The descriptions of sites, cores, and data included in these site reports were completed within one year of the cruise, but many of the topical chapters that follow were finished several months later. More data were acquired and authors' interpretations matured during this interval, so readers may find some discrepancies between site reports and topical papers. The timely publication of the *Initial Reports* series, which is intended to report the early results of each leg, precludes incurring the delays that would allow site reports to be revised at a later stage of production.

2. SITE 565[1]

Shipboard Scientific Party[2]

HOLE 565

Date occupied: 13 January 1982, 1600 hr.

Date departed: 19 January 1982, 0400 hr.

Time on hole: 132 hr.

Position: 09°43.69′N; 86°05.44′W

Water depth (sea level; corrected m, echo-sounding): 3099

Water depth (rig floor; corrected m, echo-sounding): 3109

Bottom felt (m, drill pipe): 3111

Penetration (m): 328.3

Number of cores: 34

Total length of cored section (m): 328.3

Total core recovered (m): 287.28

Core recovery (%): 87.5

Oldest sediment cored:
Depth sub-bottom (m): 328.3
Nature: dark greenish gray mudstone
Age: early Pliocene–late Miocene
Measured velocity (km/s): 1.8

Basement: not reached

Principal results: Only 328 m were drilled at Site 565, which was abandoned about 500 m short of the main target because the drill string was sticking. A continuous sequence of Quaternary to latest Miocene homogenous dark greenish gray mud at the top of section through well-consolidated mudstone toward the base was recovered. Two thin layers of sandstone were observed, and only two ash layers were recovered.

The mud was very stiff at the top of the section. In the Pleistocene sequence, folds were observed; deeper, we noted that the mudstone does not show any faults or folds. Thus a normal stratigraphic sequence is suggested.

On the basis of calcareous nannofossils and benthic foraminifers, lithostratigraphy is identified as follows:
0.0 to 105.5 m—Pleistocene;
105.5 to 276.5 m—late Pliocene;
276.5 to 286.0 m—early Pliocene;
286.0 to 328.0 m—early Miocene-late Miocene.

No reversal of faunas was observed, which confirms a normal stratigraphic sequence.

Ecologic analysis of the benthic foraminifers indicates a gradual uplift from abyssal depths (4000 m) in the early Pliocene-late Miocene to lower middle bathyal depths (1500–2000 m) in the late Pleistocene, and perhaps a subsidence to the present depth of 3100 m.

Hydrocarbon gases C_1 to C_5 were found in samples from Site 565, with C_1 being the dominant gas. Ratios of C_1 to C_2 increase by two orders of magnitude from 7.5 m to 54 m, then decrease exponentially, as commonly observed at DSDP sites.

Cores containing high concentrations of gas were recovered below 175 m. Gas hydrates were recovered two times: at sub-bottom depths of 285 m (Section 565-30-1) and 318 m (565-33,CC). The last sample gave a volume of gas 133 times greater than the volume of water, the gas being predominantly C_1 (89.1%), the water salinity being only 1.1‰.

BACKGROUND AND OBJECTIVES

The Nicoya Peninsula of Costa Rica is composed of an ophiolitic complex that has been studied by several investigators since Dengo (1962, 1967) first described it, and many believe it to be an accretionary complex. In 1977, on the UTMSI (University of Texas Marine Sciences Institute) ship *Ida Green*, J. Watkins made a seismic reflection record from the Nicoya Peninsula across the Middle America Trench that shows the structure of the Costa Rican margin seaward of the Peninsula (Shipley et al., 1982). Reflections from the ocean crust dip gently landward and can be followed about 60 km from the Middle America Trench under the landward slope of the margin to within 2 or 3 km of the shore. Above the ocean crust is a wedge of seismically unstructured rock that is in turn overlain by a thick blanket of stratified slope deposits. Site 565 is on the lower part of the slope where the blanket is sufficiently thin so that the *Glomar Challenger* could sample the unstructured seismic basement. The site is about 20 km landward of the Trench axis and 1700 m above it at a water depth of 3111 m. The slope deposits here are approximately 900 m thick, and the reflections within it appear to be generally undeformed.

The seismic data were interpreted by R. Buffler (Shipley et al., 1982) indicating a Mesozoic accretionary complex, similar to the Nicoya complex, or similar to the rock encountered at Site 494 near the Middle America Trench off Guatemala. Buffler and his colleagues proposed drilling at a site that would establish the age and lithology of the basement. A range of various informal interpretations proposed, on the one hand, that the age of the basement is Mesozoic or early Cenozoic, and on the other, that the basement consists of an accreted complex, if the seismic record is interpreted in accord with the constant accretionary model; in this case, the age of the basement should be about late Miocene. A spread of ages between late Miocene and Cretaceous should have been easily tested, if the acoustic basement

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[1] von Huene, R., Aubouin, J., et al., *Init. Repts. DSDP*, 84: Washington (U.S. Govt. Printing Office).

[2] Roland von Huene (Co-Chief Scientist), U.S. Geological Survey, Menlo Park, California; Jean Aubouin (Co-Chief Scientist), Département de Géotectonique, Université Pierre et Marie Curie, Paris, France; Miriam Blatuck, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California (present address: Department of Geological Sciences, Tulane University, New Orleans, Louisiana); Robert Arnott, Department of Geology, University of Oxford, Oxford, United Kingdom (present address: Shell International, The Haag, Holland); Jacques Bourgois, Département de Géotectonique, Université Pierre et Marie Curie, Paris, France; Mark Filewicz, Union Oil Company, Ventura, California; Roger Helm, Institut Für Geologie, Ruhr-Universität Bochum, Bochum, Federal Republic of Germany; Keith A. Kvenvolden, U.S. Geological Survey, Menlo Park, California; Barry Leinert, Hawaii Institute of Geophysics, University of Hawaii, Manoa, Honolulu, Hawaii; Thomas J. McDonald, Department of Oceanography, Texas A&M University, College Station, Texas; Kristin McDougall, U.S. Geological Survey, Menlo Park, California; Yujiro Ogawa, Department of Geology, Kyushu University, Hakozaki, Fukuoka-Shi, Japan; Elliott Taylor, Department of Oceanography, Texas A&M University, College Station, Texas; Barbara Winsborough, Espey, Houston, and Associates, Austin, Texas (present address: Department of Geology, Princeton University, Princeton, New Jersey).

were recovered, and this was one of the main objectives at Site 565.

A second objective at Site 565 was the study of gas hydrate. Several bases of gas hydrate reflections were noted in the suite of seismic records off Costa Rica that were made by the University of Texas (Shipley et al., 1979), and although none appears in the seismic record on which this site was located, the presence of hydrate was suspected. The development of gas hydrate in the marine environment is a poorly understood phenomenon. Our understanding of it would benefit greatly not only from recovery of a hydrated sample, but also from knowledge of the organic and inorganic constituents in the associated pore fluid and gases. Thus pressure cores and ample monitoring of hydrocarbons were required for the hydrate study as well as for reasons of safety.

OPERATIONS

Glomar Challenger transited 2.5 days from Panama to Site 565 operating geophysical instruments. The ship intersected the University of Texas seismic track line CR-7 at 1400L (local time) 13 January and was positioned not only from points on land but also by a satellite position that was received shortly after turning on line from 270° to 302°. A geophysical line about 20 mi. long across the proposed site locations and the Trench was necessary to identify some bathymetric features that could be used in establishing the desired position. The *Challenger* positions and those established from water depths and features on line CR-7 differed consistently by 1.5 to 2 mi. Because the *Challenger* seismic system was unable to penetrate sufficiently deeply to identify the acoustic basement feature on which the site was selected, the site position was determined by the bathymetric configuration and depths. An 8-knot wind was setting the ship, making navigation by dead reckoning uncertain, and just prior to the beacon drop a second satellite position was received indicating ship's position about 1 mi southeast of the positions given for CR-7. Because the depth and bathymetric configuration were correct, the beacon was dropped at 1732L, 13 January. Subsequent satellite positions indicate a 1-mi. difference between the *Challenger* and the CR-7 positions for the equivalent bathymetric features at the site, an error that is permissible in the CR-7 navigation.

Once on site the *Challenger* received a message to stand by for written permission from the government of Costa Rica prior to any operations. The *Challenger* dead time was used to make a detailed bathymetric survey around the site until 0600L, 14 January, using the beacon as a primary navigational aid. The survey confirmed the previous indications of a suitable site position and thus no offset on the beacon was thought necessary.

At 1010L, 14 January, permission from Costa Rica was received, and the ship was allowed to begin operations. Lowering of the drill string began immediately, but the loss of operation time severely jeopardized some objectives off Guatemala so we reluctantly decided to omit logging. At 1600L a Costa Rican ship brought two observers to the *Challenger* and, to make room for them, took two DSDP persons ashore.

The first core was recovered at about 0400L, 5 January, and normal operations continued. Core recovery was excellent until the last six cores. Gas content was sufficient from top to bottom for vacutainer sampling. The sediment became increasingly gassy with depth, and the first gas voids appeared in Core 27; icy hydrates were recovered in Cores 30 and 31.

New drill string was used at Site 565, and it was noticed, after several cores had been recovered that the core length was slightly longer than joints used on previous legs (which were 9.5 m). A correction for the cumulative error of 4 m was made at Core 31, and a core length of 9.6 m was used thereafter.

Drilling time increased from top to bottom during drilling of Core 32, rotation began to be difficult and the pipe had a tendency to stick. Drilling of Cores 33 and 34 was very difficult; the tendency of the drill string to stick was very high, and it was necessary to pull 30 m of drill stem from the hole. Finally, after recovering Core 34 at 0825L, 18 January, and trying unsuccessfully to drill deeper until 1500L we decided to abandon the hole because of the high risk of sticking. Cementing of the hole was achieved at 1900L, 18 January, and the drill string was aboard at 0500L, 19 January.

The *Glomar Challenger* departed immediately to rendezvous with a Costa Rican coastal patrol boat off Cabo Blanco, Costa Rica. At 1200L 19 January, the two Costa Rican observers disembarked and the two DSDP personnel embarked.

At 1230L, 19 January, *Glomar Challenger* was en route to Site 566 off Guatemala.

Table 1 shows the coring summary for Site 565.

LITHOSTRATIGRAPHY

Site 565 is located at a water depth of 3111 m on the lower slope of the landward side of the Middle America Trench, about 27 km east of the Trench axis and only 42 km west of the mountainous coast of Costa Rica (Fig. 1).

Hole 565 was cored continuously with excellent recovery to a depth of 328 m; one lithological unit was recovered over this entire length except for a small section of probably redeposited limestone recovered in the core catcher of the last core (Core 34). Figure 2 summarizes the lithostratigraphic sequence recovered.

Unit I

Unit I comprises Cores 1 to 34, 0 to 328 m sub-bottom depth, and ranges from upper Pleistocene to lower Pliocene.

Major lithology. This is a very thick, relatively uniform Pliocene–Pleistocene section of generally massive dark olive gray to dark greenish gray (5Y 3.5/2 to 5GY 4/1) mud and mudstone.

Sedimentary structures, although rare within the unit, are mainly found in the upper half of the section. They are composed of subtly graded silt beds up to 2 cm in thickness (Cores 4, 5, 9), thin silty laminae (Core 5), and a few isolated silty beds of a slightly lighter color (Cores 2, 6, 7). Small clasts (up to 2–3 cm in diameter

Table 1. Coring summary, Site 565.

Core no.	Date (Jan. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Recovery (%)
1	15	0431	3111.0-3121.5	0.0-10.5	10.5	9.66	92
2	15	0553	3121.5-3131.0	10.5-20.0	9.5	9.66	100+
3	15	0705	3131.0-3140.5	20.0-29.5	9.5	9.03	95
4	15	0828	3140.5-3150.0	29.5-39.0	9.5	6.46	68
5	15	0945	3150.0-3159.5	39.0-48.5	9.5	9.69	100+
6	15	1310	3159.5-3169.0	48.5-58.0	9.5	9.78	100+
7	15	1435	3169.0-3178.5	58.0-67.5	9.5	9.02	95
8	15	1555	3178.5-3188.0	67.5-77.0	9.5	9.25	97
9	15	1730	3188.0-3197.5	77.0-86.5	9.5	9.43	99
10	15	1905	3197.5-3207.0	86.5-96.0	9.5	9.56	100+
11	15	2300	3207.0-3216.5	96.0-105.5	9.5	9.68	100+
12	16	0029	3216.5-3226.0	105.5-115.0	9.5	9.57	100+
13	16	0200	3226.0-3235.5	115.0-124.5	9.5	9.61	100+
14	16	0331	3235.5-3245.0	124.5-134.0	9.5	9.25	97
15	16	0440	3245.0-3254.5	134.0-143.5	9.5	9.16	96
16	16	0846	3254.5-3264.0	143.5-253.0	9.5	8.14	86
17	16	1015	3264.0-3273.5	153.0-162.5	9.5	9.17	97
18	16	1145	3273.5-3283.0	162.5-172.0	9.5	9.42	99
19	16	1319	3283.0-3292.5	172.0-181.5	9.5	9.10	97
20	16	1455	3292.5-3302.0	181.5-191.0	9.5	8.96	94
21	16	1631	3302.0-3311.5	191.0-200.5	9.5	9.55	100+
22	16	2036	3311.5-3321.0	200.5-210.0	9.5	9.69	100+
23	16	2236	3321.0-3330.5	210.0-219.5	9.5	9.71	100+
24	17	0024	3330.5-3340.0	219.5-229.0	9.5	9.67	100+
25	17	0211	3340.0-3349.5	229.0-238.5	9.5	9.58	100
26	17	0350	3349.5-3359.0	238.5-248.0	9.5	9.59	100+
27	17	0530	3359.0-3368.5	248.0-257.5	9.5	9.63	100+
28	17	0715	3368.5-3378.0	257.5-267.0	9.5	3.15	33
29	17	0911	3378.0-3387.5	267.0-276.5	9.5	9.24	97
30	17	1140	3387.5-3397.0	276.5-286.0	9.5	9.37	99
31	17	1444	3397.0-3406.5[a]	286.0-295.5	9.5	7.66	81
32	17	1858	3410.5[a]-3420.1	299.5-309.1	9.6	1.60	17
33	18	0245	3420.1-3429.7	309.1-318.7	9.6	2.75	29
34	18	0825	3429.7-3439.3	318.7-328.3	9.6	2.49	26
Total					328.3	287.28	88

[a] New drill string was use at Site 565; it was noticed after several cores had been recovered that the core length was slightly longer than joints used on previous legs (which were 9.5 m). A correction for the cumulative error of 4 m was made at Core 31 and a core length of 9.6 m was then used.

and of the same lithology as the matrix mud) characterize parts of the upper half of the section (Cores 1, 3, 4, 6, 7, 9, 11, 17, and 27). Yellowish mottling (10YR 2/1) at the top of the section grades downsection into more clearly defined calcareous burrows (2.5Y 7/6). The extensive bioturbation common throughout the length of the hole may help to explain the paucity of distinct sedimentary structures and compositional horizons.

The average sand-silt-clay percentages for this unit based on shipboard examination of smear slides are 6, 13, and 80%, respectively. The major detrital component is clay, with minor amounts of quartz, mica, plagioclase feldspar, and other terrigenous material present in the coarser fractions. Fresh-appearing volcanic shards occur throughout the length of the section dispersed within the mud. Distinct ashy horizons (Cores 8, 9, 10, 25, 26, and 34) are remarkably rare considering the proximity to on-land volcanism in Costa Rica. Glauconite occurs in very small amounts (usually less than 3%) throughout the hole. The carbonate content of the major lithology is seldom greater than 1% except within burrows, where it may be as high as 30%. Sandy horizons (Cores 21 and 3) also seem few in view of the high sediment accumulation rates (see the Biostratigraphy section) and the proximity to land of high relief.

Nannofossils and foraminifers are generally rare and of mediocre preservation, as are diatoms and radioarians (see the Biostratigraphy, section). The benthic foraminifers represent upper bathyal (Cores 1-4), lower to middle bathyal (Cores 5-6), as well as abyssal provinces (Cores 7-29). Carbonized plant remains are also present throughout the cores.

A postdepositional penetrative fabric, best described as a "scaliness," is common in the upper half of the hole (Cores 11, 12, 13, 14, 16) and is interbedded with massive bioturbated mud or laminated sediment. There is strong evidence of an inherited *in situ* fabric, because the scaliness pervades through a wide range of sediment induration and corresponding degrees of drilling disturbance (commonly present in the centers of biscuits, i.e., stiff mud or mudstone broken into squarish chunks during drilling). A similar postdepositional structure has been described for Legs 66 and 67 in the Middle America Trench and Leg 78A off Barbados.

Minor lithologies. Fine-grained, muddy limestone (5GY 4.5/1) containing angular sand-sized grains of possibly volcanic origin was recovered at two horizons (Cores 25 and 34,CC). The latter contained reworked Miocene and Cretaceous foraminifers (see the Biostratigraphy section).

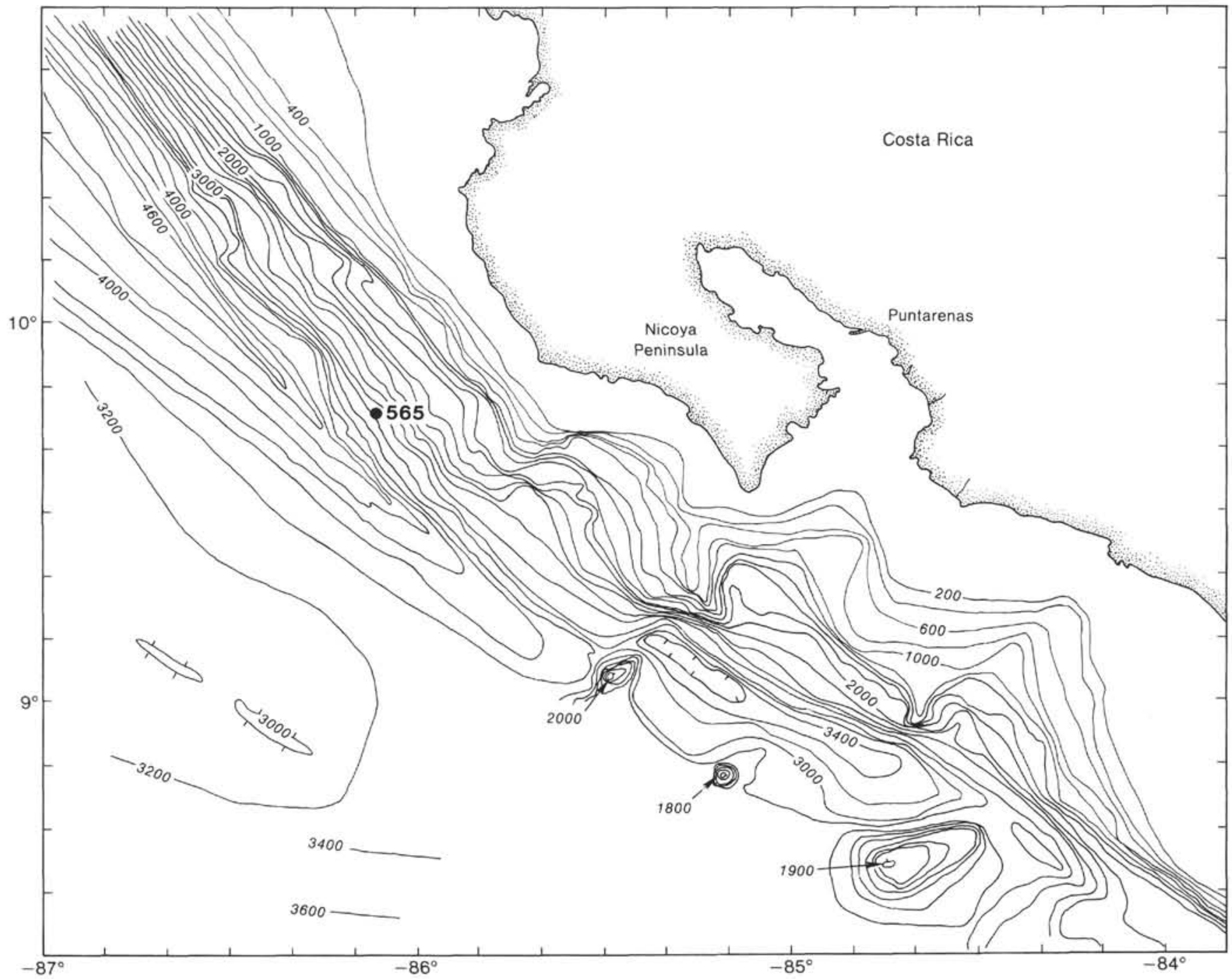

Figure 1. Bathymetric map of the Costa Rica margin showing the location of Site 565 (Volpe and Shipley, this volume).

A dark brownish (10R 4/1) tuffaceous sand about 15 cm thick, recovered in Core 21, comprises predominantly angular grains of quartz, plagioclase feldspar, minor hornblende, augite, K-spar, zircon, apatite, and authigenic pyrite or marcasite. Another dark brownish sandy layer (5Y 2.5/1) was recovered in 565-33,CC. The angular grains contained a broad range of unweathered volcanic rock fragments.

DOWNSLOPE SEDIMENT TRANSPORT AND SEDIMENTARY PROVENANCE

The lower slope of the landward side of the Middle America Trench is dissected by deep submarine canyons. Drilling at Site 565 penetrated between two canyons into a thick sequence of fine-grained slope deposits. Coarse-grained sediment probably bypassed the slope through the submarine canyons, accounting for its absence in the cores recovered.

Several lines of evidence support the argument that much of the sediment at Site 565 was derived from sources upslope (Baltuck et al., this volume). Evidence from reworked benthic foraminifers clearly demonstrates downslope movement of sediment, whether by mass movement or deposition by turbidites from an environment 1.5 km shallower than the present seafloor (see Biostratigraphy section). Scattered paleomagnetic data indicate a disturbed sedimentary section, particularly below 50 m sub-bottom (see Paleomagnetics section). Observations of physical properties show that by Core 3 (less than 20 m) the sediment is firmer than would be expected from normal overburden pressures (see Physical Properties section). This overconsolidation could have resulted from an earlier, greater pile of sediment overburden that has since been removed by mass flow.

Sedimentary facies encountered at Site 565 show that the predominant mechanism of downslope movement in between canyons was mass movement. The main sedimentary facies encountered are: (1) scaly mud–mudstone, (2) pebbly mud–mudstone; and (3) massive mud–mudstone.

The scaly mud of much of the section could be an expression of microshearing of clay particles during mass flow downslope, as was suggested by Leg 78A data. Debris flow deposits are commonly characterized by dis-

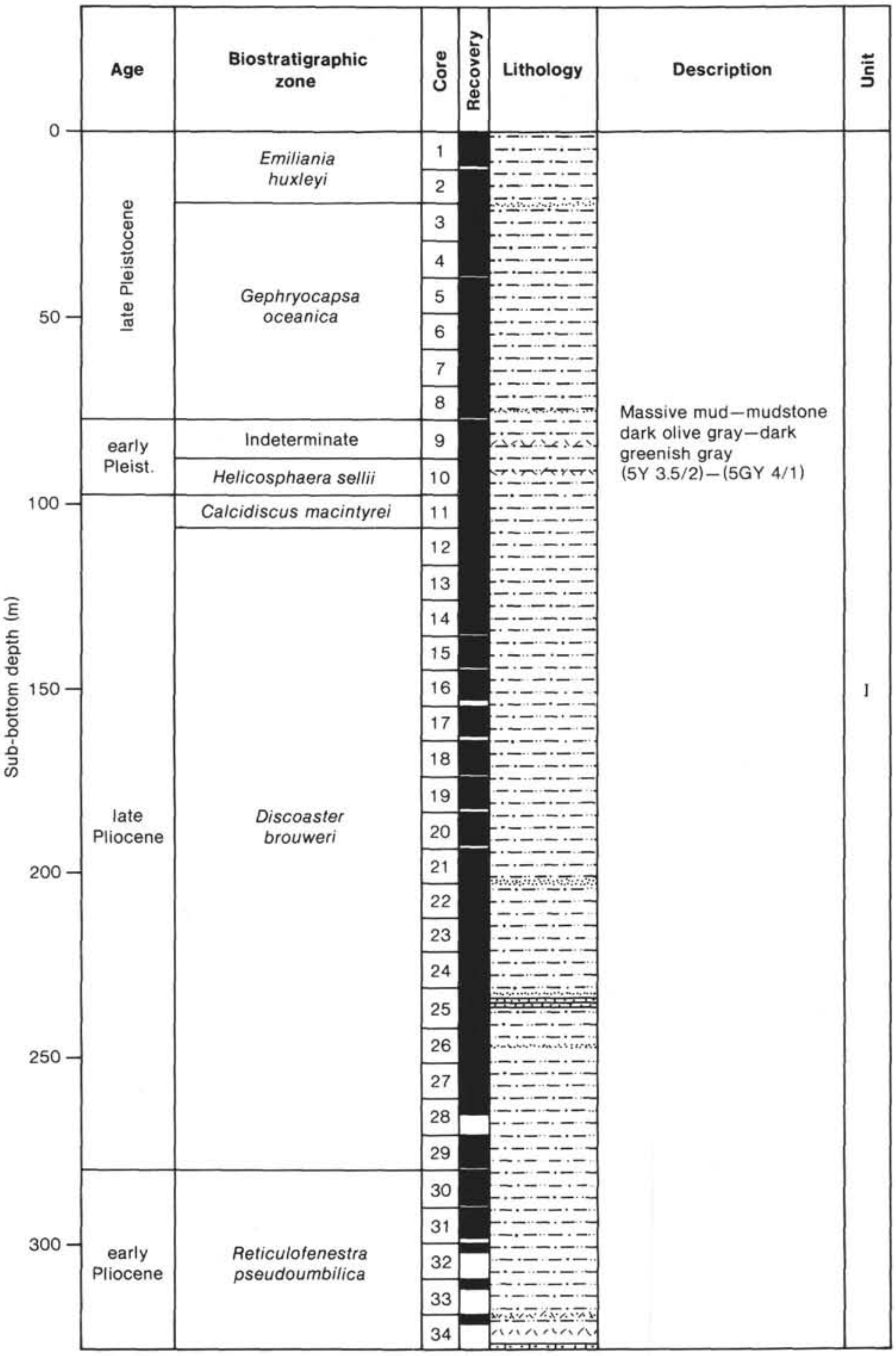

Figure 2. Lithostratigraphy at Site 565. See Introduction and Explanatory Notes chapter (this volume) for an explanation of lithologic symbols.

persed pebbles within massive mud, which indicates that during transport there was sufficient matrix strength to prevent internal sorting. The massive mud contains sand- and silt-sized grains dispersed through the core. These could originally have been contained within bedding that was subsequently disrupted or "homogenized" by mass movement. Evidence of slumping was visible in core one that contained folded bedding. Bioturbation occurs throughout the section and may account for the further admixture of the sediment, both during sedimentation and after redeposition.

The presence of mass flow deposits might also account for the relatively high sediment accumulation rates (160 m/10^6 yr. for Cores 1-8, 150 m/10^6 yr. for Core 9, and 125 m/10^6 yr. for Cores 10-32—see Biostratigraphy section) in an area of predominantly silt or mud deposition. Bioturbation occurs throughout the section and may account for the further admixture of the sediment, both during and after deposition of the mass flow deposits.

The source of the sediments is problematical, and four main alternatives are suggested: (1) the Mesozoic Nicoya complex exposed onshore in Costa Rica; (2) Tertiary and Quaternary volcanics outcropping extensively onshore in Costa Rica; (3) strata now covered by slope deposits west of the Costa Rica shore; and (4) strata displaced laterally or vertically by faulting.

The second alternative is favored, although the sediment does not contain a high enough percentage of pristine volcanic shards to positively indicate derivation from the Tertiary and Quaternary volcanic rocks that outcrop in Costa Rica, at least not without extensive mechanical reworking and diagenetic alteration.

Several observations of diagenesis were made throughout the core. Volcanic glass and mafic minerals (hornblende, augite) lacked any alteration. Early carbonate diagenesis was noted from the lithification of sediment within burrows throughout the hole. In Cores 24 to 34, authigenic pyrite or marcasite is common. The sulphur was possibly derived from organic material. All of the glauconite was detrital, and the dominant clay mineral was a montmorillonite. Montmorillonite is probably derived from weathering of volcanics, a phenomenon commonly observed at DSDP sites.

BIOSTRATIGRAPHY

Introduction

A thick section of Quaternary–late Neogene homogeneous trench slope deposits was continuously cored to 328 m (Fig. 3). Benthic foraminifers occur consistently throughout the cored section in relatively abundant, well-preserved numbers and offer good statistical data to identify paleobathymetries and downslope terrigenous admixture. Calcareous nannofossils are also present throughout, but in low abundances with moderate preservation typical of sediments deposited in close proximity to a terrigenous source. Several key nannofossil zonal markers occur with enough consistency, however, to allow utilization of Gartner's (1977) and Okada and Bukry's (1980) zonation. Diatoms occur in low abundances through much of the section and can only be utilized for general Pleistocene ages at this site.

Early to late Pleistocene sediments are present from the surface to 565-12-4, 74 cm and can be subdivided by four nannofossil zones. Late Pliocene sediments occur from 565-12,CC through 565-30-4, 130 cm, whereas 565-30,CC is early Pliocene, on the basis of nannofossil data. Late Miocene benthic foraminifers occur sporadically in Cores 29 and 30. Cores 565-31 through 565-34,CC contain sediments that range in age from late Miocene–early Pliocene, on the basis of both nannofossils and benthic foraminifers. Reworked Late Cretaceous nannofossils are most prevalent in 565-30,CC through 565-34,CC.

Sediment accumulation rates uncorrected for compaction (Fig. 4) are high through most of the cored interval. Late Pleistocene sediments (approximately 0–80 m) accumulated at the rate of 165 m/m.y. The 10-m interval from 80 to 90 m is bracketed by two nannofossil zones and represents close to 1 m.y. of sedimentation, which yields an accumulation rate of 13 m/m.y. or suggests the occurrence of a slight unconformity. Sedimentation resumed a high rate of accumulation in the early Quaternary–late Neogene (90–328 m), when the average rate was 125 m/m.y.

Ecologic analysis that is based on benthic foraminiferal faunas indicates a gradual uplift from abyssal depths (≥4000 m) in the early Pliocene–late Miocene to lower middle bathyal depths (1500–2000 m) in the late Pleistocene and then subsidence to the present depth of 3100 m. Throughout the Pleistocene and late Pliocene, material was transported from the upper and middle slopes. Transported specimens compose over 50% of the benthic fauna and thus obscure the abyssal fauna. During this interval, water depths may have been great enough to have encountered the foraminiferal CCD and thus be responsible in part for the low numbers of *in situ* specimens. In Sample 565-29,CC and below, transport from the upper and middle slopes decreases abruptly. In this lower interval, transported specimens from the lower middle bathyal and lower bathyal biofacies occur in association with well-developed abyssal faunas.

Calcareous Nannofossils

Calcareous nannofossils occur consistently throughout this section in rare to frequent abundances, with preservation ranging from poor to moderate because of dissolution. Heavy terrigenous mixing throughout the interval and close proximity to the nannofossil CCD, especially in 565-7,CC to 565-28,CC, as documented by benthic foraminifers, are the significant factors contributing to the low nannofossil abundances and etched preservation. Species that indicate cold surface-water temperatures, such as *Coccolithus pelagicus*, are extremely rare, which suggests that paleotemperatures were not prohibitive.

Nannofossil zonal markers, though rare, are present throughout the section and allow utilization of Gartner's (1977) detailed zonation for the Pleistocene and Okada and Bukry's (1980) zonation for the Pliocene and older (see Fig. 3). Low diversity of the *Discoaster* assemblage until terrigenous admixture became less (565-29,CC) does not allow a precise subdivision of Bukry's *Discoaster brouweri* Zone, but both the top and bottom of this zone are well defined by last appearance datums (LAD) of both *D. brouweri* and *Sphenolithus neoabies*.

