrast sharply with those at previously drilled sites according to the following criteria: discoasters are missing or extremely rare in the upper Pliocene, and comparatively common Cretaceous reworked specimens and fairly abundant Oligocene–Eocene reworked specimens are found in the Quaternary and in the upper Miocene sequences, respectively.

Hole 610

The abundant occurrence of *Emiliania huxleyi* suggests that Sample 610-1,CC can be correlated with the upper Pleistocene to Holocene *Emiliania huxleyi* Zone (NN21). This sample contains abundant *Gephyrocapsa caribbeanica, G. oceanica, Coccolithus pelagicus, Syracosphaera* sp. and *Calcidiscus leptoporus*. In addition to these species, Cretaceous specimens such as *Watznaueria barnesae, Prediscosphaera cretacea*, and *Microrhabdulus decoratus* are found. Samples 610-2,CC and 610-3,CC are placed in the Pleistocene *Gephyrocapsa oceanica* Zone (NN20), based on the abundant occurrences of *Gephyrocapsa caribbeanica* and *G. oceanica* and the absence of *Emiliania huxleyi* and *Pseudoemiliania lacunosa*. Sample 610-2,CC contains very abundant *Coccolithus pelagicus*, which is a typical cold-water species. In Sample 610-3,CC, Cretaceous species *Prediscosphaera cretacea, Arkhangelskiella cymbiformis, Eiffellithus turriseiffeli, Watznaueria barnesae*, and Tertiary species *Calcidiscus formosus, Dictyococcites hesslandii, Reticulofenestra pseudoumbilica*, and *Sphenolithus moriformis* occur. Samples 610-4,CC and 610-5,CC contain abundant *Pseudoemiliania lacunosa* and gephyrocapsids and may thus represent the Pleistocene *Pseudoemiliania lacunosa* Zone (NN19). Cretaceous reworked specimens such as *Watznaueria barnesae* and *Eiffellithus turriseiffeli* also occur in these samples. Judging by the coexistence of *Calcidiscus macintyrei* and a small number of specimens of discoaster such as *Discoaster surculus, D. brouweri, D. tamalis*, and *D. variabilis* and the absence of gephyrocapsids, Samples 610-6,CC through 610-9,CC are upper Pliocene, and assigned to the *Discoaster surculus* Zone (NN16). Sample 610-10,CC contains very abundant *Coccolithus pelagicus* together with *Calcidiscus leptoporus, C. macintyrei, Reticulofenestra pseudoumbilica, Sphenolithus abies, Discoaster surculus, D. intercalaris*, and *D. variabilis*. However, because of the absence

[4] For an updated version of the biostratigraphic summary, see Baldauf et al. (this volume).

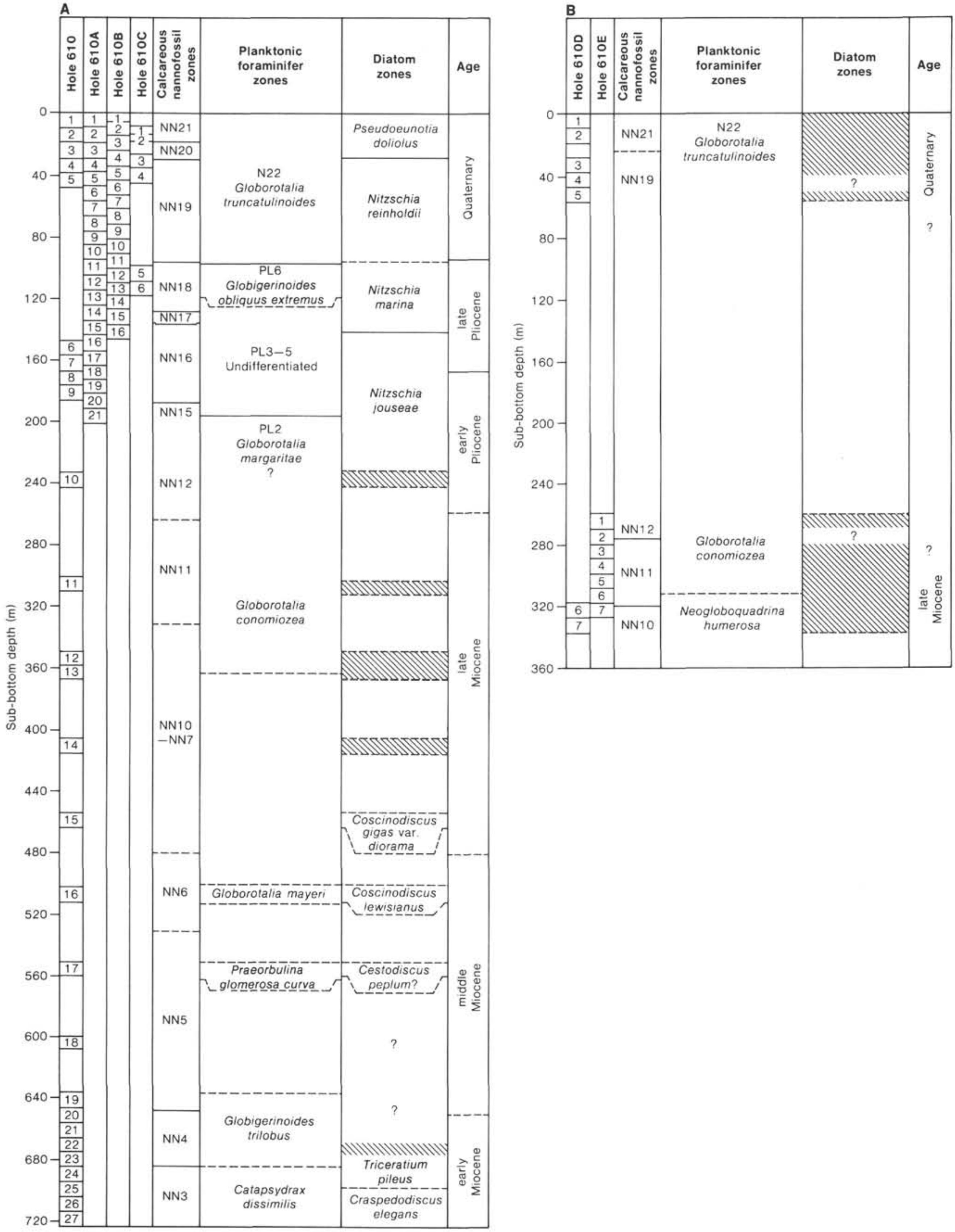


Figure 20. Biostratigraphic summary, Site 610. A. Holes 610 through 610C, on the crest of the mud wave. B. Holes 610D, 610E, in the trough. (Hachures in the Diatom column indicate samples that contain rare non-age-diagnostic fragments or are barren of diatoms.) For an updated version, see Baldauf et al. (this volume).

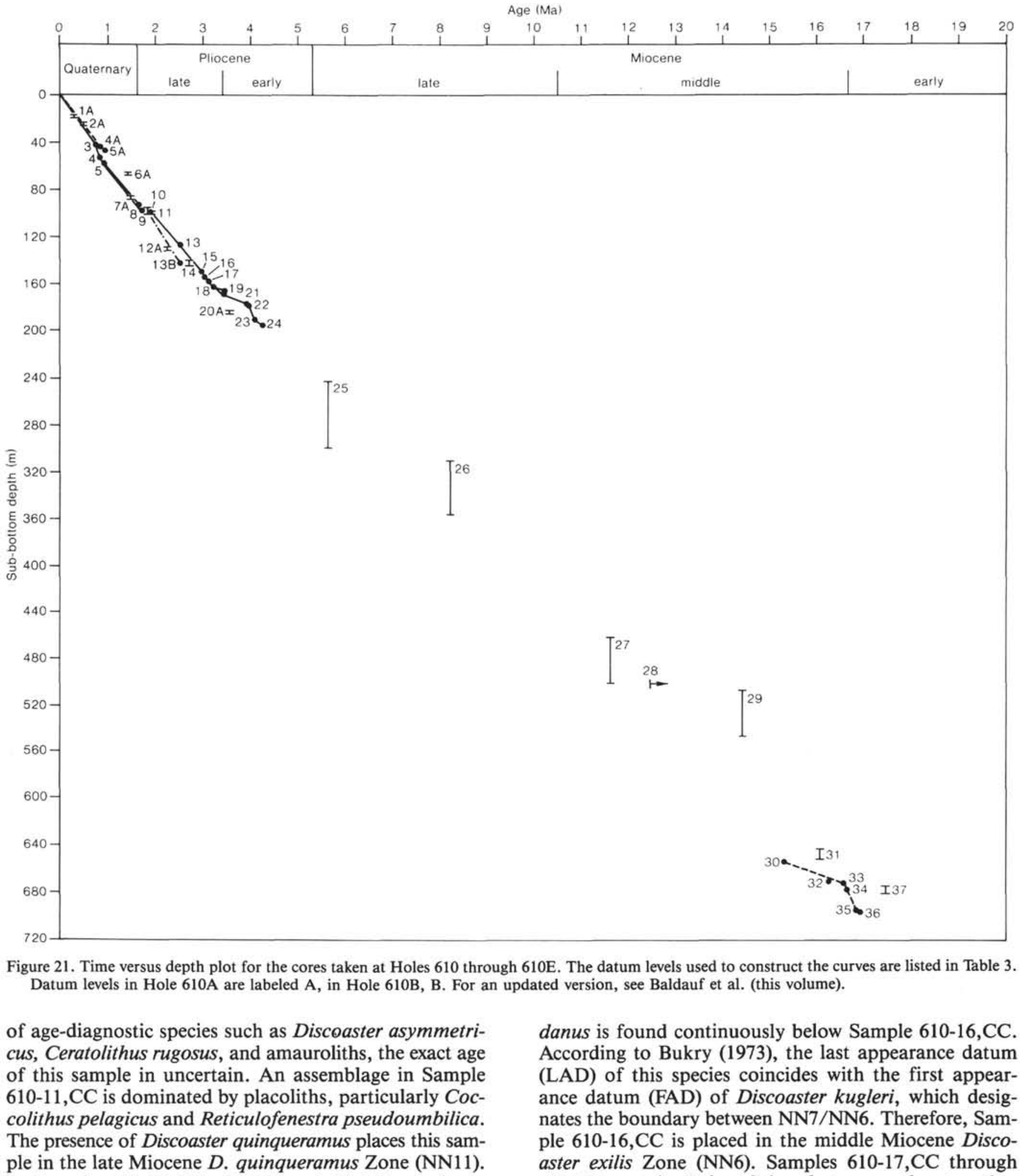


Figure 21. Time versus depth plot for the cores taken at Holes 610 through 610E. The datum levels used to construct the curves are listed in Table 3. Datum levels in Hole 610A are labeled A, in Hole 610B, B. For an updated version, see Baldauf et al. (this volume).

of age-diagnostic species such as *Discoaster asymmetricus, Ceratolithus rugosus*, and amauroliths, the exact age of this sample in uncertain. An assemblage in Sample 610-11,CC is dominated by placoliths, particularly *Coccolithus pelagicus* and *Reticulofenestra pseudoumbilica*. The presence of *Discoaster quinqueramus* places this sample in the late Miocene *D. quinqueramus* Zone (NN11). As Samples 610-12,CC, -13,CC, and -14,CC contain no age-diagnostic species, the ages of these samples are uncertain. However, the absence of five-rayed discoasters suggests that these samples may be placed below NN11. Sample 610-15,CC may belong to the NN8 *Catinaster coalitus* Zone or to the NN17 *Discoaster kugleri* Zone, on the basis of the occurrences of *Coccolithus miopelagicus* and *Discoaster deflandrei. Cyclicargolithus floridanus* is found continuously below Sample 610-16,CC. According to Bukry (1973), the last appearance datum (LAD) of this species coincides with the first appearance datum (FAD) of *Discoaster kugleri*, which designates the boundary between NN7/NN6. Therefore, Sample 610-16,CC is placed in the middle Miocene *Discoaster exilis* Zone (NN6). Samples 610-17,CC through -19,CC contain *Sphenolithus heteromorphus* together with *Coccolithus pelagicus, C. miopelagicus, Cyclicargolithus floridanus*, and *Reticulofenestra pseudoumbilica* and can be referred to the middle to early Miocene NN5 *Sphenolithus heteromorphus* Zone. Samples 610-20,CC, -21,CC, and -22,CC may belong to the lower Miocene *Helicosphaera ampliaperta* Zone (NN4), on the basis of the presence of *H. ampliaperta*. Sample 610-

Table 3. Datum levels used to construct Figure 21.

Number	Datum level	Age (Ma)
1	Bottom of *Emiliania huxleyi*	0.28
2	Top of *Pseudoemiliania lacunosa*	0.47
3	Matuyama/Brunhes	0.73
4	Top of Jaramillo	0.79
5	Bottom of Jaramillo	0.91
6	Top of *Helicosphaera sellii*	1.37
7	Top of *Calcidiscus macintyrei*	1.45
8	Top of Olduvai	1.66
9	Bottom of *Globorotalia truncatulinoides*	1.78
10	Bottom of Olduvai	1.88
11	Top of discoasters	1.90
12	Bottom of *Globorotalia inflata* (PL6)	2.20
13	Top of Gauss	2.47
14	Top of *Nitzschia jouseae*	2.65
15	Top of Kaena	2.92
16	Bottom of Kaena	2.99
17	Top of Mammoth	3.08
18	Bottom of Mammoth	3.18
19	Gilbert/Gauss	3.40
20	Top of *Reticulofenestra pseudoumbilica*	3.50
21	Top of Cochiti	3.88
22	Bottom of Cochiti	3.90
23	Top of Nunivak	4.05
24	Bottom of Nunivak	4.20
25	Top of *Discoaster quinqueramus*	5.60
26	Bottom of *Discoaster quinqueramus*	8.20
27	Top of *Cyclicargolithus floridanus*	11.60
28	*Coscinodiscus lewisianus* Zone	Older than 12.9
29	Top of *Sphenolithus heteromorphus*	14.40
30	Bottom of Chron C5B	15.27
31	Top of *Helicosphaera ampliaperta*	16.00
32	Top of Chron C5C,N1[a]	16.22
33	Bottom of Chron C5C,N1[a]	16.52
34	Top of Chron C5C,N2[a]	16.56
35	Bottom of Chron C5C,N2[a]	16.73
36	Top of Chron C5C,N3[a]	16.80
37	Top of *Sphenolithus belemnos*	17.40

[a] See Clement and Robinson (this volume) for an alternative correlation.

23,CC on down to the bottom of this hole may belong in the early Miocene *Sphenolithus belemnos* Zone (NN3), based on the occasional occurrences of *S. belemnos* and the absence of *Triquetrorhabdulus carinatus*.

Holes 610A and 610B

Nannofossil assemblages ranging from Quaternary to lower Pliocene occur in these holes. These assemblages are similar to those observed in Hole 610.

The late Pleistocene to Holocene *Emiliania huxleyi* Zone (NN21) occurs in Sample 610A-1,CC and in Samples 610B-1,CC and -2,CC, where abundant *Emiliania huxleyi, Gephyrocapsa caribbeanica*, and *G. oceanica* occur, together with several reworked specimens from the Cretaceous such as *Watznaueria barnesae, W. britannica, Eiffellithus turriseiffeli, Arkhangelskiella cymbiformis*, and *Prediscosphaera cretacea*. Samples 610A-2,CC and 610B-3,CC are assigned to the *Gephyrocapsa oceanica* Zone (NN20), based on the coccolith assemblage without *Emiliania huxleyi* and *Pseudoemiliania lacunosa*. Cretaceous specimens such as *Micula staurophora. Arkhangelskiella cymbiformis, Watznaueria barnesae*, and *Prediscosphaera cretacea* are also found in Sample 610A-2,CC. The occurrence of abundant *Pseudoemiliania lacunosa* places Samples 610A-3,CC through -10,CC and 610B-4,CC through -11,CC in the lower Pleistocene *Pseudoemiliania lacunosa* Zone (NN19). Among them, Samples 610A,10,CC and 610B-11,CC contain no *Gephyrocapsa oceanica* and *G. caribbeanica*. Therefore these two samples are assigned to the earliest Pleistocene. Many of these samples (especially 610A-5,CC) contain comparatively abundant Cretaceous reworked specimens: *Arkhangelskiella cymbiformis, Cribrosphaerella ehrenbergii, Eiffellithus turriseiffeli, E. trabeculatus, Prediscosphaera cretacea, Rucinolithus wisei, Watznaueria barnesae, W. britannica, Zygodiscus diplogrammus*, and *Z. sigmoides*.

As discoasters are missing or extremely rare in the upper Pliocene sequences in these holes, the Pliocene/Pleistocene boundary is not sharply marked as it was at previously drilled sites. Samples 610A-11,CC and 610B-12,CC contain no gephyrocapsids except for *Gephyrocapsa aperta*. According to Haq and Takayama (1984), *Gephyrocapsa aperta* makes its first appearance above the top of the Gauss and is assigned an age of 2.0 Ma. Therefore, the Pliocene/Pleistocene boundary is placed between Samples 610A-10,CC and -11,CC and 610B-11,CC and -12,CC. Below this boundary, the nannofossil assemblages progressively change, with a gradual increase in the number of species and the number of specimens of discoasters. In the intervals represented by Samples 610A-11,CC through -19,CC and by 610B-12,CC through the bottom of Hole 610B, the number of discoasters is still limited. Therefore the distinction between the *Discoaster brouweri* Zone (NN18), the *Discoaster pentaradiatus* Zone (NN17), and the *Discoaster surculus* Zone (NN16) is not clear. However, in Samples 610A-11,CC, -12,CC, and 610B-12,CC through -14,CC, no discoasters or only *Discoaster brouweri* are recognized. Therefore these samples may be placed in the uppermost Pliocene *Discoaster brouweri* Zone (NN18). The remaining samples in this interval contain *Discoaster pentaradiatus* and/or *D. surculus* and are all placed in NN17 and NN16. As in the previous hole, *Helicosphaera sellii* and *Pseudoemiliania lacunosa* occur only in the upper part of NN16. Cretaceous specimens such as *Arkhangelskiella cymbiformis, Zygodiscus diplogrammus, Watznaueria barnesae*, and *Lucianorhabdus cayeuxii* occur in Samples 610A-17,CC and 610B-12,CC and -13,CC. In Hole 610A, comparatively abundant *Reticulofenestra pseudoumbilica* occur throughout NN16. Their abundance, however, drastically increases in Sample 610A-20,CC, and this is interpreted to mean that this species becomes extinct in Core 610A-20 and that the occurrences of this species above this sample represent reworking. Therefore Samples 610A-20,CC and -21,CC are placed in the lower Pliocene *Reticulofenestra pseudoumbilica* Zone (NN15). According to Haq and Takayama (1984), *Reticulofenestra pseudoumbilica* disappears below magnetic Anomaly 2A, which corresponds to 3.5 Ma. This is well confirmed by the present shipboard study. *Sphenolithus abies* occurs in Sample 610A-21,CC slightly below the extinction level of *Reticulofenestra pseudoumbilica*.

Hole 610C

The microflora in Samples 610C-1,CC and -2,CC generally consists of *Emiliania huxleyi, Coccolithus pelagi-*

cus, Calcidiscus leptoporus, Helicosphaera carteri, Syracosphaera sp., *Discolithina japonica, Gephyrocapsa oceanica*, and *G. caribbeanica*. This assemblage may belong to the *Emiliania huxleyi* Zone (NN21). In addition, a few coccoliths reworked from the Cretaceous are recognized. Samples 610-3,CC and 610-4,CC contain *Pseudoemiliania lacunosa* and gephyrocapsids and are placed in the lower Pleistocene *Pseudoemiliania lacunosa* Zone (NN19). These samples also contain Cretaceous specimens such as *Arkhangelskiella cymbiformis, Watznaueria barnesae*, and *Eiffellithus turriseiffeli*. Samples 610C-5,CC and 610C-6,CC contain *Pseudoemiliania lacunosa, Helicosphaera sellii*, and *Calcidiscus macintyrei*. As discoasters are absent, these samples are placed in the uppermost Pliocene *Discoaster brouweri* Zone (NN18). Occasional occurrences of Cretaceous specimens are also recognized in these samples.

Hole 610D

Samples 610-1,CC and 610-2,CC are assigned to the upper Pleistocene to Holocene *Emiliania huxleyi* Zone. *Emiliania huxleyi* is dominant. *Coccolithus pelagicus, Gephyrocapsa oceanica*, and *G. caribbeanica* are frequent. A few Cretaceous reworked specimens occur. In Sample 610D-2,CC *Watznaueria barnesae, Micula staurophora, Prediscosphaera cretacea*, and *Eiffellithus turriseiffeli* are found. The occurrence of *Pseudoemiliania lacunosa* in Samples 610D-3,CC to -5,CC indicates an early Pleistocene age in the NN19 *Pseudoemiliania lacunosa* Zone for these samples. These samples also contain similar Cretaceous specimens. Samples 610D-6,CC and -7,CC which were obtained from the bottom of this hole after washing down, contain calcareous nannoflora characterized by the occurrences of *Coccolithus pelagicus, Calcidiscus leptoporus, C. macintyrei, Helicosphaera granulata, Reticulofenestra pseudoumbilica, Sphenolithus abies, Discoaster variabilis, D. brouweri*, and *D. loeblichii* and the absence of *Discoaster quinqueramus*. In addition, Sample 610D-7,CC contains *Discoaster prepentaradiatus, D. neorectus*, and *D. pansus*. Therefore these two samples are placed in the upper Miocene *Discoaster calcaris* Zone (NN10). In Sample 610D-7,CC, fairly abundant Oligocene–Eocene reworked specimens such as *Reticulofenestra umbilica, R. hillae*, and *Coccolithus eopelagicus* are found.

Hole 610E

In Hole 610E, five calcareous nannofossil datum levels are detected. These datums are as follows in descending order:

LAD of *Discoaster quinqueramus*	between Samples 1,CC and 2,CC
FAD of *Amaurolithus* spp.	between Samples 3,CC and 4,CC
FAD of *Discoaster surculus*	between Samples 5,CC and 6,CC
LAD of *Discoaster neohamatus*	between Samples 5,CC and 6,CC
FAD of *Discoaster berggrenii* and/or *Discoaster quinqueramus*	between Samples 6,CC and 7,CC

Mazzei et al. (1979) studied the Miocene–Pliocene sequence from Site 397 on Cape Bojador, eastern Atlantic (DSDP Leg 47) for the nannofossil and planktonic foraminiferal biostratigraphy, and paleomagnetics. A sequence ranging from magnetic Epoch 7 through the Gauss is recorded with some gaps. According to them, *Discoaster neohamatus* has its last occurrence near the bottom of the normal polarity interval of magnetic Epoch 7, and *D. berggrenii* and *D. quinqueramus* both disappear simultaneously within the upper of the two normal polarity intervals of Epoch 5. They have also shown the first amauroliths to appear within an interval where they have no magnetic information; however, they interpret this interval to be equivalent to magnetic Epoch 6. Haq and Takayama (1984) compiled these data; on the basis of these datum planes, Samples 610-1,CC, -2,CC through -6,CC and -7,CC are placed in the lower Pliocene–upper Miocene *Amaurolithus tricorniculatus* Zone (NN12), the upper Miocene *Discoaster quinqueramus* Zone (NN11), and the upper Miocene *Catinaster calcaris* Zone (NN10), respectively. According to Haq and Takayama's compilation, *Discoaster neohamatus* has its FAD near the bottom of Epoch 8. Therefore the absolute age assigned to the bottom sediments of Hole 610E is between 8.0 and 8.5 Ma. Samples 610D-6,CC and -7,CC contain fairly abundant Oligocene–Eocene reworked specimens such as *Dictyococcites bisectus, Reticulofenestra umbilica, R. hillae, Helicosphaera reticulata, Coccolithus eopelagicus, Micrantholithus* sp., and *Chiasmolithus* sp.

Reworked Specimens

The Quaternary sediments at Site 610 are characterized by occasional occurrences of Cretaceous reworked specimens. The stratigraphic ranges of these species, according to Thierstein (1976), are limited to the Upper Cretaceous, except for *Watznaueria britannica* and *Rucinolithus wisei*, which are Lower Cretaceous species. Based on the composite ranges of these species, it is concluded that these nannofossils were reworked from Cretaceous sediments ranging in age from Berriasian to early Valanginian and Coniacian to Maestrichtian. These reworked specimens seem to be dominant during glacial intervals.

It also remarkable that Oligocene–Eocene reworked specimens are dominant in Samples 610D-7,CC, and 610E-6,CC and -7,CC. Sediments represented by these samples accumulated at low sedimentation rates.

Planktonic Foraminifers

Planktonic foraminifers from this site are abundant and well preserved throughout the upper Miocene, Pliocene, and Quaternary. Species diversity is less at this site than at sites to the south, with cooler-water species such as *Neogloboquadrina atlantica, N. pachyderma*, and *Globigerina bulloides* being the most common species. Warmer-water species such as *Globigerinoides sacculifer* and *Sphaeroidinellopsis seminulina* are only found in the lower part of the upper Miocene. The temperate planktonic foraminiferal zonation of Poore and Berggren (1975) has been found to be inapplicable to this site, therefore a simplified version of Berggren's subtropical temperate zonation is used instead (see also Weaver and Clement; Baldauf et al., this volume).

Holes 610, 610A, 610B, and 610C

These holes on the crest of a sediment wave jointly provide a continuous sequence to 200 m sub-bottom (lower Pliocene), cores at 60-m intervals from 200 to 636 m, and continuous cores from 636 to 723 m. The middle/upper Miocene boundary occurs at approximately 440 m sub-bottom.

Globorotalia truncatulinoides can be found at this site, but its occurrence is sporadic and always rare. Its first appearance does not, therefore, provide a useful datum and the first appearance of sinistral *Neogloboquadrina pachyderma* (encrusted type) is used in preference to mark the base of the *G. truncatulinoides* Zone. Comparison to the paleomagnetic results from this leg shows that it is a useful marker. The base of this zone therefore lies in the washed interval between Cores 610-5 and 610-6, in Cores 610A-11, and 610B-11, and in the washed interval between Cores 610C-4 and 610C-5. The fauna of the *G. truncatulinoides* Zone is variable, with glacial intervals being dominated by *N. pachyderma* (s) and interglacials containing common *Globigerina bulloides, N. pachyderma* (d), *Globorotalia scitula, Globorotalia inflata*, and *Globigerina quinqueloba*.

Zone PL6 cannot be identified by the extinction of *Globorotalia miocenica*, because this species is absent at Site 610. The transition from *G. puncticulata* to *G. inflata*, however, occurred close to the base of Zone PL6 in Site 607 and can be used as a rough guide to the base of this zone. This transition occurs in the washed interval between Cores 610-5 and 610-6; in Core 610-13; and in Hole 610B between Samples 610B-12,CC and 610B-14,CC (no specimens of either species being found in 610B-13,CC). *Globigerina bulloides, Globorotalia inflata*, and *N. pachyderma* (d) are all common in this interval but *N. atlantica* (s) has not been found. This zone therefore correlates with the B_2 division referred to by Poore and Berggren (1975). They placed this interval in the Pleistocene, but paleomagnetic and nannofossil data at Site 610 suggest it belongs in the uppermost Pliocene.

As at Site 609, no distinction can be made between Zones PL3 through PL5, and they are regarded as one interval. The base is taken at the last occurrence of *Globorotalia margaritae*, which occurs in the washed interval between Cores 610-9 and 610-10 and in Core 610A-21. In this interval *G. puncticulata, Globigerina bulloides, N. atlantica* (s), and *N. pachyderma* are very common. As at Sites 608 and 609, *Globorotalia* cf. *G. pliozea* can be found near the base of this interval.

Only Core 610A-21 falls into the PL2 Zone, and PL1 has not been identified at all. This is probably because Zones PL1 and PL2 lie in the washed interval between Cores 610-9 and 610-10; Hole 610A did not penetrate beyond Zone PL2. *G. margaritae* is rare even in Sample 610A-21,CC, and the fauna of Zone PL2 is very similar to the PL3-5 interval.

Sample 610-10,CC contains no *G. margaritae, Globigerina nepenthes*, or *Globorotalia conomiozea* and is therefore impossible to date. Typical *G. conomiozea* has, in fact, not been found in this hole. Samples 610-11,CC through 610-14,CC contain *G. conoidea* and numerous *N. acostaensis* and are therefore placed in the *N. humerosa* Zone. The coiling direction change in *N. atlantica* from sinistral to dextral occurs in the washed interval between Cores 610-11 and 610-12, which is below and not at the Miocene/Pliocene boundary, as suggested by Poore (1979).

The middle Miocene *Globorotalia mayeri* Zone was recognized in Sample 610-16,CC and yielded a high diversity fauna of 17 species, which included *G. miotumida* and *G. menardii.*

Three zones were recognized in the poorly preserved lower Miocene from 610-17,CC to 610-27,CC. The uppermost zone, the *Praeorbulina glomerosa* Zone, in 610-17,CC yielded only a low diversity fauna. Below this zone in Samples 610-18,CC to 610-23,CC is the *Globigerinoides trilobus* Zone, which yielded a typical mid-latitude fauna with *Globoquadrina dehiscens, Globigerina bulloides*, and *Globigerinoides trilobus*, with *Globorotalia praescitula* appearing in the middle of the zone.

Drilling at Site 610 penetrated the *Catapsydrax dissimilis* Zone in Samples 610-24,CC to 610-27,CC, and this again yielded a relatively low-diversity fauna indicative of the mid-latitudes (see Jenkins, this volume).

Holes 610D, 610E

The upper Miocene sequence is represented by Cores 610E-1 to -7, at the base of which lies Core 610D-7. Core 610D-6 is overlapped by 610E-7 (Fig. 20).

Cores 610D-1 through 610D-5 all lie in the *Globorotalia truncatulinoides* Zone. There is then a long washed interval to the top of Core 610E-1. Cores 610E-1 and 610E-2 contain *G. conomiozea* and are placed in that Zone. Below this *G. conoidea* is present in Samples 610E-3,CC through -7,CC and Samples 610D-6,CC and 610D-7,CC, together with *Neogloboquadrina acostaensis*. These samples are, therefore, all placed in the *N. humerosa* Zone. The presence of large numbers of neogloboquadrinids in all these samples suggests that the base of this zone was not reached.

Benthic Foraminifers

Benthic foraminifers constitute less than 1% of the total foraminiferal fauna in the 63 μm fraction in all samples studied (list of samples given in Table 4). All samples contained sufficient individuals for counts of 200 specimens.

Samples below 610-16,CC (about 150 m) were dried at about 110°C for at least 1 hr., then soaked in kerosene for at least 15 min. Subsequently the kerosene was poured off, water added, and the samples were heated for about 30 min. This treatment was repeated for all samples. Generally the first treatment freed the tests from the sediment, but the second cleaning was necessary to remove adhering sediment; this treatment cleaned the fauna well.

Table 4. Samples used for the study of benthic foraminifers, Site 610.

Sample (hole-core-section, cm interval)			
610-1-1, 0-2	610-11,CC	610-19,CC	610A-14,CC
610-1,CC	610,12,CC	610-20,CC	610A-21,CC
610-3,CC	610,13,CC	610-21,CC	610E-2,CC
610-5,CC	610,14,CC	610-22,CC	610E-6,CC
610-6,CC	610,15,CC	610-24,CC	610E-7,CC
610-7,CC	610-16,CC	610-26,CC	
610-9,CC	610-17,CC	610A-8,CC	
610-10,CC	610-18,CC	610A-11,CC	

Preservation is excellent to good in samples from the uppermost 350 m. The aragonitic species *Hoeglundina elegans* is preserved in samples from the upper 50 m. Below 350 m the preservation varies from good to moderate to poor. Some specimens in Samples 610-17,CC and -18,CC are broken and show calcite overgrowth. In all samples below 610-18,CC, the tests are recrystallized and filled with clear, sparry calcite. This makes wall structure and septa hard to observe, but most specimens could be identified, and data on relative abundances in these samples appear to be reliable. Benthic foraminifers are generally not crushed in samples that contain flattened planktonic foraminifers (610-20,CC).

Relative abundances of the most common species and species groups are discussed by Thomas (this volume). The diversity is generally high (between 45 and 55 species), with the lowest values (39–42) in the upper part of the section in dark sediments (glacial cycles). Some samples of the dark sediments contain high-diversity faunas, however.

Reworking is evident in Samples 610-11,CC (Upper Cretaceous *Globotruncana contusa*, Eocene *Osangularia mexicana*), 610E-6,CC (upper Eocene through lower Miocene *Cibicidoides trinitatensis*), and 610-20,CC (Eocene through lower Oligocene *Bulimina jarvisi*).

Comparison of the benthic foraminiferal fauna with the fauna at the earlier sites is difficult because the water depth is considerably less at Site 610. *Nuttallides umbonifera*, which at the earlier sites was fairly abundant before the onset of glaciation, is rare throughout the section, as expected for this deep-water species. *Globocassidulina subglobosa, Oridorsalis umbonatus, Epistominella exigua* and *Pleurostomella* spp. are less abundant at Site 610, whereas *Bulimina* spp., *Uvigerina* spp., and *Bolivina* spp. are more abundant. At Site 608 *Stilostomella* spp. is common in sediments older than about 15 Ma, whereas at Site 610 *Stilostomella* spp. is common to abundant below about 45 m (less than 1 Ma). The lower Miocene group of "Oligocene survivors" (e.g., *Cibicidoides laurisae, Cibicidoides grimsdalei*), common at Site 608, is rare at Site 610; these differences are probably the result of the difference in depth of the sites.

Relative abundances of many species fluctuate strongly throughout the cored interval. The most variable groups are *Cibicidoides* spp., *Cassidulina laevigata, E. exigua, Ehrenbergina caribbea, Uvigerina* spp., *Bulimina* spp., and *Bolivina* spp. The fluctuations in relative abundances during the glacial–interglacial cycles cannot be directly related to lithology. The fauna in those sediments is characterized by the presence of *C. laevigata* (not found at the earlier sites), and the common occurrence of *Eilohedra weddellensis* and *E. caribbea. G. subglobosa* and *Bulimina* spp., on the other hand, are more common below the cycles. The fauna is similar to the Pleistocene and upper Pliocene fauna described from Hole 552A by Murray (1984).

The mudline sample contains common *Epistominella exigua*, and *Uvigerina* spp. is rare: thus this sample can be classified as containing the *E. exigua* fauna. This is unexpected, because Streeter (1973) describes the presence of the *Uvigerina hollicki* fauna in waters of 2000 to 3000 m. Throughout the section, below the mudline sample, species of *Bolivina, Uvigerina*, and *Bulimina* are present in variable abundances, but generally at least one species of this group is common or abundant. All these species are probably comparable to *Uvigerina* in their environmental preferences and/or tolerances. The increase in relative abundance of *Cibicidoides* spp. and *E. exigua* in some samples might indicate times of more vigorous circulation and younger water masses.

Remarkable is the presence of abundant *Bolivina spathulata* in Samples 610-21,CC and -22,CC placed in NN4 (33.7 and 16.0%, respectively). This species occurred in even larger relative abundance at Site 608 in Cores 608-37,CC and -38,CC: these samples were placed in NN5 and NN3, respectively; NN4 could not be identified. This suggests that the increase in relative abundance of *B. spathulata* is approximately coeval at those sites and thus might be a regional, not a local, phenomenon (see Thomas, this volume).

Diatoms

Lower Miocene to Quaternary sediments were recovered from the six holes drilled at Site 610. Diatoms occur in Holes 610, 610A, and 610B; are absent in samples examined from 610C, and are rare in Holes 610D and 610E. Within the Pliocene–Pleistocene sediments, diatoms are most abundant during interglacial intervals and are rare or absent during glacial intervals. The diatom assemblage observed is composed generally of warm-temperate species. However, as recorded at previous sites, an influx of cold-temperate species occurs within the upper portion of the Jaramillo Subchron. Reworked Miocene specimens as well as specimens of the fresh-water species *Melosira granulata* are occasionally observed.

With the exception of Samples 610-6,CC -8,CC and -9,CC, core-catcher samples examined from the upper 14 cores of Hole 610 either contain rare fragments or are barren of diatoms. Samples 610-6,CC and 610-8-1, 48–50 cm are assigned to the Pliocene *Nitzschia jouseae* Zone of Baldauf (1984), on the basis of the occurrence of *N. jouseae*. Reworked specimens of *Stephanogonia hanzawae* (Miocene), *Goniothecium* cf. *decoratum* (Eocene–Oligocene), and *Trinacria* sp. (Miocene?) occur within Samples 610-6-1, 48–50 cm; 610-6,CC; 610-8-1, 48–50 cm, and 610-8,CC. Rare, poorly preserved, non-age-diagnostic species occur within Sample 610-9,CC.

Rare to common diatoms occur within the interval from Cores 610-15 through -21. Sample 610-15,CC contains a diverse middle Miocene flora that includes: *Acti-*

nocyclus ingens, Hemidiscus cuneiformis, Denticulopsis hustedtii, D. lauta, D. hyalina, Mediaria splendida, Coscinodiscus yabei, Synedra jouseana*, and *Rhizosolenia barboi*. This sample is assigned to the *Craspedodiscus coscinodiscus* Zone of Barron (1985) and correlates to paleomagnetic Epoch 12. Sample 610-16-4, 48–50 cm contains common moderately preserved diatoms including *Craspedodiscus coscinodiscus, Coscinodiscus yabei, Actinocyclus ingens, Rhizosolenia praebarboi, Denticulopsis punctata* var. *hustedtii, D. hustedtii, D. lauta, D. hyalina, Synedra jouseana*, and *Rhizosolenia miocenica*, which places this sample into the *Coscinodiscus gigas* var. *diorama* Zone of Barron (1985). The presence of *Coscinodiscus lewisianus* in Section 610-16-4 and Sample 16-5, 48–50 cm suggests that these samples can be placed in the *Coscinodiscus lewisianus* Zone of Barron (1985) and Baldauf (1984).

A middle Miocene age is also indicated for Core 610-17 (Samples 610-17-1, 48–50 cm and -17,CC) based on the occurrence of *Coscinodiscus plicatus, Mediaria splendida*, and *Denticulopsis* cf. *hyalina*. These samples may correlate with the *Coscinodiscus peplum* Zone of Barron (1985), based on the rare occurrence of *Coscinodiscus peplum* in Sample 610-17-1, 48–50 cm.

Within the lower portion of Hole 610 (Cores 18–22), the preservation and abundance of diatoms decrease. This interval contains rare diatom fragments. Partial dissolution of these fragments as well as radiolarian tests and sponge spicules can be observed. Samples examined from Core 610-22 are barren of diatoms.

The abundance of diatoms increases below this interval with rare to common diatoms occurring in Cores 610-23 through 610-27. Cores 610-24 through 610-27 were assigned an early Miocene age based on the occurrence of *Coscinodiscus rhombicus, Synedra jouseana, Coscinodiscus praenodulifer, Stephanopyxis* cf. *hyalomarginata*, and *Thalassiosira spinosa*.

Five additional holes were drilled at Site 610. Sample 610A-1,CC is assigned to the *Pseudoeunotia doliolus* Zone of Burckle (1977) based on the occurrence of *Pseudoeunotia doliolus* stratigraphically above the last occurrence of *Nitzschia reinholdii*. Samples examined from Cores 610A-3 through -10 are assigned to the *Nitzschia reinholdii* Zone of Burckle (1977). Sample 610A-6,CC contains a mixture of both cold-temperate and warm-temperate species including *Denticulopsis seminae, Rhizosolenia barboi, Pseudoeunotia doliolus, Nitzschia fossilis*, and *Nitzschia reinholdii*.

The upper Pliocene *Nitzschia marina* Zone of Baldauf (1984) occurs from 610A-11,CC (48–50 cm) through 610B-15-5, 48–50 cm. The remaining cored interval (610A-15 through -21, and -22) is assigned to the *Nitzschia jouseae* Zone of Baldauf (1984) based on the occurrence of *N. jouseae*.

Samples examined from Cores 610B-1 through 610B-8 contain rare nondiagnostic fragments or are barren of diatoms. Samples examined from Samples 610B-9,CC through 610B-12,CC are assigned to the *Nitzschia reinholdii* Zone of Burckle (1977), as *Pseudoeunotia doliolus* and *Nitzschia reinholdii* are observed in all samples. The *Nitzschia marina* Zone of Baldauf (1984) extends from Sample 610B-15,CC. The presence of *Nitzschia jouseae* in Sample 610B-16,CC allows this sample to be placed into the *Nitzschia jouseae* Zone of Baldauf (1984).

With the exception of Samples 610D-4,CC and 610E-1,CC, all other core-catcher samples examined from Holes 610C, 610D, and 610E either contain rare fragments or are barren of diatoms. Sample 610D-4,CC is assigned to the *Nitzschia reinholdii* Zone of Burckle (1977), based on the occurrence of *Pseudoeunotia doliolus, Nitzschia reinholdii*, and *Nitzschia fossilis*. Samples 610E-1,CC contains no age-diagnostic species.

Radiolarians

Radiolarians are present in the Pleistocene, upper Pliocene, and Miocene sediments of Site 610 (Table 5). The glacial cycles of the Pliocene and Pleistocene yield samples that alternate between very well preserved, abundant, diverse assemblages, and sparse assemblages of a few taxa indicating cold or deep water, as well as samples in which there are no radiolarians at all. In Hole 610A radiolarians were found in at least one sample from nearly every core down to Core 21,CC.

Table 5. Preservation and abundance of radiolarians in Holes 610 and 610A.

Hole 610			Hole 610A		
Sample (core-section, interval in cm)	Abundance	Preservation	Sample (core-section, interval in cm)	Abundance	Preservation
1,CC	B		1-4, 56–58	B	
2,CC	B		1,CC	B	
3,CC	B		2-5, 56–58	B	
4,CC	B		2,CC	B	
5-2, 46–48	B		3-3, 46–48	B	
5-6, 46–48	B		3,CC	B	
6-2, 46–48	R	M	4-3, 46–48	B	
6-5, 46–48	R	M	4,CC	B	
7-2, 46–48	F	M	5,CC	B	
7-5, 46–48	F	M	6-3, 46–48	R	M
8-2, 46–48	F	P	6,CC	F	G
8-5, 46–48	F	M	7-2, 46–48	F	M
9-2, 46–48	F	M	7,CC	R	M
9-5, 46–48	R	M	8-4, 46–48	R	M
10-2, 46–48	R	M	8,CC	F	M
10-4, 46–48	R	M	9-3, 46–48	B	
11-2, 36–38	R	M	9-5, 46–48	B	
11-6, 46–48	R	M	10-3, 46–48	B	
13-2, 21–23	R	M	10,CC	F	G
14-2, 40–42	C	M	11-2, 46–48	R	P
15-2, 46–48	F	G	11,CC	R	P
16-2, 66–68	F	G	12-2, 46–48	C	G
16-6, 46–48	F	G	12,CC	R	P
16,CC	F	G	13-3, 46–48	F	M
17-3, 46–48	F	M	13,CC	B	
17,CC	R	P	14-4, 46–48	A	G
18-2, 55–57	R	P	14,CC	R	M
19-3, 40–42	R	P	15,CC	F	G
19,CC	B		16,CC	F	G
20-1, 106–108	R	P	17,CC	F	G
20,CC	R	P	18,CC	F	G
21-2, 46–48	F	P	19,CC	F	G
21,CC	R	M	20,CC	F	G
22-4, 116–118	R	P	21,CC	F	G
22,CC	R	P			
23-2, 46–48	R	P			
23,CC	F	M			
24-3, 42–44	R	P			
24,CC	R	P			
25-3, 36–38	F	G			
25,CC	F	M			
26-3, 70–72	F	M			
26,CC	R	P			
27-2, 40–42	F	G			
27-6, 40–42	R	P			
27,CC	F	G			

Note: A = >10,000 specimens/slide; C = 5,000–10,000 specimens/slide; F = 1000–5000 specimens/slide; R = <1000 specimens/slide; B = Barren. G = Good; M = Moderate; P = Poor.

The Miocene cores also contain radiolarian assemblages in varying degrees of abundance and preservation. Sample 610-15-2, 46–48 cm is placed in the *Didymocyrtis antepenultima* Zone, based on the presence of that species and absence of its ancestor, *D. laticonus*. Samples from Cores 610-16, -17, and -18 contain species characteristic of the middle Miocene zones, *Diartus petterssoni* Zone and *Dorcadospyris alata* Zone. Although these species are found in small numbers, they are all in at least two consecutive samples in this interval: *Didymocyrtis laticonus, Dorcadospyris alata, Lithopera renzae*, and *L. neotera*. In Cores 610-19 and -12, radiolarians are either too rare and poorly preserved for age determination, or they are entirely dissolved. Between Samples 610-21-2, 46–48 and 610-27,CC, radiolarian assemblages are more abundant and moderately well-preserved, and appear to be from the lower Miocene *Cyrtocapsella tetrapera* Zone. This age is based on the presence of *C. tetrapera, C. cornuta*, and *Lychnocanoma elongata*, and the absence of *Stichocorys delmontensis* and *S. wolffii*. In Samples 610-21-2, 46–48 cm, and 610-26-3, 70–72 cm there are single specimens of late Eocene *Lithocyclia aristotelis* group.

PALEOMAGNETISM

Hole 610

Paleomagnetic samples were taken at intervals of one sample per 1.5 m (one per core section) through intervals that were continuously cored (for three or more consecutive cores). Samples were not taken from intervals that were spot cored, because three consecutive cores are needed to provide a readily interpretable polarity sequence with the observed sedimentation rate.

Pilot samples from selected intervals throughout the hole were subjected to progressive alternating field (AF) demagnetization studies. The sediments generally exhibited single-component magnetizations, with some samples having soft overprints that were readily removed by AF treatment at 10 mT.

The inclination record obtained after AF treatment at 10 mT was correlated to the time scale of Berggren et al. (in press) as discussed in Clement and Robinson (this volume). The depths of polarity reversals are given in Table 6. The polarity sequences in Cores 610-6 through -9 and 610-19 through -25 are determined by data of only moderate quality (as a result of very low intensities). Because of poor recovery in Cores 19, 20, 21, and 22 it was not possible to obtain a continuous polarity record. A sequence of three normal polarity zones was observed in Cores 22 through 26, although a confident correlation of this interval to the time scale cannot be made on the basis of the paleomagnetic data alone. Two correlations appear to be possible, the first of which is indicated in Table 6. This correlation places the three normal polarity zones in Chronozone C5C and Cores 19 through 21 in Chronozone C5B. The alternative correlation is that the three normals correlate to Chrons C5C, C5E, and 6, whereas the polarity zones in Cores 19 through 21 correlate to Chron C5C. This correlation is described further in Clement and Robinson (this volume).

Table 6. Depths of reversal boundaries, Site 610.

