5. SITE 584[1]

Shipboard Scientific Party[2]

HOLE 584

Date occupied: 5 August 1982

Date departed: 12 August 1982

Time on hole: 85 hr., 30 min.

Position (latitude; longitude): 40°28.0′N; 143°57.1′E

Water depth (sea level; corrected m, echo-sounding): 4078

Water depth (rig floor; corrected m, echo-sounding): 4088

Bottom felt (rig floor; m, drill pipe): 4124

Penetration (m): 941.0

Number of cores: 98

Total length of cored section (m): 941.0

Total core recovered (m): 478.7

Core recovery (%): 51

Oldest sediment cored:
Depth sub-bottom (m): 941.0
Nature: Mudstone
Age: early middle Miocene
Measured velocity (km/s): V_p = 2.00 (at 932 m sub-bottom)

Principal results: See Summary and Conclusions section.

HOLE 584A

Date occupied: 12 August 1982

Date departed: 14 August 1982

Time on hole: 10 hr., 24 min.

Position (latitude; longitude): 40°28.0′N; 143°57.6′E

Water depth (sea level; corrected m, echo-sounding): 4094

Water depth (rig floor; corrected m, echo-sounding): 4104

Bottom felt (rig floor; m, drill pipe): 4125

Penetration (m): 901.5

Number of cores: 3

Total length of cored section (m): 28.9

Total core recovered (m): 10.66

Core recovery (%): 37

Oldest sediment cored:
Depth sub-bottom (m): Core H4 (804.8 to 901.5 m sub-bottom)
Nature: Mudstone
Age: early middle Miocene
Measured velocity (km/s): V_p = 1.86 (at 796 m sub-bottom)

Principal results: See Summary and Conclusions section.

HOLE 584B

Date occupied: 15 August 1982

Date departed: 16 August 1982

Time on hole: 13 hr., 42 min.

Position (latitude; longitude): 40°28.0′N; 143°56.7′E

Water depth (sea level; corrected m, echo-sounding): 4086

Water depth (rig floor; corrected m, echo-sounding): 4096

Bottom felt (rig floor; m, drill pipe): 4152

Penetration (m): 954

Number of cores: 3

Total length of cored section (m): 22

Total core recovered (m): 11.89

Core recovery (%): 54

Oldest sediment cored:
Depth sub-bottom (m): 954
Nature: Paisley mudstone
Age: early middle Miocene

Principal results: See Summary and Conclusions section.

BACKGROUND AND OBJECTIVES

Drilling at Site 584 was devoted to the study of the structure and the evolution of the Japan Trench off Sanriku, Honshu, an area of concentrated study ever since modern geoscience began. Recently, the Japanese earthquake prediction project and the IPOD project have both focused research efforts on this area and have accumulated a wealth of information in the fields of seismicity, magnetics, heat flow, gravity, and petrology. The results of DSDP Legs 56 and 57 (Scientific Party, 1980) together with other studies are summarized as follows:

Late Cretaceous

The area around the Site 584 was the Cretaceous Sanriku-oki forearc basin (Ishiwada and Ogawa, 1976). Cretaceous rocks dip toward the island arc at an angle of 20°, reaching a total apparent stratigraphic thickness of 45 km. This great thickness can not be accommodated by subsidence of normal crust and simple basin filling.

[1] Kagami, H., Karig, D. E., Coulbourn, W. T., et al., *Init. Repts. DSDP*, 87: Washington (U.S. Govt. Printing Office).

[2] LEG 87B: Hideo Kagami (Co-Chief Scientist), Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164, Japan; Daniel E. Karig (Co-Chief Scientist), Department of Geological Sciences, Cornell University, Ithaca, New York 14853; William T. Coulbourn (Science Representative), Deep Sea Drilling Project, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92093 (present address: Hawaii Institute of Geophysics, University of Hawaii, 2525 Correa Road, Honolulu, Hawaii 96822); Fumio Akiba, Japan Petroleum Exploration Co., Ltd., 3-5-5 Midorigaoka, Hamura-cho Nishitama-gun, Tokyo 190-11, Japan; Cynthia J. Bray, Department of Geological Sciences, Cornell University, Ithaca, New York 14853; Jean-Paul Cadet, Sciences de la Terre, ERA 601, Université d'Orléans, 45046 Orléans, France; Jacques Charvet, Sciences de la Terre, Université d'Orléans, 45046 Orléans, France; Kantaro Fujioka, Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164, Japan; Martin Lagoe, ARCO Exploration Company, Denver, Colorado 80217 (present address: Department of Geologic Science, University of Texas at Austin, Austin, Texas 78712); Thomas H. Lang, Department of Geology, Florida State University, Tallahassee, Florida 32306; Jeremy K. Leggett, Department of Geology, Imperial College of Science and Technology, London SW7 2BP, United Kingdom; Gail A. Lombari, Graduate School of Oceanography, University of Rhode Island, Kingston, Rhode Island, 02881; Ryo Matsumoto, Geological Institute, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113, Japan; Nobuaki Niitsuma, Institute of Geosciences, Shizuoka University, 836 Oya, Shizuoka 422, Japan; and Carol L. Stein, Earth Sciences, Division 6331, Sandia National Laboratories, Albuquerque, New Mexico 87185.

The landward-dipping section is probably tectonically repeated by thrust faulting and is perhaps an accretionary prism (von Huene et al., 1982). This basin may continue northward to the Yezo geosyncline developed in the Ishikari-Tomakomai lowland during the middle to Late Cretaceous, and southward toward the Kinkazan and Joban basins. Extensive arc volcanism took place during the Late Cretaceous, a time characterized by subduction, accretion, and arc volcanism (von Huene et al., 1982).

Paleogene

During the early Paleogene, subduction slowed considerably or stopped, as did arc volcanism, owing to a change from convergent to largely strike-slip plate motion (Kuwahara, 1982). A strike-slip motion of the Tanakura Fracture Zone reflects the movement on land (Kuwahara, 1982). The region near the site rose considerably, but whether it was eroded subaerially is not clear. The reason for this episode of relative uplift and erosion is not fully understood. On seismic profiles, the Paleogene formations are easily traced offshore of the Kinkazan-oki and Joban-oki basins.

Early Miocene (22 to 15 Ma)

Dacite boulders found at Site 439 were isotopically dated as 22 to 24 Ma old and were probably deposited soon after their initial extrusion (Shipboard Scientific Party, 1980a). Short-lived magmatic activity reported for the Ishikari-Tomakomai lowland during the deposition of Takinoue Formation (Fig. 1) might relate to the dacite boulders found at Site 439.

During this period, the forearc region began to subside. Arc volcanism was particularly active along the present "green tuff" region, and the Japan Sea basin was probably spreading.

Middle Miocene (15 to 10 Ma)

The forearc region continued to subside and its depocenter shifted seaward with time. The fundamental cause of this subsidence is not well understood. Tectonic erosion and sediment subduction are a possibility because no Miocene accretionary prism was found at the toe area (von Huene et al., 1982). A thermal origin of the subsidence in the upper plate is also a possibility (Burch and Langseth, 1981).

During this time (12 to 13 Ma) of warm to temperate climate, the first wave of the cold Oyashio flow arrived at this region (Koizumi et al., 1980). Porcellanitic and siliceous facies represent this event. This change is not as distinct in this area as in the Japan Sea, which was still actively rifting and spreading.

Late Miocene (10 to 5 Ma)

The orientation of dikes and faults indicates that the stress vector perpendicular to the trench axis was first tensional and then compressional. The tensional field developed as early as 21 to 16 Ma and lasted until about 7 to 6 Ma (Nakamura and Uyeda, 1980). On the present backbone range of the northeast Honshu, extensive dacitic eruptions and consequent formation of calderas were associated with the compressional stress interval (Nakamura and Uyeda, 1980).

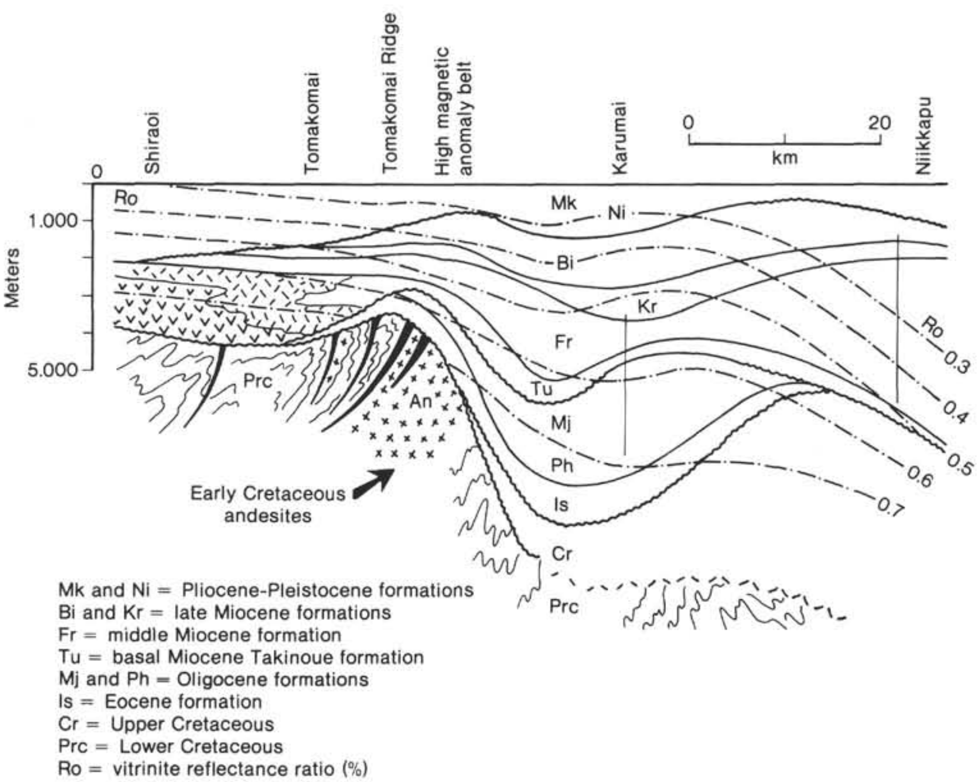


Figure 1. Restored geologic section in the southern Ishikari-Tomakomai lowland and dacitic volcanic activity during the time of deposition of the Takinoue Formation (Masatani, 1982).

Pliocene to Recent

Relative uplift of the forearc region began and caused steepening of anticlinal ridges and deepening of basins. The lower trench slope reached a maximum accumulation rate during the Pliocene, owing partly to biogenic siliceous productivity and partly to local slumping (von Huene et al., 1982).

The present stress fields are estimated from analyses of focal mechanisms (Nakamura and Uyeda, 1980). Normal faults offset the ocean crust near the trench axis, low-angle thrust faults develop frequently at the Eurasian and Pacific plate boundary, and dip-slip motions of either normal or thrust faults prevail under the trench slope. Explosive volcanism recurred between about 5 and 2 Ma.

Summary of Objectives

Our specific scientific objectives for drilling at the middle trench slope seaward of the known edge of the Oyashio landmass, an area that has alternately undergone rapid subsidence and uplift, are: (1) to recover a detailed stratigraphic record that will allow us to assess the role of tectonic erosion or sediment subduction using seismic reflection profiles; well-log records; heat flow measurements; and rates of sediment accumulation, convergence, and accretion (all values perhaps related to the horst and graben topography developed on the ocean crust and to the extensional first-motion solutions for the ocean crust underlying the trench); (2) to estimate the paleotopography, slope gradient (or depth of slope), and the migration of the Neogene depocenter through time; (3) to assess the deformational features of the middle trench slope deposits in time and space and to determine the stress field, which was presumably a continuation of both lithostatic and tectonic stress; (4) to establish a high-resolution stratigraphy using biostratigraphy, paleomagnetics, tephrachronology, and stable isotopes, in order to correlate that result with the record from Sites 438 and 439 and from the island arc of Japan, a task complicated by the slight difference in reported tectonic phases of uplift between the arc and the slope area; and (5) to determine whether, on the basis of authigenic analcime, some 2000 m of Cretaceous basement has been eroded or whether, on the basis of hornfelsic Cretaceous shale, the temperature decreased some 50°C since the early Miocene.

OPERATIONS

Driven from Site 583 by the approach of Typhoon Bess, the *Glomar Challenger* steamed northward for approximately five days en route to Site 584, only to be intercepted by the eye of the storm. Typhoon Bess, designated Typhoon 10 by the Japanese Meteorological Agency, had winds gusting to 70 knots and a minimum atmospheric pressure of 968 mbar.

Hole 584

Approaching Site 584, we commenced a survey on a course of 268° at 1412 (0512Z) on 4 August 1982 (Fig. 2). Underway geophysical gear was pulled in as we passed over the site. From 1600 (0700Z), the vessel held steady on a course of 093° with a speed of 4 knots and dropped a 16 kHz beacon at 1651Z (Fig. 3). The site is located at shot point 270 on ORI 78-3 line (see Fig. 31A); its position is 40°28.0′N, 143°57.1′E.

A mudline core established the depth as 4114 m, measured by meters of drill pipe from sea level, which agrees with the precision-depth-recorder (PDR) depth of 4116 m to within 2 m. This PDR depth, however, corresponds to the second reflector, the shallowest being from 4088 m.

After continuously coring to 77 m sub-bottom with fairly good recovery (Table 1), we lowered the first heat-flow–pore-water–pressure-measuring instrument (HF-PW-PMI) down the pipe and collected *in situ* pore water, but the instrument failed to record temperature and pressure because of electrical problems. The experiment was repeated at 153.7 m sub-bottom with worse results. The needle of the probe bent when caught in the float valve, causing a circuit malfunction.

The bottom-hole assembly was stable with a drift angle of 2° at 29.4 m and again at 15.37 m sub-bottom. Low recovery between 50 to 60 m sub-bottom may have been due to a carbonate nodule, and between 130 to 170 m to soft and watery sediments, probably related to coarse-grained ash layers. Drill mud was first pumped at 221.3 m sub-bottom in an effort to clear the hole.

A third HF-PW-PMI probe was lowered to a depth of 230.8 m sub-bottom. The electrical circuit was reactivated when the pressure valve opened, therefore no reliable data were obtained. Pore water intake was blocked by clay at the filter. A fourth probe at 287.8 m sub-bottom finally "scored the hat trick."

Inclination of the beds gradually steepened downhole below 300 m sub-bottom. Hole drift angles were measured as 2° at 402.6 m and as 2.5° at 508.1 m. Drilling character indicated softer intervals between Cores 46 and 47 and very fine sand layers were encountered in Core 48 (460 m sub-bottom). Below 584 m sub-bottom, the hole angle was still stable 2°, but the formation became progressively harder with intercalated silty layers, and core recovery decreased gradually downhole. Occasionally, the hole filled with cuttings, and it required periodic mud flushes.

Coring recovery improved again when the hole penetrated into middle Miocene sediment (757.5 m sub-bottom) (Table 1). The drift angle of the hole varied from 2° at 719.1 m to 1.5° at 815.5 m.

By 2325Z on 10 August, the pipe had penetrated to 883.1 m, recovering lower middle Miocene mudstone with almost 70° inclination of bedding. At 941.0 m sub-bottom, the pipe nearly became stuck in about 8 m of hole fill, despite mud flushing between every core. Apparently, the trouble came from a interval at ~900 m sub-bottom, where the hole finally bridged after several hours of maneuvering to clean it. From the appearance of the core, an intensely fractured shear zone may occur near this interval. The hole was terminated and the pipe was retrieved above mudline by 1800Z on 11 August.

Hole 584A

The vessel began offsetting westward to Hole 584A at 1810Z and arrived at the new position of 40°28.0′N, 143°57.6′E. This location is 524.2 m west of the Site

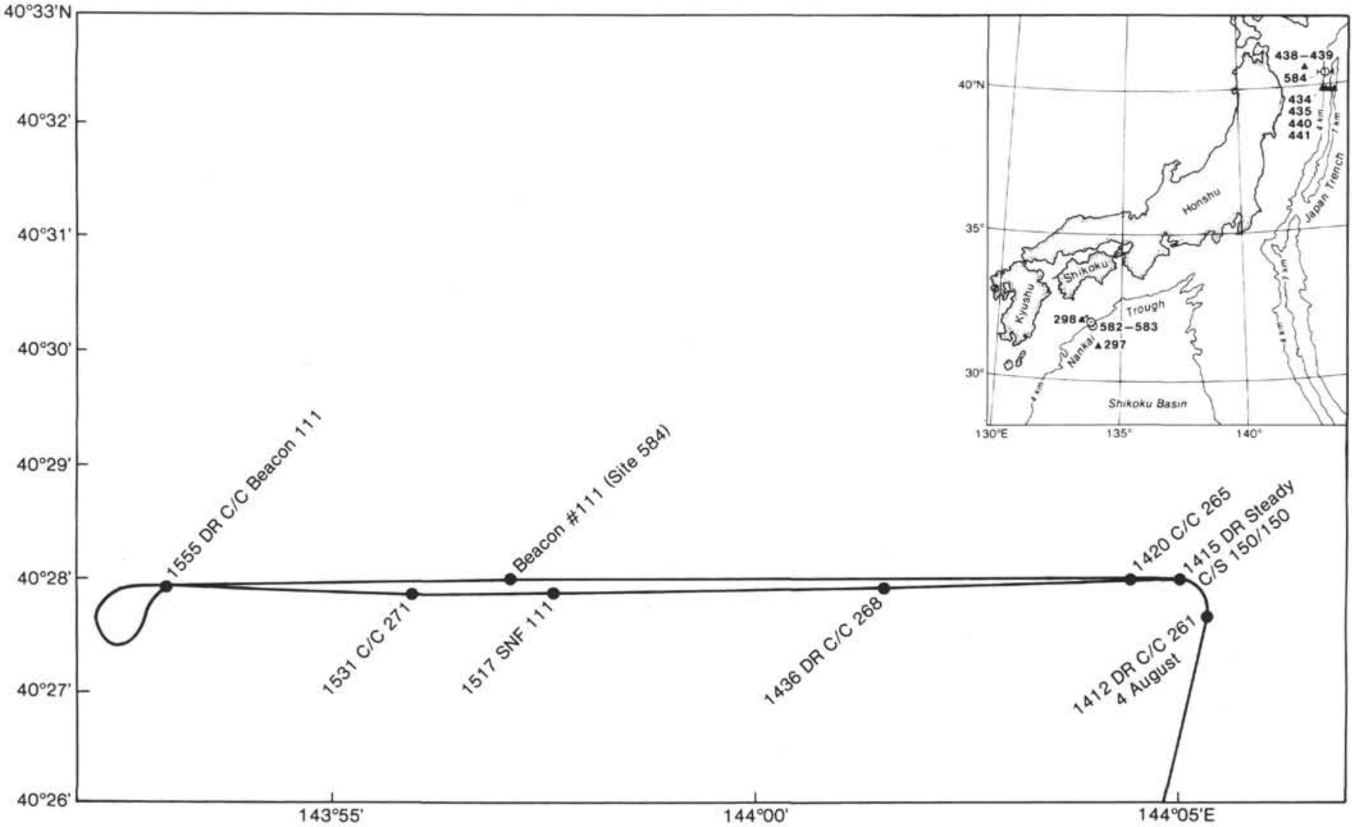


Figure 2. Site 584 approach track; location of Site 584. Times are local times. Inset figure is Leg 87 site location map. C/C = course change, C/S = change speed, SNF = satellite navigation fix, DR = dead reckoning.

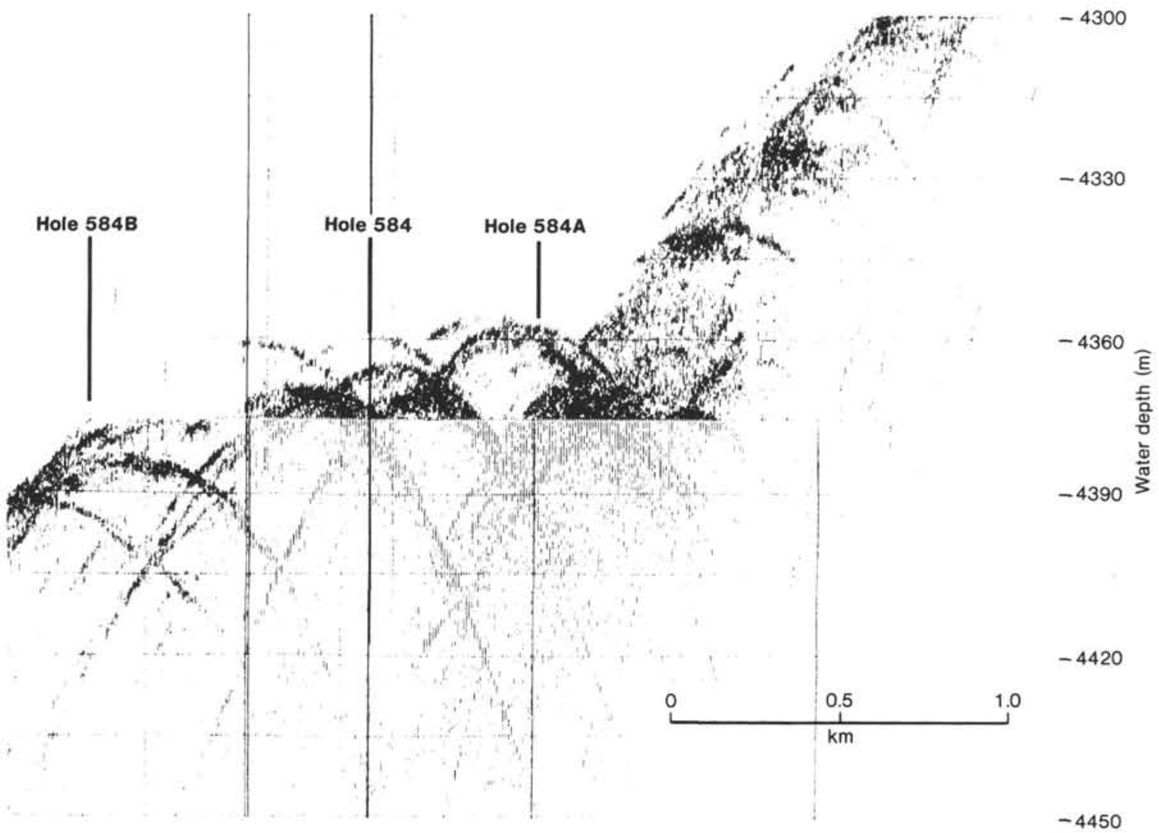


Figure 3. *Glomar Challenger* 3.5-kHz seismic profile, showing the relative positions of Holes 584, 584A, and 584B.

Table 1. Coring summary, Site 584.

Core	Date (August 1982)	Time (L)[a]	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Percent recovered
Hole 584							
1	5	0245	4124.0–4134.3	0.00–10.3	10.3	9.40	91
2	5	0450	4134.3–4144.0	10.3–20.0	9.7	5.39	56
3	5	0622	4144.0–4153.4	20.0–29.4	9.4	5.98	64
4	5	0747	4153.4–4162.8	29.4–38.8	9.4	9.62	102
5	5	0910	4162.8–4172.2	38.8–48.2	9.4	9.71	103
6	5	1042	4172.2–4181.8	48.2–57.8	9.6	3.54	37
7	5	1200	4181.8–4191.4	57.8–67.4	9.6	2.97	31
8	5	1321	4191.4–4201.0	67.4–77.0	9.6	3.01	31
9	5	1615	4201.0–4210.5	77.0–86.5	9.5	2.43	26
10	5	1735	4210.5–4220.0	86.5–96.0	9.5	5.27	55
11	5	1905	4220.0–4229.5	96.0–105.5	9.5	8.28	87
12	5	2025	4229.5–4239.1	105.5–115.1	9.6	8.89	93
13	5	2155	4239.1–4248.7	115.1–124.7	9.6	9.46	98
14	5	2323	4248.7–4258.3	124.7–134.3	9.6	0.82	9
15	6	0105	4258.3–4268.0	134.3–144.0	9.7	6.15	63
16	6	0240	4268.0–4277.7	144.0–153.7	9.7	4.23	44
17	6	0545	4277.7–4287.4	153.7–163.4	9.7	3.97	41
18	6	0700	4287.4–4297.1	163.4–173.1	9.7	0.73	8
19	6	0830	4297.1–4306.8	173.1–182.8	9.7	9.55	98
20	6	0940	4306.8–4316.5	182.8–192.5	9.7	9.47	98
21	6	1055	4316.5–4326.1	192.5–202.1	9.6	9.62	100
22	6	1205	4326.1–4335.7	202.1–211.7	9.6	5.06	53
23	6	1330	4335.7–4345.3	211.7–221.3	9.6	8.91	93
24	6	1525	4345.3–4354.8	221.3–230.8	9.5	8.79	93
25	6	1841	4354.8–4364.3	230.8–240.3	9.5	2.32	24
26	6	2005	4364.4–4373.8	240.3–249.8	9.5	8.54	90
27	6	2130	4373.8–4383.3	249.8–259.3	9.5	8.82	93
28	6	2245	4383.3–4392.8	259.3–268.8	9.5	7.83	82
29	7	0005	4392.8–4402.3	268.8–278.3	9.5	8.10	85
30	7	0135	4402.3–4411.8	278.3–287.8	9.5	7.27	77
31	7	0450	4411.8–4421.3	287.8–297.3	9.5	0.49	5
32	7	0555	4421.3–4430.8	297.3–306.8	9.5	4.70	50
33	7	0718	4430.8–4440.4	306.8–316.4	9.6	1.27	13
34	7	0838	4440.4–4450.0	316.4–326.0	9.6	8.97	93
35	7	1000	4450.0–4459.6	326.0–335.6	9.6	4.90	51
36	7	1115	4459.6–4469.1	335.6–345.1	9.5	7.40	78
37	7	1255	4469.1–4478.6	345.1–354.6	9.5	8.51	90
38	7	1422	4478.6–4488.1	354.6–364.1	9.5	6.63	70
39	7	1545	4488.1–4497.7	364.1–373.7	9.6	4.89	51
40	7	1710	4497.7–4507.3	373.7–383.3	9.6	6.03	63
41	7	1840	4507.3–4516.9	383.3–392.9	9.6	1.04	11
42	7	2000	4516.9–4526.6	392.9–402.6	9.7	8.30	86
43	7	2120	4526.6–4536.3	402.6–412.3	9.7	5.55	57
44	7	2240	4536.3–4546.0	412.3–422.0	9.7	7.75	80
45	8	0005	4546.0–4555.5	422.0–431.5	9.5	0.08	—
46	8	0125	4555.5–4565.0	431.5–441.0	9.5	1.50	16
47	8	0305	4565.0–4574.5	441.0–450.5	9.5	4.97	52
48	8	0438	4574.5–4584.1	450.5–460.1	9.6	6.62	69
49	8	0550	4584.1–4593.7	460.1–469.7	9.6	6.12	64
50	8	0715	4593.7–4603.3	469.7–479.3	9.6	1.30	14
51	8	0920	4603.3–4612.9	479.3–488.9	9.6	5.77	60
52	8	1030	4612.9–4622.5	488.9–498.5	9.6	4.82	50
53	8	1205	4622.5–4632.1	498.5–508.1	9.6	5.16	54
54	8	1335	4632.1–4641.6	508.1–517.6	9.5	9.78	103
55	8	1500	4641.6–4651.1	517.6–527.1	9.5	7.52	79
56	8	1630	4651.1–4660.6	527.1–536.6	9.5	6.15	65
57	8	1800	4660.6–4670.1	536.6–546.1	9.5	4.95	52
58	8	1925	4670.1–4679.6	546.1–555.6	9.5	2.53	27
59	8	2055	4679.6–4689.1	555.6–565.1	9.5	4.35	46
60	8	2225	4689.1–4698.6	565.1–574.6	9.5	3.81	40
61	9	0010	4698.6–4708.1	574.6–584.1	9.5	2.80	29
62	9	0145	4708.1–4717.6	584.1–593.6	9.5	7.89	83
63	9	0345	4717.6–4727.2	593.6–603.2	9.6	3.77	39
64	9	0505	4727.2–4736.8	603.2–612.8	9.6	1.83	19
65	9	0655	4736.8–4746.4	612.8–622.4	9.6	3.14	33
66	9	0905	4746.4–4756.1	622.4–632.1	9.7	1.55	16
67	9	1105	4756.1–4765.8	632.1–641.8	9.7	2.77	29
68	9	1250	4765.5–4775.5	641.8–651.5	9.7	2.68	28
69	9	1505	4775.5–4785.2	651.5–661.2	9.7	0.17	2
70	9	1655	4785.2–4794.9	661.2–670.9	9.7	3.36	35
71	9	1825	4794.9–4804.6	670.9–680.6	9.7	2.97	31
72	9	2035	4804.6–4814.2	680.6–690.8	9.6	1.46	15
73	9	2220	4814.2–4823.8	690.2–699.8	9.6	3.65	38
74	10	0010	4823.8–4833.4	699.8–709.4	9.6	2.44	25
75	10	0205	4833.4–4843.1	709.4–719.1	9.7	3.24	33
76	10	0400	4843.1–4852.8	719.1–728.8	9.7	3.93	41
77	10	0555	4852.8–4862.5	728.8–738.5	9.7	2.69	28
78	10	0735	4862.5–4872.0	738.5–748.0	9.5	4.28	45
79	10	0910	4872.0–4881.5	748.0–757.5	9.5	3.80	40
80	10	1045	4881.5–4891.0	757.5–767.0	9.5	6.86	72
81	10	1224	4891.0–4900.7	767.0–776.7	9.7	5.21	54
82	10	1435	4900.7–4910.4	776.7–786.4	9.7	1.06	11
83	10	1620	4910.4–4920.1	786.4–796.1	9.7	6.61	68
84	10	1805	4920.1–4929.8	796.1–805.8	9.8	0.82	8
85	10	2000	4929.8–4939.5	805.8–815.5	9.7	3.05	31
86	10	2140	4939.5–4949.2	815.5–825.2	9.7	2.83	29
87	10	2316	4949.2–4958.8	825.2–834.8	9.6	4.29	45
88	11	0100	4958.8–4968.4	834.8–844.4	9.6	8.18	85
89	11	0240	4968.4–4978.0	844.4–854.0	9.6	6.10	64
90	11	0500	4978.0–4987.7	854.0–863.7	9.7	5.05	52
91	11	0635	4987.7–4997.4	863.7–873.4	9.7	1.65	17
92	11	0825	4997.4–5007.1	873.4–883.1	9.7	1.43	15
93	11	1020	5007.1–5016.8	883.1–892.8	9.7	5.08	52
94	11	1225	5016.8–5026.5	892.8–902.5	9.7	2.21	23
95	11	1436	5026.5–5036.2	902.5–911.2	9.7	4.14	43
96	11	1650	5036.2–5045.8	911.2–921.8	9.6	7.65	80
97	11	1910	5045.8–5055.4	921.8–931.4	9.6	1.52	16
98	11	2135	5055.4–5065.0	931.4–941.0	9.6	0.55	6
					941.0	478.7	51

Table 1. (Continued).

Core	Date (August 1982)	Time (L)[a]	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Percent recovered
Hole 584A							
H1	12	1540	4125.0–4727.2	0.0–602.2	Drilled		
1	12	1730	4727.2–4736.8	602.2–611.8	9.6	2.45	26
H2	12	2120	4736.8–4823.8	611.8–698.8	Drilled		
2	12	2325	4823.8–4833.4	698.8–708.4	9.6	5.02	52
H3	13	0405	4833.4–4920.1	708.4–795.1	Drilled		
3	13	0615	4920.1–4929.8	795.1–804.8	9.7	3.19	33
H4	13	1130	4929.8–5026.5	804.8–901.5	Drilled		
					28.9	10.66	37
Hole 584B							
1	15	1252	4152.0–4153.4	0.0–1.4	1.4	1.64	117
H1	15	2240	4153.4–4661.7	1.4–509.7	Drilled		
H2	16	0315	4661.7–4796.1	509.7–644.1	Drilled		
2	16	0450	4796.1–4805.8	644.1–653.8	9.7	7.19	74
H3	16	1415	4805.8–4998.8	653.8–846.8	4.52 Drilled	4.52	100
H4	16	2103	4998.8–5095.1	846.8–943.1	Drilled		
3	16	2220	5095.1–5106.0	943.1–954.0	10.9	3.06	28
					26.52	16.41	62

[a] Time in this table is expressed as local time. To convert to Z times (Zulu times given in text), subtract 9 hours from local time.