Reworking of Cretaceous nannofossils is rare to absent from the Pleistocene to late Pliocene interval through 565-29,CC. Late Cretaceous reworking becomes more prevalent within the late Miocene to early Pliocene interval from 565-30,CC to 565-34,CC. Very rare species reworked from the Oligocene and Pliocene are also in 565-5,CC (Pleistocene) but are never a significant assemblage constituent.

Core 1 is tentatively assigned to the *Emiliania huxleyi* Zone and contains frequent *Emiliania* cf. *huxleyi*.

Section 565-2-1 through Sample 565-8-2, 109 cm are assigned to the late Pleistocene *Gephyrocapsa oceanica*

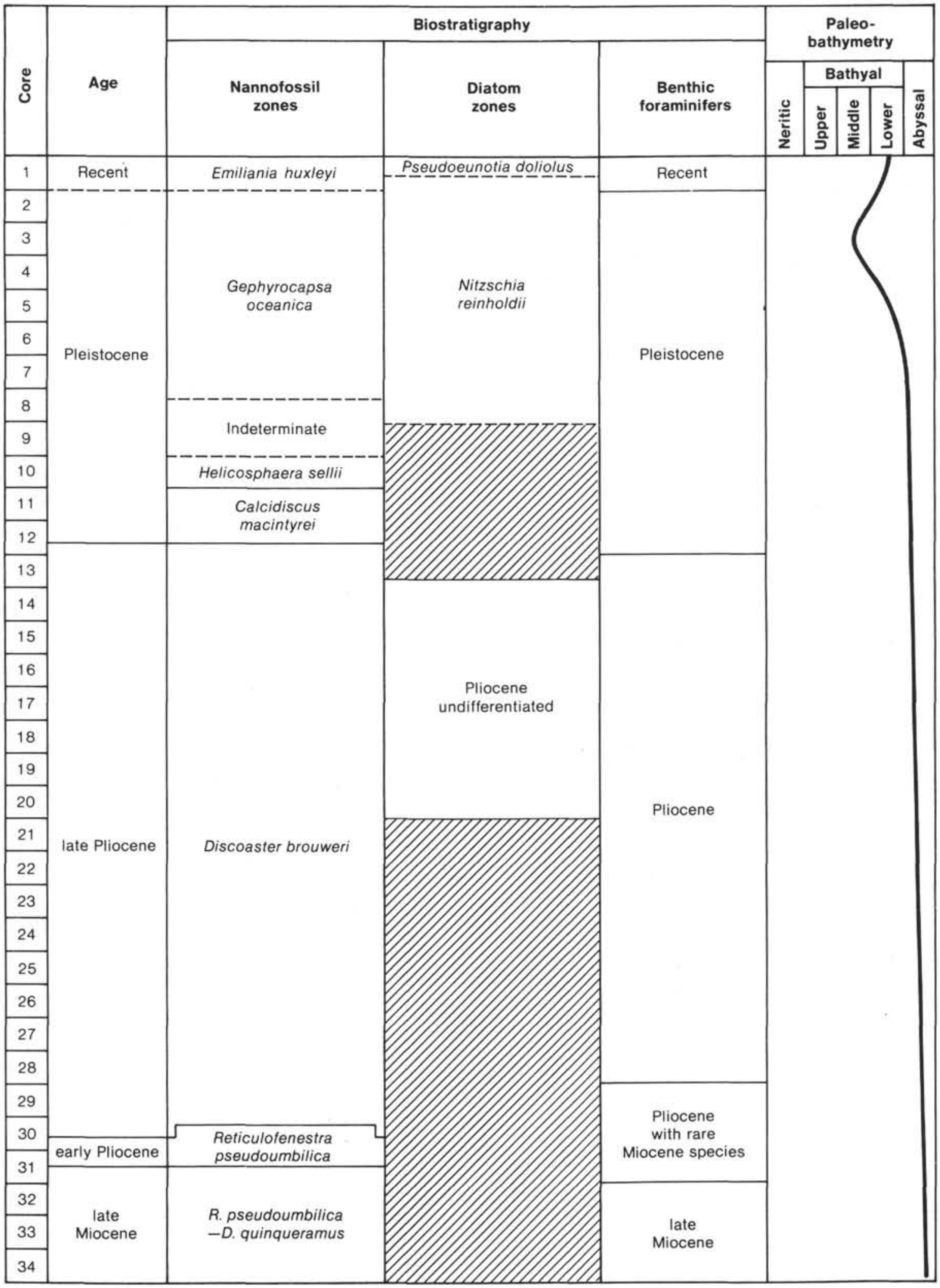

Figure 3. Biostratigraphic and paleoecologic summary of Site 565. Hachures indicate barren intervals.

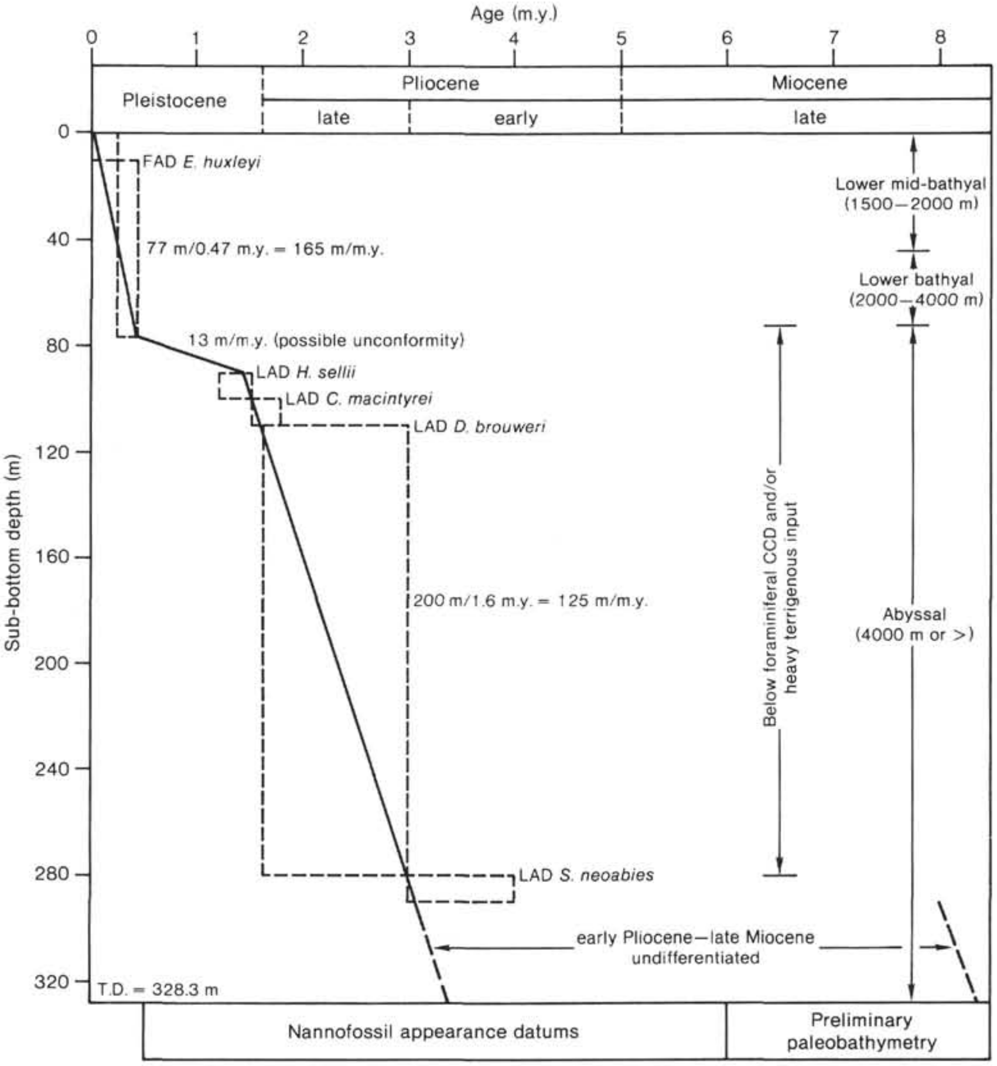

Figure 4. Sediment accumulation rates (uncorrected for compaction) for Site 565.

Zone and are dominated by *Calcidiscus leptoporus* and small *Gephyrocapsa* spp. (sensu Gartner, 1977). Core 7, which has a common abundance of nannofossils with moderate preservation, contains the first rare but consistent appearance of the reworked Cretaceous species *Watznaueria barnesae*. Soft, light gray angular calcareous blebs in Core 2, Section 3, which are well lithified in Core 4, Section 4, contain overgrown Neogene species and are therefore not reworked from significantly older sediments.

The interval at 565-9-4, 106 cm through 565-9,CC is barren of nannofossils, but 565-10,CC contains the first appearance of *Helicosphaera sellii* along with *Pseudoemiliania lacunosa*. The combined presence of these two species is indicative of the early Pleistocene *Helicosphaera* Zone.

The interval of 565-11,CC through 565-12-4 contains the first rare appearance of *Calcidiscus macintyrei*, which would place it within the early Pleistocene *C. macintyrei* Zone.

The first consistent occurrence of *Discoaster brouweri* occurs at 565-12,CC which indicates that the Pliocene/Pleistocene boundary falls within Core 12; 565-12,CC through 565-30-4, 130 cm are assigned to the late Pliocene *Discoaster brouweri* Zone and contain a nannofossil assemblage that is not of sufficient diversity to warrant further subdivision. *Discoaster brouweri* ranges throughout this interval, but other important *Discoaster* zonal markers such as *D. pentaradiatus* and *D. surculus* are absent until 565-29,CC. *Discoaster tamalis* and other significant early Pliocene-late Miocene *Discoaster* species were not observed.

Section 565-30,CC contains the first appearance of *Sphenolithus neoabies* and is assigned to the early Pliocene *Reticulofenestra pseudoumbilica* Zone. Reworked Late Cretaceous species, including the late Maestrichtian species *Micula mura*, become most consistent within this core and continue to occur with regularity to 565-34,CC.

Sections 565-31,CC to 565-34,CC contain the same low-diversity nannofossil assemblage present in 565-30,CC, along with the rare occurrence of Miocene species *Catinaster* aff. *mexicanus* and very rare *Discoaster berggrenii*. A specific zonal assignment for this interval is not possible, and only a general age designation of late Miocene–early Pliocene is applicable.

Benthic Foraminifers

Pleistocene through latest Miocene benthic assemblages are recognized at Site 565. The Pleistocene assemblages (Cores 1 through 11) are dominated by numerous species of *Bolivina* and *Uvigerina (U. peregrina, U. hispida,* and *U. rustica*). Most of these species are living today off Central America (Smith, 1964). Pliocene assemblages are recognized in Cores 12 through 28. Bolivinid species disappear from the assemblages, whereas the uvigerinids and buliminids (*Bulimina mexicana, B. rostrata,* and *B. marginata*) dominate. Because downslope transport remains high throughout these intervals, this faunal change is only partially the result of the increased water depths. A Pliocene age is corroborated by the nannofossils. Core catchers of Cores 29 and 30 are interpreted as early Pliocene, based on nannofossils. *Cibicidoides bradyi* and *Nodosaria lamellata,* which are thought to range no higher than the Miocene/Pliocene boundary, are rare in this interval. These species may be reworked into the lower Pliocene. In Cores 31 through 34, the benthic foraminiferal assemblage changes and numerous new species appear. Rare to few Miocene species such as *Pleurostomella alternans, Cibicidoides bradyi, C. kullenbergi, Osangularia culteri,* and *Nodosaria lamellata* appear.

Benthic foraminiferal species at Site 565 indicate that deposition occurred in the lower middle bathyal to abyssal biofacies. These biofacis today correspond to depths of 1500 to 4000 m (Smith, 1964; Ingle, 1980). Faunas in Cores 1 and 3 are dominated by lower middle bathyal species such as *Uvigerina hispida* and *U. rustica*. Transported specimens are from the upper bathyal and upper middle bathyal biofacies. Lower bathyal species appear rarely in 565-3,CC and commonly in 565-5,CC thus suggesting an increase in water depth downhole. Transport from the upper bathyal and upper middle bathyal biofacies continues to be high. These lower bathyal faunas are dominated by the smoother forms of *Uvigerina (U. hispida* and *U. senticosa)*, smoothly finished agglutinated species *(Eggerella bradyi* and *Karreriella bradyi)*, abundant gyroidinids, and *Pullenia bulloides*. Abyssal species are rare in the upper cores but become a significant portion of the fauna in Cores 7 to 34.

In Cores 7 to 28, abyssal species (*Bulimina rostrata,* m various species of *Cibicidoides*, and *Laticarinina pauperata*) constitute 5 to 10% of the fauna, diversity is relatively low in this interval (less than 30 species/sample), and transported slope species are abundant. In Cores 29 to 34, the abyssal faunas become more dominant. This change is accompanied by a rapid drop in the amount of transported shelf and upper-slope species. Transported specimens are not principally from the lower middle bathyal and lower bathyal biofacies.

Diatoms

Siliceous microfossils are rare in abundance throughout most of Hole 565. Preservation is also generally poor. The siliceous remains consist mostly of small diatom and radiolarian fragments that exhibit effects of both dissolution and mechanical destruction. Selected intervals were cleaned of organic matter and concentrated in the hope of obtaining an assemblage with sufficient diagnostic species to allow for biostratigraphic interpretation.

Relatively high diversities were encountered in Cores 1, 2, 4, 8, 13, and 16. Below 565-16,CC there were no significant accumulations of diatoms or radiolarians.

The most stratigraphically useful diatom species that occur at this site are *Coscinodiscus nodulifier, Hemidiscus cuneiformis, Nitzschia reinholdii, Roperia tesselata, Nitzschia cylindrica, Thalassiosira oestrupii, Pseudoeunotia doliolus,* and *Rhizosolenia praebergonii. P. doliolus* occurs in Cores 1 through 8. This diatom makes its earliest appearance in the lower part of the Olduvai Event (Burckle, 1977a), suggesting that the Pliocene/Pleistocene boundary falls below this interval. *Rhizosolenia praebergonii* ranges from mid-Pliocene to just after the Olduvai Event in the lower Pleistocene (Burckle, 1977a). This species was encountered in Cores 1, 3, 4, 8, and 16. An increase in abundance of *Thalassiosira oestrupii*, which occurs just below the Brunhes/Matuyama boundary in the lowermost Pleistocene (Burckle, 1977a), is further support for the placement of the Pliocene/Pleistocene boundary below Core 8. *Mediaria splendida* is a species that became extinct by the mid-Miocene (Barron, 1976). Its occurrence in Core 8 is an indication of reworking of Miocene sediments. The top or last occurrence of *Nitzschia cylindrica* is put in the middle of the Gilbert, or lower Pliocene (Saito et al., 1975). It also occurs in Core 13, which places the Pliocene/Pleistocene boundary above this interval.

The silicoflagellate *Mesocena elliptica* is reported to have been deposited from the late Pliocene to early Pleistocene (Burckle, 1977a and b). Its occurrence in Core 13 suggests an age of late Pliocene at the earliest. Low numbers and poor preservation prevent any age determinations other than to suggest that the core represents a range from middle or early Pleistocene to middle or late Pliocene, with reworked Miocene material included.

PHYSICAL PROPERTIES

Methods

Measurements of bulk density, water content, shear strength, and sonic velocity were performed on samples from this site. Bulk density measurements obtained by continuous analog GRAPE are questionable because of the amount of gas disturbance within some cores and the undersized core resulting from the use of a smaller-diameter bit. Two-minute GRAPE counts were utilized for the bulk densities discussed as well as to calculate porosity, assuming a grain density of 2.65 Mg/m^3 and a fluid density of 1.025 Mg/m^3 (an exception is a limestone sample for which the grain density is assumed to be 2.70 Mg/m^3). Water content was obtained by drying and also utilized in combination with bulk density to provide another measurement of porosity. Vane Shear (shear strength) measurements were performed utilizing a hand-held Torvane on split cores, perpendicular to the bedding plane. Sonic velocities were measured in the Hamilton Frame velocimeter. Further discussion of methods may be found in Boyce (1976).

Results

Bulk density, wet-water content, and porosity for the sediment column are shown graphically in Figure 5. Bulk densities show an inverse relationship to wet-water contents and porosities, as expected. Wet-water content shows a rapid decrease in the upper 20 m from 60 to 40% and then becomes variable around an average, decreasing to approximately 35% at 300 m. Porosity and bulk densities show similar trends of gradual decrease and increase, respectively. The variability of these data points reflects the presence of gas-charged sediments, which upon release of *in situ* pressure become disturbed to variable degrees. Sampling for physical properties was lim-

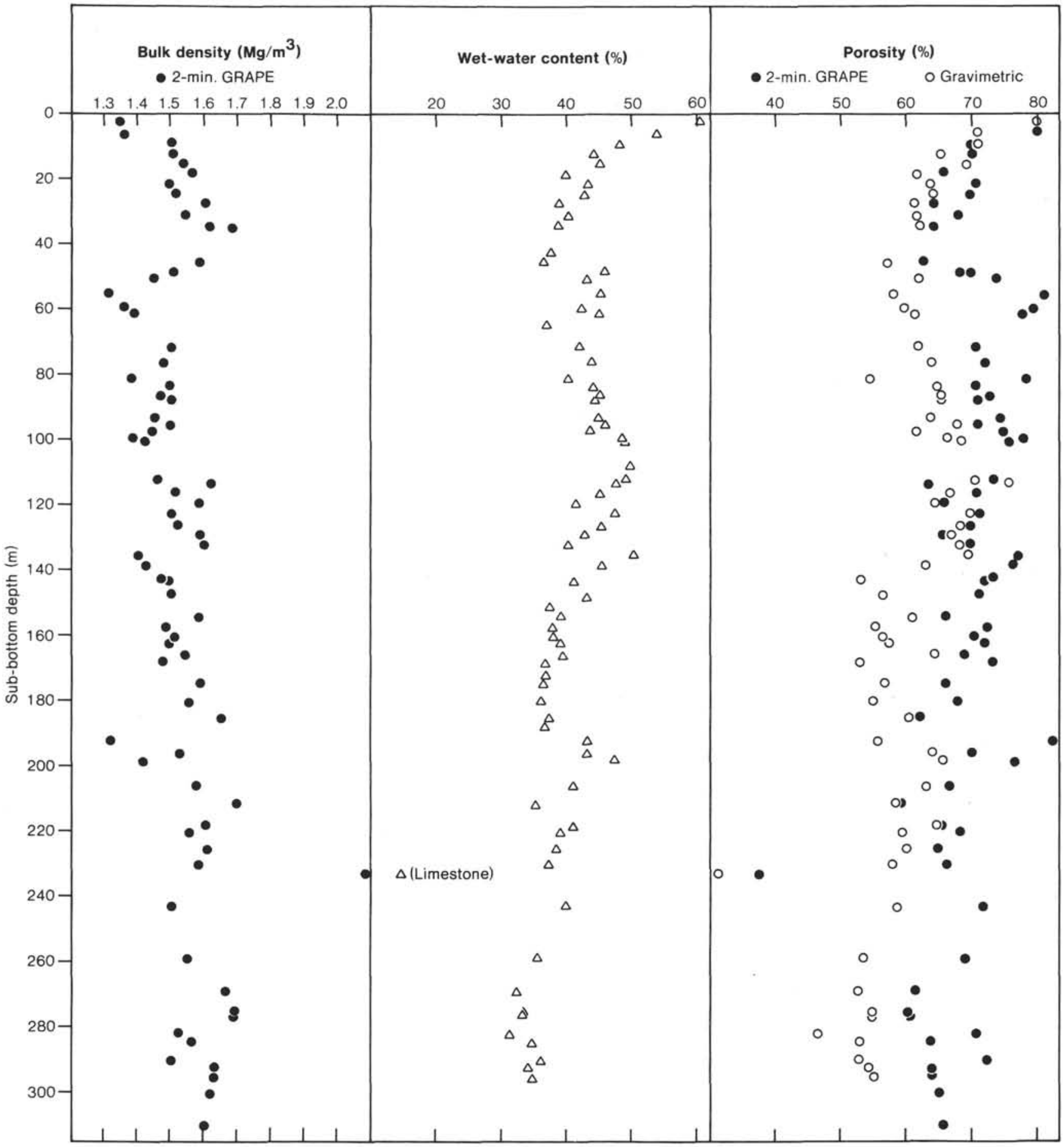

Figure 5. Index properties of sediments from Site 565.

ited to least-disturbed sediments and to lithified chunks of mudstone encountered below a depth of 126 m. These mudstones often show scaly or platy fracture and were easily crumbled when they were prepared for 2-minute GRAPE and sonic velocity measurements.

Sonic velocities obtained show an overall increase with depth from approximately 1.5 km/s at surface to about 1.7 km/s at 300 m subsurface (Fig. 6). The sharp decrease shown between 40 and 70 m is probably the result of the degassed structure of unindurated sediments and their corresponding high attenuation. Below 90 m the velocities follow the overall trend, although attenuation was also quite high at times. The degassing in more indurated sediments may have occurred along bedding planes and thus preserved the sediment structure, allowing more successful measurements of the received sonic signal.

Shear strength measurements were performed until the gas disturbance within the cored sections had altered these to the extent of making any further measurements simply a study of sediment remolding, not at all characteristic of the *in situ* condition. Figure 7 shows the rapid increase in shear strength encountered in the drilled column and also plotted is the effective overburden for the uppermost 35 m. Gas is present below 20 m, causing extreme variability of results, although a few points may still be indicative of the true rate of change in shear strength with depth. This rate increases abruptly from 10 kPa at 2.5 m to 58 kPa at 27.9 m; then a slower rate emerges, which is questionable because it is difficult to assess the degree of disturbance caused from degassing.

Discussion

The physical properties from Site 565 reflect the lithologic continuity and presence of gas within the sedimentary column. Two interesting observations from the obtained data are (1) the rapid increase of shear strength within the upper 30 m, also reflected in the rapid increase of bulk density and decrease of porosity and wet-water content, and (2) the uniformity of the remainder of the column. These profiles are typical of many marine sediments as presented by Hamilton (1976). The rapid decrease of water content and porosity may in effect reflect the typical dewatering stage in consolidation of clays, suggesting good permeability paths that may also provide a mechanism for loss of generated methane to the water column in the upper sedimentary column.

GEOPHYSICS

The geophysical data around Site 565 include some bathymetric records and magnetometer measurements made by the *Challenger*, a University of Texas (UT) common depth-point (CDP) seismic reflection record crossing the Trench and extending up the slope to within 2 or 3 km of the Nicoya Peninsula, and three measurements of temperature in the drill hole to a depth of 200 m. This section also discusses evidence of possible elevated pore pressures at about 300 m depth where the hole seemed to constrict around the drill pipe, finally causing us to abandon the site.

Passing Cabo Blanco at the southeastern end of the Nicoya Peninsula and transiting about 50 km north to the UT seismic transect, the *Challenger's* echo sounder defined a broad canyon in the landward slope of the Trench (Fig. 8). This canyon is a broad swale in the charts of general bathymetry. Just beyond, on a rilled slope to the northwest, is the UT seismic transect. Smaller channels were revealed in bathymetric records from the *Challenger* survey around Site 565 (Fig. 9). Thus the Trench slope just seaward of the Nicoya Peninsula is characterized by canyons tens of kilometers across to channels hundred of meters across. A detailed survey might reveal individual sites of deposition or erosion and tectonic escarpments only suggested by the present data.

The CDP seismic reflection record was made in 1977 using a Maxipulse sound source and a 24-channel recording system. Emphasis on the low frequencies in the processing of these data brought out reflections from the igneous ocean crust. This crust can be traced from the Middle America Trench essentially to the Nicoya Peninsula (Fig. 10). At the Trench, sediment being subducted with the ocean crust is seen clearly in the first 12 km before the strata are obscured by seismic noise. Above the subducting ocean crust is a body of rock that appears seismically structureless. This body of rock is an extension from the Nicoya Peninsula of the rock that forms the continental framework. It has velocities characteristic of consolidated sedimentary rock or altered igneous rock (i.e., serpentinite), although its velocity structure has not been established in detail. A somewhat irregularly stratified sequence of slope deposits has covered the structureless body. The drilling at Site 565 was in the upper part of the slope deposits.

At Site 565, reflections in the lower part of the slope deposits have high amplitudes. These reflections are broken by a series of small normal and reverse faults (Fig. 11). The upper part of the slope deposits have few reflections, and thus little structure can be seen. The low amplitudes of these reflections are consistent with the massive mudstones recovered.

The magnetic anomalies observed during the *Challenger* transect show a smooth, 130-gamma seaward decrease in the Earth's total magnetic field values. This fact suggests an absence of igneous materials in the rock sequence that makes up the continental framework seaward of the Nicoya Peninsula, however serpentinite or the product of low-temperature diagenesis could have a low magnetic field also.

Temperatures in the hole were measured during drilling with the *in situ* probe. The first of three measurements is suspect, but good results were obtained from the last two attempts (Fig. 12). A minimum gradient of 10°C/km can be read using only the subsurface points, but a conservative maximum value using the temperature of the water at the seafloor is 25°C/km. The latter value is consistent with the temperature gradients measured off Guatemala.

The last 30 m of the hole were difficult to drill because the bottom-hole assembly became stuck as the hole constricted. This sticking was accompanied by back

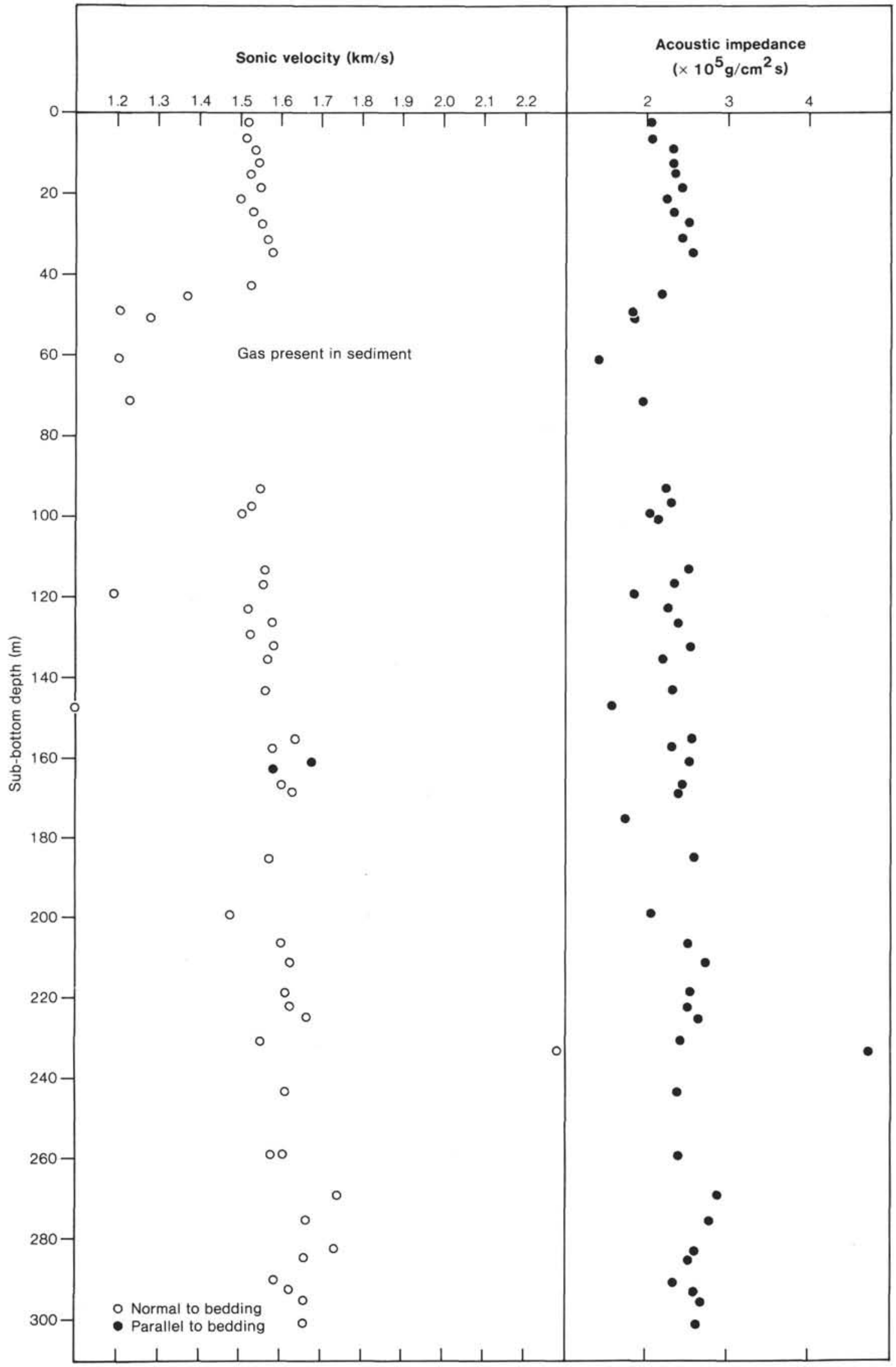

Figure 6. Velocities and impedances of sediments at Site 565.

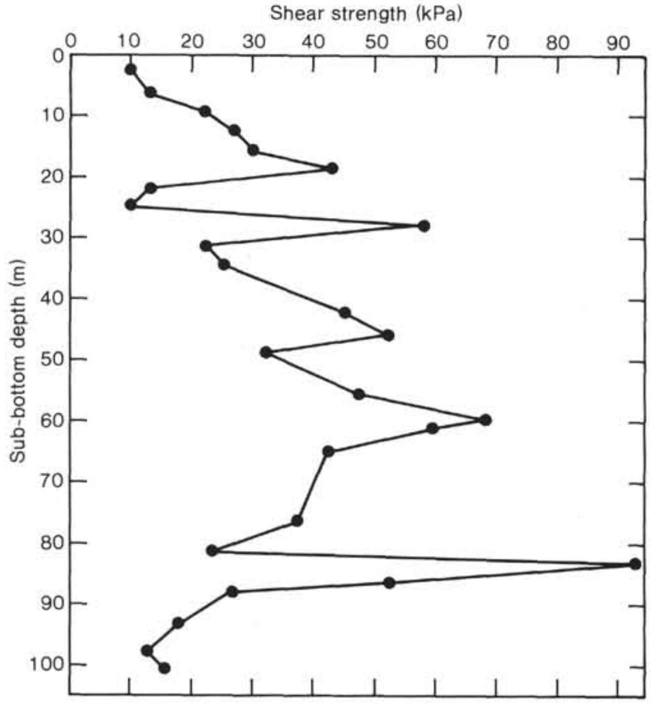

Figure 7. Shear strength-depth relationship as measured with hand-held Torvane, Site 565.

pressures measured at the drill rig of 250 to 350 lb, and during 5- to 10-min. periods water flowed out of the drill stem at the rig floor, which is 10 m above sea level. This reverse flowage could have been caused by (1) a normal back flow from settling of the weighted column of fluids carrying chips up the anulus of the drill hole or (2) a zone of overpressured fluids and resultant heaving or closing of the drill hole where sticking began. The zone of drilling difficulty corresponds to the zone of recoverable gas hydrate.

The drilling evidence for distinguishing between elevated pore pressure and back flow is inconclusive. Nonetheless, elevated pore fluid pressure is a likely phenomenon in zones of convergent tectonism, and its presence was anticipated along the Costa Rican subduction zone. The 300 m of rapidly deposited massive mudstone will impede any fluids migrating from below. If large amounts of sediment are being subducted and underplated at the front of the margin, as suggested by the seismic records and by the rapid uplift at Site 565, the pore fluids are quickly in disequilibrium and they will tend to migrate upward.