Reversal		Age (Ma)	Sample (core-section, cm level)	Sub-bottom depth[a] (m)
Hole 610				
Brunhes		0.73	5-2, 67/5-4, 107	40.58/43.98
Kaena	(top)	2.92	6-2, 98/6-3, 98	149.49/150.99
	(bottom)	2.99	6-4, 98/6-5, 98	152.49/153.99
Mammoth	(top)	3.08	7-1, 97/7-2, 97	157.58/159.08
	(bottom)	3.18	7-4, 97/7-5, 97	162.08/163.58
Gauss/Gilbert		3.40	7-7, 30/8-1, 97	165.91/167.19
Chron C5B	(bottom)	15.27	21-1, 131/21-2, 91	657.12/658.22
Chron C5C,N1	(top)	16.22	22-4, 124/22-5, 120	671.15/672.61
Chron C5C,N1	(bottom)	16.52	22-6, 90/23-1, 139	673.81/676.40
Chron C5C,N2	(top)	16.56	23-2, 57/24-1, 61	677.08/685.22
Chron C5C,N2	(bottom)	16.73	25-2, 73/25-3, 136	697.07/697.94
Chron C5C,N3	(top)	16.80	25-3, 136/25-4, 48	697.94/699.19
Hole 610A				
Brunhes		0.73	5-3, 80/5-4, 100	41.61/43.31
Jaramillo	(top)	0.91	6-4, 85/6-5, 97	52.76/54.38
	(bottom)	0.98	6-6, 97/7-1, 97	55.88/57.98
Olduvai	(top)	1.66	10-5, 75/10-6, 108	92.56/94.39
	(bottom)	1.88	11-2, 97/11-3, 97	97.88/99.38
Reunion	(top)		12-1, 94/12-2, 97	104.95/107.48
	(bottom)		12-2, 97/12-3, 124	107.48/109.25
Matuyama/Gauss		2.47	14-2, 97/14-3, 97	126.68/128.18
Kaena	(top)	2.92	16-5, 97/17-1, 97	150.38/153.98
	(bottom)	2.99	17-1, 97/17-2, 97	153.98/155.48
Mammoth	(top)	3.08	17-3, 97/17-4, 99	156.98/158.48
	(bottom)	3.18	17-6, 99/18-1, 97	161.50/163.58
Gauss/Gilbert		3.40	18-4, 97/18-5, 97	168.08/169.58
Cochiti	(top)	3.88	19-3, 97/19-4, 97	176.18/177.68
	(bottom)	3.97	19-5, 97/19-6, 57	179.18/180.28
Nunivak	(top)	4.10	20-6, 97/21-1, 97	190.28/192.38
	(bottom)	4.24	21-3, 97/21-4, 97	195.38/196.88
C1	(top)	4.40	21-4, 97/21-5, 97	196.88/198.38
Hole 610B				
Brunhes		0.73	6-1, 97/6-2, 97	44.18/44.68
Jaramillo	(top)	0.91	7-1, 97/7-2, 97	53.78/55.28
	(bottom)	0.98	7-5, 97/7-6, 97	59.78/61.28
Cobb Mtn.	(top)		8-2, 97/8-3, 97	64.88/66.38
	(bottom)		8-3, 97/8-4, 97	66.38/68.88
Olduvai	(top)	1.66	11-4, 97/11-5, 97	96.68/98.18
	(bottom)	1.88	12-2, 95/12-3, 101	103.26/104.86
Reunion	(top)		13-2, 97/13-3, 101	112.88/114.42
	(bottom)		13-2, 101/13-4, 101	114.42/115.92
Matuyama/Gauss		2.47	16-3, 99/16-4, 97	141.20/142.68
Hole 610C				
Brunhes		0.73	4-4, 31/4-4, 102	40.42/41.13
Reunion	(top)		5-4, 123/5-5, 97	104.74/105.98
	(bottom)		5-4, 97/5-6, 95	105.98/107.48
Hole 610D				
Brunhes		0.73	3-5, 97/3-6, 95	34.58/36.06
Jaramillo	(top)	0.91	4-4, 110/4-5, 80	42.81/43.44
	(bottom)	0.98	4-6, 60/4-6, 96	45.31/45.67
Cobb Mtn.	(top)		5-2, 140/5-3, 115	49.71/50.96
	(bottom)		5-4, 92/5-5, 97	52.23/63.78
Hole 610E				
Chron 6	(bottom)	6.50	3-2, 97/3-3, 75	281.68/181.96
Chron 7,N1	(top)	6.70	5-1, 97/5-2, 75	299.38/300.66
Chron 7,N1	(bottom)	6.78	5-2, 75/5-3, 75	300.66/302.16
Chron 7,N2	(top)	6.85	6-3, 103/6-4, 12	312.04/312.63
Chron 7,N2	(bottom)	7.28	7-2, 128/7-3, 126	320.39/321.87

[a] Midpoint depths of samples in third column.

Hole 610A

The same procedures were followed at Hole 610A as at 610, with paleomagnetic samples (one per section) taken throughout the 200 m that were recovered. The interpretation of the polarity sequence with the depths and ages of the major reversals is given in Table 6. The interpretation of the polarity sequence was straightforward down to a depth of approximately 130 m. Below this level, the quality of the data decreased as a result of a drop in the magnetization intensities. It was, however, still possible to identify the Gauss and Gilbert Chronozones, including the major subchronozones within each of these.

Hole 610B

As at Hole 610A, the magnetic data are of exceptional quality to a depth of approximately 130 m, below which the intensities drop coincident with an increase in carbonate content. The predominately normal polarity directions observed below this level are tentatively correlated to the Gauss Chronozone. The detail obtained in the record above this level permits detection of both the Cobb Mountain and Reunion Subchronozones. It should be noted that the polarity boundaries occur at different depths in this hole than in the other holes at this site. For example, the base of the Brunhes Chronozone varies in depth by more than 9 m in the five holes in which it is detected at this site. In the crest holes the base of the Brunhes occurs at 42, 43, 45 and 41 m (610, 610A, 610B, and 610C, respectively) whereas in the trough hole (610D) it occurs at 36 m. This variation in depth might suggest local variation in sedimentation rates even between the crest holes, with a more pronounced variation existing between the crest and trough holes.

The results from Hole 610D (as will be discussed later), however, suggest the possibility of a repeated section. Observation of possible repeated sections near the top of holes at Site 609 based on lithologic correlations (Ruddiman, Cameron, and Clement, this volume) has raised the possibility that the hydraulic piston corer may be capable of recoring the same interval in the tops of holes. Therefore, further lithologic correlations between holes at this site are needed before the variations in thicknesses of the polarity chronozones in these holes can be adequately explained.

Hole 610C

The same procedures were followed at this Hole as at the previous holes, and the polarity boundaries are likewise shown in Table 6. The short normal polarity subchronozone in Core 610C-5 is most likely correlated to the Reunion Subchronozone, although the incomplete section obtained at this hole makes this correlation uncertain.

Hole 610D

The polarity sequence obtained from Hole 610D (see Table 6) is complicated by the two short normal polarity subchronozones observed below the Jaramillo Subchronozone (at 46, 48, and 50–53 m). As discussed earlier, these two zones could represent a repeated sequence of the Jaramillo Subchronozone. Lithologic tie lines confirm that the lower of these two normals occurs in a repeated sequence; however, the upper one is problematic because of significant contortions in the upper part of Core 610D-5 (see Clement and Robinson, this volume).

Hole 610E

Although the magnetic intensities were extremely weak (0.01×10^{-6} emu/cm^3) in the samples at this hole, it was possible to determine a preliminary polarity sequence using the shipboard magnetometer. Shore-based measurements using a cryogenic magnetometer indicate that the preliminary polarity sequence may be incorrect, and a more intensive sampling scheme will be necessary to define confidently the magnetozones and correlate them to the time scale (see also Clement and Robinson, this volume).

SEDIMENTATION RATES

The five holes drilled near the axis of Feni Ridge resulted in an almost complete stratigraphic section for the Quaternary through late Miocene (NN11), which was well controlled by biostratigraphic and paleomagnetic datums. Beyond that to the lower middle Miocene (NN5), our strategy in the deep Hole 610 was to wash down and spot core, resulting in less biostratigraphic control and no magnetic stratigraphy. Two pre-Pliocene intervals, however, were continuously cored. At the bottom of Hole 610, we continuously cored almost 77 m of the lower Miocene (NN4 and NN3) and in Hole 610E over 67 m of the upper Miocene (NN21–NN10). In both intervals, interpretation of the biostratigraphic and paleomagnetic datums is difficult.

The sedimentary drift sequence at Feni Ridge is characterized by relatively high rates of sedimentation (Fig. 21), but they are exceeded by the rates at our so-called pelagic Site 609 farther south. Another unexpected feature is that the accumulation rate curves are linear; relatively constant rates of 51 m/m.y. occur through the Quaternary and Pliocene in Holes 610 and 610A. Below, in the middle and lower Miocene of Hole 610, a best-fit line though the error bars results in a rate of around 46 m/m.y.

A particularly significant observation at this site is that no large hiatuses were detected. Drift sequences have hitherto been imagined as locations where intermittent changes in current velocity would erode the sediment sequence, making it less attractive than pelagic sites for fine-scale stratigraphic studies. Clearly, if intermittent erosion does occur, it is at a scale below the resolution of our present stratigraphy.

Stratigraphical control is not good below 650 m in the region of the supposed regional reflector. Between 676 m sub-bottom and the base of Hole 610 (723 m), the curve is apparently steep, giving a rate of around 65 m/m.y. whereas between 656 and 676 m sub-bottom the rate is apparently about 14.7 m/m.y. However, a different interpretation of the paleomagnetic data and biostratigraphic data is possible (see Clement and Robinson, this volume, and Baldauf et al. this volume).

GEOCHEMISTRY

Carbonate Bomb

Samples taken from Hole 610 for carbonate bomb analysis did not adequately cover the full range of lithologies within Unit I. In Hole 610A, the upper 200 m were sampled to achieve better resolution of the carbonate content within the glacial cycles. The $CaCO_3$ content varies between 0 and 80% in the upper 100 m (Fig. 22) and gradually increases to over 90% between 100 and 200 m sub-bottom. Below 250 m, carbonate decreases gradually to 650 m, below which it fluctuates between 50 and 90%.

Interstitial Water

Analyses of pH, alkalinity, and salinity were run on board, using samples from Holes 610 and 610A (Fig. 23). The pH decreases downhole to a minimum of 6.8 by 150 m. Below 500 m, the pH increases to 7.5. Alkalinity shows a corresponding increase to a high of 8.2 meq dm^{-3} at 150 m, but then decreases to a value of 2 meq dm^{-3} by 600 m. Salinity decreases gradually downhole from near-surface values of around 35 to below 33‰ below 500 m.

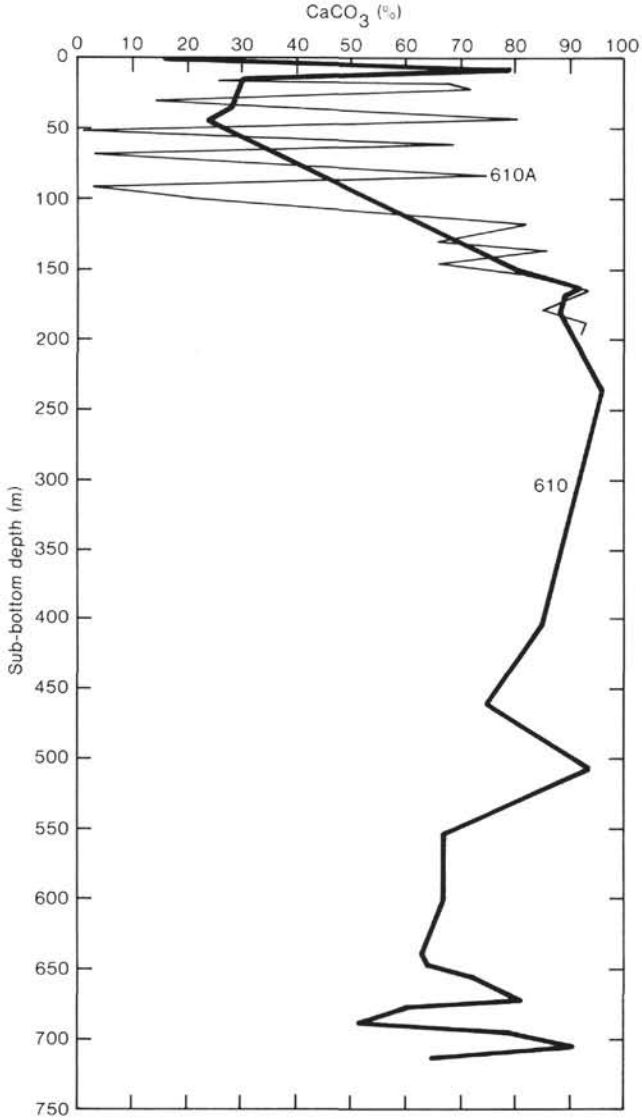


Figure 22. Carbonate bomb analyses, Site 610.

SUMMARY AND CONCLUSIONS

Six holes were drilled near the axis of the Feni Ridge sediment drift in Rockall Trough (Fig. 8). Four holes (610, 610A, 610B, 610C) were located on the crest of a sediment wave. Two holes (610D and 610E) were in the axis of an adjacent trough, 0.7 km away from and 28 m deeper than the crest, so that we could examine local sediment variation on the surface of the drift. Continuous VLHPC and XCB coring in two of the holes (610A and 610B) provided an almost complete composite section through the glacial-interglacial cycles to 2.47 Ma (Gauss Chronozone). Three of the holes (610, 610D, and 610E) were drilled beyond the Pliocene-Quaternary to date regional reflectors within the drift sequence.

Seismic Reflectors

Our prime objective at Feni Ridge was to examine the history of this major sediment drift through dating of some of its seismic reflectors. This was accomplished by a strategy of washing and spot coring to allow us to penetrate the sequence relatively quickly. Two major reflectors were within striking distance of our operations at this site. One was at 0.75 s two-way traveltime sub-bottom; a major regional reflector that had been characterized by some workers (Roberts, 1975) as the base of the drift sequence but by others (Dingle et al., 1982) as a mid-drift reflector representing a change to the modern bottom water circulation through Rockall Trough. The other target was a faint reflector at 0.37 s sub-bottom, which might represent another circulation event in the sedimentary history of the drift.

Our seismic records obtained arriving and departing Site 610 showed no clear reflector at 0.75 s sub-bottom (Fig. 19); rather, they display a zone between 0.65 and 0.85 s, which we believe masks the regional reflector seen in the reference site survey profiles. We nevertheless did penetrate a marked change in the sedimentary sequence just below 0.75 s sub-bottom which appears to represent this seismic reflector (Table 2). A sharp rise in hardness, recognized by an increase in drilling time (Fig. 9), and a consequent rise in seismic velocity (Fig. 18H), occurs over the interval 625 to 675 m sub-bottom. The hardness change is due to an increase in biogenic silica content (Fig. 12) within the lower and middle Miocene nannofossil chalks but does not represent a major lithologic change in the overall sequence. No hiatus is observed, but there is an apparent change in sedimentation rate, dropping from 46 m/m.y. to 14.7 m/m.y. in the interval between 656 and 676 m and then increasing again to over 67 m/m.y. from 676 m to the base of the hole. Three features of the sediment point to the geologic significance of this reflector:

1. Selective dissolution of the biogenic silica component occurs, such that diatoms are almost lost over the interval from Cores 610-19 to -23 (636–684 m sub-bottom), and dissolution features are observed on the remaining diatoms, sponge spicules, radiolarians, and silicoflagellates. No carbonate dissolution of the foraminifers or nannofossils is observed. Below Core 610-24, some silica dissolution is apparent, but it is much less

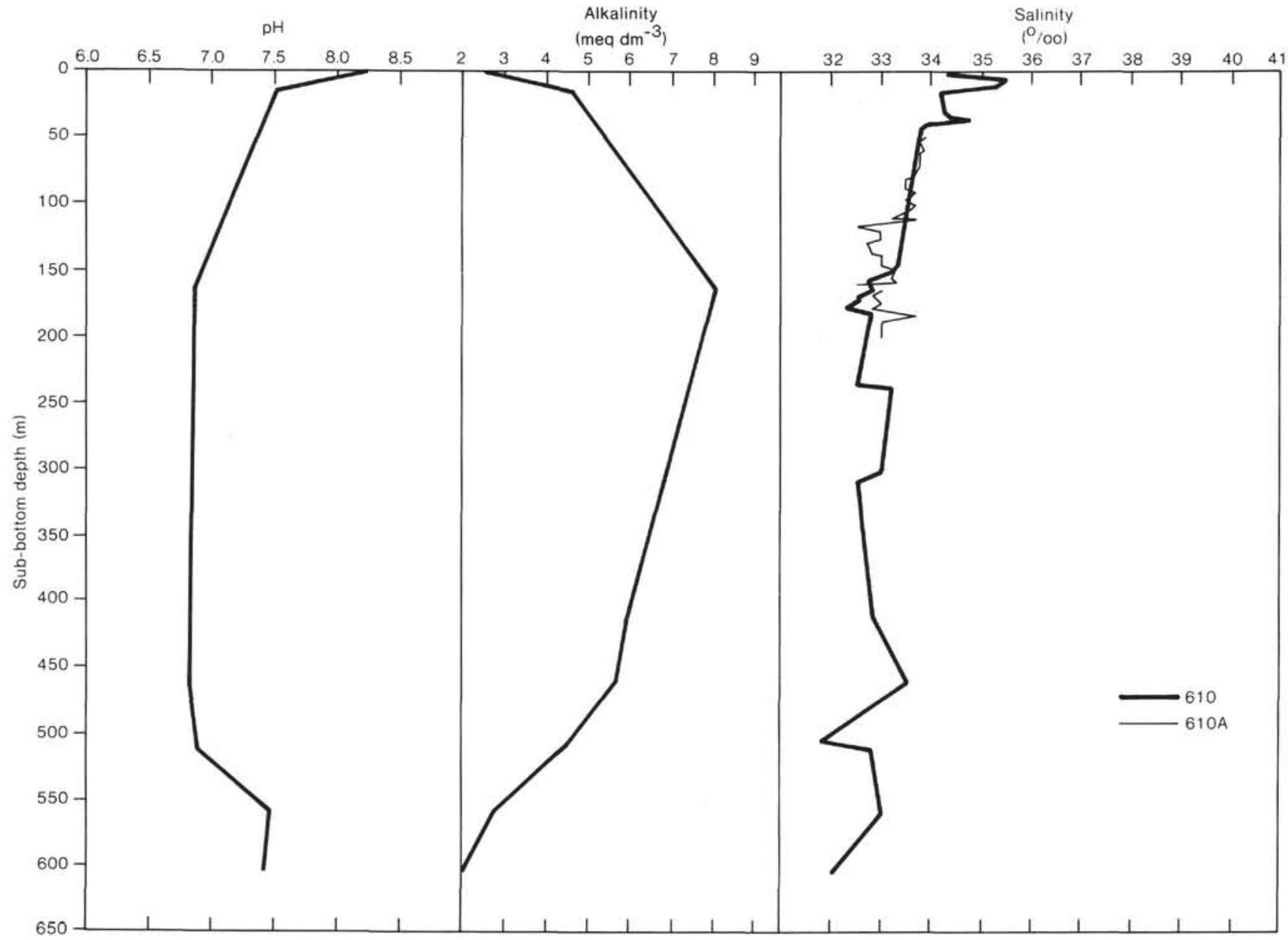


Figure 23. Interstitial water analyses, Site 610.

severe and the diatom content reverts to levels equal to those above Core 610-19 (see Baldauf; Dolan, this volume).

2. Pressure solution features (Fig. 2) are very common in the sediments within the interval from Cores 610-24 to -27 (684.6–723.0 m sub-bottom). These are presumably related to carbonate rather than to silica solution (see Hill, this volume).

3. Microfaulting and inclined bedding are commonly associated with the pressure solution features. Crushed foraminifers are common in Core 610-20, are almost absent in Core 610-22, and are slightly more common again in Cores 610-24 to -27 (see Hill; Dolan, this volume).

The lessening of silica solution below the level of Core 610-24, as evidenced by the return of abundant diatoms, suggests that the silica solution is linked to an oceanographic event rather than to diagenetic causes related to burial or tectonics (Baldauf; Dolan, this volume). A number of global oceanographic adjustments took place around this time (Keller and Barron, 1983). A major enrichment of silica occurred in the Pacific and Indian oceans, coinciding with a major decline in the Atlantic at around 16 Ma. This could correspond to the sharp decline in biogenic silica above Core 610-18. Keller and Barron (1983) map an oceanwide early Miocene hiatus at 20 to 18 Ma that they thought might extend to the Rockall region (presumed to be due to intensified bottom-current circulation and carbonate dissolution). We have no evidence of such a major hiatus of this age at Site 610.

The pressure solution features are likely to be diagenetic in origin, and the microfaulting and inclined bedding may simply be an adjustment to these solution processes within the sediment column. However, at this stage we cannot entirely rule out a tectonic origin: possibly a general warping of the sedimentary sequence and localized faulting. Crushed foraminifers are commonly found near fault zones in Paleogene sequences on land.

Pressure solution features and microfaulting occur again in middle Miocene Core 610-16 (NN6). We suspect that their presence at two levels in the sedimentary section may be the cause of the mixed acoustic return on the seismic records between 0.65 and 0.85 s sub-bottom.

The faint reflector at 0.37 s sub-bottom is clearly seen on the Leg 94 air-gun profiles and is traceable throughout the ridge crest area that we surveyed (Fig. 19). It corresponds in the continuously drilled record in Hole 610E to an interval of rapid lithification downward from white nannofossil ooze (Unit IIA) at 280 m sub-bottom to hard pale green chalk at 310 m. Reworking of foraminifers and nannofossils occurs in the lower part of the interval, which is dated as late Miocene (NN10–NN12), and may correspond to the Messinian isolation of the Mediterranean (5.5–6.3 Ma).

Masson and Kidd (this volume) have reexamined three major northwest- to southeast-trending multichannel profiles over Feni Ridge (NA-1, GSI-1, and WI-32; the latter section passes close to Site 610—Fig. 4) in the light of our drilling results. The three uppermost regional reflectors on these profiles have clearly been penetrated at Site 610. These reflectors are at 0.37, 0.64, and 0.76 s (two-way) at the relevant shot point (2500 on WI-32). Velocities measured on the cores recovered at Site 610 (Fig. 18G, H) correspond well with the stacking velocities obtained at this shot point. Calculation of the depths to the three reflectors from both lines of evidence predicts 330-m, 530-m, and 653-m sub-bottom depths for the reflectors. In Hole 610 the first reflector represents the rapid lithification downhole from ooze to chalk. The second reflector represents an appreciable jump in seismic velocity from 1.74 to 2.6 km/s and a decrease in drilling rate, whereas the third represents another hardness change and a coincident drop in sedimentation rate. Significantly the next major reflector identified in the WI-32 multichannel profile occurs at more than 1.6 s (two-way) sub-bottom. All three of the upper reflectors define seismic units that are positive accumulations above this deep reflector, which is the top of a unit that appears to fill in lows in the acoustic basement. It seems most likely, therefore, that the onset of drift accumulation at Feni Ridge began above this deep reflector, as suggested by Dingle et al. (1982), and not at the deepest reflector penetrated at Site 610 (see also Kidd and Hill, this volume).

Sediment Waves

From our extensive presite survey and our crossings of the beacon on leaving Site 610, we learned that the sediment waves near the crest of Feni Drift are probably more complex than hitherto recognized. Interpretation of the GLORIA sonograph over the site (Roberts and Kidd, 1979; Fig. 8) had indicated a general east–west trend to the sediment wave axes (Fig. 5), but also suggested that other wave trends were present. Our 3.5- and 12-kHz profiles showed that wave crests were spaced at intervals of 1 to 2 km along track and were of variable apparent amplitude, up to 30 to 40 m. Preliminary attempts to match wave axes promoted an impression of generally east-west trends, but in detail they do not entirely match the GLORIA plan-view. Mismatches could be due to navigational effects and/or intersection of wave trends. In general, crest heights vary with the regional bathymetry, but some waves appeared to change markedly in crest height along their axes. In addition, at least half the sediment wave crests traversed appeared symmetrical and showed no obvious migration on either the 3.5-kHz or air-gun profiles.

Inconsistencies with the accepted view of sediment waves on drifts continued at the scale of the individual wave. Preliminary plots were made of distances, as measured along our survey crossings, from the beacon on the crest of the sediment wave to the troughs on either side. This wave is asymmetrical, with its steeper side to the north, and the crossings suggested a whale-backed feature, elongate in an east–west direction. Postcruise analysis of the Leg 94 and other echo-sounder records has resulted in a bathymetric map of the vicinity of Site 610 contoured at 10-m intervals (Kidd and Hill, this volume), a portion of which is illustrated in Figure 8A.

Drift Sedimentation

The uppermost sediments drilled at Site 610 (Fig. 10) proved to be remarkably similar to those recovered at Site 609, a site that is without the characteristic seismic signature or wave ornamentation of a sedimentary drift. The Pliocene–Quaternary sediment section (0–135 m sub-bottom) at Feni Ridge is made up of the ooze-marl-mud sequences that reflect the glacial–interglacial cycles (lithologic Unit I). Below this, a typically pelagic nannofossil ooze and chalk sequence makes up the remainder of the 173-m-thick section penetrated (lithologic Unit II). Sedimentation rates are linear and are indeed high at 51 to 46 m/m.y., but they are not so high as at the "pelagic" Site 609 (89 m/m.y.). More surprisingly, no primary sedimentary structures that could be interpreted as due to bottom-current sedimentation were observed, although general reworking of the nannofossil component was recognized throughout. The softer sediments were cut with an electro-osmotic knife in an attempt to reveal primary structures, but enhancement of burrow structures was all that resulted. Neither was lamination discovered when the cores were X-rayed ashore to check for current structures not visible to the naked eye (Hill, this volume).

Some individual beds of sandy and silty material did occur other than the generally disseminated ice-rafted material. A minor lithology in Unit I comprised a series of dark gray to black volcanic ash-rich beds. These typically occurred with sharp basal contacts that suggest local redeposition of silt- to sand-size material. Two compositional types were observed, one containing both detrital, presumably ice-rafted, material and volcanic ash, and the other made up almost entirely of volcanic components suggesting a primary ash-fall origin.

No obvious sediment wave crest-to-trough facies variations were apparent. Our limited depth sampling in the trough allows us only to comment that sedimentation-rate differences were observed, but it remains unclear whether these are sedimentologically significant or the result of core recovery defects as observed at the other sites (Ruddiman, et al., this volume).

Other Objectives

Our objectives related to Neogene paleoclimatic studies depended, as at the other sites, on recovery of a complete section for shore-based studies. Two VLHPC–XCB cored holes, 610A and 610B, were devoted primarily to this task. Heave-related core disturbance, as detected by detailed cross correlation, resulted in contorted sections and under-recovery. This effect was severe in the upper 50 m of all holes and only moderate below this depth. It was possible, however, to demonstrate that an apparently 100% complete composite section could be pieced together to 2.5 Ma using overlapped cores from five of the holes (610, 610A–610D) (Ruddiman et al., this vol.).

Although our recovered time-range extended only to the early Miocene, numerous biostratigraphic and paleomagnetic datums were refined at Site 610 (see also Baldauf et al., this volume).

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SITE 610 HOLE CORE 1 CORED INTERVAL 0.0–9.6 m

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

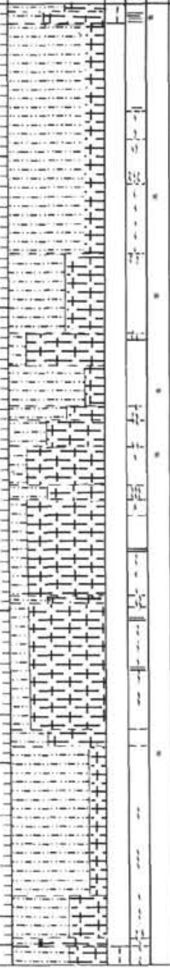
Biostratigraphic zone: N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone

Fossil character: AG AG B B

Sub-bottom depth: 1.50, 3.00, 4.50, 6.00, 7.50, 9.00, 9.48, 9.56

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

Meters: 0.5, 1.0



Colors: 5Y 5/2, 10YR 5/4, 2.5Y 4/2, 2.5Y 5/2, 10YR 6/1, 5Y 5/2, 2.5Y 5/2, 5Y 6/1, 5Y 7/1, 10YR 5/2, 10YR 6/2, 2.5Y 7/2, 10YR 8/1, 10YR 6/2, 10YR 8/1, 10YR 6/2, 10YR 8/1, 10YR 6/1, 2.5Y 4/2, 2.5Y 6/2, 5Y 7/2, 5Y 5/2

LITHOLOGIC DESCRIPTION

(MARLY) FORAMINIFERAL NANNOFOSSIL OOZE interbedded with CALCAREOUS MUD

Light gray ooze layers generally homogeneous with mottled transitions to olive gray calcareous mud. Occasional gray green (5G 5/2–5G 6/2) layers and pyrite halos. Calcareous mud layers mottled to homogeneous, sometimes slightly sandy intervals. Dropstones of Cretaceous mudstone and pumice. Open burrows common and *Zoophycos*.

SMEAR SLIDE SUMMARY (%)

	1, 14	2, 51	2, 141	3, 81	3, 144	5, 145
	M	D	D	D	D	D
Composition:						
Quartz	2	6	1	15	1	16
Feldspar	–	TR	TR	TR	–	1
Heavy minerals	–	TR	TR	TR	TR	1
Clay	35	57	35	62	10	54
Volcanic glass	–	4	2	6	TR	8
Micronodules	1	–	–	–	–	–
Carbonate unspec.	3	8	7	11	TR	15
Foraminifers	3	7	3	2	9	2
Calc. nannofossils	57	18	52	4	80	3
Diatoms	–	–	–	–	TR	–
Sponge spicules	TR	–	TR	–	TR	–

ORGANIC CARBON AND CARBONATE (%)

	2, 19–20	5, 76–77
Organic carbon	–	–
Carbonate	11	79

SITE 610 HOLE CORE 2 CORED INTERVAL 9.6–19.2 m

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

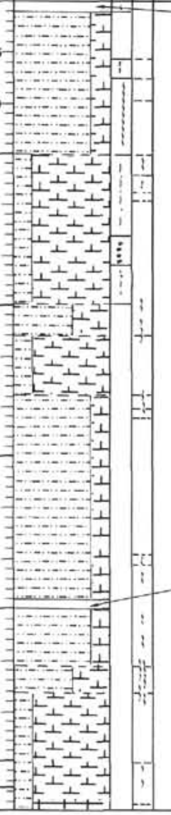
Biostratigraphic zone: N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone; NN20 *Gephyrocapsa oceanica* Zone

Fossil character: AG AG B B

Sub-bottom depth: 11.10, 12.60, 14.10, 15.60, 16.10, 16.33

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

Meters: 0.5, 1.0



Colors: 5Y 5/2, 5Y 6/1, 2.5Y 6/2, 5Y 5/2, 5Y 6/1, 5Y 7/1, 5BG 7/2, 5Y 7/1, 5Y 5/1, 5Y 7/1, 5Y 5/1 to 2.5Y 6/2, 5Y 7/1, 2.5Y 6/2 to 2.5Y 5/2, 2.5Y 5/2, 5Y 5/1 to 5Y 5/2, N4/1, IW, 5Y 5/2, 5Y 5/2, 2.5Y 6/2, 2.5Y 7/1, 2.5Y 6/2, 5Y 7/2, 2.5Y 6/2

LITHOLOGIC DESCRIPTION

0–10 cm badly disturbed to soupy

NANNOFOSSIL OOZE interbedded with CALCAREOUS MUD

Light gray ooze layers homogeneous with pyrite halos and occasional gray green laminae. Dropstone (pumice). Olive gray and brown calcareous mud mottled to homogeneous. Occasional dropstones. *Zoophycos*, *Chondrites*, and *Planolites*.

SMEARS SLIDE SUMMARY (%)

	2, 65	3, 126	4, 56
	D	D	D
Composition:			
Quartz	1	10	3
Feldspar	TR	1	TR
Heavy minerals	TR	2	TR
Clay	3	60	71
Volcanic glass	2	8	4
Carbonate unspec.	1	13	13
Foraminifers	4	3	5
Calc. nannofossils	89	3	4

ORGANIC CARBON AND CARBONATE (%)

	4, 56–57
Organic carbon	–
Carbonate	30

SITE 610 HOLE CORE 3 CORED INTERVAL 19.2–28.8 m

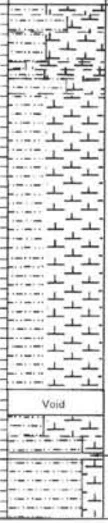
TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | Sub-bottom depth | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Biostratigraphic zone: N22 *Globorotalia truncatulinoides*; NN20 *Gephyrocapsa oceanica* Zone

Fossil character: AG AG B B

Sub-bottom depth: 20.70, 22.20, 23.70, 24.27

Sections: 1, 2, 3, 4; Meters: 0.5, 1.0



5Y 7/1
2.5Y 5/2
5Y 7/1
5Y 4/1
2.5Y 5/2
5Y 7/1
5Y 8/1
5Y 7/1
5Y 8/1
5Y 4/2
OG sample
5Y 4/2 to
2.5Y 6/2

Very deformed interbedded NANNOFOSSIL OOZE and CALCAREOUS MUD, gray to olive gray, vertical streaks throughout. ?Dropstones of sandy mud, mudstone and volcanic rock. Mud at 237.7 m contain volcanic glass (12%).

SMEAR SLIDE SUMMARY (%)

	4, 7 M	3, 1 D
Composition:		
Quartz	45	50
Feldspar	5	5
Mica	1	TR
Heavy minerals	–	TR
Clay	20	TR
Volcanic glass	12	–
Pyrite	–	5
Carbonate unspec.	10	15
Foraminifers	–	5
Calc. nannofossils	7	20

SITE 610 HOLE CORE 4 CORED INTERVAL 28.8–38.4 m

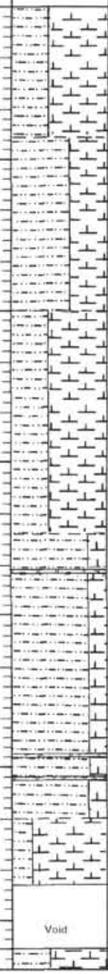
TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | Sub-bottom depth | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Biostratigraphic zone: N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone

Fossil character: AG AG B B

Sub-bottom depth: 30.30, 31.80, 33.30, 34.80, 36.30, 37.47

Sections: 1, 2, 3, 4, 5, 6, 7, CC; Meters: 0.5, 1.0



5Y 7/1
5GY 7/2
5Y 7/1
to
2.5Y 5/2
5Y 6/1
5Y 7/1
2.5Y 5/2
5Y 4/1
2.5Y 4/2
5Y 6/2
to
2.5Y 5/2
5Y 7/1
5Y 5/2
5Y 8/1
5Y 7/2

Very deformed to 33.30 m. Moderately deformed 33.30 to 34.00 m.

Interbedded MARLY NANNOFOSSIL OOZE and CALCAREOUS MUD.

Light gray ooze is homogeneous with pyrite patches and green gray laminae. Mud is olive gray to brown mottled to homogeneous with dropstones, mudclasts, *Chondrites* at transitions. Volcanic ash beds at 5.53 to 5.56 m, 7.37 to 7.40 m, and 7.60 to 7.63 m. Sharpbased.

SMEAR SLIDE SUMMARY (%)

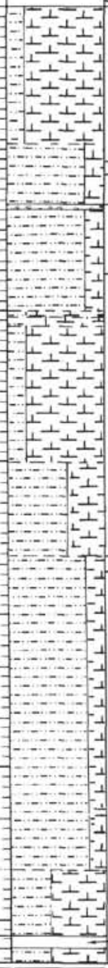
	5, 41 D	6, 70 M
Composition:		
Quartz	30	5
Feldspar	3	–
Mica	TR	TR
Heavy minerals	TR	–
Volcanic glass	5	–
Glauconite	–	TR
Carbonate unspec.	10	–
Foraminifers	7	35
Calc. nannofossils	45	60

ORGANIC CARBON AND CARBONATE (%)

Organic carbon	–
Carbonate	28

SITE 610 HOLE CORE 5 CORED INTERVAL 38.4–48.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG	B, B, B, B	RP	39.90, 41.40, 42.90, 44.40, 45.90, 47.40, 47.58	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0				*	5Y 8/1 to 5Y 5/1; 5Y 5/2; 5G 4/1; 5Y 5/2; 2.5Y 7/1; 10YR 6/2; 10YR 8/1; 10YR 5/2 to 10YR 7/1; 5Y 7/2; 10YR 5/2; 2.5Y 4/2; 10YR 5/3; 10YR 4/2; 2.5Y 5/2; 5GY 6/1; Void; 5Y 6/1



LITHOLOGIC DESCRIPTION

Disturbed to varying degrees in Section 1 to 4.

NANNOFOSSIL OOZE and CALCAREOUS MUD interbeds, light gray to olive gray. Homogeneous to mottled with occasional gray green laminae and pyrite patches. Volcanic ash bed at 1.92 to 1.96 m. Sharpbased.

SMEAR SLIDE SUMMARY (%)

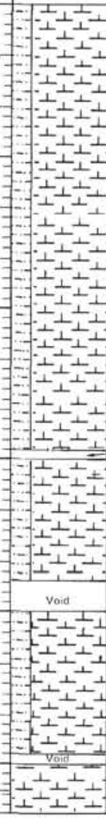
	4, 64
	D
Composition:	
Quartz	45
Feldspar	5
Mica	TR
Heavy minerals	TR
Volcanic glass	5
Glauconite	TR
Carbonate unspec.	10
Foraminifers	5
Calc. nannofossils	30

ORGANIC CARBON AND CARBONATE (%)

	5, 65–66
Organic carbon	–
Carbonate	24

SITE 610 HOLE CORE 6 CORED INTERVAL 147.0–156.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	
	PL3–5 undifferentiated; NN16 *Discoaster surculus* Zone; *Nitzschia jouseae* Zone	AG	AM	RM, RM	CM, FM	148.50, 150.00, 151.50, 153.00, 154.90	1, 2, 3, 4, 5, 6, CC	0.5, 1.0	Void; Void			*	5Y 8/1; 5Y 7/1; Void



LITHOLOGIC DESCRIPTION

SILICEOUS NANNOFOSSIL OOZE, very light gray, lightly mottled with gray (N8/1) pyritiferous patches and halos. Occasional diffuse gray green (5GY 7/1) laminae. *Zoophycos* common.

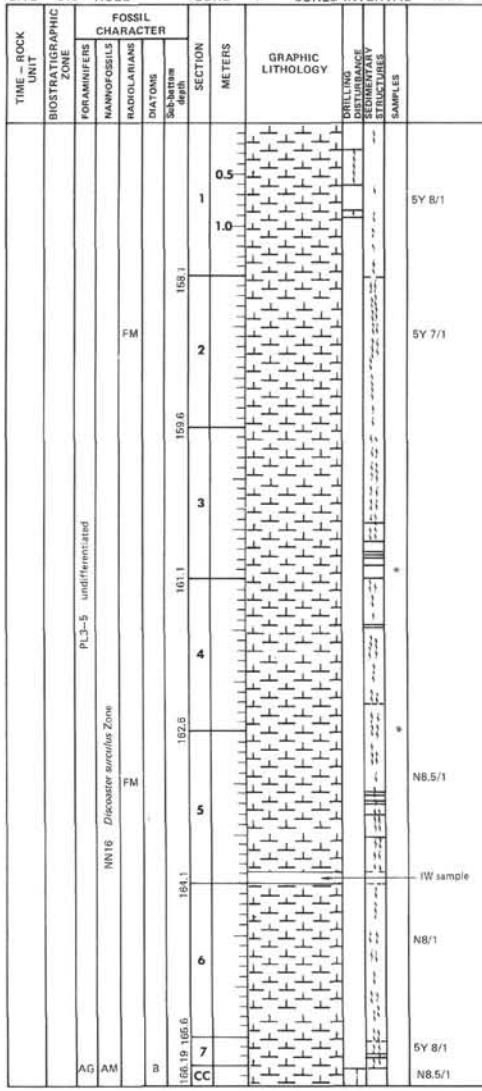
SMEAR SLIDE SUMMARY (%)

	1, 90
	D
Composition:	
Quartz, Feldspar, Mica, Heavy minerals, Clay	10
Volcanic glass	1
Foraminifers	4
Calc. nannofossils	75
Diatoms	8
Sponge spicules	2

ORGANIC CARBON AND CARBONATE (%)

	1, 90–91
Organic carbon	–
Carbonate	79

SITE 610 HOLE CORE 7 CORED INTERVAL 156.6–166.2 m



LITHOLOGIC DESCRIPTION

SILICEOUS NANNOFOSSIL OOZE, white to light gray with gray (N5–6/1) mottling and gray green diffuse laminae. Pyrite halos.

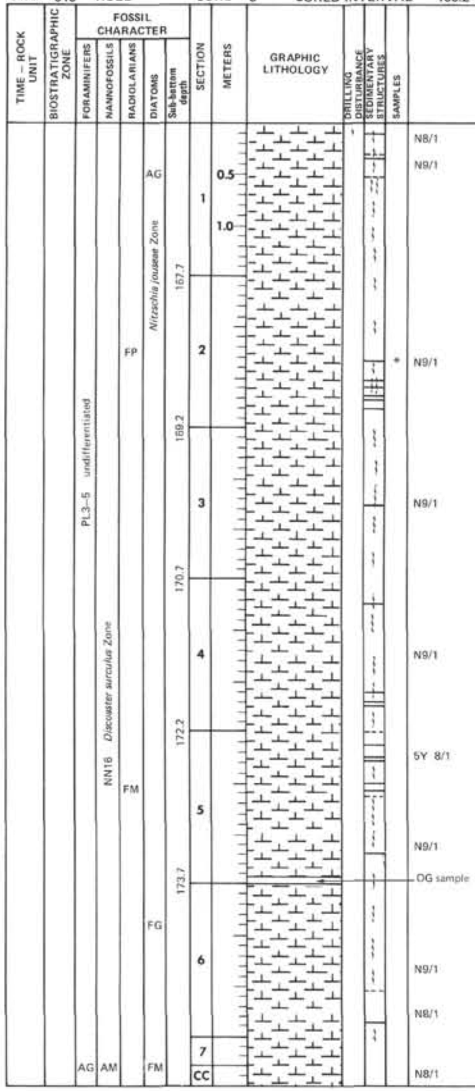
SMEAR SLIDE SUMMARY (%)

	3, 140 D	4, 140 D
Composition:		
Quartz, Feldspar, Mica, Heavy minerals, Clay	10	5
Volcanic glass	1	1
Carbonate unspec.	2	1
Foraminifers	8	5
Calc. nannofossils	69	86
Diatoms, Radiolarians, Sponge spicules	10	2
Silicoflagellates	TR	–

ORGANIC CARBON AND CARBONATE (%)

	4, 140–141
Organic carbon	–
Carbonate	92

SITE 610 HOLE CORE 8 CORED INTERVAL 166.2–175.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white with gray (N4/1–N5/1) and gray green (5GY 8/1–5GY 7/1) mottling. Some gray green diffuse laminae. Pyrite halos. *Zoophycos*.

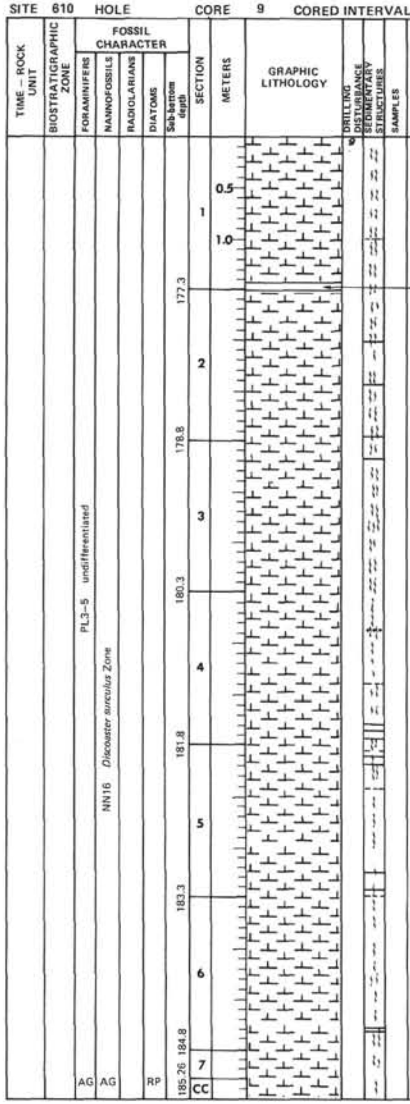
SMEAR SLIDE SUMMARY (%)

	2, 80
Composition:	
Quartz	10
Feldspar	TR
Volcanic glass	TR
Glauconite	TR
Carbonate unspec.	TR
Foraminifers	3
Calc. nannofossils	86

ORGANIC CARBON AND CARBONATE (%)

	2, 80–81
Organic carbon	–
Carbonate	89

SITE 610 HOLE CORE 9 CORED INTERVAL 175.8–185.4 m



5Y 8/1

N8.5/1

Void

N8.5/1

N8.5/1

Lenticular foram sand

N8.5/1

5GY 8/1

N8/1

N8.5/1

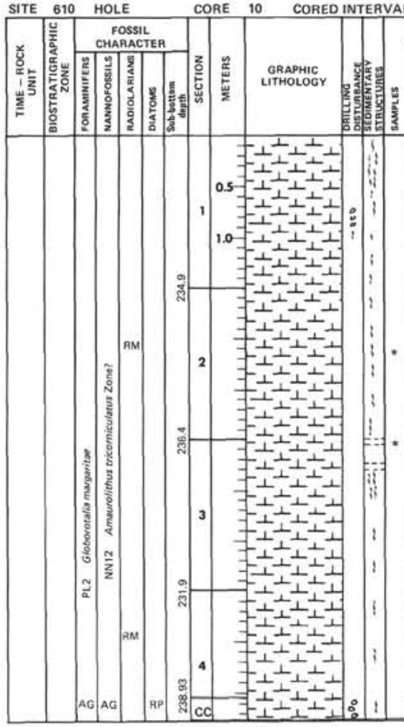
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white to pale gray, mottled with gray (N4/1–N6/1) and gray green (5GY 8/1–5Y 6/2). Pyritized burrow, diffuse green laminae. Foram sand in lenticular bed at 180.65 m.

ORGANIC CARBON AND CARBONATE (%)

	3, 65–66
Organic carbon	–
Carbonate	88

SITE 610 HOLE CORE 10 CORED INTERVAL 233.4–243.0 m



N9/1

* N9/1

* 5Y 7/1

N9/1

5Y 7/1

N9/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white with gray (N6/1) mottling.

SMEAR SLIDE SUMMARY (%)

	2, 70	3, 2
	D	M
Composition:		
Quartz	5	5
Clay	2	–
Volcanic glass	TR	–
Carbonate unspec.	1	1
Foraminifers	2	2
Calc. nannofossils	90	91
Diatoms	–	TR
Sponge spicules	–	TR

ORGANIC CARBON AND CARBONATE (%)

	2, 70–71
Organic carbon	–
Carbonate	96

SITE 610 HOLE CORE 11 CORED INTERVAL 300.6–310.2 m

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

Biostratigraphic zones: *Globorotalia margaritae*; NN11 *Discoaster quinqueramus* Zone

Fossil character: RM; RM; AG AM RP

Sub-bottom depth: 300.6, 302.1, 302.58, 308.1, 309.6, 310.1

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

Graphic lithology: Void; Void; Void

N8.5/1
N8.5/1
N8.5/1
Void
N8.5/1

34–44 Soupy

NANNOFOSSIL OOZE, white with minor gray (N6/1) mottling.

SMEAR SLIDE SUMMARY (%)

	1, 110
Composition:	
Quartz, Feldspar, Mica, Heavy minerals, Clay	5
Carbonate unspec.	3
Foraminifers	5
Calc. nannofossils	87

ORGANIC CARBON AND CARBONATE (%)

	1, 110–111
Organic carbon	–
Carbonate	92

SITE 610 HOLE CORE 12 CORED INTERVAL 348.6–358.2 m

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

Biostratigraphic zones: *Globorotalia conomiozea*; NN10 *Discoaster calcaris* Zone – NN7 *Discoaster kugleri* Zone

Fossil character: RP; AG AM

Sub-bottom depth: 348.6, 349.1

Section: CC

Void
N8

NANNOFOSSIL CHALK, generally homogeneous, wispy gray laminations.

SMEAR SLIDE SUMMARY (%)

	CC,41 D
Composition:	
Quartz	10
Feldspar	TR
Carbonate unspec.	TR
Foraminifers	5
Calc. nannofossils	85
Sponge spicules	TR

SITE 610 HOLE CORE 13 CORED INTERVAL 358.2–367.8 m

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

Biostratigraphic zones: *N. humerosa*; NN10 *Discoaster calcaris Zone* – NN7 *Discoaster kugleri Zone*

Fossil character: RM; AG AP RP

Sections: 1, 2, 3, CC

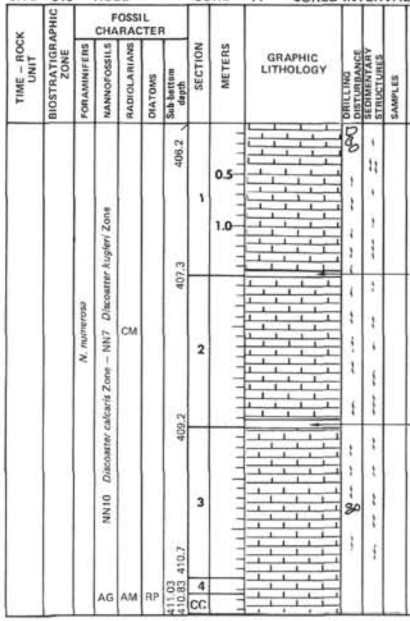
5B 9/1
5B 9/1 to 5G 9/1

NANNOFOSSIL CHALK, bluish white to greenish white (5B 9/1–5G 9/1); *Zoophycos*; thin blue to gray laminations, pyrite staining; slickensides present at Section 1, 133 cm. Core disturbed by fracturing during drilling.