584 beacon and the same distance away from Hole 584, which is located at the beacon. The location was selected to delineate the structural continuity of Hole 584, to determine the local structure, and in particular, to penetrate deeper than Hole 584. Because all bedding observed at Hole 584 is inclined east or northwest, westward offsetting was chosen in the hope of intercepting like horizons at shallower sub-bottom levels.

The drill string spudded in at a depth of 4115 m at 2011Z on 11 August. The PDR depth indicated 4094 m but the next deep reflector was 4117 m corresponding well with the drill pipe length. The hole was washed down to 602 m.

Core 1 was recovered from the depth of 611.8 m; its equivalent uppermost Miocene stratigraphic horizon in Hole 584 is some 50 m deeper. Another 100 m was washed down before taking Core 2 at 708.4 m sub-bottom. This core again indicated a 50-m stratigraphic offset. Core 3 was recovered from 804.8 m and is middle Miocene in age. Another 100 m was washed down, then Core H4 was retrieved from 901.5 m, the same lower-middle Miocene stratigraphic horizon as at Hole 584. Attempts to drill Core 4 were unsuccessful, because of a highly fractured zone, encountered near 870 m sub-bottom. Ultimately, the drill pipe stuck at 890 m at 0700Z, Friday, 13 August. After the pipe was freed, a shifting tool was pumped down, and the mechanical bit released at 0944Z in preparation for logging. After filling the hole with heavy mud, the pipe was pulled up to 120 m sub-bottom. Sonic and induction logs were run, but the tools malfunctioned. The second run (density, neutron, gamma ray, caliper) recorded data down to 495 m sub-bottom, at which point the hole was bridged. During a repeat run, the hole bridged at near 430 m sub-bottom. The sonde was on deck at 0415Z on 14 August, and the drill pipe was on deck at 1328Z the same day.

Hole 584B

The vessel started offsetting from the Site 584 beacon at 1331Z on 14 August, and arrived at the new hole

701.2 m to the east of the Site 584 beacon at 1325Z. Hole 584B is located at 40°28.0′N, 143°56.7′E. This position was selected to delineate the structural continuity of bedding inclination and of the paleontologic horizons from Hole 584, and, above all, to penetrate deeper.

After two water cores, the drill string spudded in at a depth of 4142.0 m. Evidently, PDR depth of 4113 m is not true bottom, but a second reflector from 4139 m does correspond to the drill pipe length to within 4 m. The hole was washed down to 509.7, then to 644.1 m sub-bottom. A spot core was taken at 644.1 to 653.8 m sub-bottom interval for stratigraphic control. Other wash cores were retrieved from 846.8 and 943.1 m sub-bottom. During the attempt to retrieve the last core barrel, the drill string began torquing and the pump pressure climbed. With time for Leg 87 fast running out, the final core was cut at 954 m. The hole was then filled with weighted mud. The pipe cleared mudline at 1657Z on 16 August and the bit was on deck at 1900Z.

The vessel, sounding its fog signal, left Site 584B at 2315Z on 16 August.

SEDIMENTOLOGY

Introduction

Hole 584, drilled about 42.5 km upslope from a midslope terrace, penetrated 941 m of Pleistocene to middle Miocene diatomaceous argillites. Variations in diatom content, number of ash beds, abundance of thin silt and very fine sand beds, abundance of pumice granules, and intensity of bioturbation enable us to distinguish three distinct lower Pliocene and Miocene units, divided into seven subunits (Fig. 4; Table 2). The thin Pleistocene mud at Site 584 (less than 4 m in Core 1) composes a fourth unit. Though we were unable to distinguish it visually from the soft lower Pliocene mud that it overlies in Hole 584, we assign the Pleistocene to a separate unit because the first wash core of our spot-coring program nearby in Hole 584A yielded a noticeably sandy Pleistocene mud. Most of the Hole 584 section is lower Pliocene and upper Miocene. The entire upper Pliocene and the upper part of the lower Pliocene are missing; this sequence may once have amounted to as much as several hundred meters of sediment or may never have been deposited.

We emphasize that unit or subunit boundaries are nowhere completely sharp. Many of the features that we use to subdivide our essentially rather monotonous mudstone section at Site 584 are minor components of the section. We expect some variation in any lithologic correlation with other drill sites in the Honshu forearc.

We will first describe the lithostratigraphy of Hole 584, then analyze the lithostratigraphic correlation of spot cores taken in Holes 584A and 584B. Next we will comment on ash content and on the evidence for late Miocene redeposition in the Site 584 area, and briefly describe the diagnostic abyssal *Chondrites-Zoophycos-Planolites-Cylindrichnus* ichnofauna that was beautifully preserved throughout the 584 section.

Strata below about 250 m sub-bottom (lower Pliocene) contain claystone-filled veins that cut bedding subperpendicular or at high angles (for details see following discussion of structural geology). The majority of these healed fractures indicate extension where offsets are evident, a conclusion supported by a spectacular fracture-fill system at 673 m sub-bottom (Core 584-71-2, Fig. 20). Anastomosing claystone-filled veinlets of probable dewatering origin, most commonly perpendicular to bedding, occur below 400 m (Core 584-42). The entire Miocene section is tilted from low to high angles (up to 70°), with an overall tendency for dip angle to increase downsection.

Throughout the descriptions below, core numbers refer to Hole 584 unless otherwise indicated.

Unit 1 (0 to 4 m sub-bottom, Sections 584-1-1 to 584-1-3)

Quaternary, dark olive gray diatomaceous mud occurs in the first three sections of Core 1, and the remainder of the core is lower Pliocene. Soft, locally soupy, sediments do not preserve an obvious lithologic or structural break between the two series. A thick glauconite layer at Core 584A-H1 marks a sharp break between Quaternary and lower Pliocene sediments.

Unit 2 (4 to 240.3 m sub-bottom, Section 584-1-3 to bottom of Core 25)

Predominantly olive gray diatomaceous mud and mudstone, Unit 2 is distinguished from Unit 3 by the paucity of sand and silt layers, and by the absence of dipping strata.

Subunit 2a (4 to 173.1 m sub-bottom, Section 584-1-3 to bottom of Core 18)

This subunit consists of lower Pliocene bioturbated dark olive gray to olive gray diatomaceous mud and local muddy diatomaceous ooze, consolidating below 88 m (Core 10) to diatomaceous mudstone and local muddy diatomite. Diatom contents locally in excess of 60% require that in places we call this sediment muddy diatomite (see Explanatory Notes chapter, this volume), but most of the section is diatomaceous mudstone. Smear-slide observations and X-ray diffraction analyses (see Inorganic Geochemistry section) define a continuous decreasing trend in the relative abundance of diatoms and opal-A throughout the Hole 584 units. Olive gray is the dominant color, but mottling to various hues of olive and gray occurs throughout the unit. Color mottling in places takes the form of obvious sharp burrow outlines and is clearly a manifestation of bioturbation; commonly mottling is more abstruse and less clearly associated with burrowing. Some light olive gray mottles are slightly calcareous, containing nannofossil concentrations of up to about 5% (e.g., Sections 584-13-2 and 584-13-4). Local vague lamination, defined by slight color changes in the mud, survives bioturbation.

Burrow forms include *Chondrites*, and minor *Zoophycus* and *Cylindrichnus*. The most common form is a large (up to 1 × 2 cm) *Planolites* trace. In such burrows, a common olive or pale olive color reflects slightly elevated diatom contents and/or a calcareous content (nannofossils or irresolvable micrite). Burrow margins are ovoid and, commonly, somewhat serrate; they are often marked by black rims.

Pumice clasts, ranging in size from coarse sand up to 15 mm pebbles, are present throughout the unit. These are commonly ovoid, and clearly *in situ*, enclosed within firm sediment. Rounded shale and acidic igneous rock fragments occur in drilling breccia at the top of several cores (Cores 10, 13, 15–17), which indicates that they are hole cavings. Ice-rafted pebbles of rocks exposed on Honshu are common in Pleistocene sections drilled during Legs 56 and 57 (Scientific Party, 1980), and the pebbles at Site 584 probably have a similar provenance.

Coarse-grained layers, mainly fine sand and silt, from several millimeters to several centimeters thick, are a minor feature throughout the unit. Commonly darker gray because of the concentration of pyrite grains, these are too diffuse to merit description as beds; their original features have doubtless been destroyed by bioturbation. At 105 m sub-bottom (Section 584-11-6), a 4-cm concentration of pumice and shale grains up to 3 mm in size, which contains a large benthic foraminifer, may conceivably have been introduced as a sandy turbidite. A sharp, irregular, inclined contact between light olive gray and olive gray mud at 107.6 m (Section 584-12-3) might be a slump scar.

Gray, muddy to sandy ash layers (up to 20 cm thick) are common throughout the unit. Many have bioturbated tops, and most are underlain by a zone of ash-filled burrows.

Carbonate concentrations occur at 12.5, 16.4, and 77 m sub-bottom. The example at 16.4 m is a nodule preserving dewatering veins. At 77 m (top of Core 9), a pale yellow calcareous nodule is associated with a 75 × 40 mm cobble of light yellowish brown barite nucleated on dark plant fragments (see Inorganic Geochemistry section of this chapter).

White sponge spicules are ubiquitous in this unit. Displaced bivalve fragments occur at 107 m (Section 584-12-1), 125 m (Section 584-14-1), and 146 m (Section 584-16-2). Greenish blebs, reflecting slightly glauconite-rich spots, are present locally (e.g., Section 584-13-6). Woody fragments are a minor component and include a 3-mm black lignitic layer at 103.5 m (Section 584-11-6).

The mudstone becomes indurated at 87 m (first saw cut in Section 584-10-2), and the first drill biscuits occur at 96 m sub-bottom. Poorly developed fissility occurs in Sections 584-15-4 and 584-17-2. The sediment texture is best described as firm throughout the unit.

Subunit 2b (173.1 to 202.1 m sub-bottom, Cores 19 to 21)

This subunit contains lower Pliocene light olive gray to olive gray firm laminated diatomite and diatomaceous mudstone, only locally bioturbated. Thin (1 to 3 mm) laminations of lighter-colored diatom-rich sediment alternating with more muddy laminae predominate in Cores 19 to 21. A strong H_2S odor, local dark organic-carbon-rich streaks, and pyritic laminae combine with only local burrowing to indicate a period of relative oxygen-impoverishment in the bottom waters. The parallel-laminated sections are interlayered with burrowed levels, and the burrows in Section 584-20-2 attain the large dimensions of the best-developed examples of *Planolites* in the previous unit. The most complete laminated interval occupies Sections 584-20-1 to 584-20-5.

Other features of Subunit 2a persist: several thin ash layers, and a very fine sand layer in Section 584-20-2. Sponge remains occur in Core 20. Slight fissility is developed in Sections 584-20-5 and 584-20-6.

The laminated nature of this unit may indicate that diatom productivity fluctuated in the Pliocene waters off Honshu, explaining the alternation on a millimeter-scale of thin laminae rich in diatoms and more muddy sediment. If so, evidence of such a means of sedimentation would have been obliterated by burrowing or drilling deformation in the majority of the section at Site 584.

Subunit 2c (202.1 to 240.3 m sub-bottom, Cores 22 to 25)

Like Subunit 2a (lower Pliocene), Subunit 2c marks a return to well-aerated bottom conditions, with bioturbation generally prominent in the mud. Most of the features listed for Subunit 2a occur also in 2c. Fine sandy layers up to 1 cm are a minor feature of Cores 22, 24, and 25. In Core 24, a diffuse concentration of fine-sand grains includes quartz, feldspar, brown and green hornblende, and plant debris. In Section 584-24-2 a large pumice clast (8 × 5 mm) occurs, and in Section 584-24-3 more than 14 ovoid to flattened pumice granules are concentrated in a 15-cm interval, perhaps representing transported ejecta from one major arc eruption.

The top of Core 25, the last belonging to Subunit 2c, contains granules and pebbles (28 mm maximum) of red chert, limestone, sandstone, siltstone, shale, and dacite. Although this segment is probably best interpreted as hole cavings, it is surprising that we recovered no exotic pebbles or granules in our *in situ* Pleistocene recovery (Core 1).

Unit 3 (240.3 to 536.6 m sub-bottom, Cores 26 to 56)

Predominantly dark olive gray to olive gray diatomaceous mudstone, Unit 3 is distinguished from Unit 2 by relatively common thin fine sand and silt beds, and scattered concentrations of grains in mudstone, especially in Subunit 3b. Strata are inclined and contain healed fractures. Unit 3 is distinguished from Unit 4 by higher diatom content, more abundant ash layers, and relative abundance of large carbonate-rich burrow mottles.

Subunit 3a (240.3 to 354.6 m sub-bottom, Cores 26 to 37)

This subunit contains lower Pliocene diatomaceous mudstone, noticeably more indurated than Subunit 2c, with inclined beds and healed fractures. There is little difference in lithology between Subunits 3a and 2c. Most significant, however, is the appearance of inclined bedding in Core 26. Slightly inclined lamination is visible locally in Core 24, but in Core 26 and below, to the base of the hole, all bedding traces (sandy layers, lamination, and, most commonly, burrow alignments) are inclined. The sediments first merit description as completely lithified rock in Core 27. Although the lithologic contrast is not marked, we choose to distinguish Units 2 and 3 because the inclined bedding would be an easily mappable

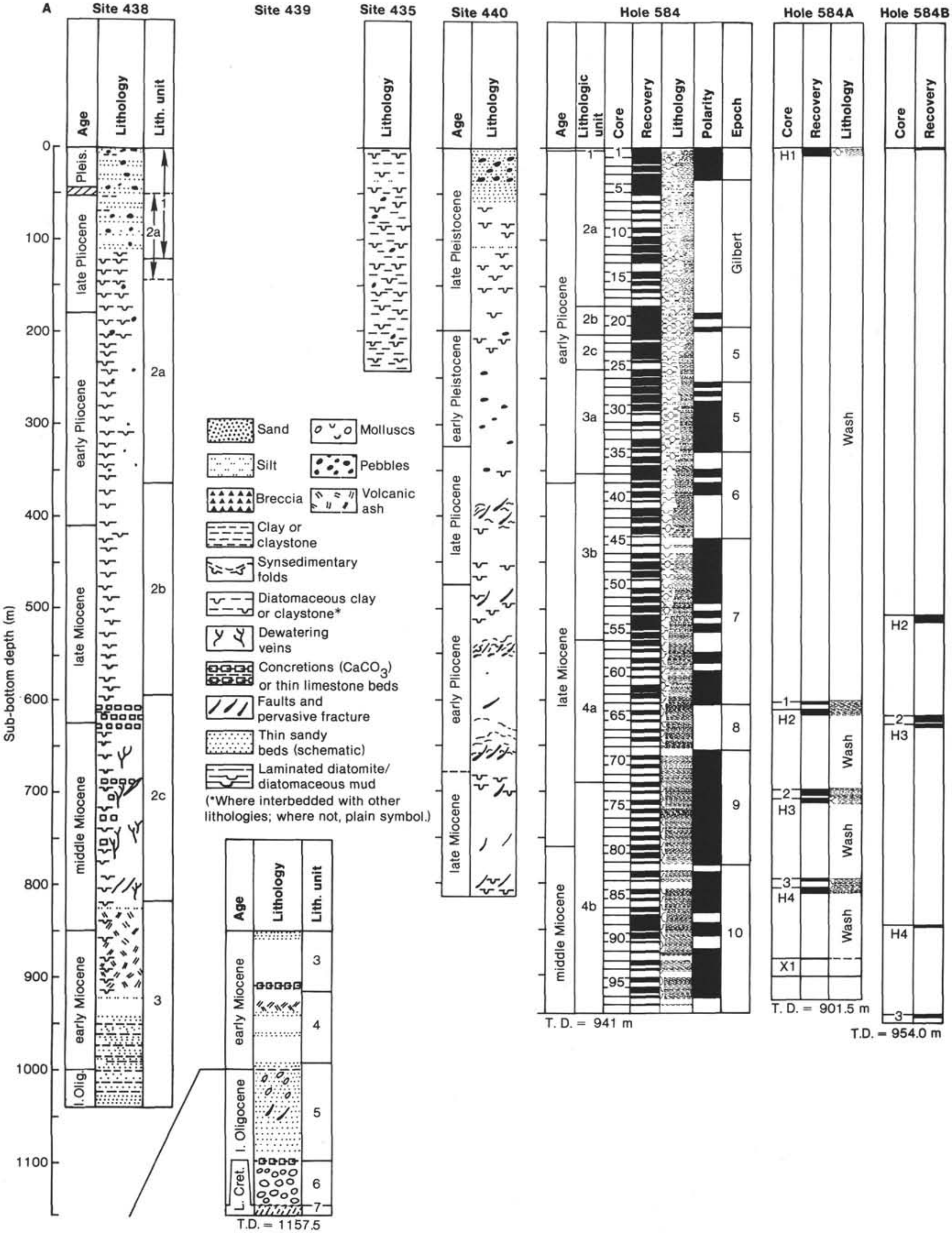


Figure 4. A. Summary lithology for Sites 438, 439, 435, 440, and 584, visual smear-slide estimates, and number of ash layers per Ma for Site 584. T.D. = total depth. B. The frequency of volcanic activity through time, as recorded in ash layers at Site 584. Inset figure is the plot of number of ash layers per year versus sub-bottom depth and stratigraphic assignment (based on diatoms).

A (cont.) B

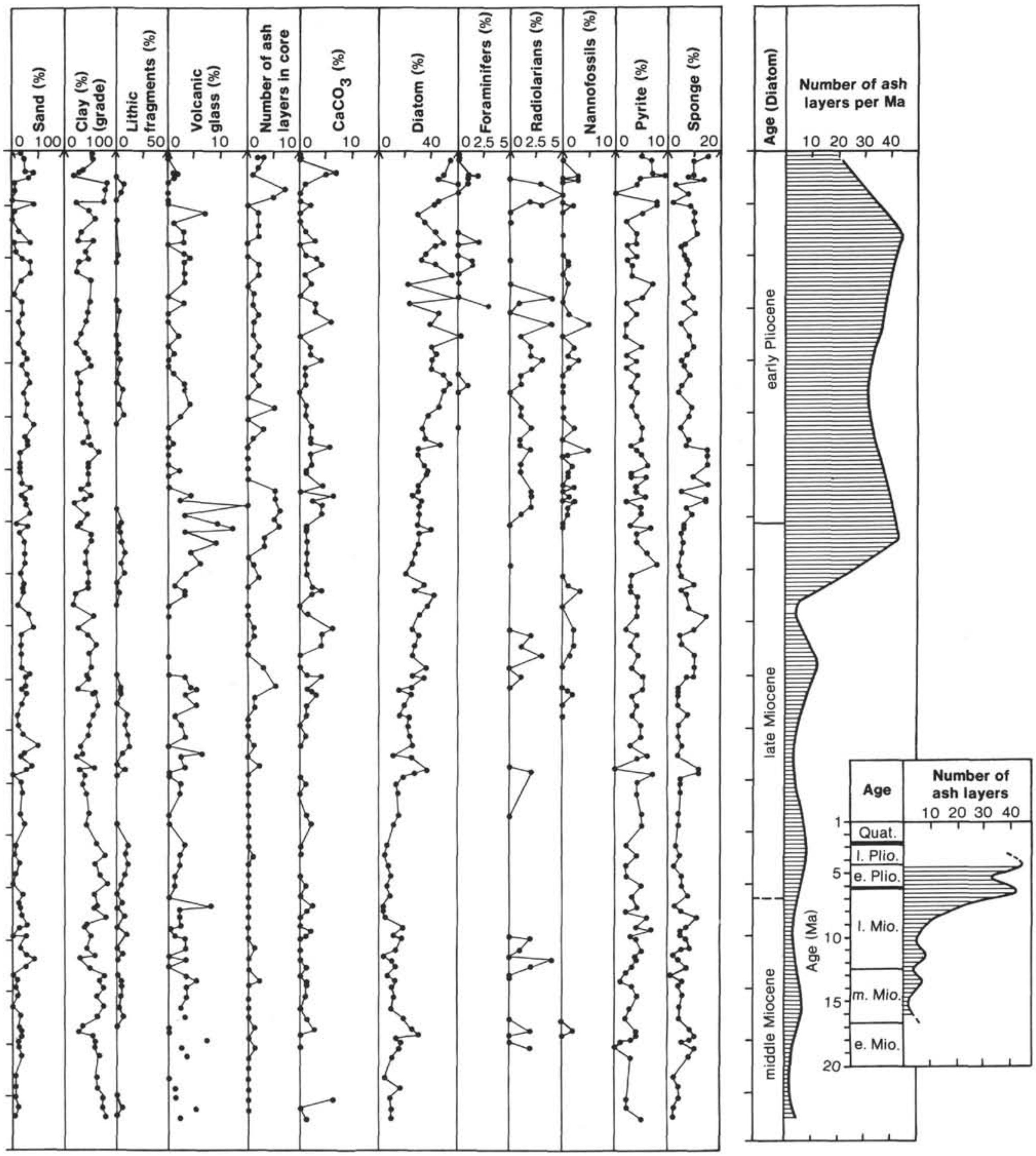


Figure 4. (Continued).

feature were the Site 584 area to be exposed subaerially. Additionally, we suspect that Core 25, as a zone of poor recovery with abundant hole cavings in a portion of the section otherwise characterized by excellent recovery, may represent a tectonic break of some kind.

Burrows are abundant throughout. Many are large *Planolites* traces, more olive than the surrounding mudstone, imparting a characteristic greenish gray and olive blotchy appearance to the sediment. *Zoophycos* trails pick out the bedding clearly, in all but a very few cases being exactly parallel to fine-sand layers and laminations.

Thin ash beds are common in Subunit 3a, though pumice granules are less common than in Unit 2, occurring only in Cores 27, 30, and 37.

Table 2. Lithologic units, thickness, age and description for Hole 584.

Lithologic unit (Thickness in m)	Core or Section	Sub-bottom depth (m)	Age	Lithology
Unit 1 (4)	1-1 to 1-3	0 to 4	Quaternary	Dark olive gray diatomaceous mud—erratic pebbles?
Unit 2 (236)	1-3 to 25	4 to 240.3	early Pliocene	Predominantly olive gray diatomaceous mud and mudstone; distinguished from Unit 3 by paucity of sand and silt layers, and by absence of dipping strata.
Subunit 2a (169.1)	1-3 to 18	4 to 173.1	early Pliocene	Dark olive gray to olive gray diatomaceous mud and local muddy diatomaceous ooze, consolidating below 88 m (Core 10) to diatomaceous mudstone and local muddy diatomite; bioturbated throughout.
Subunit 2b (29)	19 to 21	173.1 to 202.1	early Pliocene	Light olive gray to olive gray firm laminated diatomite and diatomaceous mudstone; only local bioturbation.
Subunit 2c (28.7)	22 to 25	202.1 to 240.3	early Pliocene	Like Subunit 2a—some pure sandy layers.
Unit 3 (305.8)	26 to 56	240.3 to 536.6	early Pliocene to late Miocene	Predominantly dark olive gray to olive gray diatomaceous mudstone; distinguished from Unit 2 by relatively common thin fine sand and silt beds, and scattered concentrations of grains in mudstone especially in Subunit 3b; strata inclined, with healed fractures; distinguished from Unit 4 by higher diatom content, more abundant ash layers, and relative abundance of large carbonate-rich burrow mottles.
Unit 4 (404.4)	57 to 98	536.6 to 941.0	late to middle Miocene	Predominantly diatomaceous mudstone and mudstone (various green, gray, olive, and bluish hues); lower diatom content (and very minor olive burrow mottles) and fewer ash layers than Unit 3.
Subunit 4a (153.6)	57 to 71	536.6 to 680.6	late Miocene	Intensely bioturbated predominantly dark olive gray diatomaceous mudstone; sandy layers continued from Subunit 3a, but much more abundant, commonly graded, and in some cases overlain by gray, relatively structureless mudstone (probable muddy turbidites).
Subunit 4b (250.8)	72 to 98	680.6 to 941.0	late and middle Miocene	Intensely bioturbated diatomaceous mudstone, varicolored including dark greenish gray, grayish olive green, local dusky green, and olive gray streaks, with abstruse bluish hues, especially in lower cores; reduced number of sandy and silty layers, minor mud turbidites.

Glauconitic spots (Core 37), pyritic streaks and laminae (Cores 29, 35, and 36), flecks of organic carbon (Core 34), sponge spicules, and wood flakes (Core 37) are minor features of the section. Another barite nodule, similar to the one seen recovered in Subunit 2a, occurs at 283 m sub-bottom (Section 584-30-4).

Subunit 3b (354.6 to 536.6 m sub-bottom, Cores 38 to 56)

This subunit consists of upper Miocene highly bioturbated olive gray diatomaceous mudstone. There is a progressive increase in fine sand and silt with increasing sub-bottom depth.

The Pliocene/Miocene boundary occurs between 584-38,CC and 584-39,CC: the absence of an obvious lithologic contrast in Core 39 suggests that the transition is not marked by a hiatus in sedimentation.[3]

In Section 584-38-2, very fine sand is scattered in the mudstone. In Section 584-38-3, a thin, very fine sandy layer occurs in association with a very diffuse slight increase in sand comprising grains of volcanic glass, quartz, and feldspar. Below this level, sand and silt become progressively more important, but do not approach the status of the other major constituents.

Large olive-colored burrows are abundant and some of the best examples of their serrated form occur in Core 52 (Fig. 5). These occur in discrete intervals throughout the subunit and are generally richer in carbonate than the surrounding groundmass. At 522 m (Section 584-55-4), a 30-cm olive interval comprises calcareous matrix as well as burrow fills. Smear slides show that carbonate is a finely disseminated micrite.

Minor components of Subunit 3b are glauconite (nucleated on dark organic matter in Core 43), and a shell fragment, possibly from a gastropod, at 442 m sub-bottom (584-47-1, 120 cm). Sponge spicules are less common in this subunit than anywhere else, occurring only in Cores 38, 43, 47, and 53. Most of the sand is very fine grained, occurring as thin abstruse layers or being finely

[3] The position of the Pliocene/Miocene boundary was revised several times after the initial shipboard analyses. That contact is now placed between Cores 45 and 46. For details, see Akiba (this volume).

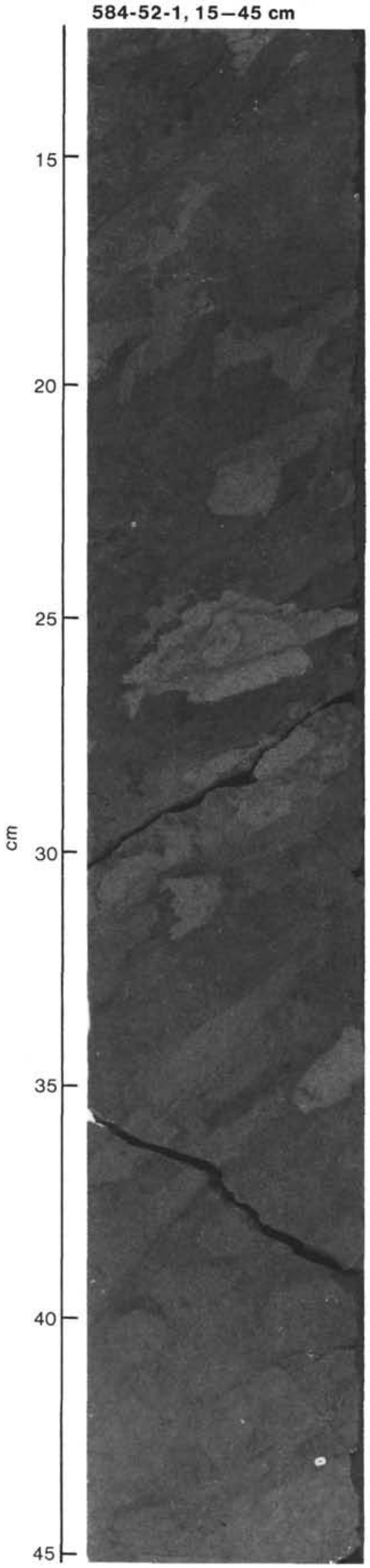


Figure 5. Serrated burrows in Core 584-52.

disseminated in the mud, probably as a result of bioturbation. The coarsest occurrence is at 402.5 m, a 5-cm soft coarse muddy sand in the core catcher of Core 42. In Section 584-36-4, two distinctive coarse pumiceous sand beds occupy 13 cm of section. Both have sharp bases and are mud rich. Their coarse to medium grains are distribution-graded. They may represent low-density muddy turbidity currents, capable of grading sand of up to coarse grain size because of the low density of pumice.

Unit 4 (536.6 to 941 m sub-bottom, Cores 584-57 to 584-98)

This unit contains upper to middle Miocene predominantly diatomaceous mudstone and mudstone (various green, gray, olive, and bluish hues). It has a lower diatom content (and very minor olive burrow mottles) and fewer ash layers than Unit 3.

Subunit 4a (536.6 to 680.6 m sub-bottom, Cores 57 to 71)

Upper Miocene intensely bioturbated diatomaceous mudstone, predominantly dark olive gray, composes this subunit. Sandy layers continue from Subunit 3a, but are much more abundant, commonly graded, and in some cases are overlain by gray relatively structureless mudstone (probable muddy turbidites).

The large olive mottles so prominent in Core 56 are missing in Core 57 and do not reappear. Two further examples of the olive carbonate-rich horizons seen in Subunit 3b (Core 55) occur. The first occupies 12 cm of section in Section 584-58-1, the second 30 cm in Section 584-63-3. A 2-cm limestone concretion occurs at 594 m (Core 63-1).

The first clear example of a muddy turbidite occurs in Core 57 (Fig. 6). These deposits are discussed in a later part of this section.

Subunit 4b (680.6 to 941 m sub-bottom, Cores 72 to 98)

This upper and middle Miocene diatomaceous mudstone, varicolored including dark greenish gray, grayish olive green, local dusky green, and olive gray streaks, with abstruse bluish hues (especially in lower cores), is intensely bioturbated. The numbers of sandy and silty layers and minor mud turbidites are reduced.

Subunit 4b commences in Core 83, where the diversity of colors, bioturbation, and intense dewatering veinlets led us to christen the facies "paisley" mudstone. Diatom and opal-A concentrations are higher than in Subunit 4a (Fig. 4). Pumice granules are more common than in 4a, but ash layers are still few (Cores 83, 88, and 89). Mud turbidites are limited to Core 95. An interesting 4-cm olive calcareous bed (and underlying burrow fill) at 626.7 m (Section 584-87-2) and a 4-cm-thick dolomitic sandy mudstone bed at 903 m sub-bottom (Section 584-95-1, Fig. 7) may be carbonate turbidites; the bases are sharp, and tops gradational. Smear slides show no nannofossils and structureless clay-grade carbonate. Glauconitic concentrations are more common than in any of the previous subunits, locally tinting the sedi-

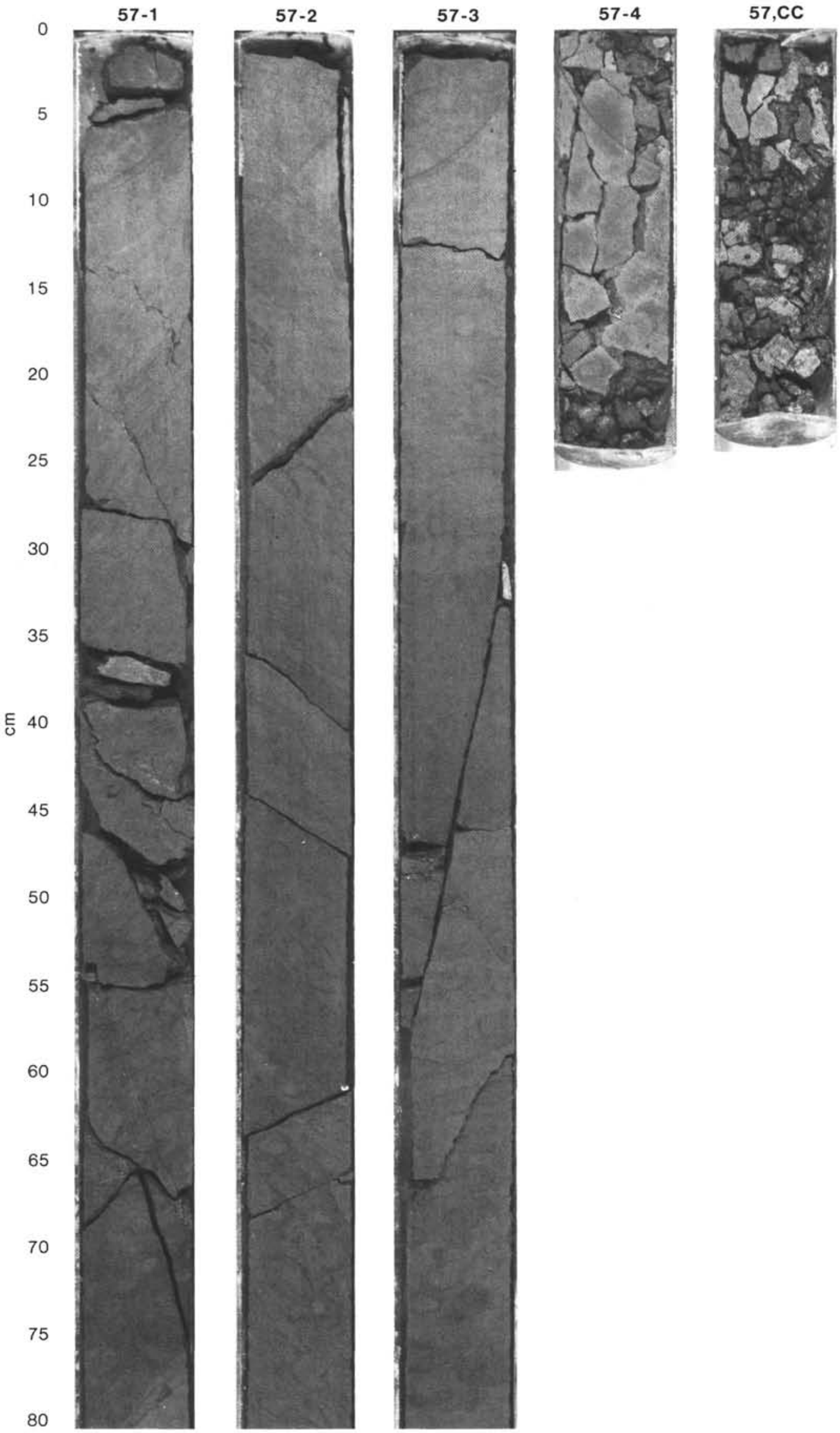


Figure 6. Mud turbidites in Core 584-57. Sub-bottom depth = 536.6–546.1 m.