PALEOMAGNETICS

At least one oriented sample was taken from each 1.5-m section of core where the core material was consolidated. Unconsolidated core material was not sampled. Samples were taken by pressing 2.5-cm plastic cubes into the flat split core surface. The natural remanent mag-

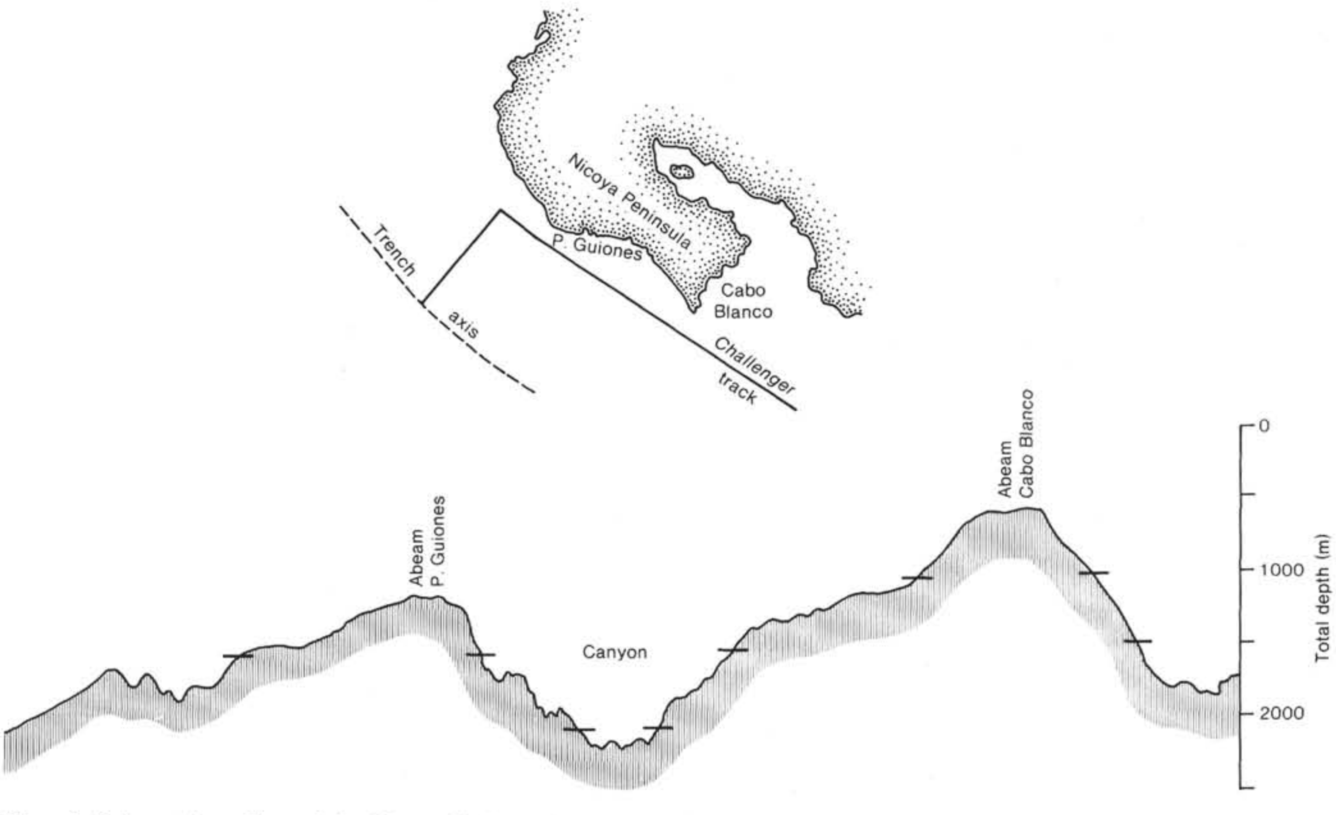

Figure 8. Bathymetric profile made by *Glomar Challenger* in transect to Site 565.

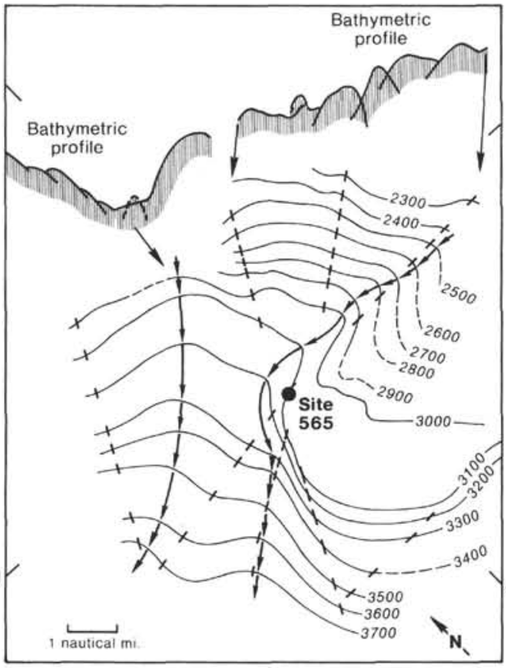

Figure 9. Detailed bathymetry around Site 565 from a survey made by the *Glomar Challenger*. Track lines are shown by ticks on contours. Further detail is shown in sketches of the fathometer records, with black arrows indicating locations.

netization (NRM) of each sample was then measured using the on-board Digico spinner magnetometer.

The NRM inclinations and intensities for Hole 565 are plotted in Figure 13. Inclinations are calculated with respect to the horizontal plane, assuming that each core was oriented vertically, and are positive in the down direction, corresponding to normal magnetic polarity at this site. The inclinations are scattered, with many showing very high positive values much greater than the expected value for a site at this latitude (11°N). However, a tentative assignment of polarity zones is presented in Figure 13, along with ages of magnetozone boundaries that are relatively well defined. The NRM intensities are initially high (10^{-5} emu/cm^3) but drop rapidly to about 10^{-6} emu/cm^3 at a depth of 20 m. Between depths of 20 and 40 m the intensities are very scattered. A possible reason for this scatter is the inclusion of relatively large fragments of magnetic material, possibly tuffaceous. Below 40 m the intensities decrease fairly smoothly to the mean value for the remainder of the hole; approximately 2×10^{-7} emu/cm^3. Detailed alternating-field-demagnetization experiments were performed on several of the samples. The change in intensity of magnetization for one of these samples is shown in Figure 14. During demagnetization, the magnetic inclination decreased from an initial value of $-30°$ to $-7°$ at 350 Oe peak field. It then remained fairly constant up to 650 Oe. This behavior indicates the presence of two magnetic components, with the least stable one being responsible for almost all of the initial NRM intensity. All samples down to a depth of 100 m were demagnetized at 150 and 350 Oe. Below 100 m, the samples were too weakly magnetized to measure after demagnetization. Stratigraphic plots of the demagnetized inclinations did not differ greatly from the NRM data in Figure 13, with little or no decrease occurring in the scatter at either 150 or 350 Oe. However, the magnetic intensities were very low after 350 Oe demagnetization, and much of the scatter oc-

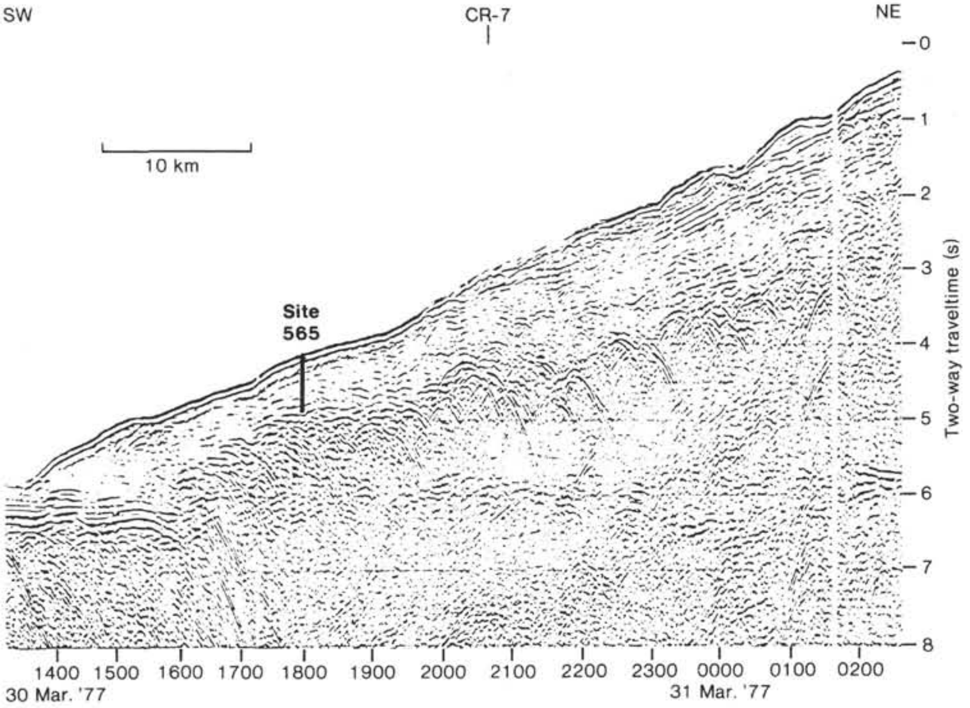

Figure 10. Seismic profile CR-7 of the Middle America Trench and slope off Costa Rica.

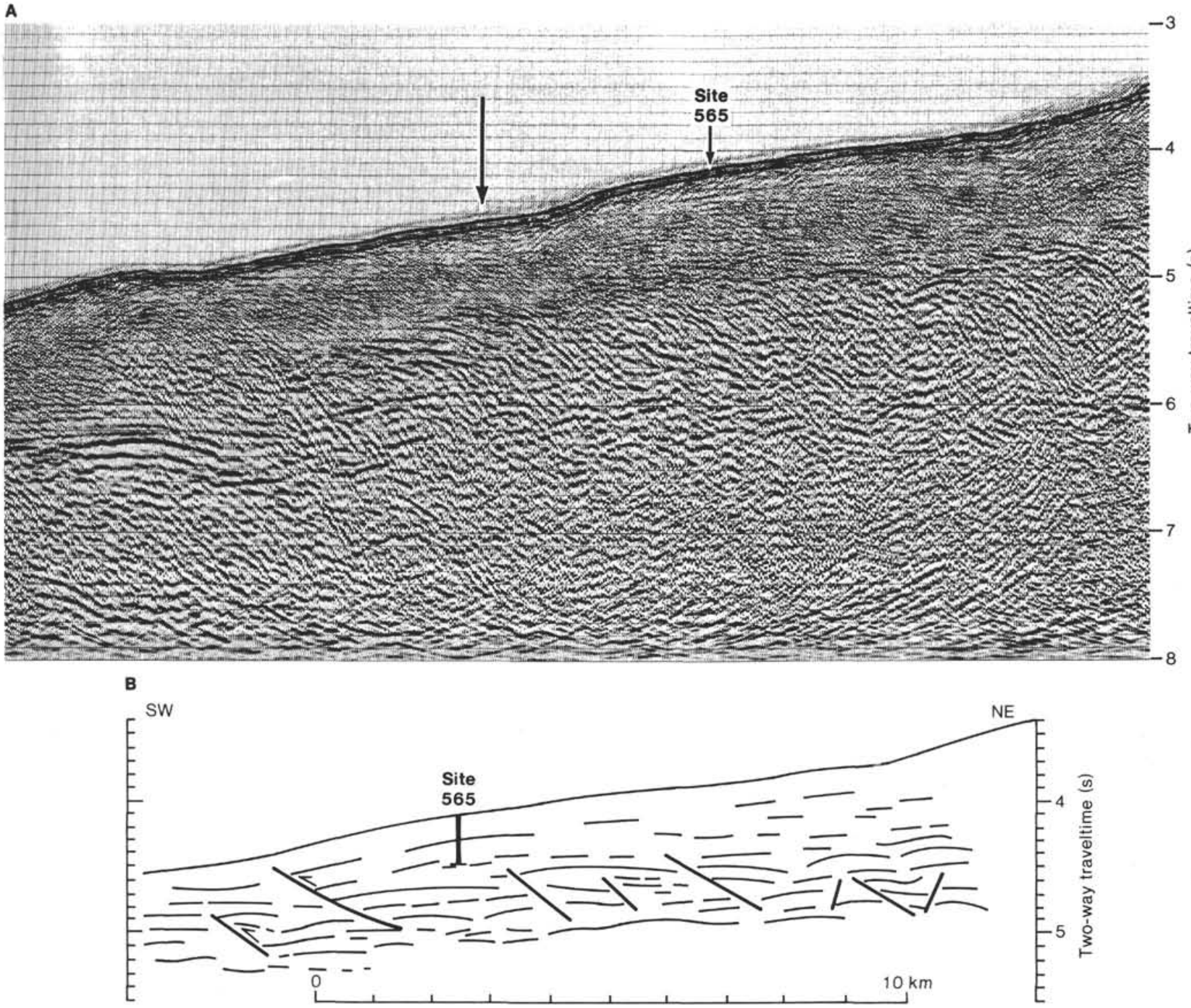

Figure 11. A. Seismic record processed by Shipley et al. (personal communication). Large arrow shows approximate location of left (SW) boundary of line drawing (B.). B. Line drawing interpretation showing reflections and small faults.

curring at this point could have resulted from instrumental noise.

GEOCHEMISTRY

The shipboard geochemistry program for this site was designed to study the history of hydrocarbon gas generation in order to gain background information on the origin of gas hydrates (in case they were encountered here). Although no bottom simulating reflector (BSR) characteristic of the base of gas hydrate had been observed on seismic records crossing this site, other seismic lines from offshore Costa Rica commonly show BSRs which suggested that gas hydrates might be present (Shipley et al., 1979). In addition, the observations of gas hydrates during drilling on Leg 66 (Moore, Watkins, et al., 1979) and Leg 67 (von Huene, Aubouin, et al., 1980) on the landward wall of the Middle America Trench, offshore Mexico and Guatemala, point to the likely occurrence of gas hydrates in similar geologic settings offshore Costa Rica.

Gas Analyses

Gases were obtained directly from gas pockets that developed as sediment separated in the core liner as a result of gas expansion. Gas pockets were sampled by means of a hollow punch with a valve to prevent immediate gas release. After the punch penetrated the core liner, gas was vented through the valve into standard 20-ml evacuated containers called vacutainers. The collected gases were analyzed by gas chromatography. Hydrocarbon gases, methane (C_1), ethane (C_2), propane (C_3), iso and normal butane (i-C_4 and n-C_4), and iso, normal, and neopentane (i-C_5, n-C_5, and neo-C_5) were measured in gas pockets developed below about 57 m depth subbottom (Table 2). C_1 was the dominant gas; C_1/C_2 ratios decrease exponentially with depth (Fig. 15, a trend commonly observed at many DSDP sites; Claypool, 1976).

In addition to the analyses of gases in gas pockets, two sets of sediment samples were collected for gas analyses by headspace techniques. One set was analyzed on

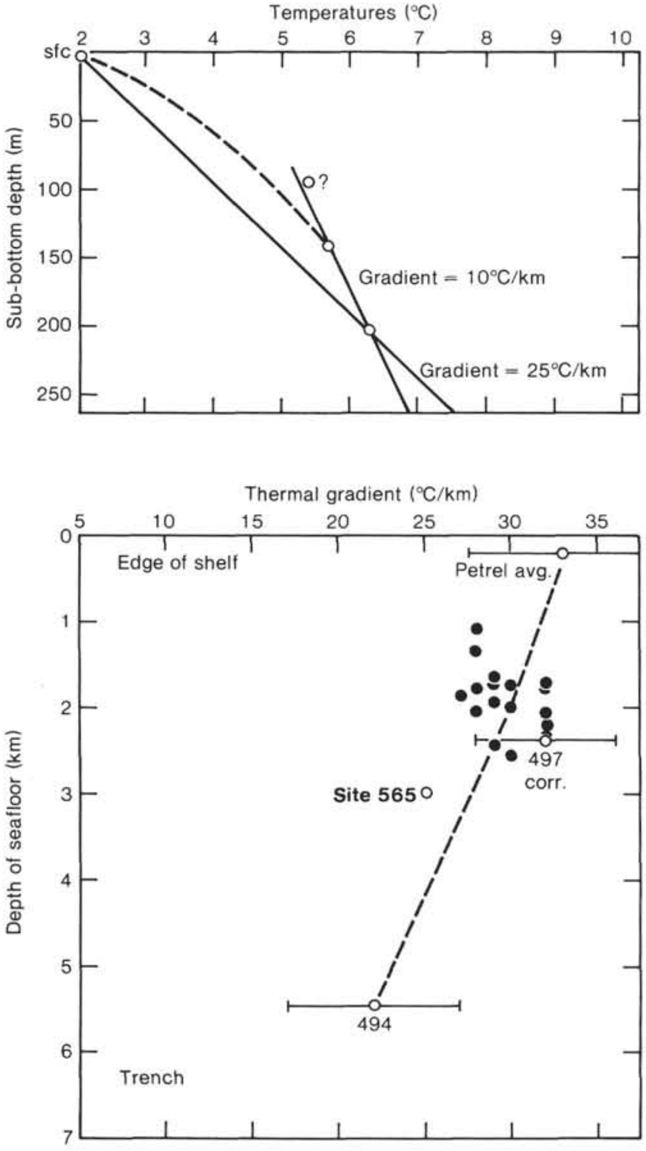

Figure 12. Temperature measurements and geothermal gradient at Site 565 and off Guatemala; SFC = sediment surface.

shipboard (Kvenvolden and McDonald, this volume) and the other on shore (McDonald et al., this volume).

Gas Hydrates

Cores containing high concentrations of gas were generally recovered at sub-bottom depths below 175 m. At a sediment depth of 285 m, a white, icelike material (about 1 × 1 × 0.3 cm) was observed through the core liner in a region of degassing sediment, indicated by bubbles. The core liner was cut at this point and two pieces of the material were removed. The pieces decomposed before appropriate analyses could be made. The behavior of the material suggested gas hydrate.

At a sub-bottom depth of 319 m the material expelled from the lower end of the core barrel of Core 33 contained several pieces of muddy sandstone that fizzed and were cold to the touch. When these pieces were broken open, the expulsion of gas increased and fizzing continued. No quantitative measurements could be made on these samples, but the samples very likely contained gas-hydrated sediment.

In the core catcher of Core 33, probably just below the sandstone bed, was a 1.67-g (about 1.5-cm^3) piece of white, icelike substance that was recovered from very stiff mud. This sample was placed in a pressure device. The calculated volume of gas released upon sample decomposition was about 133 times greater than the volume of water. Salinity of this water was determined to be 1.1 parts per thousand (‰).

A sample of this released gas was analyzed by gas chromatography aboard ship. Of the gas within the pressure device, 89.1 vol.% was C_1 and the remainder mostly air that could not be purged from the device before the gas samples were removed for analyses. C_2 and C_3 were present in amounts of 444 and 5 parts per million (ppm) by volume, respectively. Of particular interest is the fact that the relative concentrations of gases larger than i-C_4, that is, *n*-C_4, i-C_5, and *n*-C_5, are essentially absent (i-C_5 was present in concentrations less than 1 ppm). This observation contrasts with the distribution of hydrocarbon gases recovered elsewhere at this site where C_1 through C_5 hydrocarbons commonly are present (Table 2). The results from the pressure device indicated that the white substance was probably gas hydrate, because the observed distribution of gas could be explained on the basis of the sizes of the cages in the hydrate structure. Hydrocarbon gases larger than i-C_4 cannot be included in gas hydrate structures, whereas C_1, C_2, C_3, and i-C_4 fit within the cages (Hand et al., 1974).

Therefore, three lines of evidence indicate that the white, frothing, icelike substance sampled in Core 33 was gas hydrate: (1) The ratio of the volume of C_1 to the volume of water resulting from the decomposition of the substance was about 133 to 1. The maximum, theoretical ratio for fully saturated C_1 hydrate is 170 to 1. In contrast, the solubility of C_1 in water at the *in situ* pressure–temperature conditions of this sample is about 4 to 1. Clearly, the amount of C_1 released exceeds its solubility in water by a factor of about 30. (2) The salinity of the liquid remaining after sample decomposition is 1.1‰. This value contrasts with the pore fluid salinity of nearby sediment of about 25‰. The low salinity value suggests water from a decomposed gas hydrate, because in gas hydrate formation inorganic ions are excluded from the lattice structure of water molecules. (3) The distribution of hydrocarbon gases recovered from the decomposition of the sample can readily be explained in terms of the crystallography of the gas hydrate structure.

Interstitial Water Chemistry

Inorganic geochemical parameters measured from the pore water samples were calcium, magnesium, chlorinity, salinity, alkalinity, and pH (Fig. 16). The trends of these parameters approximate trends seen earlier on Leg 67 (Hesse and Harrison, 1981). The unusual decrease with depth of salinity from about 35 to 24‰ and of chlorinity from about 19 to 14‰ may result from the presence of gas hydrate.

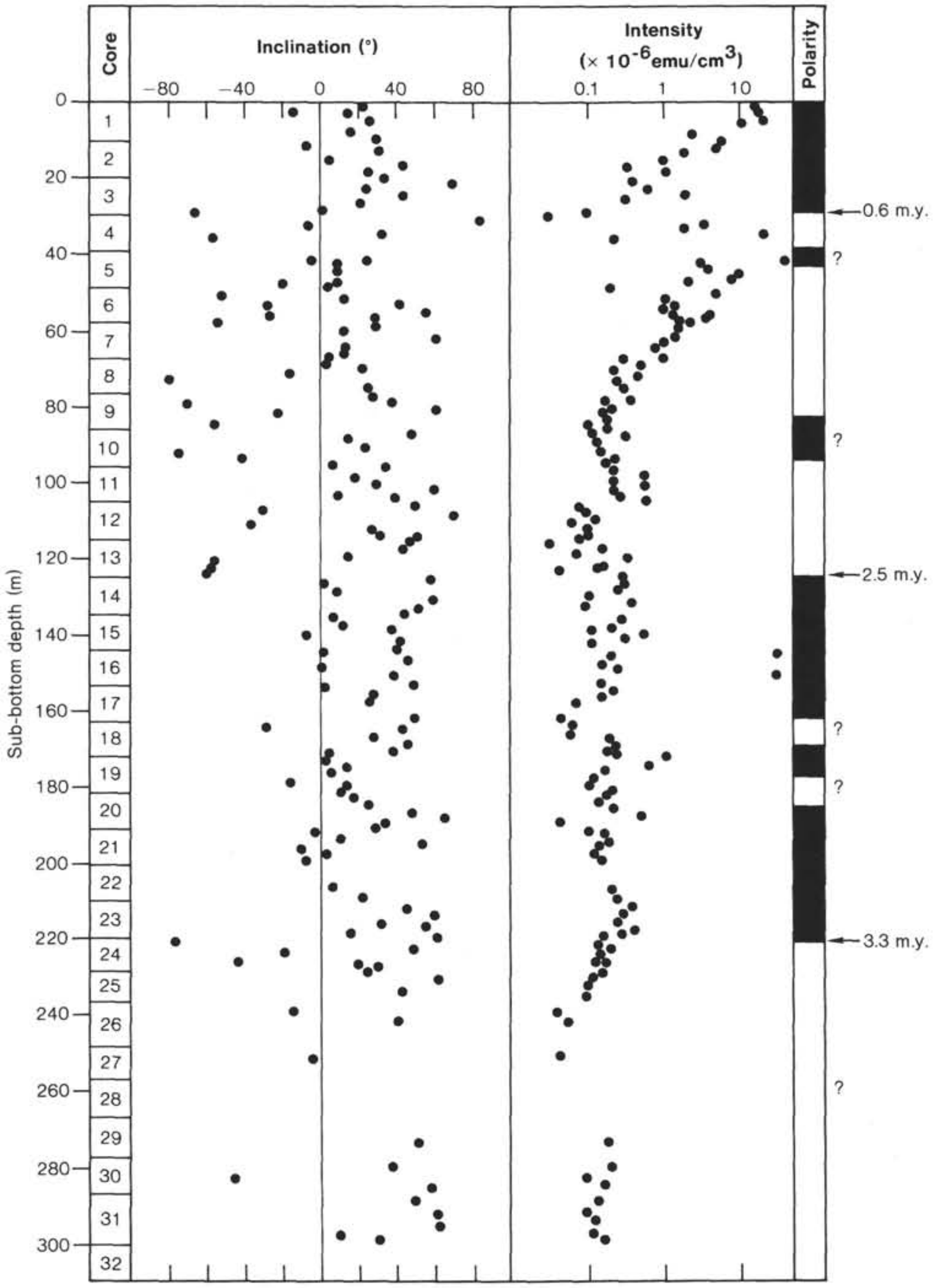

Figure 13. Stratigraphic plot of NRM data for Site 565. A tentative correlation of magnetozones with the standard polarity time scale appears on the right-hand side (black areas indicate normal, white, reverse polarity).

Summary

How the gas hydrates are distributed in sediments at Site 565 is not known. Most of the gas hydrate may have decomposed as a result of the drilling process. Apparently the gas hydrate at this site does not form massive, solid layers. The gas hydrate may be dispersed throughout these fine-grained mudstones, but preferentially may favor the sandstone encountered. Gas in hydrate and nonhydrate form is probably intimately associated in the sediments at this site with the gas hydrates more likely to be found in the more porous sediments.

SUMMARY AND CONCLUSIONS

Site 565 on the landward slope of the Middle America Trench off the Nicoya Peninsula of Costa Rica was drilled in 3111 m of water to 328 m below the seafloor. The site is about 27 km landward of the Trench axis on a

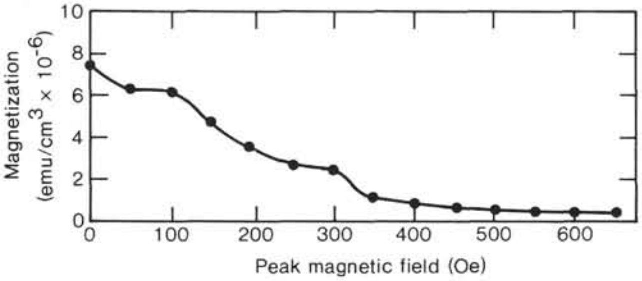

Figure 14. Alternating field demagnetization of Sample 565-1-7, 39–41 cm.

small raised area between two of the numerous small canyons, spaced 1 to 3 km apart, that are common to this slope.

The problems that brought *Glomar Challenger* to this site are revealed in a seismic reflection record taken in the field by J. Watkins with the University of Texas facilities and studied by R. Buffler and T. Shipley (Shipley et al., 1982). The record has three basic geologic units. The upper unit is a somewhat irregularly stratified slope deposit in which the upper part has reflections of low amplitude and the lower part has more continuous high-amplitude reflectors. (The hole was only drilled through the low-amplitude upper part; about 550 m of lower slope deposits were undrilled.) At the base of the slope deposits, a strong and commonly diffracted reflection marks the top of the next unit and indicates a fundamental geologic break. This unit has few reflections and shows little structure. The main tectonic objective was to identify the age and characteristics of the rock that makes up either the front of the continent or an accretionary complex. The seismically structureless unit is in turn underlain by clear reflections from the subducting oceanic crust. The crust can be traced in this seismic record from the Trench to the Nicoya Peninsula, and at the site the crust is about 5 km below the ocean floor. Along the first 12 km of the subduction zone, clear reflections from strata are seen above igneous ocean crust that indicate extensive subduction of sediment. No structure indicating an imbricated accretionary prism can be seen.

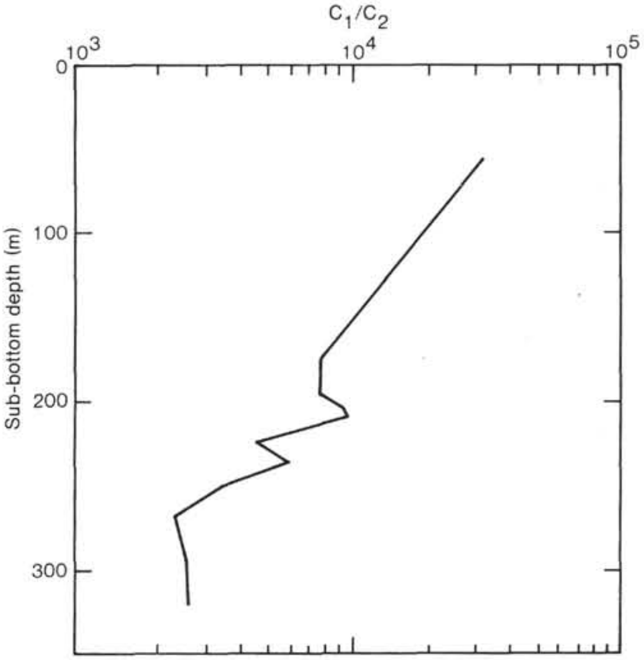

Figure 15. Ratios of methane to ethane (C_1/C_2) with depth at Site 565.

Another objective at this site was to recover and study naturally occurring gas hydrate. Gas hydrate from two cores was not only observed visually but was contained prior to total decomposition and was studied physically and chemically.

The first 30 of the 34 cores recovered at Site 565 contained a dark, olive gray mud and mudstone with only two recognizable ash layers and two thin beds of sandstone in the 328 m drilled. Despite sediment accumulation rates of more than 100 m/m.y., the sediment became surprisingly stiff in the first 30 m. The sediment was locally highly bioturbated, showed two small slump folds, and locally contained calcareous mudstone clasts of older materials in a pebbly mudstone lithology. At Core 30, a 10-cm thick, hydrated, muddy, fine-grained sandstone was recovered that seemed to mark a major lithologic change. Drilling rates indicated hard and soft layers, but recovery was very poor and consisted only of

Table 2. Distribution of hydrocarbon gases at Site 565.

Core-section	Sub-bottom depth (m)	C_1 (%)	C_2 (ppm)	C_3 (ppm)	i-C_4 (ppm)	*n*-C_4 (ppm)	neo-C_5 (ppm)	i-C_5 (ppm)	*n*-C_5 (ppm)
6-6	56	50	16	2.9	1.10	0.17	—	0.48	0.08
19-4	177	85	110	5.2	1.90	0.28	0.02	1.70	0.07
21-3	195	78	100	7.8	2.40	0.37	0.01	2.70	—
22-3	204	80	97	6.8	1.90	0.42	—	2.00	—
22-6	209	80	92	6.1	1.80	0.38	0.03	2.20	0.03
23-5	217	79	130	5.2	1.60	0.27	0.02	1.50	0.04
25-6	236	43	71	4.9	1.40	0.26	—	1.00	0.03
26-4	243	55	130	6.2	1.80	0.23	—	1.10	—
27-2	250	48	140	7.7	2.30	0.32	—	1.30	0.03
29-2	270	65	280	11.0	3.00	0.43	—	1.30	—
31-5	293	32	130	3.5	0.85	0.11	0.11	1.00	0.04
34-1	320	69	280	5.7	1.70	0.26	—	1.50	0.16

Note: — indicates no perceptible quantity.