SMEAR SLIDE SUMMARY (%)

	1, 40 D
Composition:	
Quartz	5
Carbonate unspec.	TR
Foraminifers	5
Calc. nannofossils	90

SITE 610 HOLE CORE 14 CORED INTERVAL 406.2–415.8 m



LITHOLOGIC DESCRIPTION

5G 9/1
OG
IW

NANNOFOSSIL CHALK, pale green (5G 9/1); few faint wispy laminations; *Zoophycos*; pyrite halos and staining. Core brecciated and fractured by drilling.

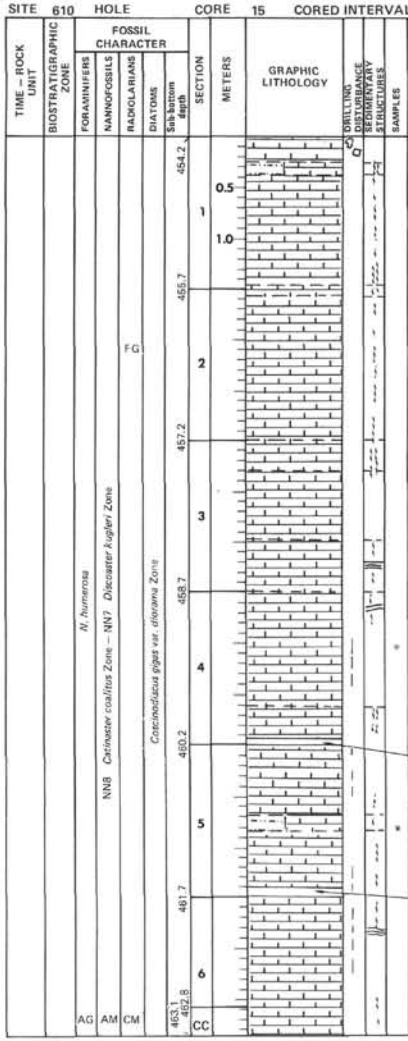
SMEAR SLIDE SUMMARY (%)

	1, 41
	D
Composition:	
Quartz	12
Feldspar	TR
Heavy minerals	TR
Carbonate unspec.	TR
Foraminifers	3
Calc. nannofossils	85
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE (%)

	1, 35–36
Organic carbon	–
Carbonate	85

SITE 610 HOLE CORE 15 CORED INTERVAL 454.2–463.8 m



LITHOLOGIC DESCRIPTION

5G 8/1
5GY 7/1
5G 8/1
5GY 7/1
5GY 8/1
5GY 7/1
5G 8/1
5GY 7/1
5G 8/1
5GY 7/1
OG
5G 8/1
5GY 7/1
5G 8/1
IW
5G 8/1

NANNOFOSSIL CHALK, greenish gray (5GY 7/1–5G 8/1); occasional *Zoophycos*; occasional wispy bedding; pyrite halos and staining. Coring deformation in the form of breccia and "biscuits".

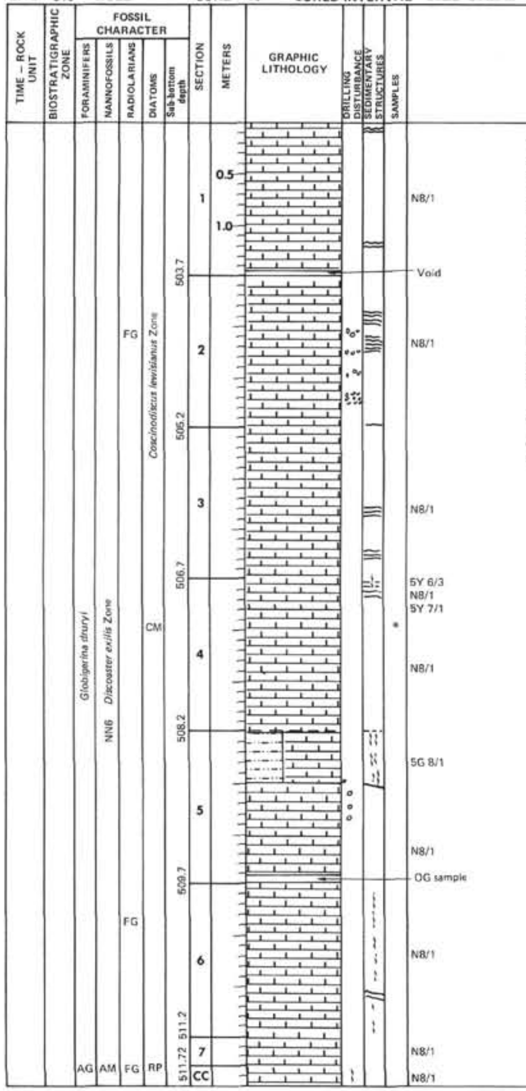
SMEAR SLIDE SUMMARY (%)

	4, 57	5, 80
	D	M
Composition:		
Quartz	3	40
Volcanic glass	–	TR
Pyrite	TR	–
Carbonate unspec.	TR	TR
Foraminifers	1	TR
Calc. nannofossils	96	60
Diatoms	TR	TR
Radiolarians	TR	–
Sponge spicules	TR	TR
Silicoflagellates	–	TR

ORGANIC CARBON AND CARBONATE (%)

	5, 70–71
Organic carbon	–
Carbonate	75

SITE 610 HOLE CORE 16 CORED INTERVAL 502.2–511.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK with thin unit of MARLY CHALK, white to light gray, homogeneous to mottled. Occasional pyrite mottles and halos. *Zoophycos* very common throughout core. Very thin wavy bedding common to 4.70 m. Microfault at 4.70 m which shows a sharp lithological break.

Coring disturbance limited to drill biscuit rotation and rare flow-in.

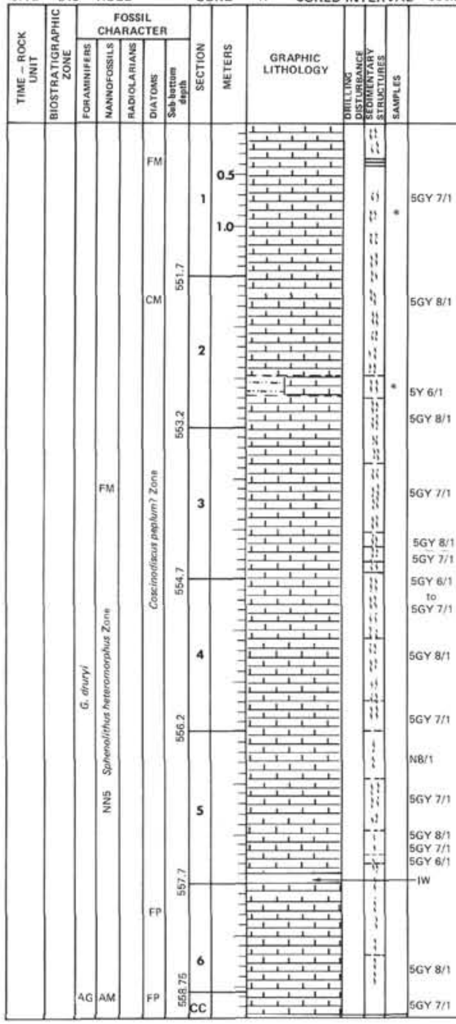
SMEAR SLIDE SUMMARY (%)

	4, 40
Composition:	
Clay	TR
Carbonate unspec.	TR
Foraminifers	2
Calc. nannofossils	98
Radiolarians	TR
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE (%)

	4, 62–66
Organic carbon	–
Carbonate	94

SITE 610 HOLE CORE 17 CORED INTERVAL 550.2–559.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK with interval of MARLY CHALK, light greenish gray to very mottled with abundant *Chondrites* and *Zoophycos*, pyrite mottles and wispy gray green laminae.

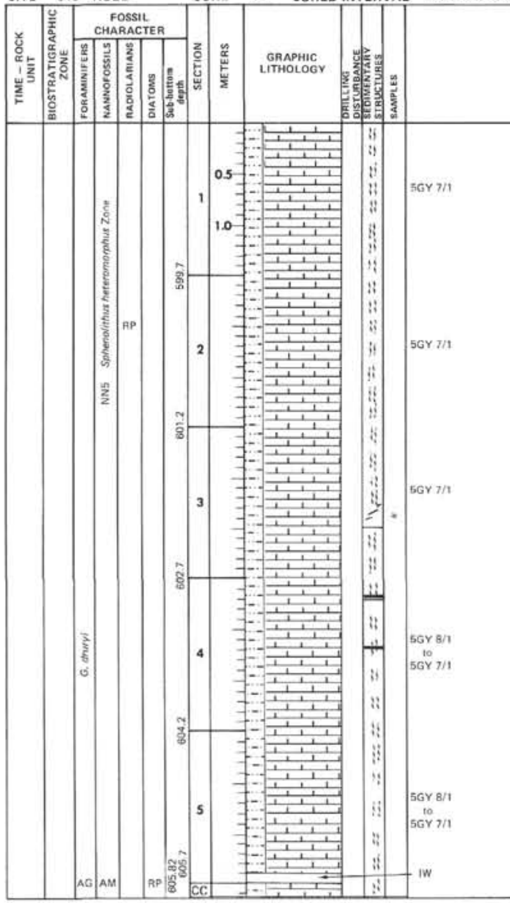
SMEAR SLIDE SUMMARY (%)

	2, 105 M	1, 85 D
Composition:		
Quartz	5	–
Feldspar	TR	–
Mica	TR	–
Clay	25	10
Carbonate unspec.	35	38
Foraminifers	2	2
Calc. nannofossils	28	50
Diatoms, Radiolarians, Sponge spicules, Silicoflagellates	5	–

ORGANIC CARBON AND CARBONATE (%)

	2, 105–106
Organic carbon	–
Carbonate	67

SITE 610 HOLE CORE 18 CORED INTERVAL 598.2–607.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, light greenish gray, highly mottled throughout, with pale green (5GY 6/1), white (N9/1) and gray (N2–4/1). *Zoophycos*, *Chondrites*. Occasional very thin horizontal lamination unaffected by bioturbation.

Drilling disturbance limited to break-up into 3–14 cm coherent blocks.

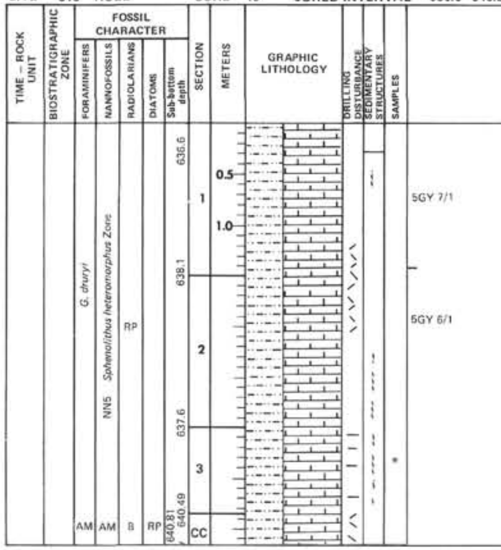
SMEAR SLIDE SUMMARY (%)

	3, 88
	D
Texture:	
Clay	10
Composition:	
Volcanic glass	TR
Carbonate unspec.	1
Foraminifers	TR
Calc. nannofossils	87
Radiolarians	TR
Sponge spicules	2

ORGANIC CARBON AND CARBONATE (%)

	3, 88–89
Organic carbon	–
Carbonate	67

SITE 610 HOLE CORE 19 CORED INTERVAL 636.6–646.2 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK

Top 30 cm is chalk breccia to conglomerate, mostly angular clasts; inclined burrows and/or laminations at Section 1, 96 to 114 cm, sandy clast (3 cm) containing foraminifera (recrystalized) at Section 1, 105 cm. Occasional *Zoophycos* throughout.

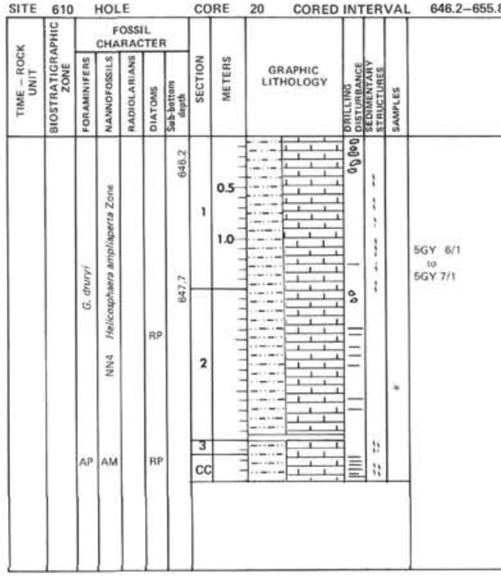
SMEAR SLIDE SUMMARY (%)

	3, 34
	D
Composition:	
Quartz	TR
Feldspar	TR
Clay	45
Volcanic glass	TR
Glauconite	TR
Carbonate unspec.	24
Foraminifers	TR
Calc. nannofossils	30
Sponge spicules	1

ORGANIC CARBON AND CARBONATE (%)

	3, 33–34
Organic carbon	–
Carbonate	63

SITE 610 HOLE CORE 20 CORED INTERVAL 646.2–655.8 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK

Occasional *Zoophycos*, some small offsets and vertical faults especially Section 3.

Disturbance is in the form of breccia and flowage around coherent pieces.

SMEAR SLIDE SUMMARY (%)

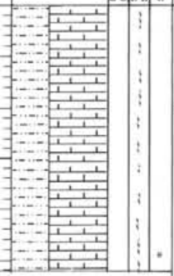
	2, 97
	D
Composition:	
Quartz	TR
Feldspar	TR
Heavy minerals	TR
Clay	75
Volcanic glass	TR
Carbonate unspec.	21
Calc. nannofossils	33
Sponge spicules	1

ORGANIC CARBON AND CARBONATE (%)

	1, 35–36
Organic carbon	–
Carbonate	64

SITE 610 HOLE CORE 21 CORED INTERVAL 655.8–665.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	G. druryi / NN4 *Helicosphaera ampliaperta* Zone	AM	AM, FP	RM	RP	655.8, 657.3	1, 2	0.5, 1.0				*



5GY 6/1

LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK

Occasional *Zoophycos* in Section 1. This core has no Core Catcher.

SMEAR SLIDE SUMMARY (%)

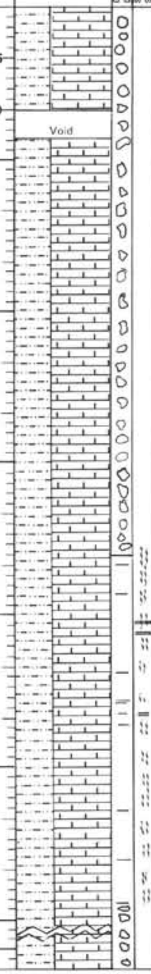
	2, 97
	D
Composition:	
Quartz	TR
Feldspar	TR
Heavy minerals	TR
Clay	40
Volcanic glass	TR
Carbonate unspec.	26
Calc. nannofossils	33
Sponge spicules	1

ORGANIC CARBON AND CARBONATE (%)

	1, 97–98
Organic carbon	–
Carbonate	74

SITE 610 HOLE CORE 22 CORED INTERVAL 665.4–675.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	C. dissimilis / NN4 *Helicosphaera ampliaperta* Zone	CP	AP	RP, RP	B, B	665.4, 666.9, 668.4, 669.9, 671.4, 672.9, 674.4, 675.03, 675.29	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	Void			*



5GY 7/1 to 5GY 6/1

LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK

Zoophycos; irregular green fine laminae in Section 5. Occasional pyrite halos and burrow fillings (pyrite?). Section 7 badly fractured but pieces in correct relative position. Disturbance in Sections 1–4 occurs as drill breccia surrounded by flow of groundup material.

SMEAR SLIDE SUMMARY (%)

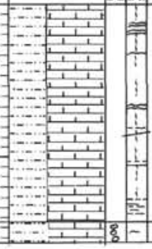
	5, 81
	D
Composition:	
Quartz	5
Feldspar	TR
Heavy minerals	TR
Clay	35
Volcanic glass	TR
Carbonate unspec.	22
Calc. nannofossils	38
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE (%)

	5, 81–82
Organic carbon	–
Carbonate	82

SITE 610 HOLE CORE 23 CORED INTERVAL 675.0–684.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS
	NN3 *Sphenolithus belemnos* Zone / NN4 *Helicosphaera ampliaperta* Zone; *C. dissimilis*; *Denticulopsis nicobarica* Zone?	CP	AP	RP, FM	RP, RP	676.5, 677.14	1, 2, CC	0.5, 1.0



5GY 7/1
5GY 8/1
5GY 6/1
5GY 7/1
5GY 6/1
5GY 7/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, light greenish gray, mottled. Faint wispy laminations. Microfault at 121 m.

SMEAR SLIDE SUMMARY (%)

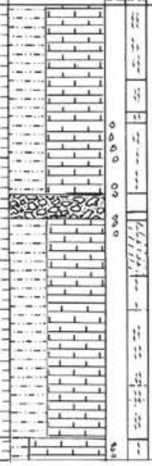
	1, 149
	D
Composition:	
Heavy minerals	TR
Clay	15
Volcanic glass	TR
Glauconite	TR
Carbonate unspec.	20
Foraminifers	5
Calc. nannofossils	60

ORGANIC CARBON AND CARBONATE (%)

	1, 149–150
Organic carbon	–
Carbonate	61

SITE 610 HOLE CORE 24 CORED INTERVAL 684.6–694.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS
	NN3 *Sphenolithus belemnos* Zone; *C. dissimilis*; *Triceratium pileus* Zone	CP	AP	RP, RP	FM, CG, FP	686.1, 687.6	1, 2, 3, CC	0.5, 1.0



5GY 7/1
5Y 8/1
5GY 7/1
5Y 8/1
5GY 5/1 to 6/1
5Y 6/1
5GY 8/1
5Y 7/1
5Y 5/2
5Y 7/1
5Y 6/1

LITHOLOGIC DESCRIPTION

0.00–1.86 m: NANNOFOSSIL CHALK, pale gray green, mottled. Interbedded lighter and darker layers with sharp boundaries. Lighter layers show extensive, very fine veining.

1.86–2.11 m: BRECCIA, elongated chalk clasts in chalky matrix. Maximum clast size ~1 cm. Flow structures.

2.11–4.25 m: SILICEOUS NANNOFOSSIL OOZE, bedding inclined at 10°, 2.11 to 2.61 m, pale green, mottled. Darker, ?organic-rich layer at 3.75–3.89 m. Flattened and elongated burrows common.

Whole core is broken up by microfaults with slickenside planes.

SMEAR SLIDE SUMMARY (%)

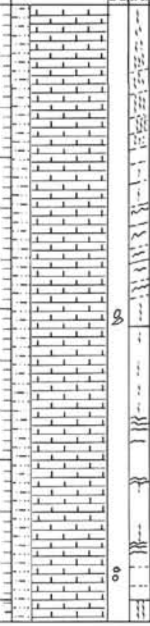
	1, 90	3, 85
	D	M
Composition:		
Quartz	10	–
Feldspar	TR	–
Clay	10	10
Carbonate unspec.	10	15
Foraminifers	–	TR
Calc. nannofossils	68	40
Diatoms		} 15
Radiolarians		} 15
Sponge spicules	2	} 15
Silicoflagellates		
Organic material	15	

ORGANIC CARBON AND CARBONATE (%)

	3, 85–86
Organic carbon	–
Carbonate	52

SITE 610 HOLE CORE 25 CORED INTERVAL 694.2–703.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS
	NN3 *Sphenolithus belemnos* Zone; *C. dissimilis*; *Craspedodiscus elegans* Zone	CM	AM	FG, FM	AG, FM, RP		1, 2, 3, 4, CC	0.5, 1.0



5GY 7/1
N9/1
5GY 7/1
N9/1
5GY 7/1
5GY 7/1

LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, slightly siliceous.
(a) Pale gray green, mottled, inclined bedding (Section 5, 80 cm), 0.60 to 2.90 m.
(b) White with wispy laminae, some characteristically stylolitic.
Both sharp and gradational boundaries present.

SMEAR SLIDE SUMMARY (%)

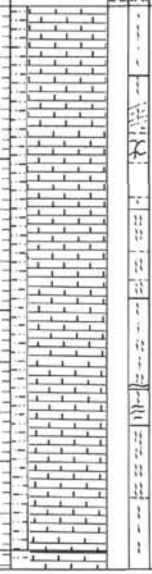
	1, 90
	D
Composition:	
Quartz	5
Clay	5
Carbonate unspec.	15
Foraminifers	1
Calc. nannofossils	68
Diatoms	1
Sponge spicules	5

ORGANIC CARBON AND CARBONATE (%)

	1, 65–66
Organic carbon	–
Carbonate	79

SITE 610 HOLE CORE 26 CORED INTERVAL 703.8–713.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
	C. dissimilis / NN3 *Sphenolithus belemnos* Zone	CM	AP	RM; RP	FP		1, 2, 3, 4, CC	0.5, 1.0				* *	



Colors: N9/1; 5Y 8/1; N9/1; 5GY 6/1 to 5/1; 5GY 7/1; 5GY 6/1; 5GY 7/1; 5GY 6/1; 5GY 7/1; 5GY 6/1; 5GY 7/1; 5GY 6/1

NANNOFOSSIL CHALK, slightly siliceous, pale green to white, mottled. Inclined bedding 0.90 to 1.25 m, 20° decreasing downwards to horizontal. Common, thin, veins in lighter layers *Zoophycos, Chondrites* common. Wispy laminations (possible solution features common).

SMEAR SLIDE SUMMARY (%)

	1, 15 D	2, 48
Composition:		
Quartz	5	10
Carbonate unspec.*	10	5
Calc. nannofossils	83	75
Diatoms	TR	–
Radiolarians	TR	TR
Sponge spicules	2	10

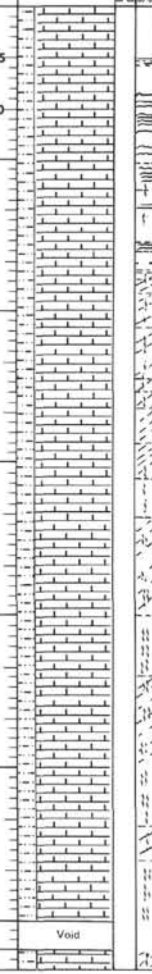
*Detrital

ORGANIC CARBON AND CARBONATE (%)

	2, 15–16
Organic carbon	–
Carbonate	91

SITE 610 HOLE CORE 27 CORED INTERVAL 713.4–723.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
	C. dissimilis / NN3 *Sphenolithus belemnos* Zone	CM	AP	FG	FG; CM; RP; FM		1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	Void (Section 7)			* * *	



Colors: N9/1; 5GY 6/1; N9/1 to 5GY 8/1; 5GY 7/1; N9/1; 5GY 7/1; 5GY 6/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 8/1; 5GY 7/1; 5GY 7/1 to 5GY 8/1

NANNOFOSSIL CHALK, variously colored from green to white. Highly mottled with abundant wispy lamination and stylolites. Below 2.30 m, predominantly inclined bedding. Pyrite patches and laminae common. Slightly siliceous.

SMEAR SLIDE SUMMARY (%)

	1, 56	1, 23	1, 24
Composition:			
Quartz	–	5	15
Clay	5	5	5
Pyrite	–	–	TR
Carbonate unspec.	10	10	10
Foraminifers	1	TR	–
Calc. nannofossils	63	80	60
Diatoms	TR	–	–
Radiolarians	1	–	TR
Sponge spicules	10	TR	10

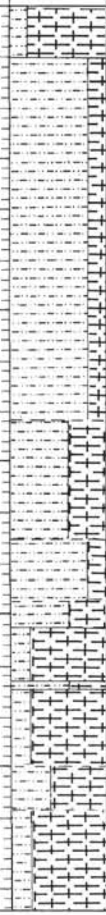
ORGANIC CARBON AND CARBONATE (%)

	1, 55–56
Organic carbon	–
Carbonate	65

Note: Core Catcher is 34 cm long.

SITE 610 HOLE A CORE 1 CORED INTERVAL 0.0–9.0 m

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



Biostratigraphic zones: N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone; *Pseudoeunotia doliolus* Zone

Fossil character: AG AG B CM

Sections: 1 (0.5, 1.0), 2, 3, 4, 5, 6, CC

Colors: 2.5Y 7/4, 2.5Y 6/2, 2.5Y 7/3, 2.5Y 6/2, 2.5Y 8/2, 2.5Y 8/2; 2.5Y 7/2 to 5Y 5/2; 5Y 5/2; 5GY 6/1, 10G 6/2, 5GY 6/1; N6/1 to 5GY 6/1; N5/1, 5Y 5/3; N5/1, 5Y 5/3, 5Y 6/3, 5Y 7/2; N7/1; 5Y 7/2; N6/1 to N7/1; N7/1 to 2.5Y 7/2; N7/1; N7/1

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, light gray to olive gray and brown. Gradational boundaries. Burrow mottling. Occasional gray green layers (5G 5/2–5G 7/2). *Zoophycos* and open burrows common. Pyrite halos in ooze layers. Sandsized ice-rafted debris common in calcareous mud layers.

SMEAR SLIDE SUMMARY (%)

	1, 19 M	1, 140 D	5, 35 D
Composition:			
Quartz	2	67	2
Feldspar	–	–	1
Heavy minerals	3	5	TR
Clay	3	15	3
Volcanic glass	1	1	2
Micronodules	4	–	–
Carbonate unspec.	3	9	2
Foraminifers	18	1	10
Calc. nannofossils	66	2	80
Diatoms	–	–	TR
Sponge spicules	TR	–	TR

ORGANIC CARBON AND CARBONATE (%)

	2, 110–111	5, 110–111
Organic carbon	–	–
Carbonate	20	67

SITE 610 HOLE A CORE 2 CORED INTERVAL 9.0–18.6 m

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

Biostratigraphic zones: N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone; NN20 *Gephyrocapsa oceanica* Zone

Fossil character: B; AG AG B B

Sections: 1 (0.5, 1.0), 2, 3, 4, 5, 6, 7, CC

Colors: 5Y 5/2; 5GY 6/1, 2.5Y 6/2 to 6/4, 5Y 7/2; 5Y 7/2 to N7/1; N7/1 to N6/1; N7/1; 5Y 5/2; N7/1; 2.5Y 6/2; 2.5Y 5/2; N5 to 2.5Y 5/2; N2/1; 2.5Y 5/2; 5Y 5/3; 2.5Y 6/2; N7/1; N7/1 to 5Y 6/1; N7/1, 5Y 7/1 to 6/1

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray and brown to very light gray. Gradational boundaries and mottling. Pumice pebbles at 6.90 m. Gneiss gravel dropstone at 7.43 m. Occasional bioturbated laminae of light gray green and gray.

Very deformed to moderately deformed above 6.00 m.

SMEAR SLIDE SUMMARY (%)

	5, 66 D	6, 98 D
Composition:		
Quartz	63	3
Feldspar	1	1
Heavy minerals	3	TR
Clay	10	7
Volcanic glass	4	2
Carbonate unspec.	12	2
Foraminifers	3	12
Calc. nannofossils	4	72

ORGANIC CARBON AND CARBONATE (%)

	5, 70–71	6, 83–84
Organic carbon	–	–
Carbonate	26	67

SITE 610 HOLE A CORE 3 CORED INTERVAL 18.6–28.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN20 *Gephyrocapsa oceanica* Zone; NN19 *Pseudoemiliania lacunosa* Zone; *Nitzschia reinholdii* Zone	AG	AG	B	AM	1–7, CC	0.5, 1.0

Colors: 5Y 7/1, 5Y 5/1, 5Y 5/2, 5Y 5/2, 2.5Y 6/2, 2.5Y 7/2, 2.5Y 6/2, N7/1, 2.5Y 6/2, N7/1 to N8/1, 5Y 7/2, 2.5Y 6/2, 2.5Y 5/2, 5Y 5/2, 5Y 4/2, 5Y 5/2, N4/1, 5Y 5/2, N4/1, 5Y 5/2 to 2.5Y 6/2, 5Y 5/2, 2.5Y 6/2, 2.5Y 5/2, 2.5Y 4/2, N7/1 to N8/1, 5Y 5/2, N8/1 to N9/1, 10YR 8/1, N8/1, 5Y 8/2, N8/1

LITHOLOGIC DESCRIPTION

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE (becoming NANNOFOSSIL OOZE below 7.30 m). Gradational boundaries with much mottling. Olive gray and brown to white and light gray. Gravel dropstones of basalt and tuff. Dark gray layer rich in volcanic ash at 6.27 to 6.35 m. Sharpbased volcanic ash beds at 5.04 to 5.06 and 5.28 to 5.30 m. *Zoophycos* and open burrows common.

SMEAR SLIDE SUMMARY (%)

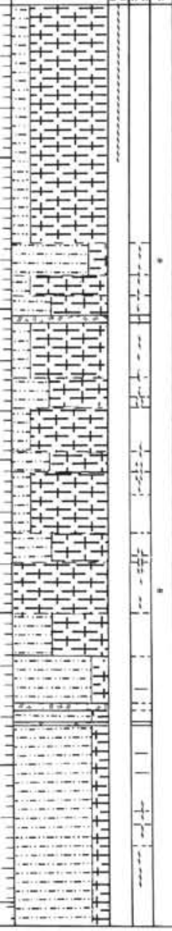
	5, 30 M	6, 55
Composition:		
Quartz	60	TR
Feldspar	–	TR
Heavy minerals	3	–
Clay	15	2
Volcanic glass	9	TR
Micronodules	1	–
Carbonate unspec.	5	1
Foraminifers	3	8
Calc. nannofossils	4	89

ORGANIC CARBON AND CARBONATE (%)

	3, 80–81
Organic carbon	–
Carbonate	72

SITE 610 HOLE A CORE 4 CORED INTERVAL 28.2–37.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG	B	B	1–6, CC	0.5, 1.0



Colors: N7/1 to N8/1, N6/1 to N7/1, N8/1, N6/1, N4/1, N6/1 to N7/1, 10YR 7/2, 2.5Y 6/2, N8/1 to 2.5Y 7/2, 5Y 6/1, 5Y 7/2, 5GY 7/1 to 2.5Y 6/2, N7/1, 5GY 7/1, 2.5Y 7/2, 2.5Y 6/2, 2.5Y 5/2, 5BG 4/1, N4/1, 2.5Y 5/2, N5/1, 2.5Y 5/2 to 5Y 6/1, 5Y 5/2, 5GY 5/1, 5Y 5/2, 2.5Y 6/2, 5Y 5/1 to 5Y 4/1

LITHOLOGIC DESCRIPTION

Interbedded CALCAREOUS MUD and NANNOFOSSIL OOZE with interval of NANNOFOSSIL FORAMINIFERAL OOZE at 5.48 to 6.00 m, olive gray and brown to very light gray. Burrow mottled with gray green and gray bioturbated laminae. Ashy intervals with sharp bases at 3.07 to 3.12, 6.88 to 6.94, and 7.04 to 7.06 m. Rare *Zoophycos*.

SMEAR SLIDE SUMMARY (%)

	2, 100 D	4, 125 –
Composition:	–	
Quartz	55	–
Feldspar	1	TR
Mica	–	TR
Heavy minerals	3	TR
Clay	15	2
Volcanic glass	4	TR
Carbonate unspec.	5	3
Foraminifers	3	40
Calc. nannofossils	14	55
Sponge spicules	TR	TR

ORGANIC CARBON AND CARBONATE (%)

	2, 100–101
Organic carbon	–
Carbonate	14

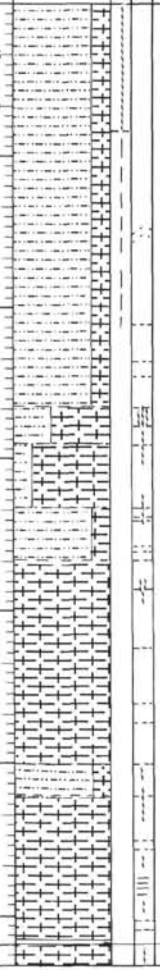
SITE 610 HOLE A CORE 5 CORED INTERVAL 37.8–47.4 m

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

Biostratigraphic zones: N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone

Fossil character: AG AG B B

Sections: 1 (0.5, 1.0), 2, 3, 4, 5, 6, 7, CC



N8/1
to
5Y 4/2
and
N3/1
2.5Y 6/2 to
N6/1
5G 6/2
N6/1
5Y 6/1
5Y 5/1
5Y 6/1
2.5Y 7/2
5Y 7/1
N8/1
5Y 5/2
5GY 5/1
10YR 6/2
5BG 5/1
2.5Y 6/2
2.5Y 7/2
10YR 8/1
to
N8/1
5G 7/2
10YR 8/1
10YR 7/2
10YR 8/1
to
10YR 7/1
10YR 7/1
to
10YR 6/2
N8/1
10YR 6/2
N8/1
to
N6/1
10YR 7/1
5Y 5/2
Void
5Y 5/2

Interbedded CA'.CAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray and brown to very light gray. Mottled with burrows. Gray green laminae common.

Highly to slightly disturbed 0.00 to 3.00 m.

SMEAR SLIDE SUMMARY (%)

	4, 14 D	4, 65 D
Composition:		
Quartz	TR	59
Feldspar	TR	2
Heavy minerals	–	5
Clay	1	15
Volcanic glass	1	4
Carbonate unspec.	1	11
Foraminifers	28	2
Calc. nannofossils	69	2

ORGANIC CARBON AND CARBONATE (%)

	4, 14–15
Organic carbon	–
Carbonate	81

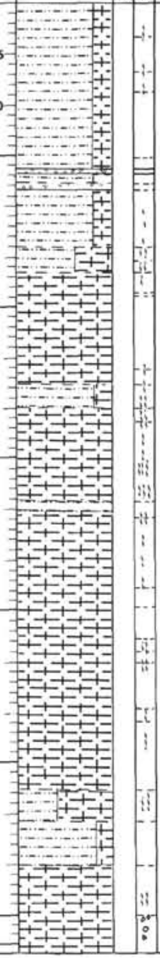
SITE 610 HOLE A CORE 6 CORED INTERVAL 47.4–57.0 m

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

Biostratigraphic zones: N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone; *Nitzschia reinholdii* Zone; RM

Fossil character: AG AG FG CM

Sections: 1 (0.5, 1.0), 2, 3, 4, 5, 6, 7, CC



10YR 5/2
5GY 7/1
10YR 6/2
5Y 6/1
5Y 5/1
N4/1
5Y 5/1
5BG 4/1
10YR 6/2
10YR 7/1
5Y 7/1
N8/1
5B 7/1
N8/1
5Y 7/2
5Y 5/1
5Y 6/1
5Y 7/1
5G 5/1
5Y 7/1
5G 5/1
5Y 6/1
5Y 7/1
5Y 5/1
5Y 7/1
5Y 5/1
5GY 7/1
5Y 7/1
to
10YR 7/1
5Y 6/1
10YR 6/2
N7/1–8/1

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light brown gray. Mottled and burrowed. Some sandy mud intervals and dropstones. Rare *Zoophycos*. Volcanic ash intervals with sharp bases at 1.63 to 1.65 and 1,77 to 1.85 m.

SMEAR SLIDE SUMMARY (%)

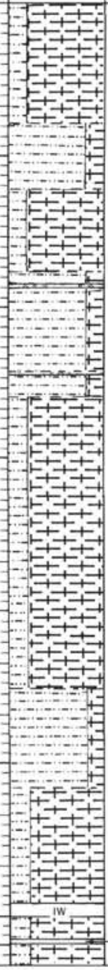
	2, 65 D	3, 30 D	4, 52 M
Texture:			
Sand	–	–	15
Silt	–	–	50
Clay	–	–	35
Composition:			
Quartz	59	–	54
Feldspar	1	TR	1
Mica	TR	–	TR
Heavy minerals	–	TR	5
Clay	15	5	30
Volcanic glass	4	1	5
Micronodules	TR	–	–
Carbonate unspec.	14	TR	3
Foraminifers	3	10	1
Calc. nannofossils	4	84	1
Sponge spicules	TR	TR	–

ORGANIC CARBON AND CARBONATE (%)

	4, 51–52
Organic carbon	–
Carbonate	1

SITE 610 HOLE A CORE 7 CORED INTERVAL 57.0–66.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG	FM; RM	RP	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	IW			*



Colors: N7/1; 10YR 6/2; 5Y 5/2; 5G 6/2; 5Y 5/2; 5GY 7/1; 5G 6/2; 5GY 7/1 to 5GY 6/1; 5Y 5/1; 5BG 4/1; 5Y 5/1; 10YR 5/2; 5GY 4/1; 2.5Y 5/2; 5GY 7/1; 5G 6/2; 5GY 7/1; 5GY 7/1; 5GY 7/1; 5G 5/1; 10YR 5/2; 5GY 7/1; 5G 6/2; 5GY 7/1 to 5Y 7/1; 5Y 7/1; Void; 5Y 7/1

LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD. Very light gray to light brown gray. Some sandy mud intervals. Ash-rich layers at 2.78 to 2.80 m and 3.62 to 3.65 m. Mottled. Occasional light gray green laminae. *Zoophycos* common.

SMEAR SLIDE SUMMARY (%)

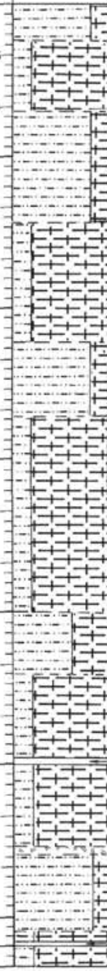
	3, 30	7, 5
	D	D
Texture:		
Sand	12	–
Silt	20	–
Clay	68	–
Composition:		
Quartz	50	–
Feldspar	1	TR
Heavy minerals	4	TR
Clay	20	15
Volcanic glass	2	1
Carbonate unspec.	6	–
Foraminifers	9	11
Calc. nannofossils	8	73
Sponge spicules	TR	TR

ORGANIC CARBON AND CARBONATE (%)

	3, 120–121
Organic carbon	–
Carbonate	69

SITE 610 HOLE A CORE 8 CORED INTERVAL 66.6–76.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone; *Nitzschia reinholdii* Zone	AG	AG	RM; FM	FM	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0				*



Colors: 2.5Y 5/2; 5GY 7/1 to 5Y 6/1; 5G 5/1; 5Y 6/1; 5Y 6/1; 5BY 4/1; 5Y 6/1; 5Y 5/1; 5Y 6/1; 5Y 5/1; 5Y 6/1; 5G 5/2; 5BG 5/2; 5Y 7/1; 5GY 7/1; 5Y 6/1 to 10YR 6/2; 5GY 7/1; N8/1 to 5GY 7/1; 5GY 7/1; 5Y 6/1; 5GY 7/1; OG; 5G 4/1; 5Y 6/1; 5Y 5/1; 5Y 6/1; 5Y 5/1; Void; N8/0; N8/0

LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD. Very light gray to light gray brown. Mottled. Pyrite halos common in ooze layers. Ashy interval at 8.30 to 8.37 m. Sharpbased.

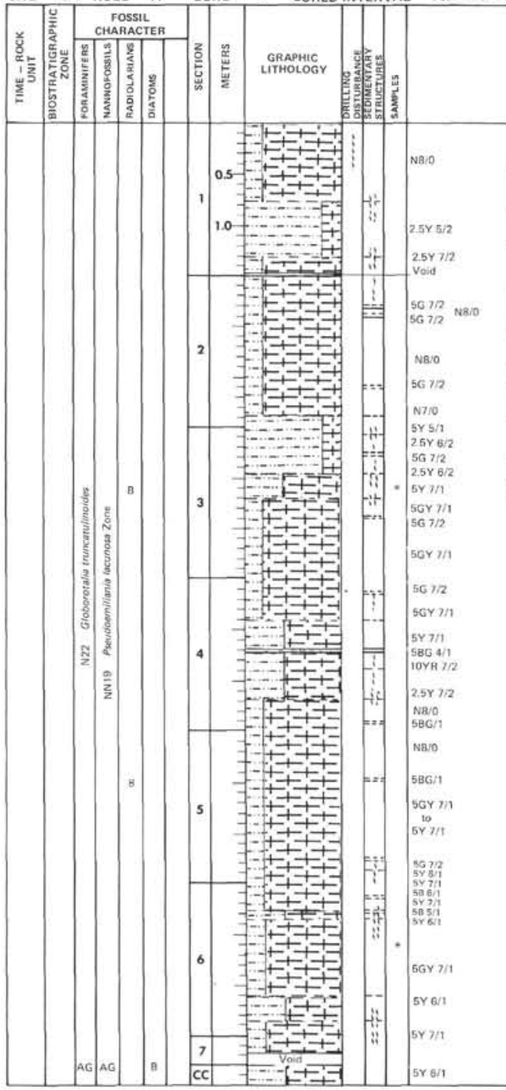
SMEAR SLIDE SUMMARY (%)

	2, 120
	D
Composition:	
Feldspar	1
Heavy minerals	TR
Clay	5
Foraminifers	12
Calc. nannofossils	80
Diatoms	1
Radiolarians	TR
Sponge spicules	1

ORGANIC CARBON AND CARBONATE (%)

	2, 38–39
Organic carbon	–
Carbonate	3

SITE 610 HOLE A CORE 9 CORED INTERVAL 76.2–85.8 m



LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE, MARLY NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light gray brown, mottled to homogeneous. Pyrite burrow casts. Volcanic ash-rich layer with sharp base at 5.19 to 5.22 m

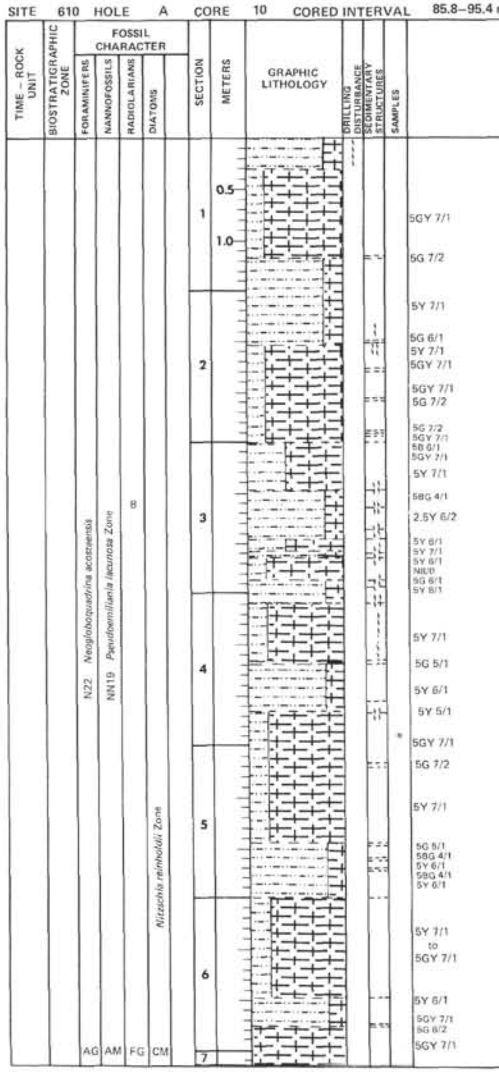
SMEAR SLIDE SUMMARY (%)

	3, 60	6, 58
	D	D
Composition:		
Quartz	30	16
Feldspar	1	–
Heavy minerals	TR	TR
Clay	10	–
Volcanic glass	TR	–
Carbonate unspec.	–	1
Foraminifers	16	11
Calc. nannofossils	43	72
Diatoms	–	TR
Sponge spicules	–	TR

ORGANIC CARBON AND CARBONATE (%)

	5, 65–66
Organic carbon	–
Carbonate	75

SITE 610 HOLE A CORE 10 CORED INTERVAL 85.8–95.4 m



LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light gray brown, mottled to homogeneous. Pyrite patches in oozes. Gray green layers common. Volcanic ash-rich layers with gradational bases at 3.50 to 3.67 m, 5.15 to 5.18 m, and 7.10 to 7.20 m.

SMEAR SLIDE SUMMARY (%)

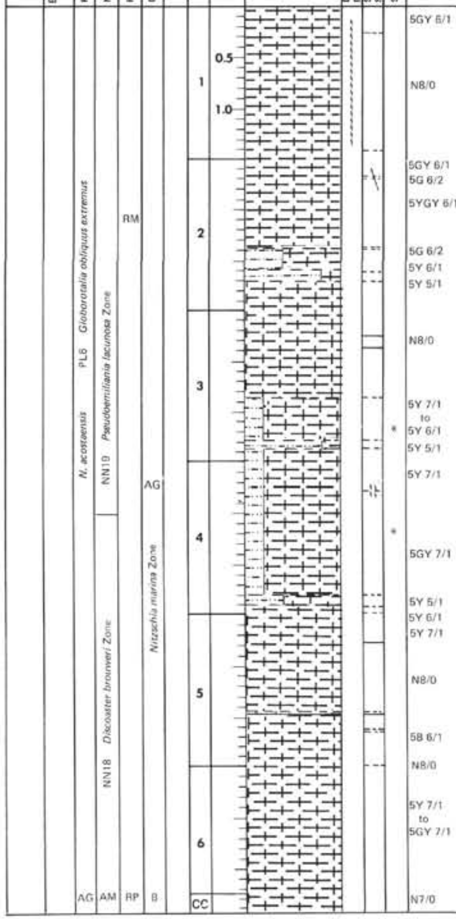
	4, 140
	D
Composition:	
Clay	25
Carbonate unspec.	2
Foraminifers	10
Calc. nannofossils	60
Diatoms	2
Radiolarians	TR
Sponge spicules	1
Silicoflagellates	TR

ORGANIC CARBON AND CARBONATE (%)

	4, 110–111
Organic carbon	–
Carbonate	3

SITE 610 HOLE A CORE 11 CORED INTERVAL 95.4–105.0 m

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



Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light gray. Homogeneous with a few mottled intervals at gradational boundaries. Gray green laminae common. Volcanic ash-rich bed with sharp base at 6.95 to 6.97 m.

SMEAR SLIDE SUMMARY (%)

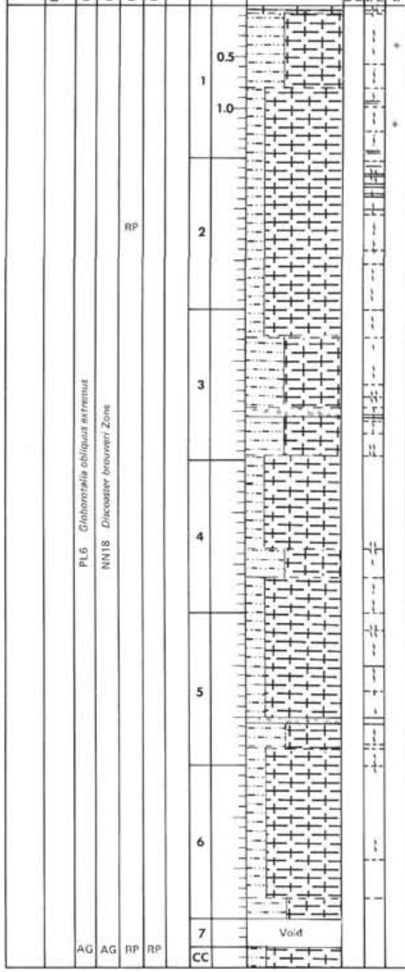
	3, 120 M	4, 65 D
Composition:		
Feldspar	–	1
Heavy minerals	TR	TR
Clay	40	15
Volcanic glass	TR	–
Foraminifers	12	12
Calc. nannofossils	47	69
Diatoms	TR	2
Radiolarians	–	TR
Sponge spicules	1	1
Silicoflagellates	–	TR

ORGANIC CARBON AND CARBONATE (%)

	3, 129–130
Organic carbon	–
Carbonate	22

SITE 610 HOLE A CORE 12 CORED INTERVAL 105.0–114.6 m

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



FORAMINIFERAL NANNOFOSSIL OOZE with marly intervals and volcanic ash layers with sharp bases at 4.03 to 4.05 m and 7.02 to 7.06 m. Slightly mottled to homogeneous, with extensive pyrite mottles.