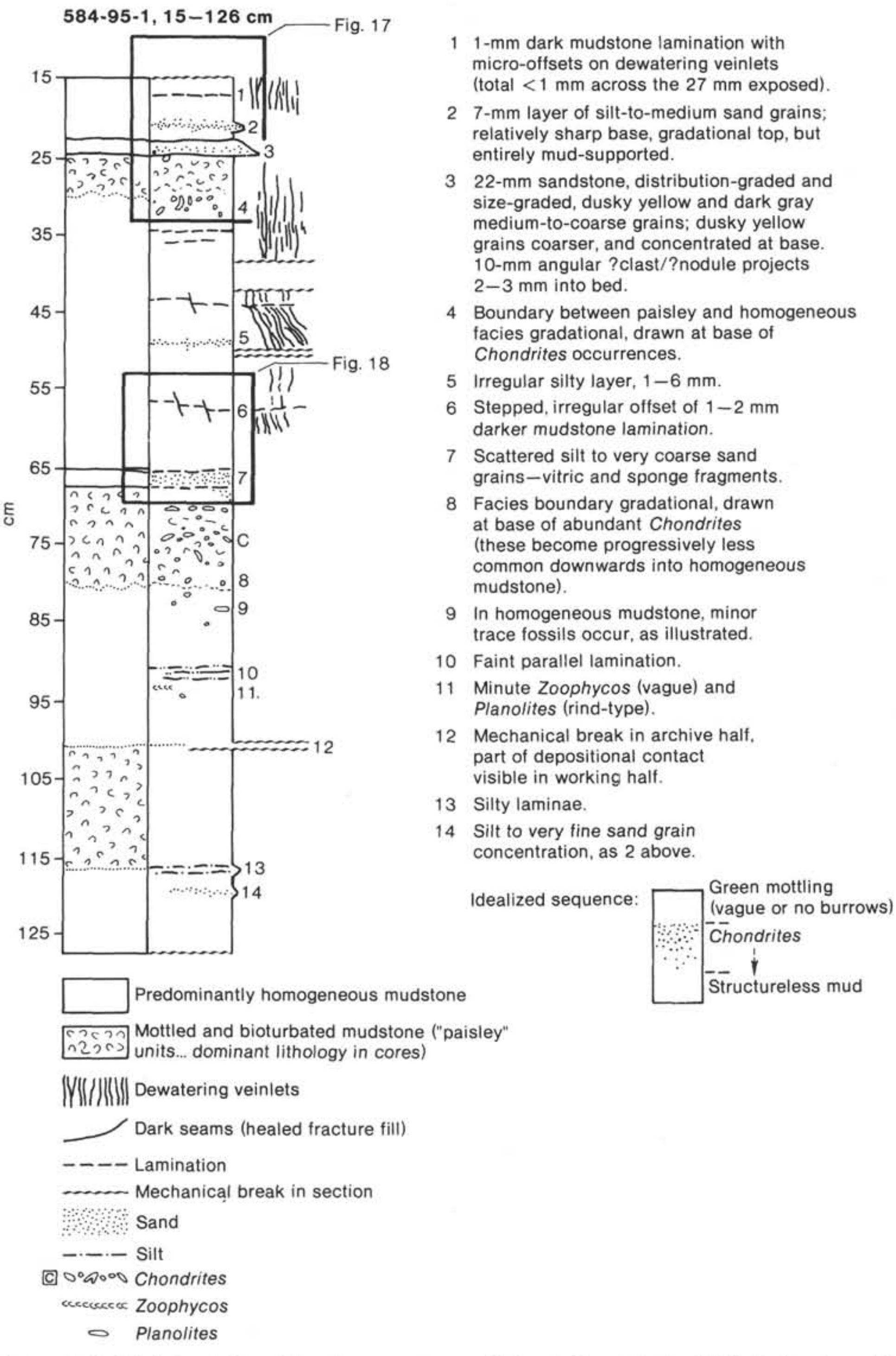


Figure 7. Detailed description of lithology, structure, and ichnofacies of Section 584-95-1. Numbers refer to features discussed in text.

ment dusky green. At 817.2 m (584-58-2, 120 cm), an 8-mm dusky green muddy bed has a sharp base and fills underlying burrows. The bed grades back to the normal greenish gray color, and smear slides show glauconite grains, pyrite, and minute zircons, suggesting a turbiditic origin. Carbonate nodules occur at 873.7 and 885.5 m sub-bottom.

Hole cavings, including limestone pebbles, occur at the top of Cores 84 and 92.

Spot Cores and Wash Cores at Holes 584A and 584B: Description and Correlation with Hole 584

We sampled the Miocene section briefly in holes 524 m upslope (Hole 584A) and 700 m downslope (Hole 584B) of Hole 584. Despite steep dips in all cores recovered, the lithologies correlate remarkably well with those retrieved at similar depths in Hole 584 (Fig. 4).

Core 584A-1 (602.2 to 611.8 m sub-bottom), taken at the equivalent level of middle Subunit 4a, recovered classic "mud turbidite" facies of Subunit-4a type. Several thin sand layers are overlain by graded silty mudstones, with *Chondrites*-burrowed tops. This facies is superbly preserved in the next core, Core H2 (611.8 to 698.8 m sub-bottom), which most likely represents the section immediately below Core 1 (about 615 m; A. C. Wheeler, Jr., drilling superintendent, pers. comm.). Some of these mud turbidites are illustrated in Figures 6 and 8 and discussed in the Upper Miocene Mud Turbidites section.

Core 584A-2, 698.8 to 708.4 m sub-bottom (a level equivalent to the top of Subunit 4b), recovered grayish olive burrow-mottled mudstone with common *Zoophycos* traces and dewatering veinlets. The absence of sand in this core, and the fact that it does not possess the typical "paisley" mudstone attributes of the lower portion of Subunit 4a are consistent with a position in the upper part of the subunit. Wash Core H3 (708.4 to 795.1 m sub-bottom) contains a similar facies to Core 2; it includes a well-developed healed fracture network and a thin ash layer.

Core 584A-3, 795.1 to 804.8 m sub-bottom (a level equivalent to the middle portion of Subunit 4b), contains many though not all the attributes of the "paisley" mudstone facies. It is a dark olive gray bioturbated mudstone with common *Zoophycos* tracks, healed fractures, and microveins. Blue green hues in the mudstone from Core 584A-H4 (804.8 to 901.5 m sub-bottom) are even more reminiscent of the "paisley" mudstones.

Hole 584A caved in at about 890 m sub-bottom, several tens of meters higher than had been the case in Hole 584.

The first core in Hole 584B (0 to 1.4 m sub-bottom) recovered soupy surface diatomaceous mud. Wash Core 584B-H1 (1.4 to 509.7 m) retrieved coarse vitric sand with a variety of granules and pebbles, and included a light yellow calcareous layer, which conceivably derives from the same level as the prominent carbonate layer in Subunit 2a in Hole 584 (Section 584-9-1, 77 m sub-bottom).

Diatomaceous mudstone in Core 584B-H2 (509.7 to 644.1 m sub-bottom) makes up a well-preserved and nearly complete section containing large yellow serrated burrow fills typical of Subunit 3b (see Fig. 5). The lithologic correspondence of these features suggest that the core derives from the top of the washed interval, at a depth equivalent to the lower part of Subunit 3b.

Core 584B-2, 644.1 to 653.8 m (a level equivalent to the lower middle portion of Subunit 4a in Hole 584), recovered sediment devoid of the large olive serrated burrows. Next, a wash core H3 (655.8 to 846.8 m sub-bottom) contains splendidly preserved mud turbidite facies, suggesting that it derives from the top of the washed interval, at a level equivalent to the lower part of Subunit 4a. Numerous thin, fine sand layers grade into dark silty mudstone and mudstone layers, commonly with *Chondrites*-burrowed tops, in Core H3. Well-preserved cross lamination, minute mudstone rip-ups, and a small-scale slump fold (overturned up-dip!) strongly argue for a turbiditic origin for these cyclic beds.

Wash Core 584B-H4 (846.8 to 943.1 m sub-bottom) recovered classic "paisley" mudstone facies at the same depth as it occurs in Hole 584. The greenish gray, bluish gray, and locally olive gray hues, intense anastomosing veinlets, and abundant burrows with common *Zoophycos* make this a highly distinctive rock type that would be worthy of ornamental stone if exposed on land.

Core 584B-3 recovered more "paisley" mudstone between 943.1 and 945.0 m sub-bottom. Hole 584B caved, 13 m deeper than in Hole 584. Three hole cavings at the same depth along a 1-km line perpendicular to the trench is surely significant (see Structural Geology section, this chapter). In the words of the eminent British philosopher James Bond, "Once is happenstance, twice is circumstance, three times is enemy action."

Volcanogenic Sediments

The Japan Trench provides an excellent opportunity to examine the Tertiary and Quaternary record of explosive volcanic activity of the Tohoku (northeastern Japan) Arc preserved at Site 584, located downwind, approximately 300 km to the east, from the volcanic source area. The history of explosive volcanism is related to tectonic processes occurring on the active margin.

Volcanogenic sediment recovered at Site 584 includes pumice fragments, distinct ash layers, bioturbated ash "pods" or "pockets," and dispersed glass shards. Pumice fragments were probably transported primarily by surface currents or by wind, eventually becoming waterlogged and sinking through the water column. These fragments are present more or less throughout Site 584 sediments and are abundant in some cores (e.g., Cores 1, 10, 11, and 37). Their shape is variable, generally rounded, sometimes angular, ranging from 1 mm to 5 cm in diameter. They are white or whitish gray in color and show typical degassing structure.

Volcanic ash layers are numerous (more than 100). Most of the ash is probably deposited by settling through the water column after being transported to the area through the atmosphere by the prevailing westerlies. Graded beds are frequent, however, and ash is sometimes intimately mixed with terrigenous or biogenic components, suggesting redistribution and resedimentation by either turbidity currents or other bottom currents. Thickness of these ash horizons is also very variable, but generally they are thin (2 to 3 cm) because of their distance from the volcanic arc. Some layers are as much as 10-cm thick (Sections 584-16-2; 584-38-2; and 584-53-2), with a maximum thickness of 20 cm (Section 584-17-3). Color ranges from dark gray to bluish gray (2.5Y 4/2), light gray, and white; coarser horizons (sandy or silty) appear to be darker in color than the finer-sized deposits. Bioturbation and mottling of the ash-containing sediments occurs frequently (Sections 584-15-3 and 584-15-4; and 584-24-4), and ash layers are redistributed as pods or pockets. Burrow fillings composed almost wholly of ash are also common and are usually found in the sediments immediately beneath the ash layers.

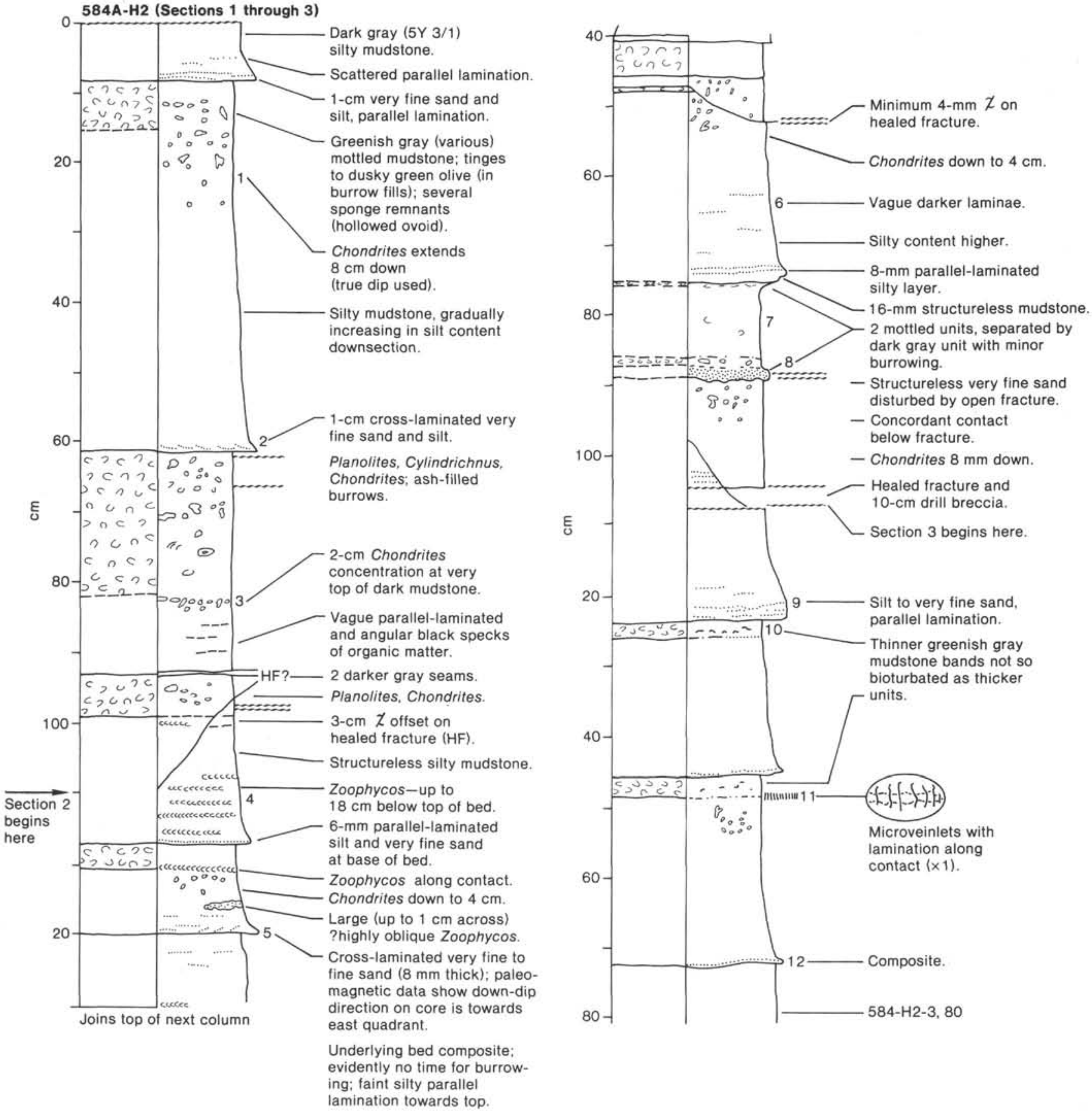


Figure 8. Detailed description of lithology, structure, and ichnofacies of Core 584A-H2. Healed fractures with <3 mm offset are omitted. Numbers refer to features discussed in text. For symbols, see Figure 7 key.

Optical petrography of the glass shards shows two different shapes: bubble wall and pumice types, as angular and elongated grains. These shards are translucent and isotropic, and they have low refractive indexes. Compositions are estimated visually to be primarily dacitic, rhyodacitic, and rhyolitic. Minor occurrences of dark to pale brown shards dispersed throughout the cores are more basic in composition (basaltic to andesitic). Grains are mostly of silt-sized clear glass shards, suggesting transport over a considerable distance from the volcanic source region. Phenocrysts range in abundance from 2 to 3% to a maximum of 20%, and consist mainly of quartz, plagioclase, brown and green hornblende, biotite, clinopyroxene, and opaque minerals. Rarely, they include large amounts of tiny round pyrite micronodules. Sand-sized volcanic ash layers often include variable amounts (from 10 to 25%) of lithic fragments, diatoms, and sponge spicules.

In addition to the occurrence of volcanic ash as distinct layers, small amounts of glass shards (0 to 3%) are dispersed within the sediment. Variation of the dispersed component with sub-bottom depth follows the number of volcanic ash layers. Where distinct ash layers are abundant, slightly higher concentrations (from 10 to 30%) of dispersed shards occur in adjacent sediments, as determined by smear-slide observations.

Alteration of the volcanic glass shards is negligible throughout. Petrographic examination of glass shards as old as middle Miocene (the oldest sediment penetrated at this location) shows them to be optically isotropic and virtually unaltered.

The occurrence and distribution of volcanic ash layers in these sediments record episodes of explosive volcanism along the Japanese island arc. More than 200 distinct volcanic ash units were recovered in the various sites drilled during DSDP Legs 56 and 57; the data were used in establishing curves correlating frequency with age of the volcanic activity. Analysis of the distribution of the volcanic ash layers in Hole 584 sediments (Fig. 4A) shows that they are mainly concentrated between Cores 3 and 6 and between 33 and 43, and they are scarce below Core 63 (Fig. 4A). The number of volcanic ash layers reaches a distinct maximum in the Pliocene sediments of Cores 33 to 43 (Fig. 4B and Fujioka, this volume). This concentration of ash units strongly suggests an increase in volcanic activity since the early Pliocene. This pattern is quite similar to the results obtained at Sites 438 and 440, Leg 57 (Shipboard Scientific Party, 1980a, c) where volcanic ash abundance begins to increase at the end of Miocene and remains high during the first two-thirds of the Pliocene. After a period of decreased abundance, ash layers are again numerous in the upper Pleistocene.

The history of late Pliocene and Quaternary explosive volcanism in this area is poorly known because of the scarcity of data; at Site 584 the thickness of Quaternary sediments is only about 4 m, and no volcanic ash layers were found within this interval. Leg 56–57 sites having thick Quaternary sections show a slightly higher concentration of volcanic ash layers. Also, in the nearshore Japan Trench region, several diagnostic volcanic ash layers were obtained by piston-coring (Ocean Research Institute Cruise reports, Cruises KH80-1, KH81-3, in prep.; Cruise KH77-1, Nasu et al., 1980). By their chemical composition, these tephras were correlated with the eruption of the Towada volcanoes (about 26,000 yr. and younger). In the northeastern Japan Arc, many active volcanoes are known, and Towada, Iwaki, Nasu, and Chokai are just a few examples. Therefore, high concentrations of acidic volcanic ash layers are expected in the Quaternary sediments. Evidently, explosive volcanism was much more intense during the Pliocene than in the Quaternary (Cadet and Fujioka, 1980), a conclusion tentatively confirmed by our drilling in the Japan Trench during Leg 87.

Upper Miocene Mud Turbidites

In Subunit 4a, and to a lesser extent in 4b, thin sandy beds are in places overlain by several decimeters of structureless or less than normally bioturbated mudstone, darker than the normal mudstone. A crude cyclicity is evident in such cases. A thin silt, very fine sand or sand layer (several mm to about 1 cm) sits with a sharp contact on normal mottled diatomaceous mudstone. In many cases, lamination is preserved in the sand, most commonly parallel lamination, but in places cross lamination, ripple drift lamination, or rarely climbing ripple lamination. The sandy layer passes gradationally into mudstone, in some cases with diffuse laminae of very fine sand in the lower part. The mudstone is commonly dark gray, contrasting with the greenish and grayish hues of the normal mottled mudstone. Such darker mudstone layers reach a maximum thickness of 45 cm (Section 584A-H2-1, Fig. 8), are commonly structureless for much of their thickness, and in many cases grade diffusely from silty mud in the lower portion to claystone or less silty mud in the upper portion. A distinctive and very common feature of such layers is a concentration of *Chondrites* in the upper few centimeters, with a progressively decreasing number of *Chondrites* burrows up to 10 cm down into the dark gray mudstone layer.

Smear slides show the mottled mudstone comprises 75% clay and 20% silt; the dark mudstone contains up to 70% silt and 20% clay, being richer in quartz, feldspar, lithic fragments, and heavy minerals. Preliminary X-ray mineralogy results show the mottled mudstone richer in smectite than the dark mudstone.

These cycles in a thick diatomaceous mudstone section (moderately to intensely burrowed more or less throughout) pose two interesting questions. First, how are the thin sandy or silty layers at the base of the cycles preserved from destruction by burrowing, as has clearly been the case in Subunit 3a? Second, how can much of the dark gray mudstone overlying the sandy or silt layers be devoid of burrowing?

We suggest that the thin sand-silts and dark mudstones are deposited by muddy, low-density turbidity currents. The thin sands and silts would represent the coarse fallout, and the dark structureless mudstone would represent deposition from the main body of the muddy current. Rapid deposition of the lower, commonly more silty, portion of the dark mudstone favors preservation of the thin basal sand or silt. Deposition of the remainder of the mud before recolonization by benthic organisms means that only the deeper burrowers reach the lower levels of the dark mudstone. In this way, the thicker dark mudstone units remain structureless or preserve vague parallel lamination probably formed during deposition from suspension as the muddy current waned. The cycle is completed by ambient hemipelagic sedimentation, forming the normal intensely burrowed and mottled diatomaceous mudstone.

First observed at ~540 m sub-bottom (top of Subunit 4a, Core 584-57), the muddy turbidite cycles are best preserved in Cores 584-95 (~905 m sub-bottom, Subunit 4b; Fig. 7), and 584A-H2 (about 615 m sub-bottom, Subunit 4a; Fig. 8). Measured sections from these cores illustrate the cycles, and highlight some complexities that qualify our interpretation. Numbers on Figures 7 and 8 refer to items in the following text. Numbering is sequential down the sections.

Sandy layer bases are invariably sharp, and usually flat (Fig. 8). Rare erosional bases are particularly well displayed in Core 584B-H3 (Subunit 4a, 654 m sub-bottom). Between the 115 and 120 cm levels in Section 584B-H3-1, a highly irregular bed base has a relief of several millimeters across the width of the core, and the underlying mud intrudes into the sand layer as a tilted mud-stringer ($\sim 10 \times 1$ mm), lying at a low angle to bedding in the manner of a rip-up clast. Elsewhere in the core, several isolated lenticles of mudstone in sand layers probably represent detached rip-up clasts.

Cross-laminated sandy layers (Fig. 8, #2, and #5) are less common than parallel-laminated layers. Measurements suggest that the downdip direction is east throughout the core. In Core 584A-H2, several cross laminations demonstrate (in dip-section) downdip paleocurrents (i.e., eastwards). As expected, that flow-direction followed the present downslope direction. However, in Cores 584B-2 and 584B-H3, several micro-cross-laminated sandy layers show the opposite direction of paleocurrent flow. From this sequence we can infer either a local slope reversal in the Hole 584B area sometime in the late Miocene or a highly irregular current flow (not inconceivable in low-density, muddy turbidity currents).

The depth to which the *Chondrites* organism penetrated the newly deposited mud varies between 2 cm (Fig. 8, #3) and 8 cm (Fig. 8, #1). Nowhere did we observe more than 10 to 15 cm of penetration (allowing for dip correction). The *Zoophycos* organism may have been able to penetrate slightly deeper. One 18-cm dark, otherwise structureless mudstone contains *Zoophycos* throughout (Fig. 8, #4). These maximum depths of penetration agree with Ekdale's (1974) estimates based on an exhaustive study of abyssal bioturbation in DSDP cores. They require that completely structureless dark mudstone is only likely in turbidite sand-mud couplets more than 20 cm thick. This relationship is clear in Figure 8,and we found it generally reliable elsewhere in Subunit 4a.

As in any kind of mass-flow facies, however, breaks in cyclicity are common. Sand-mud couplets occur in places (Fig. 8, #5 and 12; Fig. 7, #2). Probable mud turbidites, without the basal thin sand or silt layer, also occur (see possible example at #7, Fig. 8). If amalgamated sequences of essentially ungraded mud turbidites formed, they would be particularly difficult to recognize. Sand layers without the characteristic dark gray, overlying, graded silty mud (Fig. 8, #8) might represent coarse fraction deposition under a muddy turbidity current that carried its fine-fraction load to another part of the slope.

A further complicating factor may arise in the nature of the turbidity-current generating process. The mud turbidites clearly derive from a source area devoid of coarse terrigenous detritus. Many are relatively thick (40 to 50 cm). A relatively local source on the slope therefore appears most likely. In slope settings, failure of oversteepened or tectonically mobilized muddy sediment piles often occurs in a series of steps, cutting back from an initial, major failure scar. This sequential caving can generate pulses of mass-flow (retrogressive flow sliding). One failure event on a slope may therefore generate a series of mass-flow deposits, generally decreasing in magnitude, essentially inseparable in terms of geologic time. Sequential muddy turbidity currents may therefore have been involved in deposition of the thicker mud turbidites at Site 584. The thin basal sandy layer and graded portion of the overlying dark mudstone may represent the initial major failure and consequent mass flow. If there were one or more additional compensating failures on the same source scarp, consequent low-density, muddy turbidity currents could be represented in the bulk of the dark mudstone.

Bioturbation

The *Chondrites-Zoophycos-Planolites-Cylindrichnus* assemblage, characteristic of the abyssal environment, occurs throughout Site 584. The form taken by these trace fossils is as described by Ekdale (1974). Here we comment only on their distribution. There is no obvious pattern downsection. We suspect a slight overall increase in bioturbation downwards, although this is unquantified. Certainly the lower cores of Subunit 4b ("paisley" facies) are excessively bioturbated, compared with many cores above, though this may in part derive from diagenetic enhancement. Large (up to 2 cm) olive, commonly slightly serrate *Planolites* burrows are absent below ~ 530 m sub-bottom (base of Subunit 3b), and we detect a more obvious downhole increase in *Zoophycos* traces, reaching the status of abundant in the "paisley" facies.

Indistinct mottling is more or less a characteristic of the whole section, suggesting that the more clear-cut burrows are the latest in a long history of reworking. The disseminated nature of many sandy concentrations (especially Subunit 3b), suggestive of reworking of original thin sand beds into overlying and underlying mud, supports this view. Burrow alignments are usually obvious, and in almost all cases are parallel to laminations, ash beds, and sandy layers.

Evidence of relative timing of burrows is abundant. In most cases large, ovoid *Planolites* burrows are cut by *Chondrites* and *Zoophycos*. *Zoophycos* is evidently the latest burrower in many sections. We observed "pelleted," "fat," and "simple" forms (sensu Ekdale, 1974) throughout the section. Width of traces varied greatly from <2 to 36 mm (Section 584-96-3). Average width is 1.5 to 2 cm.

Planolites traces are commonly lighter colored than the normal mudstones, in many cases olive or light olive gray. This coloration variously reflects higher diatom content and/or calcareous content. We detected no obvious pattern downsection in the type of *Planolites* burrows. In Pliocene cores, nannofossils are detectable in the calcareous burrow fills; in Miocene cores, they are generally not.

In Miocene cores, large (up to several cm) spheroidal, ovoid granular-looking, olive balls are a minor component. Following Okada (1980), we interpret these as armored mud pellets, probably of fecal origin. Discolored diffusion fronts often form halos to these balls.

Sequential sections are required to assess the dimensions and interrelationships of some of these trace fossils (Fig. 9; numbers in the following text refer to numbers in Fig. 9). For example, sections of Section 584-96-2 show that a large granulose ovoid body (#1) is spheroidal and is probably not a burrow but an armored mud pellet; it is surrounded by a diffusion front (#2). Bed-

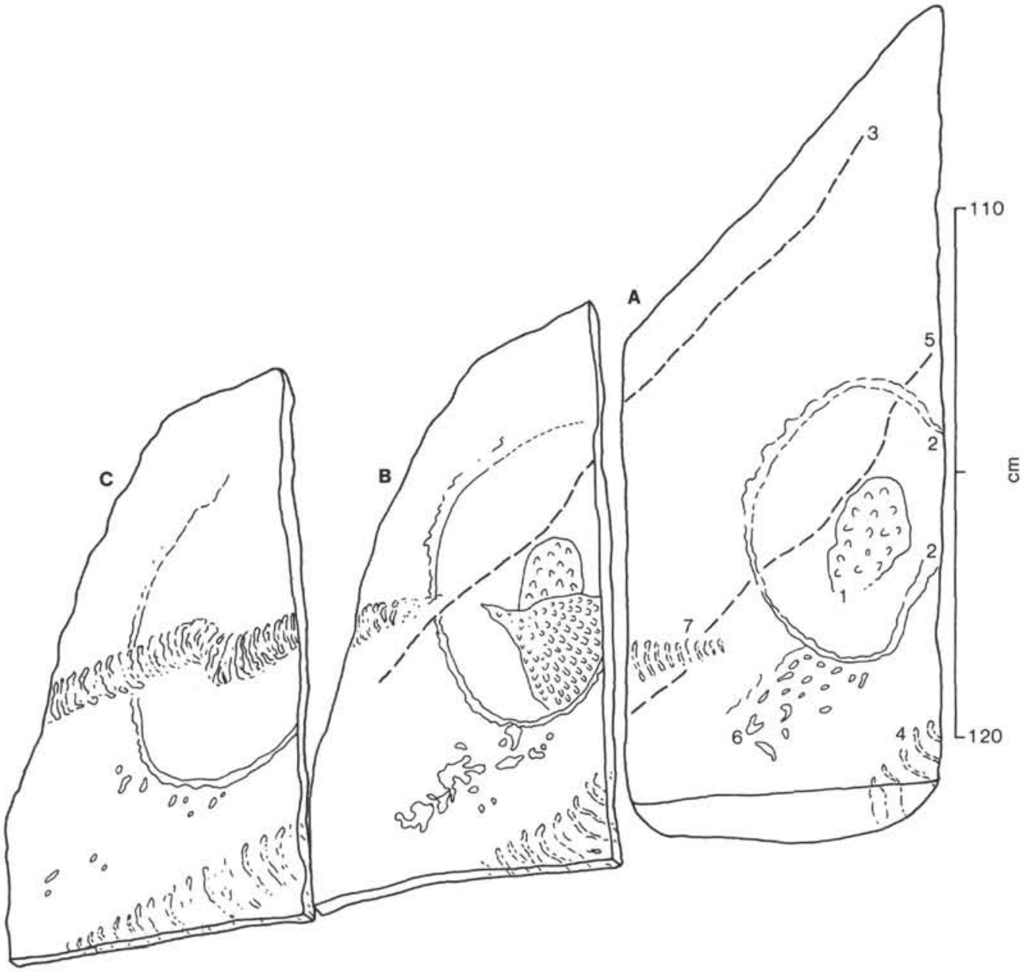


Figure 9. Serial sections of trace fossils, Section 584-96-2 (Miocene, Subunit 4b). Numbers refer to features discussed in text. A–C are longitudinal core sections.

ding, defined by vague color laminations in the predominantly dark greenish gray diatomaceous mudstone, is steeply inclined, as it is everywhere in the lower part of the Site 584 section. *Zoophycos* trails are nearly everywhere parallel to all sedimentary bedding indicators, the traces curved either dextrally or sinistrally. A *Chondrites* concentration (Fig. 9, #6), crudely aligned with bedding in Plane A, passes to a rather uncommon stubby, branching form in Plane B. The diffusion front seems to have truncated this *Chondrites* concentration. Perhaps the diagenetic processes associated with this front homogenize chemistry between the burrow-fill and the matrix mudstone, rendering them invisible.