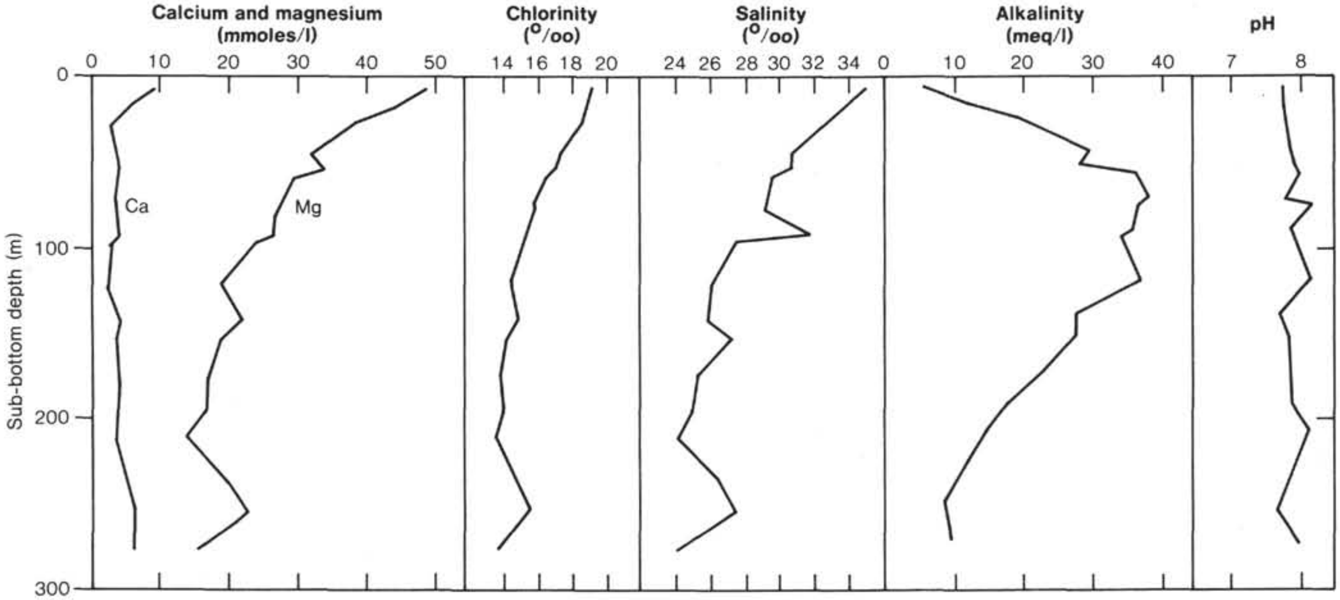

Figure 16. Interstitial water geochemistry at Site 565.

hard mudstone; the softer materials were probably washed away. The upper slope sequence thus consists of a hemipelagic mudstone, and perhaps its position in an intercanyon channel area explains the very small amount of sand recovered. The lithologic evidence of abundant reworked material from upslope, slumping, and the disruption and mixing of ash layers and perhaps sandstones all argue for considerable downslope mass movement and some density current transport on a slope that averages about 2.5° and is locally 5°.

Nannofossils, benthic foraminifers, and diatoms indicate a normal stratigraphic sequence from Quaternary probably to the top of the Miocene. The benthic foraminiferal communities from upslope are abundant and show the same downslope transport as seen in the lithostratigraphy. At Core 30 a change in provenance with a marked decrease in upper slope materials and an increase in mid-slope components corresponds with the change in lithology. Also beyond Core 29 the nannofossil flora contain a significant number of reworked Cretaceous forms, one of which is restricted to the Maestrichtian period. It would appear that a Cretaceous outcrop occurred in the upslope of this site during the latest Miocene or early Pliocene.

Physical properties measurements show a very rapid increase of shear strength in the upper 30 m and a slower rate of change thereafter. These measurements indicate probable overconsolidation at the top of the section and an underconsolidation near the bottom. One explanation for the overconsolidation consistent with the other observations is a disturbance from downslope mass movement that rearranges particles, thereby releasing gas or draining fluids from the upper part of the sequence. The scatter of paleomagnetic poles and weak remanent magnetism are attributed to this process also. The possible underconsolidation cannot be attributed convincingly either to degassing or to elevated pore pressure, but the latter is also one of two explanations for the behavior of the drilling fluids as the hole conditions deteriorated and finally caused us to abandon the hole.

Core and geophysical data indicate very little tectonism in the upper 300 m of slope deposits at Site 565. In the last 3 to perhaps 8 m.y. the upper plate of the Middle America Trench subduction zone seems to have been uplifted. The upper plate has not been faulted or folded sufficiently to produce a detectable surface scarp, or to show faults at the tens of meters resolved in the seismic reflection record, or to produce faults at the scale of the core. These observations indicate considerable decoupling of the upper from the lower plate, because in 3 m.y. about 300 km of ocean crust have been subducted. Decoupling could be caused by high or near lithostatic pore pressure, as suggested for thrust faults by Hubbert and Ruby (1959), but at Site 565 such overpressure could not be convincingly documented. The uplift must result from some form of underplating, because the slope deposits are not rotated by the successively imbricate slices observed elsewhere in subduction accretion complexes.

Three lines of evidence document the recovery of gas hydrate: (1) the 133 to 1 ratio of the volume of methane gas to the volume of water resulting from decomposition of the white icelike substance, or 30 times more methane than can be contained in methane-saturated, nonhydrated water; (2) a water salinity about 25 times lower than the salinity of the pore fluids; (3) the composition of the liberated gas, which is most easily explained in terms of the crystal structure of hydrate. The interstitial water chemistry is also appropriate for the existence of gas hydrate in this sediment, as suggested by Harrison et al. (1982). But just how the hydrate is distributed in the sediment was not resolved. The hydrate at this site does not appear to form massive layers. It was not found in the massive mudstone except perhaps in very small amounts dispersed in fractures or other rare voids. Despite a careful watch for hydrate as the core came on deck, no amounts large enough to remain in the solid form during core recovery were seen. Hydrate appeared in associated with a 10-cm sandstone and in a zone that may have been relatively more porous because of fracturing, as suggested by poor core recovery and unstable hole conditions. Gas hydrate may be dispersed in small concentrations throughout the massive mudstone but it appears to form 1- to 3-cm masses in fractures or it fills the voids in a sandstone. Thus free gas and gas hydrate may coexist at this site, with gas hydrate found preferentially in porous sediment.

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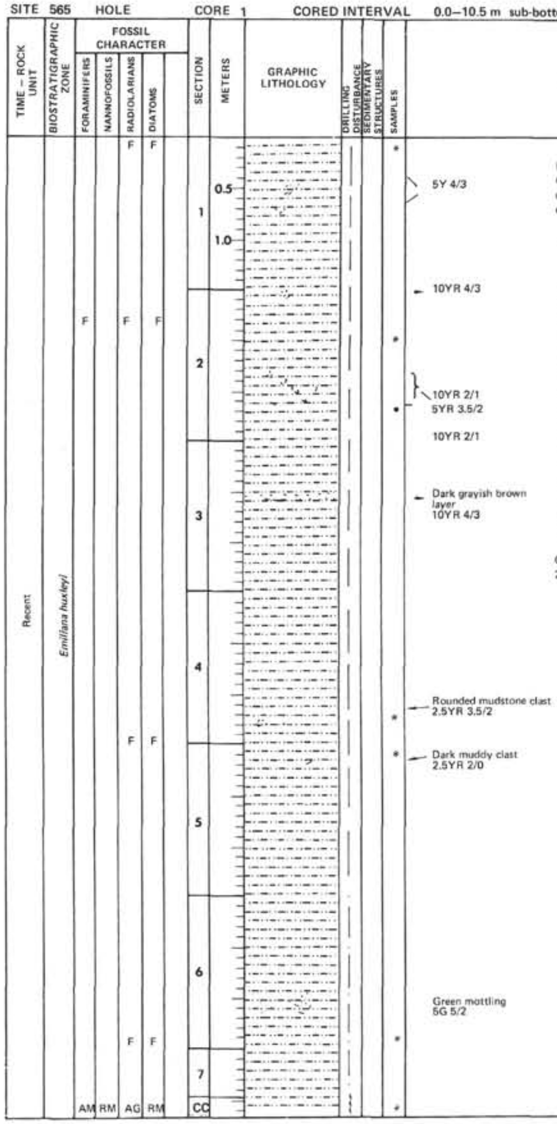
SITE 565 HOLE CORE 1 CORED INTERVAL 0.0–10.5 m sub-bottom



LITHOLOGIC DESCRIPTION

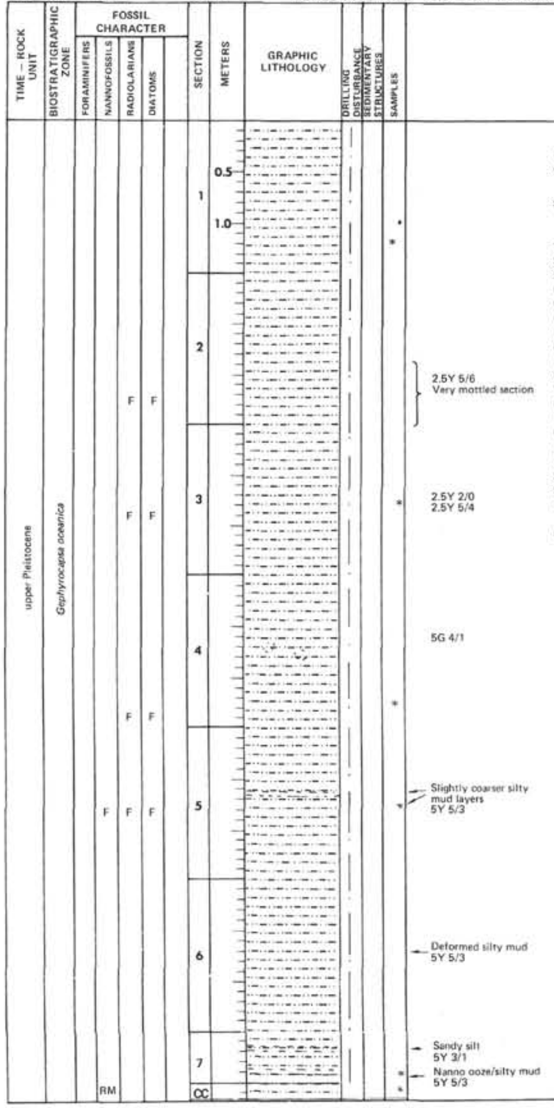
Dominant lithology: massive mud with minor mottling. Color: dark olive gray (5Y 3.5/2) grading down core to dark greenish gray (5G 2.5/1 and 5G 4/1) at bottom of core.

SMEAR SLIDE SUMMARY (%):

	1, 10	2, 50	4, 120	5, 10	6, 145
	D	D	D	D	D
Texture:					
Sand	5	1	1	5	4
Silt	15	9	5	5	16
Clay	80	90	94	90	80
Composition:					
Quartz	6	15	3	2	3
Feldspar	3	1	1	–	–
Mica	–	–	–	1	–
Heavy minerals	–	Tr	1	5	–
Clay	70	60	80	80	80
Volcanic glass	2	1	1	–	5
Glauconite	–	–	1	7	2
Foraminifers	–	2	–	–	–
Diatoms	3	2	3	–	2
Radiolarians	4	1	4	–	5
Sponge spicules	5	1	2	–	–
Silicoflagellates	1	–	2	–	–
Fish remains	–	–	3	–	2

CARBONATE BOMB (% $CaCO_3$):
2, 120 cm = 0

SITE 565 HOLE CORE 2 CORED INTERVAL 10.5–20.0 m sub-bottom



LITHOLOGIC DESCRIPTION

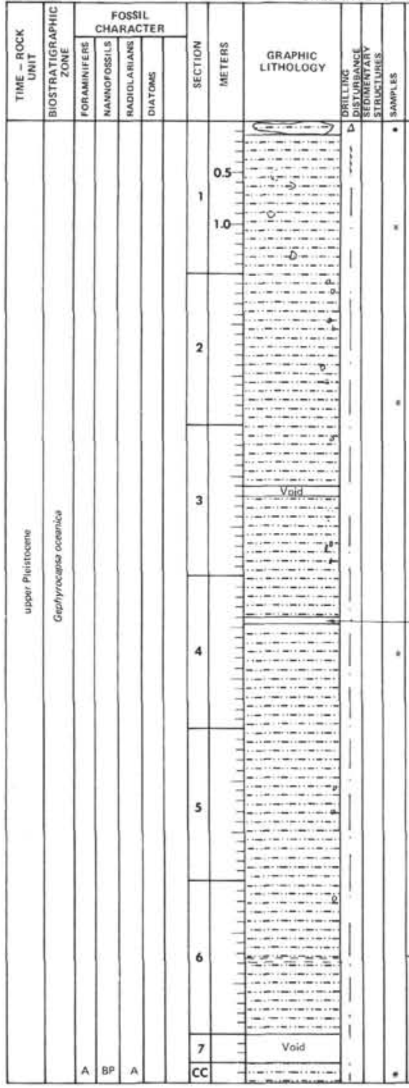
Dominant lithology: massive mud with mottling throughout core. Color: dark greenish gray (5GY 4/1).

SMEAR SLIDE SUMMARY (%):

	1, 120	3, 80	4, 128	5, 77	7, 44
	D	D	D	M	M
Texture:					
Sand	2	1	5	10	5
Silt	10	15	20	15	10
Clay	88	84	75	75	85
Composition:					
Quartz	4	2	3	3	2
Feldspar	3	1	1	1	–
Mica	–	1	1	–	–
Heavy minerals	5	1	1	3	1
Clay	70	80	80	5	4
Volcanic glass	5	3	2	3	–
Glauconite	5	3	5	5	1
Foraminifers	–	–	–	–	2
Calc. nannofossils	–	–	–	70	90
Diatoms	2	3	1	1	–
Radiolarians	2	3	1	–	–
Sponge spicules	10	5	2	–	–
Silicoflagellates	1	–	–	–	–
Fish remains	–	–	–	1	–

CARBONATE BOMB (% $CaCO_3$):
1, 100 cm = 0

SITE 565 HOLE CORE 3 CORED INTERVAL 20.0–29.5 m sub-bottom



LITHOLOGIC DESCRIPTION

Silty mud
5Y 6/4

Carbonate
cemented
clast

Dark subrounded
to angular pebbles

5Y 5/6 mottling

5Y 5/1 mottling

5Y 2.5/2

Silty mud-filled mottles
5Y 6/4

Carbonate cemented siltstone pebbles

5Y 6/1

Void

Silty mottle
5Y 6/1

White nodule
5Y 5/1

5Y 4/4

5Y 4/3

Very thin-bedded, graded silty mud

Silty mud horizon

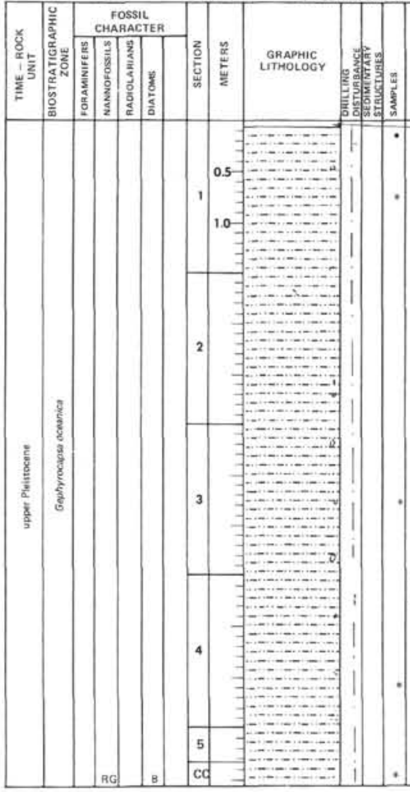
Dominant lithology: massive mud with mottling throughout core. Color: dark greenish gray (5GY 4/1) through most of core. Mottling is predominantly 5Y 3/1.

SMEAR SLIDE SUMMARY (%):

	1, 106	2, 123	4, 76
	D	D	M
Texture:			
Sand	10	5	12
Silt	15	20	20
Clay	75	75	68
Composition:			
Quartz	2	1	–
Feldspar	1	–	–
Heavy minerals	5	3	20
Clay	82	70	–
Volcanic glass	4	20	1
Glauconite	2	6	–
Carbonate unspec.	–	–	60
Sponge spicules	1	–	–

CARBONATE BOMB (% $CaCO_3$):
1, 10 cm = 0

SITE 565 HOLE CORE 4 CORED INTERVAL 29.5–39.0 m sub-bottom



LITHOLOGIC DESCRIPTION

Void

Nodule

Mottling
5Y 6/3

Mottling
5Y 2.5/1

5Y 5/3

Large (4 cm diameter)
carbonate nodule

Graded silt beds up to 2 cm thick

5Y 7/6

Dominant lithology: massive mud with common mottling. Color: dark greenish gray (5GY 4/1).

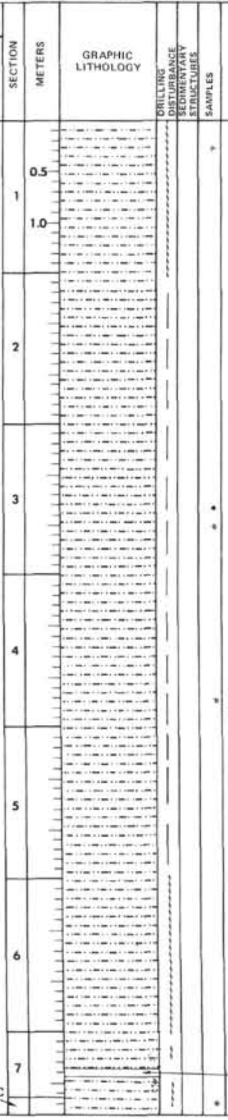
SMEAR SLIDE SUMMARY (%):

	1, 77	3, 73	4, 105
	D	D	M
Texture:			
Sand	4	5	25
Silt	16	10	30
Clay	80	85	45
Composition:			
Quartz	2	1	–
Feldspar	1	1	–
Heavy minerals	3	12	30
Clay	70	75	45
Volcanic glass	10	5	–
Glauconite	3	5	22
Sponge spicules	–	1	–
Fish remains	1	–	–

CARBONATE BOMB (% $CaCO_3$):
1, 20 cm = 0

SITE 565 HOLE CORE 5 CORED INTERVAL 39.0–48.5 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Pleistocene	*Gephyrocapsa oceanica*	FM			



LITHOLOGIC DESCRIPTION

Mottling 5Y 4/2.5

Sponge spicules

Thin graded silt bed

Dark mottling

Finely laminated silt and mud

Mottling 5Y 4/2

Subtly graded beds up to 2 cm

Subtly graded beds up to 2 cm

Mottling 5Y 6/3

5Y 4.5/3

Void

5Y 4.5/3

Dominant lithology: mud, mostly massive with common mottling and some laminated, possibly graded beds of a few mm thickness. Color: dark greenish gray (5GY 4/1).

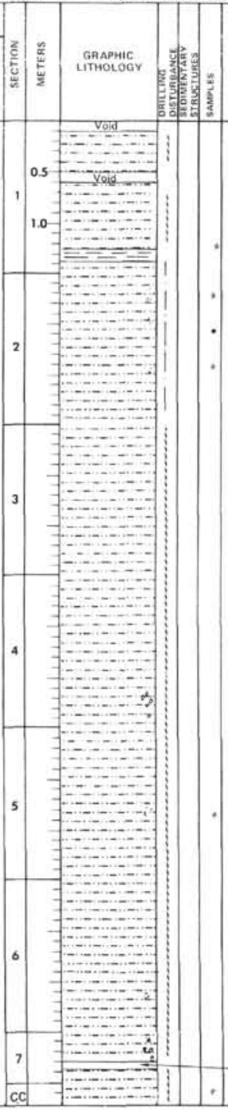
SMEAR SLIDE SUMMARY (%):

	1, 30	3, 108	4, 123
	M	M	D
Texture:			
Sand	20	2	4
Silt	10	20	11
Clay	70	78	85
Composition:			
Quartz	5	5	5
Feldspar	2	1	1
Heavy minerals	–	–	2
Clay	70	68	85
Volcanic glass	1	8	1
Glauconite	3	8	1
Zeolite	–	10	–
Fish remains	–	–	1

CARBONATE BOMB (% $CaCO_3$):
3, 90 cm = 0

SITE 565 HOLE CORE 6 CORED INTERVAL 48.5–58.0 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Pleistocene	*Gephyrocapsa oceanica*		RP		



LITHOLOGIC DESCRIPTION

Silt layer

Mottling 5Y 7/6

Dark mottling 5Y 2.5/1

Dark mottling

White clast and sponge spicules

5Y 7/6

Dark gray (N4) FeS_2 pebble

Small white carbonate clasts

Void

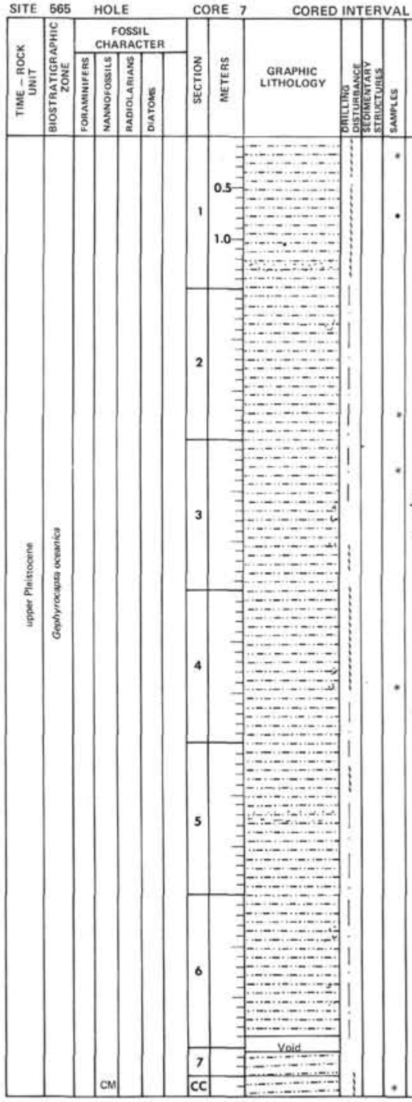
Dominant lithology: massive mud with common mottling. Color: 5G 4/1 to 5G 4/2 at bottom of core.

SMEAR SLIDE SUMMARY (%):

	1, 129	2, 26	2, 92	5, 81
	D	M	D	
Texture:				
Sand	1	7	2	6
Silt	12	13	8	10
Clay	87	80	90	84
Composition:				
Quartz	2	2	–	1
Feldspar	1	–	–	2
Mica	–	1	–	–
Heavy minerals	2	–	7	2
Clay	83	80	87	83
Volcanic glass	6	1	3	10
Glauconite	3	1	1	1
Zeolite	1	–	Tr	–
Foraminifers	–	1	Tr	–
Diatoms	–	1	Tr	–
Sponge spicules	1	1	1	1
Fish remains	1	–	–	–

CARBONATE BOMB (% $CaCO_3$):
2, 60 cm = 0

SITE 565 HOLE CORE 7 CORED INTERVAL 58.0–67.5 m sub-bottom



LITHOLOGIC DESCRIPTION

Whitish (5Y 8/1) mottle

Silty yellow (5Y 7/6) layer

Dark organic mottling

5Y 7/6 mottling, slightly harder, 20% $CaCO_3$

5G 4/2 mottling

5Y 7/6 mottling slightly more cemented

Grayish silt layer

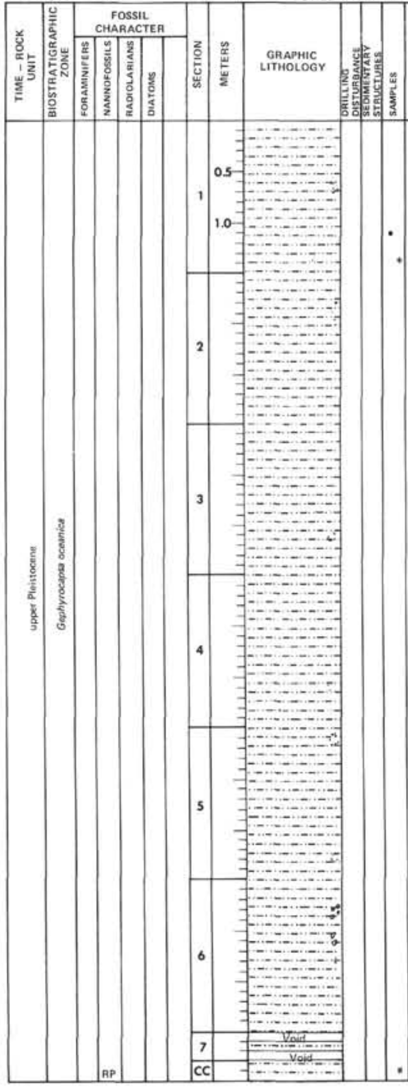
Dominant lithology: massive mud with common mottling. Color: dark greenish gray (5GY 4/1).

SMEAR SLIDE SUMMARY (%):

	1, 20	2, 127	3, 52	4, 99
	D	M	M	
Texture:				
Sand	3	3	12	8
Silt	12	8	2	20
Clay	85	89	86	72
Composition:				
Quartz	8	1	1	8
Feldspar	2	1	–	3
Heavy minerals	1	3	1	3
Clay	85	78	–	78
Volcanic glass	2	16	–	–
Glauconite	1	1	–	7
Zeolite	–	1	–	1
Calc. nannofossils	–	–	84	–
Fecal pellets	–	–	12	–

CARBONATE BOMB (% $CaCO_3$):
1, 80 cm = 0

SITE 565 HOLE CORE 8 CORED INTERVAL 67.5–77.0 m sub-bottom



LITHOLOGIC DESCRIPTION

Mottling 5Y 7/6

5Y 7/6 Yellowish (5Y 7/6) mottling of 15% $CaCO_3$

Slight trace of carbonate (<1%)

Yellowish mottling as above

Light clast (ash?)

Yellowish mottling as above

Mottling as above

Cemented mottling (50% $CaCO_3$)

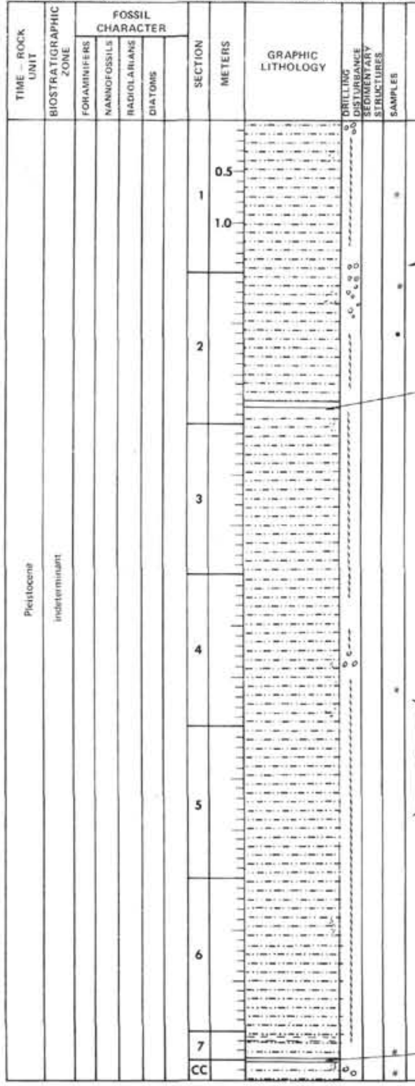
Dominant lithology: massive mud with mottling common throughout the core. Color: dark greenish gray (5G 4/1).

SMEAR SLIDE SUMMARY (%):

	1, 133
	M
Texture:	
Sand	10
Silt	12
Clay	78
Composition:	
Quartz	6
Feldspar	2
Heavy minerals	Tr
Clay	76
Volcanic glass	Tr
Glauconite	3
Fecal pellets	10

CARBONATE BOMB (% $CaCO_3$):
1, 115 cm = 0

SITE 565 HOLE CORE 9 CORED INTERVAL 77.0–86.5 m sub-bottom



Slightly calcareous mottling

Light tuffaceous mottling

Void

Slightly calcareous mottling

Mottling as above

Slightly firmer layers in this section

Mottling as above

Dark (5Y 3/1) tuffaceous layer

Void

Dark mottling as at base of Section 7

LITHOLOGIC DESCRIPTION

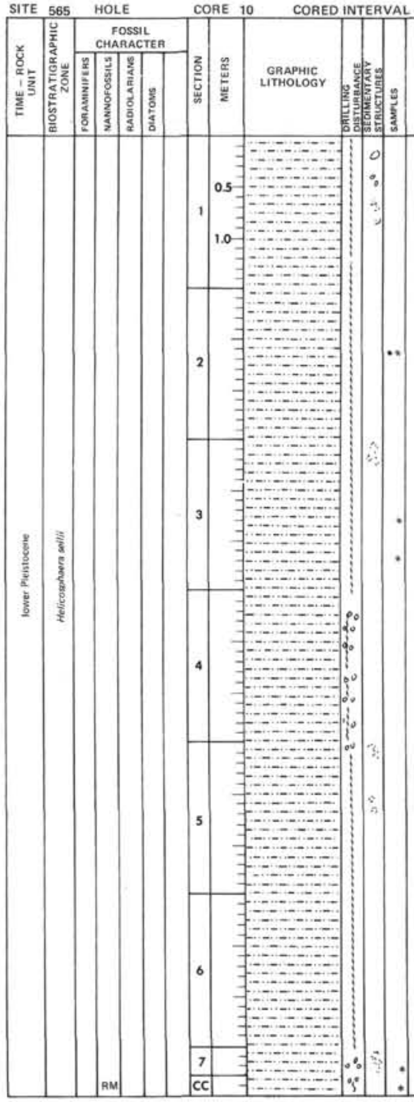
Dominant lithology: massive mud with mottling common throughout the core. Color: dark greenish gray (5GY 4/1). Dark mottling as at base of Section 7.

SMEAR SLIDE SUMMARY (%):

	1, 87	2, 13	4, 115	7, 25
	D	D	D	M
Texture:				
Sand	—	—	—	20
Silt	6	9	4	10
Clay	94	91	96	70
Composition:				
Quartz	1	1	1	5
Feldspar	2	1	1	5
Mica	Tr	2	—	—
Heavy minerals	—	1	1	5
Clay	94	91	96	15
Volcanic glass	—	3	1	70
Glauconite	2	1	1	1
Pyrite	1	Tr	Tr	1
Diatoms	Tr	—	Tr	—
Radiolarians	—	Tr	—	—
Sponge spicules	Tr	—	Tr	—

CARBONATE BOMB (% $CaCO_3$):
2, 65–67 cm = 0

SITE 565 HOLE CORE 10 CORED INTERVAL 86.5–96.0 m sub-bottom



Ashy particle

Yellowish, slightly calcareous mottling

Slightly darker mottling

Slightly calcareous mottling

White (5Y 8/1) tuffaceous mottling

LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud with common mottling throughout the core. Color: dark greenish gray (5G 4/1).

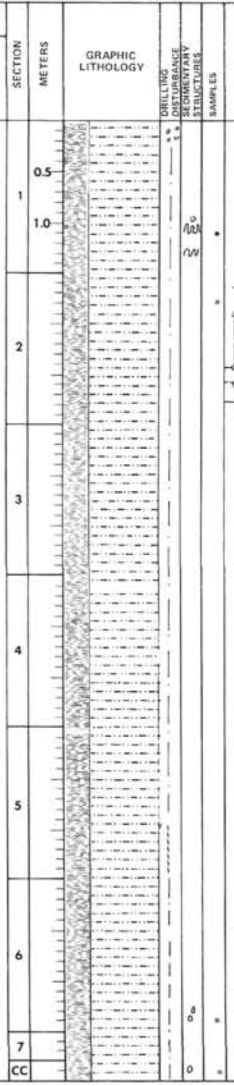
SMEAR SLIDE SUMMARY (%):

	2, 65	3, 82	3, 123	7, 28
	D	D	D	D
Texture:				
Sand	5	2	2	2
Silt	10	10	18	38
Clay	85	88	70	60
Composition:				
Quartz	3	1	1	1
Feldspar	2	1	1	2
Mica	1	Tr	Tr	—
Heavy minerals	1	Tr	Tr	1
Clay	86	93	90	96
Volcanic glass	—	2	5	2
Glauconite	3	1	—	Tr
Pyrite	—	—	—	Tr
Carbonate unspec.	5	—	—	—
Radiolarians	—	1	2	1
Sponge spicules	—	1	1	1

CARBONATE BOMB (% $CaCO_3$):
2, 65–70 cm = 0

SITE 565 HOLE CORE 11 CORED INTERVAL 96.0–105.5 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Pliocene	*Calcidiscus macintyrei*		RP		



Silty convolutions 5Y 6/2 and silt clast

Scaly fabric in in mud

Contorted bedding with some scaly fabric

Scaly fabric

Wispy convolutions of silty 5Y 6/3

Siltstone clasts 5Y 5/3

Glauconitic pebble

LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud alternating in parts of the core with a slightly siltier mud. Mottling is common throughout the core. Color: dark greenish gray (5Y 4/1). Scaliness continues to varying degrees throughout core.