SMEAR SLIDE SUMMARY (%)

	1, 40 D	1, 115 D	3, 104 M
Texture:			
Sand	–	–	5
Silt	–	–	55
Clay	–	–	40
Composition:			
Quartz	30	25	35
Feldspar	–	–	5
Mica	TR	–	10
Heavy minerals	TR	TR	2
Clay	5	–	25
Volcanic glass	3	–	20
Glauconite	–	–	TR
Carbonate unspec.	10	10	–
Foraminifers	2	3	TR
Calc. nannofossils	50	62	5

ORGANIC CARBON AND CARBONATE (%)

	1, 37–38
Organic carbon	
Carbonate	44

SITE 610 HOLE A CORE 13 CORED INTERVAL 114.6–124.2 m

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

Biostratigraphic zones: Foraminifers: PL3–5 undifferentiated; Nannofossils: NN18 *Discoaster brouweri* Zone; Diatoms: *Nitzschia marina* Zone

Fossil character: CG; AG; AG AG RP RP

Sections: 1, 2, 3, 4, 5, 6, 7, CC; Meters: 0.5, 1.0

Colors: 5Y 8/1, 5Y 5/1, N8/0, 5Y 8/1, 5Y 7/1, 5Y 6/1, N8/0 to 5Y 8/1, 5Y 7/1, 5Y 6/1, N8/0, 5Y 6/1, 5Y 5/1, N8/0, OG, 5Y 6/2, 5Y 2/1, 5Y 5/2, N8/0, 5Y 8/1, Void, 5Y 6/1, 5Y 7/1

SILICEOUS NANNOFOSSIL OOZE with marly intervals, very light gray to light gray. Mottled with olive gray and gray mottles. Volcanic ash lamina at 5.47 m; ash bed at 7.91 to 7.98 m.

SMEAR SLIDE SUMMARY (%)

	2, 80 D	4, 88
Composition:		
Quartz	–	20
Feldspar	–	2
Mica	–	TR
Heavy minerals	–	4
Clay	10	–
Volcanic glass	–	5
Glauconite	–	TR
Carbonate unspec.	10	15
Foraminifers	5	2
Calc. nannofossils	64	50
Diatoms } Radiolarians }	1	} 2
Sponge spicules	10	}

ORGANIC CARBON AND CARBONATE (%)

	2, 80–82
Organic carbon	–
Carbonate	82

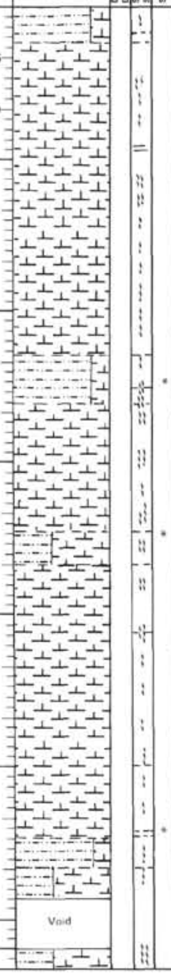
SITE 610 HOLE A CORE 14 CORED INTERVAL 124.2–133.8 m

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

Biostratigraphic zones: Foraminifers: PL3–5 undifferentiated; Nannofossils: NN18 *Discoaster brouweri* Zone; NN17 *Discoaster pentaradiatus* Zone; Diatoms: *Nitzschia marina* Zone

Fossil character: AG; AG AG RM CM

Sections: 1, 2, 3, 4, 5, 6, 7, CC; Meters: 0.5, 1.0



Colors: 5Y 5/1, 5Y 6/1, N9/0, N9/0, 5Y 5/1, 5Y 6/1, 5Y 8/1, 5Y 8/1, 5Y 7/1, 5Y 8/1, N8/0 to N9/0, 5Y 7/1, 5GY 4/1, 5Y 6/1, 5Y 7/1, Void, 5Y 7/1

Interbedded NANNOFOSSIL OOZE and CALCAREOUS MUD with marly and siliceous intervals. Mottled with gray (pyrite) and gray-green. *Zoophycos* common.

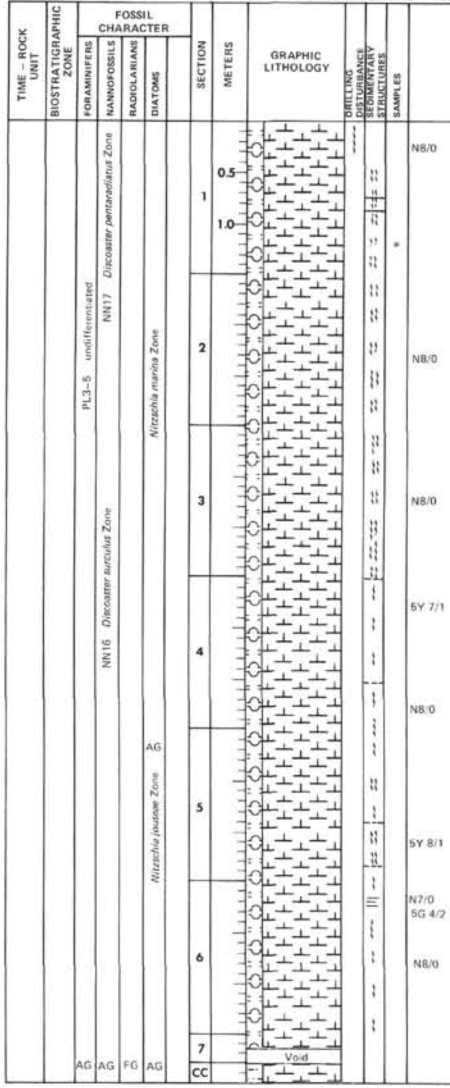
SMEAR SLIDE SUMMARY (%)

	3, 70 M	4, 70 D	6, 66 M
Texture:			
Sand	3	–	–
Silt	32	–	–
Clay	65	–	–
Composition:			
Quartz	25	10	15
Feldspar	–	–	2
Mica	2	TR	–
Heavy minerals	–	–	2
Clay	10	–	–
Volcanic glass	3	–	1
Glauconite	TR	–	TR
Carbonate unspec.	10	7	25
Foraminifers	2	3	TR
Calc. nannofossils	40	70	57
Diatoms	TR	1	–
Radiolarians	1	2	–
Sponge spicules	7	7	–
Silicoflagellates	–	TR	–
?Dolomite	–	TR	–
Acicular crystals	–	–	2

ORGANIC CARBON AND CARBONATE (%)

	4, 70–71
Organic carbon	–
Carbonate	86

SITE 610 HOLE A CORE 15 CORED INTERVAL 133.8–143.4 m



LITHOLOGIC DESCRIPTION

SILICEOUS NANNOFOSSIL OOZE, very light gray with darker gray and green gray mottles. Pale green gray laminae and pyrite patches.

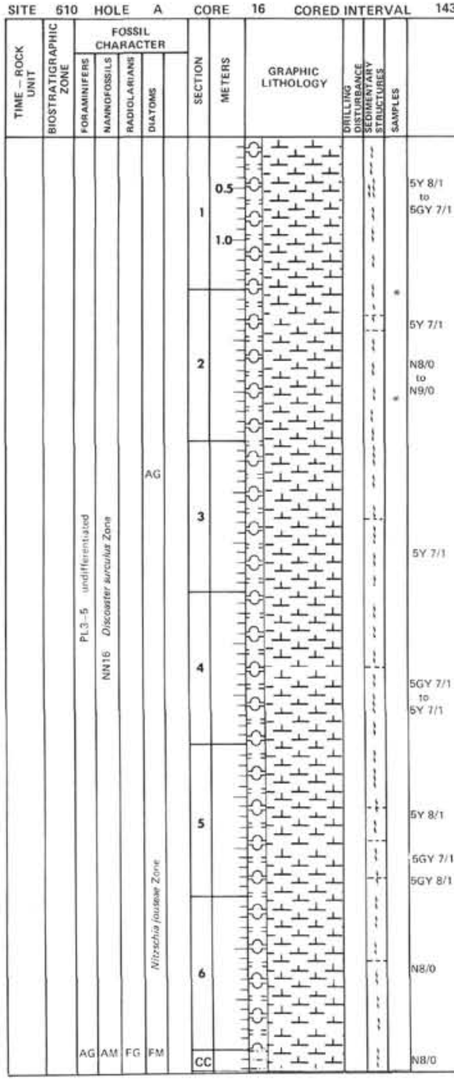
SMEAR SLIDE SUMMARY (%)

	1, 120	4, 21
	D	–
Composition:		
Quartz	5	5
Volcanic glass	–	TR
Carbonate unspec.	2	2
Foraminifers	10	2
Calc. nannofossils	67	77
Diatoms	1	1
Radiolarians	–	TR
Sponge spicules	15	12
Silicoflagellates	TR	1

ORGANIC CARBON AND CARBONATE (%)

	1, 120–121
Organic carbon	–
Carbonate	86

SITE 610 HOLE A CORE 16 CORED INTERVAL 143.4–153.0 m



LITHOLOGIC DESCRIPTION

SILICEOUS NANNOFOSSIL OOZE, very light gray with darker gray and green gray mottles and/or diffuse laminae. Pyrite patches.

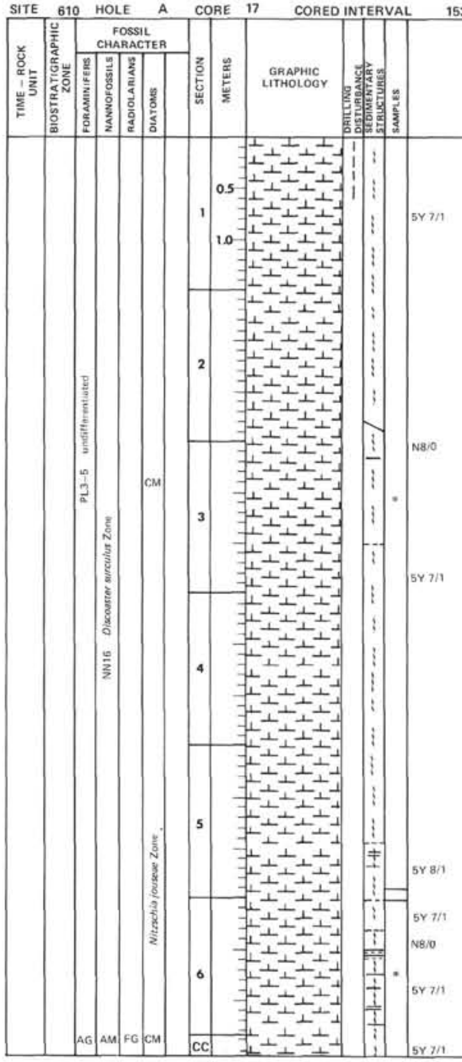
SMEAR SLIDE SUMMARY (%)

	2, 3	2, 106
	D	D
Composition:		
Quartz	10	–
Pyrite	2	–
Carbonate unspec.	3	TR
Foraminifers	7	8
Calc. nannofossils	68	82
Diatoms	2	2
Radiolarians	2	2
Sponge spicules	6	6

ORGANIC CARBON AND CARBONATE (%)

	2, 5–6
Organic carbon	–
Carbonate	66

SITE 610 HOLE A CORE 17 CORED INTERVAL 153.0–162.6 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray with darker gray and green gray mottles and/or diffuse laminae. Pyrite patches.

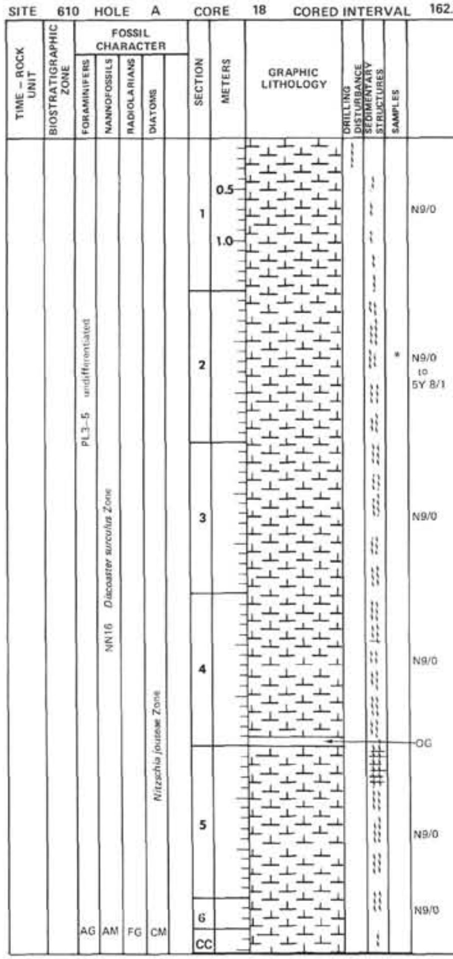
SMEAR SLIDE SUMMARY (%)

	3, 50	6, 70
	D	D
Composition:		
Quartz	10	5
Volcanic glass	–	TR
Carbonate unspec.	5	–
Foraminifers	8	3
Calc. nannofossils	71	80
Diatoms	1	TR
Radiolarians	2	TR
Sponge spicules	3	2

ORGANIC CARBON AND CARBONATE (%)

Section–Interval (cm)	3, 50–51
Organic carbon	–
Carbonate	87

SITE 610 HOLE A CORE 18 CORED INTERVAL 162.6–172.2 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white to very light gray. Mottled with gray and pale gray green. Gray green diffuse laminae common.

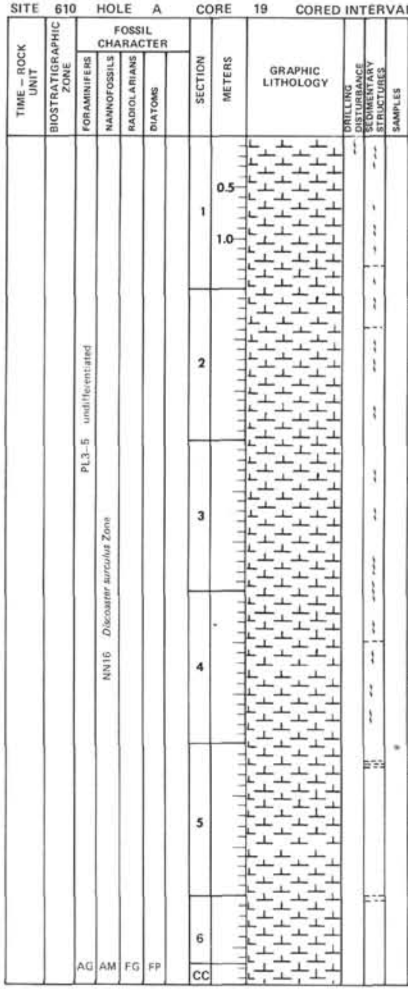
SMEAR SLIDE SUMMARY (%)

	2, 65
	D
Composition:	
Quartz	2
Carbonate unspec.	5
Foraminifers	5
Calc. nannofossils	87
Diatoms	1
Radiolarians	TR
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE (%)

Section–Interval (cm)	2, 65–66
Organic carbon	–
Carbonate	93

SITE 610 HOLE A CORE 19 CORED INTERVAL 172.2–181.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white to very light gray. Mottled with gray pyrite and light green gray. Occasional green gray laminae.

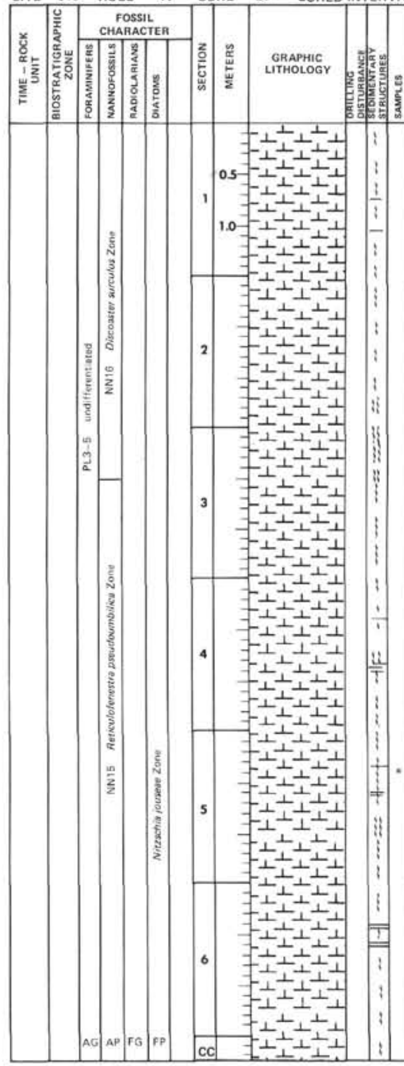
SMEAR SLIDE SUMMARY (%)

	5, 8
	D
Composition:	
Quartz	10
Carbonate unspec.	3
Foraminifers	2
Calc. nannofossils	83
Diatoms	1
Radiolarians	TR
Sponge spicules	1
Silicoflagellates	TR

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	5, 7–8
Organic carbon	—
Carbonate	85

SITE 610 HOLE A CORE 20 CORED INTERVAL 181.8–191.4 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, mottled with pyrite, white to gray. Common diffuse green laminations.

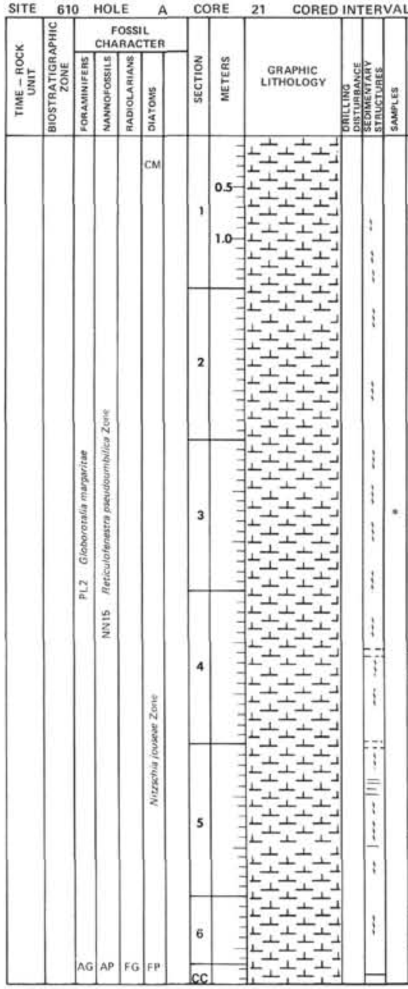
SMEAR SLIDE SUMMARY (%)

	5, 40
	D
Composition:	
Quartz	10
Carbonate unspec.	5
Foraminifers	5
Calc. nannofossils	79
Diatoms, Radiolarians, Sponge spicules	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	5, 40–41
Organic carbon	—
Carbonate	93

SITE 610 HOLE A CORE 21 CORED INTERVAL 191.4–201.0 m



LITHOLOGIC DESCRIPTION

N9/0

N9/0

N9/0

5Y 7/1

N9/0

N9/0

N9/0 to 5GY 8/1

N8/0 to N9/0

NANNOFOSSIL OOZE, white to gray, with pyrite mottles and pale green gray diffuse laminae.

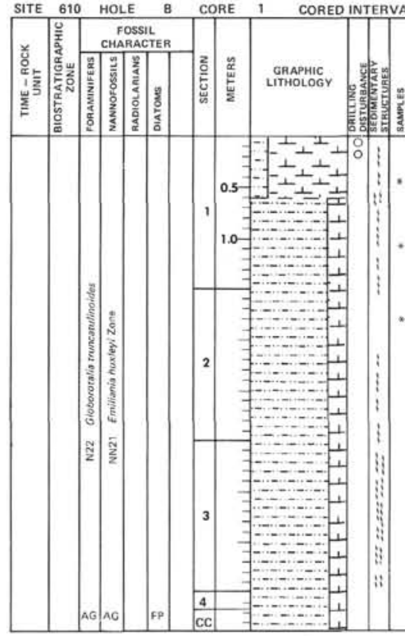
SMEAR SLIDE SUMMARY (%)

	3, 70
	D
Composition:	
Quartz	10
Carbonate unspec.	3
Foraminifers	5
Calc. nannofossils	80
Sponge spicules	2

ORGANIC CARBON AND CARBONATE (%)

	3, 70–71
Organic carbon	–
Carbonate	92

SITE 610 HOLE B CORE 1 CORED INTERVAL 0.0–4.8 m



LITHOLOGIC DESCRIPTION

10YR 6/4

5Y 5/2

5Y 5/2

5Y 5/3

CALCAREOUS MUD with thin interval of NANNOFOSSIL OOZE (0.00 to 0.80 m). Olive gray and yellow brown. Mottled. Common open burrows and diffuse gray green laminae. Occasional dropstones. Volcanic ash-rich interval at 1.57 to 1.85 m.

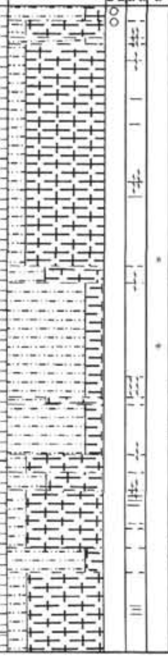
SMEAR SLIDE SUMMARY (%)

	1, 40	1, 105	2, 25
	D	D	M
Composition:			
Quartz	5	20	5
Feldspar	5	5	5
Heavy minerals	2	–	TR
Clay	–	–	30
Volcanic glass	5	3	25
Carbonate unspec.	20	15	25
Foraminifers	2	5	–
Calc. nannofossils	60	48	10
Sponge spicules	TR	–	–
Organic matter	1	2	–

SITE 610 HOLE B CORE 2 CORED INTERVAL 4.8–14.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone	AG	AG		B	1, 2, 3, 4, 5, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

2.5Y 5/2
N8/0
10YR 5/2
N8/0
5Y 7/1 to 2.5Y 7/1
5Y 7/1
2.5Y 7/1
2.5Y 5/2
2.5Y 6/2
5Y 6/1
10YR 7/1
10YR 6/2
5Y 7/1
5Y 5/1
5Y 6/1 to 5Y 7/1
5Y 7/1

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to olive gray and brown. Homogeneous to mottled with burrows and pyrite halos. Occasional green gray diffuse lamine. Abundant dropstones.

SMEAR SLIDE SUMMARY (%)

	2, 100	3, 35
	D	D
Composition:		
Quartz	–	54
Feldspar	TR	1
Heavy minerals	TR	5
Clay	3	20
Volcanic glass	TR	2
Carbonate unspec.	1	12
Foraminifers	13	3
Calc. nannofossils	83	3
Diatoms	TR	–
Radiolarians	TR	–
Sponge spicules	TR	–
Silicoflagellates	TR	–

SITE 610 HOLE B CORE 3 CORED INTERVAL 14.4–24.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN20 *Gephyrocapsa oceanica* Zone	AG	AG		FP	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

5Y 7/1
2.5Y 5/2
5Y 7/1
5Y 5/1
10YR 6/2
5Y 7/1
5GY 7/1
5Y 6/1 to 5Y 7/1
5Y 7/1
5GY 7/1
5Y 6/1
5GY 7/1
5Y 6/1
5Y 7/1
5Y 5/1
N4/0
5Y 5/2
10YR 6/2
5Y 7/1

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to olive gray and brown. Mottled. Pyrite halos. *Zoophycos* rare. Volcanic ash-rich layer at 7.80 m.

Very deformed bedding 0.00 to 3.80 m, inclined bedding at 5.00 to 7.50 m.

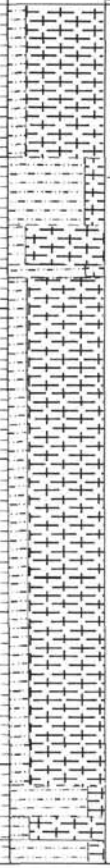
SMEAR SLIDE SUMMARY (%)

	3, 95	5, 85
	D	D
Composition:		
Quartz	58	–
Feldspar	1	–
Clay	25	4
Carbonate unspec.	10	1
Foraminifers	5	12
Calc. nannofossils	1	83
Radiolarians	–	TR
Sponge spicules	–	TR

SITE 610 HOLE B CORE 4 CORED INTERVAL 24.0–33.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG		RP	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

N7/0
5Y 6/1
5Y 5/1
5Y 6/1
N8/0 to 5Y 7/1
5Y 7/1
N8/0 to 10YR 7/1
N8/0
N8/0 to 5GY 7/1
5Y 7/1
N8/0 to 5Y 7/1
5Y 7/1
5Y 6/1
5GY 7/1
5Y 6/1

LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Occasional gray green laminae.

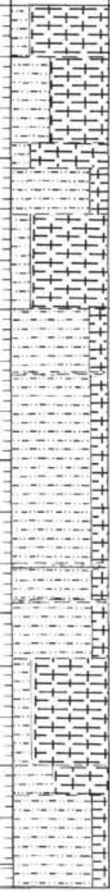
SMEAR SLIDE SUMMARY (%)

	2, 112 D	2, 140 D
Composition:		
Quartz	63	–
Feldspar	1	TR
Heavy minerals	3	TR
Clay	15	TR
Volcanic glass	4	TR
Carbonate unspec.	3	1
Foraminifers	3	10
Calc. nannofossils	8	89
Sponge spicules	TR	–

SITE 610 HOLE B CORE 5 CORED INTERVAL 33.6–43.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG		B	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

N8/0
5Y 7/1 to 5GY 7/1
5Y 7/1
10YR 6/2
5GY 7/1
5Y 6/1
5BG 4/1
5Y 6/1
5G 6/1
5Y 5/1
5G 5/1
5Y 6/1 to 5Y 5/1
5G 4/1
5Y 5/1
5Y 4/1
N8/0 to 5GY 7/1
5Y 7/1 to 5Y 6/1
5Y 5/1
5Y 5/1

LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Volcanic ash-rich layers at 3.60 to 3.62 m, 5.49 to 5.53 m, and 5.85 to 5.87 m.

Highly disturbed by coring 0.0 to 3.0 m.

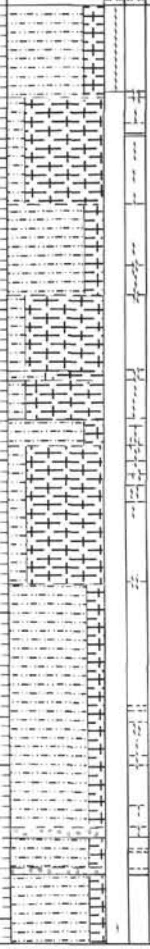
Inclined bedding at 6.80 to 7.10 m.

SMEAR SLIDE SUMMARY (%)

	3, 105 D	5, 85 D
Texture:		
Sand	10	–
Silt	25	–
Clay	65	–
Composition:		
Quartz	42	–
Feldspar	1	TR
Heavy minerals	4	TR
Clay	20	1
Volcanic glass	4	TR
Carbonate unspec.	8	–
Foraminifers	9	10
Calc. nannofossils	12	89
Sponge spicules	–	TR

SITE 610 HOLE B CORE 6 CORED INTERVAL 43.2–52.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	N22 *Globorotalia truncatulinoides* / NN19 *Pseudoemiliania lacunosa* Zone	AG	CG		B	1, 2, 3, 4, 5, 6, CC	0.5, 1.0				*



5Y 7/1 to 5Y 4/1
5Y 6/1
5Y 7/1
N8/0 to 5Y 7/1
5Y 5/1 to 5Y 6/1
5Y 5/1
N8/0
5Y 6/1
5Y 7/1 to N8/0
2.5Y 5/2
N8/0
5Y 7/1
N8/0
5Y 7/1
N8/0 to 5Y 7/1
2.5Y 5/2 to 5Y 5/3
5G 5/1
2.5Y 5/2
5GY 6/1
2.5Y 6/2
2.5Y 5/2
5GY 6/1
5Y 5/1
5G 4/1
2.5Y 4/2
5G 4/1
2.5Y 4/2
2.5Y 5/2

LITHOLOGIC DESCRIPTION

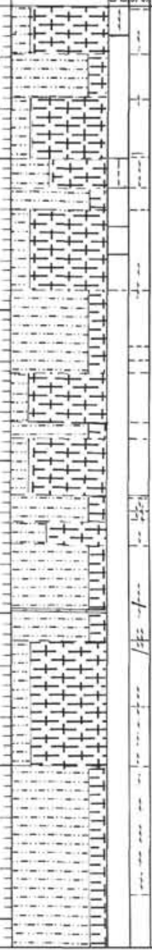
Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Occasional dropstones and gray green laminae. Rare *Zoophycos*. Volcanic ash layers with sharpbases at 8.13 to 8.20 m and 8.50 to 8.57 m. Coring disturbance 0.00 to 0.85 m.

SMEAR SLIDE SUMMARY (%)

	1, 125 D	5, 30 D
Composition:		
Quartz	–	68
Feldspar	TR	–
Heavy minerals	–	3
Clay	TR	18
Volcanic glass	TR	2
Carbonate unspec.	1	8
Foraminifers	11	4
Calc. nannofossils	88	7
Diatoms	TR	–
Sponge spicules	TR	–

SITE 610 HOLE B CORE 7 CORED INTERVAL 52.8–62.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	N22 *Globorotalia truncatulinoides* / NN19 *Pseudoemiliania lacunosa* Zone	AG	CG		B	1, 2, 3, 4, 5, 6, 7	0.5, 1.0				* *



2.5Y 5/2
N8/0 to N7/0
5Y 6/1 to 5Y 5/1
5GY 7/1 to 5Y 7/1
5Y 7/1 to 5Y 6/1
5G 5/1
5Y 7/1 to 5GY 6/1
5GY 5/1 to 5Y 5/1
5Y 6/1
5Y 5/1
5Y 7/1
5Y 5/1
5GY 7/1
5Y 8/1
5GY 6/1
5GY 5/1
5GY 6/1
2.5Y 6/2
5GY 7/1 to N8/0
5GY 7/1
5Y 5/1

LITHOLOGIC DESCRIPTION

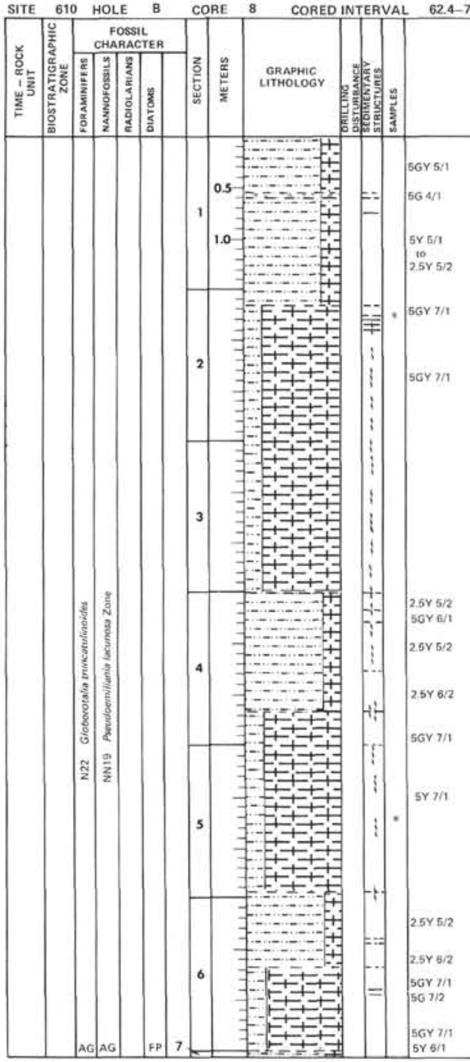
Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Rare *Zoophycos*. Volcanic ash-rich bed at 5.90 m. Inclined laminae at 5.90 and 6.35 m.

SMEAR SLIDE SUMMARY (%)

	5, 5 D	5, 60 D
Texture:		
Sand	15	–
Silt	25	–
Clay	60	–
Composition:		
Quartz	48	–
Feldspar	1	TR
Heavy minerals	3	–
Clay	25	TR
Volcanic glass	3	TR
Carbonate unspec.	6	–
Foraminifers	10	15
Calc. nannofossils	4	84
Diatoms	–	1
Radiolarians	–	TR
Sponge spicules	TR	TR
Silicoflagellates	–	TR

Note: Section 7 is 37 cm long.

SITE 610 HOLE B CORE 8 CORED INTERVAL 62.4–72.0 m



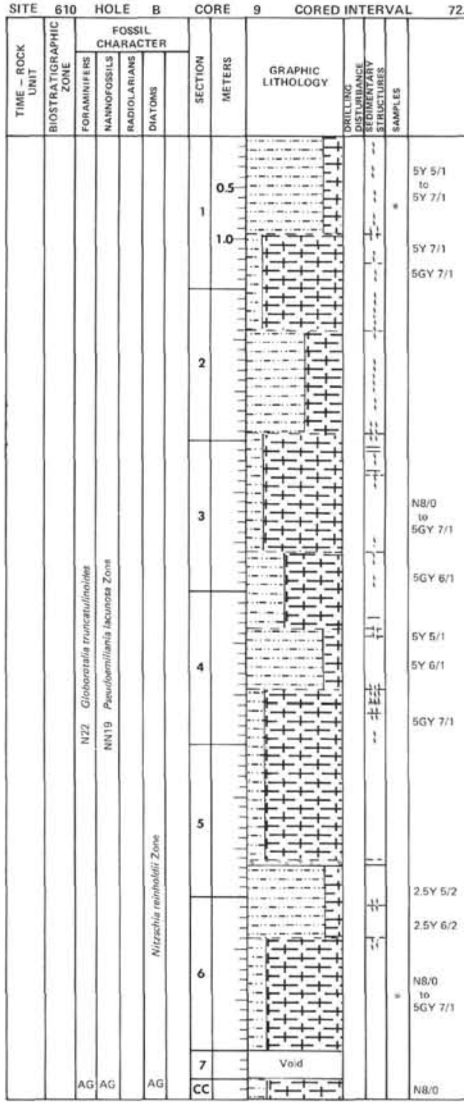
LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Rare *Zoophycos*. Volcanic ash-rich layer at 0.53 to 0.58 m. Foraminiferal sand at 1.74 to 1.76 m.

SMEAR SLIDE SUMMARY (%)

	2, 25 M	5, 70 D
Composition:		
Quartz	4	–
Heavy minerals	2	1
Clay	5	4
Volcanic glass	3	TR
Pyrite	10	2
Carbonate unspec.	3	–
Foraminifers	56	11
Calc. nannofossils	15	79
Diatoms	—	2
Radiolarians	TR	TR
Sponge spicules	2	1

SITE 610 HOLE B CORE 9 CORED INTERVAL 72.0–81.6 m



LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled. Rare *Zoophycos*. Rare dropstones. Volcanic ash-rich bed at 7.13 to 7.19 m.

SMEAR SLIDE SUMMARY (%)

	1, 65 D	6, 90 D
Composition:		
Quartz	67	–
Feldspar	1	TR
Heavy minerals	3	–
Clay	15	8
Volcanic glass	3	–
Micronodules	TR	–
Carbonate unspec.	7	TR
Foraminifers	2	12
Calc. nannofossils	2	80
Diatoms	–	1
Radiolarians	–	TR
Sponge spicules	TR	TR
Silicoflagellates	TR	–

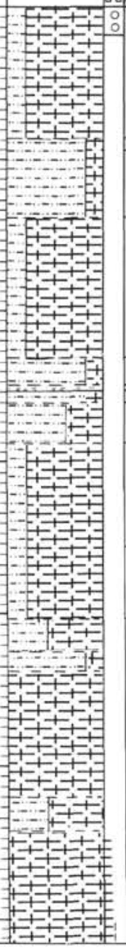
SITE 610 HOLE B CORE 10 CORED INTERVAL 81.6–91.2 m

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

Biostratigraphic zones: N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone; *Nitzschia reinholdii* Zone

Fossil character: AG AG FM

Sections: 1, 2, 3, 4, 5, 6, CC (0.5, 1.0 m)



N7/0 to 5GY 6/1; 5Y 5/1; 5Y 6/1 to 5Y 7/1; 5GY 7/1 to 5Y 7/1; 10YR 6/2; 5G 4/1; 10YR 6/2; 5Y 7/1; N8/0; 5GY 7/1; 5Y 7/1; 5Y 6/1; N8/0; 5GY 7/1; N8/0; N7/0

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE, NANNOFOSSIL OOZE, and CALCAREOUS MUD, very light gray to light olive gray and light brown. Mottled or homogeneous. Dropstones. Volcanic ash-rich layer at 3.71 to 3.76 m.

SMEAR SLIDE SUMMARY (%)

	5, 100
	D
Composition:	
Feldspar	TR
Heavy minerals	TR
Clay	3
Volcanic glass	1
Pyrite	TR
Carbonate unspec	1
Foraminifers	10
Calc. nannofossils	85

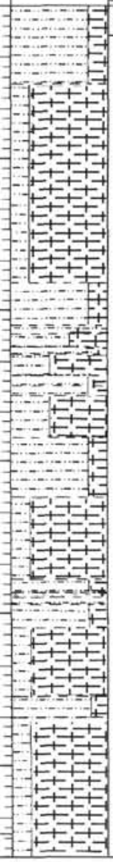
SITE 610 HOLE B CORE 11 CORED INTERVAL 91.2–100.8 m

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

Biostratigraphic zones: PL6 *Globorotalia obliquus extremus*; NN18 *Discoaster brouweri* Zone?; *Nitzschia reinholdii* Zone

Fossil character: AG AG CM

Sections: 1, 2, 3, 4, 5, 6, CC (0.5, 1.0 m)



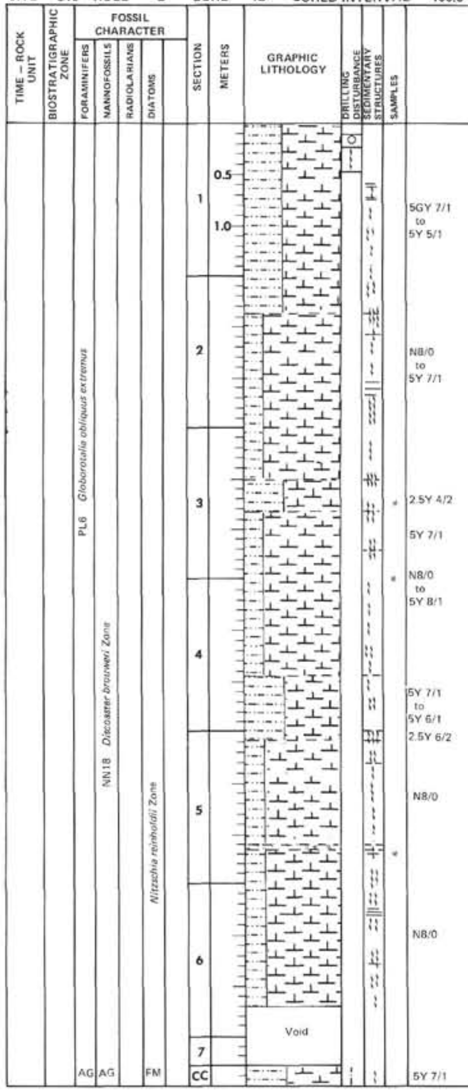
2.5Y 5/2; 5GY 7/1; 5GY 4/1; 2.5Y 5/2; 5Y 5/1, 5Y 6/1, 5GY 5/1, 5Y 7/1, 5GY 5/1, 5Y 6/1; 5Y 7/1; 5Y 6/1, 5GY 5/1, 5Y 6/1, 2.5Y 6/2, 5Y 5/1; 5GY 7/1 to 5Y 7/1; 2.5Y 6/2, 5Y 7/1, 5GY 4/1; 5Y 6/1; 5Y 7/1; 2.5Y 5/2; 5GY 7/1; 5GY 7/1

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to light olive gray. Mottled or homogeneous. Volcanic ash at 5.83 to 5.90 m.

SMEAR SLIDE SUMMARY (%)

	4, 56
	M
Composition:	
Quartz	TR
Feldspar	TR
Clay	1
Volcanic glass	TR
Carbonate unspec.	1
Foraminifers	13
Calc. nannofossils	84
Diatoms	1
Sponge spicules	TR
Silicoflagellates	TR

SITE 610 HOLE B CORE 12 CORED INTERVAL 100.8–110.4 m



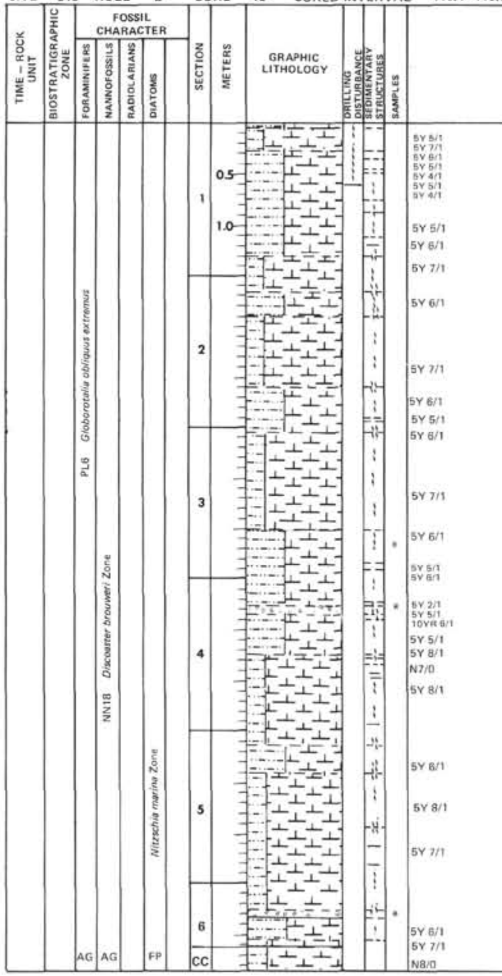
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE with marly intervals, very light gray to pale olive gray. Mottled with pale green gray laminae. Pyrite mottles common. Volcanic ash-rich interval at 7.10 to 7.14 m.

SMEAR SLIDE SUMMARY (%)

	3, 70 D	3, 142 D	5, 113 M
Composition:			
Quartz	15	–	–
Feldspar	–	TR	–
Volcanic glass	1	1	35
Glauconite	–	–	TR
Pyrite	–	–	35
Carbonate unspec.	15	10	15
Foraminifers	8	3	–
Calc. nannofossils	60	75	5
Diatoms	} 1	2	–
Radiolarians		1	–
Sponge spicules		3	–

SITE 610 HOLE B CORE 13 CORED INTERVAL 110.4–118.0 m



LITHOLOGIC DESCRIPTION

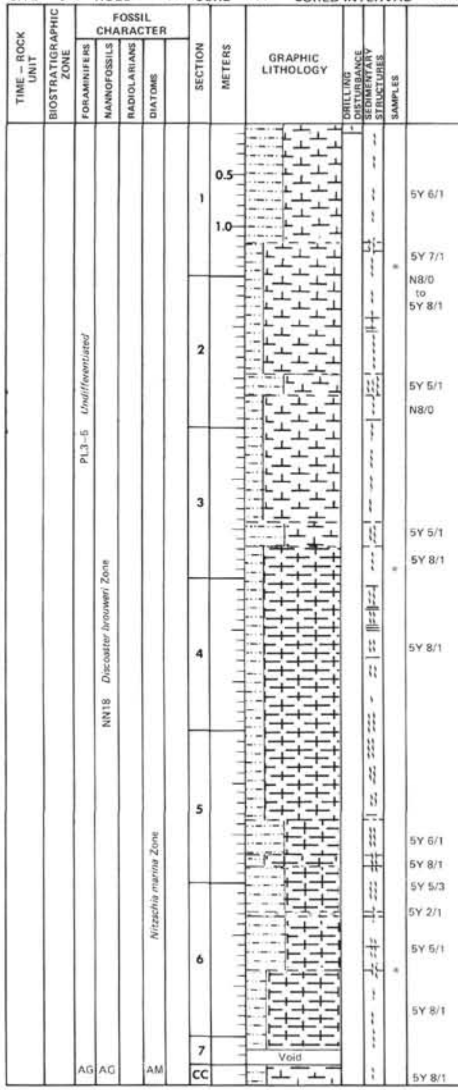
NANNOFOSSIL OOZE with marly intervals and volcanic ash-rich beds. Ooze, very light gray to light gray in marly intervals.

Mottling pervasive, pyrite common. Occasional pale green gray laminae. Dark gray ash bed at 4.75 to 4.82 m and 7.77 to 7.82 m, and patches at 0.77 to 0.89 m and 4.33 to 4.44 m.

SMEAR SLIDE SUMMARY (%)

	3, 111 D	4, 30 M	6, 31 M
Composition:			
Quartz	25	60	75
Feldspar	–	10	–
Mica	–	TR	–
Heavy minerals	–	5	5
Clay	5	–	–
Volcanic glass	–	20	15
Glauconite	–	TR	TR
Carbonate unspec.	3	–	–
Foraminifers	8	–	–
Calc. nannofossils	68	5	5
Sponge spicules	1	–	–

SITE 610 HOLE B CORE 14 CORED INTERVAL 118.0–127.6 m



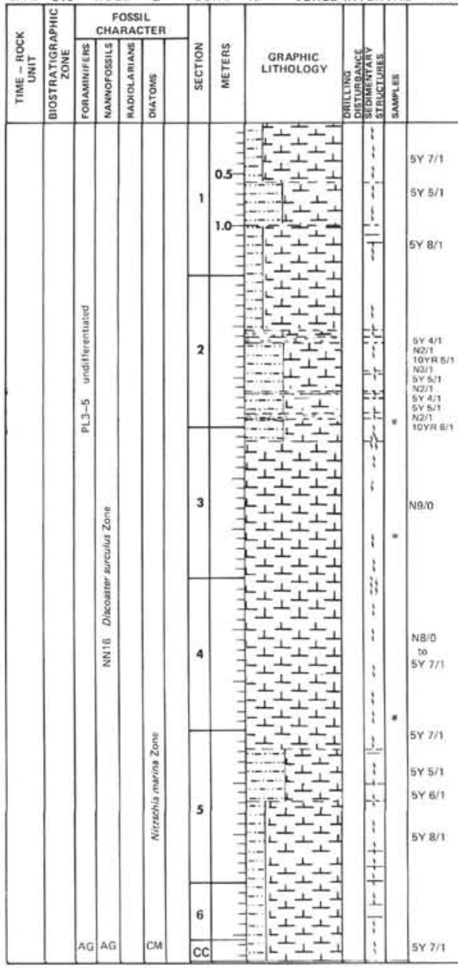
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE with SILICEOUS FORAMINIFERAL OOZE (4.15 to 8.33 m), and marly intervals. Mottled with pyrite. Diffuse pale green gray laminae. Volcanic ash-rich bed at 7.76 to 7.80 m.

SMEAR SLIDE SUMMARY (%)

	1, 140	3, 141	6, 80
	D	D	D
Composition:			
Quartz			20
Feldspar			–
Mica	15	10	–
Heavy minerals	–	–	2
Clay			–
Volcanic glass	TR	TR	5
Carbonate unspec.	10	5	20
Foraminfiers	8	20	3
Calc. nannofossils	61	53	50
Diatoms	1	–	TR
Radiolarians	–	TR	TR
Sponge spicules	5	12	TR

SITE 610 HOLE B CORE 15 CORED INTERVAL 127.6–137.2 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE with marly intervals and VOLCANIC ASH-bearing beds, very light gray to gray to dark gray. Mottled with occasional pale green gray and dark gray laminae.