Most interesting is the medial *Zoophycos*, which deflects near the ball, cutting it, but clearly deviating from the normal bedding parallel path, and swinging towards the viewer in order to do so.

STRUCTURAL GEOLOGY

Introduction

Site 584 cores recovered an abundance of structural features in Miocene (and to a lesser extent in lower Pliocene) cores. These we categorize principally as "healed" fractures and dewatering veinlets. Tensional crack-fills and slumping are minor features of the section. We describe the structural features in turn, using drawings of representative cores and presenting evidence for relative timing of the features. We then briefly discuss the regional implications of our microstructural data, commenting on the possible significance of the moderately to highly inclined strata found in all 584 sites, and compare our data with structural features recorded at the Leg 56–57 sites.

Unless otherwise indicated, all core numbers in this section refer to cores from Hole 584.

Healed Fractures

First observed at 240 m sub-bottom in Core 26, steeply inclined, dark gray, claystone-filled seams are a common feature of the section and are, in general, more abundant downhole. These seams are commonly straight, generally <1 mm but locally several millimeters in width (they are most commonly at a high angle to bedding, which they cut with minor displacement). Where the sense of offset is visible, it is generally normal, commonly from several millimeters to several centimeters (see Fig. 10). The largest measurable true throw (i.e., downdip on the claystone seam) is 2.6 cm (Fig. 10). Some seams, however, throw distances in excess of the

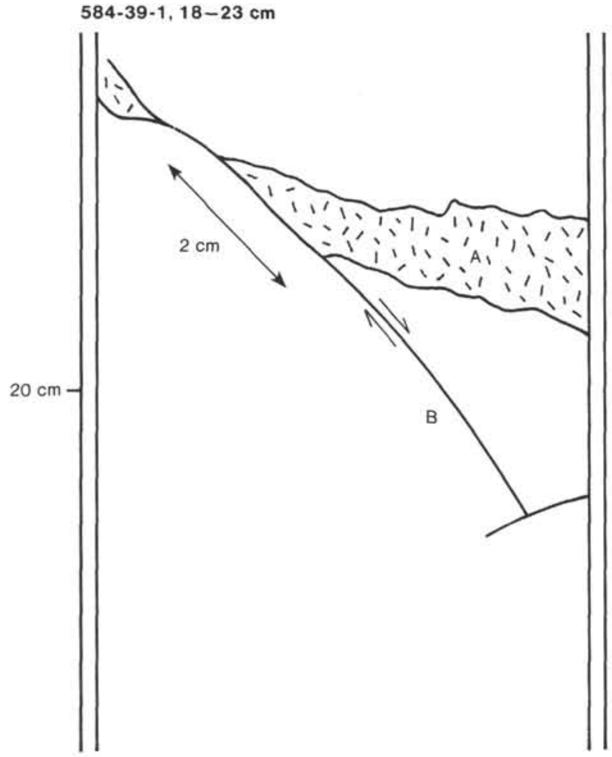


Figure 10. Moderately inclined healed fractures (B) cuts olive burrow mottle (A) (about 365 m sub-bottom, lower Pliocene).

part of the fracture plane recovered in the core. The preponderance of minor offsets leads us to suspect that such large offsets are not common.

Following Leg 57 procedure, we refer to these claystone seams as healed fractures because the initial offsets were most likely made on open fractures, with later deposition of claystone in the fractures causing reannealing. This claystone is structureless and may have been deposited in the open fractures during or after the displacement by upward-escaping water, rich in clay particles. In detail, some fractures comprise fine anastomosing stringers of dark claystone (584-15-3, 80–85 cm); small-scale stepped offsets are common (see Fig. 11). An interesting curved growth fault with 2-cm normal offset occurs in Section 584-47-2.

In all instances where cores were sectioned to give three-dimensional views, the healed fractures are either perpendicular-subperpendicular to bedding (Fig. 11) or highly inclined (50 to 70°) to bedding. Because of limited time during core descriptions, our three-dimensional observations were brief. We gained an impression that the high-angle and perpendicular healed fractures predominantly strike subparallel to bedding (Fig. 10).

Rare, low-angle healed fractures, locally bedding-parallel, are minor features of the section. We sectioned several of these to give a three-dimensional view, demonstrating that they are not high-angle features caught in strike-section. We have few observations concerning relative timing of high-angle and low-angle fractures.

Only locally did we observe more than one generation of healed fractures in the same core (Figs. 12 and 13). A 1-cm thick dark claystone seam with smeared par-

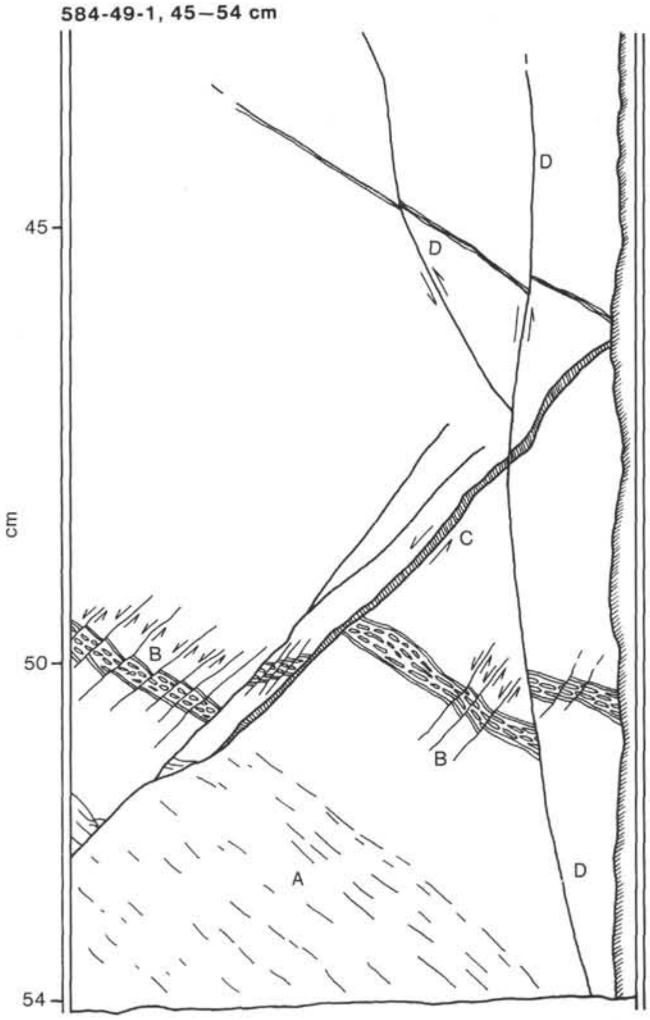


Figure 11. Open and healed fractures cutting granular burrow fill. Principal offset occurs on the left-dipping open fracture (C) accommodated by minor normal offsets on parallel minor healed fractures (B) at the level of a ledge of the major fracture. Healed fracture (D), subvertical but at a high angle to bedding (A), cuts an earlier very-low-angle healed fracture (caught in highly oblique view) in upper part of drawing.

allel streaks (x–x′, y–y′) is subperpendicular to bedding, and cut by two sets of thin healed fractures at a low angle with respect to bedding (Fig. 13). Further complex histories are well preserved in Core 584-78.

In regard to the healed fracturing phenomenon, the main inferences are that extension on a microscale affected strata in the Site 584 area before, and possibly to a lesser extent after, the tilting event, and that the healed fractures, which occur from Core 26 downwards (below 240 m sub-bottom) affect strata ranging in age from middle Miocene to earliest Pliocene.

Dewatering Veinlets

Closely spaced, subparallel, locally anastomosing claystone-filled veinlets are ubiquitous in Miocene cores, especially in the lower portion of the section. These are almost all perpendicular to bedding (Figs. 14, 15). They tend to concentrate at particular levels and commonly form bands from several millimeters to several centi-

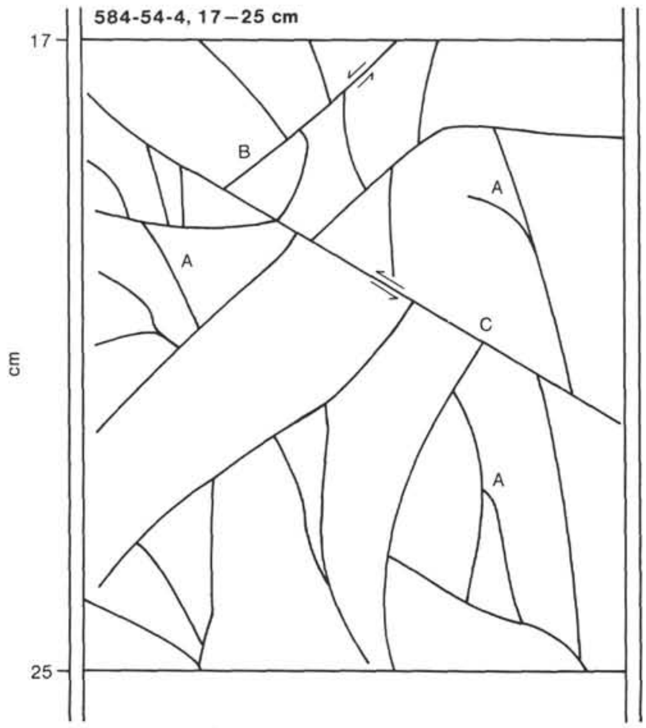


Figure 12. Two sets of thin healed fractures cut dewatering veinlets (A). The first (B) shows normal offset, the second (C) reverse offset. Bedding attitude unfortunately not clear here (~515 m sub-bottom depth; upper Miocene).

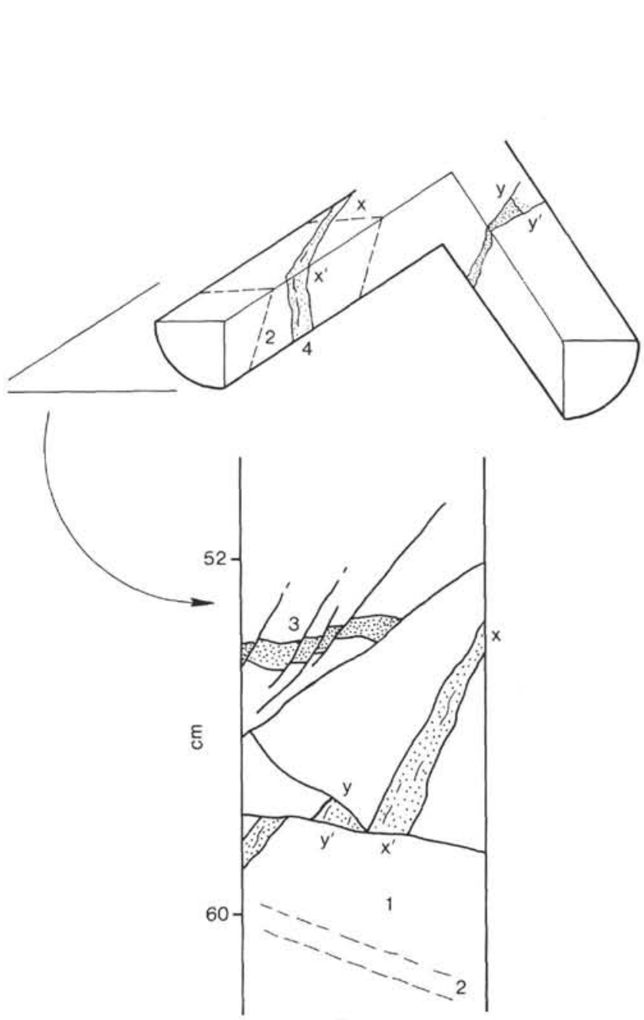


Figure 13. Complex healed fracturing in middle Miocene, 584-86-2, 52–60 cm. Diatomaceous mudstone (1) preserves bedding (2) as vague color laminations. Line of section in archive half (lower) clearly oblique from three-dimensional investigation of working half (upper). An early, thick seam (?healed fracture/?mudstone dike) x–x′, y–y′ is cut by two thin fractures. A 4-mm-thick bed of distinctive color (3) is cut by an en echelon third set of healed fractures.

meters thick. In cores from lower levels they often permeate the core more abstrusely over the entire length of sections. They first occur in Core 41, at about 385 m sub-bottom.

Our three-dimensional investigations reveal that these veinlets strike parallel to bedding, forming a dark network of irregular, subparallel, locally anastomosing traces on bedding surfaces (Fig. 15).

They commonly show minute (< 1 mm), stepped, normal displacements of fine laminae (Figs. 16 and 17) or burrows, but individual offsets only rarely exceed 1 mm (Fig. 18).

The veinlets everywhere postdate bioturbation but predate healed fracturing (Fig. 19). Following interpretations reached by the Leg 57 shipboard scientists, we infer that these features represent original water-escape microcracks (similar to the "beardlike" structure in Miocene turbidites of the Miura and Boso peninsulas, and Shimanto Belt), in which clays held in suspension in residual water have promoted resealing (Ogawa, 1980).

The veinlet bands may comprise predominantly isolated strands (Fig. 16) or intense braiding networks (Fig. 18), the latter especially so in cores lower in the section. Individual veinlets commonly show slight asymptotic curving, with the seams thicker in the middle portions (Figs. 16 and 17).

Lithologic control on veinlet formation is locally evident on a small scale. Veinlet networks terminate in places at fine sand layers (Fig. 14), presumably because water was able to escape by intergranular flow in the more permeable sand without recourse to mechanical conduits.

Open Fractures

Open fractures are relatively common in the Hole 584 section, in consolidated material below Core 10. They may derive from *in situ* fracturing, or from drilling or core-handling processes, and they may take several forms. Irregular vertical fractures, commonly central in the core, certainly arise from drilling or core handling. A close irregular hackly fracture occurs in places (Section 584-43-2), probably arising from core shrinkage. Highly inclined, often conjugate, straight fractures are interpreted with more difficulty (Arthur et al., 1980). Some have no visible offset, others have minor normal displacement, commonly with vertical or highly inclined slickensides on the fracture planes. In places, healed fractures pass into open fractures, sometimes lined with the same dark claystone that anneals the healed fractures. We do not know if such transitions are original (*in situ*) features, or whether healed fractures opened during recovery. Certainly we observed no upsection transition from healed to open fractures, as recorded in Leg 57 lower-trench-slope Sites 441 and 434 (see Arthur et al., 1980).

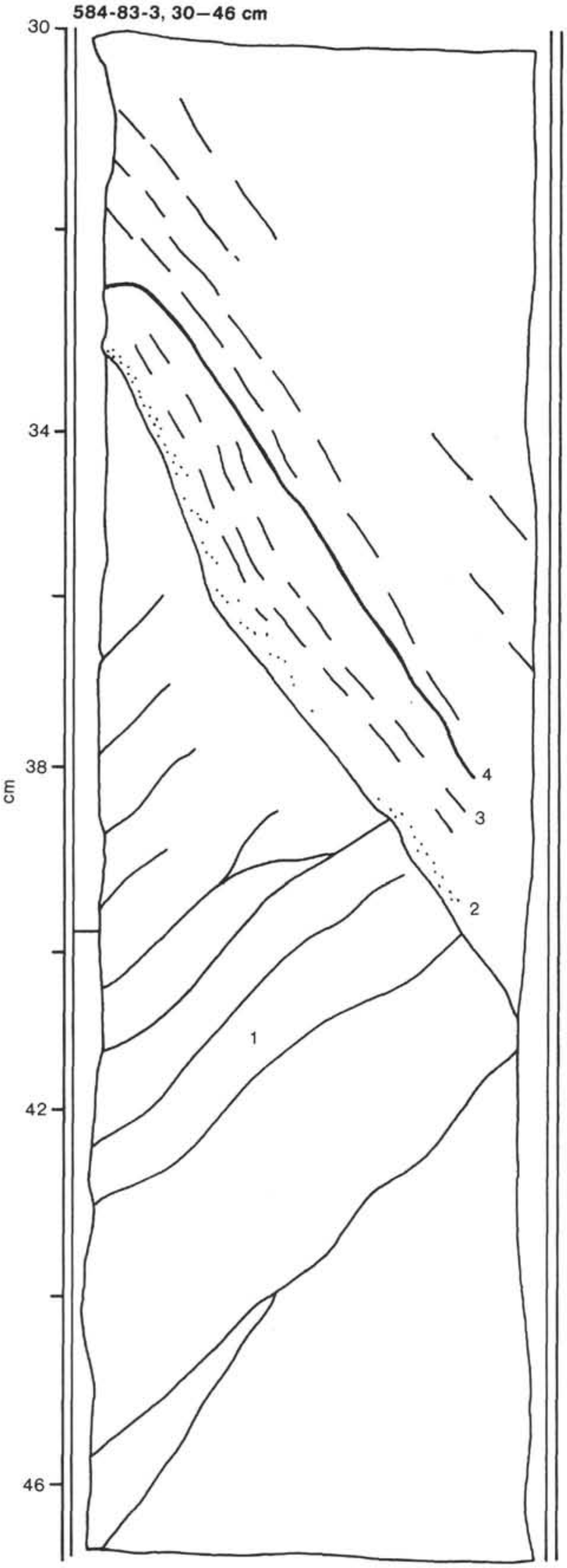


Figure 14. Dewatering veinlets (1) terminating at a fine sand bed (2); silty laminae in fine sand bed (3, abstractly drawn) truncated by a healed fracture (4), which cuts plane of view in strike section.

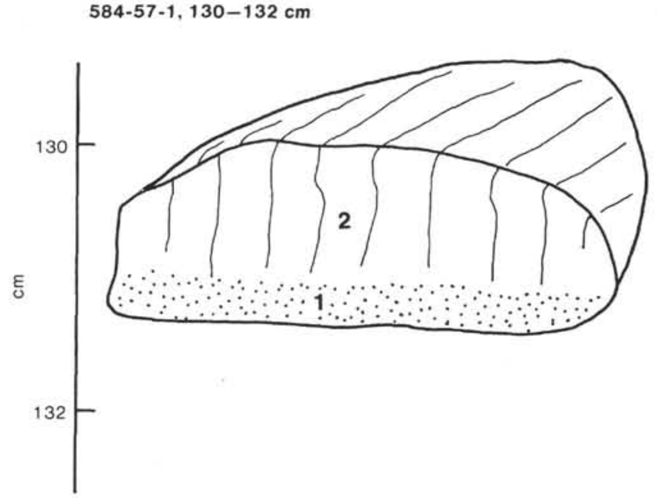


Figure 15. Dewatering veinlets (2), commencing above a silty mud layer (1), form a clear lineation on bedding.

Slumping and Synsedimentary Faulting

We observed features best explained as slump structures in three places. In Section 584-12-3 (about 110 m sub-bottom, lower Pliocene) a small-scale unconformity, marked by a sharp color change in the mudstone at a high angle to bedding, is too large to be explained by bioturbation and may represent a slump scar. In Section 584-59-1 (557 m sub-bottom, upper Miocene) a color change boundary (between grayish olive and dark gray) is highly irregular and truncates laminations in what seems to be an angular mudstone block of ~10 cm maximum visible dimension. This may best be explained as a thin slumped horizon. In Section 584-96-4 (915 m sub-bottom, middle Miocene), chaotic curved laminations occur over 24 cm of core (76–100 cm). In the working half, this feature includes sub-centimeter-scale isoclinal fold hinges, with detached lower limbs, and appears to be a complex slump unit caught in very oblique section, further complicated by abundant healed fractures.

In only one place did we observe clear evidence of synsedimentary faulting. Silt layers in Section 584-21-2 (195 m sub-bottom, lower Pliocene) show millimeter-scale normal displacement on a healed fracture, which several centimeters upsection does not displace bedding.

Crack-Fills

In Core 584-71 (about 671 m sub-bottom, upper Miocene) a unique sand-filled vein system is preserved (Fig. 20). Up to 5 cm across, the main vein is perpendicular to bedding, with slightly irregular margins stepped somewhat on one side, tapering down over a 10-cm exposed length to zero. The section is broken by two thin zones of drilling breccia. In the lower part of the vein, angular chips of mudstone, identical to the host rock, are scattered in the fill forming a matrix-supported breccia. In the upper part, offshoots of the vein penetrate laterally both parallel to, and at a high angle to, bedding. The upper part of the vein, and the offshoots, are sand filled. Unfortunately the transition between breccia-filled and sand-filled portions is obscured by the drilling breccia zone.

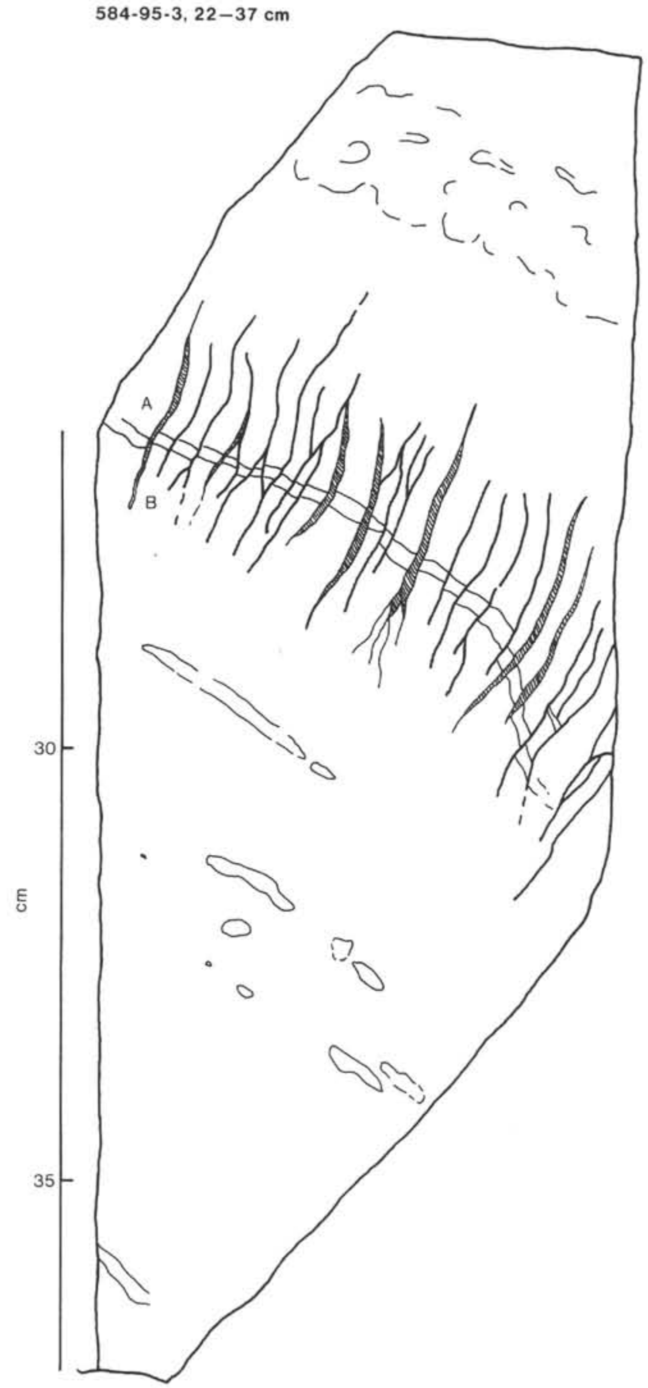


Figure 16. Stepped micro-offsets of a pale mudstone lamination (or ?elongate burrow) (A) by a network of dewatering veinlets (B). Note curved form of veinlets, and thicker claystone fill in middle portions of several.

This feature is best explained as a large tensional crack system that was filled by unconsolidated sand and spalled chips of host mudstone. The angularity of the mudstone chips indicates formation in at least semiconsolidated sediments. Such a crack system could easily form behind a slump scar.

Clastic Dykes

Many veins subperpendicular or at a high angle to bedding are claystone seams, which we infer, because of

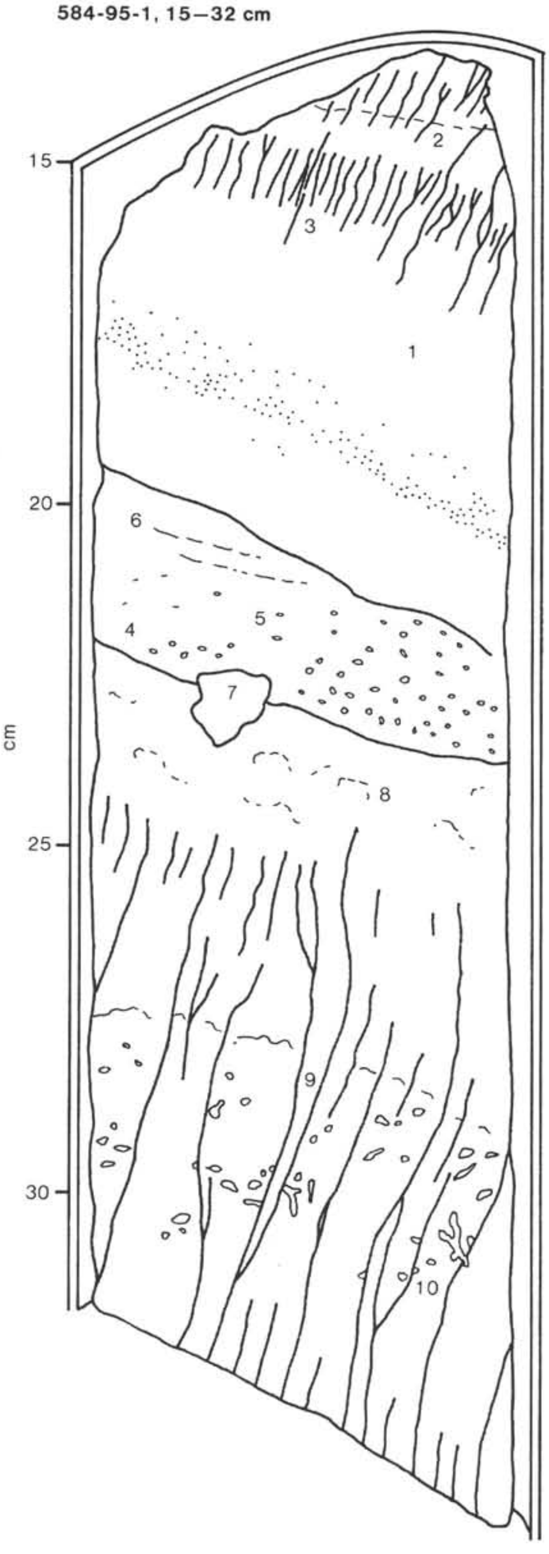


Figure 17. Dewatering vein networks. Upper veinlet layers (3) occur at the top of a homogeneous dark greenish gray mudstone (1), and greatly resemble "beardlike" veinlet arrays of Miura/Boso Shimanto (Ogawa, 1980). A thin dark mudstone scan shows normal micro-offsets (2). The thin layer of dusky yellow sideritic medium-coarse sand grains (5) has a large, angular sideritic clast at the base (7), is graded (4) although very matrix rich, and shows vague parallel lamination (6). Lower veinlet array ends in "paisley" mudstone layer (8), with no clear burrows but vague grayish green to dusky green and dusky blue green mottling. Veinlets are slightly irregular (9), as in Figure 16, and cut *Chondrites* traces (10).

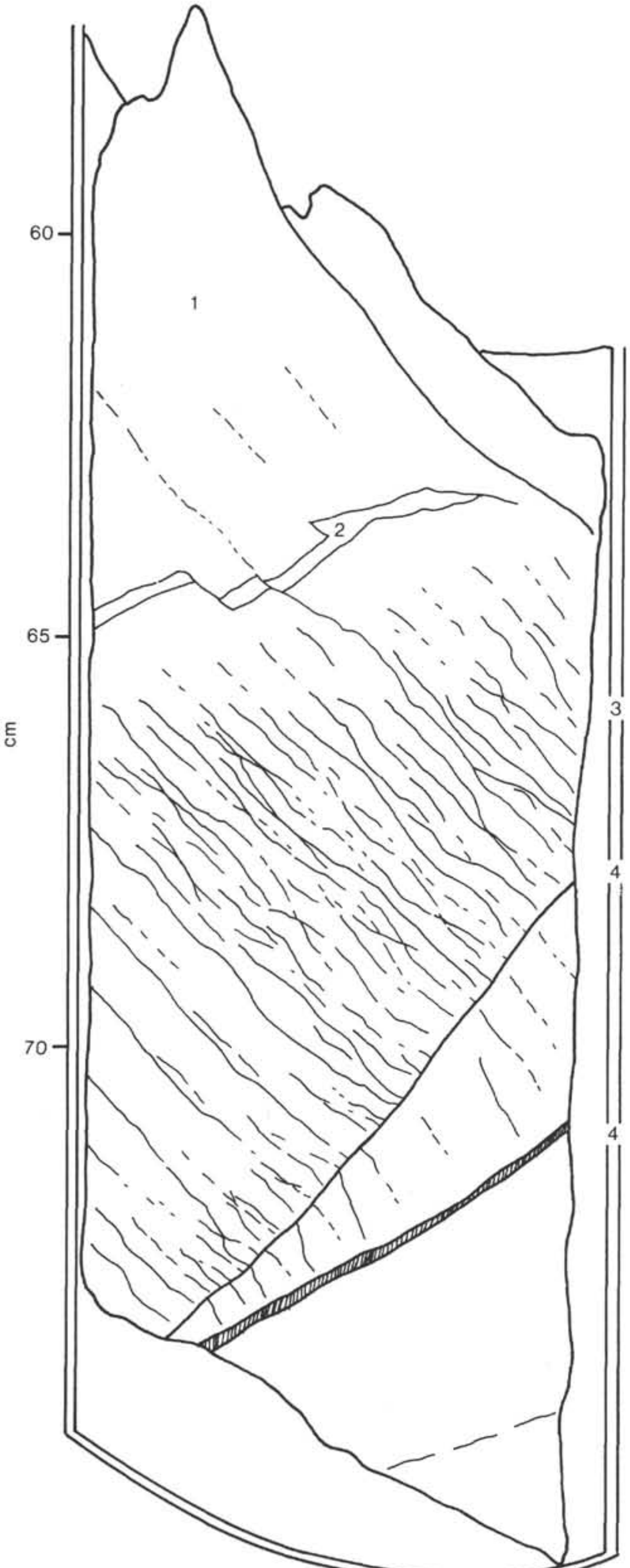


Figure 18. Core 584-95, middle Miocene, ~905 m sub-bottom. Intense, braided dewatering veinlet array (3). All structures shown are in homogeneous dark greenish gray mudstone (1). (2) is a darker lamination, with both normal and reverse micro-offsets. Dark seams (4) cut microveins, at apparently low angles. Both are moderately inclined in three-dimensional view.