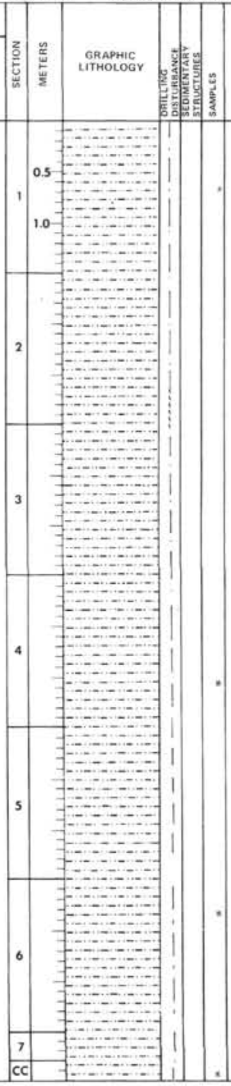
SMEAR SLIDE SUMMARY (%):

	2, 30	6, 140
	D	M
Texture:		
Sand	10	–
Silt	10	3
Clay	80	97
Composition:		
Quartz	1	–
Feldspar	10	–
Mica	1	1
Heavy minerals	2	–
Clay	84	–
Glauconite	1	–
Pyrite	1	1
Carbonate unspec.	–	87
Radiolarians	Tr	–

CARBONATE BOMB (% $CaCO_3$):
1, 112 cm = 18

SITE 565 HOLE CORE 12 CORED INTERVAL 105.5–115.0 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
Pleistocene	*Calcidiscus macintyrei*				
upper Pliocene	*Discoaster brouweri*		RP		



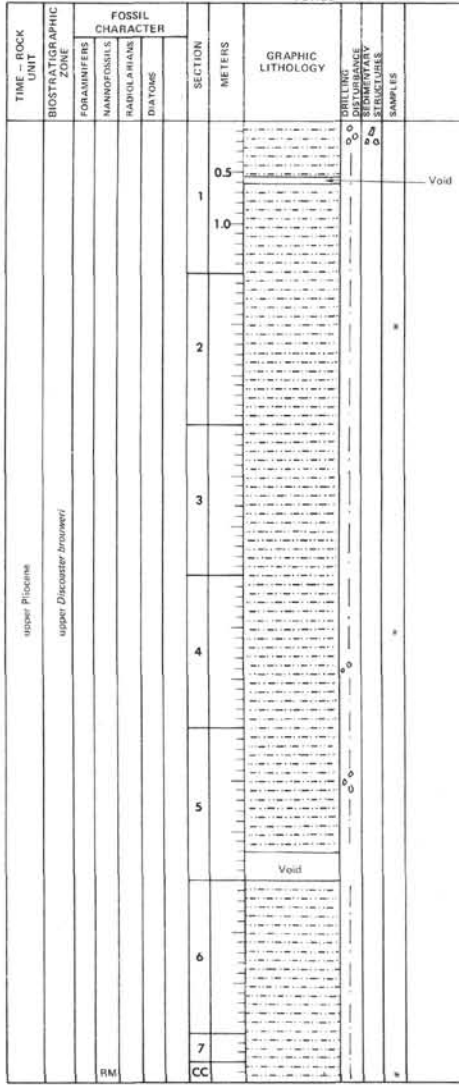
LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud alternating through much of the core with varying degrees of scaly fabric. Mottling is a common feature. Color: dark greenish gray (5GY 5/1 to 5GY 4/1). Dendritic mottling of slightly darker shade (5GY 4/1) is common throughout core.

SMEAR SLIDE SUMMARY (%):

	1, 66	4, 110	6, 38
	D	D	D
Texture:			
Sand	10	5	5
Silt	–	–	15
Clay	90	95	80
Composition:			
Quartz	–	Tr	2
Feldspar	–	1	1
Mica	Tr	Tr	–
Heavy minerals	Tr	–	–
Clay	98	95	78
Volcanic glass	–	1	5
Glauconite	1	1	2
Pyrite	–	1	–
Carbonate unspec.	–	–	10
Radiolarians	Tr	Tr	–
Sponge spicules	Tr	Tr	–

SITE 565 HOLE CORE 13 CORED INTERVAL 115.0–124.5 m sub-bottom



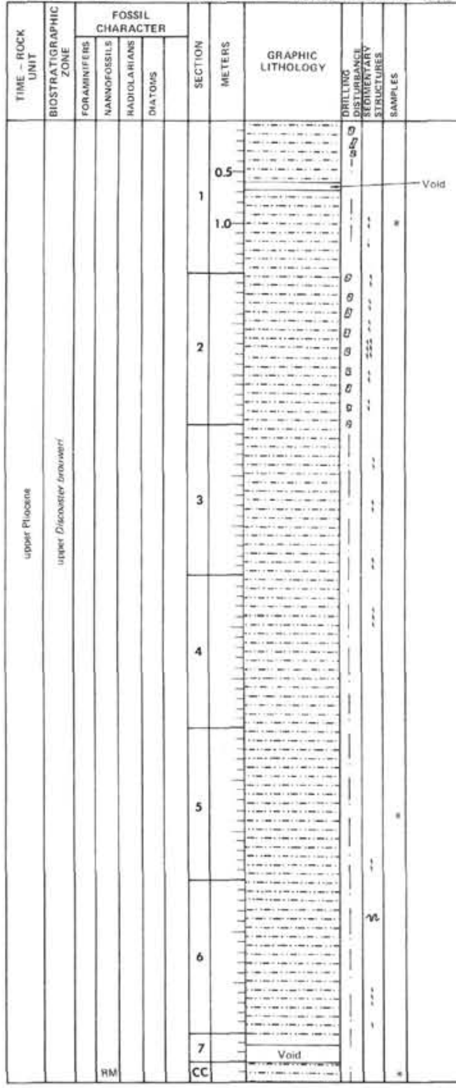
LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud containing angular-subangular clasts of silt alternating with scaly mud. Mostly structureless although some wispy remains of bedding can be discerned through the drilling disturbance. Alternations are on the order of a few tens of cm. Mud is slightly calcareous in some horizons although carbonate is still under 10%. Color: mostly 5GY 4/1.

SMEAR SLIDE SUMMARY (%):

	2, 53	4, 60
	D	D
Texture:		
Sand	10	15
Silt	8	25
Clay	82	60
Composition:		
Quartz	1	4
Feldspar	1	3
Mica	–	Tr
Heavy minerals	–	1
Clay	80	58
Volcanic glass	2	4
Glauconite	1	6
Carbonate unspec.	–	10
Foraminifers	1	–
Diatoms	1	–
Radiolarians	1	–
Sponge spicules	1	–
Fecal pellets	8	–

SITE 565 HOLE CORE 14 CORED INTERVAL 125.5–134.0 m sub-bottom



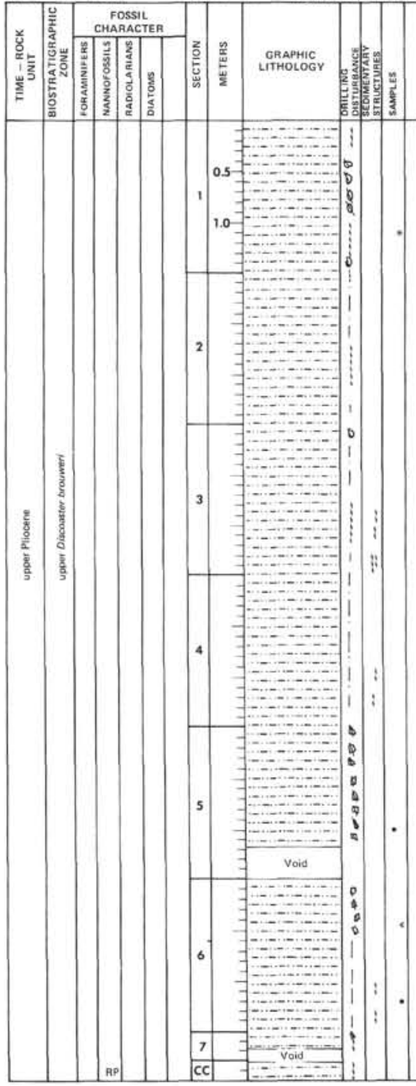
LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud alternating with thinly bedded and possibly graded silty mud. Burrowing and mottling are common throughout the core, usually slightly yellower in color and more cemented (containing a few to several tens of percent carbonate). Color: mostly dark greenish gray (5GY 4/1).

SMEAR SLIDE SUMMARY (%):

	1, 100	5, 83
	D	D
Texture:		
Sand	8	16
Silt	20	15
Clay	72	75
Composition:		
Quartz	8	3
Feldspar	7	12
Mica	Tr	Tr
Heavy minerals	4	2
Clay	70	72
Volcanic glass	3	2
Palagonite	5	–
Glauconite	–	6
Zeolite	–	Tr
Sponge spicules	1	–

SITE 565 HOLE CORE 15 CORED INTERVAL 134.0–143.5 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud with some scaly layers and mottling and bioturbation throughout the core. Many burrows are better cemented and contain several percent carbonate. Color: mostly dark olive gray (5Y 3/2).

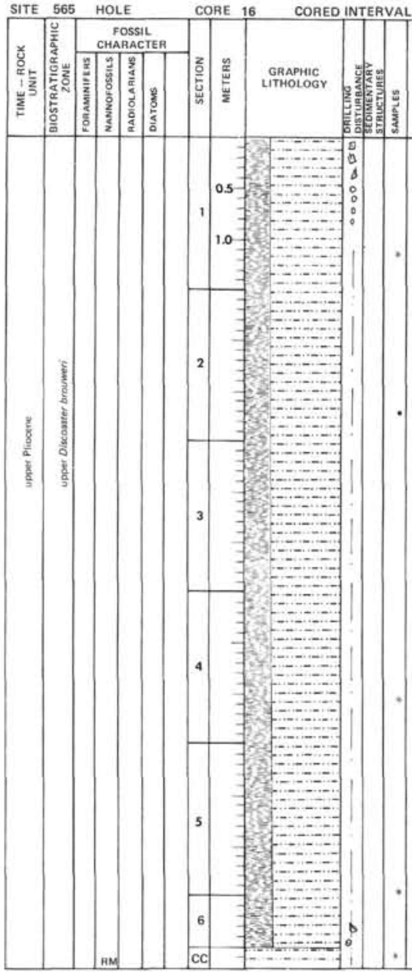
SMEAR SLIDE SUMMARY (%):

	1, 114	6, 46
	D	D
Texture:		
Sand	10	12
Silt	10	20
Clay	80	68
Composition:		
Quartz	3	4
Feldspar	2	4
Mica	5	1
Heavy minerals	3	–
Clay	78	65
Volcanic glass	1	2
Glauconite	4	4
Zeolite	Tr	–
Sponge spicules	1	2
Fish remains	–	2
Plant debris	1	2

CARBONATE BOMB (% $CaCO_3$):
6, 122 cm = 5

20% carbonate in burrow

SITE 565 HOLE CORE 16 CORED INTERVAL 143.5–153.0 m sub-bottom



LITHOLOGIC DESCRIPTION

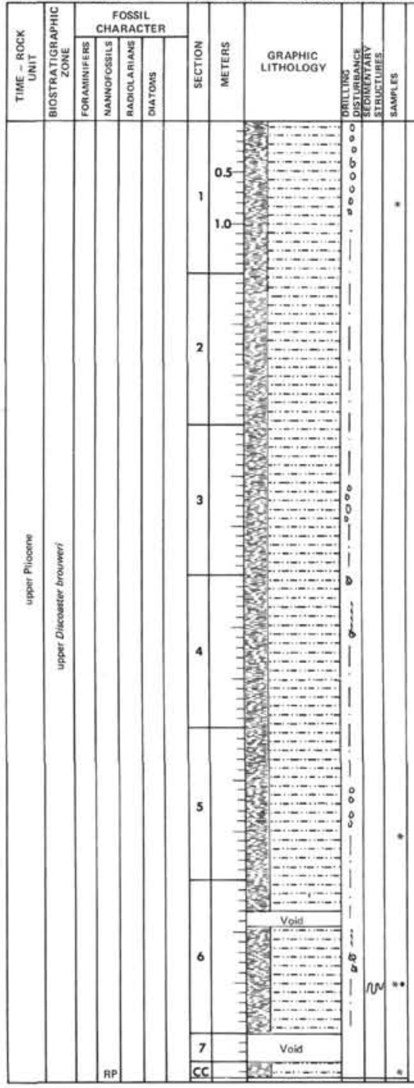
Dominant lithology: mostly massive mud to silt, with remnant wisps of bedding and mottling and burrowing common throughout the core. Several scaly layers a few tens of cm thick occur especially toward the bottom of the core. Color: mostly greenish gray (5GY 6/1).

SMEAR SLIDE SUMMARY (%):

	1, 119	4, 105	5, 144
	D	D	D
Texture:			
Sand	7	5	21
Silt	7	15	21
Clay	86	80	92
Composition:			
Quartz	3	8	2
Feldspar	2	5	2
Mica	Tr	2	–
Heavy minerals	1	–	–
Clay	82	75	90
Volcanic glass	1	Tr	–
Glauconite	1	1	4
Zeolite	–	Tr	Tr
Foraminifers	–	1	–
Calc. nannofossils	–	1	–
Sponge spicules	–	1	1
Fish remains	1	–	–
Plant debris	–	2	Tr
Fecal pellets	3	–	–

CARBONATE BOMB (% $CaCO_3$):
2, 128 cm = 15

SITE 565 HOLE CORE 17 CORED INTERVAL 153.0–162.5 m sub-bottom



LITHOLOGIC DESCRIPTION

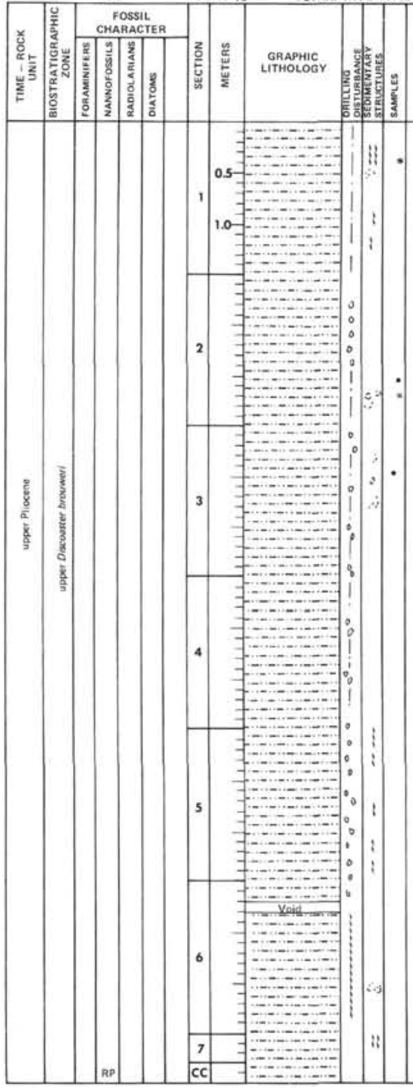
Dominant lithology: massive mud with wisps of silty horizons and bioturbation mottling and burrows common throughout the core. Burrows are slightly more calcareous and lighter in color. Silty clasts occur throughout the core. Color: mostly greenish gray (5GY 5/1).

SMEAR SLIDE SUMMARY (%):

	1, 84	5, 106	6, 105
Texture:			
Sand	6	10	4
Silt	14	15	5
Clay	80	75	91
Composition			
Quartz	4	5	1
Feldspar	3	4	1
Mica	1	–	Tr
Heavy minerals	2	7	3
Clay	75	70	70
Volcanic glass	Tr	2	1
Glauconite	5	1	1
Zeolite	Tr	Tr	–
Calc. nannofossils	–	–	20
Diatoms	Tr	1	–
Radiolarians	Tr	–	–
Sponge spicules	2	1	1
Fish remains	–	1	–
Plant debris	1	1	–

CARBONATE BOMB (% $CaCO_3$):
6, 106 cm = 20

SITE 565 HOLE CORE 18 CORED INTERVAL 162.5–172.0 m sub-bottom



LITHOLOGIC DESCRIPTION

Carbonate bomb
(7% $CaCO_3$)

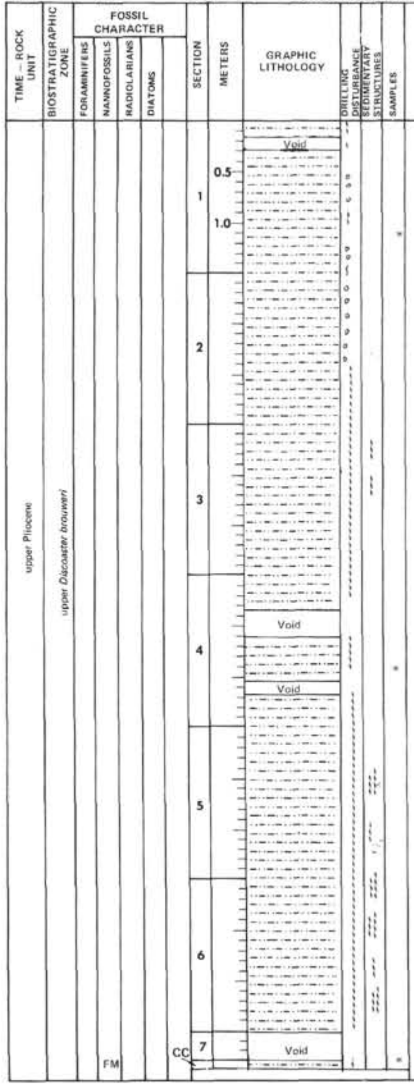
Dominant lithology: Mud, mostly structureless with burrow mottling and soft glauconitic(?) clasts. Bioturbation common, leaving slightly more calcareous mottles of yellowish color. Color: greenish gray (5GY 5/1). Mottling is mostly 2.5Y 7/6 with some bluish green (5GY 5/1).

SMEAR SLIDE SUMMARY (%):

	1, 40 D	2, 121 M
Texture:		
Sand	7	10
Silt	12	5
Clay	81	85
Composition:		
Quartz	3	1
Feldspar	2	1
Mica	–	1
Heavy minerals	1	2
Clay	75	40
Volcanic glass	1	1
Glauconite	5	1
Calc. nannofossils	–	40
Diatoms	1	1
Radiolarians	1	1
Sponge spicules	5	–
Silicoflagellates	1	–
Fish remains	–	1
Fecal pellet	–	5

CARBONATE BOMB (% $CaCO_3$):
2, 108 cm = 7

SITE 565 HOLE CORE 19 CORED INTERVAL 172.0–181.5 m sub-bottom



LITHOLOGIC DESCRIPTION

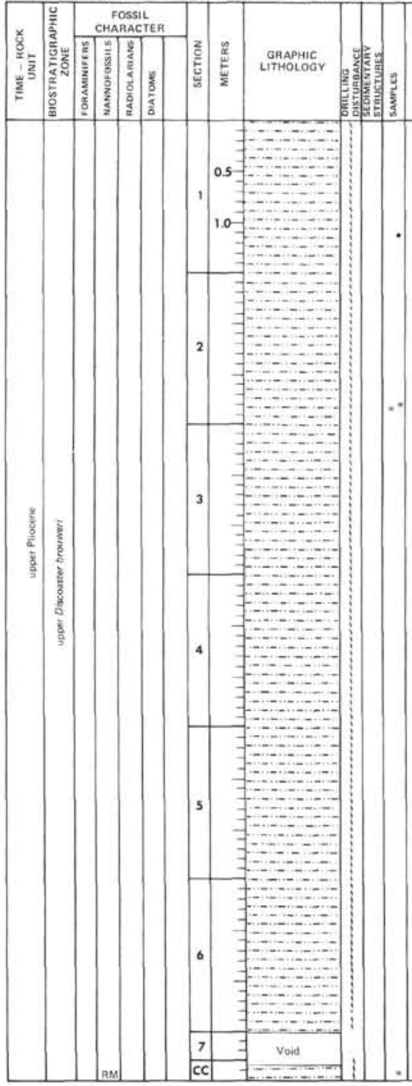
Dominant lithology: massive mud with bioturbation mottling of slightly more calcareous composition. Color: 5G 4/1 to 5BG 4/1, mottling slightly more yellow (2.5Y 7/6).

SMEAR SLIDE SUMMARY (%):

	1, 114	4, 95
	D	D
Texture:		
Sand	5	40
Silt	10	10
Clay	85	50
Composition:		
Quartz	1	1
Feldspar	1	1
Mica	1	–
Clay	90	45
Glauconite	2	–
Pyrite	1	1
Carbonate unspec.[a]	5	50
Radiolarians	–	1
Sponge spicules	–	1

[a] Fecal pellets

SITE 565 HOLE CORE 20 CORED INTERVAL 181.5–191.0 m sub-bottom



LITHOLOGIC DESCRIPTION

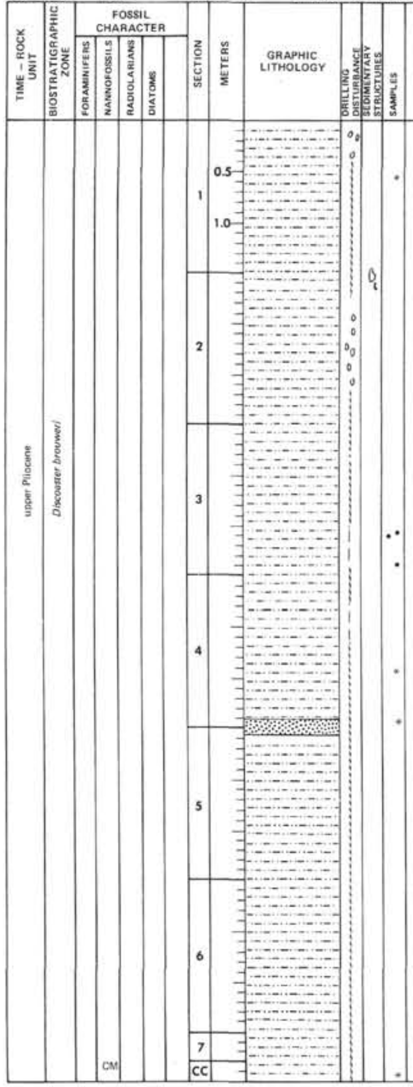
Dominant lithology: mud with mottling and bioturbated layers throughout the core. Burrows and mottling are slightly higher in calcareous content. Color: mostly 5G 4/1 with lighter mottling 5G 5/1.

SMEAR SLIDE SUMMARY (%):

	2, 136	2, 137
Texture:		
Sand	3	1
Silt	11	4
Clay	86	95
Composition:		
Quartz	5	1
Feldspar	3	–
Mica	–	1
Heavy minerals	3	2
Clay	80	92
Volcanic glass	1	Tr
Glauconite	1	1
Pyrite	Tr	2
Zeolite	Tr	–
Foraminifers	1	–
Radiolarians	–	Tr
Sponge spicules	1	Tr
Fish remains	Tr	–
Calc. fecal pellets	–	2

CARBONATE BOMB (% $CaCO_3$):
1, 114 cm = 20

SITE 565 HOLE CORE 21 CORED INTERVAL 191.0–200.5 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mud and mudstone with abundant mottling and burrowing of slightly higher carbonate content and shaley clasts throughout the core. Color: mostly dark greenish gray (5G 4/1) with mottling yellow (5Y 7/6).

SMEAR SLIDE SUMMARY (%):

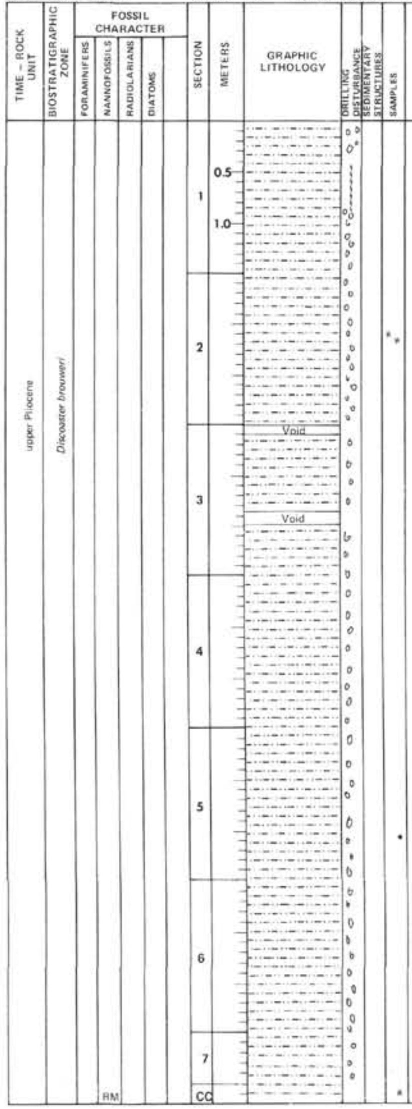
	1, 57 M	4, 93 M	4, 146 M
Texture:			
Sand	10	30	70
Silt	20	30	10
Clay	70	40	20
Composition:			
Quartz	1	1	20
Feldspar	1	–	30
Mica	1	–	–
Heavy minerals	–	–	15
Clay	70	10	20
Volcanic glass	–	–	Tr
Palagonite	–	–	Tr
Glauconite	1	–	Tr
Pyrite	Tr	–	15?
Zeolite	–	–	Tr
Foraminifers	Tr	–	–
Diatoms	Tr	–	–
Sponge spicules	Tr	–	–
Calc. fecal pellets	25	89	–

Carbonate bomb on burrow (10% $CaCO_3$)
Carbonate bomb on shaley clast (0% $CaCO_3$)

CARBONATE BOMB (% $CaCO_3$):
3, 110 cm = 0

10R 4/1

SITE 565 HOLE CORE 22 CORED INTERVAL 200.5–210.0 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mudstone and mud. Burrowing of slightly higher carbonate content and shaley clasts are common throughout the core, particularly in the middle sections. Color: mostly dark greenish gray (5G 4/1) with slightly yellower (5Y 7/6) mottling.

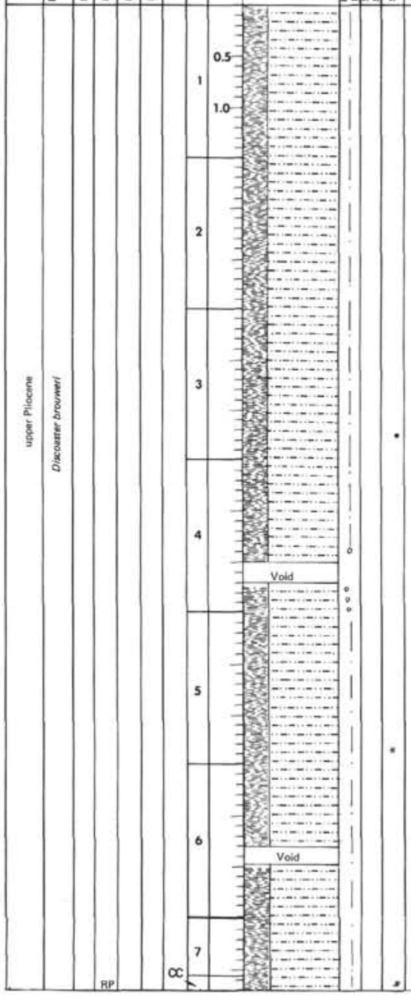
SMEAR SLIDE SUMMARY (%):

	2, 62 D	2, 68 M
Texture:		
Sand	5	20
Silt	10	10
Clay	85	70
Composition:		
Quartz	1	1
Feldspar	–	1
Mica	1	1
Heavy minerals	1	Tr
Clay	70	65
Glauconite	1	2
Pyrite	1	–
Fecal pellets	15	30

CARBONATE BOMB (% $CaCO_3$):
5, 109 cm = 0

SITE 565 HOLE CORE 23 CORED INTERVAL 210.0–219.5 m sub-bottom

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



Carbonate bomb of mottle (15% $CaCO_3$)

5Y 5/3 mottling
with some carbonate

Dominant lithology: mostly structureless mud with some burrows and mottling throughout core. Highly fractured by drilling. Color: mostly dark greenish gray (5GY 4/1).

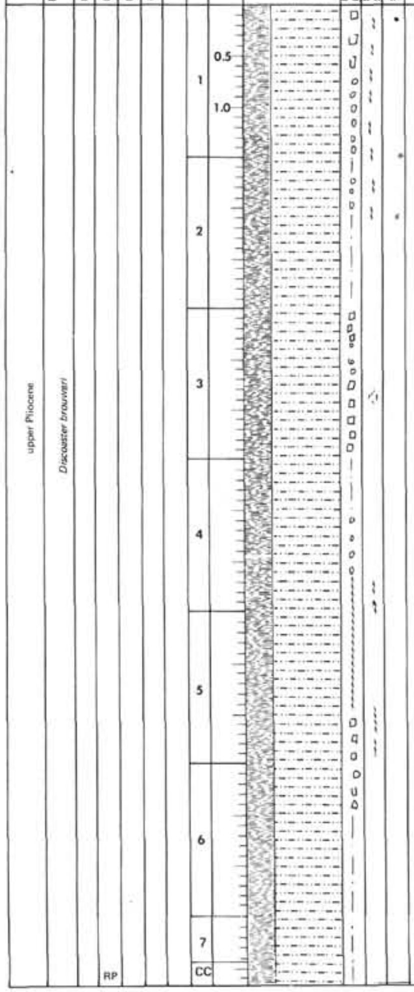
SMEAR SLIDE SUMMARY (%):

	5, 140
	D
Texture:	
Sand	15
Silt	80
Clay	5
Composition:	
Quartz	Tr
Feldspar	1
Mica	Tr
Clay	97
Glauconite	Tr
Pyrite	2
Sponge spicules	Tr

CARBONATE BOMB (% $CaCO_3$):
3, 130 cm = 13 (bomb analysis of mottle)

SITE 565 HOLE CORE 24 CORED INTERVAL 219.5–229.0 m sub-bottom

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



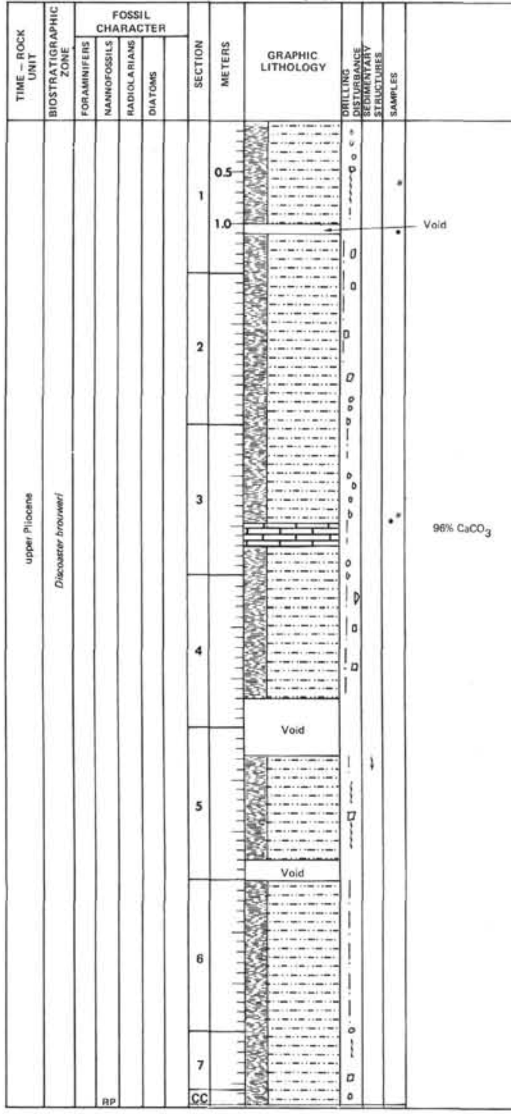
Dominant lithology: Mostly massive, structureless mud with some annealed fractures of a few cm length and small, slightly calcareous burrows that are usually concentrated in rather discrete layers. Color: mostly dark greenish gray (5GY 4/1) with lighter mottling usually 5Y 6/4 to 5Y 5/3.