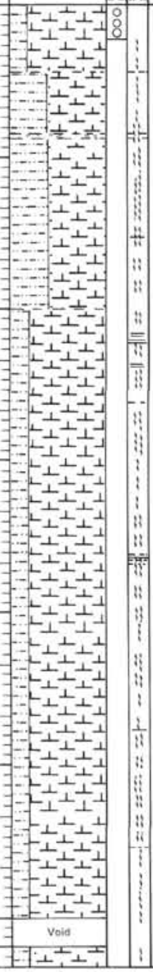
SMEAR SLIDE SUMMARY (%)

	2, 140	3, 110	4, 85
	M	D	
Texture:			
Sand	20	–	–
Silt	55	–	–
Clay	25	–	–
Composition:			
Quartz	25	5	–
Feldspar	15	–	–
Mica	3	–	–
Heavy minerals	5	–	–
Clay	15	–	5
Volcanic glass	40	–	TR
Glauconite	TR	–	–
Carbonate unspec.	–	2	10
Foraminifers	TR	8	40
Calc. nannofossils	2	87	40
Diatoms	–	TR	TR
Radiolarians	–	TR	TR
Sponge spicules	–	2	5
Silicoflagellates	–	TR	–

SITE 610 HOLE B CORE 16 CORED INTERVAL 137.2–146.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
		PL3–5 undifferentiated	NN16 *Discoaster surculus* Zone		*Nitzschia jouseae* Zone							
		AG	AG		CG							

Sections: 1 (0.5, 1.0), 2, 3, 4, 5, 6, 7 (Void), CC



Colors: 5Y 8/1; 5Y 7/1 to 5Y 6/1; 5Y 7/1 to 5Y 6/1; 5Y 8/1; N8/0; 5Y 7/1; N8/0; 5Y 8/1 to 5Y 7/1; N8/0; N8/0

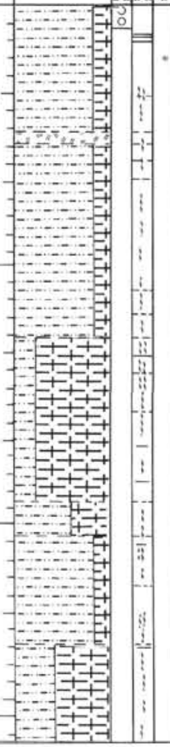
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE with marly intervals and volcanic ash-rich interval (1.24 to 1.28 m), very light gray to light gray. Mottled. Occasional pale green/gray laminae.

SITE 610 HOLE C CORE (HPC) 1 CORED INTERVAL 8.0–12.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
		N22 *Globorotalia truncatulinoides*	NN21 *Emiliania huxleyi* Zone									
		AG	AG		B							

Sections: 1 (0.5, 1.0), 2, 3, CC



Colors: 2.5Y 5/2; 10YR 4/1; 2.5Y 5/2; 10YR 6/1; 10YR 6/1; 5Y 6/1; 5Y 5/1; 2.5Y 5/2; 5Y 5/1; 5Y 7/1; 5Y 6/1; 5Y 7/1; 5Y 6/1; 5Y 5/1; 5Y 6/1; 5Y 7/1; 5Y 7/1

LITHOLOGIC DESCRIPTION

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray to very light gray. Mottled by burrowing. *Zoophycos* present. Volcanic ash layer at 0.72 to 0.79 m. Pale green/gray laminae.

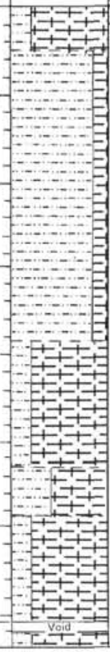
SMEAR SLIDE SUMMARY (%)

	1, 30
	D
Composition:	
Quartz	33
Feldspar	15
Volcanic glass	10
Carbonate unspec.	12
Foraminifers	5
Calc. nannofossils	25

SITE 610 HOLE C CORE (HPC) 2 CORED INTERVAL 13.0–18.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN21 *Emiliania huxleyi* Zone	AG	AG		B	1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

N8/0

5Y 6/1 to 5Y 5/1

5Y 7/1

5Y 6/1

5Y 8/1

5Y 7/1

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray to very light gray. Mottled. *Zoophycos*. Pale green/gray laminae.

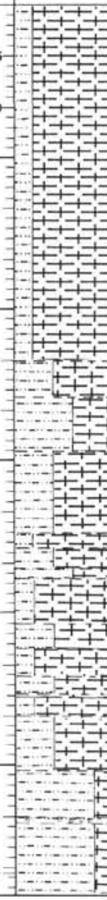
SMEAR SLIDE SUMMARY (%)

	1, 142 D	2, 81
Texture:		
Sand	2	–
Silt	25	–
Clay	73	–
Composition:		
Quartz	47	10
Feldspar	5	–
Clay	10	–
Volcanic glass	5	2
Carbonate unspec.	25	15
Foraminifers	1	8
Calc. nannofossils	5	65
Organic matter	2	–

SITE 610 HOLE C CORE 3 CORED INTERVAL 26.0–35.6 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	N22 *Globorotalia truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG		B	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

N9/0 to 5Y 8/1

5Y 7/1

5Y 8/1

N9/0

5Y 8/1

5Y 7/1

5Y 6/1

5Y 5/1

5Y 4/1

5Y 6/1

5Y 8/1

5Y 5/1

5Y 7/1

5Y 6/1

5Y 7/1

5Y 6/1

5Y 5/1

5Y 7/1

5Y 6/1

5GY 6/1

5GY 5/1

10YR 4/1

5Y 2/1

10YR 4/1

10YR 4/1

5Y 4/1

5Y 4/1

10YR 4/1

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to olive gray and brown. Dark gray patches of volcanic ash-rich mud at 4.11 to 4.40 m. Volcanic ash-rich bed at 8.02 to 8.07 m with associated bioturbated zone of ash-rich mud. Mottled. Gray/green laminae.

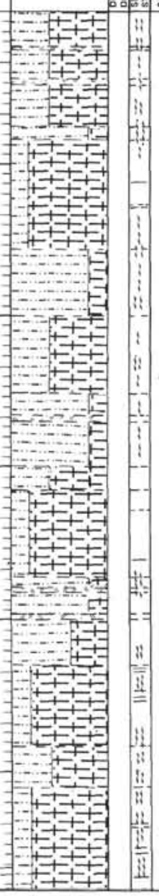
SMEAR SLIDE SUMMARY (%)

	3, 130 D
Texture:	
Sand	10
Silt	50
Clay	40
Composition:	
Quartz	40
Feldspar	5
Clay	15
Volcanic glass	3
Foraminifers	5
Calc. nannofossils	35

SITE 610 HOLE C CORE 4 CORED INTERVAL 35.6–45.2 m

Time-rock unit / Biostratigraphic zone — Fossil character: Foraminifers: N22 *Globorotalia truncatulinoides*; Nannofossils: NN19 *Pseudoemiliania lacunosa* Zone. Core catcher: Foraminifers AG, Nannofossils AG, Diatoms B.

Sections: 1, 2, 3, 4, 5, 6, CC. Meters: 0.5, 1.0.



Colors: 5Y 6/1, 5Y 2/1, 5Y 6/1, 5Y 2/1, 5Y 6/1, 5Y 5/1, N9/0, 5G 7/2, 5Y 7/1, 5Y 5/1, 5Y 6/1, 5Y 5/1, 5Y 2/1, 5Y 6/1, 5Y 6/1, 5Y 7/1, N9/0, 5Y 7/1, 5Y 5/1, 5Y 2/1, 5Y 5/1, 5Y 2/1, 5Y 5/1, 5Y 8/1, 5Y 7/1 to 5Y 5/1, 5Y 7/1 to 5Y 8/1, 5Y 7/1

LITHOLOGIC DESCRIPTION

Interbedded FORAMINIFERAL NANNOFOSSIL OOZE and CALCAREOUS MUD, very light gray to olive gray. Dark gray volcanic ash-rich intervals at 0.35 to 0.39 m, 0.67 to 0.72 m, 3.99 to 4.05 m, 5.68 to 5.71 m, 5.95 to 6.00 m. Foraminiferal-rich interval at 8.02 to 8.05 m. Occasional pale green/gray laminae.

SMEAR SLIDE SUMMARY (%)

	3, 56	6, 54
	D	M
Composition:		
Quartz	27	5
Volcanic glass	3	–
Carbonate unspec.	5	5
Foraminifers	5	20
Calc. nannofossils	58	70
Sponge spicules	TR	–
Organic matter	2	–

SITE 610 HOLE C CORE 5 CORED INTERVAL 99.0–108.6 m

Time-rock unit / Biostratigraphic zone — Fossil character: Foraminifers: PL6 *Globorotalia obliquus extremus*; Nannofossils: NN18 *Discoaster brouweri* Zone. Core catcher: Foraminifers AG, Nannofossils AG, Diatoms RP.

Sections: 1, 2, 3, 4, 5, 6, 7, CC. Meters: 0.5, 1.0.

Colors: 5Y 6/1, 5Y 7/1, N5/0, 5Y 7/1, 5Y 4/1, 5Y 6/1, 5Y 5/1, 5Y 6/1, 5Y 8/1, 5Y 6/1 to 5Y 5/1, 5Y 7/1, 5Y 8/1, 5Y 7/1, 5Y 5/1, N2/0, 10YR 5/2, 10YR 4/1, N2/0, 10YR 4/1, 10YR 5/2, 10YR 5/1, 5Y 8/1, 5Y 7/1, Void, 5Y 7/1

LITHOLOGIC DESCRIPTION

Interbedded NANNOFOSSIL OOZE and (MARLY) NANNOFOSSIL OOZE, very light gray to light olive gray and light brown. Dark gray volcanic ash layers at 1.35 to 1.40 m, 3.70 to 3.79 m, 7.69 to 7.70 m, and 7.83 to 7.86 m. Mottled. Pale green/gray laminae.

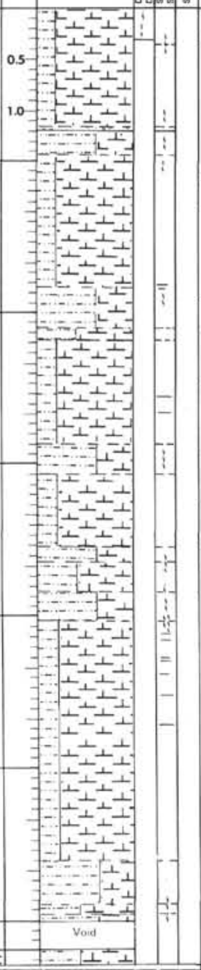
SMEAR SLIDE SUMMARY (%)

	1, 138	1, 140	4, 16
Composition:			
Quartz	4	5	25
Mica	TR	–	TR
Heavy minerals	TR	TR	–
Volcanic glass	75	79	TR
Pyrite	10	10	–
Carbonate unspec.	–	–	3
Foraminifers	1	1	6
Calc. nannofossils	10	5	65
Radiolarians	–	–	TR
Sponge spicules	–	–	1

SITE 610 HOLE C CORE 6 CORED INTERVAL 108.6–118.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	PL6 *Globorotalia obliquus extremus*; NN18 *Discoaster brouweri* Zone	AG	AG		B	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 6/1
N8/0 to 5GY 7/1
5Y 6/1
5Y 7/1
N8/0
5Y 6/1
N8/0
5Y 6/1
5Y 7/1
5Y 6/1
N8/0 to 5GY 7/1
5Y 8/1
5Y 7/1
5Y 8/1
5Y 4/2

Interbedded NANNOFOSSIL OOZE and MARLY NANNOFOSSIL OOZE, very light gray to light olive gray and light brown. Volcanic ash interval 1.15 to 1.19 m. Mottled, with green/gray laminae.

SMEAR SLIDE SUMMARY (%)

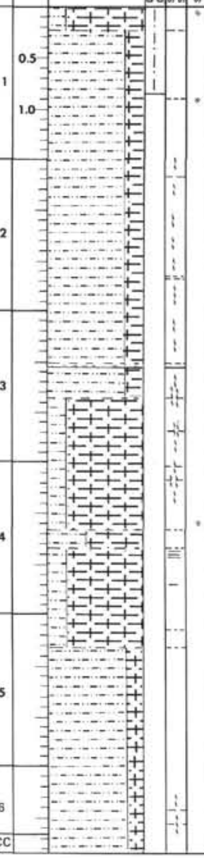
	5, 130 D
Composition:	
Quartz	37
Heavy minerals	2
Clay	20
Volcanic glass	1
Calc. nannofossils	40
Diatoms	TR
Sponge spicules	TR

* Reassessed. Questionable position (still).

SITE 610 HOLE D CORE 1 CORED INTERVAL 0.0–8.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	Globorotalia truncatulinoides; NN21 *Emiliania huxleyi* Zone	AG	AG		B	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

2.5Y 6/3
2.5Y 5/2
2.5Y 5/2 to 5Y 5/2
5Y 5/2
5GY 6/1
5Y 6/1
2.5Y 6/2
N8/0
2.5Y 7/2
N8/0
2.5Y 7/2
N8/0
5Y 7/1
2.5Y 5/2
2.5Y 7/2
2.5Y 6/7
5Y 5/2

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray and brown to very light gray. Dark gray volcanic ash-rich bed at 3.51 to 3.53 m and patch at 6.55 m. Mottled, *Zoophycos*. Occasional pale green/gray patches in ooze layers. Dropstones.

SMEAR SLIDE SUMMARY (%)

	1, 8	1, 96	4, 55
Texture:			
Sand	–	15	–
Silt	–	30	–
Clay	–	50	–
Composition:			
Quartz	TR	67	TR
Feldspar	TR	1	TR
Heavy minerals	1	2	TR
Clay	TR	15	–
Micronodules	TR	–	–
Carbonate unspec.	1	10	1
Foraminifers	15	2	12
Calc. nannofossils	83	1	87
Diatoms	TR	–	–
Radiolarians	–	–	TR
Sponge spicules	TR	–	TR

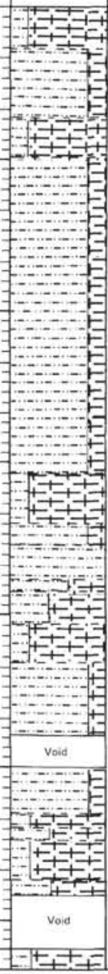
SITE 610 HOLE D CORE 2 CORED INTERVAL 8.4–18.0 m

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

Biostratigraphic zone: *G. truncatulinoides*; NN21 *Emiliania huxleyi* Zone

Fossil character: AG AG B

Sections: 1, 2, 3, 4, 5, 6, 7, CC (0.5, 1.0 m)



5Y 6/1
5Y 7/1
5Y 6/1 to 5Y 7/1
N8/0
5Y 7/1
5Y 5/1
5Y 6/1 to 5Y 5/1
5BG 4/1
5Y 5/1 to 5GY 6/1
2.5Y 5/2
5GY 6/2
5GY 7/1
5Y 6/1
5Y 7/1
5GY 7/1
5Y 6/1
5GY 7/1 to 5Y 7/1
N8/0
5GY 5/1
2.5Y 5/2
5G 5/2
2.5Y 5/2
2.5Y 5/2
2.5Y 6/2
5Y 7/1
5Y 6/1
5Y 7/1
5Y 6/1
N8/0

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray and brown to very light gray. Mottled. Dropstones. *Zoophycos*. Volcanic ash-rich interval 6.46 to 6.79 m.

SMEAR SLIDE SUMMARY (%)

	5, 20	5, 75
	D	D
Texture:		
Sand	–	20
Silt	–	35
Clay	–	45
Composition:		
Quartz	–	58
Feldspar	TR	1
Heavy minerals	–	3
Clay	1	25
Volcanic glass	–	1
Pyrite	TR	–
Carbonate unspec.	1	10
Foraminifers	15	1
Calc. nannofossils	83	1

SITE 610 HOLE D CORE 3 CORED INTERVAL 27.6–37.2 m

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

Biostratigraphic zone: *G. truncatulinoides*; NN19 *Pseudoemiliania lacunosa* Zone

Fossil character: AG AG B

Sections: 1, 2, 3, 4, 5, 6, CC (0.5, 1.0 m)

N6/0
N8/0
5Y 6/1
5G 4/1
5G 5/1
2.5Y 5/2
5G 4/1
5G 5/2
5G 5/2
5G 4/1
5G 5/1
5G 4/1
5Y 5/1
5G 4/1
2.5Y 6/2
5G 4/1
2.5Y 7/2
2.5Y 5/2
N8/0
5G 7/2
N8/0
5G 7/2
N8/0
2.5Y 6/2
2.5Y 5/2
2.5Y 6/2
2.5Y 6/2
2.5Y 5/2
5Y 6/1 to 5Y 7/1
5Y 5/2
5G 5/1
2.5Y 5/2
5G 5/1
2.5Y 5/2
2.5Y 6/2 to 5Y 6/1

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive gray and brown to very light gray. Thin (1–5 cm) volcanic ash-rich beds throughout, with sharp bases at 3.82 and 4.12 m. Foraminiferal sand bed at 6.82–6.83 m. Generally mottled.

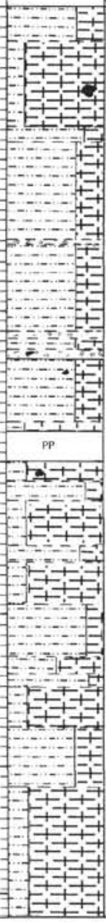
SMEAR SLIDE SUMMARY (%)

	2, 115	4, 45
	D	D
Texture:		
Sand	15	–
Silt	35	–
Clay	50	–
Composition:		
Quartz	51	–
Feldspar	1	1
Heavy minerals	5	TR
Volcanic glass	5	TR
Carbonate unspec.	10	1
Foraminifers	13	14
Calc. nannofossils	5	84
Diatoms	–	TR
Sponge spicules	TR	TR

SITE 610 HOLE D CORE 4 CORED INTERVAL 37.2–46.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	G. truncatulinoides; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG		FM	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

2.5Y 5/1
N8
2.5Y 7/1
5Y 7/1
to
2.5Y 7/2
5Y 5/2
2.5Y 5/2
5G 4/1
5GY 6/1 to 5Y 6/1
5Y 6/1 to 5Y 5/1
5Y 5/1
5Y 5/2
5G 4/1
5Y 5/2
5G 4/1
5Y 5/2
2.5Y 6/2
5GY 7/1
N8
5GY 6/1 to
5Y 5/2
5GY 7/1
5Y 6/1
5Y 7/1
5Y 6/1 to 5GY 5/1
5Y 6/1
5GY 7/1 to 5G 7/1
5G 7/1
5GY 6/1
5GY 5/1
2.5Y 6/2
2.5Y 5/2
2.5Y 7/2
2.5Y 5/2
5GY 7/2
to
5GY 6/1
5Y 5/2
to
2.5Y 5/2
5GY 7/1
to
N8
5GY 7/1

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive brown and brown to pale green and gray. Thin (1–6 cm) volcanic-rich beds throughout; occasional pebbles (dropstones); *Zoophycos*; sedimentary clast at Section 4, 10 cm (4 cm) composed predominantly of pyrite micronodules and volcanic ash.

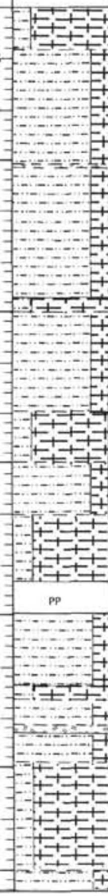
SMEAR SLIDE SUMMARY (%)

	3, 40 M	6, 45 D
Texture:		
Sand	30	–
Silt	35	–
Clay	35	–
Composition:		
Quartz	71	–
Feldspar	1	TR
Heavy minerals	3	–
Clay	10	TR
Volcanic glass	14	–
Carbonate unspec.	1	–
Foraminifers	–	11
Calc. nannofossils	TR	89
Diatoms	–	TR
Sponge spicules	–	TR

SITE 610 HOLE D CORE 5 CORED INTERVAL 46.8–56.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	Globorotalia truncatulinoides; NN19 *Pseudoemiliania lacunosa* Zone	AG	AG		B	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



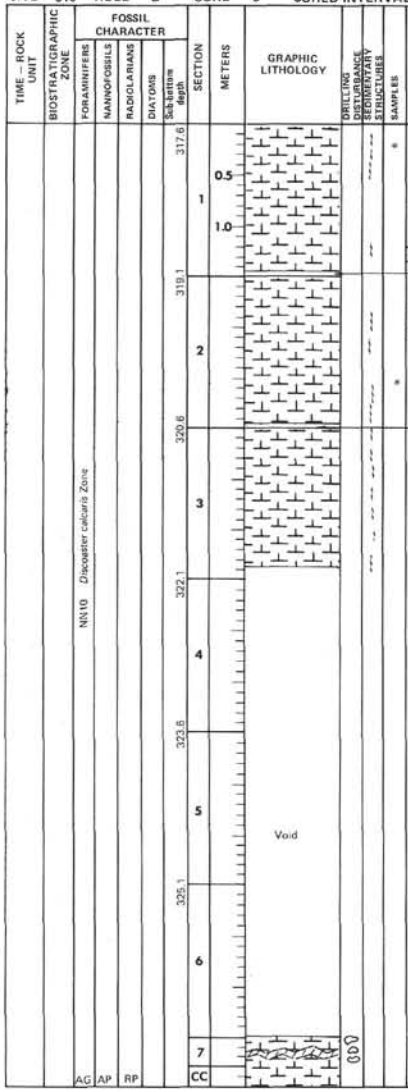
DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

5GY 7/1 to
2.5Y 5/2
5G 4/1
2.5Y 5/2
5GY 7/1
5Y 7/1 to 2.5Y 5/2
2.5Y 6/2
2.5Y 5/2
2.5Y 6/2
2.5Y 5/2
5GY 7/1 to 5GY 6/1
2.5Y 5/2
5GY 7/1
N9
5GY 7/1
5GY 7/1 to 5GY 6/1
2.5Y 5/2 to 2.5Y 6/2
5GY 7/1
5GY 6/1
5G 4/1
2.5Y 5/2
5GY 7/1
2.5Y 5/2 to 2.5Y 6/2

Interbedded CALCAREOUS MUD and FORAMINIFERAL NANNOFOSSIL OOZE, olive brown and brown to white and pale green. Thin (1–7 cm) volcanic-rich beds throughout; *Zoophycos*; occasionally mottled.

SITE 610 HOLE D CORE 6 CORED INTERVAL 317.6–327.2 m



LITHOLOGIC DESCRIPTION

N9

5GY 8/1

Void

N9 to 5GY 8/1

Void

N9 to 5GY 8/1

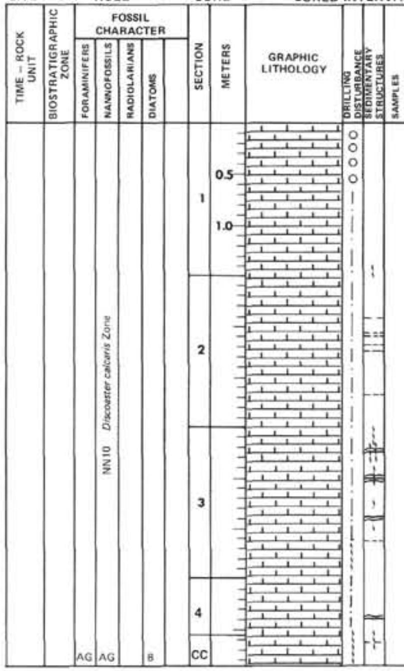
NANNOFOSSIL OOZE, occasional dark gray mottles and chalky intervals.

SMEAR SLIDE SUMMARY (%)

	1, 26	2, 100
	D	D
Composition:		
Quartz	–	9
Carbonate unspec.	5	2
Foraminifers	5	1
Calc. nannofossils	90	88
Diatoms	–	TR
Sponge spicules	TR	TR

Note: Section 7 is 54 cm long.

SITE 610 HOLE D CORE 7 CORED INTERVAL 327.2–336.8 m



LITHOLOGIC DESCRIPTION

N9 to 5GY 8/1

5GY 8/1

N9

5GY 8/1

N9

5GY 8/1

N9

5GY 8/1

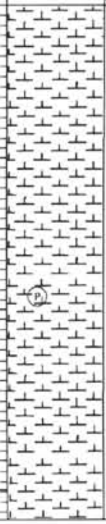
N9

5GY 8/1

NANNOFOSSIL OOZE to CHALK pale green to white; common *Zoophycos;* some dark mottling.

Disturbance is in the form of drill biscuits with occasional flowage or fragmentation.

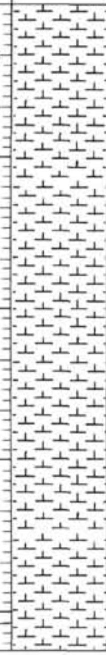
SITE 610 HOLE E CORE 1 CORED INTERVAL 260.0–269.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
	Globorotalia margaritae; NN12 *Amaurolithus tricorniculatus* Zone	AG	AM		FP		1, 2, 3, 4, CC	0.5, 1.0				*	NANNOFOSSIL OOZE, white. *Zoophycos* at Section 3, 56 cm. Pyritized worm burrow at Section 2, 135 cm; dark mottling throughout.

SMEAR SLIDE SUMMARY (%)

	2, 100
Composition:	
Quartz	9
Carbonate unspec.	2
Foraminifers	1
Calc. nannofossils	88
Diatoms	TR
Sponge spicules	TR

SITE 610 HOLE E CORE 2 CORED INTERVAL 269.6–279.2 m

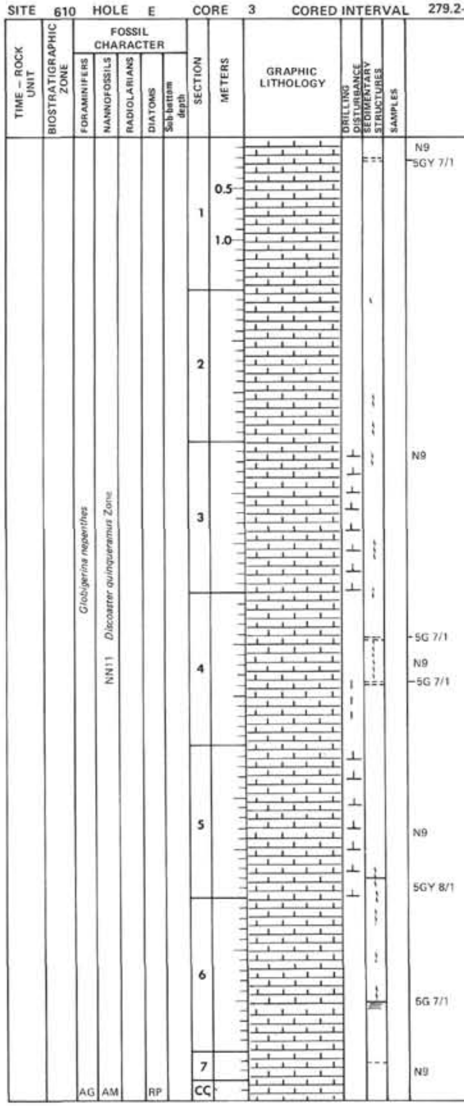
TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
	Globigerina nepenthes; NN12 *Amaurolithus tricorniculatus* Zone; NN11 *Discoaster quinqueramus* Zone	AG	AM		B		1, 2, 3, 4, 5, CC	0.5, 1.0				*	N9 to N8

NANNOFOSSIL OOZE, white, dark gray mottling throughout; 2 cm pyrite-rich layer at Section 3, 106 cm.

SMEAR SLIDE SUMMARY (%)

	3, 106 M
Composition:	
Pyrite	10
Carbonate unspec.	5
Foraminifers	2
Calc. nannofossils	81
Diatoms	1
Radiolarians	TR
Sponge spicules	1

SITE 610 HOLE E CORE 3 CORED INTERVAL 279.2–288.8 m

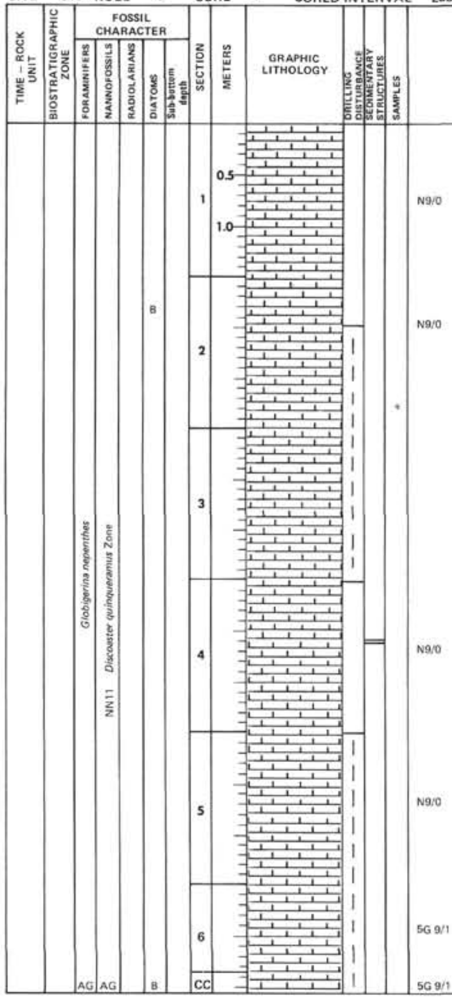


LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, white to very pale green; occasional green (5G 7/1) laminae (1 cm) with a concentration of fine green (5G 7/1) laminae at 8.46 to 8.58 m. Dark mottling throughout.

Slight drilling disturbance in the form of drill biscuits.

SITE 610 HOLE E CORE 4 CORED INTERVAL 288.8–298.4 m



LITHOLOGIC DESCRIPTION

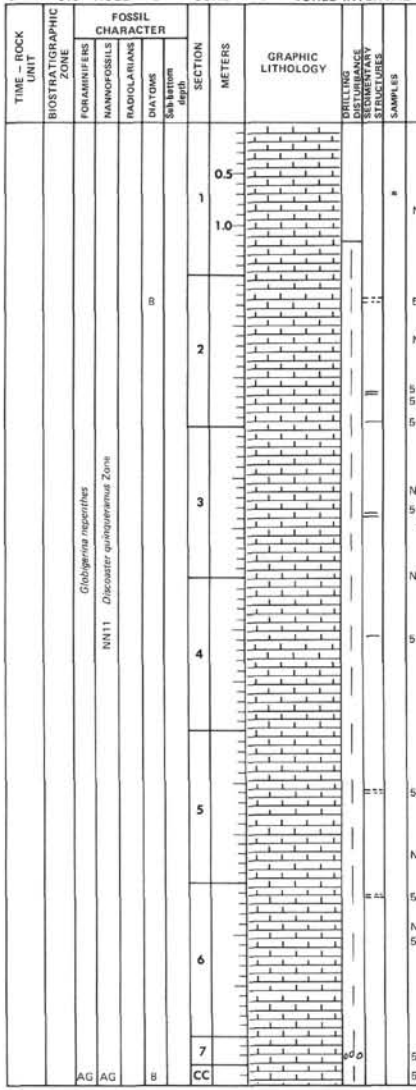
NANNOFOSSIL CHALK, white with faint green hue. Very homogeneous. Occasional *Zoophycos*. Faint green laminae at 5.10 m.

Slight drilling disturbance in the form of drill biscuits.

SMEAR SLIDE SUMMARY (%)

	2, 130
	D
Composition:	
Carbonate unspec.	1
Foraminifers	3
Calc. nannofossils	96

SITE 610 HOLE E CORE 5 CORED INTERVAL 298.4–308.0 m



LITHOLOGIC DESCRIPTION

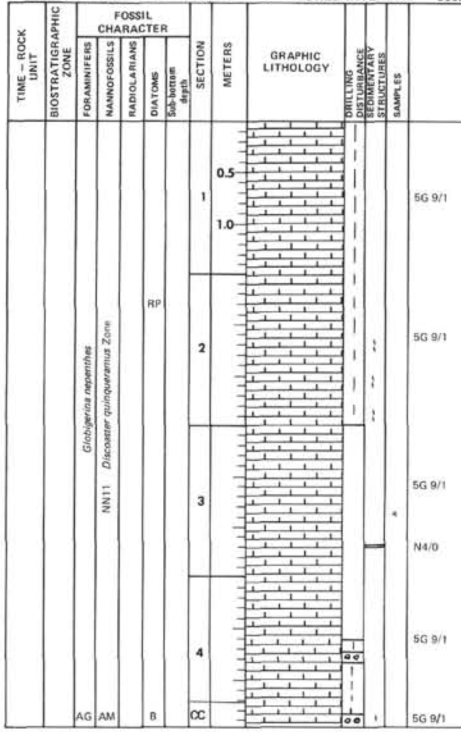
NANNOFOSSIL CHALK, white, becoming very pale green towards base. Occasional pale green/gray laminae. Common *Zoophycos*. Otherwise homogeneous.

Drilling disturbance in the form of drill biscuits.

SMEAR SLIDE SUMMARY (%)

	1, 63
	D
Composition:	
Carbonate unspec.	1
Foraminifers	9
Calc. nannofossils	90
Sponge spicules	TR

SITE 610 HOLE E CORE 6 CORED INTERVAL 308.0–317.6 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CHALK, very pale green, lightly mottled in places. Occasional *Zoophycos*. Sharp, pyritized laminae, 4.18 m. Pyrite halos.

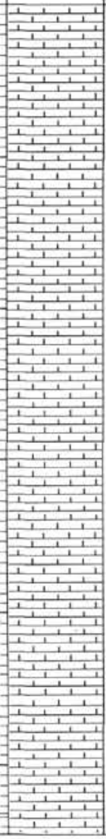
Some drill-biscuit coring deformation.

SMEAR SLIDE SUMMARY (%)

	3, 80
	D
Composition:	
Feldspar	TR
Foraminifers	9
Calc. nannofossils	90

SITE 610 HOLE E CORE 7 CORED INTERVAL 317.6–327.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	Sub-bottom depth	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
		Globigerina nepenthes	NN11 *Discoaster quinqueramus* Zone; NN10 *Discoaster calcaris* Zone				1, 2, 3, 4, 5, 6, CC	0.5, 1.0					
		AG	AG		B								



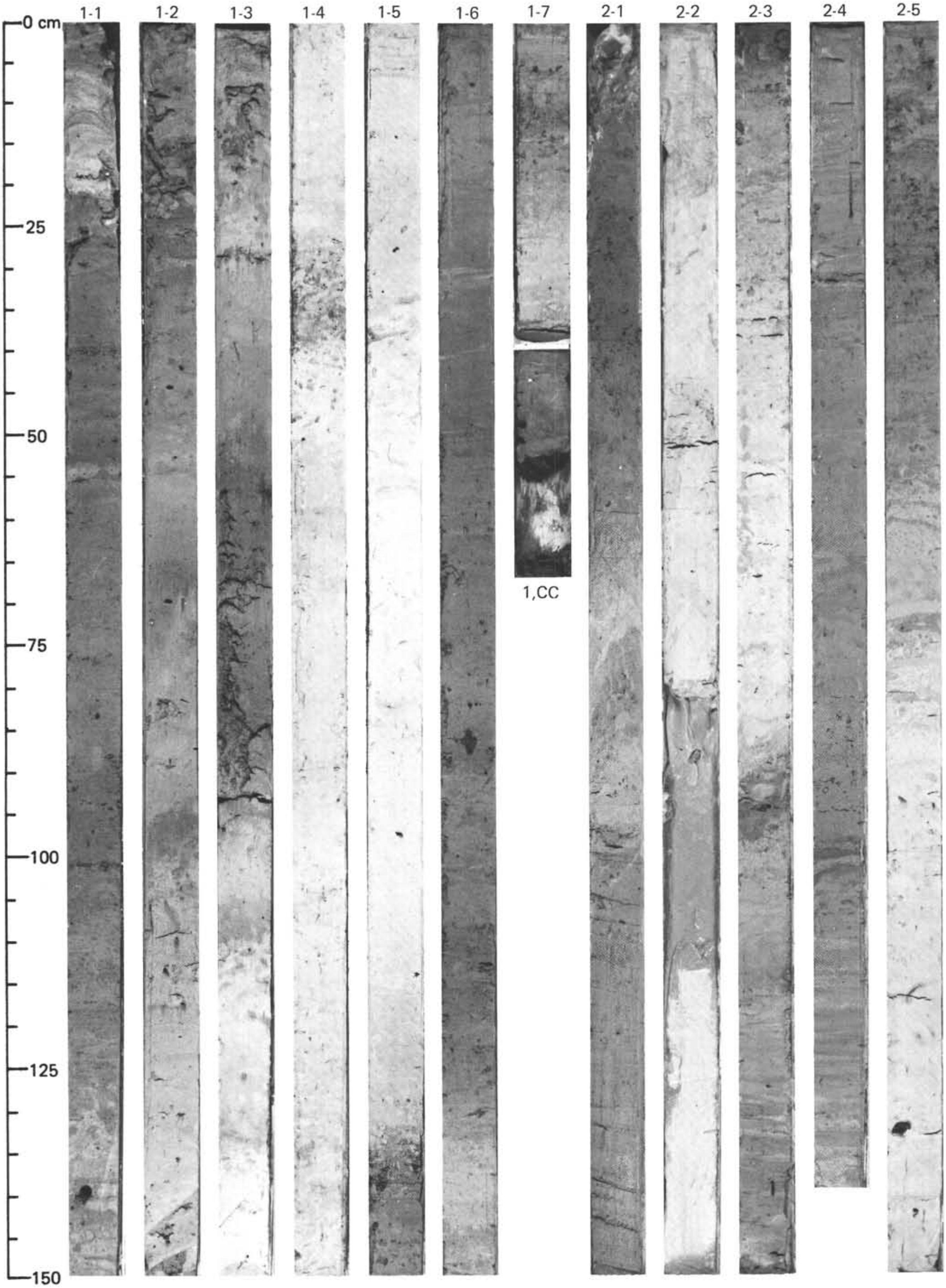
Section 1: N9/0; N8/0; N9/0
Section 2: N9/0 to 5G 8/1; 5P 8/1; 5GY 7/1
Section 3: 5GY 7/1; 5GY 7/1; N9/0 to 5G 9/1
Section 4: 5GY 7/1; 5G 9/1; 5B 6/1
Section 5: 5G 9/1 to 5G 8/1
Section 6: 5G 9/1
CC: 5G 9/1

NANNOFOSSIL CHALK, white to very pale green. Occasional mottles. Common *Zoophycos*. Occasional green/gray laminae.

Drill biscuits throughout.

SMEAR SLIDE SUMMARY (%)

	4, 111
	D
Composition:	
Carbonate unspec.	2
Foraminifers	7
Calc. nannofossils	91


0 cm
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1-7
1,CC
2-1
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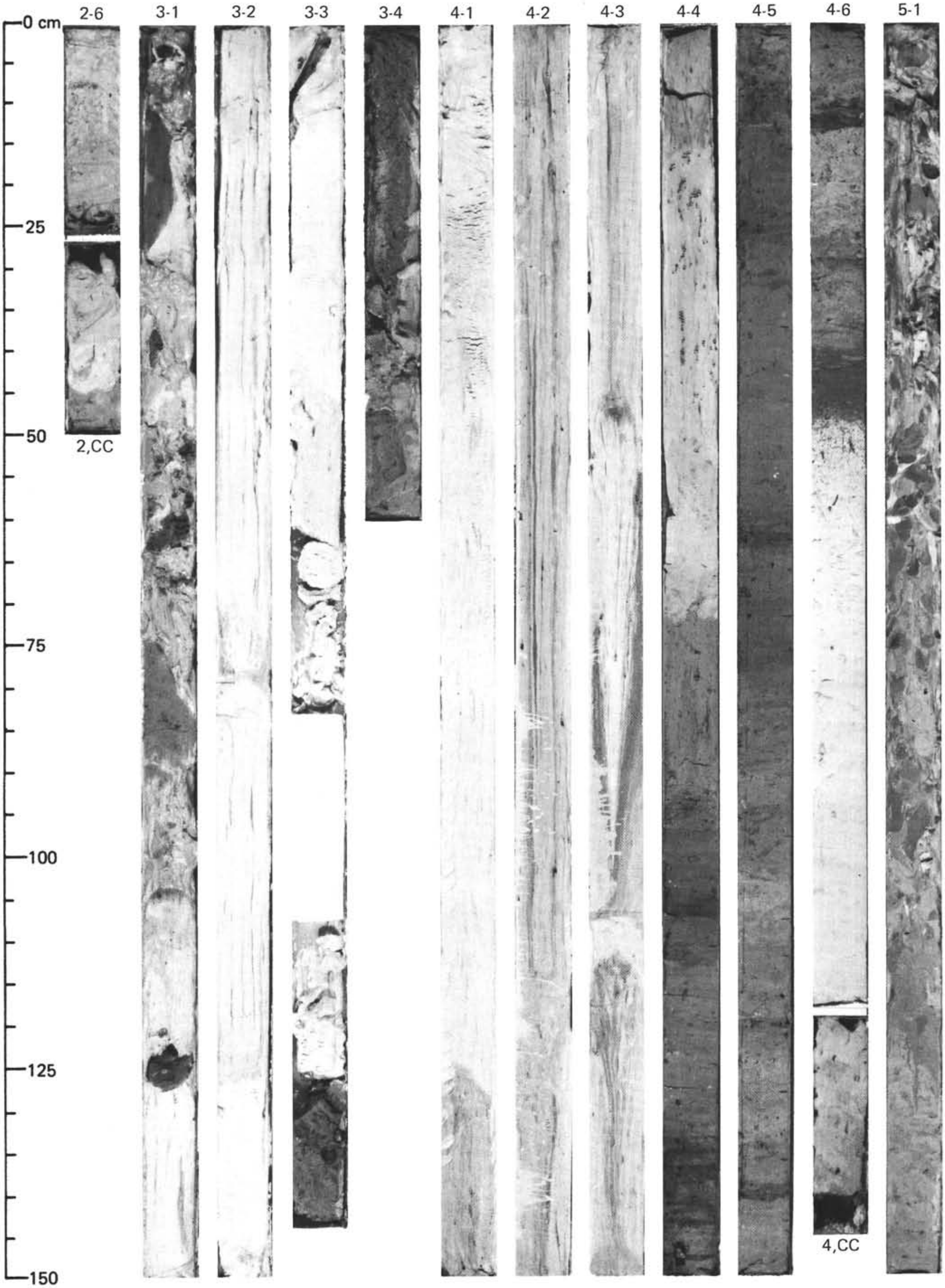
2-5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3-1
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0 cm
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2,CC
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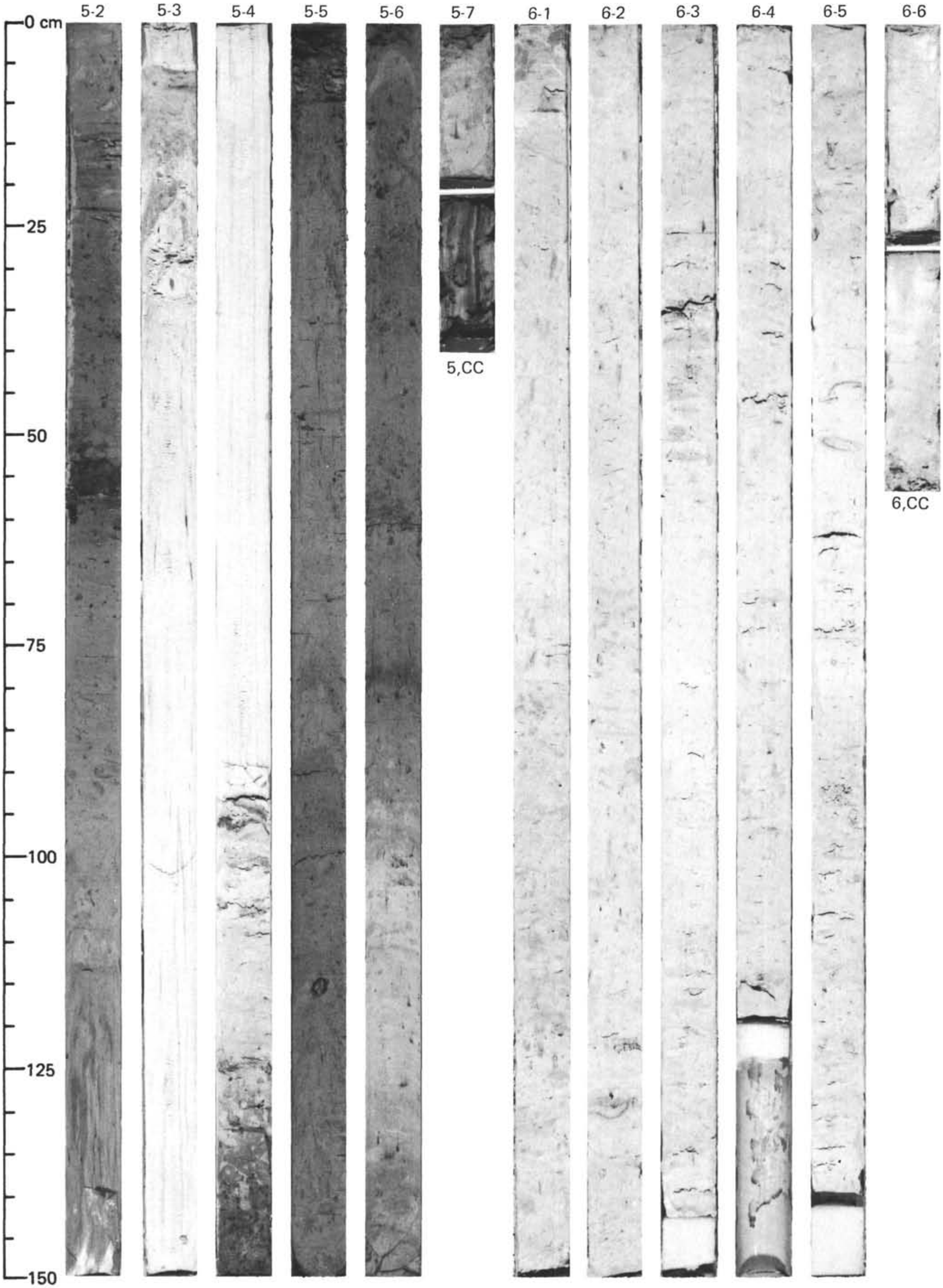
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5,CC
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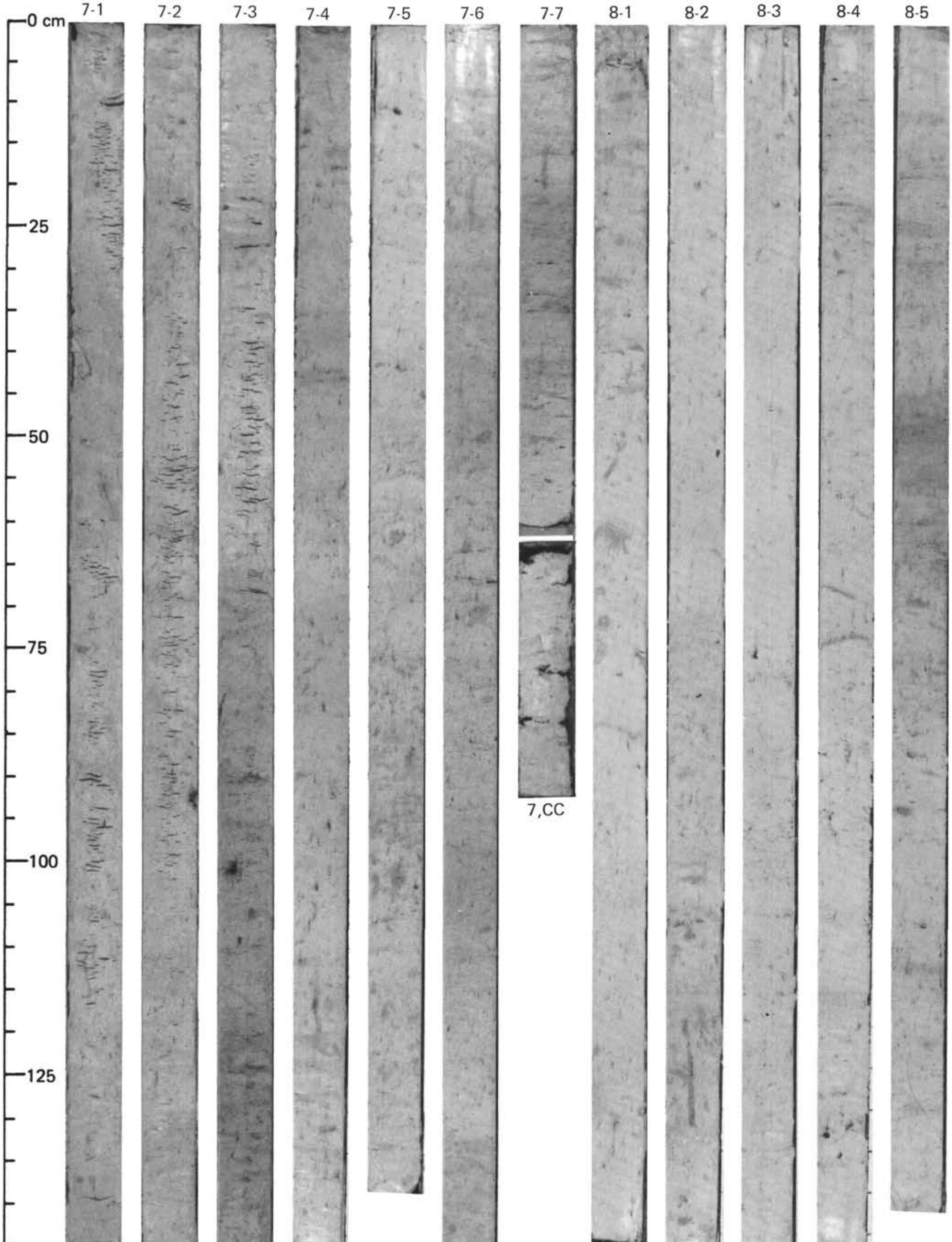
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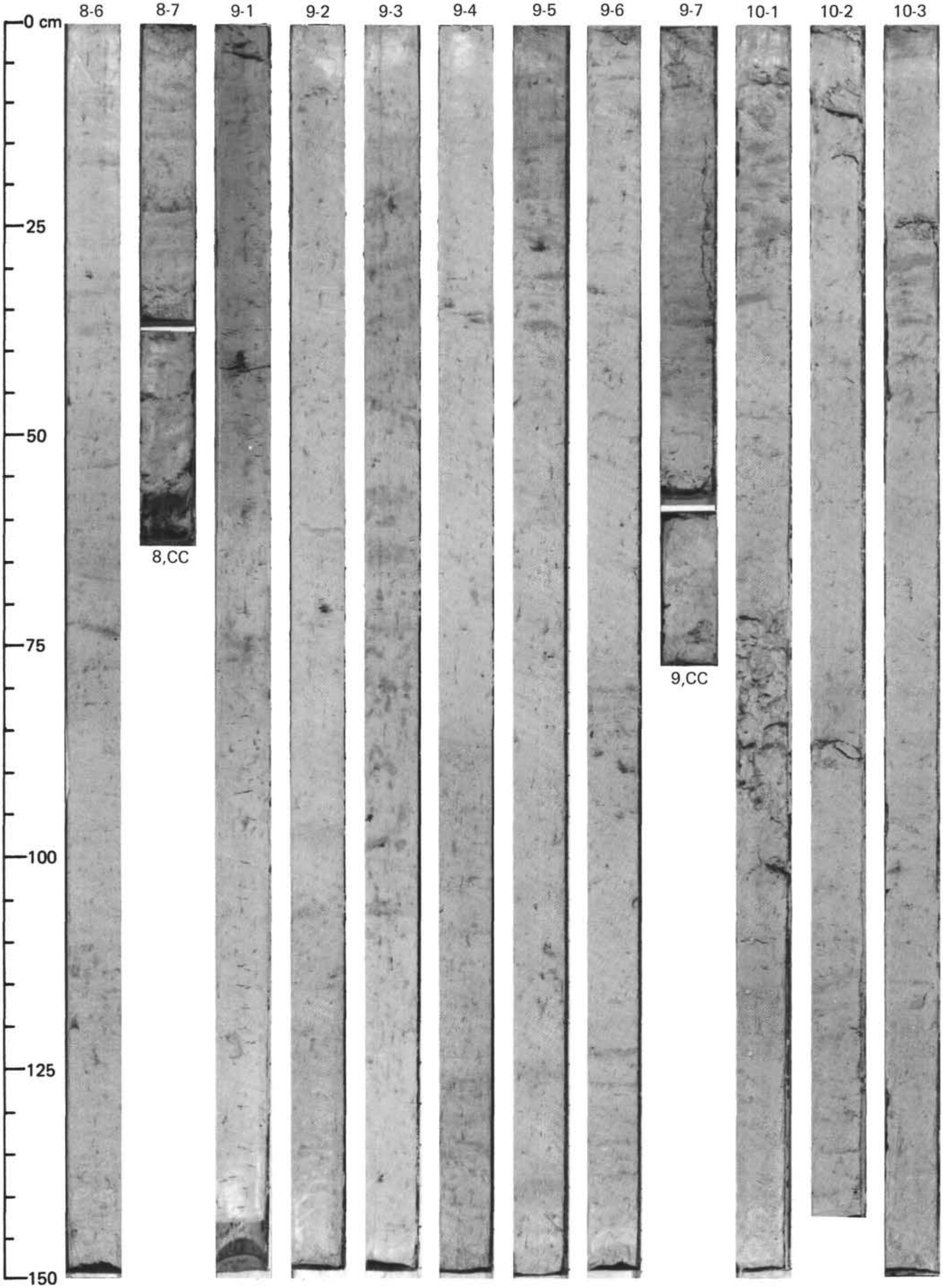
8-6
8-7
9-1
9-2
9-3
9-4
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9-6
9-7
10-1
10-2
10-3
0 cm
25
50
75
100
125
150
8,CC
9,CC