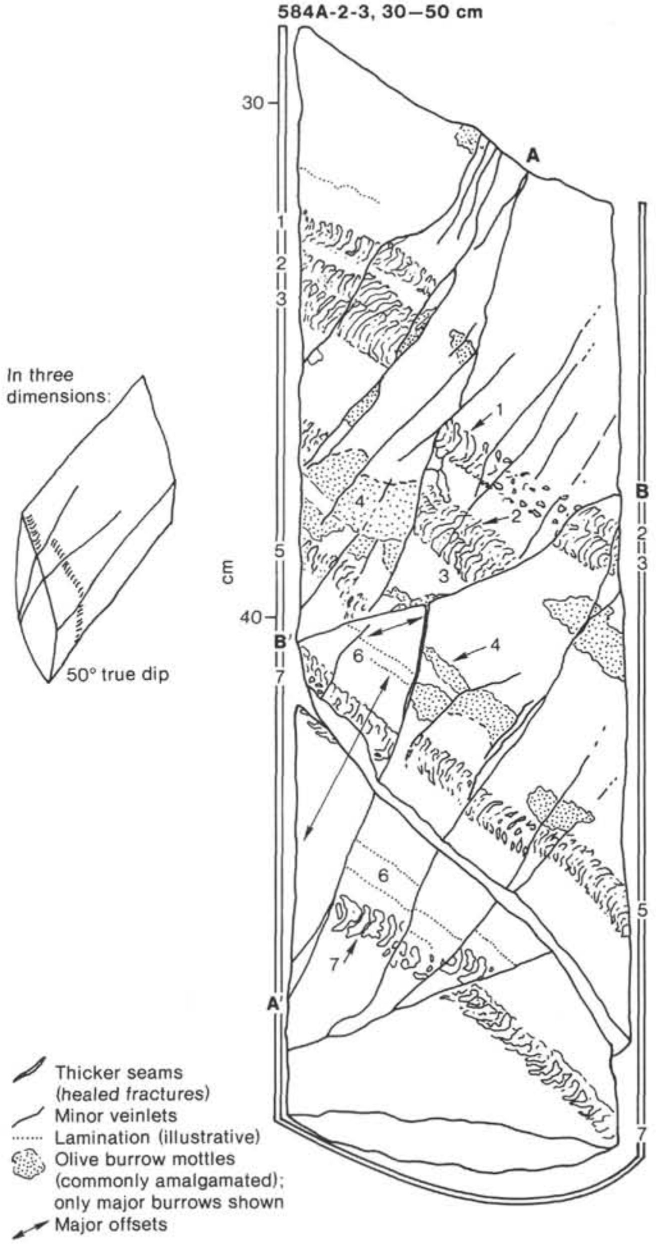


Figure 19. Structures and sequence of events recorded in Core 584A-2, archive half. A–A′, B–B′ = thick, late, healed fractures; (1) sinistral *Zoophycos;* (2, 3) amalgamated dextral *Zoophycos*, 2 formed before 3; (4) olive burrow mottles; (5) pelleted *Zoophycos;* (6) color laminations; (7) fat *Zoophycos*.

Sequence of events: (I) Burrowing. (II) Formation of anastomosing veinlets to bedding, with no, or only up to several millimeters, offset. (III) Formation of main fractures (conjugate, acute intersection vertical, strike subparallel to bedding strike); up to 26 mm normal offset. (IV) Healing of main fractures (see text discussion) (minor offsets on conjugate main fractures reflect slightly different chronologies in Stage III).

their resemblance to comparable seams offsetting bedding, to be healed fractures. In Section 584-81-1 (770 m sub-bottom, middle Miocene) two veins, each about 1 cm wide, cut bedding at about 70° (in dip section) and have a homogeneous silt fill. Because healed fractures are elsewhere filled with sediment finer than the host mudstone, these silt-filled veins may best be explained as clastic

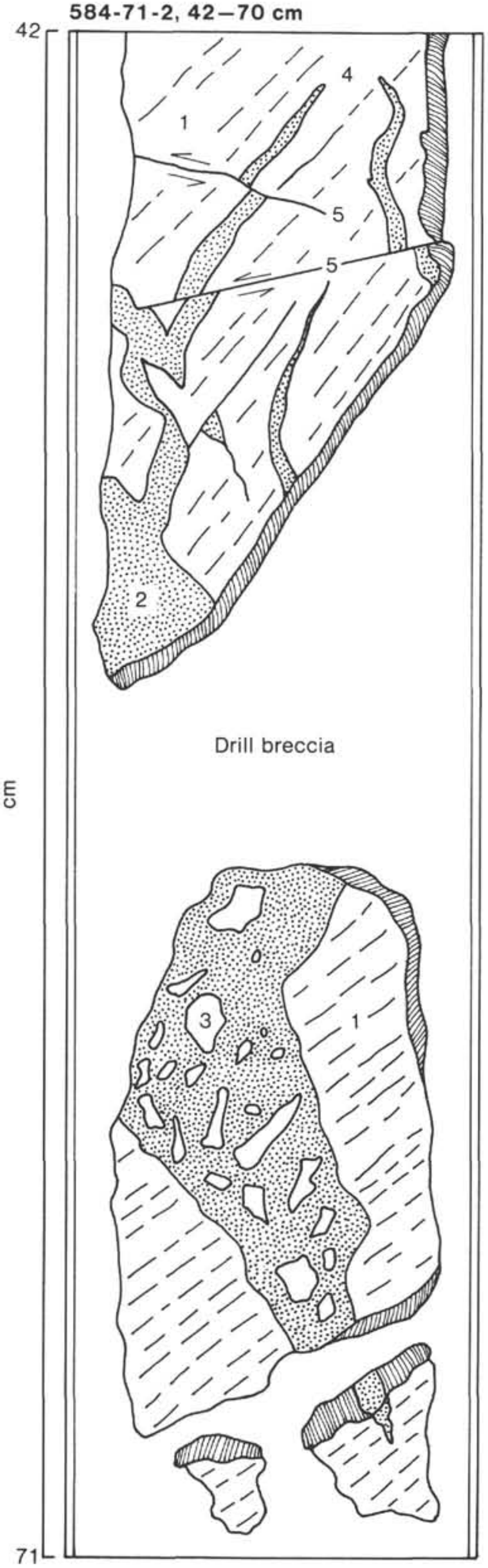


Figure 20. Crack-fill system in Core 584-71. Host gray to dark olive gray mudstone shows bedding by color change laminations, represented schematically (1). Fine sand fills a wide, irregular crack perpendicular to bedding. In the upper part of the crack the fill is solely sand (2), but in the lower part highly angular chips of mudstone (3) form a matrix-supported fill. In the upper part, other sand-filled cracks penetrate the mudstone, including one parallel to bedding (4). These are cut by healed fractures (5).

dykes. Thin silt layers are relatively common in the section hereabouts and could have provided the necessary source.

Mud dykes and sills might also be expected at Site 584, because features described hitherto provide strong evidence for extensional tectonics affecting the Miocene and lower Pliocene Japan Trench inner slope (Arthur et al., 1980). We would have no means of discriminating claystone seams that represent healed fractures with offsets greater than the cored length from claystone seams that represent mud dykes or sills.

Shear Zones

In Section 584-80-1 (760 m sub-bottom, middle Miocene) a 2.5-cm thick, bedding-parallel disrupted layer comprises an upper brecciated mudstone zone and a lower sheared claystone layer. The latter contains flow-sheared mudstone chips, which indicate normal movement (Fig. 21). The degree of displacement on such a feature could conceivably be substantial.

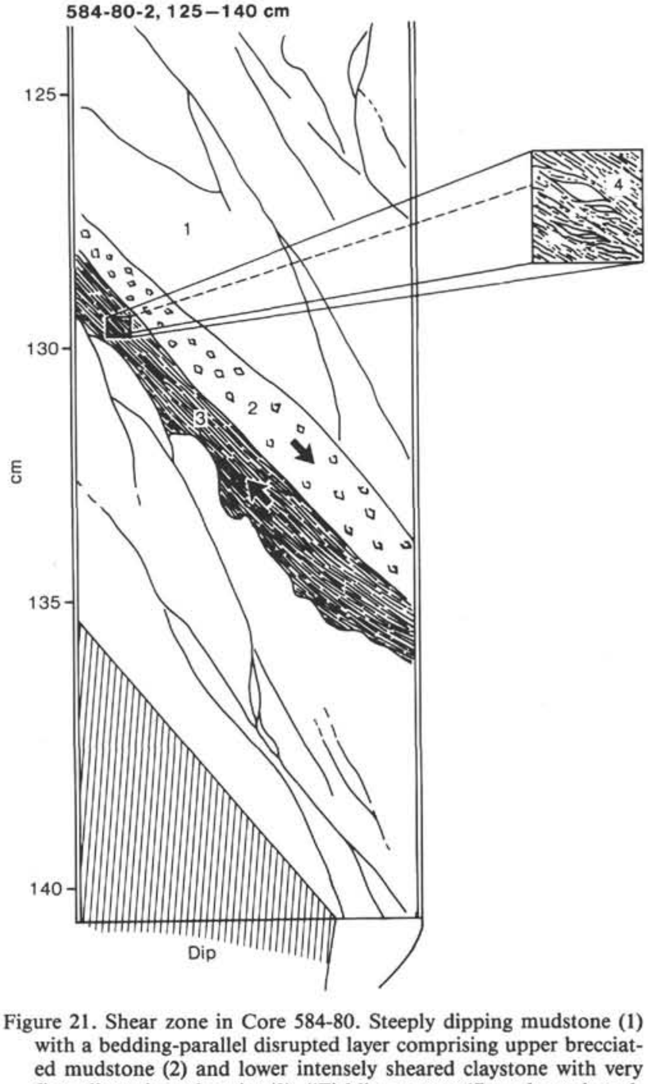


Figure 21. Shear zone in Core 584-80. Steeply dipping mudstone (1) with a bedding-parallel disrupted layer comprising upper brecciated mudstone (2) and lower intensely sheared claystone with very fine, disseminated pyrite (3). "Fish" structure (flow-sheared mudstone chips) indicates normal movement (4).

Synthesis

Dewatering veinlets and healed fractures are the two main structural features in the Hole 584 section. Dewatering veinlets are the first formed, being everywhere cut by healed fractures. The veinlets commonly occur in concentrated networks and are almost all perpendicular to bedding, suggesting lithostatic stress was responsible for their inception. Local zones of steeply inclined veinlets may indicate superimposed tectonic stress during dewatering. The dewatering veinlets would have formed initially as open microcracks, becoming annealed in the later stages of water escape as clay minerals were deposited from water going through. We found no open dewatering veinlets in the 584 section, but such features were observed in Quaternary mudstones from the Nankai Trough inner slope (site chapter, Site 583, this volume). Dewatering veinlets occur throughout the Miocene section (below about 385 m sub-bottom) and most likely formed incrementally during deposition. Their relatively constant attitude with respect to bedding indicates that they were formed before tilting of the strata. Their sharp margins and generally straight profiles indicate formation during the later stages of consolidation. There is no clear evidence concerning timing of the crack-fill system and the possible clastic dykes relative to dewatering veinlets. The slump structures described are likely to have been surface or near-surface features, and probably predate dewatering.

Healed fractures cut all these features. They are commonly subperpendicular or at a high angle to bedding, in some cases conjugate, and have determinable offsets ranging from several millimeters to several centimeters. They would have formed initially as open fractures, being reannealed in the same fashion as the dewatering veinlets. Many of the fractures require a σ_1 (axis of maximum compression) at an acute angle to vertical in their present orientation. After bedding tilt correction, σ_1 is essentially vertical. Because the fractures occur in a slope section, their orientation suggests that they formed for the most part before tilting of the bedding. Like the dewatering veinlets, the fractures most likely formed incrementally after consolidation. The predominance of normal displacements indicates a prolonged extensional regime in the Miocene and early Pliocene slope section.

The most striking structural features at Site 584 are the consistently high inclination of bedding, a feature not observed in previous sites of the DSDP Japan Trench transect. Below 350 m sub-bottom, strata dip at angles between very shallow (a few degrees) and very steep (up to 70°) towards the Japan Trench (see Paleomagnetics section, this chapter). Dips from 350 to 530 m sub-bottom range from 10 to 30°, but below 530 m the beds dip generally between 50 to 60°. We detect an overall pattern of progressive downsection steepening.

This inclined section in Hole 584 would appear to require tilting on rather steep, landward-dipping normal fault. Such features are not evident on the seismic profile across the Site 584 area (Profile ORI 78-3, Fig. 31A), though they are clearly present upslope in the region of Sites 438 and 439 (Nasu et al., 1980). Steep trenchward dips also occur about 500 m upslope of Site 584 in Hole 584A and about 700 m downslope in Hole 584B. The impressive subhorizontal correlations between lithostratigraphic and biostratigraphic markers in Holes 584A and 584B (see Sedimentology and Biostratigraphy (Diatoms) sections, this chapter) come as a further surprise, given the structural relief apparently required by the ubiquitous steep dips in the lower half of Hole 584. The geometry required by our observations at Holes 584A and 584B is best explained by a nest of normal faults giving stepped throws so that marker horizons can remain at much the same level in all three holes despite the steep dip of strata.

The very complexity of the required configuration, plus probable steepness of the normal faults, could explain its failure to show up on Profile ORI 78-3 (Fig. 31A). The required large-scale geometry is, however, consistent with microstructural evidence outlined hitherto. Evidence for extensional tectonics is found in small-scale structures throughout the Hole 584 section.

The shear zones described above would be likely manifestations of the normal faults required in the Hole 584 section. However, although the example described shows evidence of normal displacement, it is bedding-parallel, and the stepped displacements required would have to occur on faults at a high angle to bedding. In addition, we can perhaps conjecture that the zones of anomalous low recovery (for example, Core 584-33), in a hole where recovery was generally good, might represent passage of faults through the Hole 584 section.

Comparison with Previous Japan Trench Sites

Structural features of Japan Trench sites drilled on DSDP Leg 56–57 are summarized by Arthur and others (1980). Veins, fractures, and faults are present in both upper-trench-slope Sites 438 and 439 and lower-trench-slope Sites 400, 441, and 434, but not in the shallow-penetration Site 435. These features are also absent in ocean-plate-reference Site 436. Their veins are identical to our dewatering veinlets, occurring in sets up to a maximum length of 10 cm, anastomosing but generally perpendicular to bedding, and terminating at sandy layers. Arthur and others (1980) interpret these features as dewatering conduits associated with faults. "Fractures" are mostly healed, dip at between 45 and 90° to bedding, commonly occur in conjugate sets and show offsets of up to several centimeters in both the normal and reverse sense. Open fractures are common only on the lower part of the inner trench slope, between about 150 and 500 m sub-bottom (Sites 441 and 434); they do not offset bedding. No sediments younger than late Pliocene are deformed.

The depth to "consolidated" sediment (defined by Leg 56–57 scientists as sediment that required saw cutting) and the depths to the first occurrences of veins and healed fractures all shallow progressively toward the trench. Additionally, the upper 400 m of section in lower-slope sites is overconsolidated relative to upper slope sites. Arthur and others (1980) tentatively interpret these observations as a response to tectonic stress, in addition to lithostatic stress, during consolidation on lower-trench-slope sites. Their model for consolidation and deformation of lower slope sediments further involves a corona-like zone of open fractures at about 200 to 500 m sub-bottom over a healed fracture network at depth. The fractures are held open by excess fluid pressure caused by dewatering, and fostered by a fine-grained low-permeability sediment cap. They argue that such an open-fractured zone could provide an overpressured horizon capable of sufficiently reducing shear strength in the lower slope sedimentary cover to allow downslope mass movement even on low angles on the trench inner slope.

The model depends on interpretation of open fractures in cores from lower-slope Sites 440, 441, and 434 as *in situ* features. In favor of this opinion are the correlation between zones of open fractures and reverses in the density gradient, poorer recovery in the fracture intervals, and the relative paucity of open fractures in Sites 438, 439, and 436 (located away from the lower slope).

The central problem concerns the possible role of missing upper Pliocene and Pleistocene strata in consolidation of the lower slope section. Holes 441 and 434 are in the axis of a submarine canyon (see JNOC Crossline C, fig. 7 of Arthur et al., 1980). Based on the depth of this canyon, Arthur and others (1980), suggest as much as 450 m of upper Pliocene and Pleistocene section are missing. In contrast, lower-slope Site 440 (on the midslope terrace) has no missing section, but consolidation and first appearance of deformational-dewatering features are shallower than at upper-slope Sites 438 and 439.

How well do data from Site 584, drilled on the upper part of the lower slope, support the concepts of excess tectonic stress affecting the lower-slope sediment cover and of overpressuring within the slope section in a zone of open fracturing?

The depth at which sediment merits description as mudstone ("consolidation" level of Leg 56–57 scientists) is consistent with the trend observed in previously drilled sites. In a sequence upslope from the trench, the first (shallowest and youngest) mudstones were recovered at: 101 m (Site 441 on the lowermost slope, upper Pliocene); 130 m (Site 434 on the lowermost slope, upper Pliocene); 175 m (Site 440 on the midslope terrace, lower Pleistocene); 250 m (Site 584 on or above the midslope terrace, lower Pliocene); and 430 m (Site 438 on the upper slope, upper Miocene).

The first appearance of veins and fractures in Hole 584 is similarly much higher than in upper-slope sites, and slightly higher than other lower-slope sites. Healed fractures first appear in Holes 438 and 439 (upper slope) at 603 m in middle Miocene strata. At Site 440 (midslope terrace) they appear at 252 m in lower Pleistocene sediments. At Site 434 (lower slope) they first appear at 255 m in (?)lower Pliocene sediments. Healed fractures first appear in Site 584 at about 240 m in lower Pliocene sediments; dewatering veinlets first appear at about 383 m sub-bottom in upper Miocene sediments.

The data from Site 584 augment previous observations of a strong contrast between dewatering and deformation histories in the upper-slope and lower-slope sediment sections. Tectonic stress appears to affect the lower-slope section, and in addition to overburden stress, promotes earlier dewatering, consolidation, and deformation.

At Hole 584, we detected no precursory zone of open fractures before penetrating the healed fracture networks below 240 m sub-bottom. If the open-fractured corona postulated by Arthur and others (1980) for deeper on the slope at Sites 441 and 434 once existed at Site 584, it has now been annealed.

The most notable difference between Site 584 and previous sites is the high inclination of strata. In Holes 438 and 439 (upper slope) dips of 0 to 30° occur below 850 m (middle and lower Miocene strata). In Hole 440 (midslope terrace), dips of up to 10° occur between 254 to 350 m (lower Pliocene–upper Pliocene strata) and between 15 and 40° below 385 m (Pliocene and upper Miocene strata). In Hole 441 (lower slope) dips vary "... irregularly and somewhat systematically downhole, ranging from horizontal in the upper part of the hole to 35° and locally 70° at depth" (Arthur et al., 1980, p. 579).

BIOSTRATIGRAPHY

Siliceous microfossils are the dominant microfossil groups recovered from Pleistocene to middle Miocene muds and mudstones of Site 584 (Fig. 22). Diatoms in particular are extremely abundant in the upper 57 cores and are the most consistently reliable age indicators examined. Radiolarians are less common but, when present, support the diatom age determinations. Calcareous microfossils, foraminifers, and nannofossils are in general extremely rare or absent. In samples containing calcareous fossils, the preservation is typically moderate to poor.

Drilling at Hole 584A attempted to penetrate the same zone of steeply dipping, highly fractured beds that forced the cessation of drilling at Hole 584. Spot cores were taken every 100 m from 600 m to the end of drilling. Diatoms are used to date the retrieved cores as well as the sediments retrieved in the intervening wash cores. Radiolarians, foraminifers, and nannofossils are absent or rare and undiagnostic in these cores.

Foraminifers

Foraminifers, both planktonic and benthic, are rare at Hole 584. Partial explanations for this situation include dilution by other sediments, dissolution of certain intervals below the calcite compensation depth (CCD) and difficulty of processing certain lithologies on board. Although the foraminifers do not provide refined biostratigraphic information, they do indicate some key paleoenvironmental aspects about the section penetrated.

Planktonic Foraminifers, Hole 584

Planktonic foraminifers are absent to rare in all Hole 584 core catcher samples examined. The interval between Core 584-1 and 584-6,CC is barren of all foraminifers, but that from Cores 7 to 42 contains a few samples with rare, moderately to poorly preserved planktonic foraminifers. The most common species encountered are: *Globigerina bulloides* s.l., *Neogloboquadrina pachyderma, Orbulina universa, Globorotalia* cf. *puncticulata*, and

Globigerina cf. *decoraperta*. This assemblage is not characteristic of any particular zone, but the absence of *Globorotalia inflata* s.l. and presence of *Globorotalia* cf. *puncticulata* suggests an early Pliocene age. The core catcher of Core 21 does contain a diagnostic assemblage that includes, in addition to the species previously listed, *Pulleniatina primalis, Globorotalia* cf. *cibaoensis, Globorotalia tumida, Globigerinoides ruber, Globigerinoides trilobus*, and *Sphaeroidinellopsis*? sp. This assemblage is characteristic of lower Pliocene Zone N19/20 (Blow, 1969), which is in agreement with age assignments by other microfossil groups.

Planktonic foraminifers are absent below Core 42 at Hole 584.

Benthic Foraminifers, Hole 584

The distribution of benthic foraminifers at Hole 584 parallels that described for the planktonic foraminifers. They are absent from Cores 1 to 6, rare to few from Cores 7 to 42, and absent to rare below Core 42.

The assemblage in Cores 7 to 42 includes *Melonis pompilioides, Sphaeroidina bulloides, Plectofrondicularia foliacea, Globobulimina auriculata, Stilostomella* sp., *Dentalina* spp., *Eponides* cf. *tumidulus, Hoeglundina elegans, Pullenia bulloides, Cibicides wuellerstorfi*, smooth to hispid uvigerines, *Gyroidina* sp., *Martinottiella communis*, and unilocular lagenids. This assemblage indicates lower bathyal to abyssal depths, below 2000 m.

Below Core 42, benthic foraminifers are very sparse and consist of a nearly monospecific assemblage of *M. communis*. Very rare occurrences of *Gyroidina* sp. and *Dentalina* spp. are also recorded. This assemblage may represent either a bathymetric change from the assemblage above or a change in bottom-water character, possibly a shallower CCD.

Planktonic and Benthic Foraminifers

Hole 584A

All core catcher samples from the three cores taken in Hole 584A were barren of foraminifers.

Hole 584B

Foraminifers are rare to absent in core catcher samples from Hole 584B. Sample 584B-1,CC is barren, but Samples 584B-H1,CC to 584B-H3,CC contain rare *Martinottiela communis* and no calcareous foraminifers. These samples are similar to the interval below Core 584-42 and suggest deposition below the CCD.

Calcareous Nannofossils

Hole 584

Sediments recovered from rotary drilling at Hole 584 are generally lacking in calcareous nannofossils, particularly below Sample 584-38-4, 12–13 cm (358 m subbottom). Above that interval, nannofossils are few in number, moderately preserved, and do not provide continuous reliable age assignments. Sediment below Section 584-1-6 is Pliocene, but sediment immediately above is barren of nannofossils; perhaps the hiatus inferred at Hole 438A (Shaffer, 1980) involves this interval.

Several intervals of pale, rust-colored sediment are also relatively calcite rich. These zones were selectively sampled from Core 35 to the termination of coring and several show a dramatic rise in nannofossil abundance compared to the otherwise barren intervals. Unfortunately, most of these contain irregular grains and calcite rhombs of an indeterminate origin and are lacking in nannofossils.

Very few age assignments were made for sediments in Hole 584. Of the 138 samples examined on board, 67% are barren. Datable sediments in Cores 1 through 10 are assigned to the *Discoaster brouweri* Zone (Bukry, 1973). The appearance of *Reticulofenestra pseudoumbilica* in Sample 584-11-5, 136–137 cm indicates a lower Pliocene assignment for sediments below this level. The first definitively Miocene nannofossils occur in Sample 584-47-1, 20–21 cm with the appearance of *Discoaster quinqueramus*. Boundaries between these zones are masked by undiagnostic intervals occurring immediately above and below samples containing age-diagnostic species.

Nannofossils decrease in abundance below Section 584-38-4. Of the 85 samples examined from this interval on board, all but 16 are barren. Detailed age assignments and zonal boundaries for this interval were not determined with any reliability during Leg 87.

Hole 584B

Calcareous nannofossils are also rare at Hole 584B. None of the samples examined contain age-diagnostic flora. Two samples, 584B-H1-1, 70–71 cm and 584B-H1-1, 117–118 cm contain abundant calcite debris. Only the latter have nannofossils, but even these are heavily overgrown specimens of long-ranging forms such as *Calcidiscus leptoporus*. Sample 584B-H3-1, 128–130 cm contains moderately preserved nannofossil including *Reticulofenestra pseudoumbilica, Sphenolithus abies*, and *C. leptoporus*, but lacks age-diagnostic discoasters.

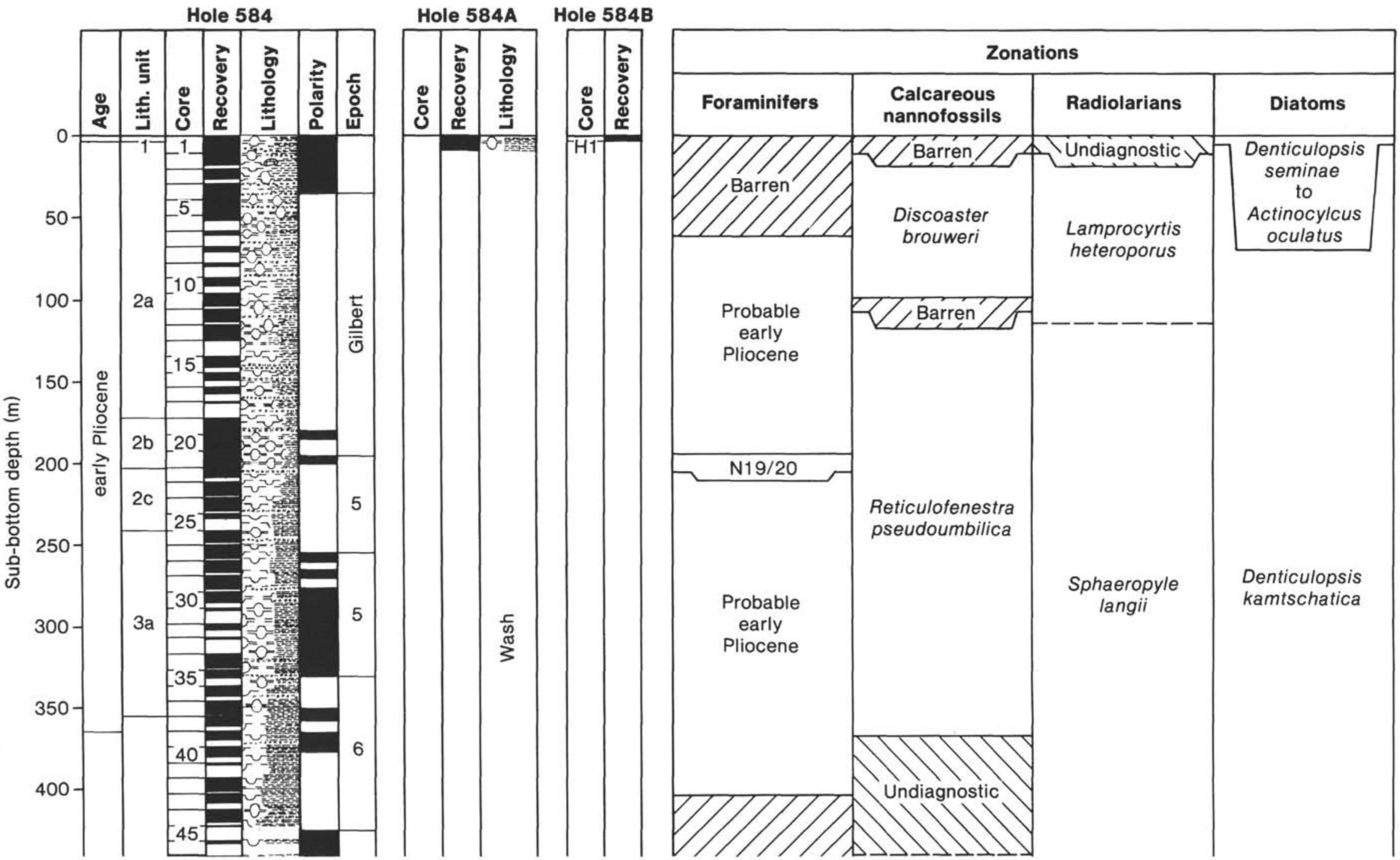
Radiolarians

Hole 584

Radiolarians are few to rare in most sediment recovered at Hole 584. Preservation is moderate through Core 58 and generally poor in the remaining cores. Zonal age assignments are not possible for much of the sediment, because of the paucity of diagnostic species, but Sample 584-1-1, 43–44 cm is older than Quaternary, suggesting a hiatus of lower Pleistocene sediments.

The *Lamprocyrtis heteroporos* Zone occurs in Cores 3 and 4. Cores 12, 16, 24, 36, and 38 to approximately Core 53 are assigned to the *Sphaeropyle langii* Zone. The most consistently present radiolarians are in the interval from Cores 38 to 53. The *Theocorys redondoensis* Zone (Reynolds, 1980) is recognized in Core 54. The *Didymocyrtis penultima* Zone and *Didymocyrtis antepenultima* Zone occur in Cores 57 and in Cores 73 to 79, respectively. The last zonal sequence recognized in this hole was the *Diartus hughesi* Zone (Reynolds, 1980), apparent in sediments from Cores 80 through 87.

The radiolarians are far less abundant than the diatoms from Cores 1 through 58. In consecutive clay-rich sediments, both siliceous microfossil groups decrease in


Hole 584
Hole 584A
Hole 584B
Zonations
Age
Lith. unit
Core
Recovery
Lithology
Polarity
Epoch
Foraminifers
Calcareous nannofossils
Radiolarians
Diatoms
Sub-bottom depth (m)
0
50
100
150
200
250
300
350
400
early Pliocene
1
2a
2b
2c
3a
1
5
10
15
20
25
30
35
40
45
Gilbert
5
5
6
Wash
H1
Barren
Probable early Pliocene
N19/20
Probable early Pliocene
Barren
Discoaster brouweri
Barren
Reticulofenestra pseudoumbilica
Undiagnostic
Undiagnostic
Lamprocyrtis heteroporus
Sphaeropyle langii
Denticulopsis seminae to Actinocylcus oculatus
Denticulopsis kamtschatica

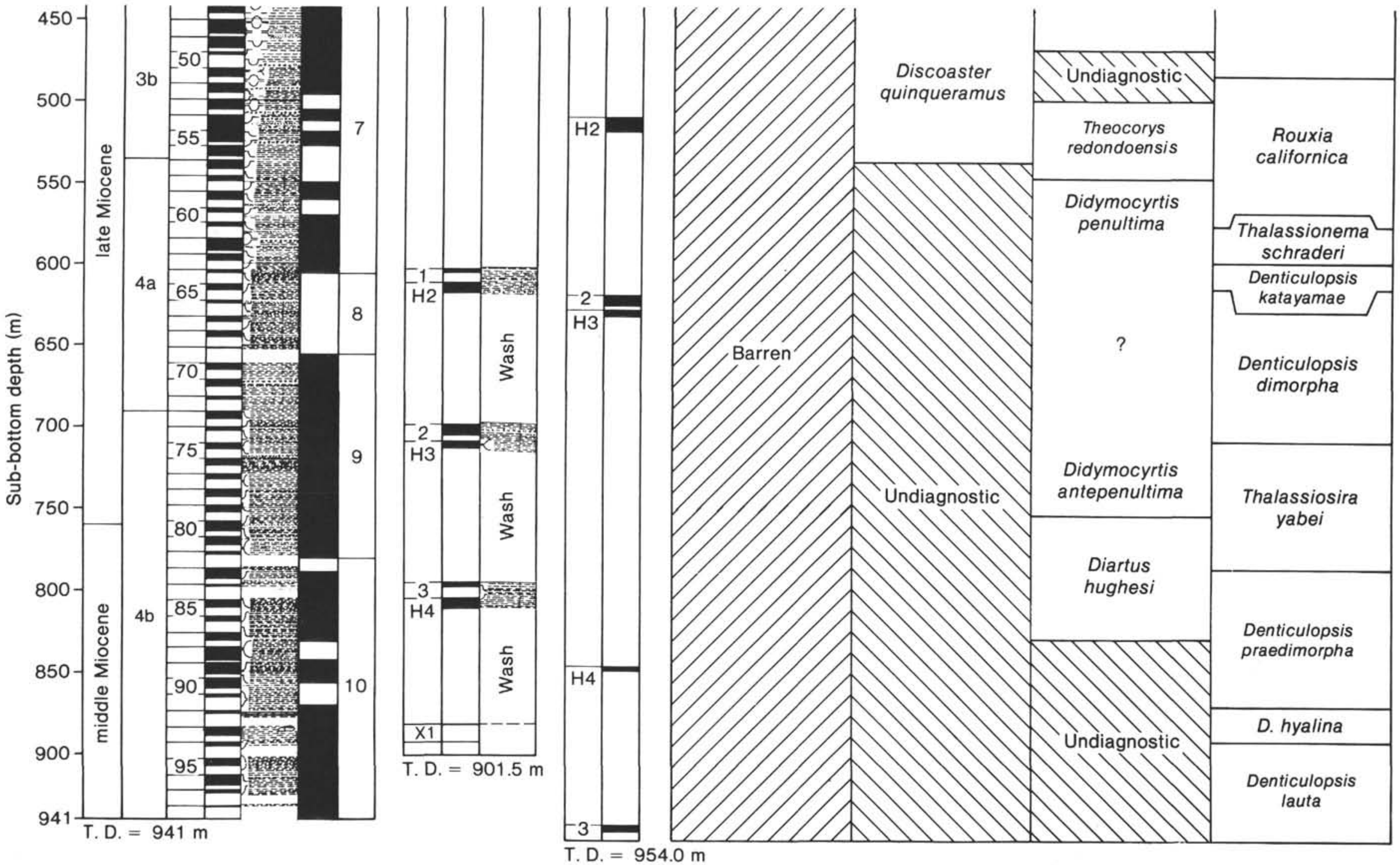


Figure 22. Summary biostratigraphy of Site 584. T.D. = total depth.

abundance and preservation. When the radiolarians are present in enough abundance for faunal analysis, the species found are characteristic of cool-water fauna with discoidal forms contributing the largest percentage of individuals.