SMEAR SLIDE SUMMARY (%):

	1, 150	2, 67
	M	M
Texture:		
Sand	5	40
Silt	90	60
Clay	5	–
Composition:		
Quartz	Tr	–
Feldspar	2	15
Heavy minerals	1	10
Clay	97	–
Volcanic glass	–	15
Glauconite	Tr	Tr
Pyrite	Tr	Tr
Radiolarians	Tr	–
Sponge spicules	Tr	–

CARBONATE BOMB (% $CaCO_3$):
1, 12 cm = 0

SITE 565 HOLE CORE 25 CORED INTERVAL 229.0–238.5 m sub-bottom



LITHOLOGIC DESCRIPTION

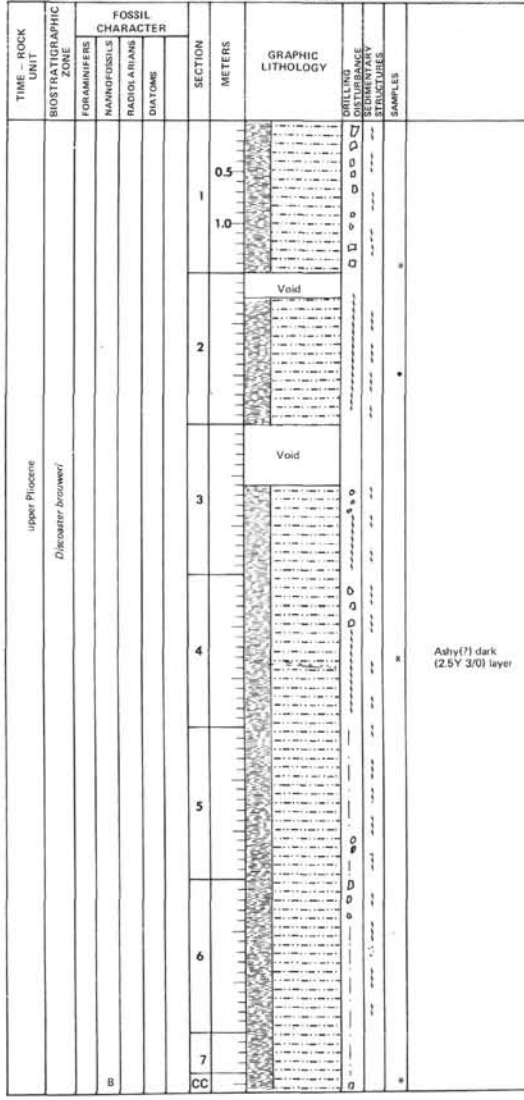
Dominant lithology: massive mud with small calcareous burrows in parts of the core. Color: dark greenish gray (5GY 4/1) with lighter (2.5Y 5/2) mottling. Section 3, 95–120 cm: 5GY 4.5/1 limestone layer rich in burrows and dark (tuffaceous?) grains.

SMEAR SLIDE SUMMARY (%):

	1, 64 M	3, 91 M
Texture:		
Sand	5	1
Silt	75	99
Clay	20	–
Composition:		
Feldspar	1	1
Heavy minerals	–	Tr
Clay	90?	49
Volcanic glass	1	Tr
Glauconite	2	–
Micronodules	Tr	–
Carbonate unspec.	–	50
Calc. nannofossils	1	1
Radiolarians	Tr	1
Sponge spicules	1	–
Silicoflagellates	Tr	–

CARBONATE BOMB (% $CaCO_3$):
1, 107 cm = 0

SITE 565 HOLE CORE 26 CORED INTERVAL 238.5–248.0 m sub-bottom



LITHOLOGIC DESCRIPTION

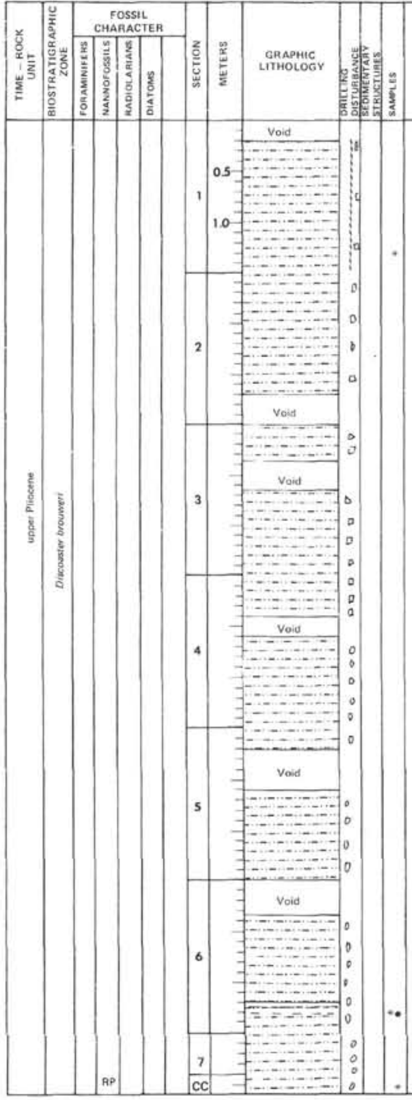
Dominant lithology: structureless mudstone with small, slightly calcareous burrows throughout the core. Color: dark greenish gray to dark grayish green (5GY 4/1 to 5GY 4.5/1), with mottling and burrows usually slightly more yellow (2.5Y 5/2 to 2.5Y 6/4).

SMEAR SLIDE SUMMARY (%):

	1, 144 D	4, 85 M
Texture:		
Sand	–	3
Silt	12	10
Clay	88	87
Composition:		
Quartz	–	2
Feldspar	2	1
Heavy minerals	Tr	6
Clay	94	85
Volcanic glass	–	Tr
Glauconite	2	1
Pyrite	Tr	Tr
Calc. nannofossils	1	–
Radiolarians	1	–
Sponge spicules	1	–
Fecal pellets	–	2

CARBONATE BOMB (% $CaCO_3$):
2, 100 cm = 5

SITE 565 HOLE CORE 27 CORED INTERVAL 248.0–257.7 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: massive mud to mudstone with small, slightly calcareous burrows throughout the core. Some small soft clasts of slightly darker mud occur in some sections, particularly Section 1, in thin layers that alternate with the usual structureless mud. Color: mostly dark greenish gray (5G 4/1 with some 5GY 4/1). Mottles are slightly lighter and yellow (2.5Y 6/4).

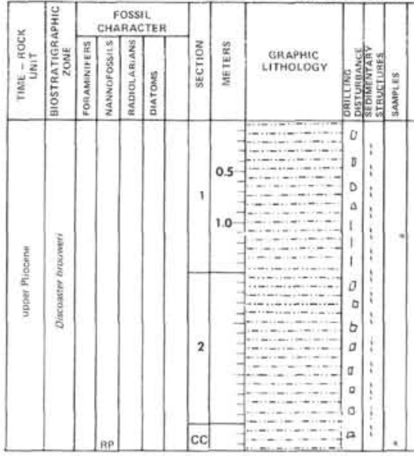
SMEAR SLIDE SUMMARY (%):

	1, 132	6, 131
	D	M
Taxture:		
Sand	5	2
Silt	20	8
Clay	75	90
Composition:		
Quartz	5	3
Feldspar	–	Tr
Mica	3	2
Heavy minerals	3	–
Clay	75	–
Volcanic glass	3	–
Glauconite	5	3
Pyrite	2	–
Carbonate unspec.	–	80
Foraminifers	2	–
Sponge spicules	1	1
Silicoflagellates	1	1

CARBONATE BOMB (% $CaCO_3$):
6, 135 cm = 12 (bomb analysis on dark layer)

Slightly darker (5BG 5/1) layer

SITE 565 HOLE CORE 28 CORED INTERVAL 257.7–267.0 m sub-bottom



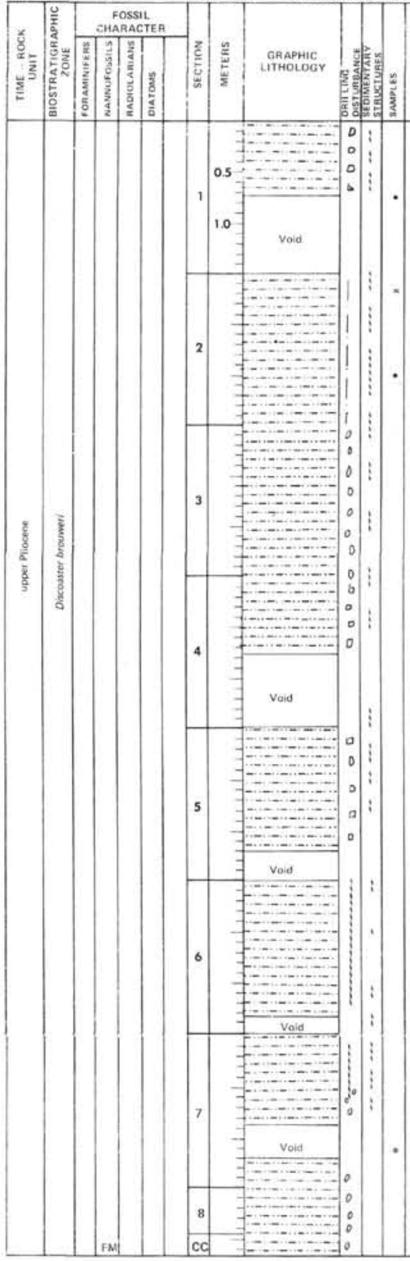
LITHOLOGIC DESCRIPTION

Dominant lithology: massive mudstone with slightly calcareous burrows throughout the core. Color: dark greenish gray (5GY 4/1) with yellowish (2.5Y 7/6) burrows.

SMEAR SLIDE SUMMARY (%):

	1, 115
Texture:	
Sand	2
Silt	12
Clay	86
Composition:	
Quartz	5
Feldspar	4
Heavy minerals	2
Clay	80
Volcanic glass	1
Glauconite	1
Pyrite	1
Carbonate unspec.	1

SITE 565 HOLE CORE 29 CORED INTERVAL 267.0–276.5 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mudstone, structureless except for small, slightly calcareous burrows which occur throughout the core. Color: dark greenish gray (5GY 4/1.5) with burrows (2.5Y 7/6).

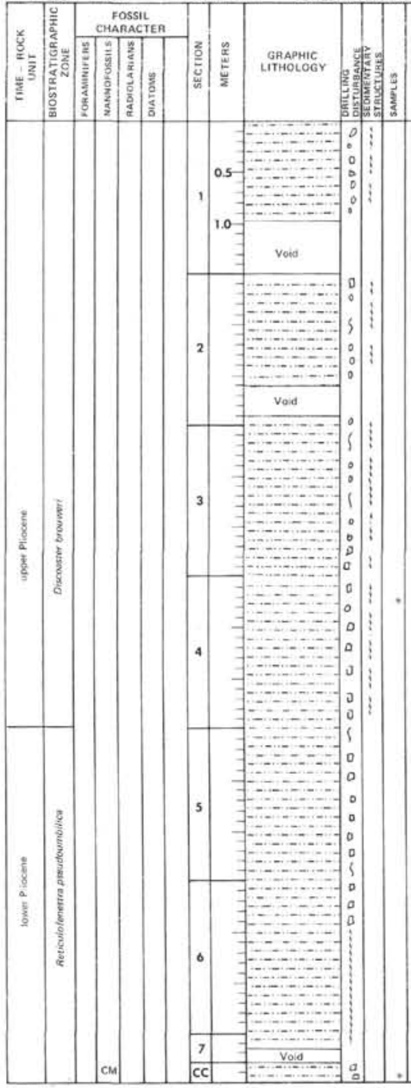
Note: This extra long core (8 sections plus Core Catcher) resulted when the top of the core spilled "biscuits" of mudstone onto the deck – the core liner appeared to be already full. Rather than compact the entire core together, the spillage from the top was collected and designated "Section 1".

SMEAR SLIDE SUMMARY (%):

	2, 29	7, 115
	M	D
Texture:		
Sand	5	15
Silt	10	15
Clay	85	70
Composition:		
Quartz	5	1
Feldspar	4	1
Mica	1	–
Heavy minerals	–	1
Clay	80	70
Volcanic glass	1	–
Glauconite	1	2
Pyrite	1	–
Zeolite	3	–
Calc. nannofossils	1	–
Fish remans	1	–
Fecal pellets	–	15

CARBONATE BOMB (% $CaCO_3$):
1, 80 cm = 1

SITE 565 HOLE CORE 30 CORED INTERVAL 276.5–286. 0 m sub-bottom



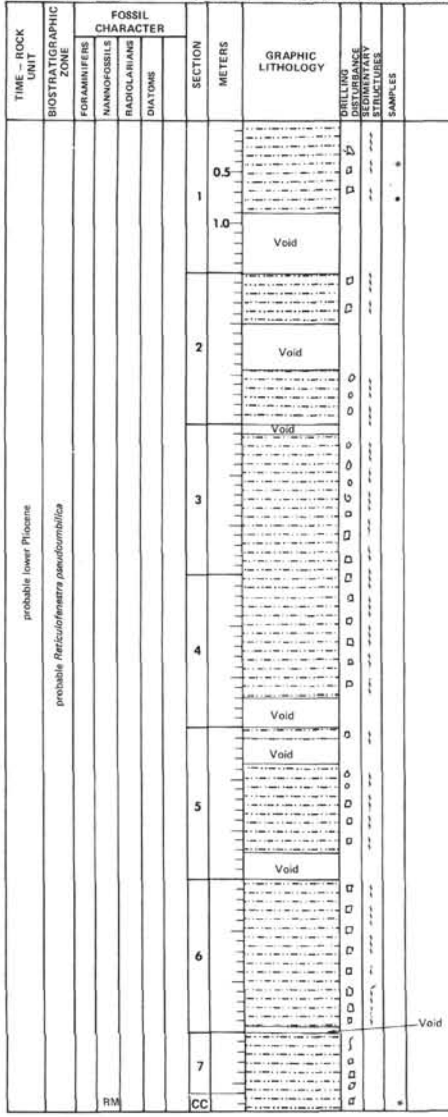
LITHOLOGIC DESCRIPTION

Dominant lithology: massive mudstone with burrowing of slightly calcareous composition throughout the core. Color: dark greenish gray (5GY 4/1.5).

SMEAR SLIDE SUMMARY (%):

	4, 26
Texture:	
Sand	10
Silt	12
Clay	78
Composition:	
Quartz	7
Feldspar	5
Heavy minerals	2
Clay	75
Glauconite	2
Pyrite	1
Zeolite	1
Carbonate unspec.	1
Sponge spicules	1
Fish remains	1

SITE 565 HOLE CORE 31 CORED INTERVAL 286.0–295.5 m sub-bottom



LITHOLOGIC DESCRIPTION

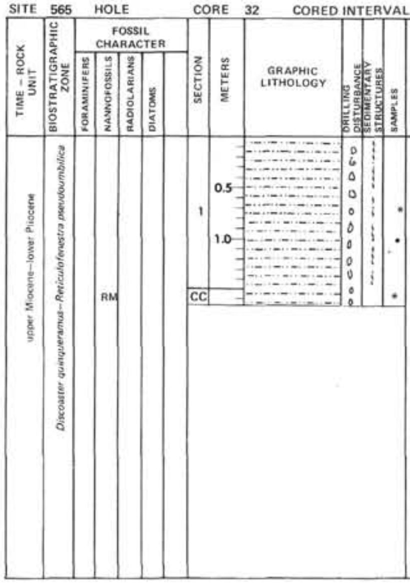
Dominant lithology: massive mudstone with slightly calcareous burrows throughout the core. Color: dark greenish gray (5GY 4/1.5).

SMEAR SLIDE SUMMARY (%):

	1, 45
	D
Texture:	
Sand	5
Silt	10
Clay	85
Composition:	
Quartz	6
Feldspar	3
Mica	1
Clay	80
Glauconite	1
Carbonate unspec.	1
Foraminifers	1
Sponge spicules	1

CARBONATE BOMB (% $CaCO_3$):
1, 80 cm = 1

SITE 565 HOLE CORE 32 CORED INTERVAL 299.5–309.1 m sub-bottom



LITHOLOGIC DESCRIPTION

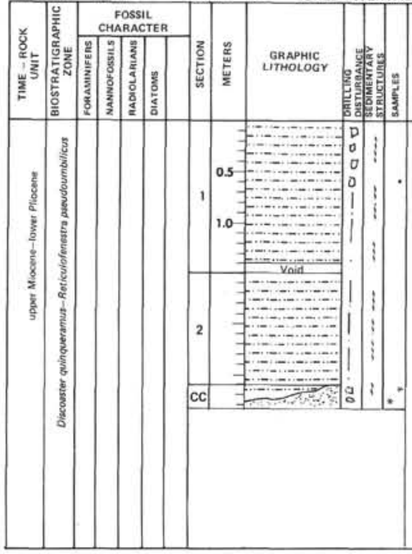
Dominant lithology: mudstone, generally structureless except for small burrows of slightly calcareous composition. Color: dark greenish gray (5GY 4/1.5), with grayish brown (2.5Y 5/2) mottling.

SMEAR SLIDE SUMMARY (%):

	1, 72
	D
Texture:	
Sand	10
Silt	15
Clay	75
Composition:	
Quartz	3
Feldspar	1
Mica	1
Heavy minerals	Tr
Clay	75
Glauconite	Tr
Pyritw	2
Micronodules	Tr
Carbonate unspec.	Tr
Calc. nannofossils	1
Radiolarians	1

CARBONATE BOMB (% $CaCO_3$):
1, 105 cm = 0

SITE 565 HOLE CORE 33 CORED INTERVAL 309.1–318.7 m sub-bottom



LITHOLOGIC DESCRIPTION

Black (5Y 2.5/1) sandy (ashy?) layer

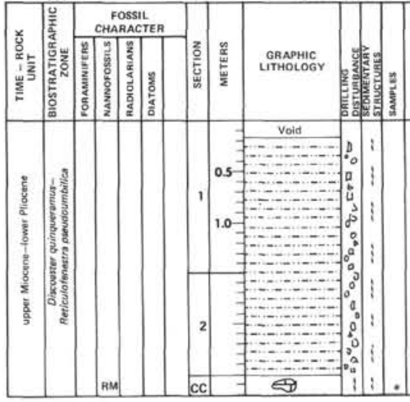
Dominant lithology: massive mudstone with burrowing common throughout the core. Color: dark greenish gray (5GY 4/5) mud with yellowish (5Y 5/3) burrows.

SMEAR SLIDE SUMMARY (%):

	CC, 3 M
Texture:	
Sand	55
Silt	30
Clay	15
Composition:	
Quartz	3
Feldspar	2
Clay	15
Volcanic glass	5
Calc. nannofossils	1
Diatoms	1
Sponge spicules	2
Rock fragments probably shards	70

CARBONATE BOMB (% $CaCO_3$):
1, 80 cm = 0

SITE 565 HOLE CORE 34 CORED INTERVAL 318.7–328.3 m sub-bottom

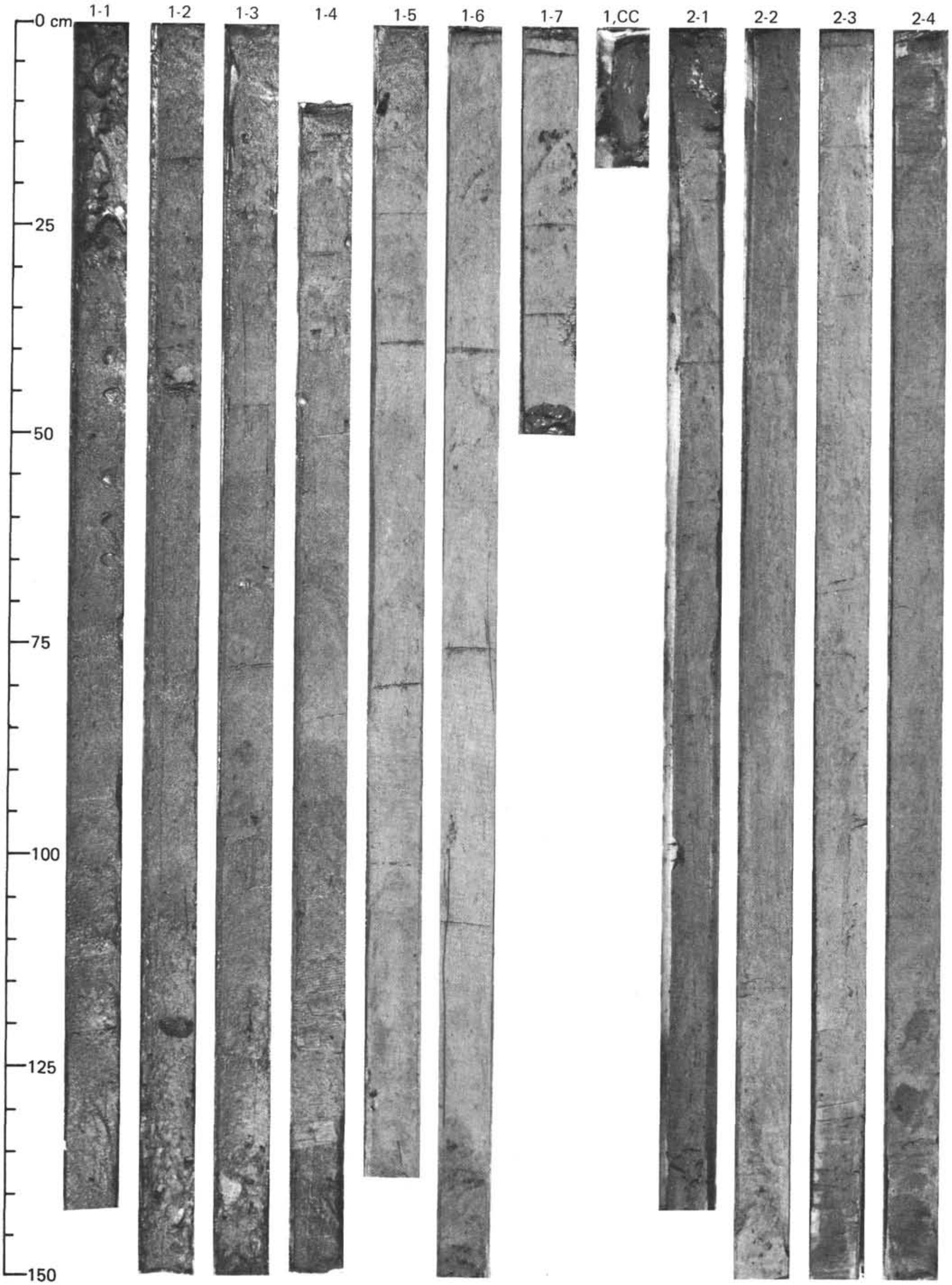


LITHOLOGIC DESCRIPTION

Dominant lithology: massive mudstone with burrows of slightly calcareous composition throughout the core.

Minor lithology: the Core Catcher contained a single fragment of fine-grained limestone with dark, angular sand-sized clasts and some burrows.

Color: dark greenish gray (5GY 4/1). Limestone is 5Y 5/2.


0 cm
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125
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1-1
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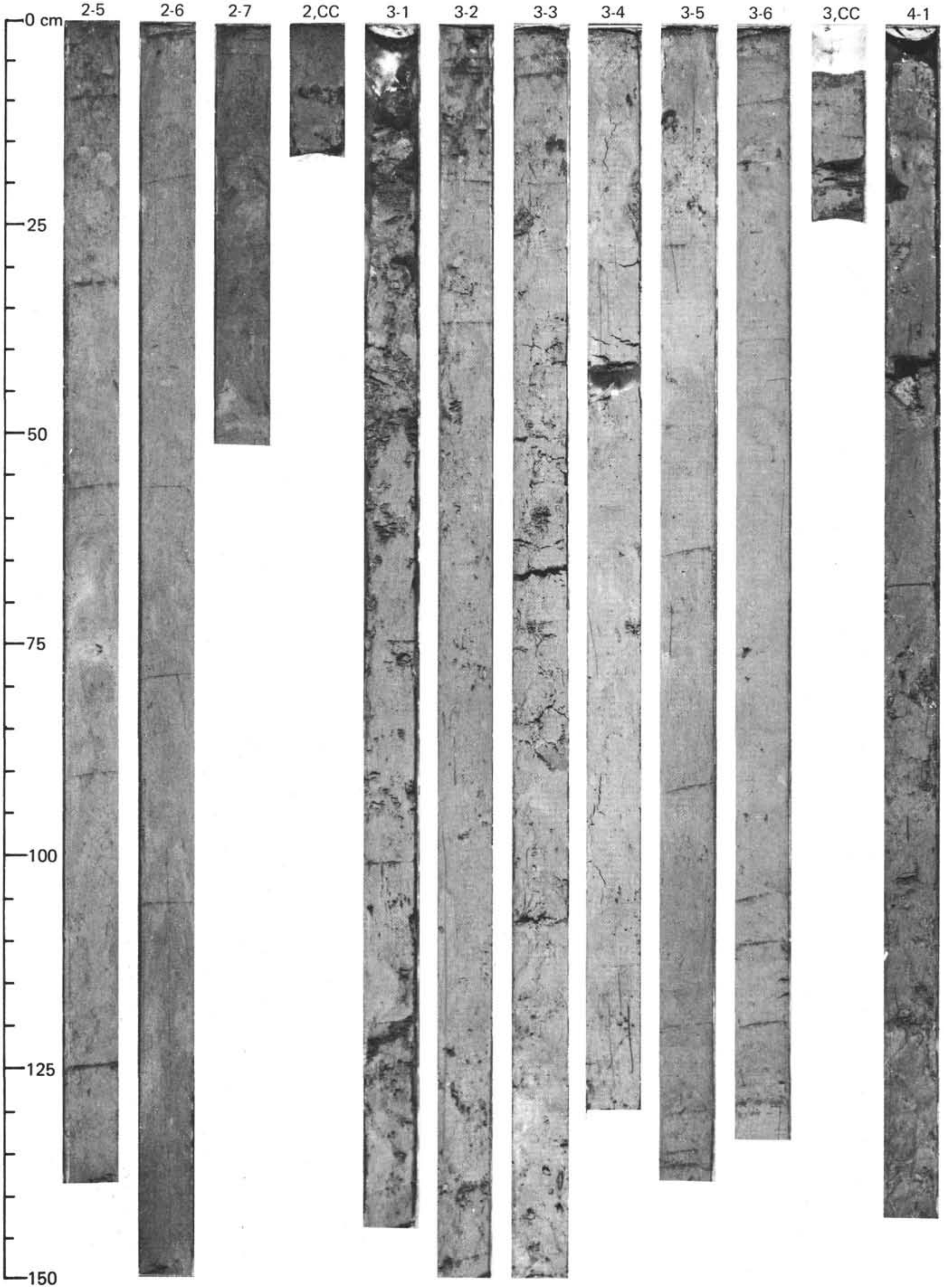
1-3
1-4
1-5
1-6
1-7
1,CC
2-1
2-2
2-3
2-4