10-4
11-1
11-2
11-6
11,CC
12,CC
13-1
13-2
13-3
14-1
14-2
0 cm
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75
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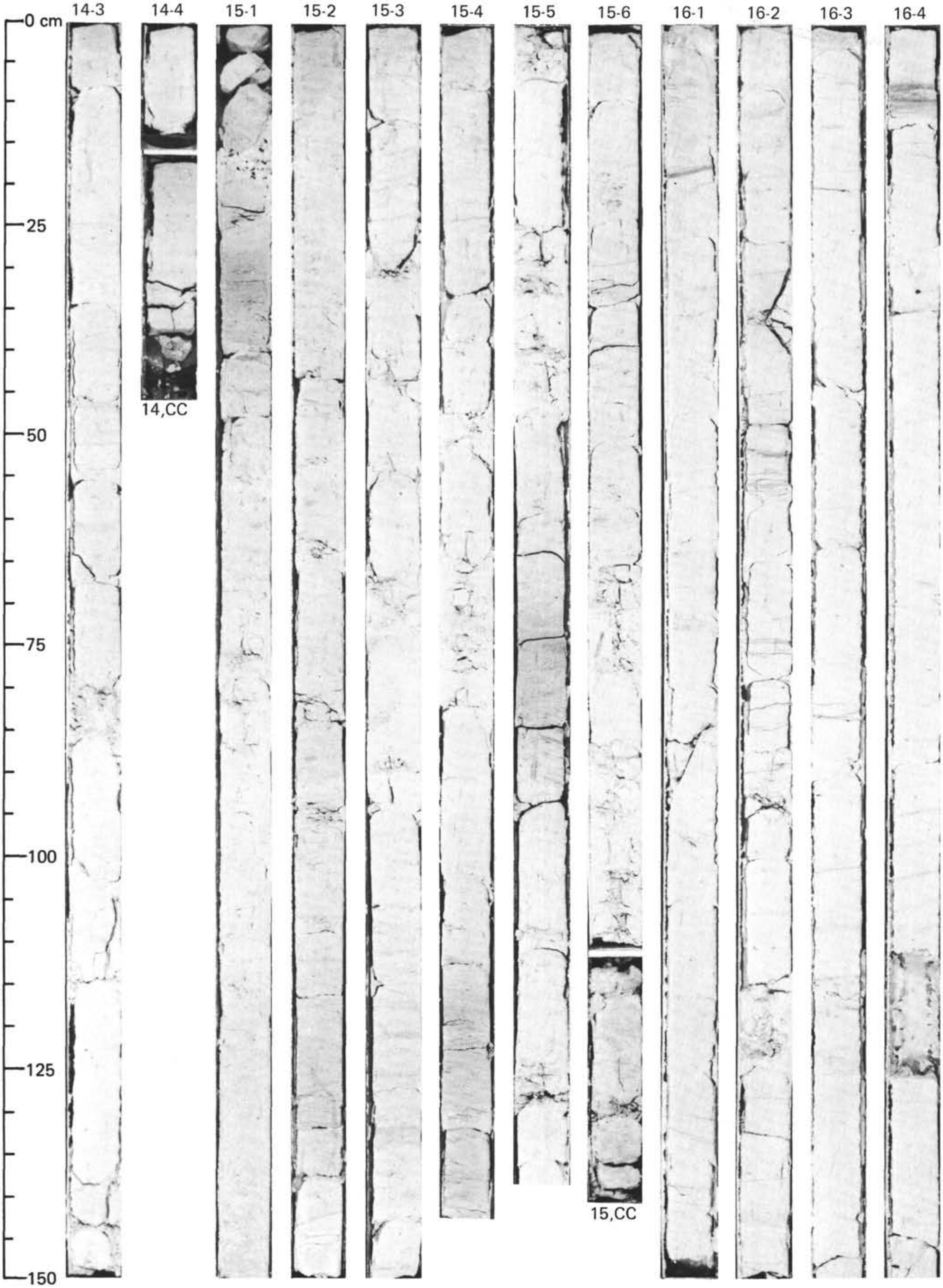
125
150
10,CC
13,CC
11-3 to 5 VOID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15,CC
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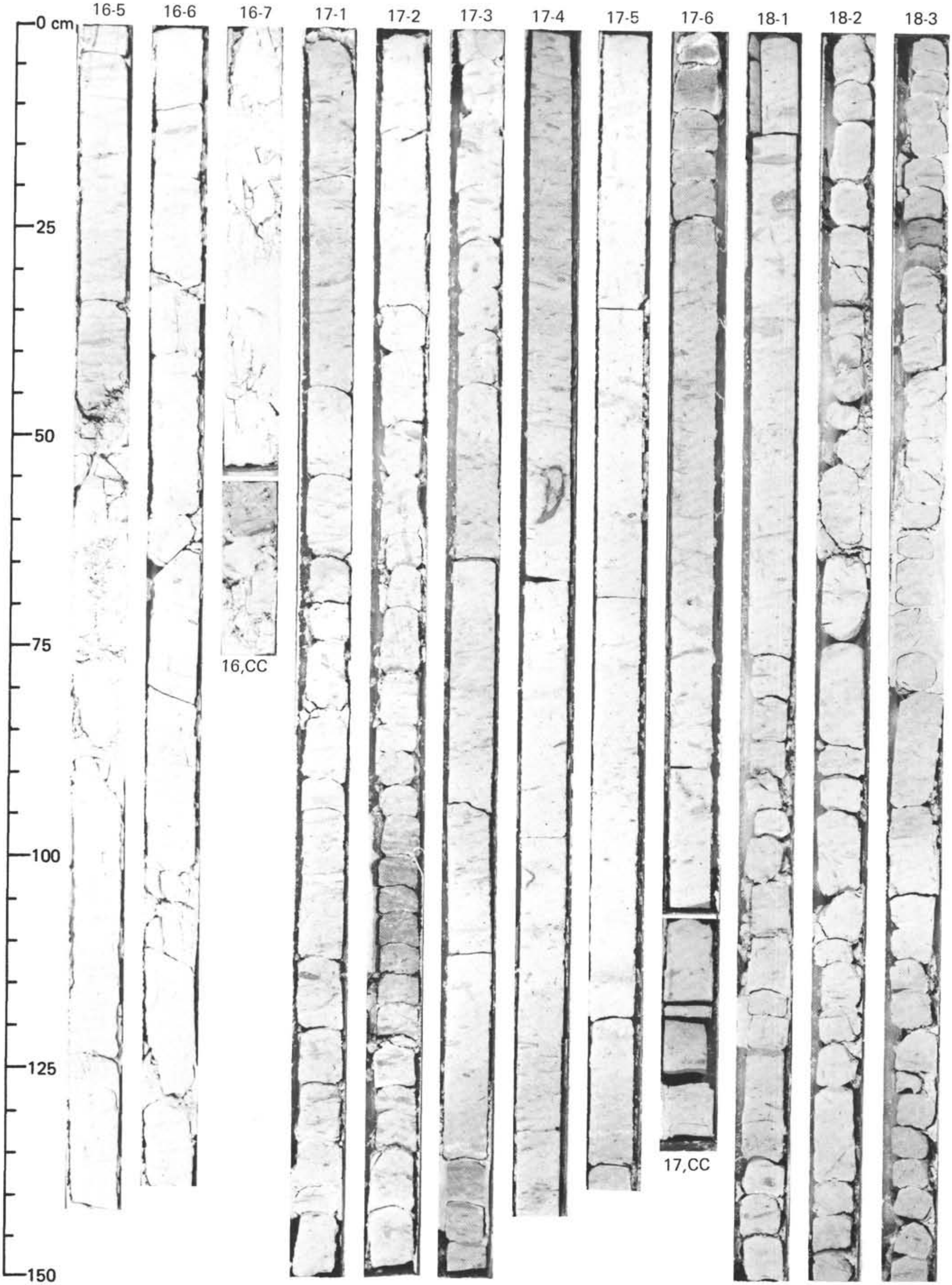
16-3
16-4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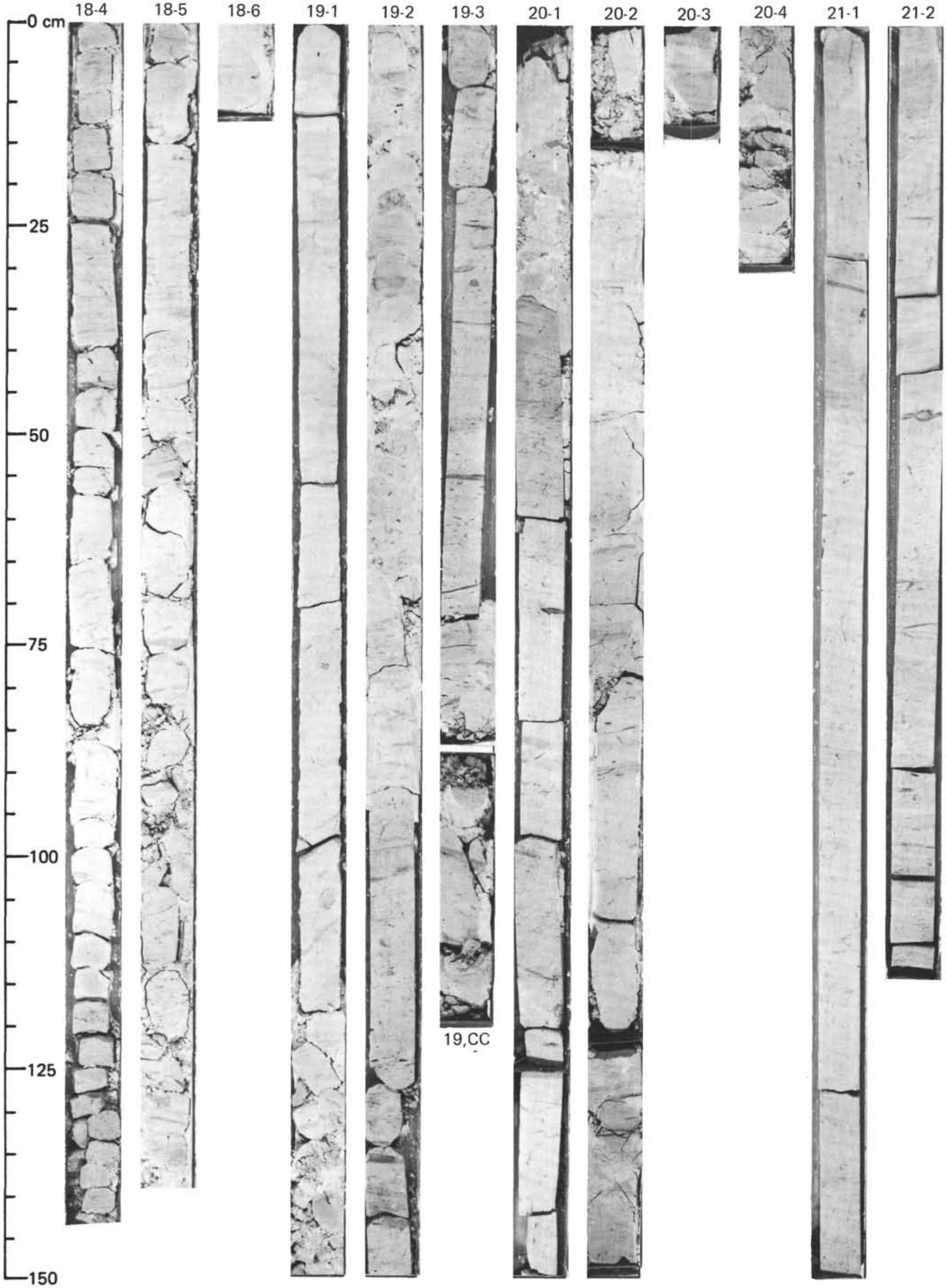
18-1
18-2
18-3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18-5
18-6
19-1
19-2
19-3
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21-1
21-2
0 cm
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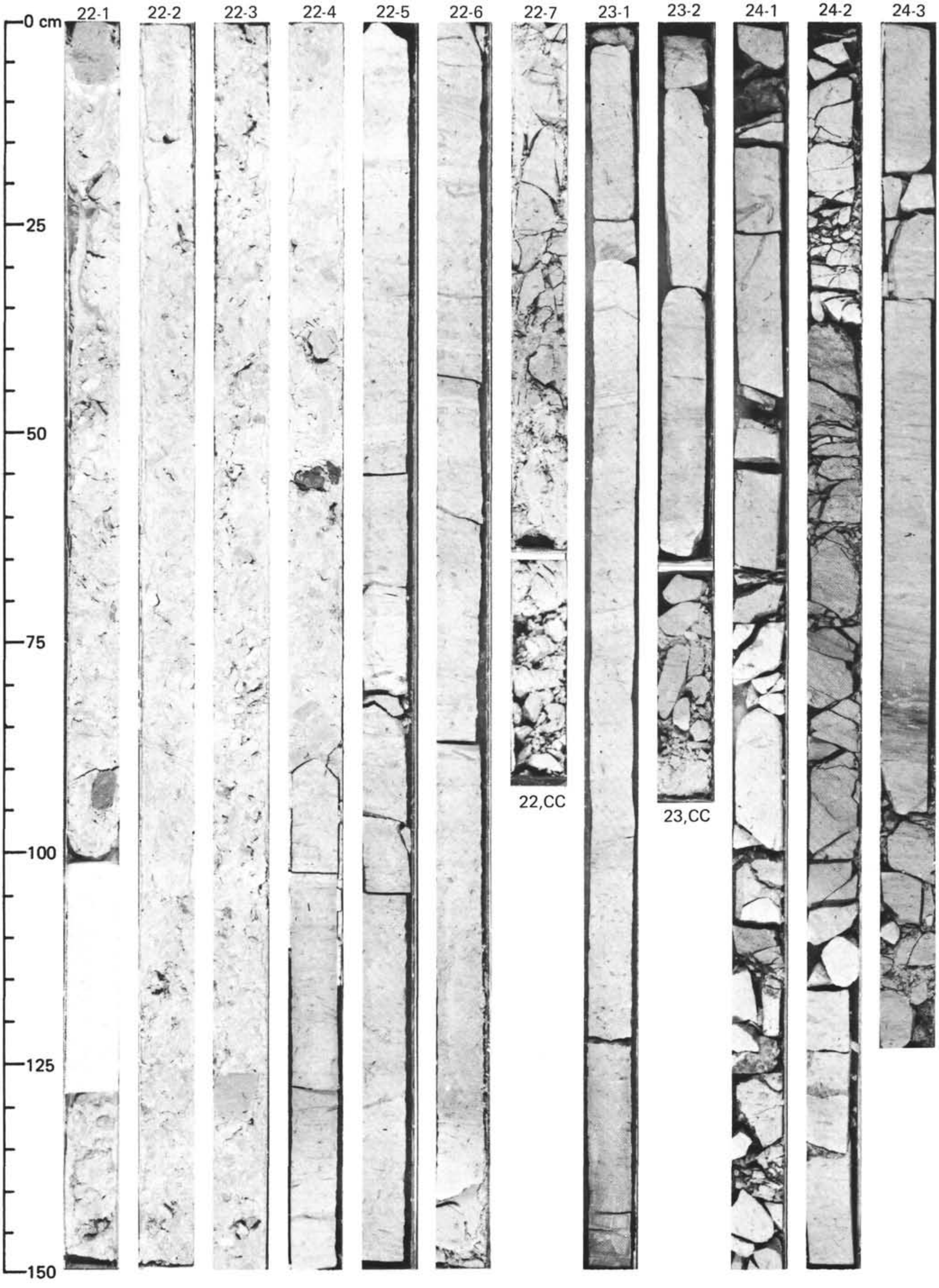
19,CC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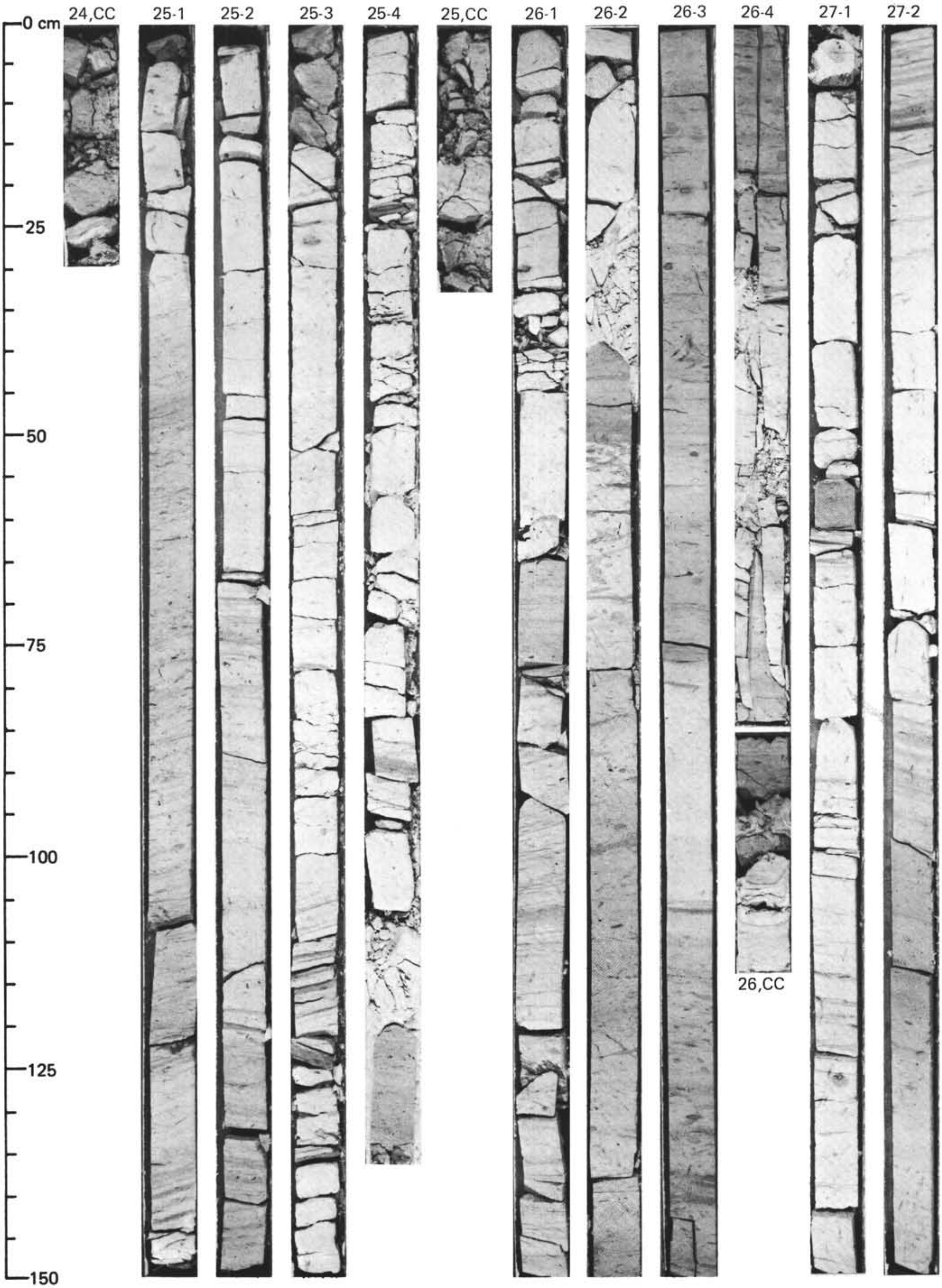
24-3
22,CC
23,CC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26,CC
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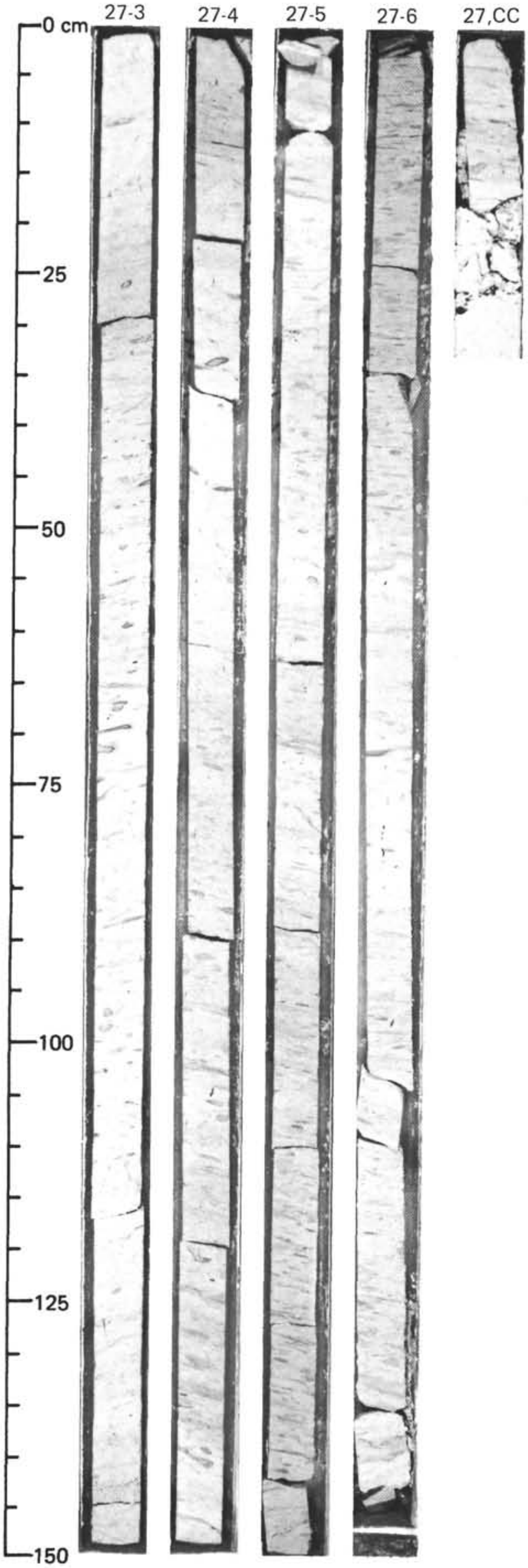
27-2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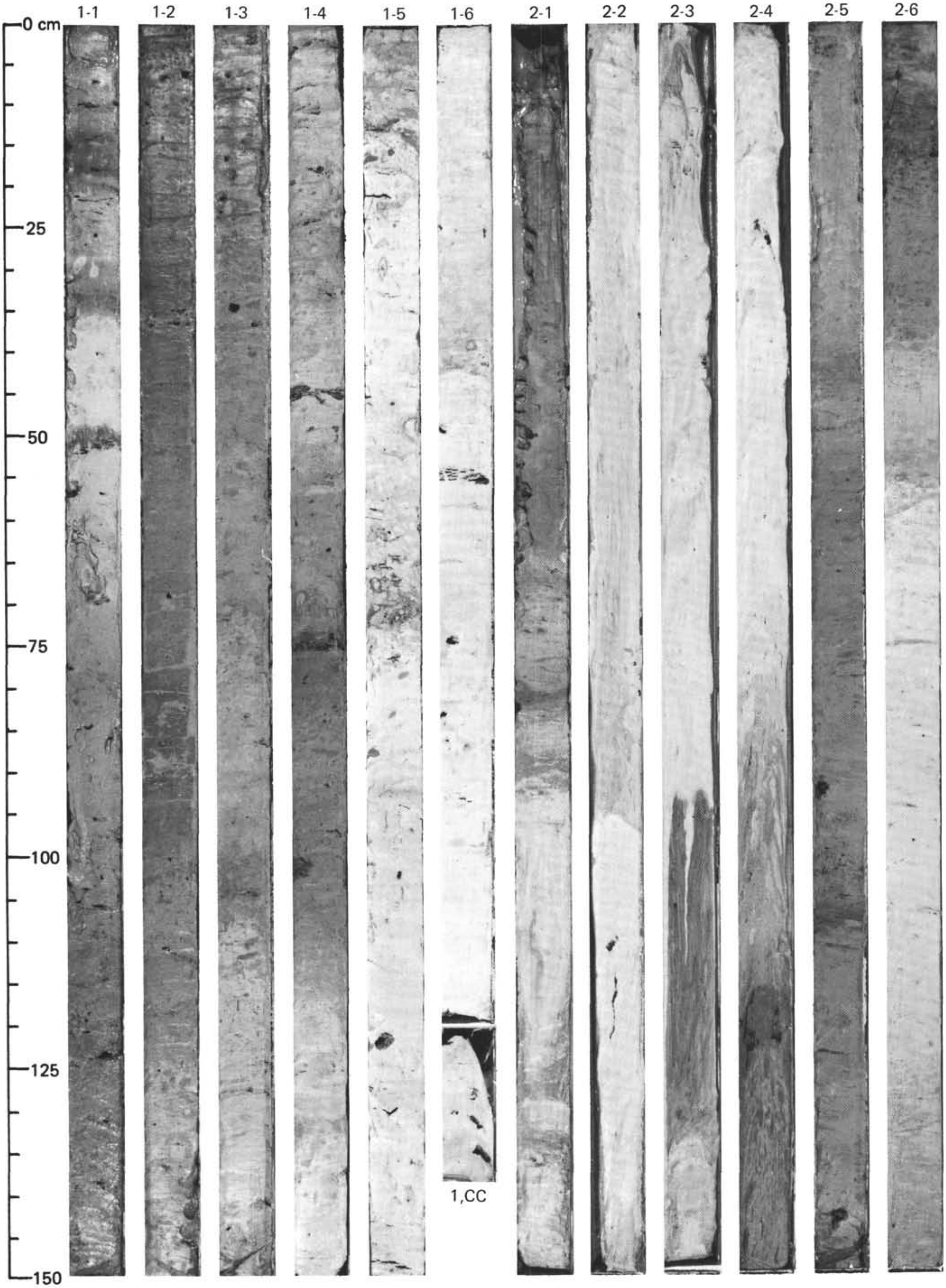
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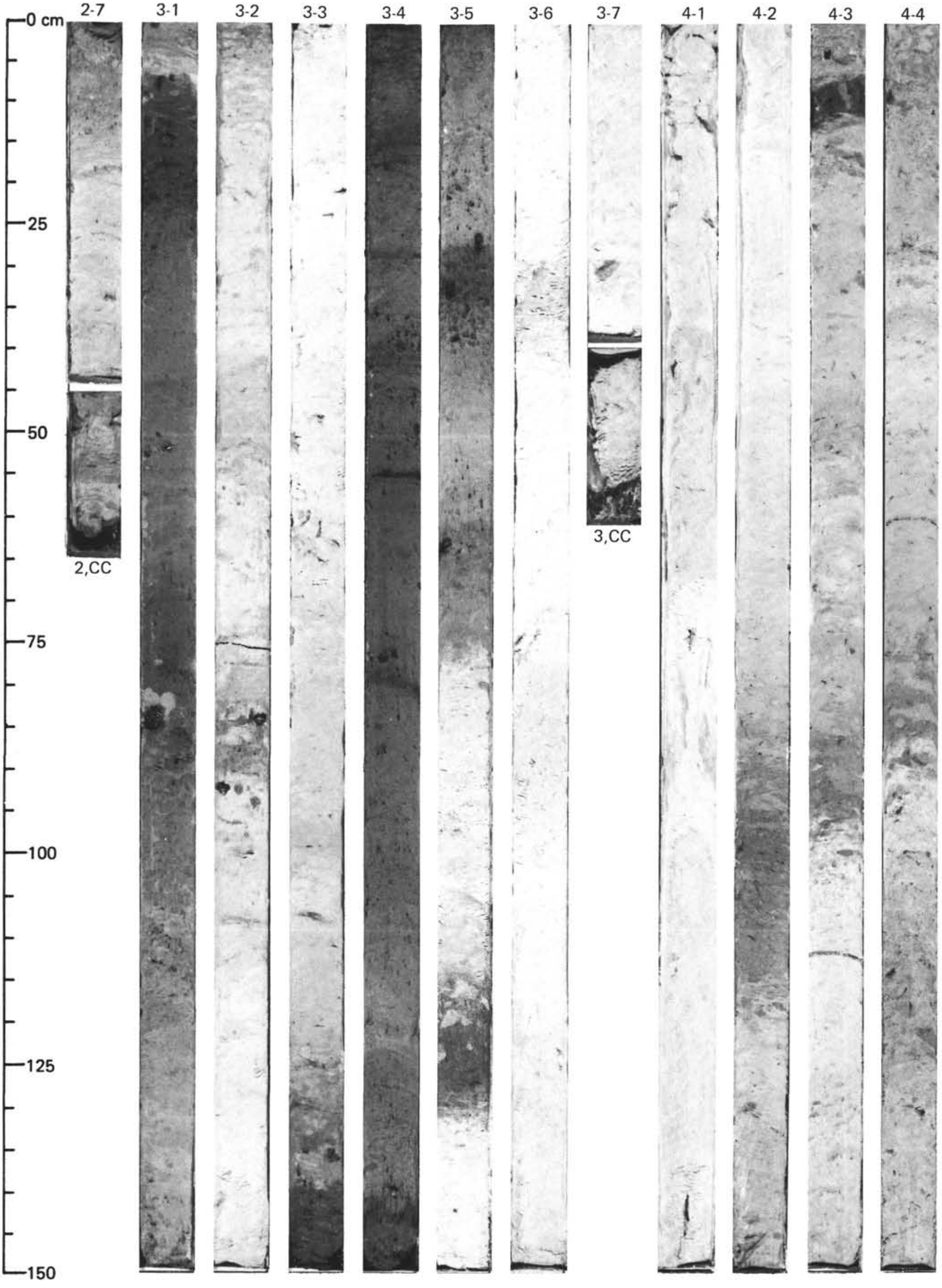
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4-4
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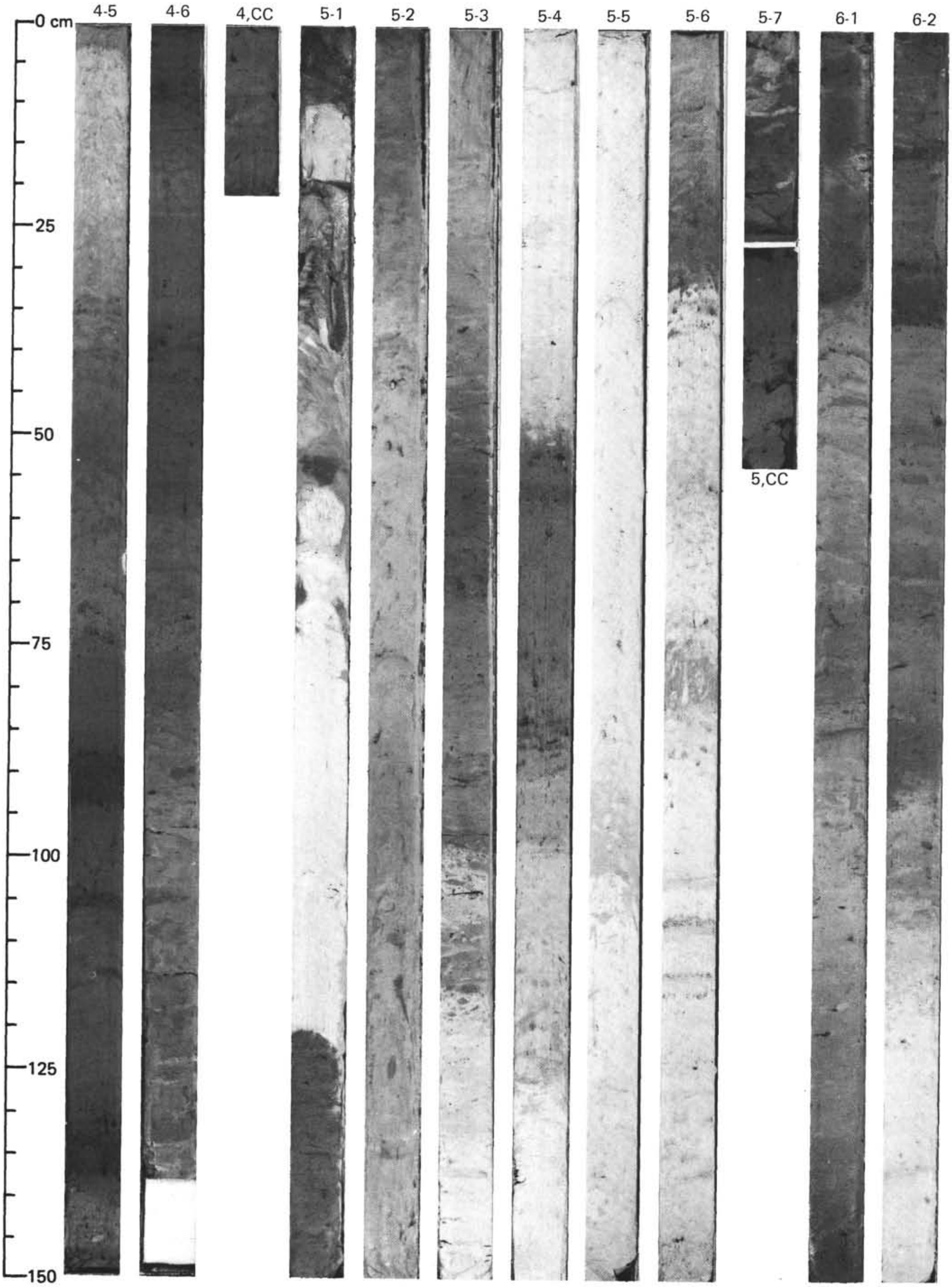
3,CC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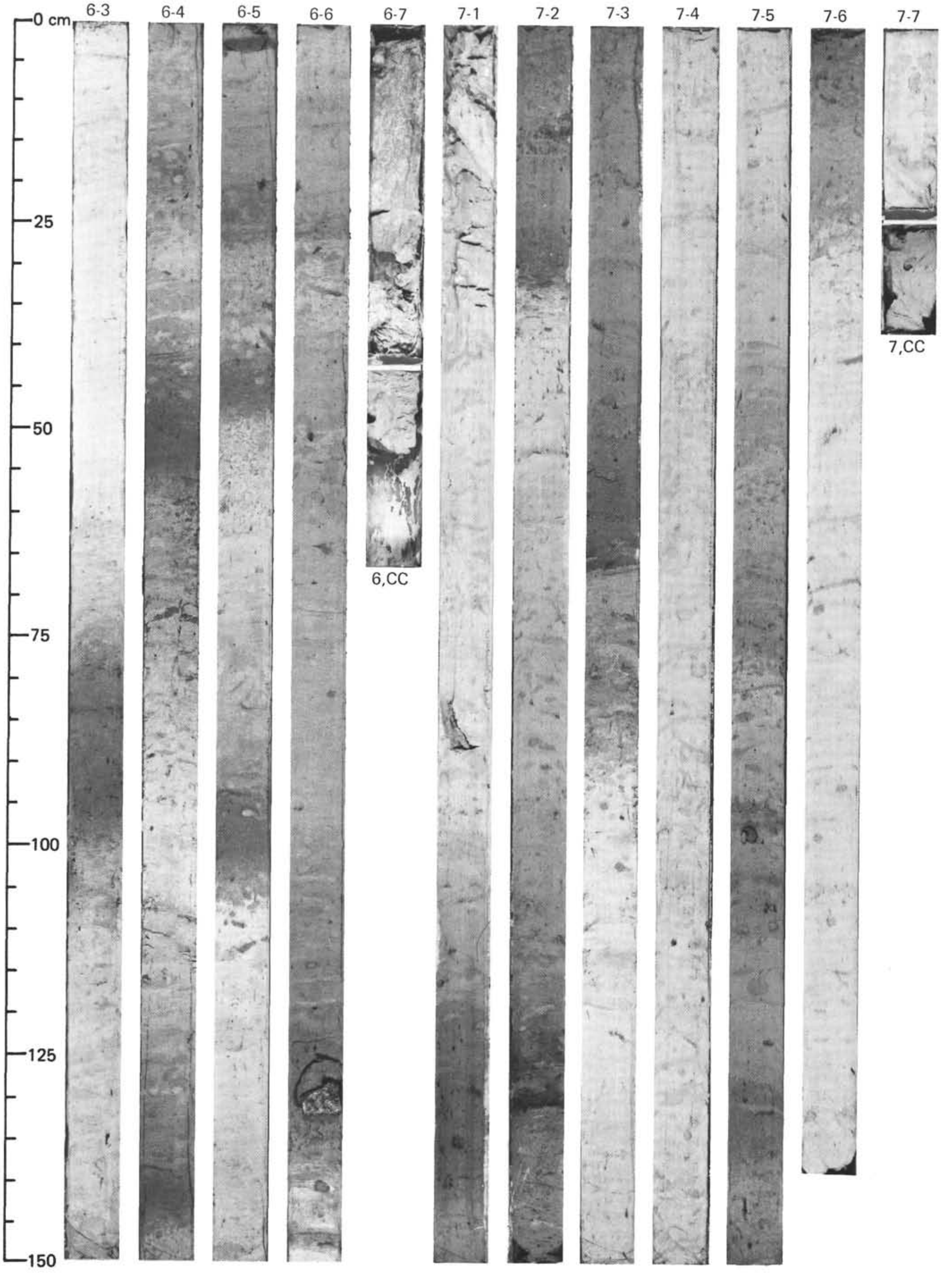
6-2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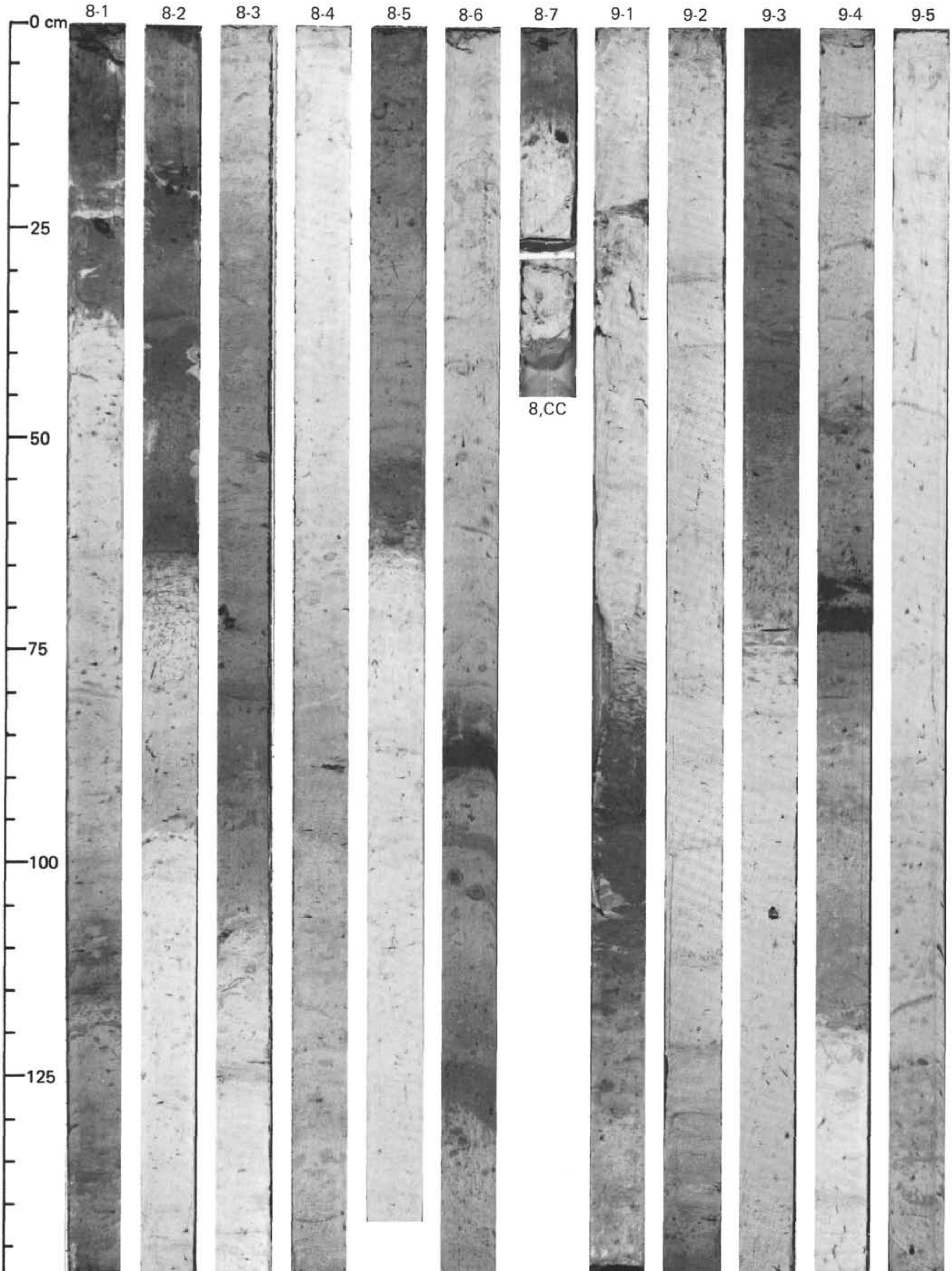