Hole 584B

Radiolarians found in Hole 584B are generally moderately preserved and few to common in Cores 1, H1, and H2, and are rare in Cores 2, H3, and H4. Core 584B-1 is placed in the *Batryostrobus acquilonaris* Zone, and this is the only sample to which a zonal age could be assigned. Core 584B-H1 contains Quaternary to upper Miocene species including *Eucyrtidium matuyamai*, a lower Pleistocene form not found in sediment cored in Hole 584.

Diatoms

Assemblages encountered at Site 584 are predominantly composed of high-latitude diatoms with a minor component of low-latitude diatoms introduced by the northern extension of the Kuroshio. Consequently, the high-latitude, Recent through middle Miocene diatom biostratigraphy of the North Pacific (Koizumi, 1973) is easily applied at this site. With some modifications, that scheme has been followed by successive workers (Barron, 1980; Akiba et al., 1982; Akiba, 1982a). In this report, a zonation modified basically by Akiba, which has been widely traced in many land sections of northeastern Honshu and Hokkaido (Akiba, et al., 1982; Akiba, this volume), is used.

Hole 584

A nearly complete lower middle Miocene through lower Pliocene section, unconformably overlain by a thin Quaternary sequence, was recovered at this hole. Diatoms occur consistently throughout the sequences with varying abundance and preservation, allowing continuous diatom zonal assignments. In general, Quaternary sediments yield common and moderately well preserved diatoms, and lower Pliocene through upper Miocene sediments contain abundant to common diatoms with good to moderate preservation. Both the abundance and preservation of diatoms decrease rapidly in the midst of the upper Miocene, until in the lower half of the upper Miocene through middle Miocene, common to few diatoms occur.

Diatom assemblages encountered in this hole are virtually identical to those in Hole 538A (Barron, 1980; Akiba, et al., 1982), drilled about 70 km northeast of the present hole. Correlation between these two holes is, therefore, straightforward.

Quaternary diatoms were recovered from Samples 584-1-1, 0–3 cm through 584-1-3, 3–5 cm. Samples 584-1-1, 0–3 and 584-1-1, 83–85 cm are assigned to the *Denticulopsis seminae* Zone and the *Rhizosolenia curvirostris* Zone respectively. Samples 584-1-2, 83–85 cm and 584-1-3, 3–5 cm belong to the *Actinocyclus oculatus* Zone.

Two upper Pliocene diatom zones, namely the *Denticulopsis seminae* var. *fossilis* Zone and the underlying *D. seminae* var. *fossilis–D. kamtschatica* Zone are missing in this hole between Samples 584-1-3, 3–5 and 584-1-3, 83–85 cm.

The lower Pliocene through uppermost Miocene *Denticulopsis kamtschatica* Zone occurs in Samples 584-1-3, 83–85 cm through 584-51-3, 15–16 cm. The Pliocene/Miocene boundary lies in the basal part of the *D. kamtschatica*, and is placed between Cores 45 and 46. The *D. kamtschatica* Zone has the best preserved diatoms of any samples in this hole.

The upper Miocene *Rouxia californica* Zone and *Thalassionema schraderi* Zone occur in the intervals from Samples 584-51-4, 31–33 cm through 584-61-2, 32–34 cm and from Samples 584-61,CC through 584-63-2, 123–124 cm, respectively. The intervals assigned to these zones yield abundant resting spores of neritic diatoms, which implies that the interval was deposited in a shallower environment than other intervals or was subjected to increased downslope transport. The interval from Samples 584-63,CC through 584-91,CC is generally characterized by abundant and limited occurrences of *Denticulopsis hustedtii.* That portion of the stratigraphic record is subdivided into the following four zones based on occurrences of other marker diatoms: the *D. katayamae* Zone from Samples 584-63,CC through 584-64,CC; the *D. dimorpha* Zone from Samples 584-65-1, 138–139 cm through 584-74,CC: the *Thalassiosira yabei* Zone from Samples 584-75,CC through 584-82,CC; and the *D. praedimorpha* Zone from Samples 584-83-1, 139–140 cm through 584-91,CC. The upper Miocene/middle Miocene boundary falls within the *T. yabei* Zone. The *D. hyalina* Zone comprises Samples 584-92,CC and 584-93,CC, and an interval from 584-94,CC through 584-98,CC is assigned to the *D. lauta* Zone. A hiatus of approximately 1 Ma occurs between Samples 584-91,CC and 584-92,CC. The middle Miocene/lower Miocene boundary lies at the base of the *D. lauta* Zone.

Hole 584A

Four wash cores and three spot cores were recovered in this hole, all of which contained few to common diatoms. Quaternary diatoms are found in Samples 584A-H1-1, 121–123 cm through 584A-H1-6, 121–123 cm. The *Denticulopsis kamtschatica* Zone, lower Pliocene, is found in Sample 584A-H1-6, 130–131 cm. The *D. dimorpha* Zone is recognized from Cores 1 to H2. The underlying *Thalassiosira yabei* Zone and the *D. praedimorpha* Zone are found in Samples 584A-2,CC and in Core 584A-H3,CC, respectively. The core catchers of Cores 3 and H4 are both assigned to the *D. hyalina* Zone, and Core 584A-X1 is assigned to the *D. lauta* Zone.

Hole 584B

All seven cores recovered from Hole 584B contain diatoms with varying abundance and preservation. Core 1 is assigned to the *Denticulopsis seminae* Zone of the upper Quaternary. Samples 584B-H1-1, 39–40 cm through 584B-H1,CC fall within the *D. kamtschatica* Zone of the lower Pliocene, whereas the two underlying samples (584B-H2,CC and 584B-2,CC) are within the upper Miocene *Rouxia californica* Zone and *Thalassionema schraderi* Zone, respectively.

The *D. katayamae* Zone occurs in Core H3, and Core H4 falls within the *Thalassiosira yabei* Zone. Core 3 is assigned to the Subzone A of the *D. lauta* Zone (lower middle Miocene).

SEDIMENT ACCUMULATION RATES

Based on microbiostratigraphic and magnetostratigraphic data, sediment accumulation rates for Hole 584 were estimated from the lower Pliocene through middle Miocene (Fig. 23). The curve is shown using sub-bottom depth, not true thickness of sediments. In general, this sedimentation rate curve is similar to that for Hole 438A (Barron, 1980). An accumulation rate of ~200 m/Ma for the lower Pliocene through uppermost Miocene (3 to 6 Ma) may reflect very high, primary productivity of diatoms. The accumulation rate is lower, 50 m/Ma, near the top of the interval. In the upper Miocene, the rate of sediment accumulation is approximately 15 m/Ma, and the upper part of this interval is almost coincidental with a horizon yielding very abundant resting spores of neritic diatoms. A hiatus might occur within this interval, at a sub-bottom depth of approximately 600 m. From the lower part of the upper Miocene through the upper part of the middle Miocene, the accumulation rate is approximately 100 m/Ma. A possible hiatus of almost 1 Ma duration (13 to 14 Ma) follows this interval. The accumulation rate is approximately 50 m/Ma in the lower part of the middle Miocene (14.0 to 15.5 Ma).

INORGANIC GEOCHEMISTRY

Bulk X-Ray Mineralogy of Site 584 Sediments

X-ray powder diffraction analyses were made on 172 samples from mud and mudstone, 6 samples from sand and sandstone, 26 samples from ash layers, and 110 samples from concretions and nodules recovered at Site 584, using a shipboard Rigaku Miniflex X-ray diffractometer. Major and minor minerals detected were quartz; feldspars; high-cristobalite; 7°, 10-Å clay minerals; calcite; dolomite; siderite; pyrite; barite; and opal-A. Plagioclase and K-feldspar could not be discriminated because of the close proximity of their major peaks around 3.15Å, so they are referred to only as feldspars. The abundance of these minerals were roughly estimated from the peak heights on the X-ray diffractograms (Fig. 24). Among these, pyrite, barite, opal-CT, and most of the carbonates are assumed to be of diagenetic origin.

Detrital Minerals

Sediments recovered at Site 584 are characterized by their high biogenic-silica content, consisting mainly of diatom frustules and less commonly of sponge spicules and tests of radiolarians, particularly in the lower Pliocene. The relatively high opal-A content in the lower Pliocene sediments decreases by about two-thirds its original value in the upper Miocene sediments (Cores 584-38 to 584-79), as estimated from the background intensity at around 22° (CuKα 2θ) on the diffractograms. This change corresponds with a decrease in biogenic-silica abundance based on visual estimates from smear slides. The opal-A content increases again slightly in the middle Miocene mudstone.

Based on the abundance of terrigenous suites (quartz, feldspars, and clay minerals) and biogenic opal, Hole 584 sediments are divided into upper (top to 540 m), middle (540 to 760 m), and lower (760 m to bottom) parts. High content of biogenic opal relative to terrigenous suites characterizes the upper part. Amounts of biogenic opal gradually decreases downhole. Terrigenous suites dominate the middle part. In particular, quartz increases markedly at around 540 m sub-bottom, more than twice its abundance in the upper part. The content of feldspars relative to quartz (feldspar/[feldspar + quartz]) is somewhat lower, mostly less than 0.2 in this part compared to 0.2 to 0.3 in the upper part. This difference probably reflects the lower contribution of volcaniclastic sediments and ash layers in this middle part because tuff and tuffaceous mudstone usually have ratios of about 0.9. The lower part is again low in quartz and feldspars, but the content of clay minerals does not seem to decline. The abundance of biogenic opal increases slightly.

The higher opal-A content and the lower terrigenous clastic content in the lower and upper parts may be explained by (1) a rapid sedimentation rate of biogenic silica during the early Pliocene followed by a constant terrigenous-sedimentation rate, or (2) a lower terrigenous-sedimentation rate and constant biogenic-silica sedimentation, or (3) a combination of both. According to the biostratigraphic and paleomagnetic studies (see Sediment Accumulation Rates section, this chapter), the sediment accumulation rate drastically increases in the lower Pliocene. This increase suggests that higher opal-A content in the lower Pliocene sediments was not caused by a deficiency of terrigenous clastics but by blooms and rapid accumulation of siliceous organisms such as diatoms, radiolarians, and sponges.

Authigenic Minerals

Authigenic calcite, dolomite, and siderite occur as carbonate concretions, veins that fill contraction cracks in concretions, and as disseminated grains in mudstones, sandstones, and ash layers.

Carbonate concretions were recovered from nine horizons: Sections 584-2-5, 584-3-1, 584-9-1, and 584-95-1 (dolomitic); Sections 584-2,CC, 584-63-1, and 584-78-1 (calcitic); and Sections 584-92-1 and 584-93-2 (sideritic). They are brownish gray to light olive gray, hard, and often brecciated and isolated from the surrounding mudstones because of drilling. Generally, the boundary between the concretions and the host sediments is distinct and marked by abrupt color changes; but in some cases compositional gradations between the concretions and the host sediments do occur. Laminations, burrowing, and bioturbation in the host sediments continue into the concretions, and laminations are sometimes bent around them because of differential compaction.

Thin-section analysis of a calcitic concretion found in Section 584-2,CC shows that it contains abundant siliceous organisms (45% diatoms, 15% sponge spicules), which have been entirely replaced and partly filled with micrite or pseudosparite matrix (4% foraminifers, 4% quartz, 2% feldspars, and 30% micrite). Micrite pseudosparite, and/or framboidal pyrite filling in foramini-

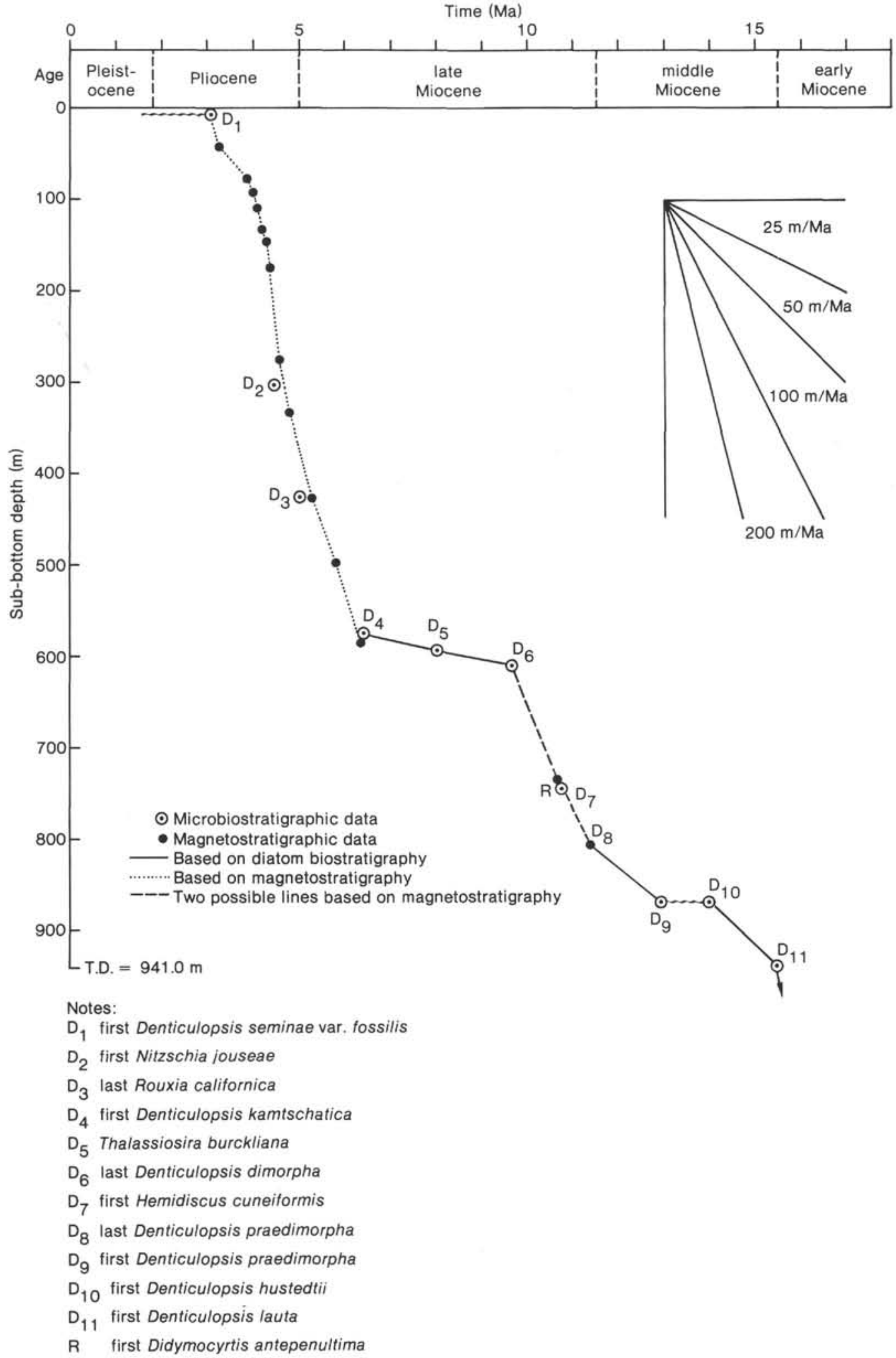


Figure 23. Sediment accumulation curve calculated for Hole 584. T.D. = total depth.

fers rarely exhibit geopetal structures. Vitric sand layers and a mud clast in Section 584-95-1 have been replaced and cemented by dolomite. The carbonate content in these vitric layers is estimated to be about 10 to 30%, as determined by carbonate bomb analysis.

We recovered olive gray, irregularly shaped barite nodules from Sections 584-9-1 and 584-30-4. Both contain wood fragments as nuclei. According to the thin-section analysis of Sample 584-9-1, 1–3 cm, this barite nodule contains 70% diatom frustules and 7% sponge spicules, both replaced and filled by barite. Wood fragments are filled with spherulitic barite crystals as large as 0.4 mm in diameter showing radial extinction. Framboidal pyrite occurs sporadically in the wood fragments.

Opal-A changes to opal-CT and fresh volcanic glass to clinoptilolite on burial with increasing temperature, serving as a general thermometer, accurate to within a few tenths of a degree centigrade. We expected the occurrence of these minerals, especially opal-CT, at Site 584, because at Sites 438 and 439, about 100 km to the west-northwest, opal-CT first appears at 700 m sub-bottom in the middle Miocene, and clinoptilolite at 930 m sub-bottom in the lower Miocene (Shipboard Scientific Party, 1980a). Surprisingly, we could not find these minerals in any of the Site 584 cores, even though these cores reached to a depth of 950 m sub-bottom. Differences in the geothermal gradient or probable erosion of the Pliocene section at Site 584 area may have caused these discrepancies.

PHYSICAL PROPERTIES

Physical properties measured at Site 584 include wet-bulk density, water content, porosity, shear strength, and sonic velocity. Grain densities of representative samples were measured postcruise. Logging of Hole 584A from 91 to 500 m sub-bottom allows some correlation between laboratory and *in situ* data (see Logging section, this chapter). Similarly, seismic reflection Profile ORI 78-3 (Fig. 31A) allows comparison with laboratory physical property data (Appendix at the end of this volume). The split Cores 1 through 8 of Hole 584 were sampled with Boyce cylinders, which were also the sampling tools for the softer sections of Cores 9 through 22. A razor blade was used to cut and trim chunks from the stiffer intervals of Cores 9 through 22. Samples from Cores 23 through 98 of Hole 584 were either slabs cut with the rock saw or minicores. All physical properties specimens from Holes 584A and 584B were cut on the rock saw or minicorer. When the sample condition allowed, 2-minute-GRAPE, water-content, and sonic-velocity measurements were performed.

Shear Strength

Shear-strength measurements (as measured by the Wykeham Farrance Vane Shear, Soil Test Torvane, and Soil Test Pocket Penetrometer) were obtained only from Hole 584. All cores recovered from Holes 584A and 584B are from >500 m sub-bottom and are too stiff to be measured by the shipboard shear-strength equipment. Shear-strength values at the sediment surface are relatively high (12 to 76 kPa), but vary widely with depth.

Reliable vane shear data were quite difficult to obtain throughout the upper 51 m because of horizontal, vertical, and radial surface cracking during testing. Shear-strength measurements obtained from the eight tests, which correctly resulted in failure on a cylindrical surface without surface cracking, range from 15.9 kPa at 12 m sub-bottom to 101.9 kPa at 51 m sub-bottom. Sensitivity (ratio of undisturbed to remolded shear strength) ranges from 4.38 to 6.77 and averages 5.53. No valid Torvane measurements were produced below 51 m sub-bottom, at which depth a value of 50.0 kPa was recorded. The rate of increase in maximum shear strength is 1.7 kPa/m for both sets of vane type measurements (Fig. 25).

Pocket penetrometer measurements were continued to 91 m sub-bottom, at which point the 216.3-kPa limit of the instrument was exceeded. This set of maximum shear-strength measurements indicates a slightly more rapid rate of increase of strength (3.0 kPa/m) than that obtained from the vane equipment.

Wet-Bulk Density, Porosity, and Water Content

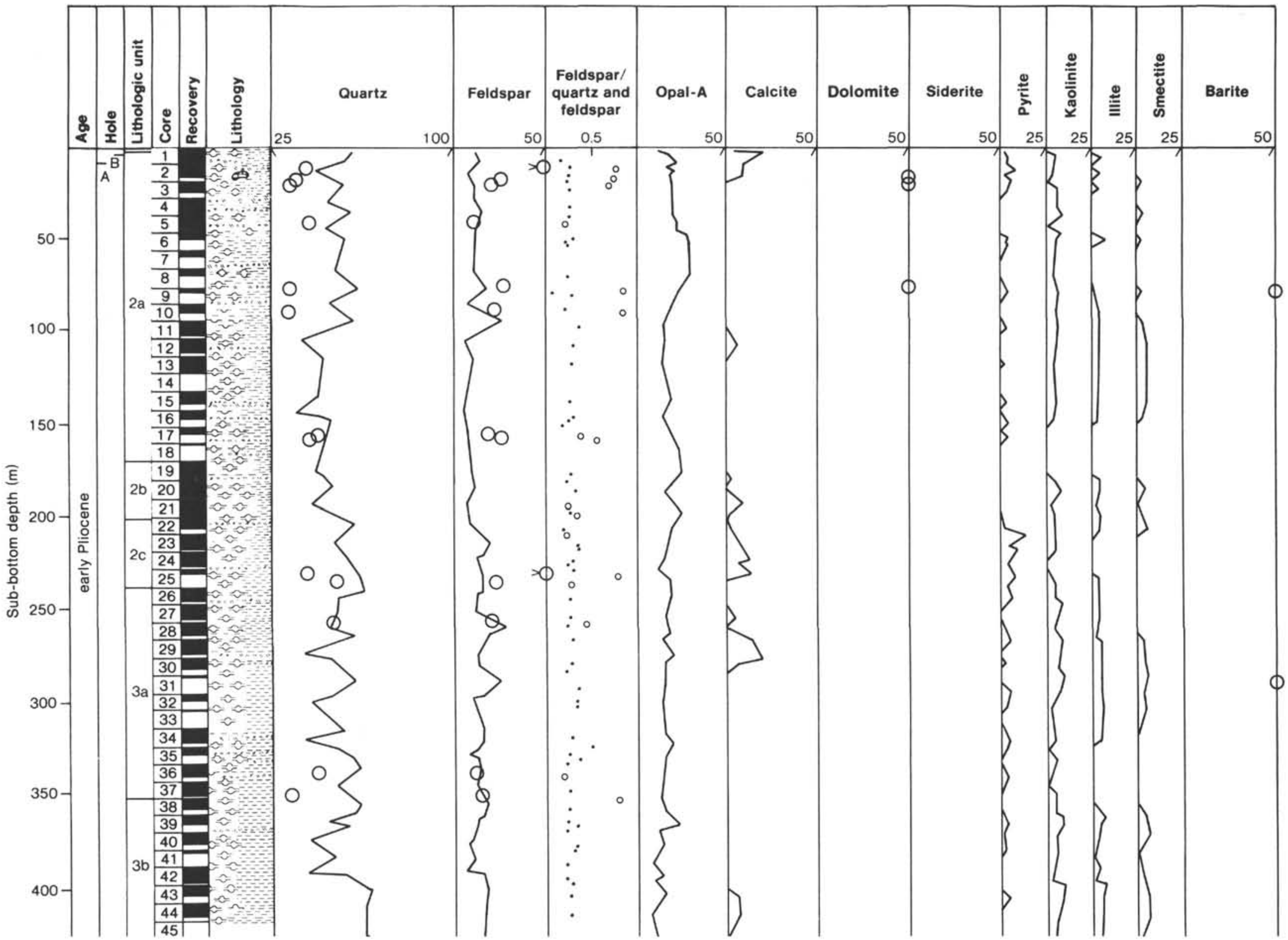
Wet-bulk densities were determined on board with the continuous analog GRAPE and special 2-minute GRAPE counts. Because gas and voids in the core sections severely reduce the continuous GRAPE measurements, only the highest values are considered reliable and are here referred to as maximum sustained wet-bulk densities. Wet-bulk densities determined from special 2-minute GRAPE counts on Boyce cylinder and chunk samples were performed on selected and prepared representative samples. The wet-bulk density profile is of the special 2-minute counts (Fig. 25), because these values are more representative of *in situ* conditions than are the continuous GRAPE values.

Porosities were calculated from three data sets, including continuous GRAPE, special 2-minute GRAPE counts, and water contents. Because we did not have the necessary equipment on board for grain density measurements of unlithified sediments, a grain density of 2.40 Mg/m^3 was assumed for the upper diatomaceous part of the section for our preliminary shipboard calculations. Calculated porosities are highly dependent on the grain density, therefore 41 grain densities were measured on shore to allow refinement of the porosity profiles (Appendix at the end of this volume). Grain densities throughout this hole are very low and highly variable because of the low density of the diatom tests. Porosities calculated from the water-content data and the grain densities measured on shore, are the most reliable and consistently reproducible of the three data sets (Fig. 25).

The wet-bulk density, porosity, and sonic profiles presented in this section are produced from measurements on one set of samples. These profiles are divided into seven depth intervals delineated by abrupt changes of physical property trends.

Interval 1 (0 to 75 m sub-bottom)

Maximum sustained wet-bulk densities, as measured by the continuous GRAPE, are anomalously high in the upper sediments of Hole 584, ranging from 1.62 to 1.50 Mg/m^3. In the upper part of Lithologic Subunit 2a, 20 to 75 m sub-bottom, the maximum sustained wet-bulk density remains nearly constant and averages 1.45 Mg/m^3. Wet-bulk densities from 2-minute GRAPE counts from the sediment/water interface to 75 m sub-bottom remain nearly constant at 1.35 Mg/m^3. Concurrently, porosity remains nearly constant at 75%. This constant value is not expected in water-rich sediments near the surface, where rapid porosity decreases have been docu-



Age
Hole
Lithologic unit
Core
Recovery
Lithology
Quartz
Feldspar
Feldspar/ quartz and feldspar
Opal-A
Calcite
Dolomite
Siderite
Pyrite
Kaolinite
Illite
Smectite
Barite
25
100
50
0.5
50
50
50
50
25
25
25
25
50
Sub-bottom depth (m)
50
100
150
200
250
300
350
400
early Pliocene
B
A
2a
2b
2c
3a
3b
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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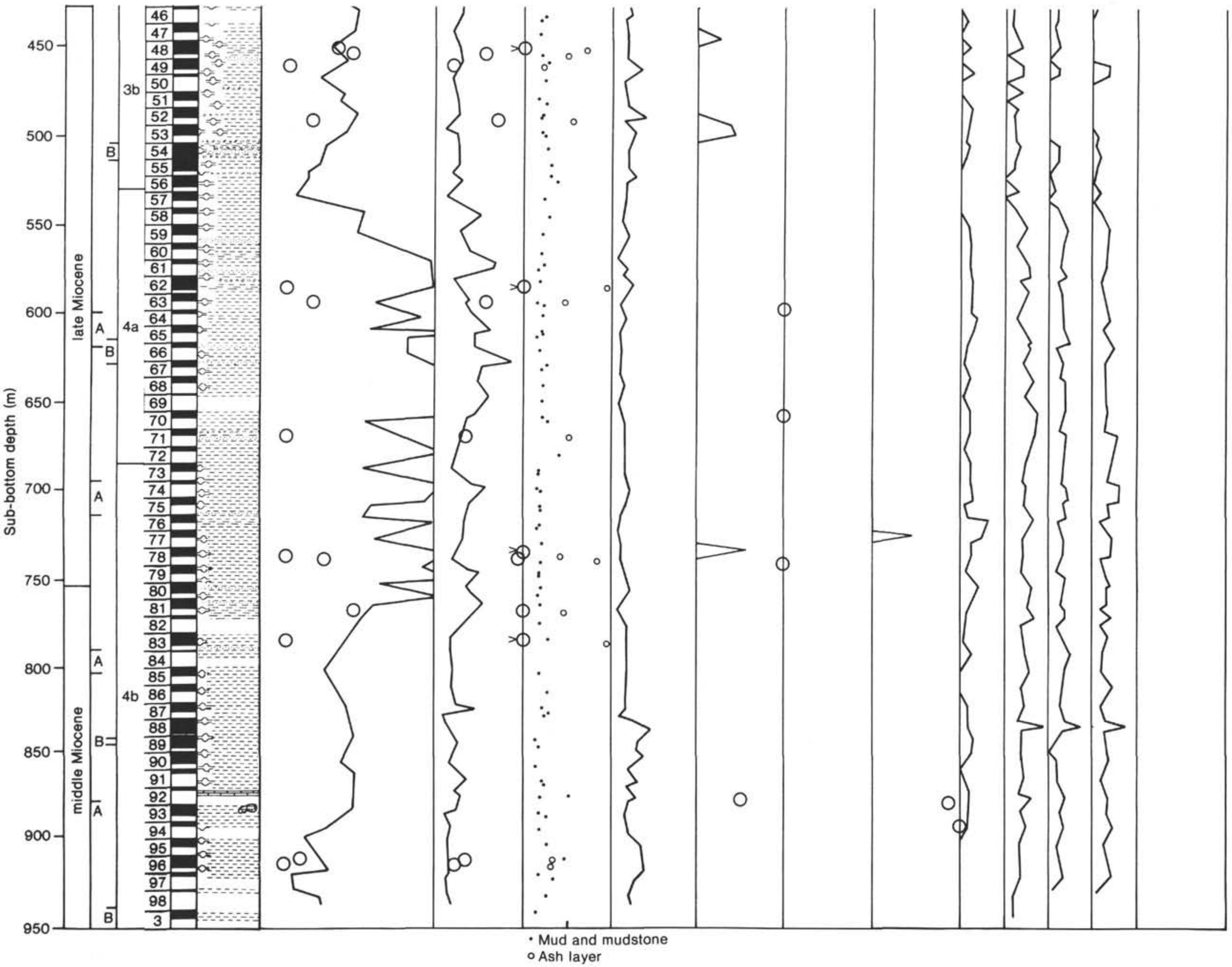

Figure 24. Summary of X-ray mineralogy for Site 584. X-ray intensity is expressed in arbitrary units. Large open circles indicate X-ray intensities measured on ash layers in Quartz and Feldspar columns and on concretions in Dolomite, Siderite, and Barite columns.

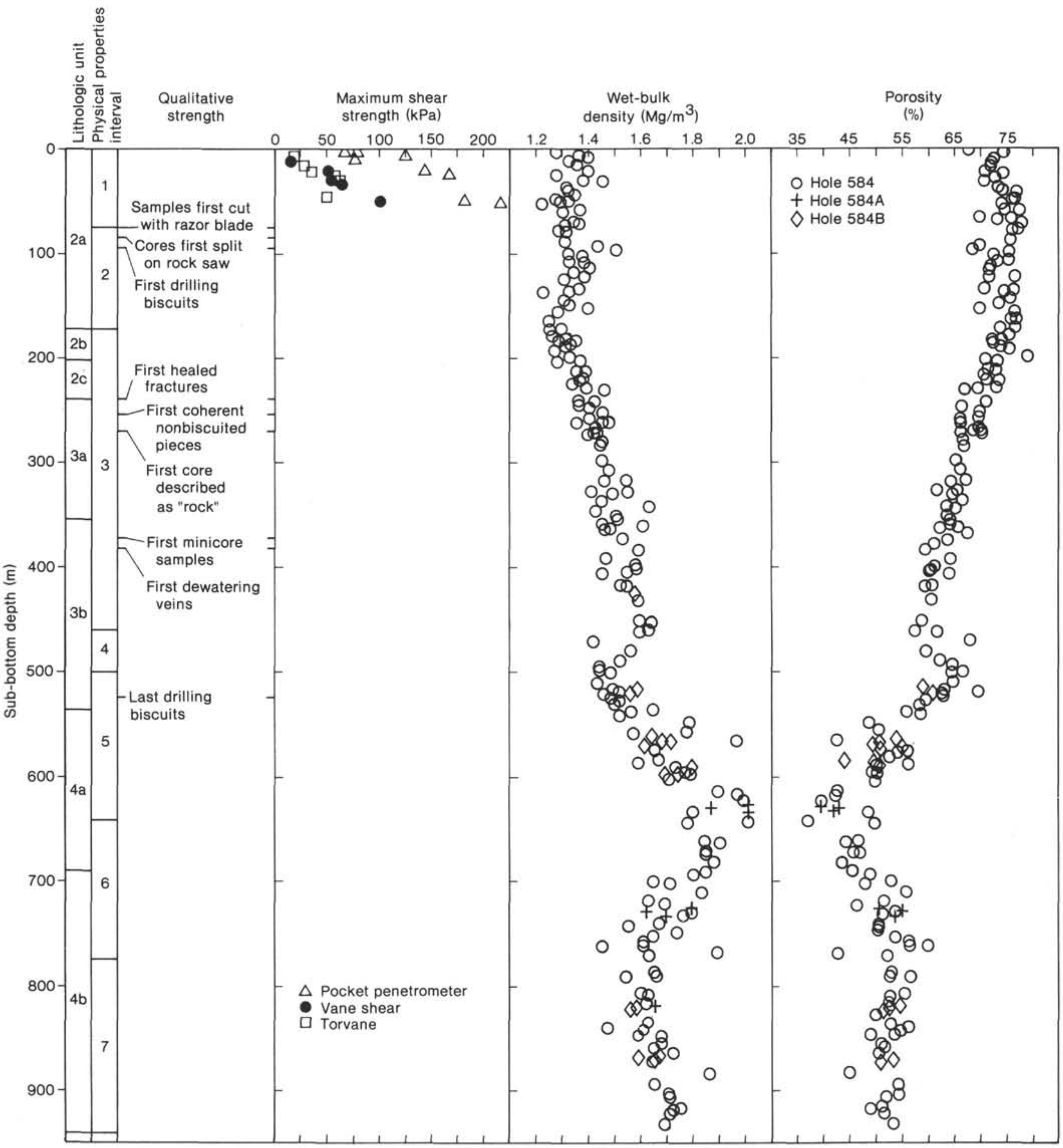

Figure 25. Wet-bulk density, porosity, and maximum shear strength versus sub-bottom depth for Site 584.

mented (Hamilton, 1976; Hedberg, 1936; Rieke and Chilingarian, 1974). This anomalous trend is attributed to the increasing diatom content, which tends to reduce the sediment density and offset the increase in wet-bulk density caused by consolidation. Diatom content, as measured from the abundance of opal-A, reaches a maximum value in this hole near a sub-bottom depth of 75 m (see Inorganic Geochemistry section, this chapter).