0 cm
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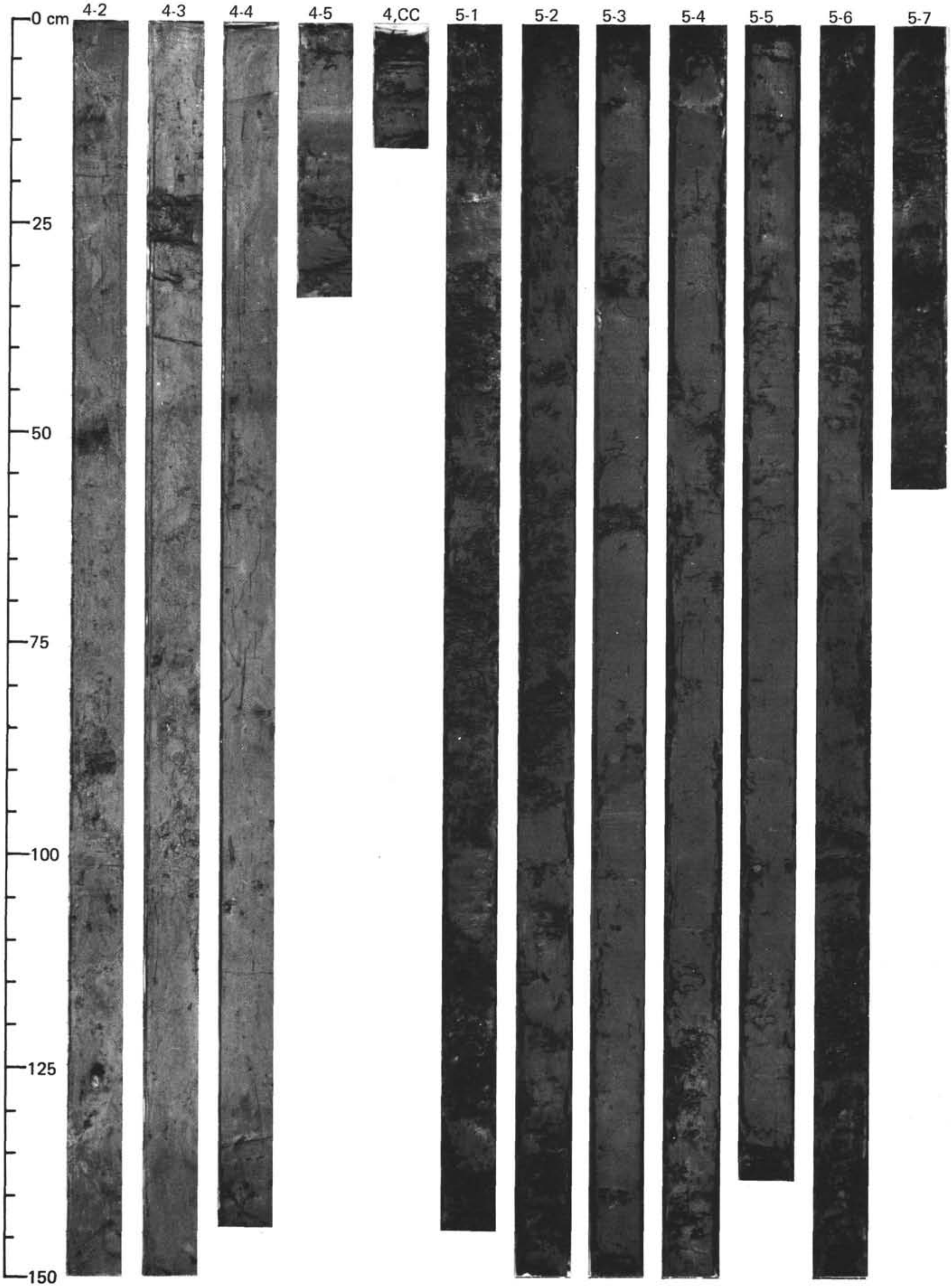
2-7
2,CC
3-1
3-2
3-3
3-4
3-5
3-6
3,CC
4-1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4-5
4,CC
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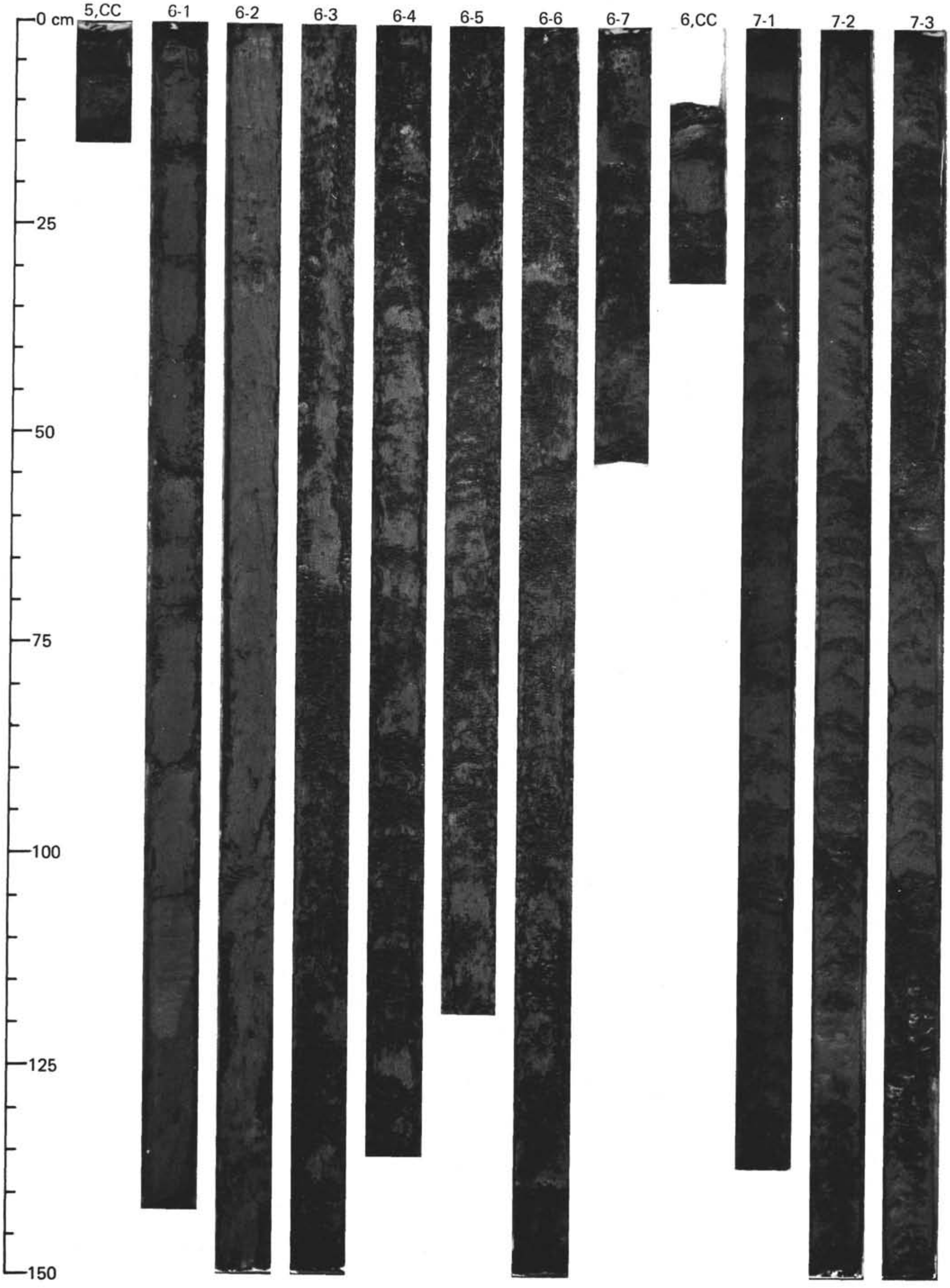
5-6
5-7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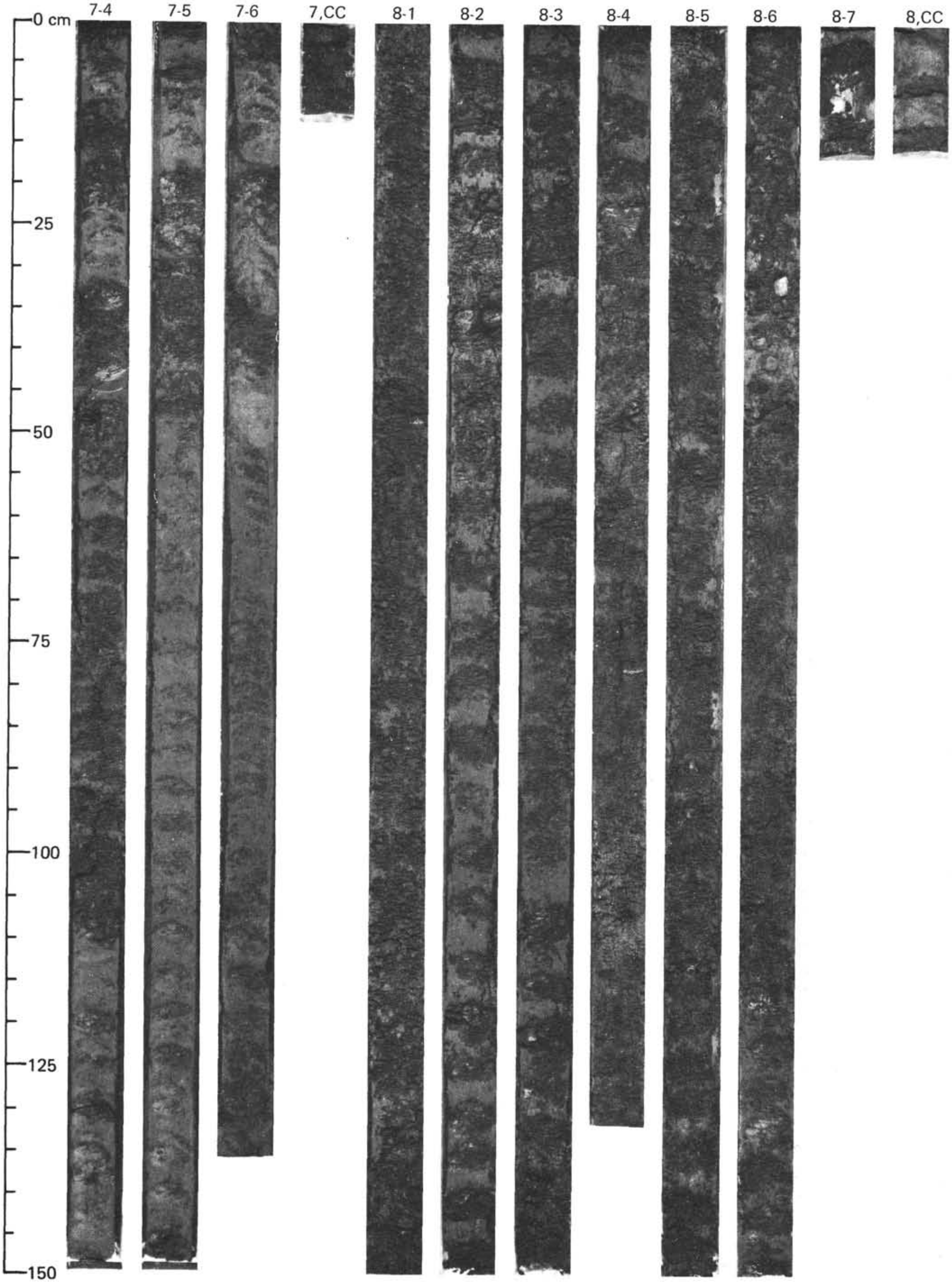
6,CC
7-1
7-2
7-3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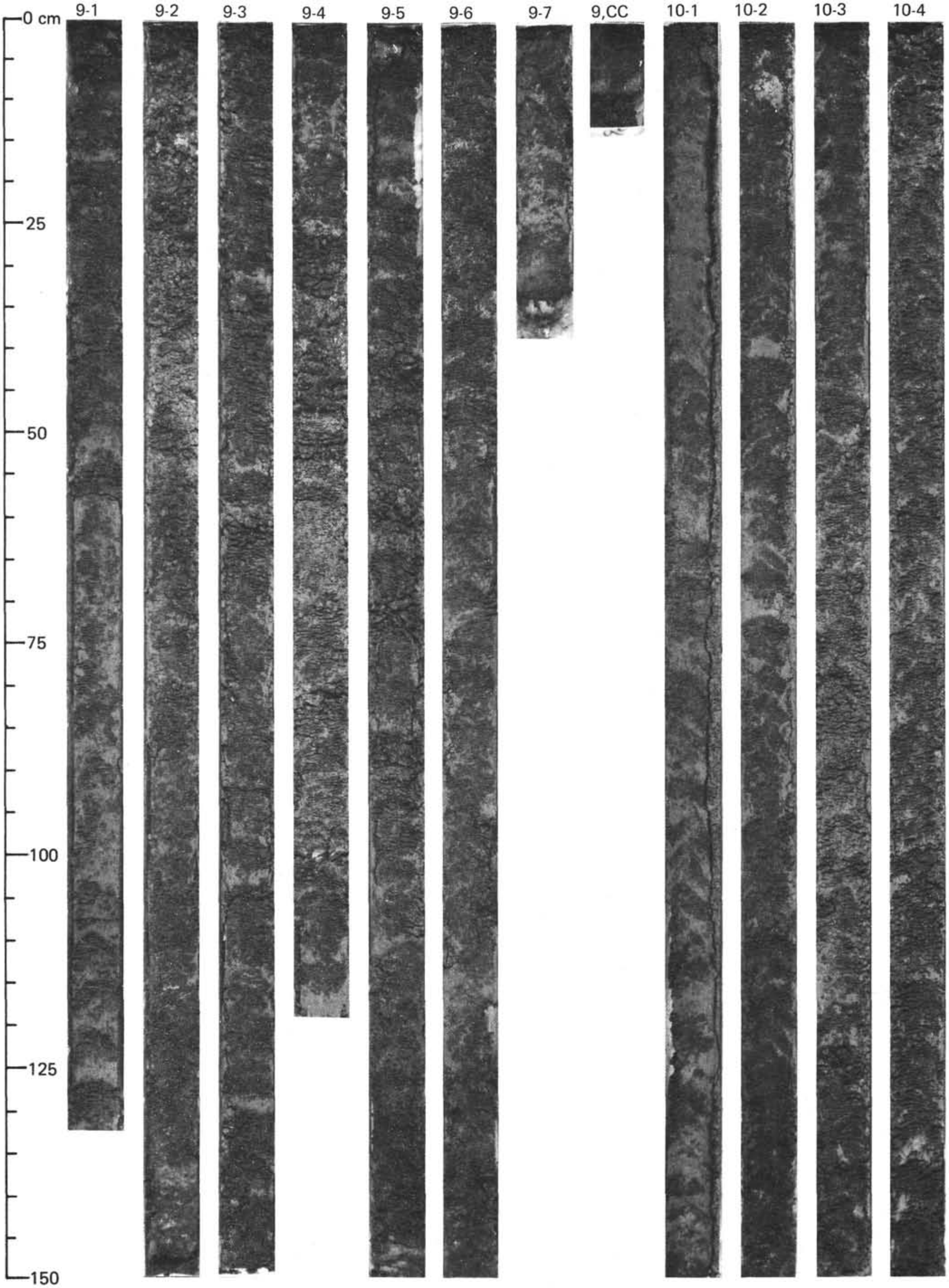
8-7
8,CC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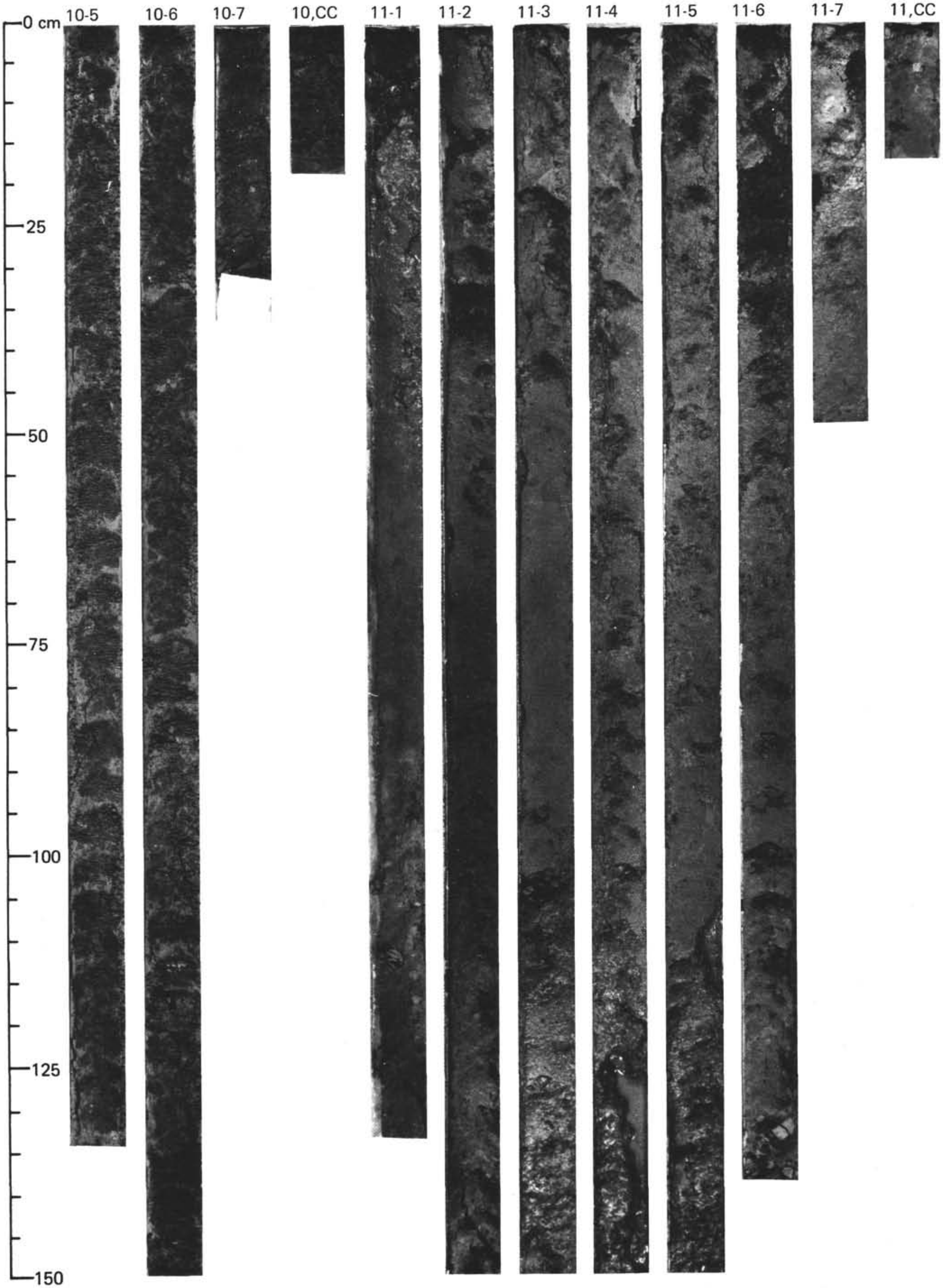
10-2
10-3
10-4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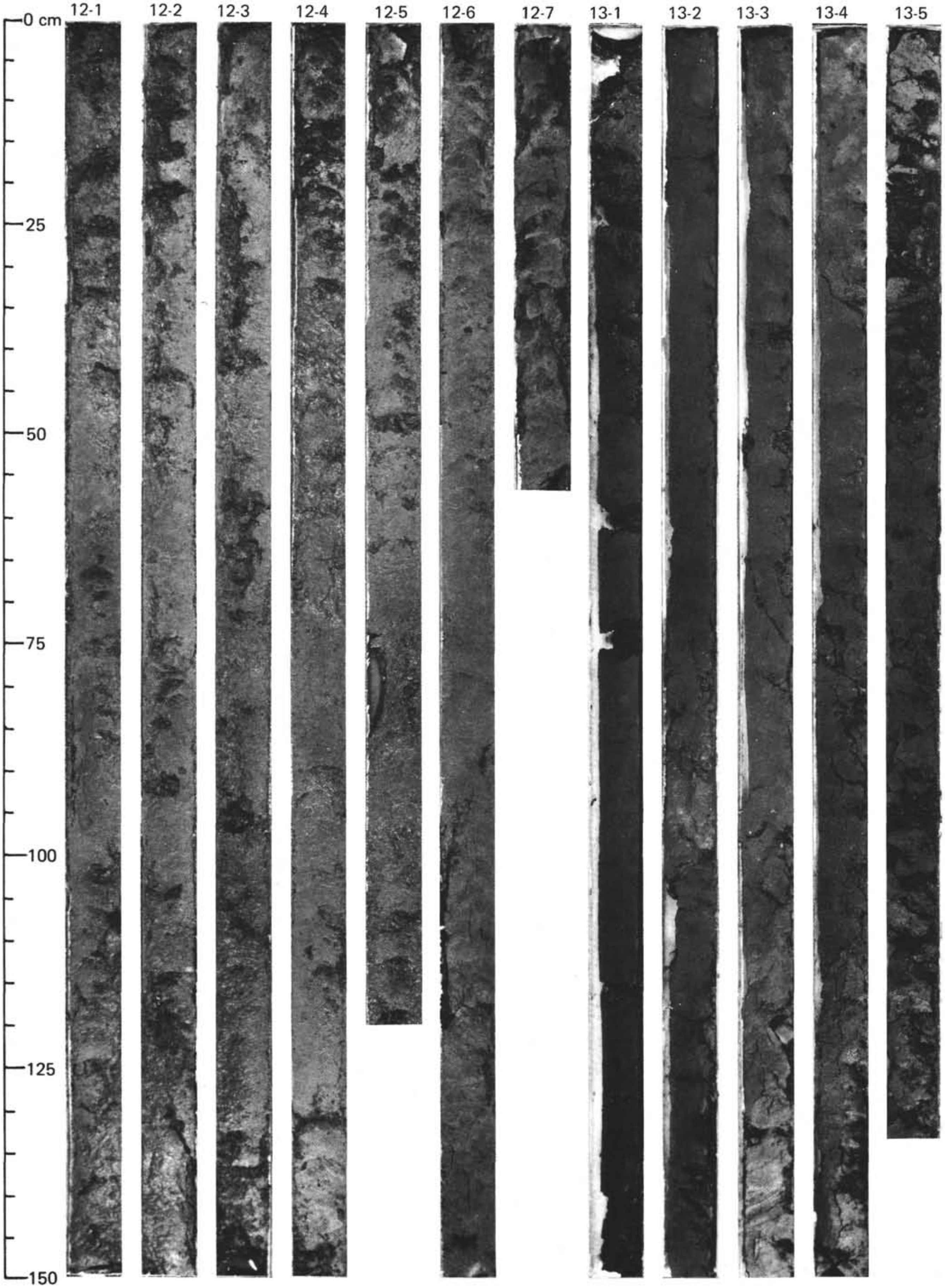
11,CC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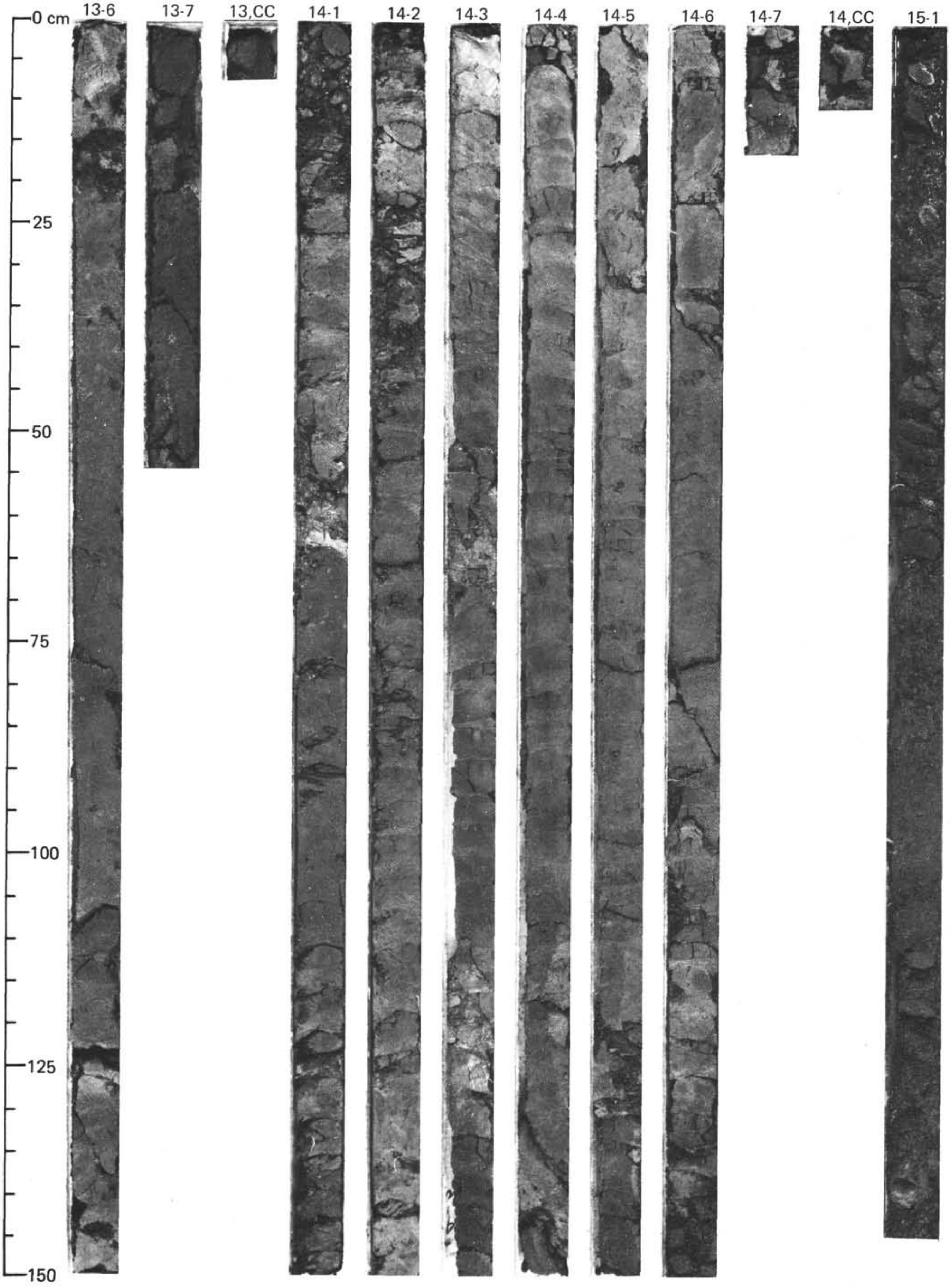
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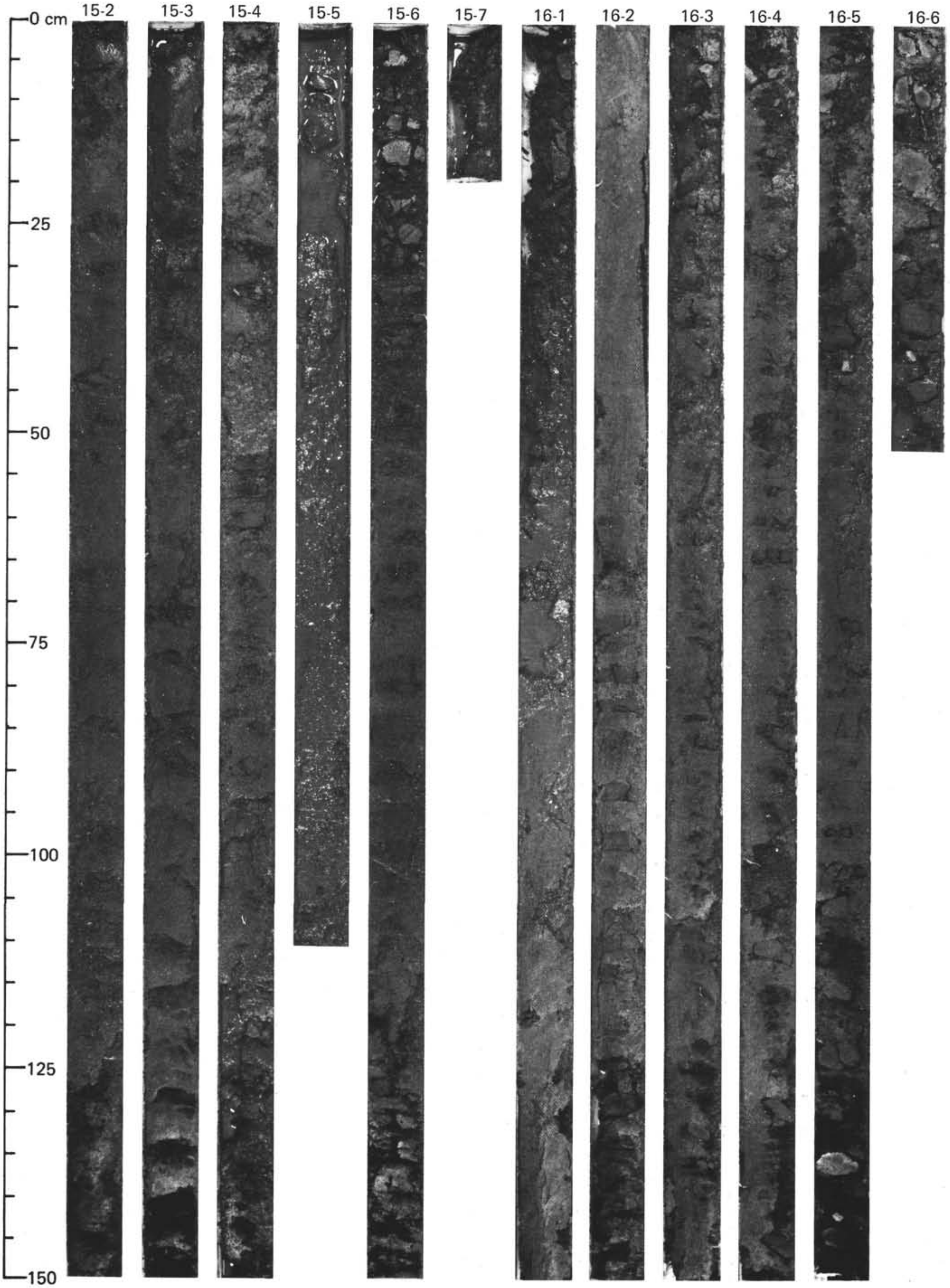
14,CC
15-1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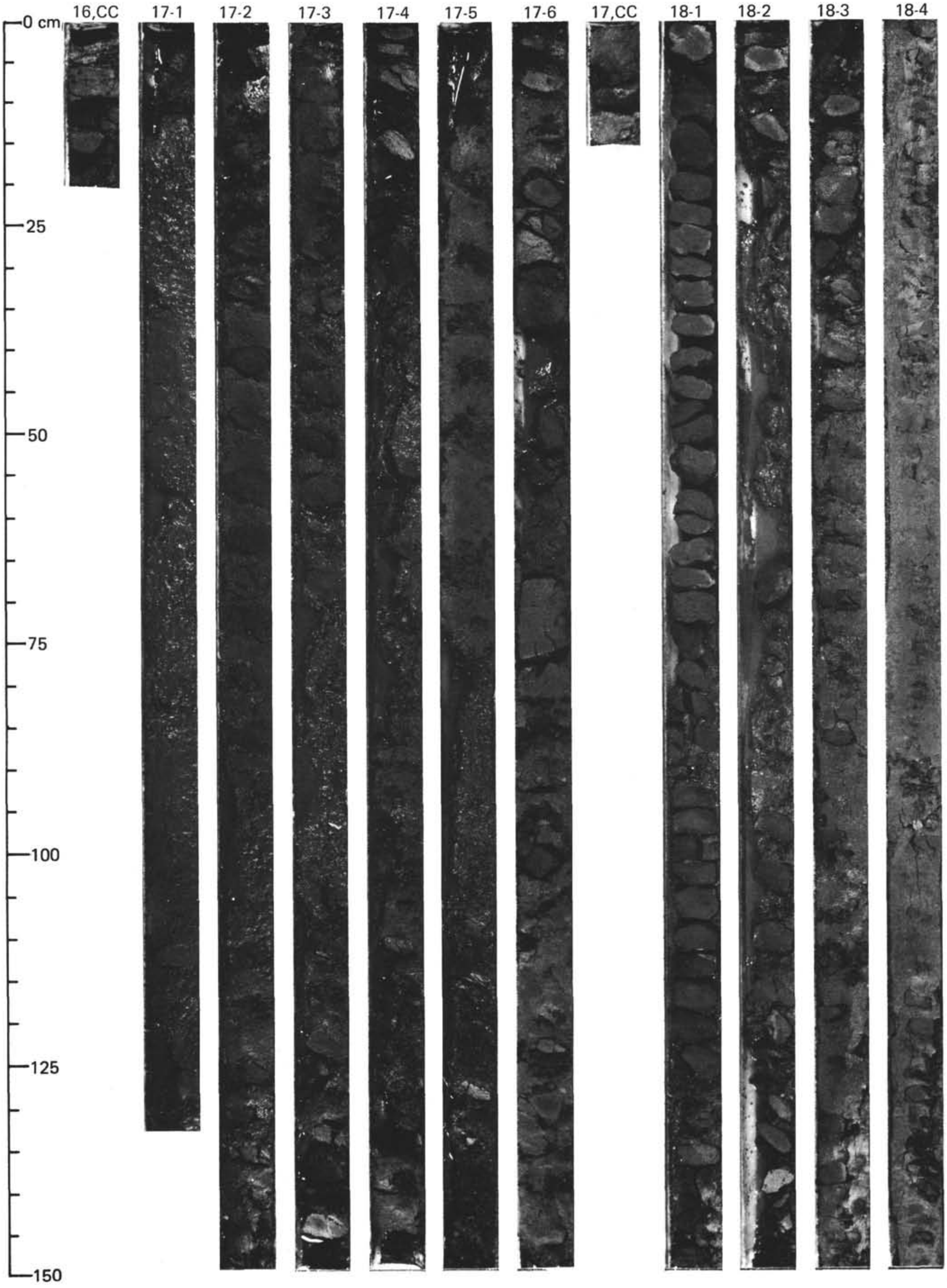
16-6