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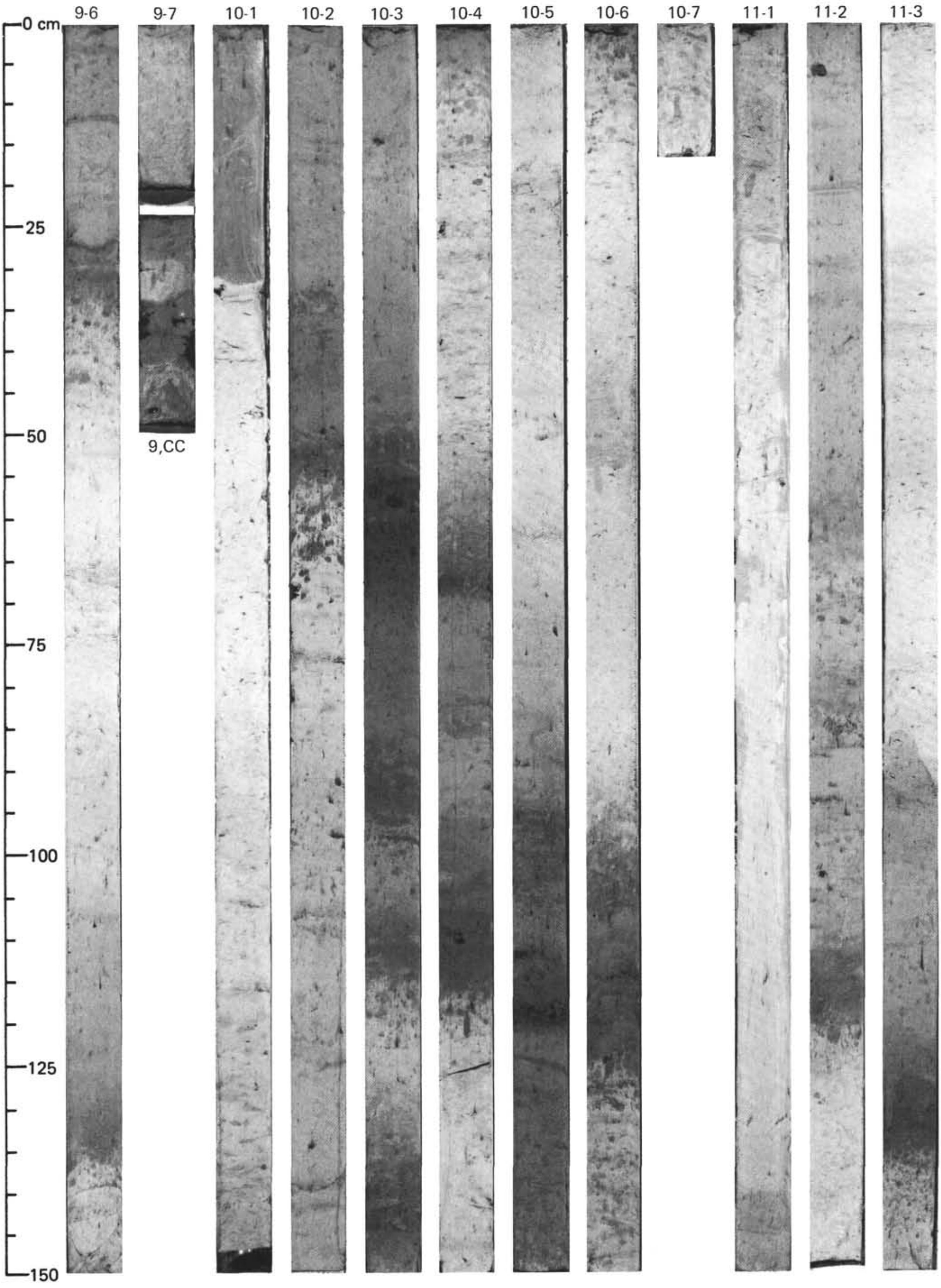
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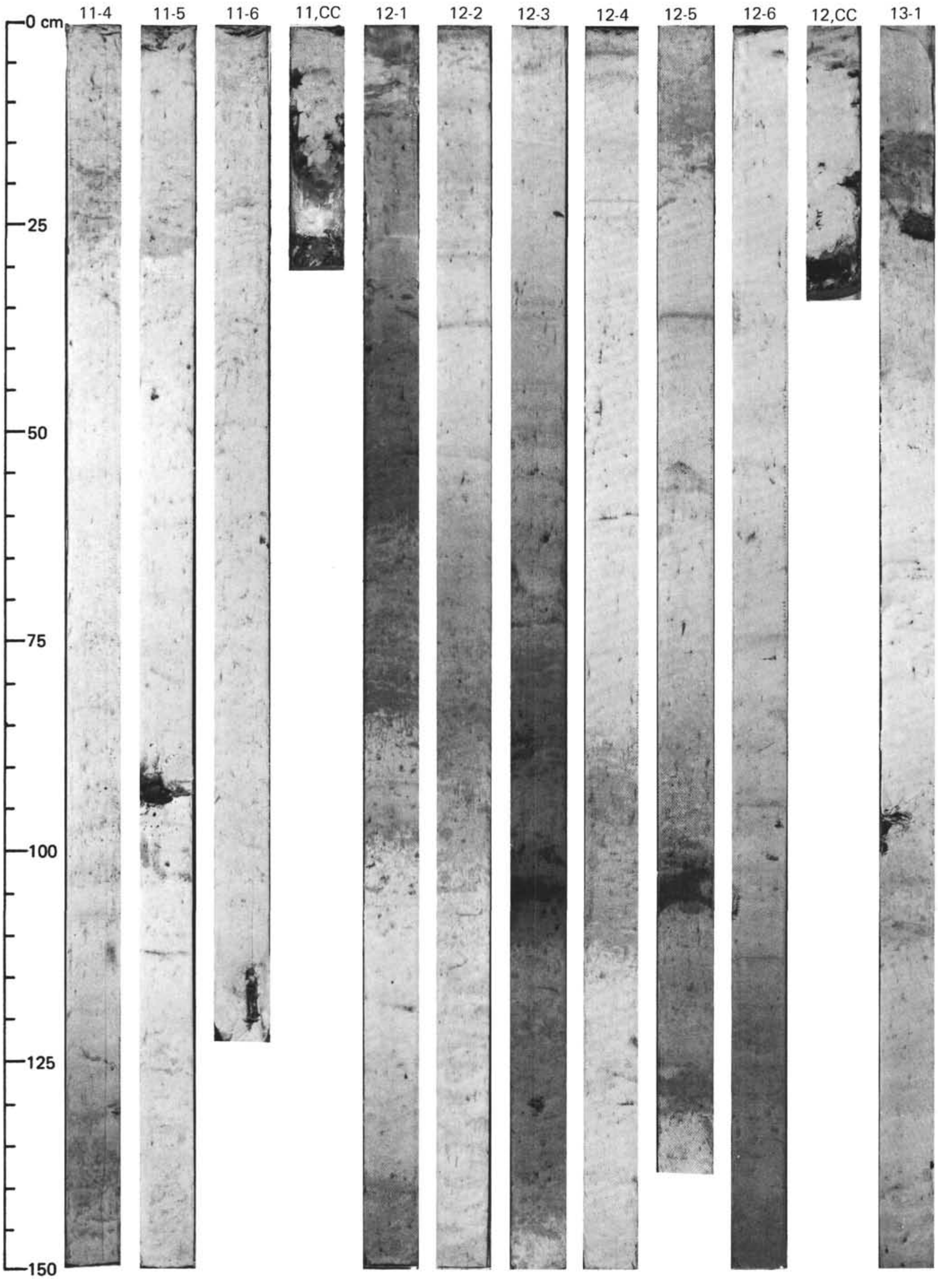
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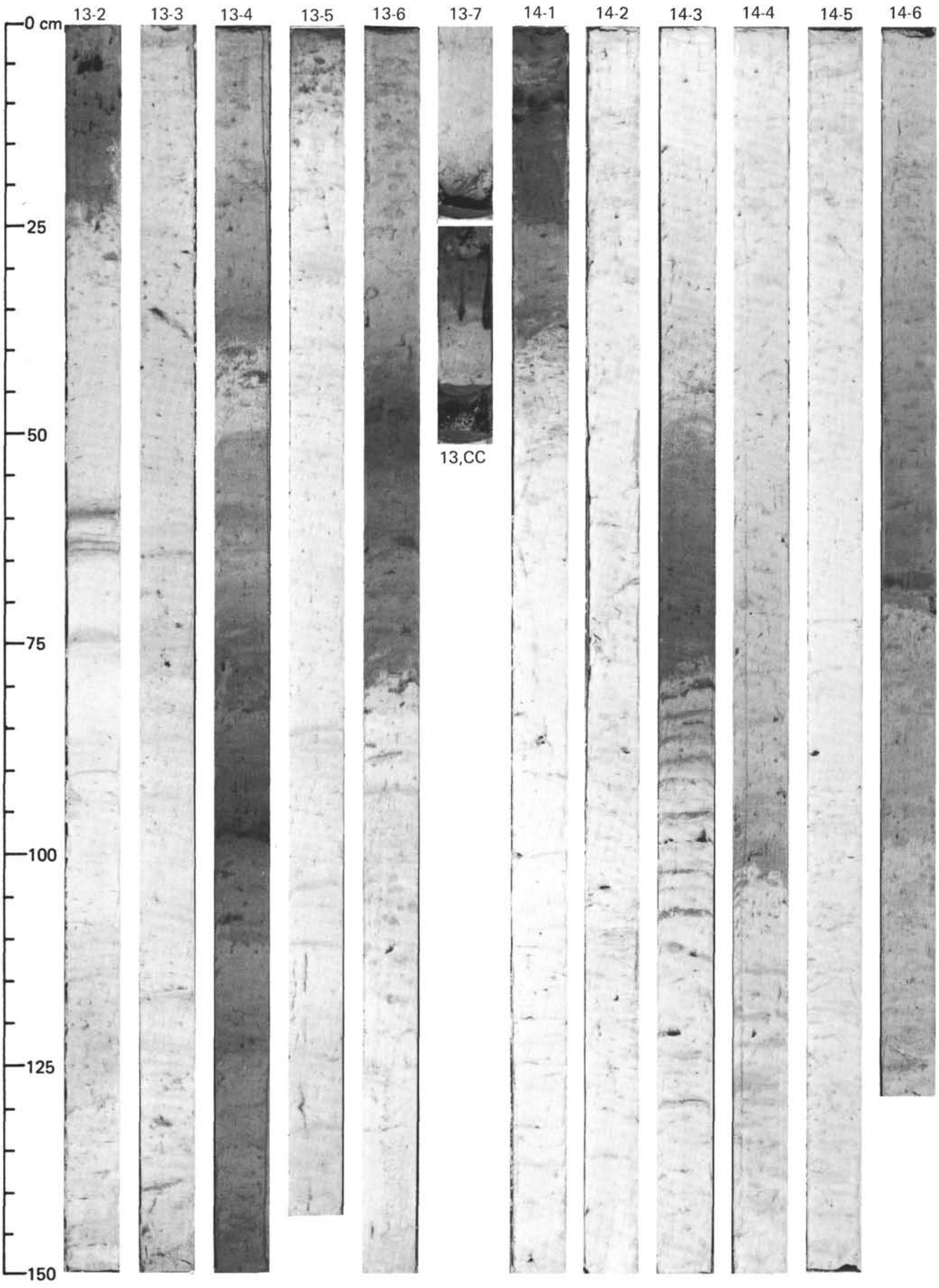
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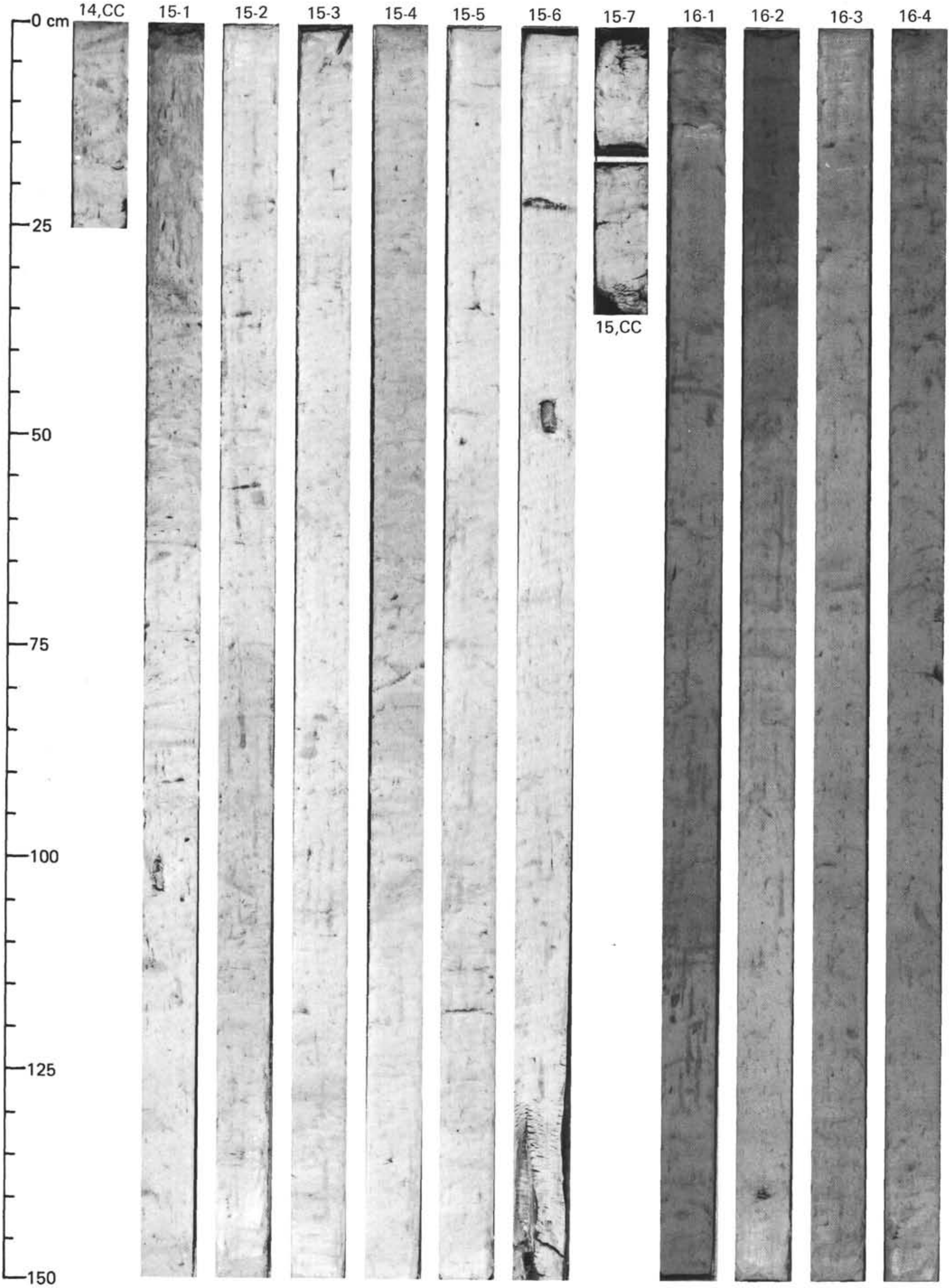
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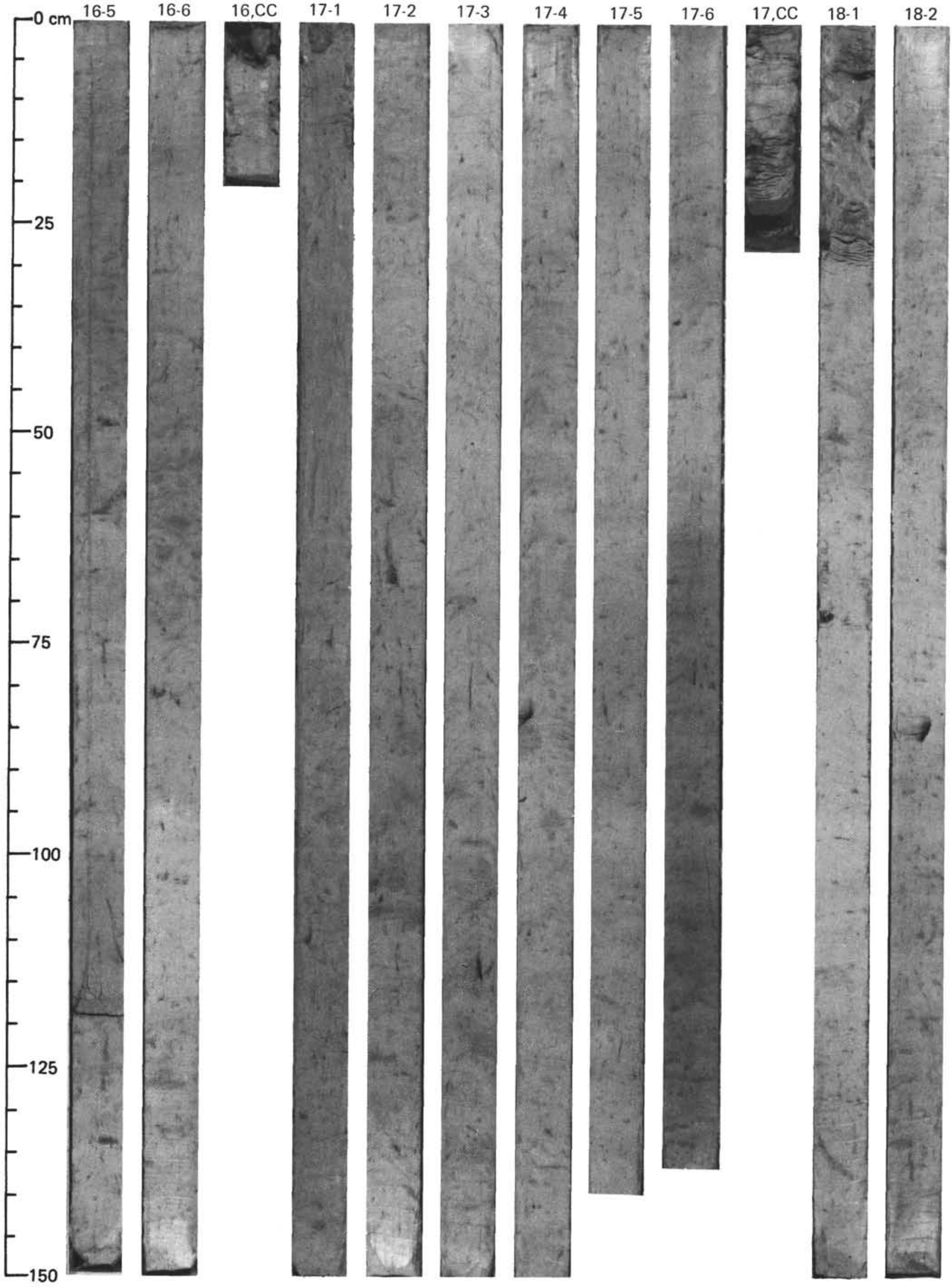
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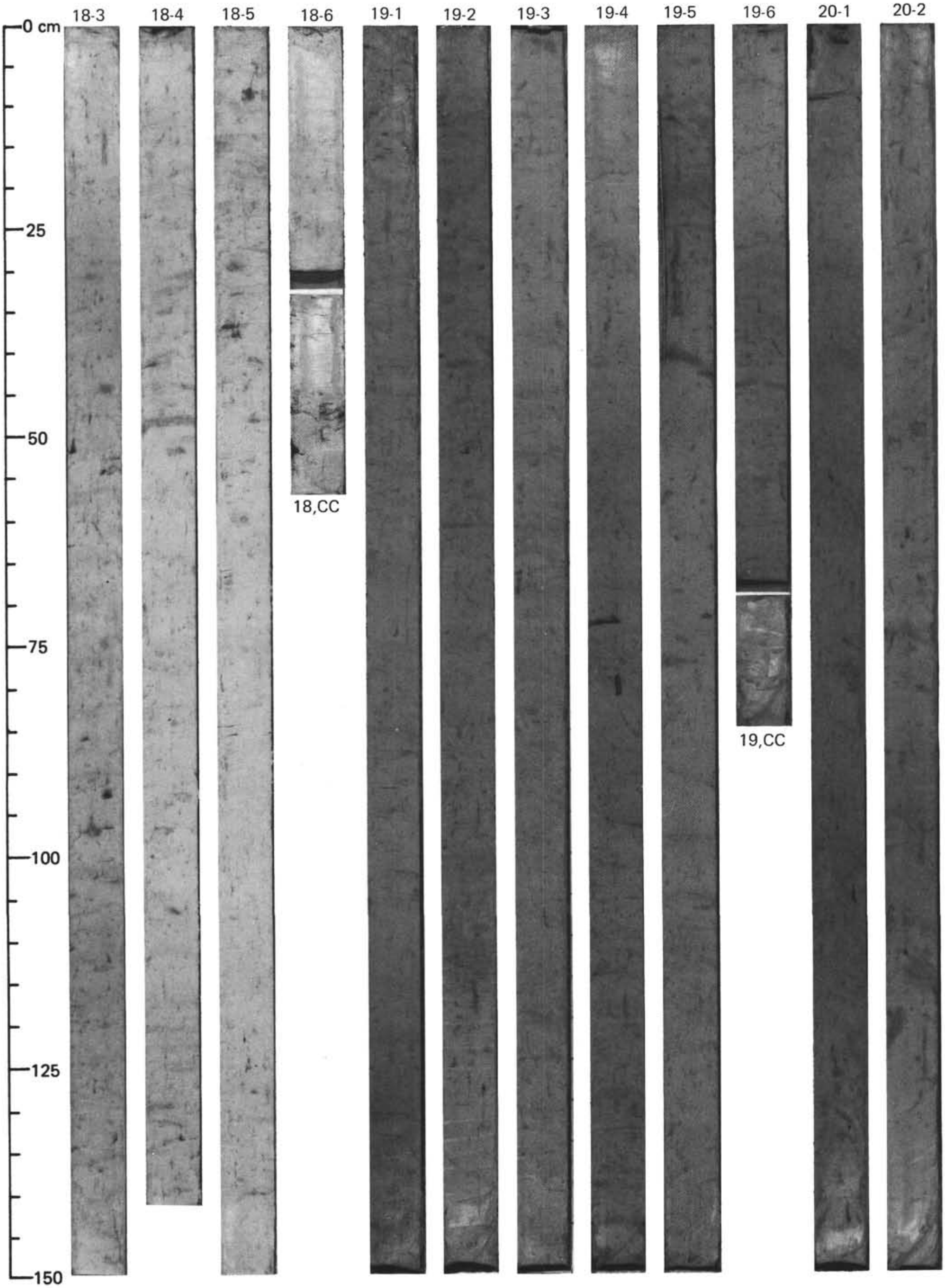
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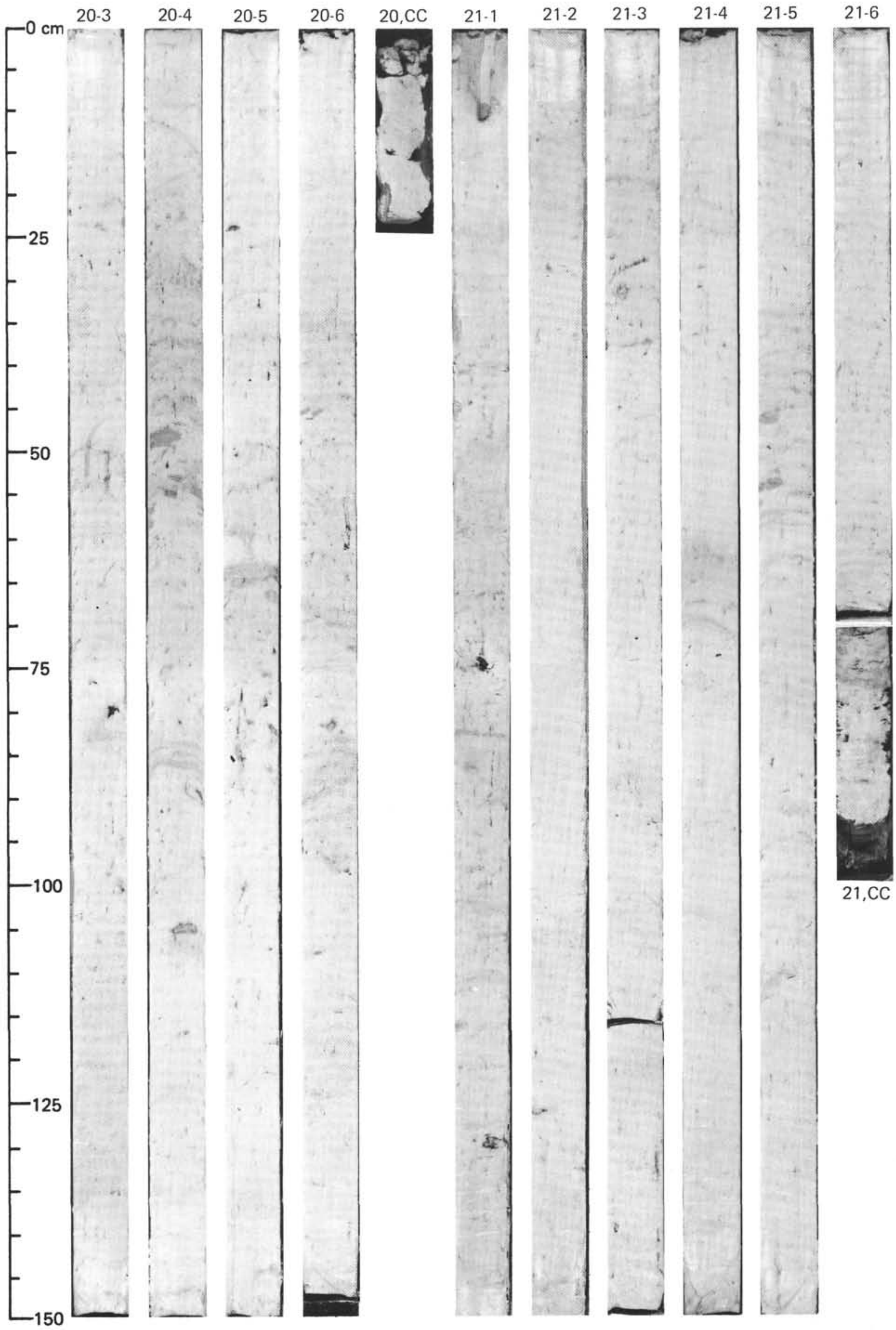
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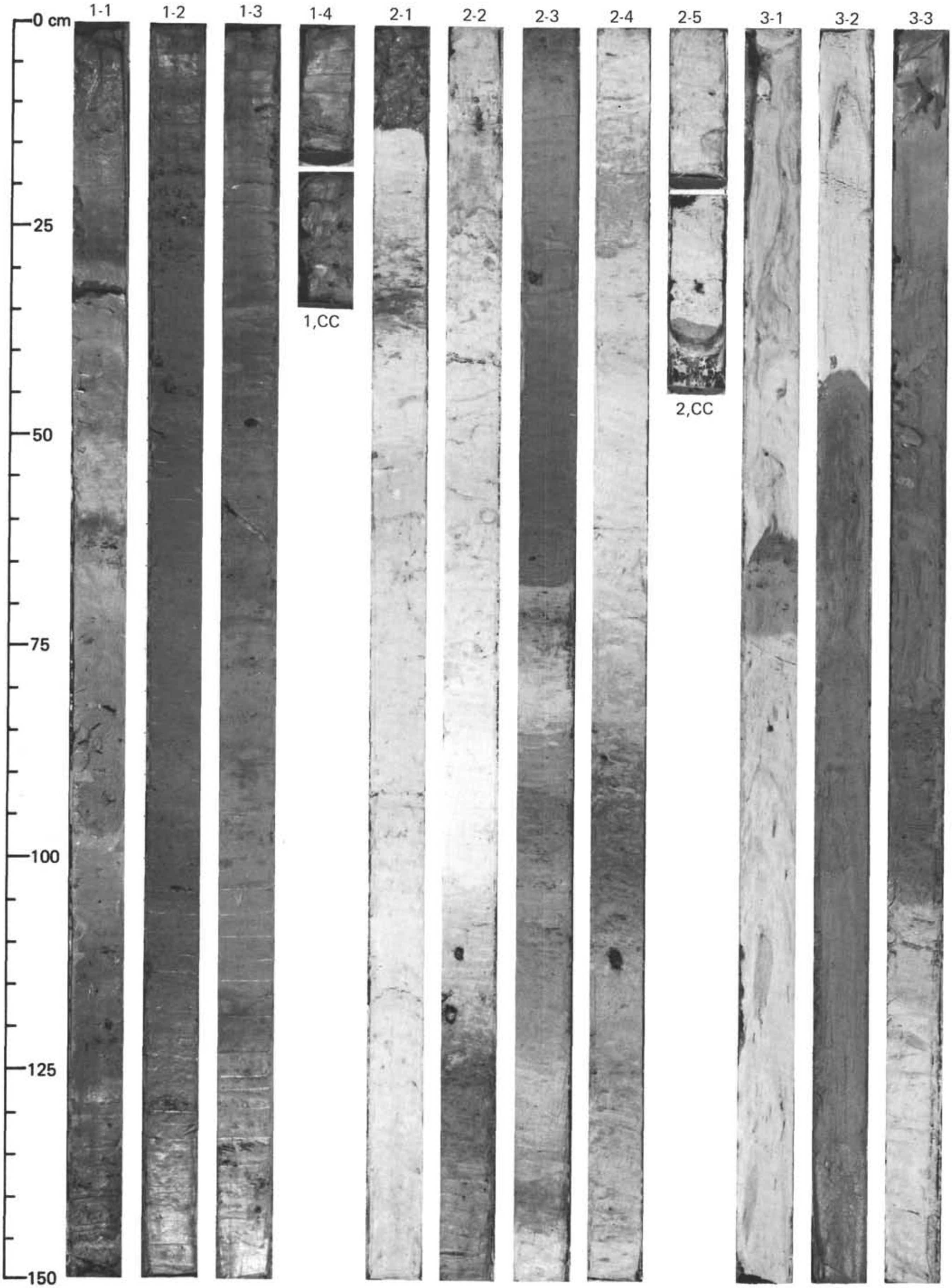
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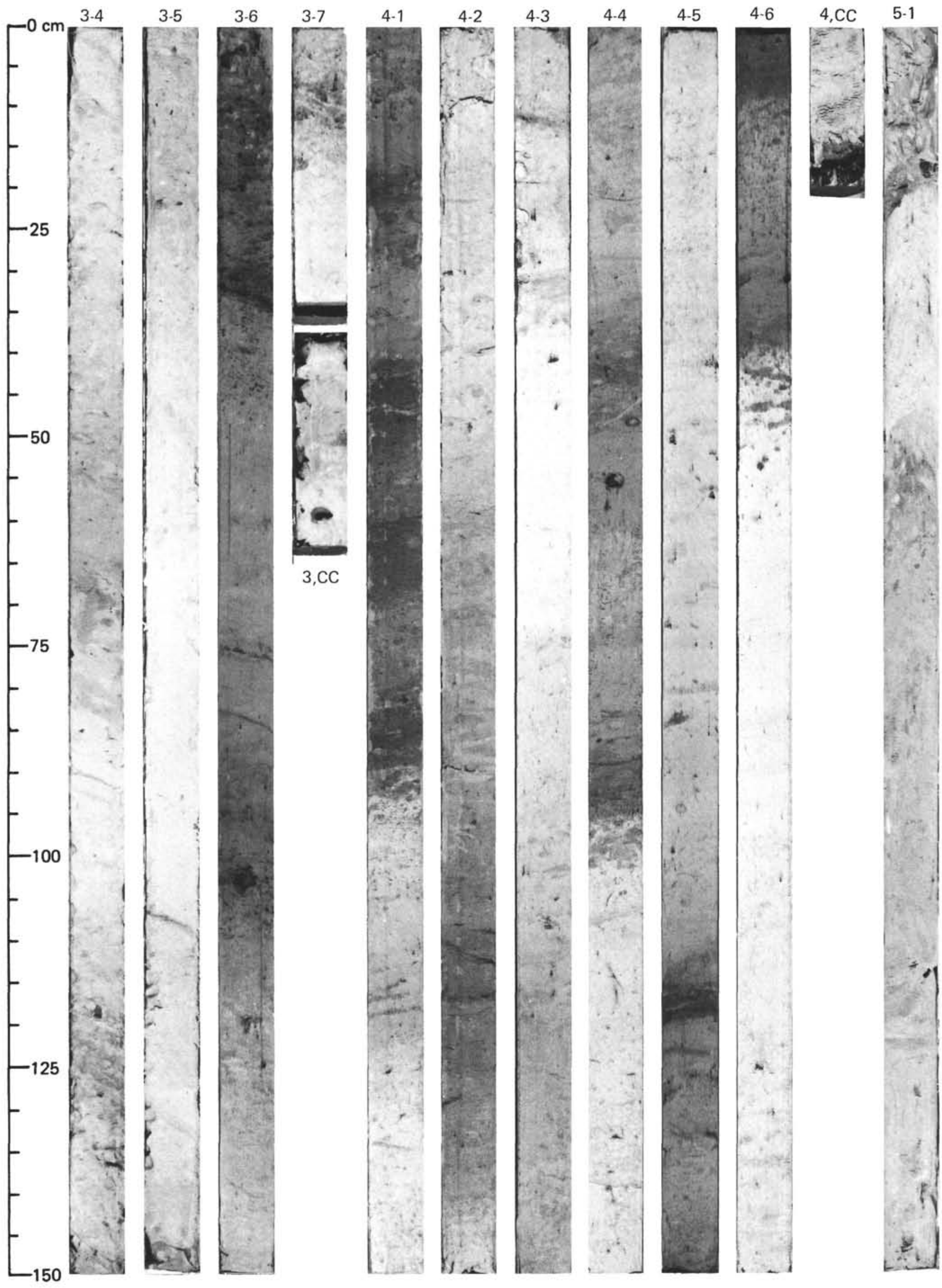
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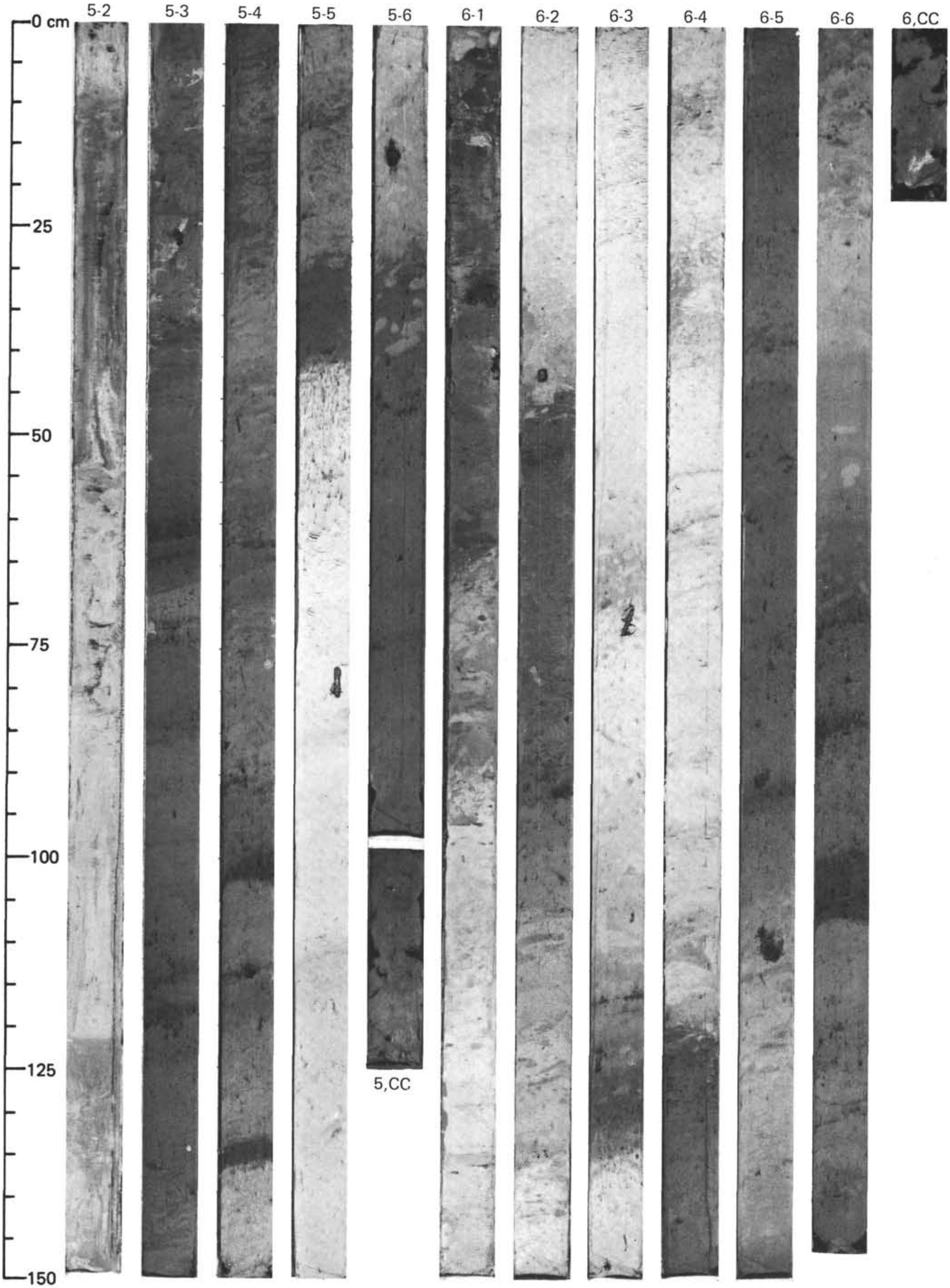
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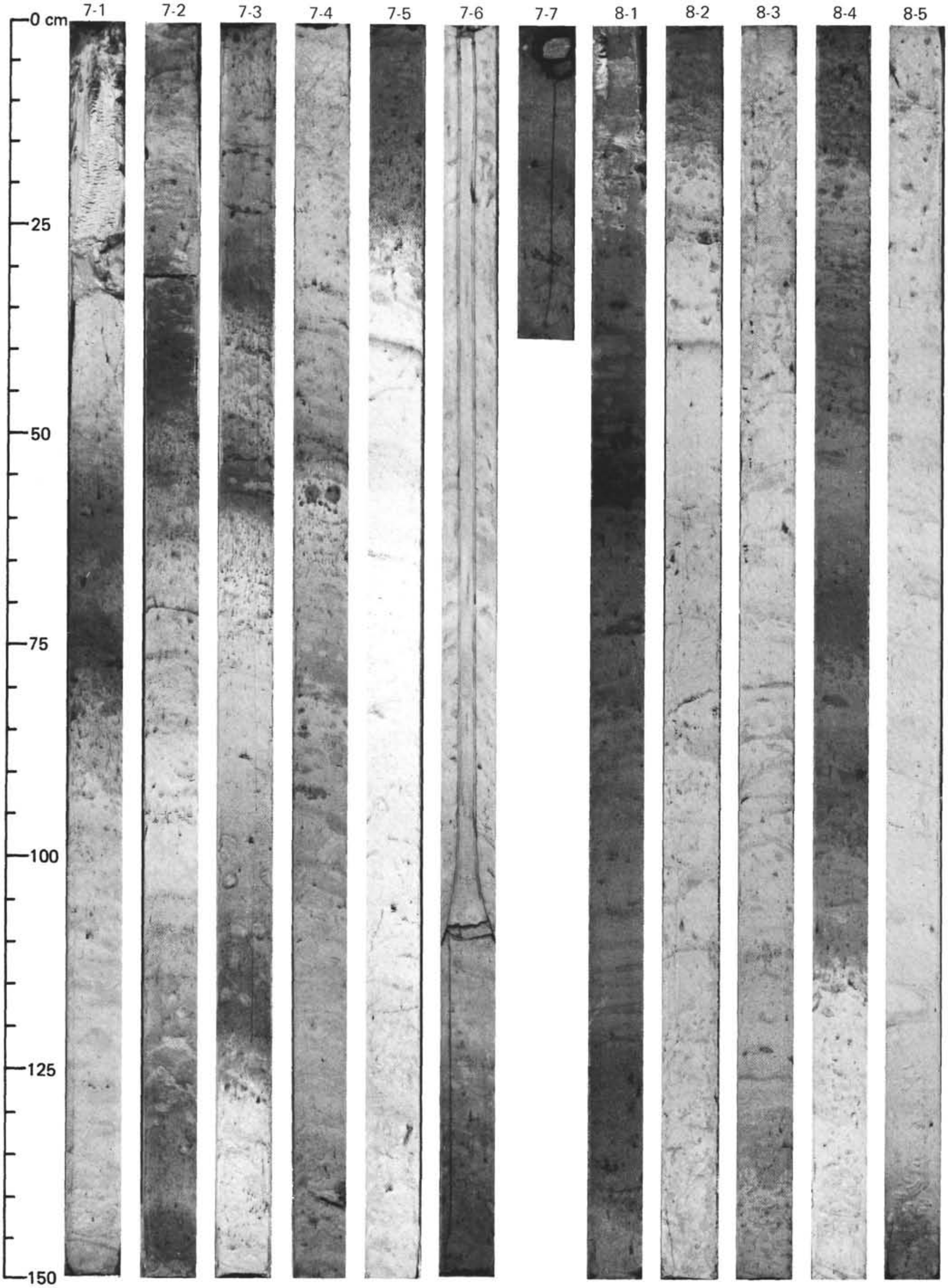
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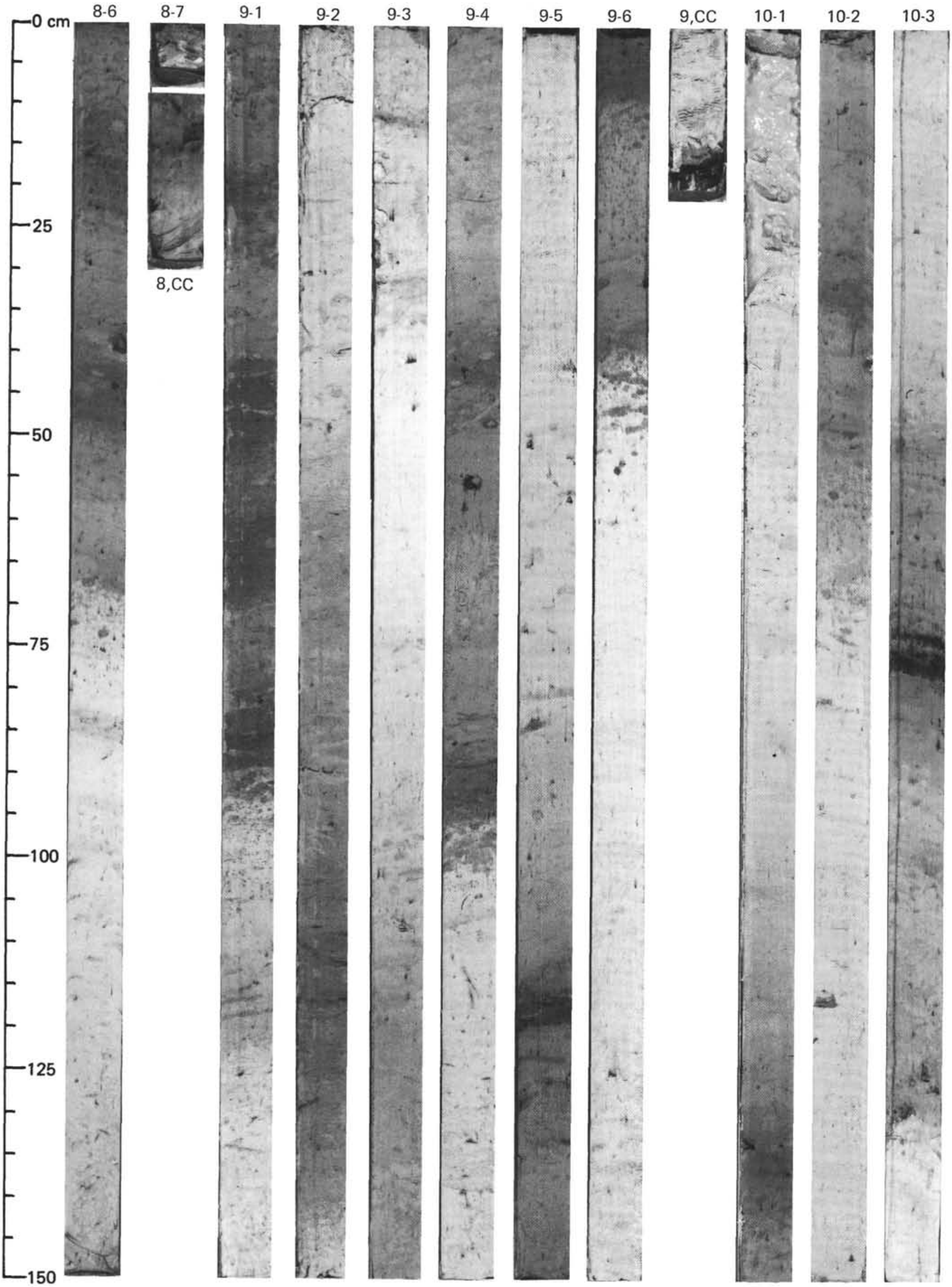
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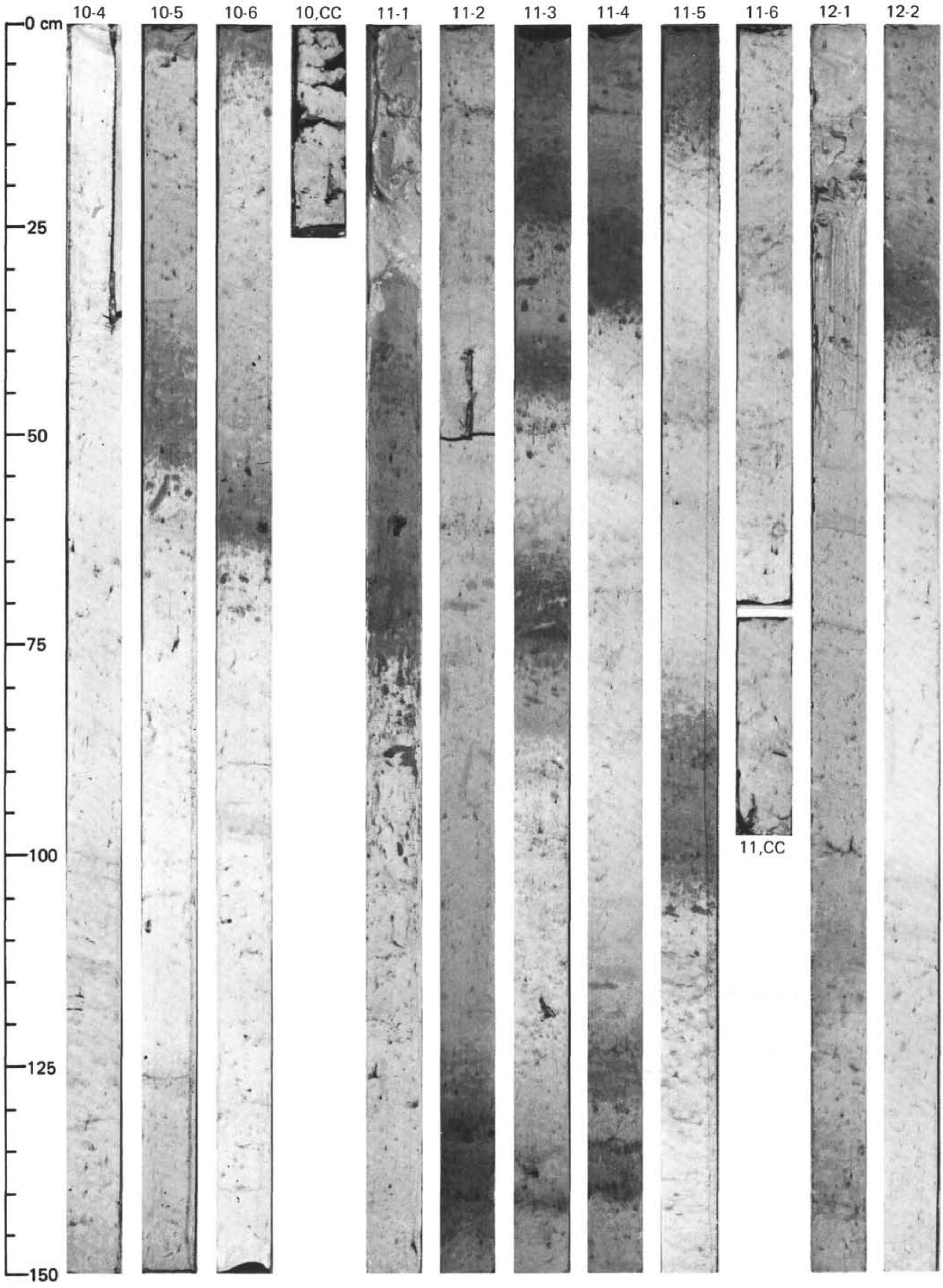