Interval 2 (75 to 173.1 m sub-bottom)

Throughout the remainder of Subunit 2a, the maximum sustained wet-bulk densities, 2-minute wet-bulk densities, and porosities all remain nearly constant at 1.45 Mg/m^3, 1.35 Mg/m^3 and 75%, respectively. The minor fluctuations in these profiles, particularly in the wet-bulk density data, correlate with increases and decreases in the diatom content of the sediments. Between 75 and 100 m sub-bottom, the diatom content decreases slightly, causing a slight increase in the wet-bulk density. A gradual increase in diatom content below 100 m, to a local maximum at ~175 m, corresponds to a slight decrease in the wet-bulk density values. These variations are minimized in the porosity profiles, because an increase in diatom content reduces the grain density as well as the bulk density of the sediments.

Interval 3 (173.1 to 460.1 m sub-bottom)

All three physical properties profiles change linearly in Interval 3, which corresponds to Lithologic Subunits 2b, 2c, 3a, and the upper portion of 3b. Maximum sustained wet-bulk densities and 2-minute wet-bulk densities increase from 1.45 to 1.60 Mg/m^3 and 1.35 to 1.60 Mg/m^3, respectively. Concurrently, porosity calculations decrease from 75 to 58% with increasing sub-bottom depth. These gradients are the expected and normal results of consolidation. Diatomaceous sediments, however, have relatively low compressibilities (Silva, 1974; Hamilton, 1976), and changes in mineralogy may also affect the profiles. Estimates of percentages of mineral content from smear slides indicate that the diatom content decreases and the clay mineral content increases within this zone. Increasing clay content may contribute to the apparent porosity decrease and density increase by increasing both the sediment compressibility and grain density.

With greater sub-bottom depths, the diameter of the recovered core decreases noticeably from its original maximum of 6.61 cm, as a result of a worn drilling bit. Below 460.1 m, wet-bulk densities obtained with the continuous GRAPE are therefore not directly comparable with those from the upper part of the hole.

Interval 4 (460.1 to 500.0 m sub-bottom)

Interval 4, which is included within Lithologic Subunit 3b, is distinguished by a reverse gradient in both the wet-bulk-density and porosity profiles. An anomalously low wet-bulk density of 1.45 Mg/m^3 and high porosity of 65% were measured at 500 m sub-bottom. This anomaly, identified in two independent data sets, is believed to be real lithologic variation and not an artifact of sampling and measuring techniques.

Interval 5 (500.0 to 642.0 m sub-bottom)

In the base of Lithologic Subunit 3b and the upper part of Subunit 4a, both the density and porosity profiles reveal normal, but very steep gradients. These steep gradients are most likely the result of an increasing abundance of fine sand and silt downhole in both units. A relative maximum in wet-bulk density (2.00 Mg/m^3) and a relative minimum in porosity (37%) occur near 640 m sub-bottom.

Interval 6 (642.0 to 775.0 m sub-bottom)

Reverse gradients within Interval 6 reduce the wet-bulk density to 1.60 Mg/m^3 and increase the porosity to 55% by 775.0 m sub-bottom (Fig. 25). This reverse gradient is apparently due to downsection decreases in sand and silt abundance, as well as increases in diatom content. This change in composition is also reflected in the gradually decreasing mean grain densities.

Interval 7 (775.0 to 941.0 sub-bottom)

Wet-bulk density increases from 1.60 to 1.70 Mg/m^3 and porosity decreases gradually from 55 to 50% in the final intervals of the Hole 584 profiles (Fig. 25). Preliminary estimates indicate no significant mineralogic change within this zone, and the reduction in porosity is attributed to normal consolidation of a relatively uniform diatom-rich sediment. Note that these values are nearly those predicted by extending the linear trends of Interval 3 to this depth, suggesting that this is a continuation of a normal dewatering profile for these diatomaceous mudstones.

Data from spot coring from 602.2 to 795.0 m sub-bottom in Hole 584A are sparse (Fig. 25). Biostratigraphic correlation based on diatom zonation indicates that stratigraphic units in Hole 584A are 10 to 25 m shallower than in Hole 584. To allow correlation of equivalent units, the data from Hole 584A are plotted 25 m below their actual measured sub-bottom depth (Fig. 25).

Wash and spot cores from Hole 584B, located 700 m downslope from Hole 584 and at almost 30 m greater water depth, yield data from 509.7 to 954.0 m sub-bottom. Again, diatom biostratigraphy indicates that horizons dip eastward. The strata of Hole 584B are approximately 35 to 60 m deeper below the sediment/water interface than the equivalent strata of Hole 584; accordingly the data from Hole 584B are shifted 50 m upsection to correlate stratigraphically with Hole 584 (Fig. 25). Note that the depth from which wash cores were actually obtained is not well defined, but experience has shown that the recovered interval is from the upper 25 m of the total washed interval.

Individual interpretation of the density and porosity data from Holes 584A and 584B is difficult because of the limited amount of data. The wash and spot coring programs at each of these two holes were selected, however, to attempt to reconfirm the results of Hole 584 and to document the lateral extent of the physical properties trends in the strata of Intervals 4 through 7. The density and porosity reversals measured in Hole 584 are also present both 500 m up and 700 m down the trench slope from Hole 584.

Sonic Velocity

The compressional-wave velocity profile very closely parallels the wet-bulk density profile (Figs. 25 and 26). In Hole 584 throughout Intervals 1, 2, and 3 (Lithologic Units 1 and 2, Subunit 3a, and the upper 100 m of Subunit 3b), compressional-wave velocities increase nearly linearly with depth. A minimum value of 1.52 km/s occurs at 43 m sub-bottom, and a local maximum of 1.79 km/s at 460.1 m sub-bottom. Between 460.1 and 510.0 m sub-bottom the velocity gradient reverses with a relative minimum of 1.50 km/s occurring at 510.0 m sub-bottom. This reversal correlates with the reversals of both wet-bulk density and porosity trends within Interval 4. Throughout Interval 5, compressional velocity in-

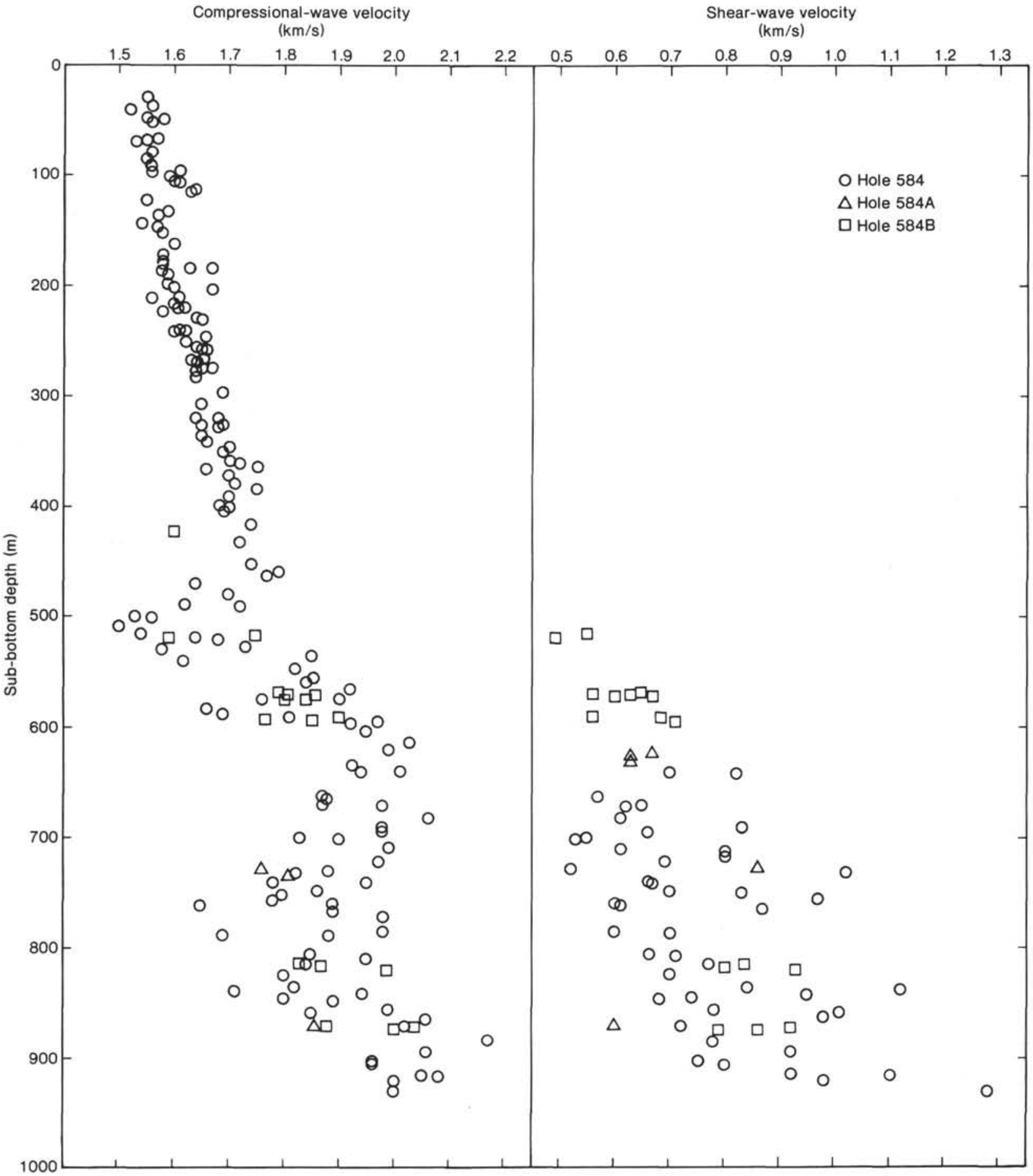

Figure 26. Compressional-wave and shear-wave velocities versus sub-bottom depth for Site 584.

creases rapidly to a maximum of 2.03 km/s at 613.0 m sub-bottom. From 613.0 to 775.0 m sub-bottom (roughly Interval 6), velocity reverses a second time, decreasing gradually to 1.85 km/s. As with the wet-bulk density profile, at 775.0 m sub-bottom the compressional velocity profile returns to a normal gradient. Within Interval 7, compressional velocity increases from 1.85 to 2.10 km/s at the base of the hole.

Shear-wave velocities are not available for the upper 640 m of Hole 584 because of very high energy attenuation. Scatter in the shear velocities is large, but the general trend is toward increasing velocity with depth. Velocities of 0.6 km/s at 640.0 sub-bottom increase to 0.9 km/s at 910.0 sub-bottom. Below this depth, velocity increases rapidly to a maximum of 1.28 km/s at 931 m sub-bottom.

Data from Holes 584A and 584B are scarce because of the wash and spot core programs, but neither compressional or shear velocities show significant deviation from the sonic profiles of Hole 584.

Discussion

Preliminary lithologic analysis yields satisfactory explanations for all fluctuations in the physical properties profiles, with the exception of the anomalously high-porosity-and-low-density zone at 500 m sub-bottom. This zone of low-density sediment was identified from the laboratory wet-bulk–density and water-content data as well as from the relatively low laboratory compressional-wave velocities (Fig. 26). *In situ* well log data also indicate this local density minimum near 500 m (see Logging section, this chapter; Fig. 28). Although the laboratory data from Hole 584B are sparse, they suggest that this anomalous zone extends laterally in a seaward direction a minimum of 500 m. Unfortunately, there is no *in situ* or laboratory data from this zone in Hole 584A to document a similar landward extension of the anomalous zone. In the absence of a lithologic interpretation for this broad anomaly, an obvious hypothesis might be that the zone is overpressured. At this time, however, we have no additional evidence to support this supposition.

Seismic reflection Profile ORI 78-3 (Fig. 31A) shows a band of strong reflectors between 450 and 800 m sub-bottom that roughly coincides with the zones of fluctuation in porosity and compressional velocity from Site 584. It is difficult to explain, however, why the reflectors are horizontal or dipping slightly westward, whereas biostratigraphic correlation of Holes 584, 584A, and 584B indicates that the lithologies are dipping eastward.

Comparison of physical properties profiles from the sites of Leg 56–57 with those from Site 584 is difficult because of the different sedimentation histories and structural positions of the various sites. The section from Hole 440 is the best for comparison with Site 584 because both sites are located in similar structural positions on midslope terraces. Physical properties are compared for the sequences from 4 to 430 m sub-bottom in Hole 584 and from 420 to 750 m sub-bottom in Hole 440, which are correlated biostratigraphically and belong to the lower Pliocene to lower Miocene *Denticulopsis kamtschatica* Zone (Biostratigraphy section, this chapter; fig. 5, Shipboard Scientific Party, 1980c).

Within the *D. kamtschatica* zone, the wet-bulk density values are higher and porosities are lower in Hole 440 than in Hole 584 because this section is buried below 420 m of Quaternary and lower Pliocene sediments in Hole 440. The shapes of these profiles, however, are identical. The upper ~200 m of these zones show abnormally low densities and high porosities, which remain nearly constant with depth. The diatom content of these sediments is the highest of any drilled in either of these two holes. These diatom-rich sediments of the *D. kamtschatica* Zone also form high-porosity zones in Holes 435, 438, and 441 (see Shipboard Scientific Party, 1980a, b, d), indicating an abundant regional bloom. The lowermost portions of the *D. kamtschatica* Zone in Holes 440 and 584 also show similar physical properties trends. The porosity profiles through this zone in both holes indicate nearly linear decreases in porosity, which correspond to decreasing diatom content as well as to increasing overburden pressure.

Carson and Bruns (1980) have hypothesized that the zone of low density at the top of the *D. kamtschatica* Zone, between about 420 and 580 m sub-bottom in Hole 440, is a zone of underconsolidated sediments that are characterized by abnormally high pore-water pressures. They suggest that the relatively unfractured, near-surface diatomaceous mud constitutes the "impervious" lithology required to maintain pore-water pressures above the hydrostatic pressure gradient. Given the high diatom content and the resulting low grain density of these sediments, it seems unnecessary to suggest that abnormally high pore-water pressures are responsible for maintaining this low-density zone.

PALEOMAGNETICS

Samples for paleomagnetic studies were taken from each core section. For the orientation of structural features, measurements were made on bedding and on fault planes within the same block of sediment from which the magnetic sample was taken. For all samples shipboard measurements were made routinely for natural remanent magnetization (NRM), and after 100-Oe alternating field (AF) demagnetization the intensity of the signal from each was strong compared with the noise level of shipboard magnetometer. All samples were remeasured routinely for NRM after 15-mT AF demagnetization with a shore-based magnetometer (noise level 1×10^{-4} A/m).

The variation in intensities of remanent magnetization is large, ranging from less than 1×10^{-4} to 1×10^{-1} A/m, and is directly related to the proportion of magnetic minerals in the samples analyzed. Three of the intervals at Site 584 are recognized as paleomagnetically distinct: (1) an uppermost 3 m of high intensity, (2) an interval from 35 to 190 m sub-bottom of extremely low intensity, and (3) a span from 605 to 650 m sub-bottom of high intensities. The remainder of the samples have normal remanent intensities. The uppermost division corresponds to Pleistocene pebbly mud, the second to diatomaceous mud, and the third to Miocene turbidites. Selected samples were examined by the stepwise AF demagnetization.

A sample from the first interval (0.74 m sub-bottom) has stable direction during stepwise AF demagnetization; however, intensity decreases to less than half of NRM after 100-Oe AF demagnetization, meaning that this sample contains coarse grains of magnetic minerals (larger than 10 μm). Samples from the second stratigraphic interval were examined only with shore-based magnetometer because of their weak intensities. Both of the samples from the third interval have negative inclination, stable direction, and stable intensity during stepwise AF demagnetization, meaning in this case that the samples contain large amounts of fine magnetic minerals. Because the changes in intensity are similar in the first and third groups, the character of magnetic minerals in the samples from those intervals are probably also similar and the small intensity variations are caused only by changes in the relative abundance of the magnetic mineral.

Inclinations and intensities after 15-mT AF demagnetization are shown in Niitsuma (this volume). Magnetostratigraphic correlation above 600 m sub-bottom depth was made from the Gauss Normal Polarity Epoch to Epoch 7 with reference to diatom biostratigraphy. Several intervals in the lower part have normal dipole inclination before bedding correction. After tilting, these sediments were probably remagnetized under a geomagnetic field of normal polarity.

The strata drilled in Hole 584 have dips as steep as 75°. Dip directions were oriented by using the measured declination of remanent magnetization after 10-mT AF demagnetization and are uniformly toward the east throughout the drill hole. The sediments recovered are continuously tilted below 300 m sub-bottom depth. The intervals between 195 and 200 m and between 250 and 255 m sub-bottom contain dipping bedding planes; however, both above and below these intervals bedding is semihorizontal.

A horizon at 613 m sub-bottom depth in Hole 584A is correlated to 630 m sub-bottom depth in Hole 584 by using magnetic polarity and intensity.

HEAT FLOW

Of a total of four attempts to measure bottom-hole temperature, one reliable reading was obtained at 278.5 m sub-bottom. Thermal conductivities of recovered cores were measured at 57 points between 0 and 280 m sub-bottom, giving average conductivity of $3.35 \pm 0.04 \times 10^{-3}$ cal/(cm·deg·s). Heat flow is herein computed by multiplying the overall temperature gradient and thermal conductivity over 280 m sub-bottom as 1.17×10^{-6} cal/(cm^2·s). This value is somewhat higher than the average value obtained previously in this area through conventional spear-type probe methods (Fig. 27).

LOGGING

Logging at Site 584 was deferred from Hole 584 to 584A because we wished to preserve as much time as possible for drilling to the deep reflectors that defined our major objective. Because Hole 584A was only spot cored, the logs in that hole must be correlated primarily with coring results in Hole 584, which contained very steeply dipping beds. However, correlation based on biostratigraphy and physical properties indicates that stratigraphic horizons in Hole 584B are 0 to 50 m higher than at Hole 584 over the logged interval.

After the extensive caving below 850 m that caused termination of drilling at Hole 584A, the pipe was "worked down" to 879 m, where the mechanical bit release was successfully shifted, and the hole was filled with heavy mud. The first logging run was to include sonic, induction, gamma ray, and caliper tools, but this run was aborted following the inability to receive recognizable signals from the sonic tool. A combination of formation density (FDC), neutron porosity (CNL), gamma ray (GR), and caliper tools was rigged.

This combination of tools was "worked down" to 4620 m (495 m sub-bottom), where it encountered a bridged section. We suspected that the tools had passed this bridge, and an extra 200 m of cable was played out. An initial run was then made up to 400 m sub-bottom in order to duplicate-sample the critical depth interval where several large density and velocity anomalies were defined from laboratory measurements and within which a major reflecting horizon lay. Attempts to return to what was thought to be the original logging depth were blocked at (what was in retrospect) the same bridge near 500 m. A second logging run was then completed to the open pipe at 91 m sub-bottom. Our limitation to 500 m is unfortunate because the interval between 500 and 700 m contains most of the large fluctuations in physical properties.

A second attempt to lower the sonic-induction combination was no more successful than the first and, with the remaining time waning for a "last ditch effort" to clarify the complex structure at this site in a third hole, logging was terminated. From the end of hole conditioning to the rigging down of logging equipment, 17½ hr. were consumed in the logging operation.

The abbreviated set of logs (Fig. 28) is of high quality because of the calm sea conditions, because most of the hole was near gauge, and because the lithology is relatively simple. Two distinctive units are defined on the basis of the log response, but difficulties arise in correlating the log responses with lithologic units delineated in the cores from Hole 584.

Logging Unit 1 extended from the open pipe at 91 m sub-bottom to about 350 m. Over this interval the FDC log shows a downward, fairly linear increase in bulk density from 1.40 to 1.55 g/cm^3 at 325 m. Superimposed on this increase are small-scale variations that do not correlate well with other logs. Over this interval the CNL values are relatively high with respect to the FDC values. A very distinctive characteristic of this unit is the low natural GR values, which average less than 20 API units near the top but rise gradually to about 25 units at 350 m. This unit correlates well with the diatom-rich muds, sediments with very low density and relatively low clay content. The downward increase in density and gamma radiation reflect the decrease in diatom content and resultant increase in clay content. Laboratory bulk densities from 2-minute GRAPE measurements are about 0.05 g/cm^3 less than the log values, as expected from pressure release rebound (Shepard et al., 1982).

The second logging unit extends from about 350 m sub-bottom to the base of the logged interval. Within this zone, gamma log anomalies have higher amplitudes and higher mean values (25 to 35 API units) than in Unit 1. The caliper log indicates that this section of hole is much more rugose than above. Bulk densities over this section rise rapidly to 1.60 g/cm^3 by 375 m and vary about this value with wave-length excursions of 0 to 2 m and amplitudes of 0.25 g/cm^3. Maximum average densities of 1.65 g/cm^3 occur near 450 m. The CNL log closely follows the FDC log and differs from that of Unit 1 in having lower values relative to the FDC log

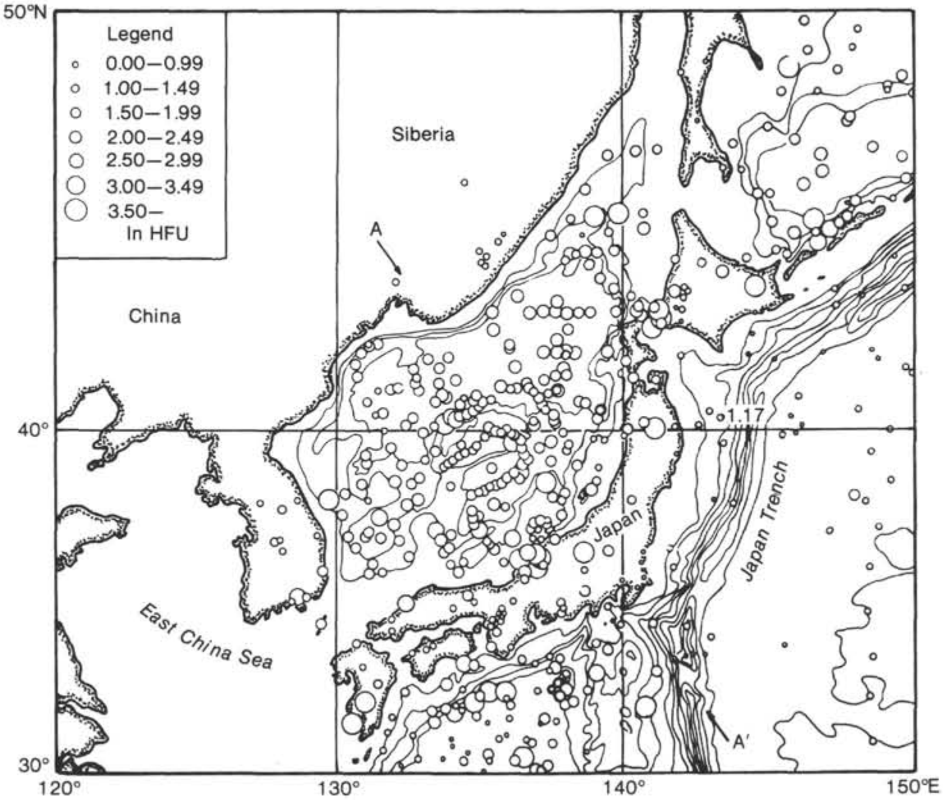

Figure 27. Heat flow in the Japan Trench (after Watanabe et al., 1976 © American Geophysical Union). 1.17 HFU is the heat flow value computed for Site 584. HFU = $\times 10^{-5}$ cal/(cm^2·s).

over the same interval. From 425 to 500 m sub-bottom, the CNL trace is consistently below the FDC trace in the stacked format. The highly variable and correlative GR, caliper and FDC logs over Unit 2 indicate interbedded sand-rich beds or silt-rich and clay-rich beds. Silt to fine-sand stringers recovered in the cores of this interval probably represent these sand-rich units, but the logs suggest that many more such intervals are present than were recovered. Several thin (0.5 m) high-density spikes, with bulk densities reaching 1.90 g/cm^3, may indicate thicker ash units, which are relatively abundant over the upper half of this interval.

In situ densities over Unit 2 compare well with the laboratory values. Both show relatively constant values with a relative density maximum near 400 to 450 m sub-bottom. In broader context of the laboratory-derived bulk-density profile, this response could better be explained as showing a general increase in density with depth, but with a superimposed local density minimum near 500 m in Hole 584 (Fig. 28).

Comparison with Sites 440 and 439

The strata logged in Hole 584B are chronologically equivalent to those logged between about 450 m and the end of logging, at 730 m in Hole 440. Bulk densities at the Pliocene/Miocene boundary in Hole 584 are significantly lower (1.50 to 1.55 g/km^3) than at the same biostratigraphic level in Hole 440 (1.60 g/km^3). In part, this difference reflects the much greater depth (670 m) to this level in Hole 440 than in 584. Tectonic factors are not thought to be the major cause of the difference, because strata at this sub-bottom depth in Hole 584 show significant dewatering veins and healed fractures. From the differences in values, we may infer that a thick section of upper Pliocene and Quaternary was never deposited at Site 584, and that nondeposition was dominant during that time span. The densities in these two sites converge downward into upper Miocene sediments, reflecting the gradual downward increase in values in Site 584 contrasted with the relatively constant profile at Site 440.

No inversion in *in situ* bulk densities comparable with that at Site 440 and at other drill sites on the inner slope was observed at Site 584. Such an inversion might have occurred in the upper Pliocene strata, missing at Site 584, but this is unlikely because the inversion at Site 440 and elsewhere occurs over a density range of 1.5 to 1.65 g/cm^3, where sediments are becoming indurated. In Hole 584B, this range is reached only in the lowermost Pliocene strata near a 300-m depth.

The deepest part of the FDC log and laboratory measurements indicate a marked density minimum between about 475 and 525 m, but for several reasons this anomaly is not correlative with that density minima at sites drilled on previous legs. First of all, the anomaly occurs where dewatering veins, healed fractures, and layer shears are already well-developed. In addition, this section of the hole was typified by very good recovery and cores with a minimum of open fractures. Moreover, both

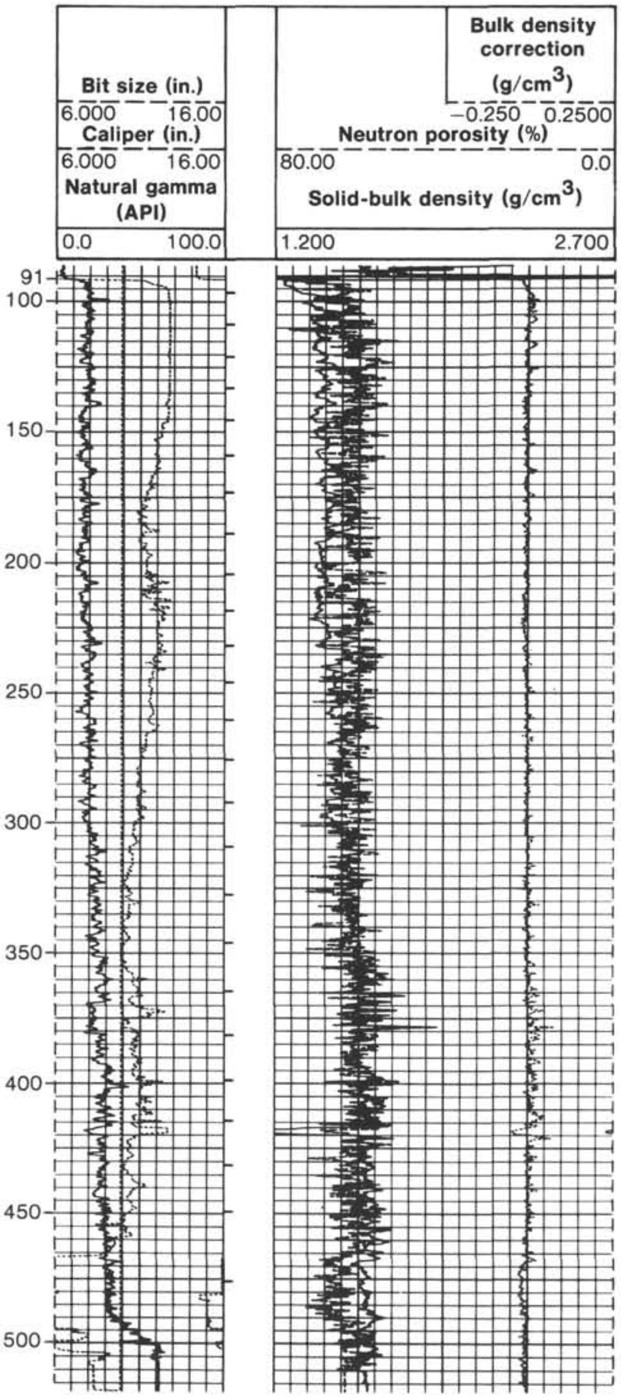

Figure 28. Logging records for Hole 584A.

the *in situ* and laboratory profiles show this anomaly, indicating that the anomalous density is an intensive characteristic and not due to larger-scale fracturing.

SEISMIC STRATIGRAPHY

Seismic Lines JNOC 1, ORI 78-3, ORI 78-4, and JNOC 2 flank DSDP Legs 56, 57, and 87 sites (Fig. 29), and of these Profile JNOC 1 was processed specifically by the Japan National Oil Corporation for Leg 87 (Fig. 30). Additionally, a new, migrated display was prepared for Profiles ORI 78-3 and ORI 78-4 (Fig. 31), and several kinds of multichannel displays were prepared for the profile-crossing proposed Site 584, particularly for Line ORI 78-3 between Shot Points (SP) 0 and 400 (see Fig. 31A). Several authors have discussed the meaning of the various seismic reflectors shown on these profiles (Nasu et al., 1980; Saki et al., 1980; Kagami et al., 1981). This report will discuss, therefore, only the problems related to Site 584, with particular emphasis on the origin of the midslope terrace in the trench slope.

The midslope terrace or bench on the trench slope is one of the most persistent topographic features of the slope and roughly parallels the trench axis (Nasu et al., 1980). The proposed site was selected on the midslope terrace because this is the seaward limit of the trace of the seismic reflectors from the landward reference Sites 438 and 439 (Shipboard Scientific Party, 1980a). Even so, reflectors traced on Profiles JNOC 1, JNOC A, ORI 81-2, and ORI 78-3 to Site 584 are not always continuous (Tsuboi et al., this volume). Drilling has shown that dips ranging between 20 and 70° occur in the cores below 350 m sub-bottom. These beds are disharmonic to the low-angle dips of seismic reflectors. Drilling results at Hole 584A clearly indicate that the vertical offset of the stratigraphic horizons does not exceed 50 to 100 m between the two holes, despite the much higher dips of the individual beds. The reflectors are, therefore, averaging structural features at a scale comparable to the distance between the Site 584 holes and are not resolving the details apparent in the lithologic section.