16,CC
17-1
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18-2
18-3
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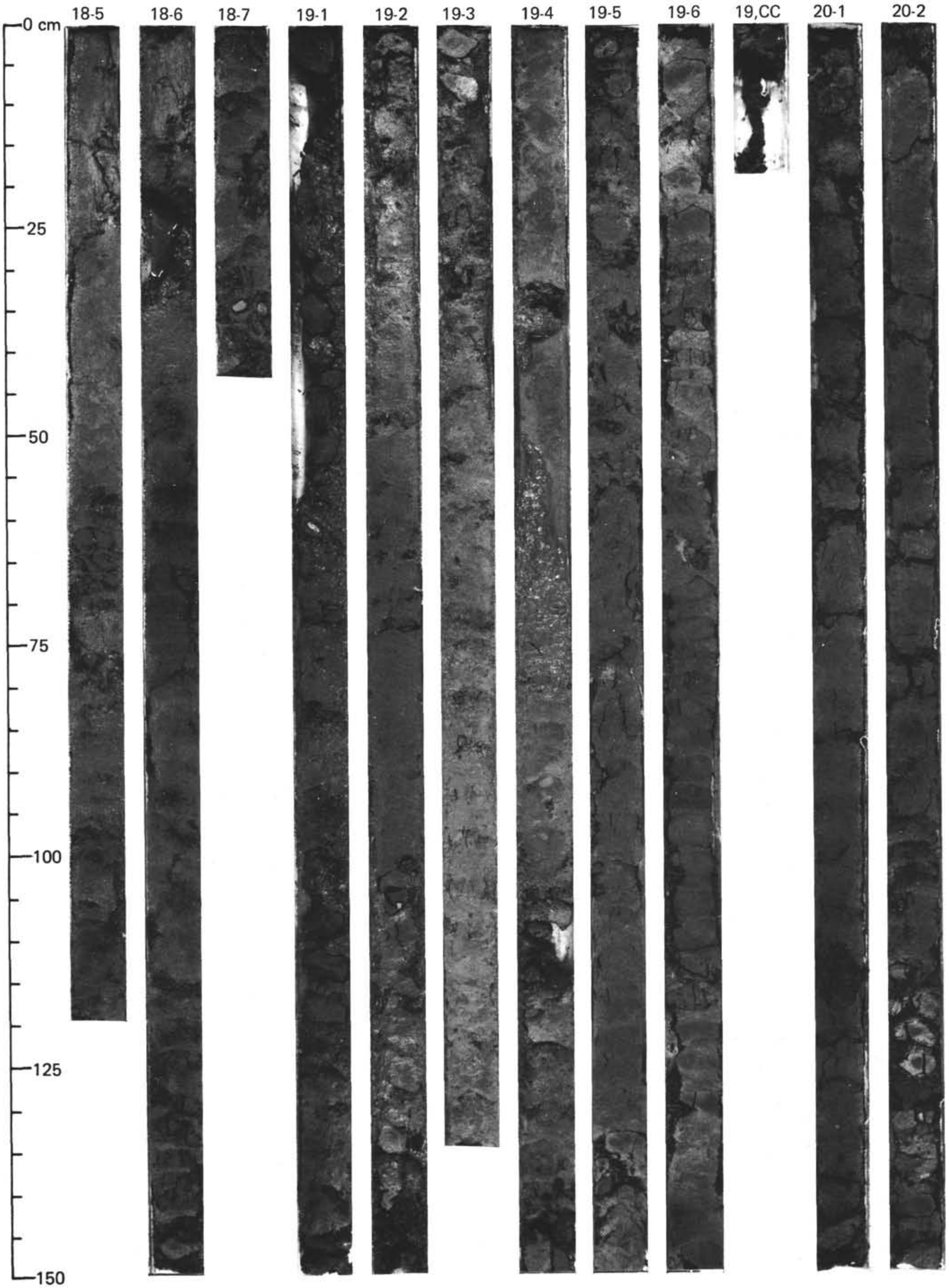
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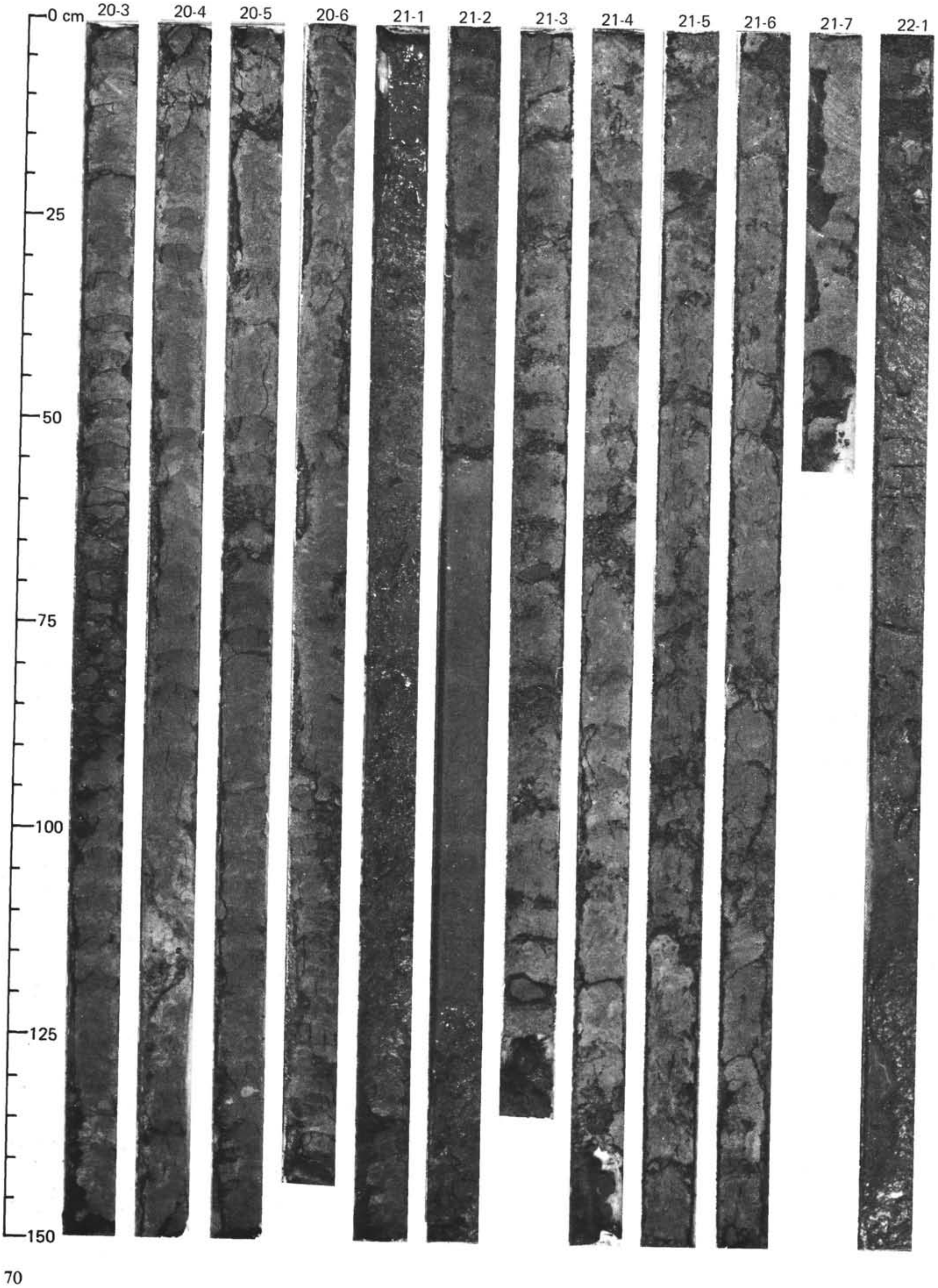
19,CC
20-1
20-2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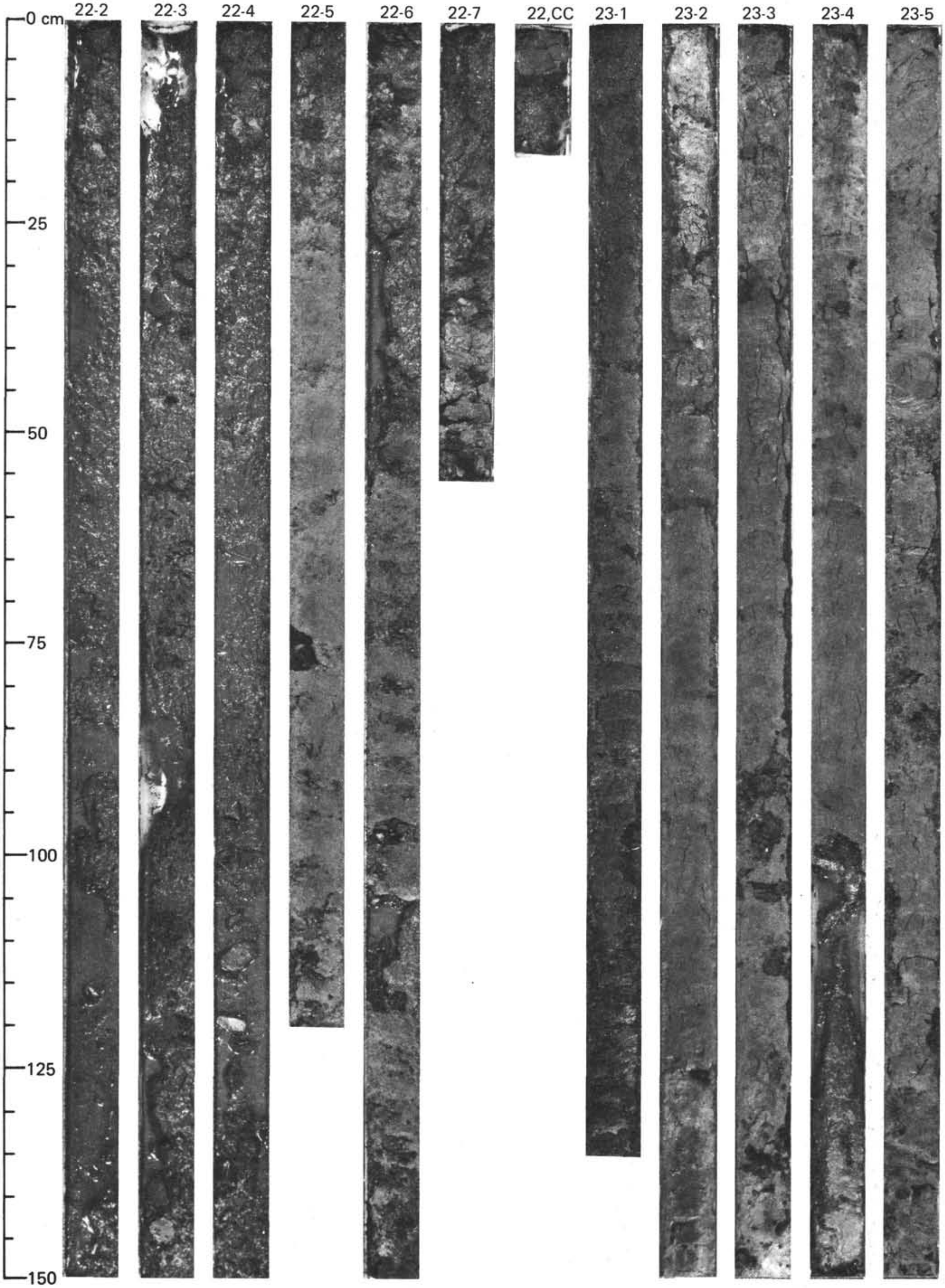
22-1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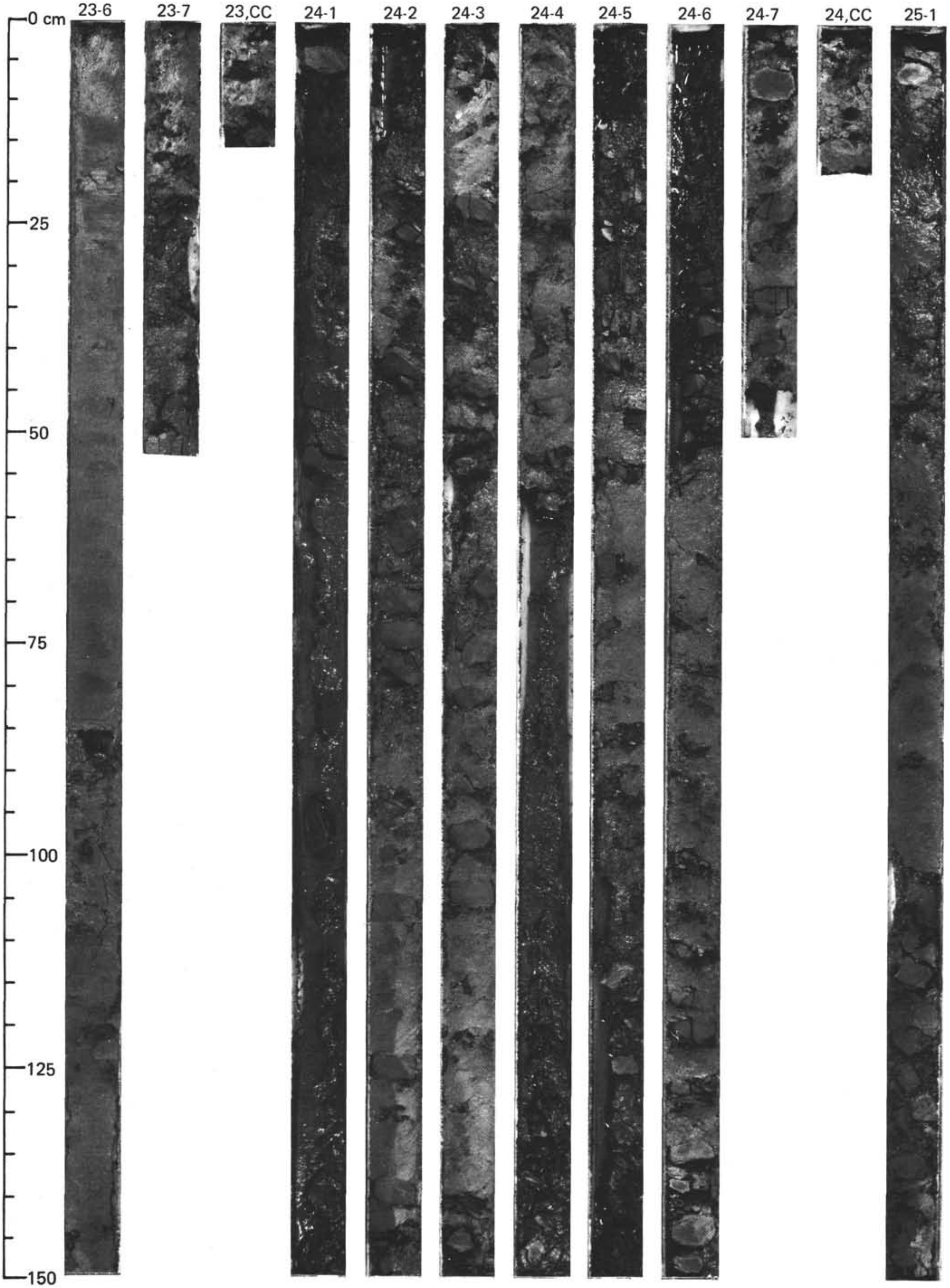
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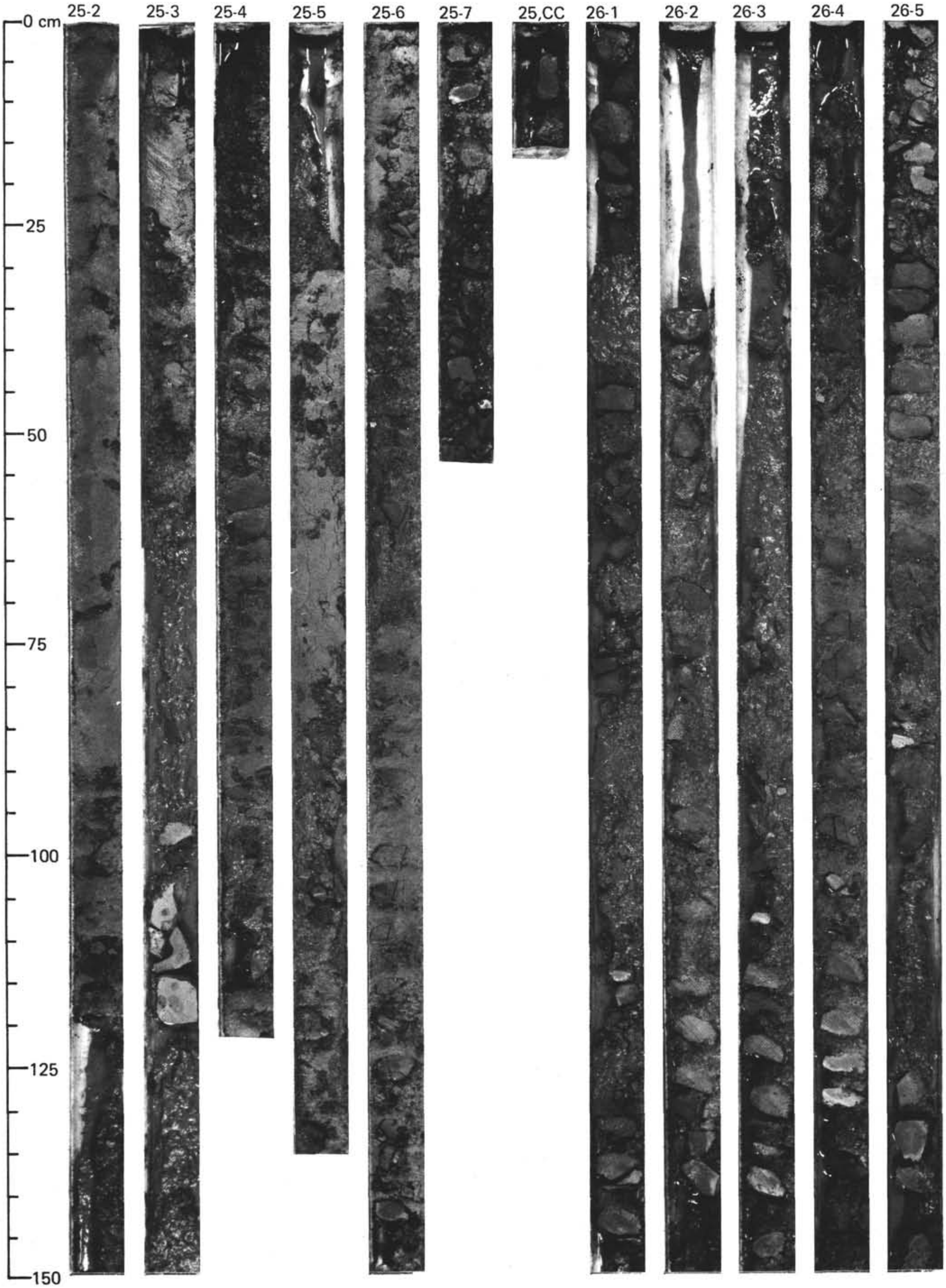
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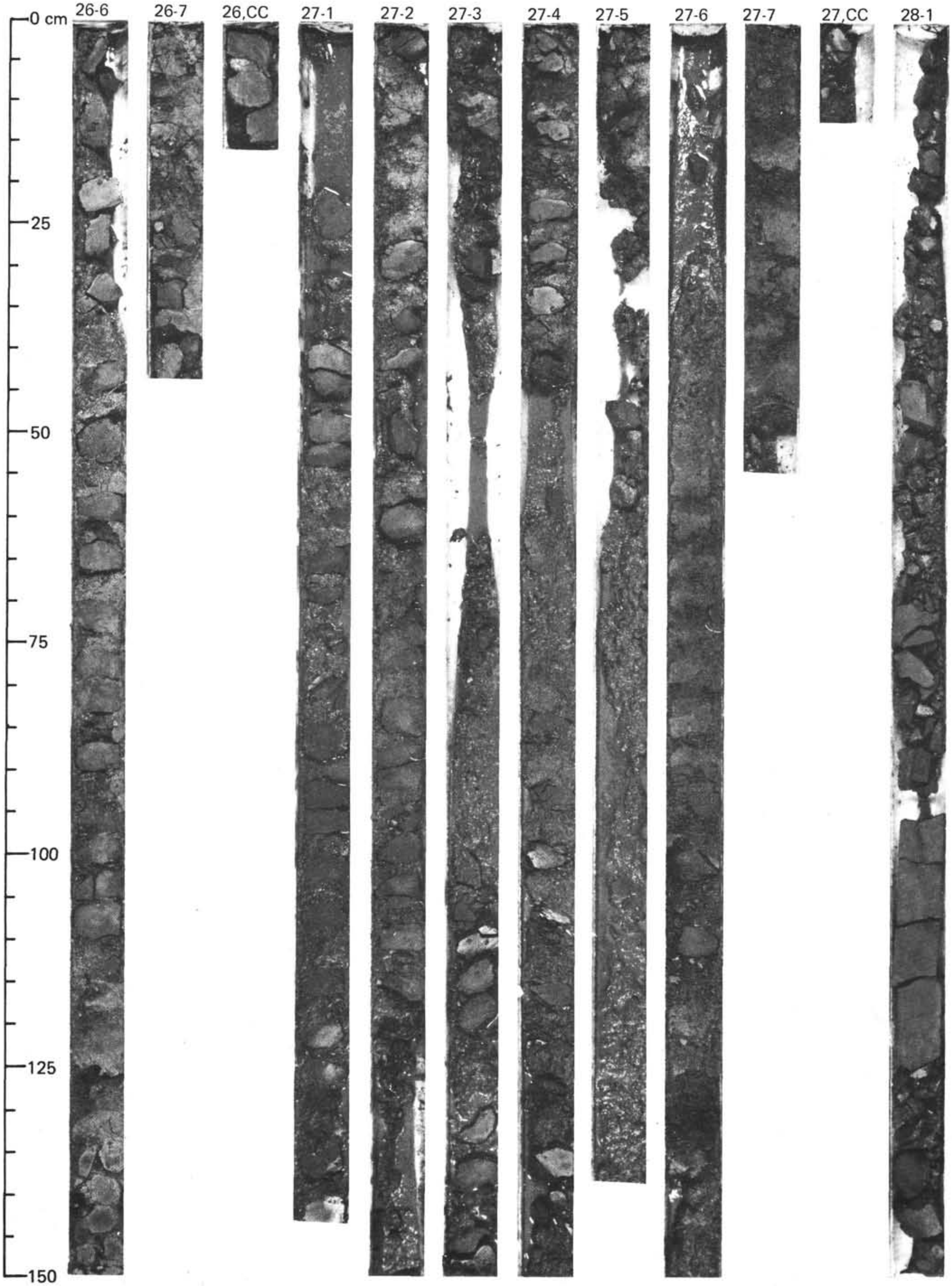
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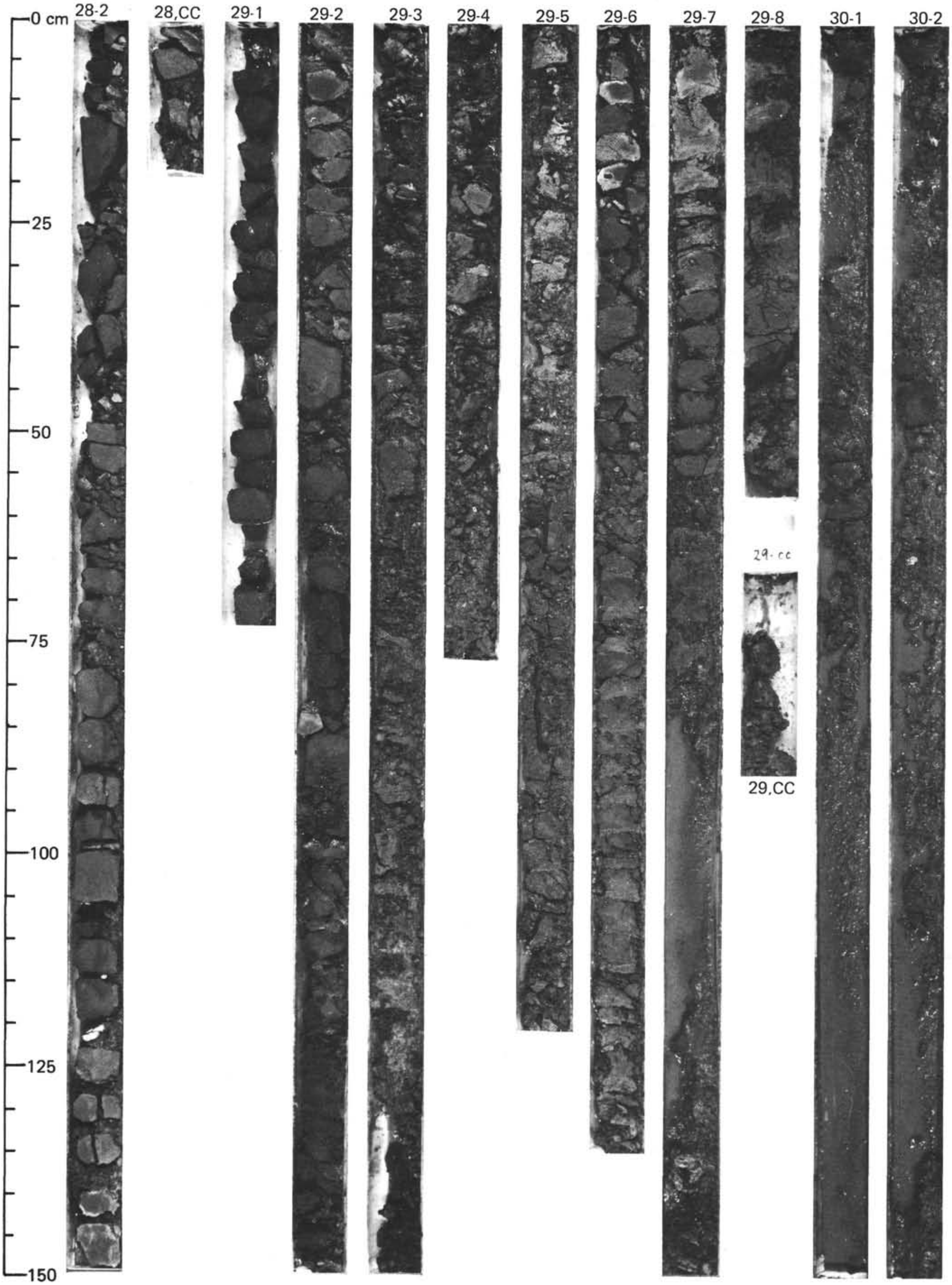
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29-cc
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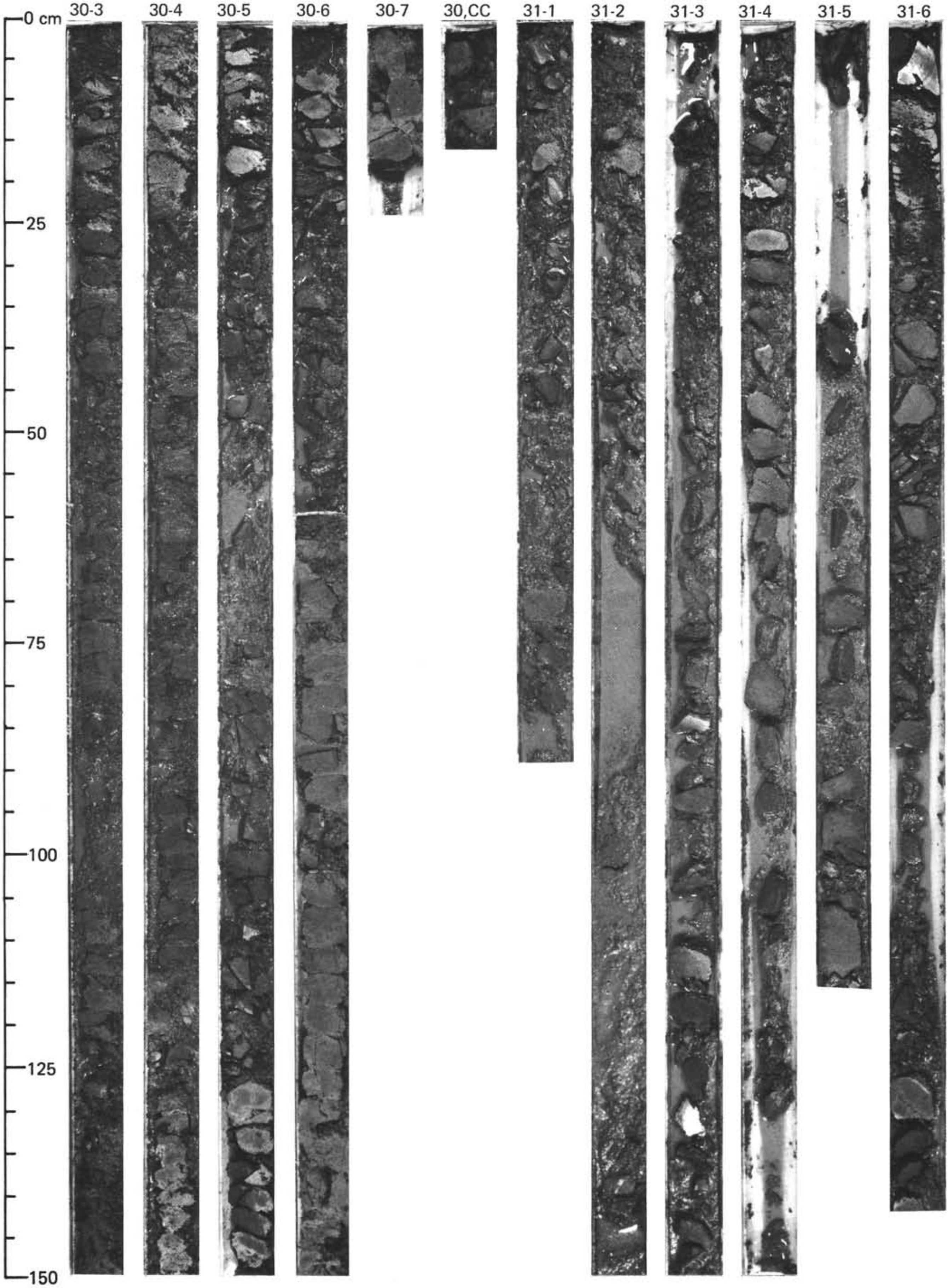
30-2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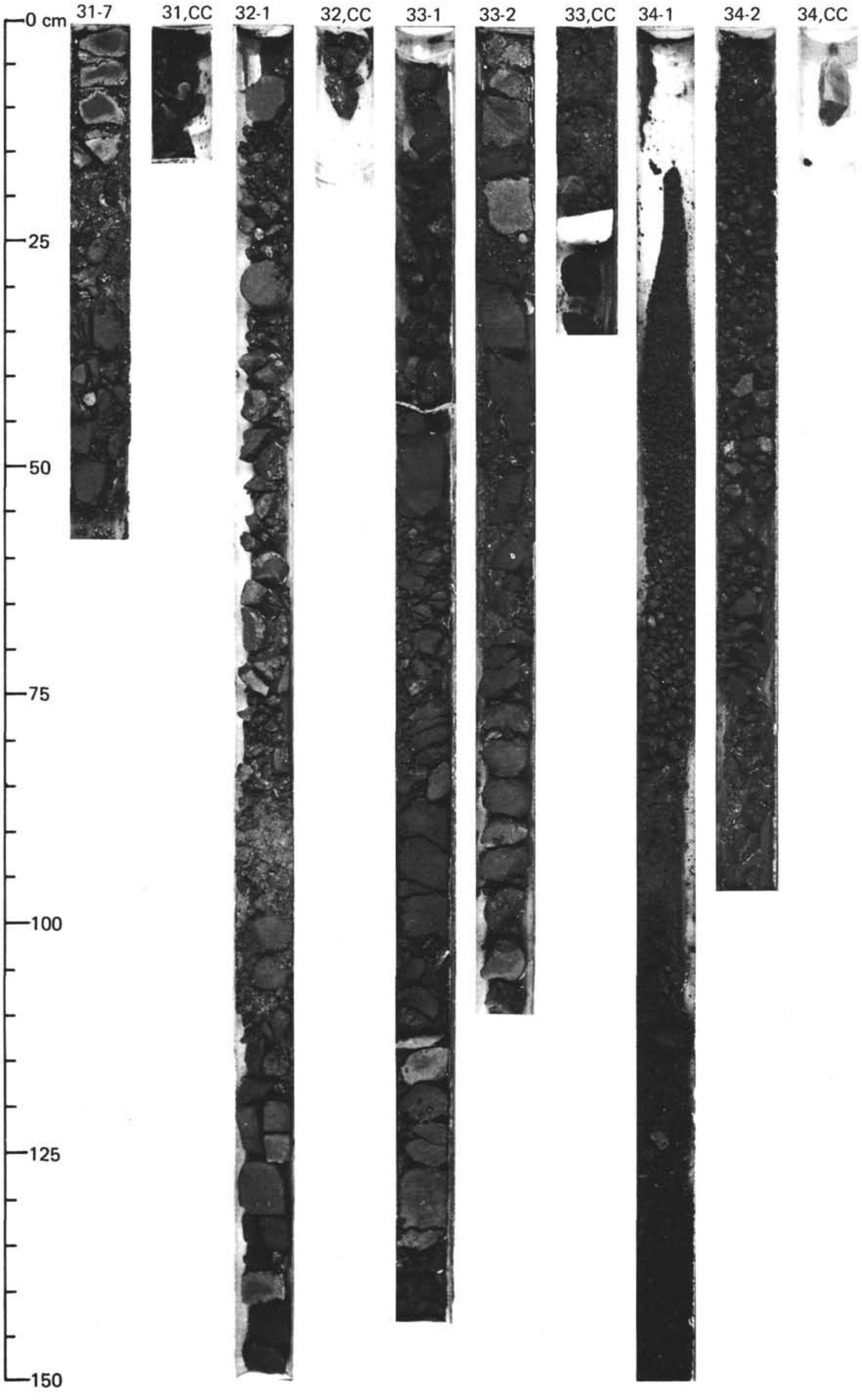
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