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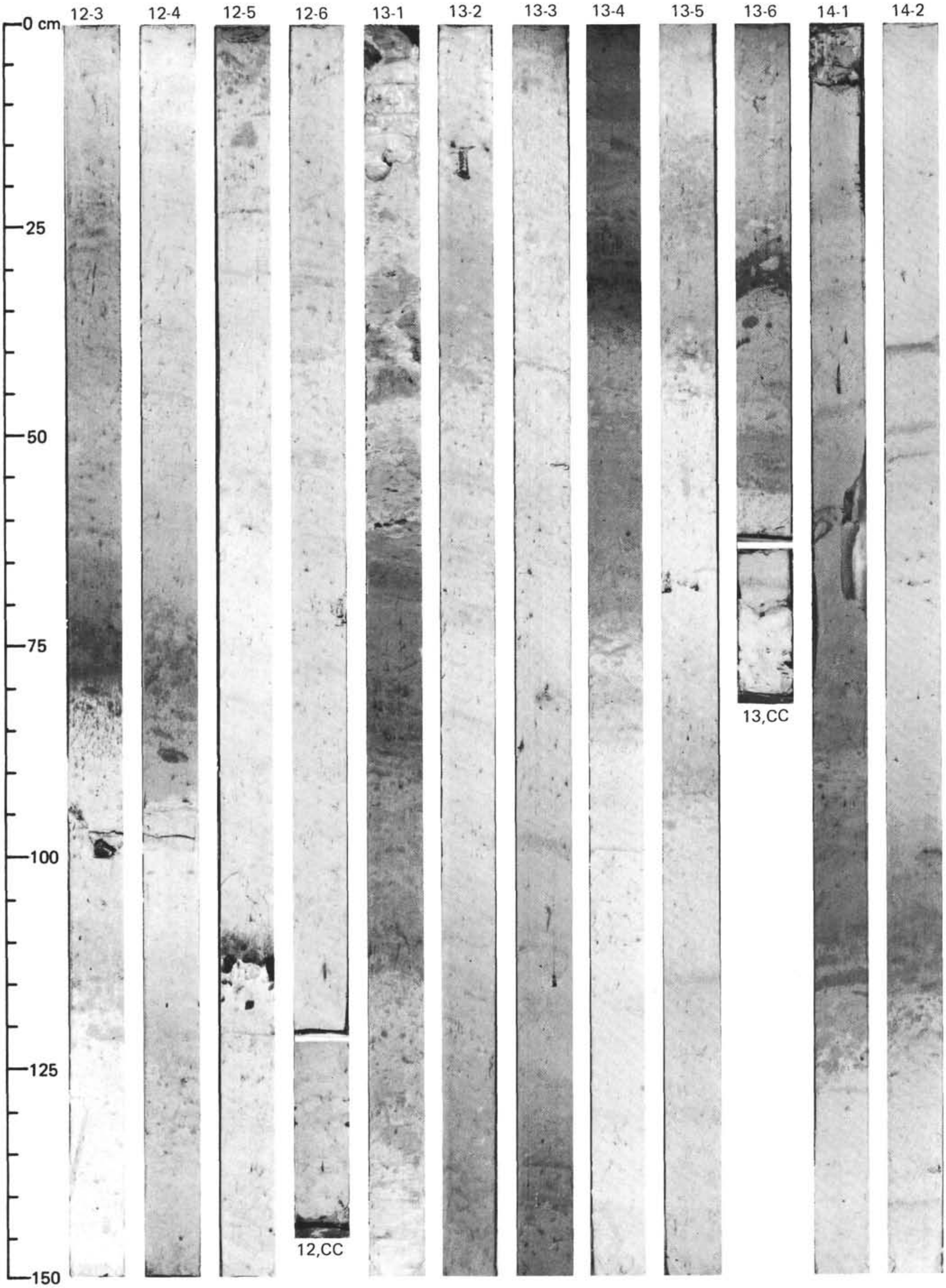
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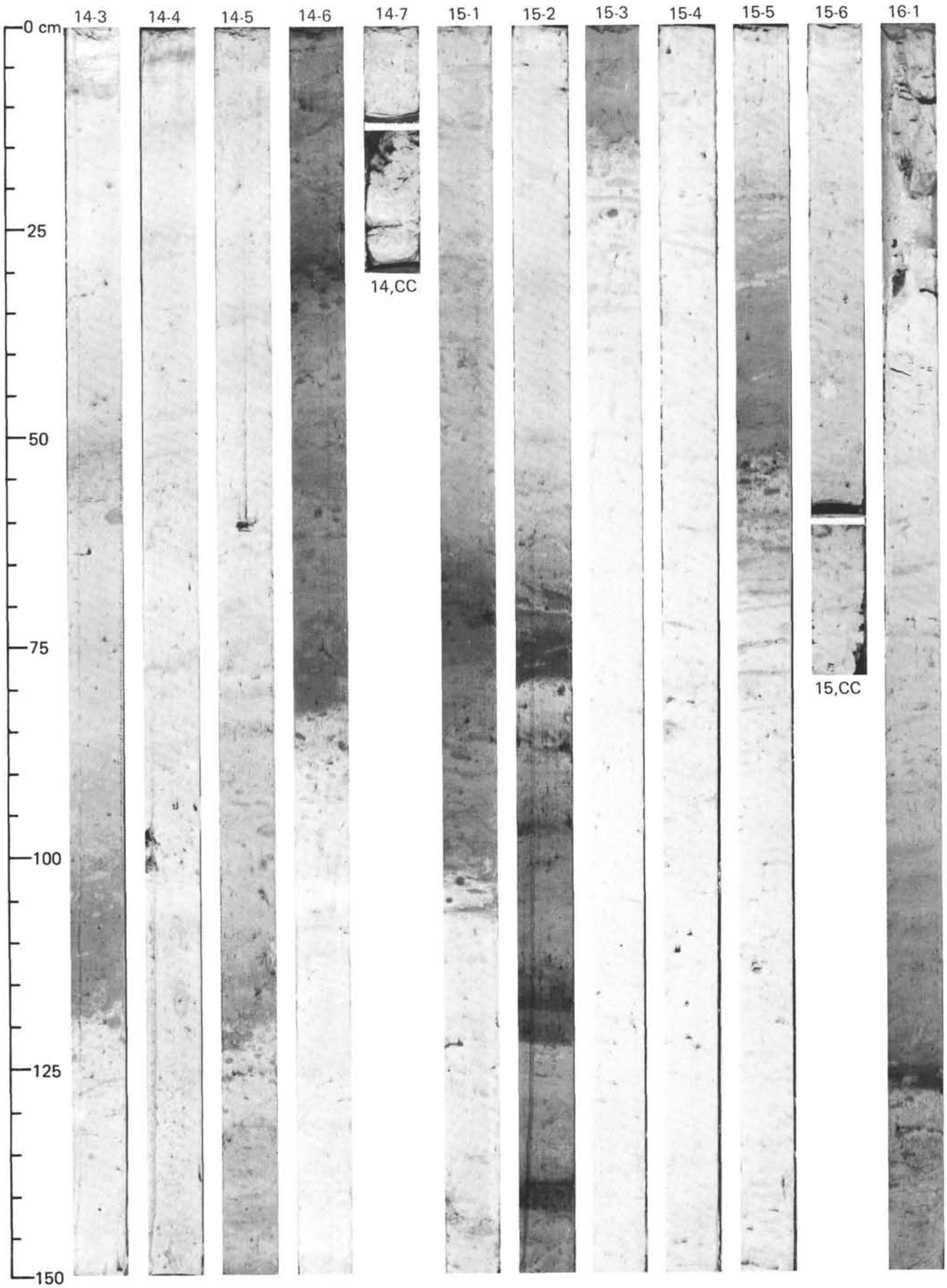
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16-1
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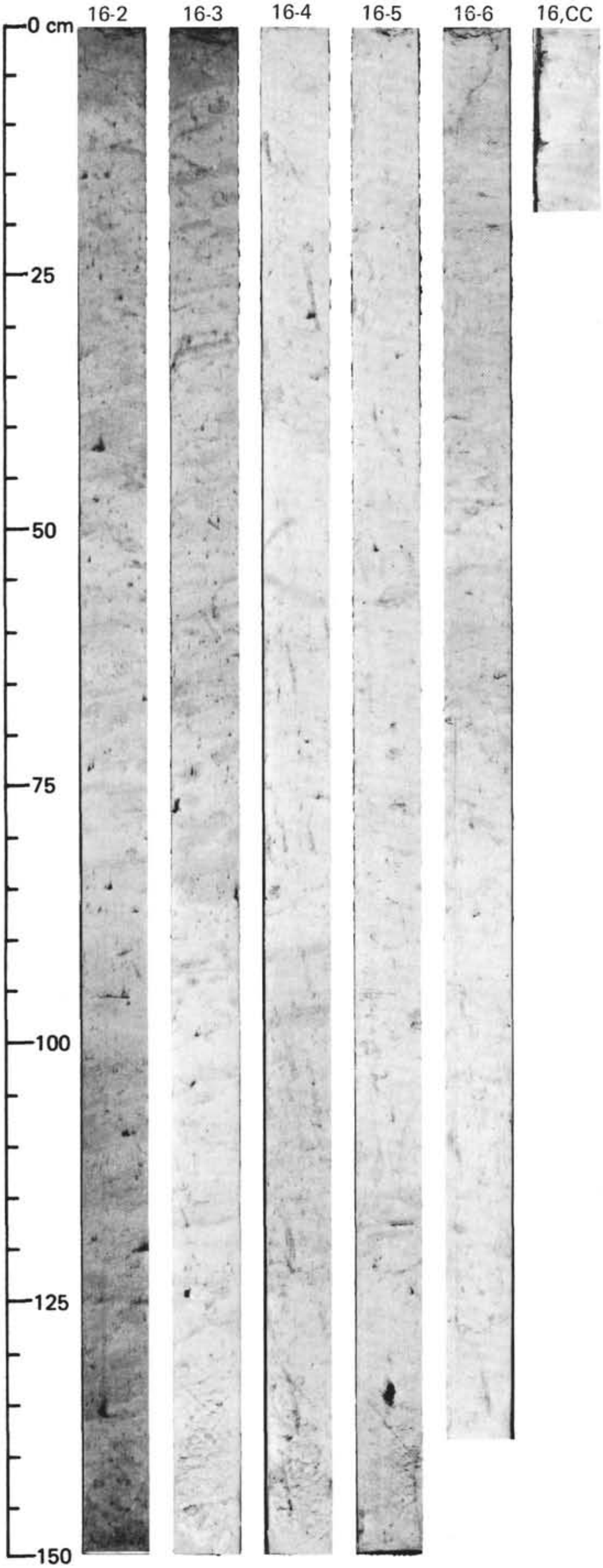
15,CC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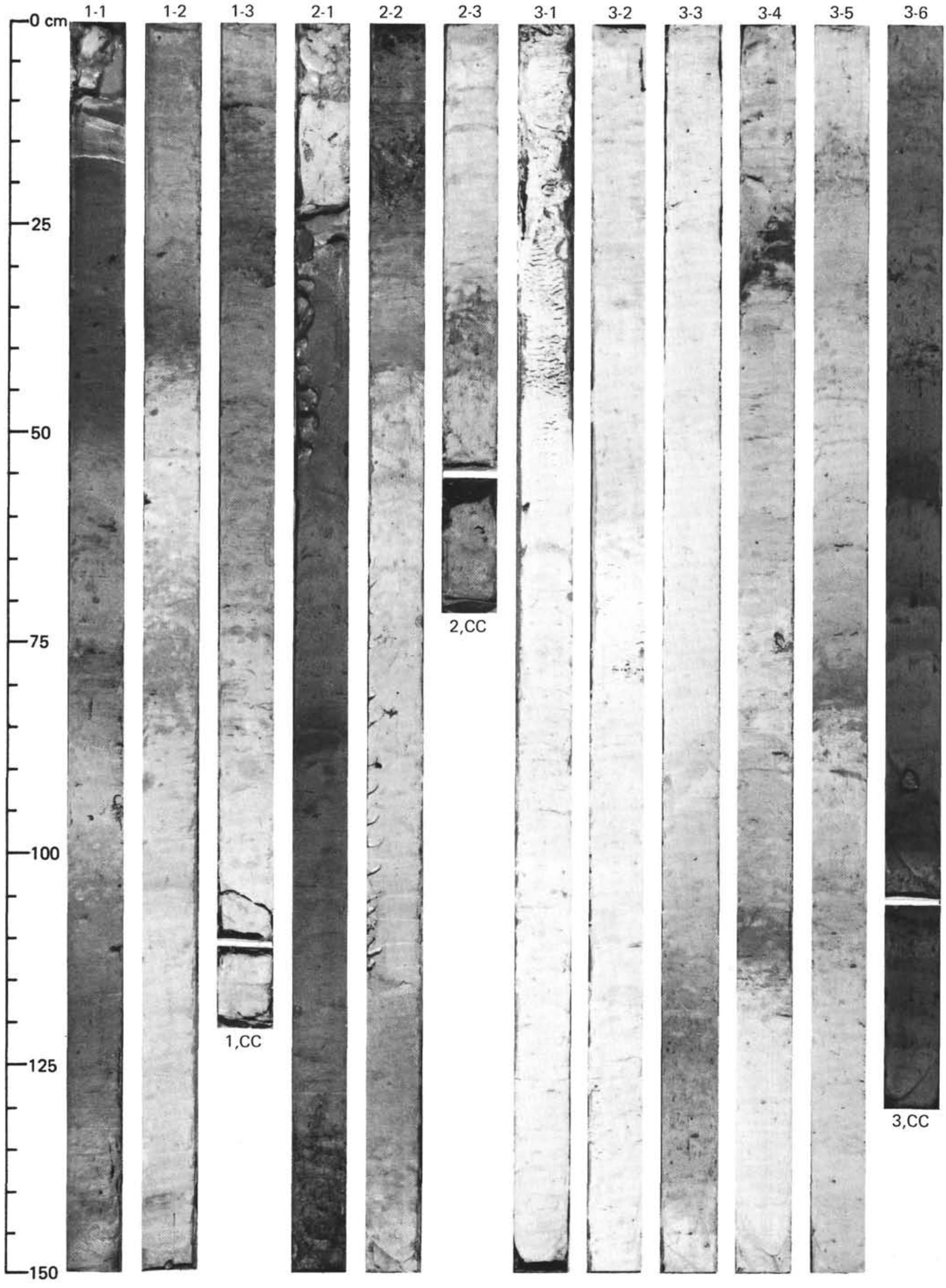
1-1
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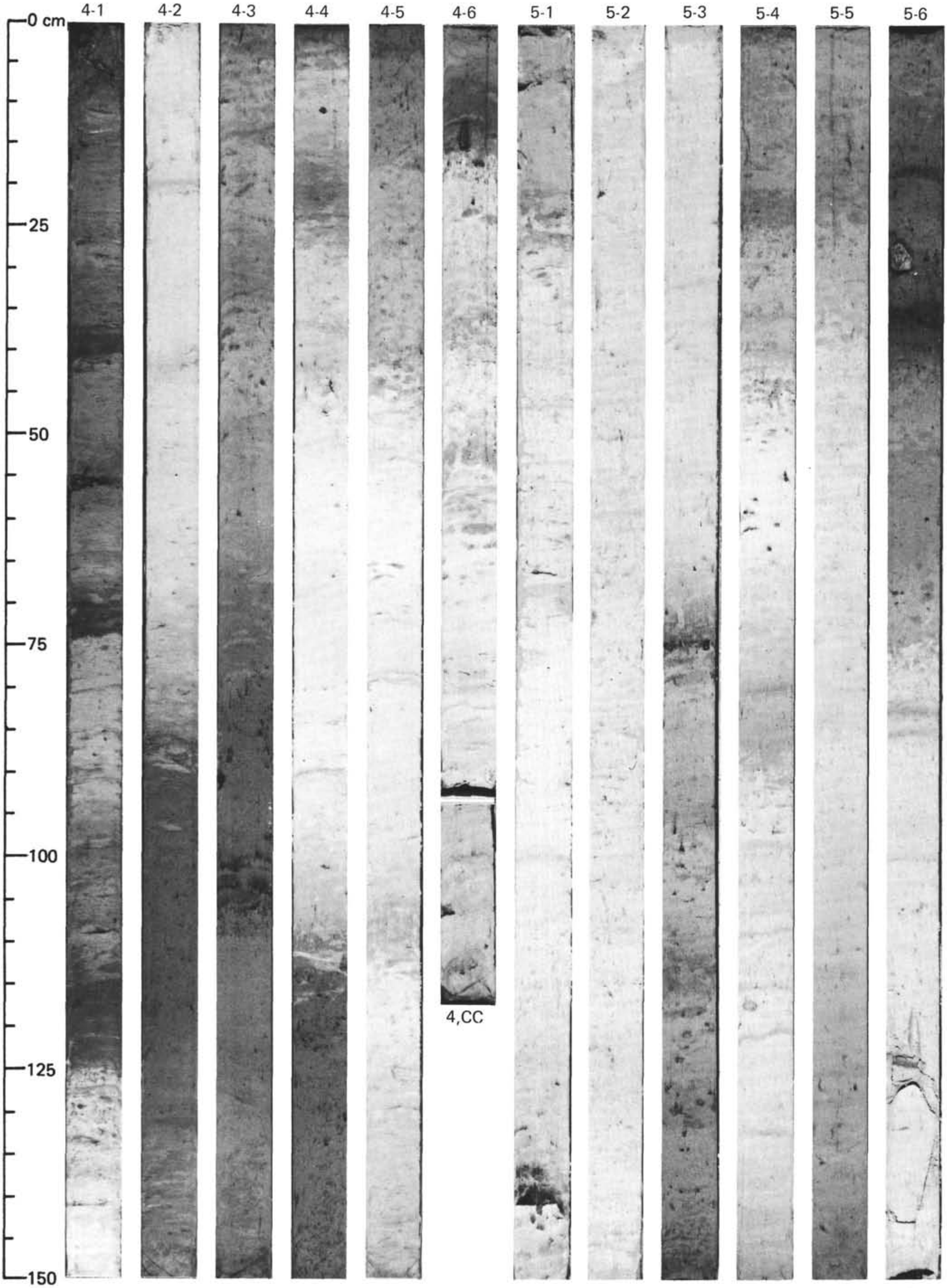
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0 cm
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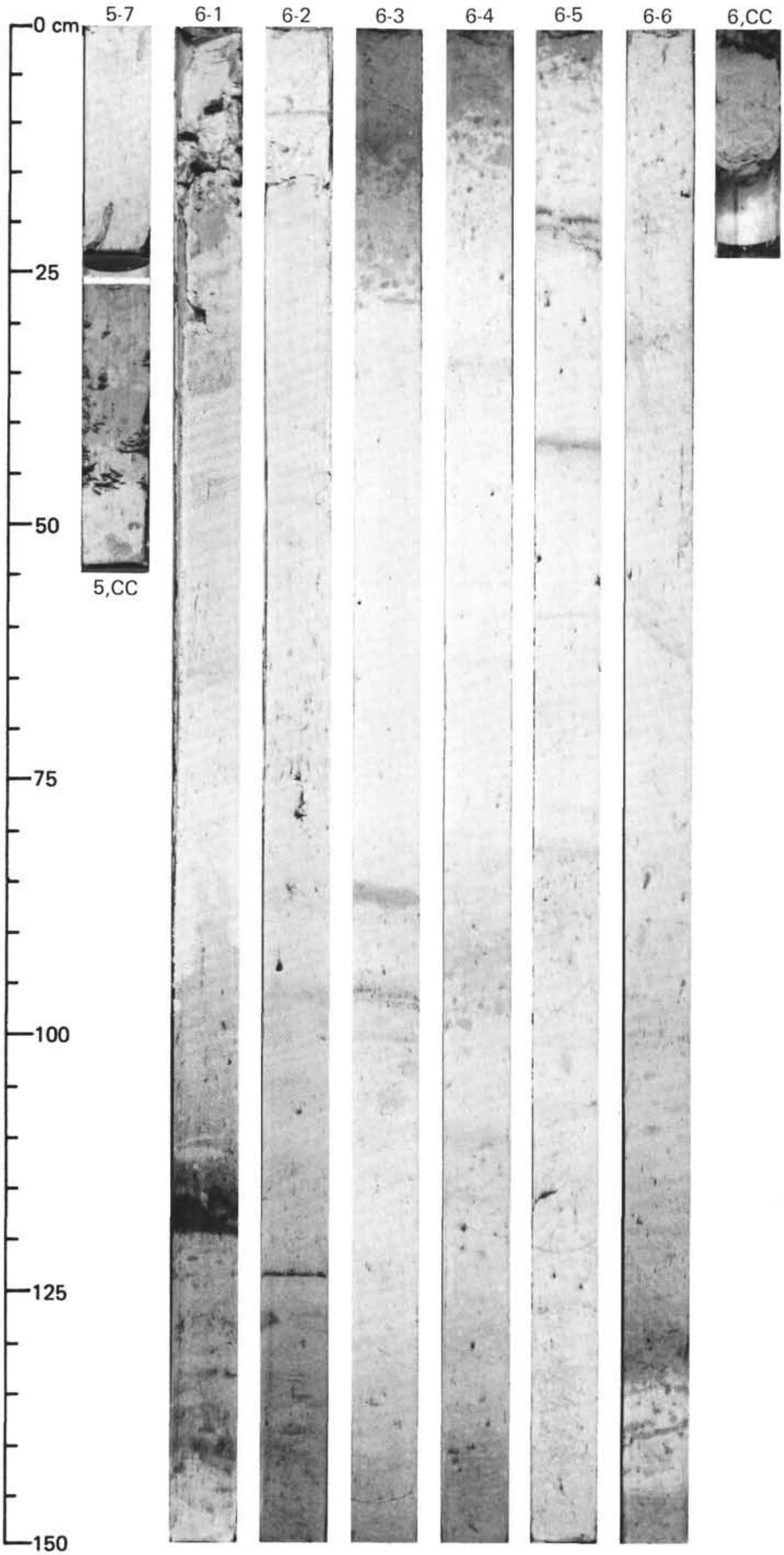
4,CC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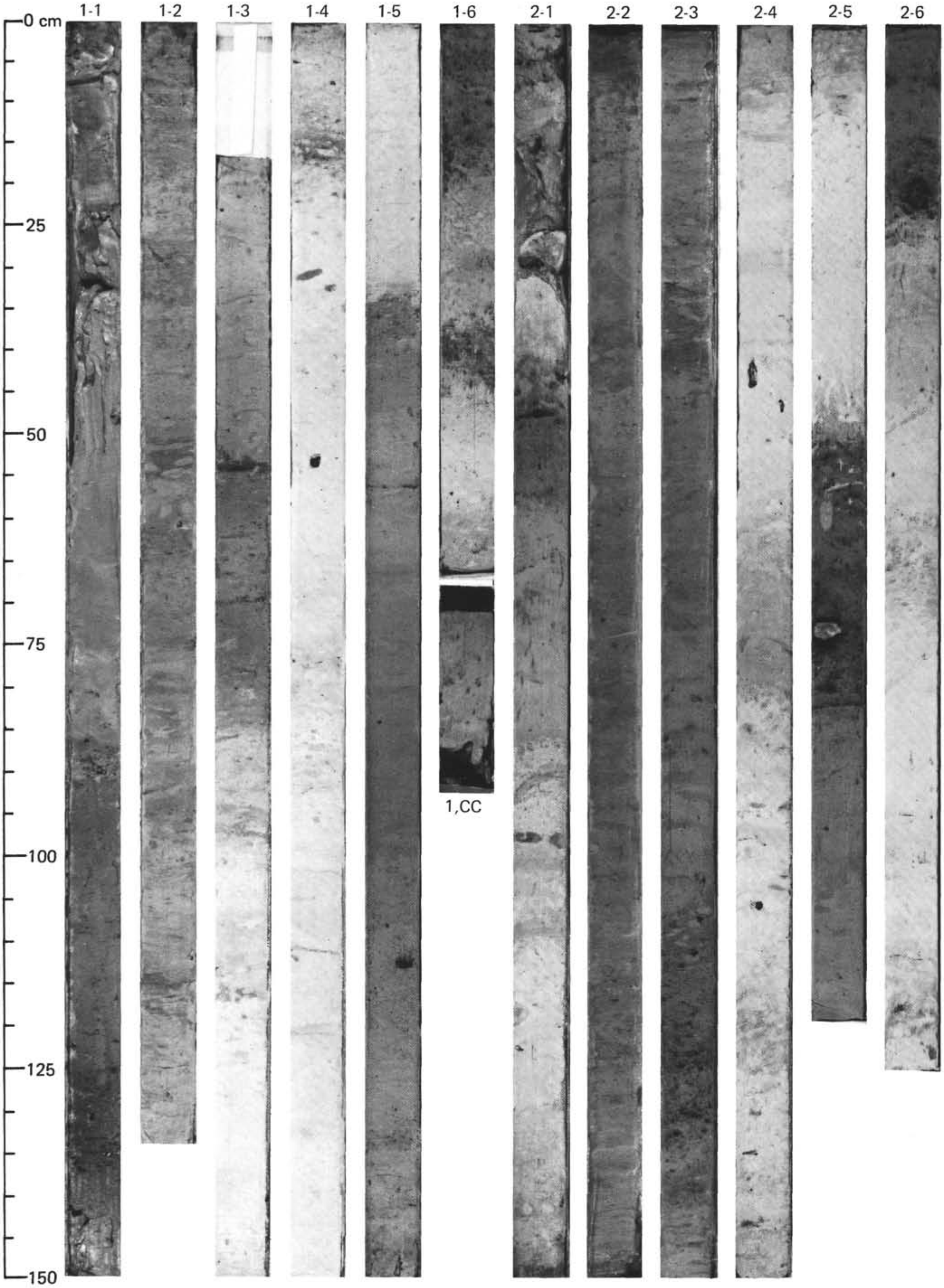
1-1
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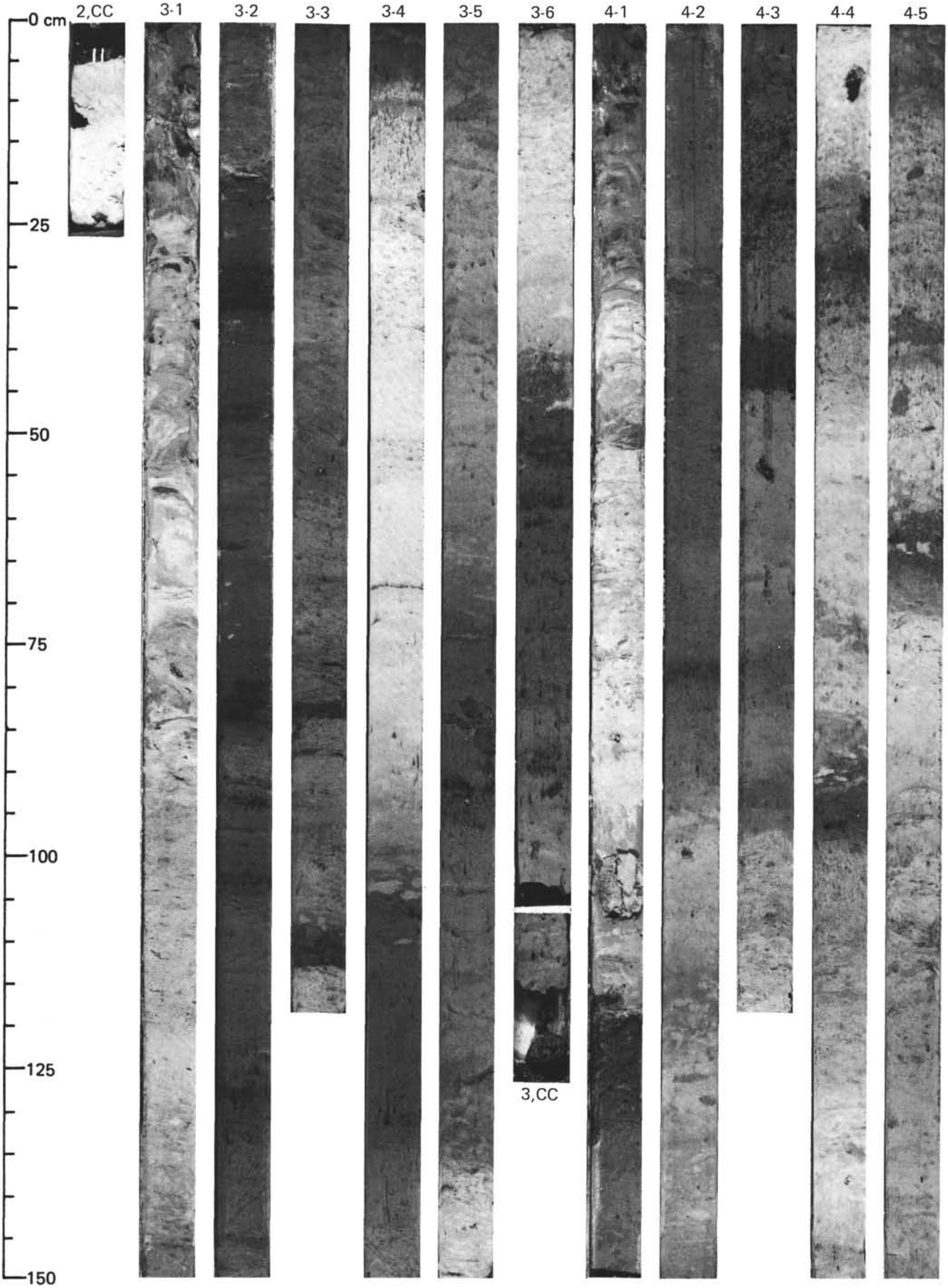
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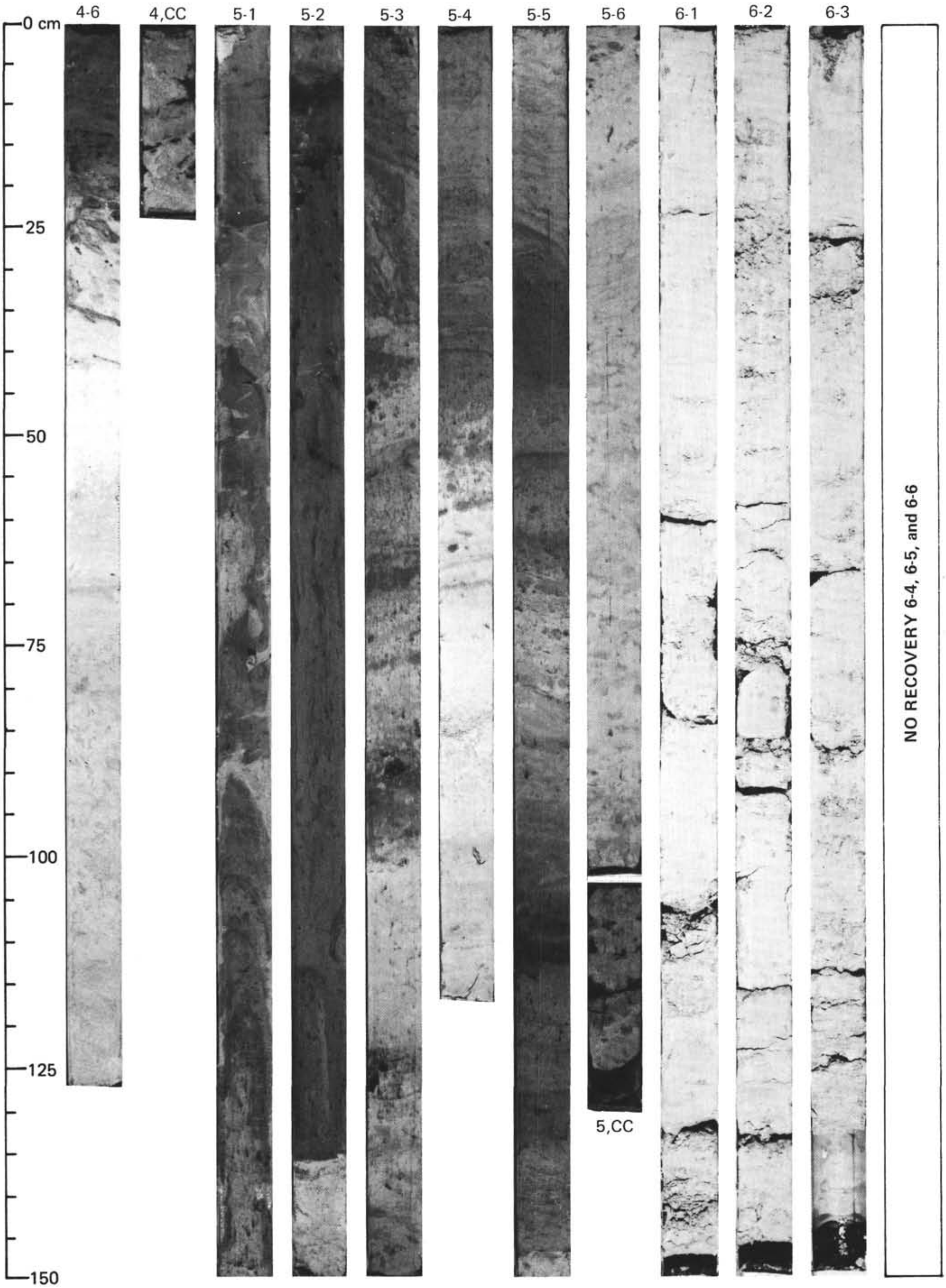
3,CC


4-6
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5-6
6-1
6-2
6-3
0 cm
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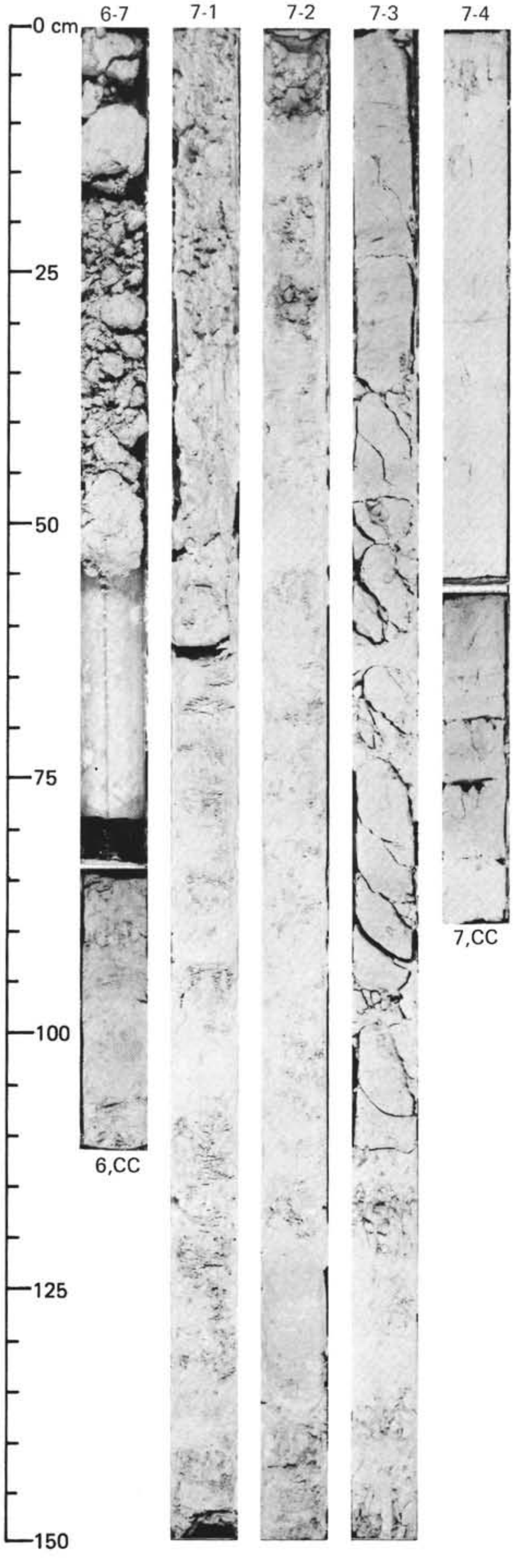
150
5,CC
NO RECOVERY 6-4, 6-5, and 6-6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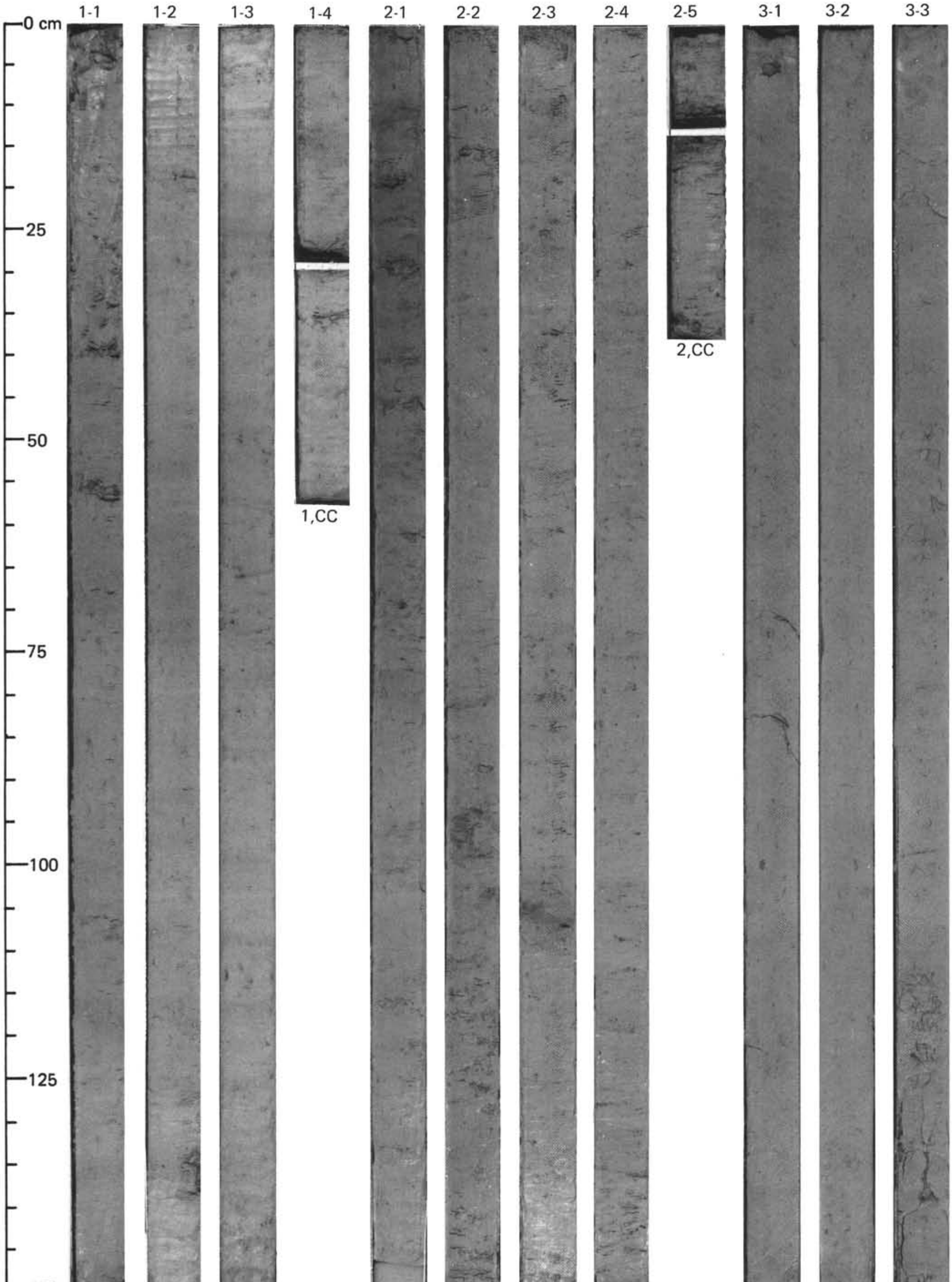
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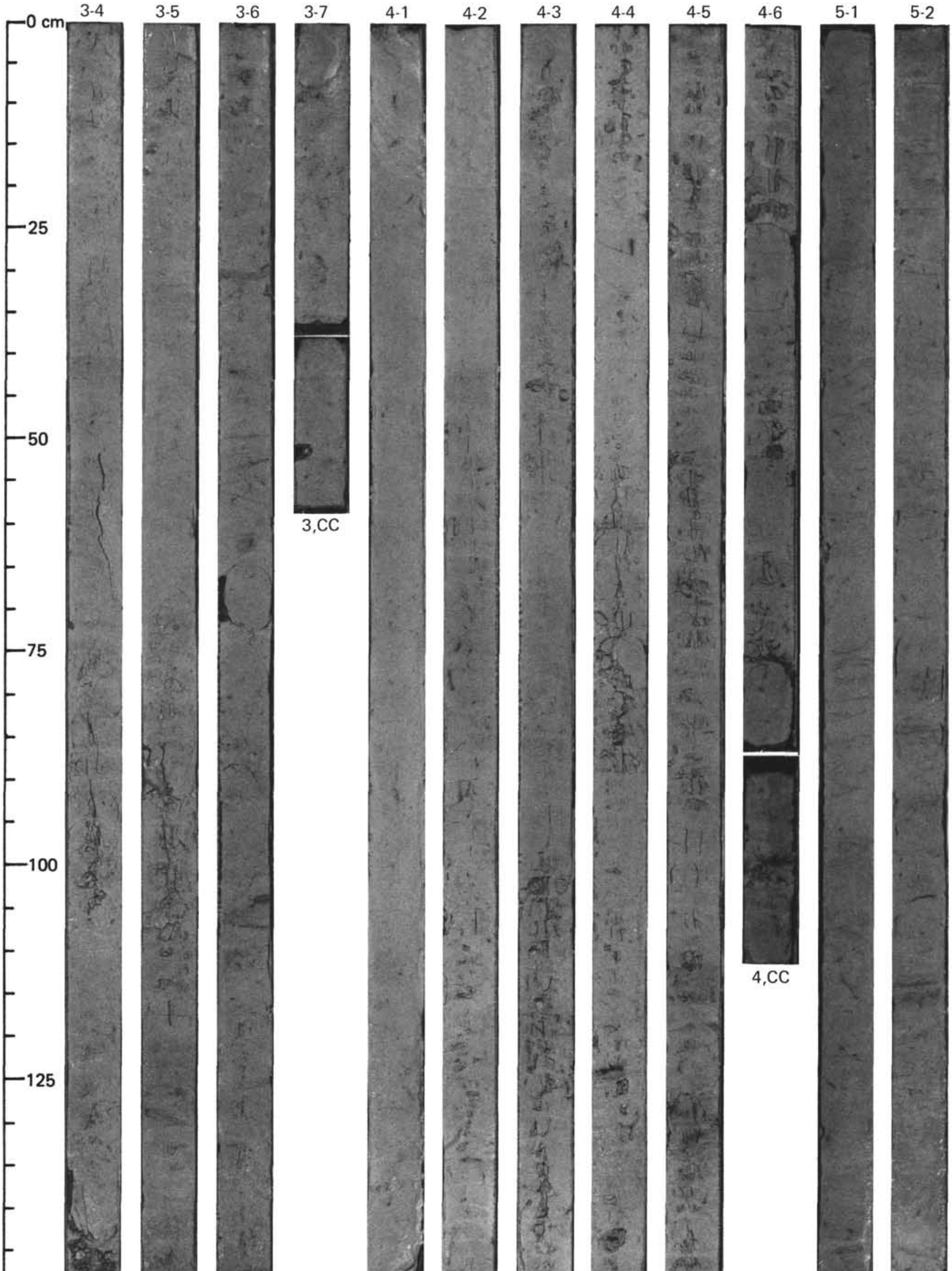
0 cm
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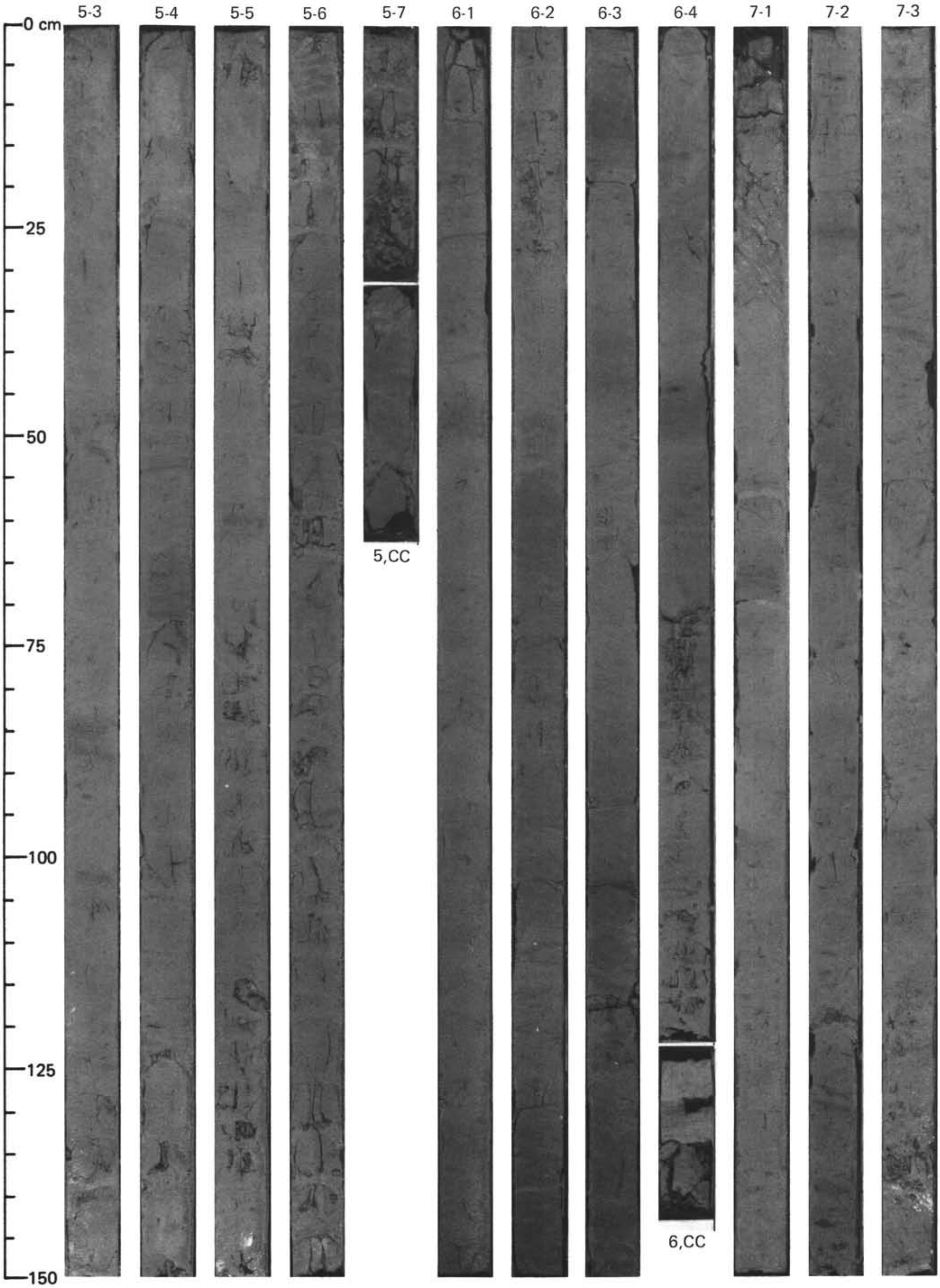
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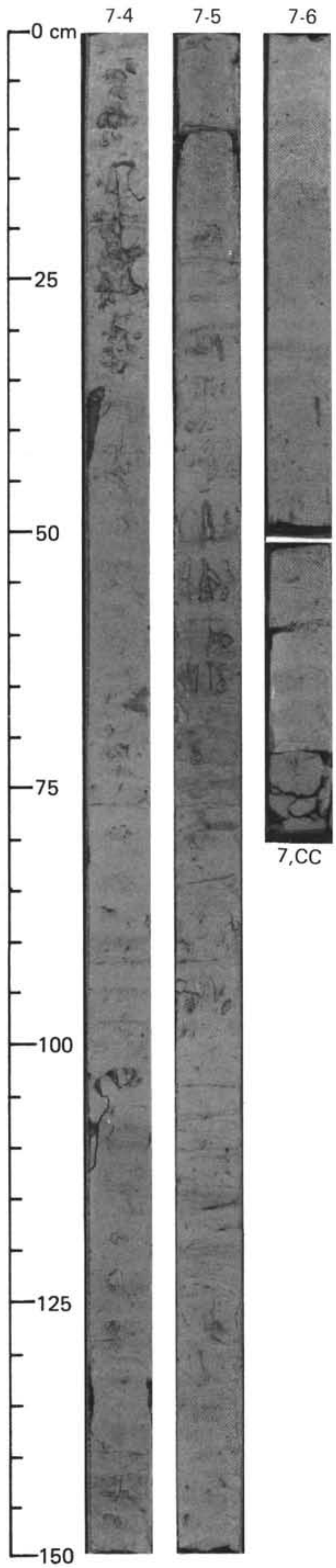
5-6
5-7
6-1
6-2
6-3
6-4
7-1
7-2
7-3
0 cm
25
50
75
100
125
150
5,CC
6,CC


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