Kagami and others (1981) constructed a synthetic profile by revising the original based on logging at Site 439 (Saki et al., 1980). In the result, Reflector X is traced seaward to SP 1790 on Profile JNOC 1, where it becomes obscured (Fig. 30 and Table 3A). Reflector C is traced to SP 1780, where it also fades. A faded pattern might arise from tectonic phenomena such as fracturing. Reflector E, on the contrary, gets stronger near SP 1760 and maintains its reflectivity toward SP 1860. Reflector F cannot be traced on the profile. Reflector J is easily traced because of its strong acoustic impedance contrast.

Reflectors can be traced from the Sites 438 and 439 on the migrated depth section of the landward segment of Profile JNOC 1, through Profile JNOC A and Profiles ORI 80-2 to ORI 78-3, to Site 584 (Fig. 29). Tracing reflectors over a distance as great as 100 km limits the accuracy of the following discussion.

According to the Leg 57 site chapter for Site 440 (Shipboard Scientific Party, 1980c), Reflector C on Profile JNOC 2 is a tectonically induced reflector (Table 3B). Physical properties at that site show decreases in density and velocity at this interval. The stacking velocity for Profile ORI 78-3 indicates that between SP 0 and SP 150 a low-velocity zone exists roughly between Reflectors C and E, similar to Reflector C of Profile JNOC 2. The velocity inversion from 1.83 above to 1.51 km/s below Reflector C may correspond either to a *Coscinodiscus* spp. bloom as shown by marked increase in opal-A, or to development of tectonically induced fractures, faults, and veins at this level. Because both phenomena develop

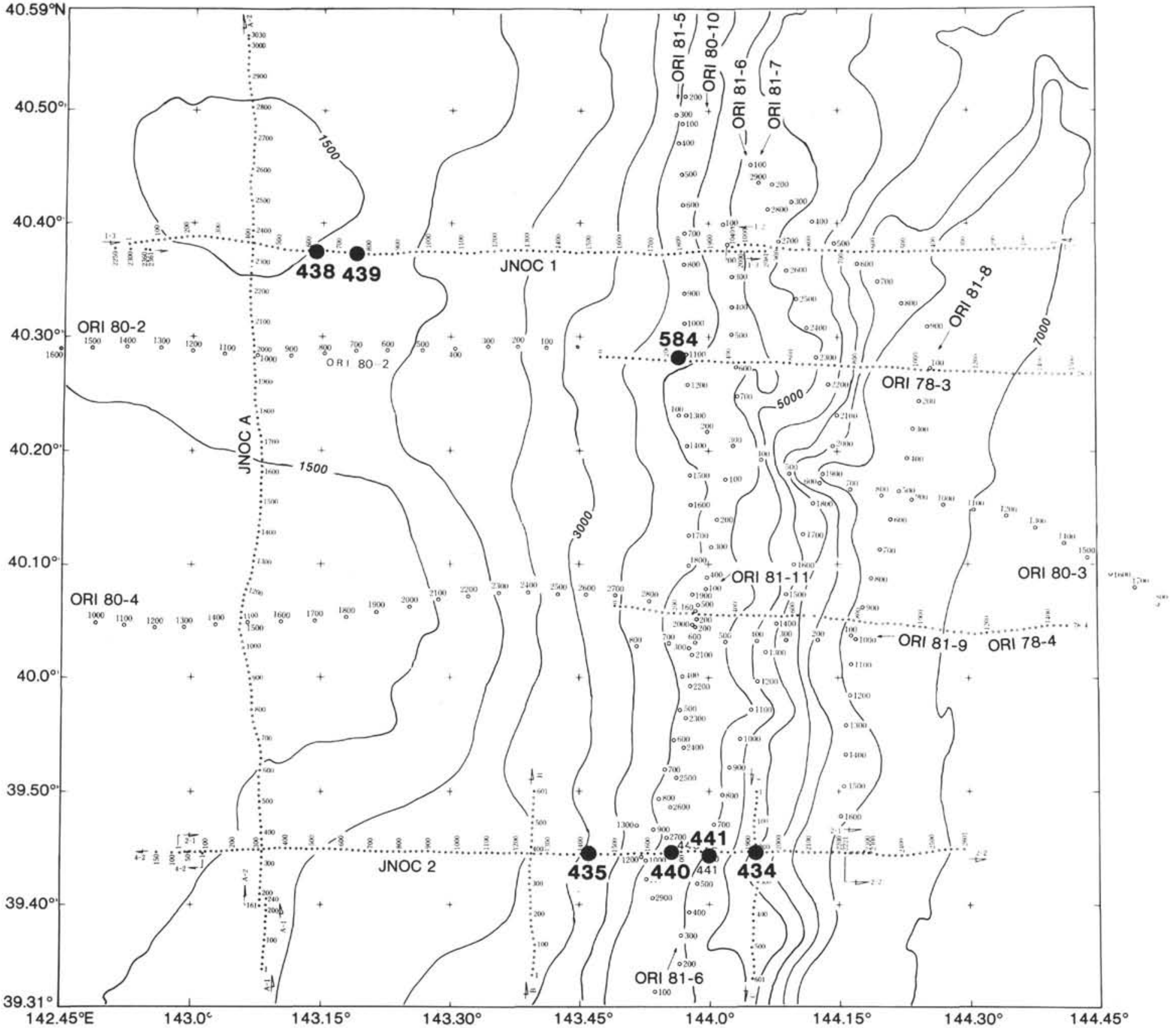

Figure 29. Location map for multichannel seismic profiles near Site 584. Location numbers in the 400s are Leg 56, 57 drill sites. Contour intervals are 500 m.

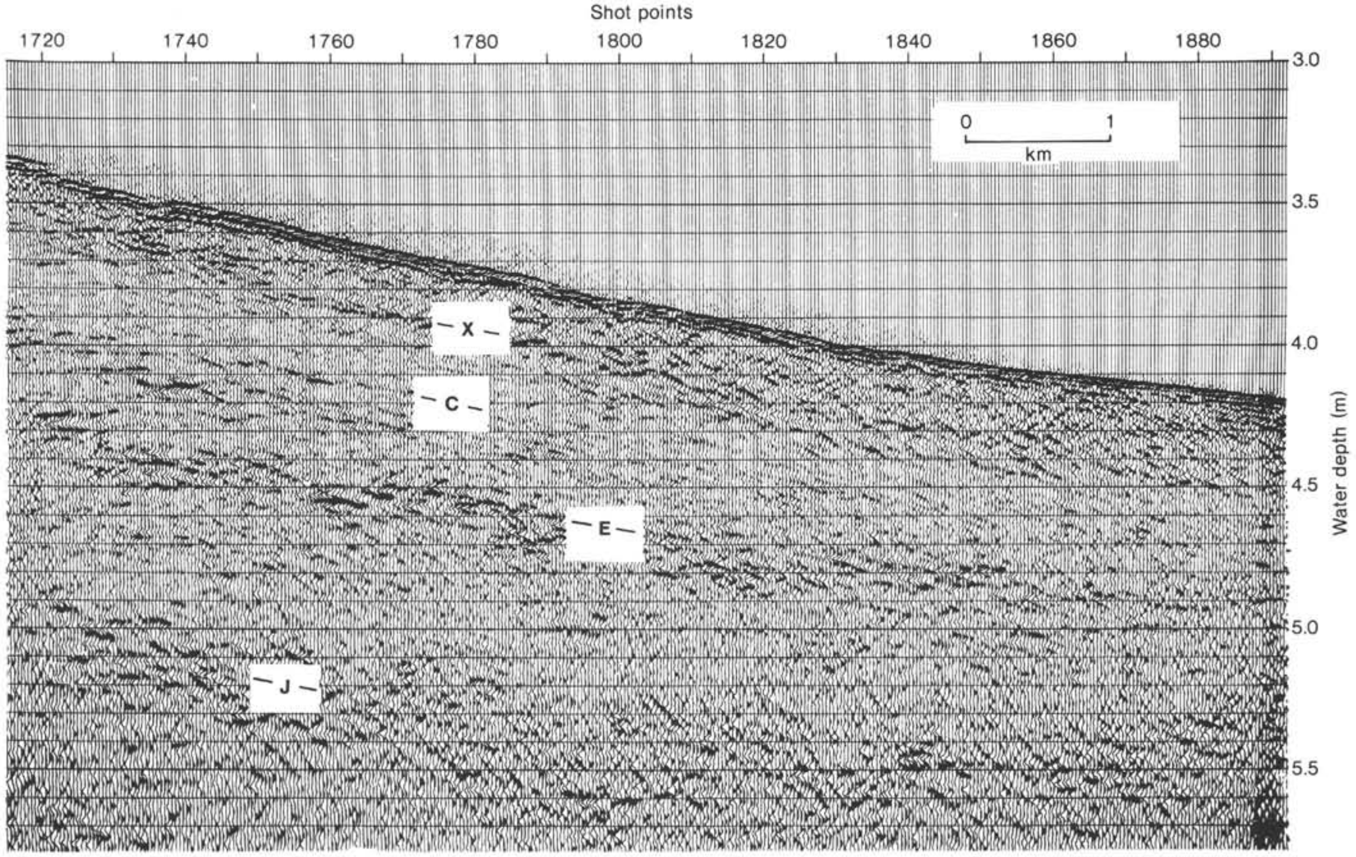

Figure 30. Multichannel seismic reflection Profile JNOC 1. Horizontal scale distance between each shot is 50 m.

at about the same level, it is difficult to evaluate which of the two is more important for the change of physical properties at Site 440. Also, seismic Line JNOC 2 was not migrated, so it is difficult to compare the reflectors at this stage.

Compared with Site 439, the lower section between Reflectors F and J on Profile ORI 78-3 (Fig. 31A and Table 3C) is three to four times thicker between SP 0 and SP 100, suggesting the presence of a Paleogene section. Reflector J dips seaward parallel to the surface of the trench slope and to a reflector probably from the Paleogene section. These supposed Paleogene rocks onlap the J reflector between SP 0 and SP 100.

The reflectors fade, the low-velocity zone disappears, and acoustic basement (Reflector J) reverses the structural gradient from seaward dipping to landward dipping from SP 150 seaward. At SP 270 on the migrated depth section, another velocity inversion of 1.82 to 1.57 km/s is estimated from the stacking velocity for the depth interval between 420 and 520 m sub-bottom. That inversion is about the same depth as the base of the abundant opal-A zone (see Inorganic Geochemistry section, this chapter) and is probably a result of tectonically induced fractures and faults or rapidly deposited mud turbidites (see Sedimentology section, this chapter).

A tentative correlation of seismic events with the drilling results is shown in Table 4 and in the segment from Profile ORI 78-3 (see Fig. 31A). Three seismic units are recognized, based on sharp velocity changes. Seismic Unit 1 ranges from 0 to 580 m sub-bottom. The interval velocity is 1.83 km/s. Seismic Unit 2 ranges from 580 to 1200 m sub-bottom where it is underlain by Reflector J, and its interval velocity is 2.10 km/s. Except for the basement reflector, no drilled lithologic horizon can be traced within seismic Unit 1. The strongest reflectors occur at 460, 499, and 584 m sub-bottom, one of which may represent Reflector E. Although they appear to be horizontal, they are subparallel to the basement high and also to the surface topography. The acoustic basement shows strong reflection because of its high velocity ranging from 3.1 to 4.2 km/s, which is within the range expected for the consolidation state of Cretaceous to Paleogene rocks. Seismic Unit 2 apparently corresponds to steeper bedding inclinations (see Structural Geology and Paleomagnetics sections, this chapter).

Drilling of Site 440 showed that the depth of the Miocene/Pliocene boundary was far below its projection from Site 435. Nasu and others (1980) deduced, therefore, that the downbowing of the seaward edge of the continent was responsible for formation of the filled trough or midslope terrace during the subsidence of the Oyashio landmass.

Profile ORI 78-4 more clearly shows relative basement uplift beginning at a hinge point under a trough and continuing to the trench slope break (Fig. 31B). The acoustic basement landward from the hinge point slopes seaward in almost a straight line, and seaward of that point basement also slopes uniformly, but with a reverse

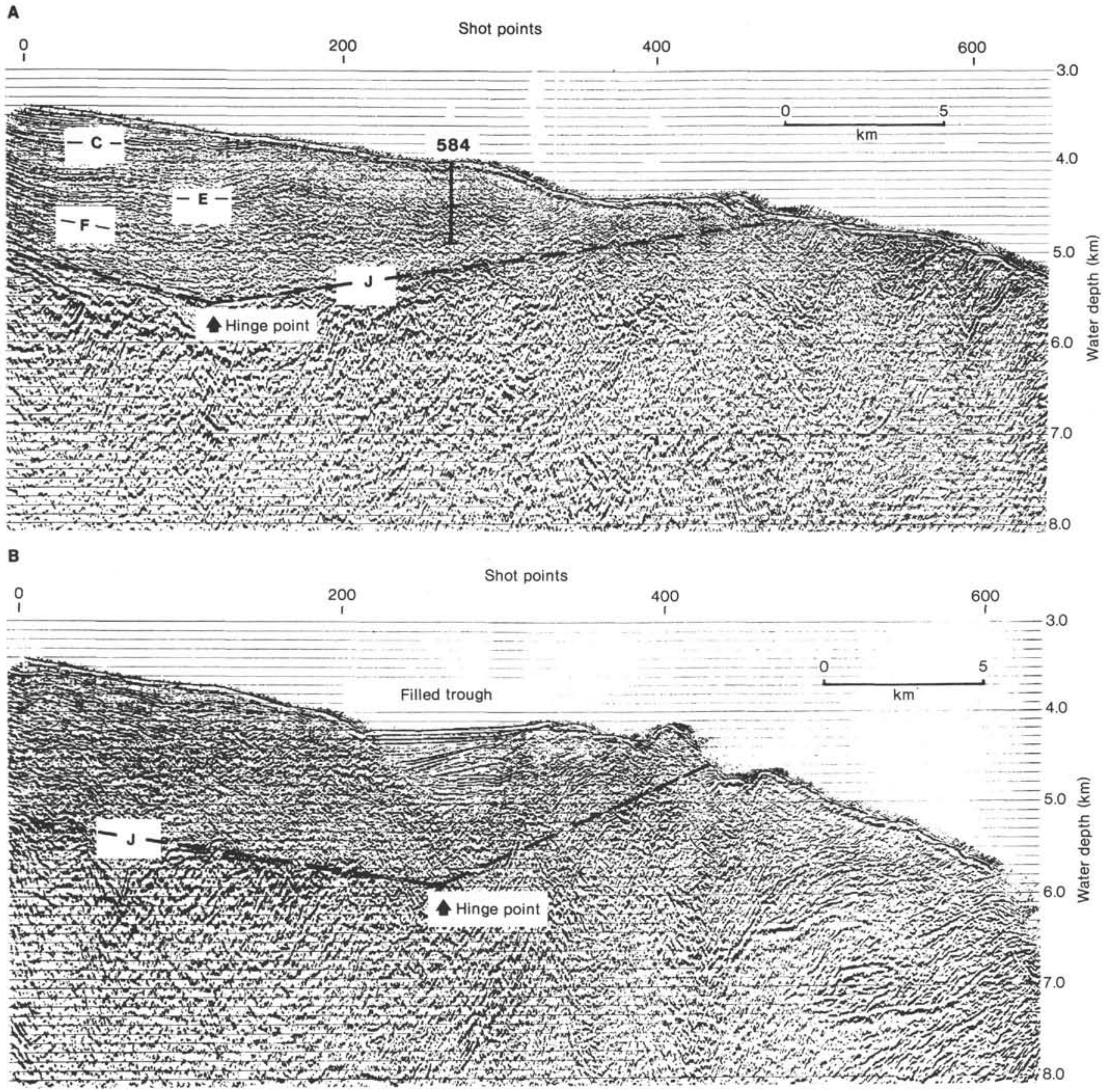

Figure 31 A. Multichannel seismic reflection Profile ORI 78-3. B. Multichannel seismic reflection Profile ORI 78-4.

gradient. Coastal terraces with a reverse gradient of topography have been discussed by many authors (Seno and Ishibashi, 1978). Uplifted subaerial coastal terraces are associated with great interplate earthquakes (Yonekura, 1975; Fitch and Scholz, 1971). During the interseismic period they subside. Of importance for topography, therefore, is the residual uplift for one seismic cycle. Seno and Ishibashi (1978) defined the residual uplift ratio as the ratio of the residual uplift (V_c) to total uplift ($V_c + V_d$) during seismic crustal movement. Total subsidence during the interseismic period is defined as V_d.

The reverse gradient observed for the acoustic basement shown on Profile ORI 78-4 might suggest that seismic crustal movement has been occurring at this convergent plate boundary. Can seismic crustal movements explain the occurrence of these filled troughs? A schematic figure represents the formation of a typical reverse gradient along the continental and ocean crust boundary (Fig. 32). Point A indicates the end of the present acoustic basement, Point C represents the estimated Pliocene position of Point A based on a straight line extrapolation. Point B corresponds to the depth of the hinge point. In this case, the residual uplift ratio indicates an integrated uplift for the time span between the Pleistocene and the Recent. The duration of the Pleistocene was taken from the previous work at Site

Table 3A. Reflectors picked at SP 1840 on seismic Profile JNOC 1.

Reflector	Sub-bottom depth (m)	Stratigraphic unit
X	290	Pleistocene
C	500	Pliocene
E	700	Strong reflector · upper Miocene
F	900	middle Miocene
J	1390	Cretaceous

Table 3B. Reflectors picked from Profile JNOC 2 at Site 440.

Reflector	Depth (s)	Sub-bottom depth (m)	Stratigraphic unit
X	6.26	290	Pleistocene
C	6.41	450	Pliocene
E	6.64	690	upper Miocene

Table 3C. Reflectors picked from SP 00 (western end) of the revised migrated section of Profile ORI 78-3 (Fig. 31A).

Reflector	Depth from sea level (km)	Sub-bottom depth (m)	Stratigraphic unit
C	3.6	320	Pliocene
(D)	4.0	720	Pliocene
E	4.25	970	upper Miocene
F	4.5	1220	middle Miocene
J	5.1	1820	Cretaceous

Table 4. Correlation of seismic events drilled at Site 584 (SP 270).

Reflectors (m)	Drilled sub-bottom depth (m)	Remarks	Seismic unit
45	48	Moderate, carbonate concretion	
55	58	Strong, carbonate concretion	
100	105	Open fracture begins	
150	153	Lithologic change	
215	212	Lithologic change	
350	345	Lithologic change (Pliocene/upper Miocene)	1
390	393	Fault?	
465	460	Moderate, unconformity	
500	499	Strong, velocity inversion	
580	584	Strong, velocity increase	
625	622	Strong, velocity maximum	
695	690	Silty to clayey	
715	719	Silt bearing (upper/middle Miocene)	2
820	825	Hard claystone	
860	873	Moderate, unconformity	
900	892	Moderate, shear zone	
(1200)		Strong	
			(3)

Note: ( ): not penetrated.

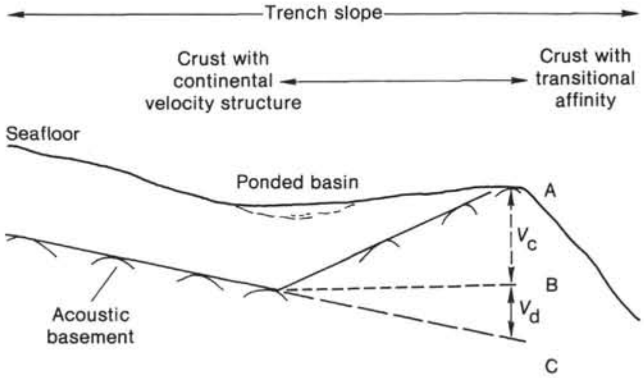

Figure 32. Schematic diagram of generalized slope features, horizons, and vectors used in relative uplift ratio determinations. See text (Seismic Stratigraphy section) for explanations of V_c, V_d, and Points A, B, and C.

438 (Keller, 1980), and the derived values are given in Table 5.

The residual uplift ratio is 0.68 for the midslope terrace shown on Profile ORI 78-4 (Fig. 31B). An almost identical value is obtained for the coastal terraces of Boso Peninsula near Tokyo, where a great uplift occurred after collision with the Izu ridge (Seno and Ishibashi, 1978).

Although they are not migrated, Profiles JNOC 1 and JNOC 2 were also examined (Fig. 33). Using the same method described above, we obtained residual uplift ratios of 0.40 and 0.60, and, although the data are limited, we tentatively conclude that this midslope trough can be formed when the ratio is higher than 0.60. This threshold value is consistent for both marine and subaerial observations (Seno and Ishibashi, 1978).

The reversed inclination at the basement complicates geometric interpretation for Profile ORI 78-3 (Fig. 31A); therefore the computed residual uplift ratios are tentative (Table 5). Site 584 is located directly above the reversed inclination. This is the first time that the reversed inclination is found along the entire trench slope off northeastern Honshu.

SUMMARY AND CONCLUSIONS—JAPAN TRENCH

The principal objective of the Japan Trench drilling was to investigate the history of vertical motion of the continental margin near the trench. Periods of subsidence associated with sediment subduction or tectonic erosion

Table 5. Residual uplift ratios calculated from seismic reflection profiles.

Seismic line	A	B	C	V_c	V_d	Residual uplift ratio
JNOC 1	4500	5350	6550	850	1200	0.40
ORI 78-3	4750	5650	7050	900	1400	0.40
ORI 78-4	4890	5710	6090	820	380	0.68
JNOC 2	4455	5425	6125	970	700	0.60

Note: Values of A, B, and C represent depth in meters. For explanation of A, B, C, V_c, and V_d, see text.

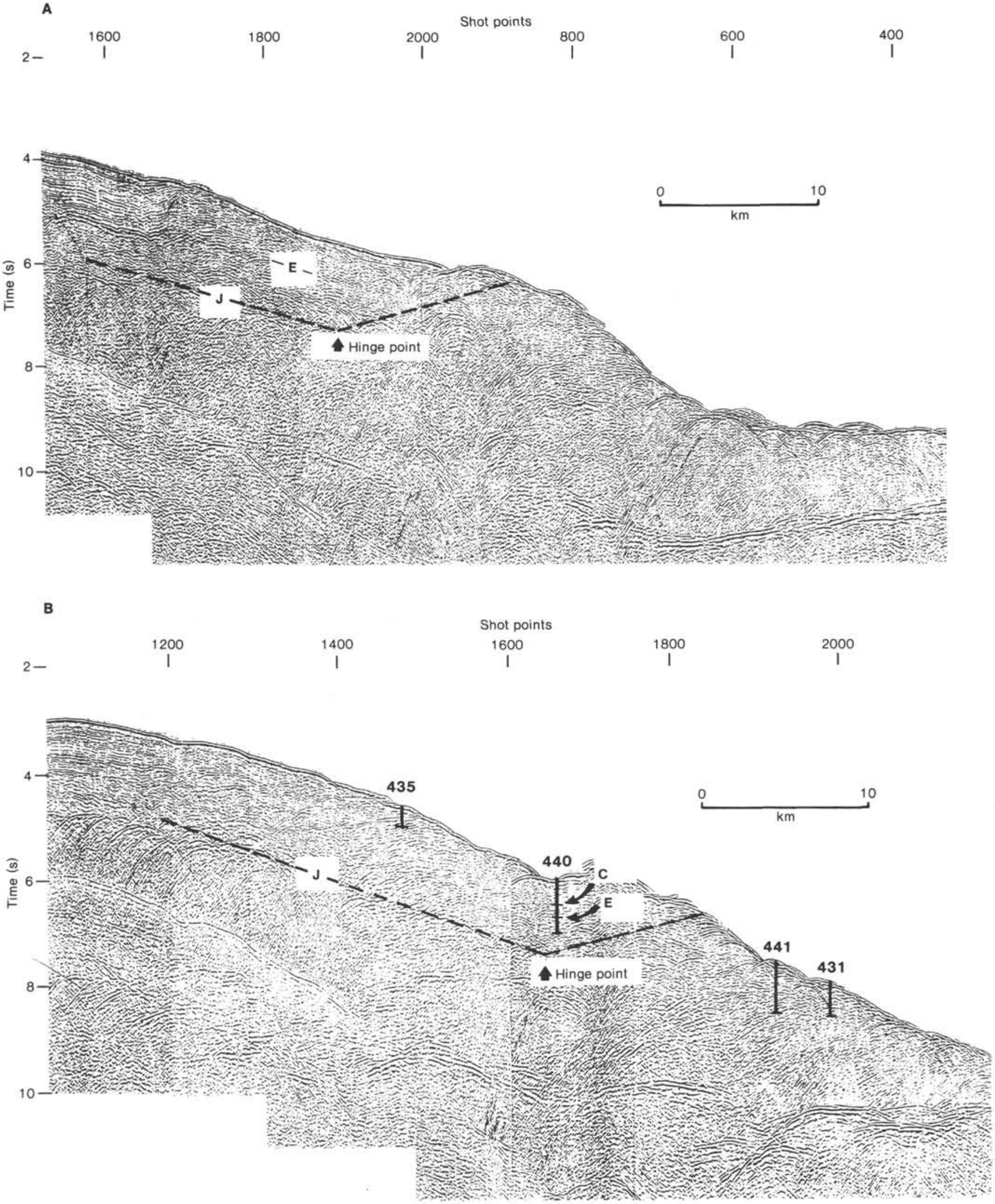

Figure 33. Residual uplift of the midslope terrace based on: A. multichannel seismic reflection Profile JNOC 1, with interpretive horizons, and B. multichannel seismic reflection Profile JNOC 2, with interpretive horizons.

apparently persisted during the Miocene, only to diminish and perhaps to revert to episodes of relative uplift and possibly accretion since the late Pliocene–Pleistocene. The combination of drilling results, logging, seismic profiles, and other geologic data should clarify the nature of deformation that controls the large-scale structural geometry in the trench-slope area.

Three holes were drilled across the midslope terrace of the Japan Trench, penetrating 954 m of the sedimentary section. The oldest sediment cored was early middle Miocene. Four lithostratigraphic units are recognized (see Sedimentology section, this chapter).

The uppermost 4 m at Hole 584 are Pleistocene sediment, underlain without a visible lithologic contact by soft, lower Pliocene diatomaceous mud and mudstone, consolidating near 88 m sub-bottom. A third lithologic unit (240 to 537 m sub-bottom) is also a diatomaceous mudstone, but is distinguished by fine sand and silt beds, seaward-dipping strata, and markedly higher induration. The Pliocene/Miocene boundary occurs within this unit, near 425 m sub-bottom, but no lithologic contrast marks this event. A varicolored, bioturbated mudstone with a much-reduced diatom content constitutes Unit 4 and the remaining 941 m drilled at Hole 584. The lower portion is noteworthy for its paisley appearance and pervasive network of dewatering veinlets. Healed fractures begin in Core 27 and become more numerous downsection; in most cases the offsets are normal, but abundant examples of reverse motion also occur.

The frequency of ash layers and of dispersed glass and ash pods suggests that onshore volcanic activity increased near the end of the late Miocene and continued through the early Pliocene.

Authigenic carbonate nodules, including siderite, are commonly disseminated in the lower Pliocene sediments and are frequently intercalated with ash layers or dispersed volcanic sediments.

The diatom biostratigraphy of Site 584 is virtually identical to that of Site 438, located about 70 km to the west. Rates of sediment accumulation are based on selected datum levels and are highest (200 to 70 m/Ma) for the lower Pliocene and upper upper Miocene (7 Ma). Lower upper Miocene through upper middle Miocene rates are less (15 m/Ma).

Logging and laboratory physical properties measurements outline large fluctuations in bulk density and in sonic velocity in a zone of prominent reflectors beginning near 500 m sub-bottom.

A seismic-interval-velocity reversal at 470 m sub-bottom coincides with a density decrease between 470 and 550 m. These reversals are interpreted as follows: the stratigraphic level is the beginning of large sediment influx and is represented by a rapidly deposited muddy turbidite containing excess pore water and sealed by overlying sediments. The density reversal reflects sound in the same manner as a BSR. This horizon is one of a few traceable reflectors despite the highly fractured and steeply inclined bedding of the trench.

All three holes drilled at Site 584 have steeply dipping Miocene formations throughout the interval drilled. The dip is east to northeast, homoclinal, and ranges from 20 to 70°, generally steepening downward, indicating that the whole block rotated seaward. Holes 584 and 584A are separated by 524 m and are at nearly the same water depth. If the bedding is inclined about 45°, the equivalent stratigraphic horizons should be offset by 524 m. Only about 50 m difference is actually recognized between the holes, indicating that some type of structure separates them (see Structural Geology section, this chapter). These offsets are not evident on the seismic reflection profiles. The acoustic basement shown on the migrated seismic section dips gradually seaward, but the dip reverses near the continental and ocean crust boundary. A hinge point located beneath the midslope terrace is clearly defined on the profile, and from that point the faults develop and the seismic horizons are obscured, owing mainly to steep bedding. Faulting may, therefore, control the landward dip of this segment of acoustic basement.

Using geometric simplifications of the available seismic reference lines, residual uplift ratios were computed, as was originally done to quantify deformation of Japanese coastal terraces (see Seismic Stratigraphy section, this chapter).

Many lines of evidence mark the commencement of the crustal movement along the Japan Trench. Foraminiferal assemblages at Site 438 indicate shallower environments since the Pleistocene (Shipboard Scientific Party, 1980a). The rate of sedimentation increased rapidly in the Pleistocene at Site 440 suggesting commencement of filling of the midslope terrace (Shipboard Scientific Party, 1980c). If we take 2 Ma as a starting time, the rate of the present phase of vertical crustal movement is 0.6 to 1.2 mm/yr., a range comparable to that measured for crustal movements on land.

Evidently, extensional tectonics from the middle Miocene continued until the early Pliocene, and Site 584 was already at bathyal depths by the late Miocene. A hiatus between lower Pliocene and Quaternary sediments found at Hole 584 might indicate commencement of reversed gradient of the acoustic basement, which can be explained by vertical crustal movement associated with great interplate earthquakes caused by a new cycle of subduction at the trench.

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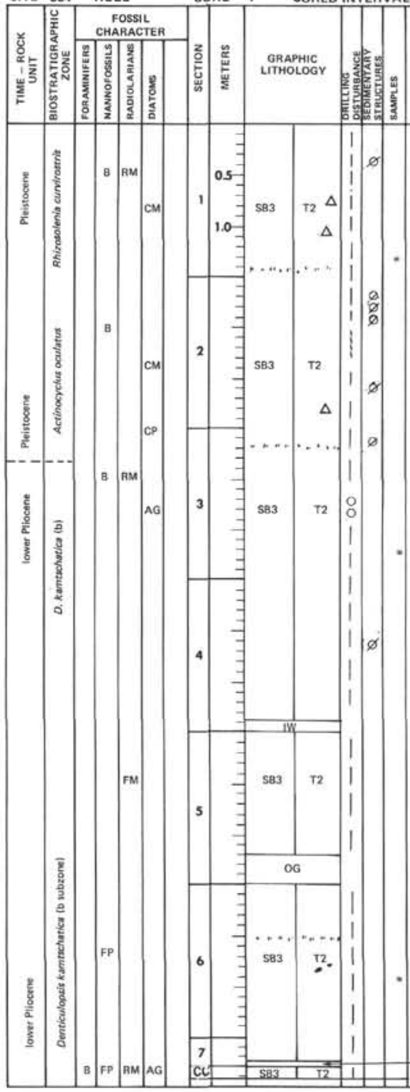
SITE 584 HOLE CORE 1 CORED INTERVAL 0.0–10.3 m



LITHOLOGIC DESCRIPTION

DARK OLIVE GRAY TO OLIVE GRAY BIOSILICEOUS MUD

5Y 4/2

T5

T5

V1 ashy patch

T5 5Y 2.5/2

V1 2.5Y N4/1–6/1

Pyrite filled with framboidal pyrite

SMEAR SLIDE SUMMARY (%):

	1, 145 M	3, 125 D	6, 92 D
Texture:			
Sand	25	15	25
Silt	52	30	20
Clay	23	55	55
Composition:			
Quartz	35	5	10
Feldspar	5	–	1
Heavy minerals	10	–	1
Clay	–	10	15
Volcanic glass	35	–	–
Pyrite	–	5	7
Micronodules	3	–	–
Diatoms	12	65	55
Sponge spicules	–	15	10
Plant debris	–	–	1

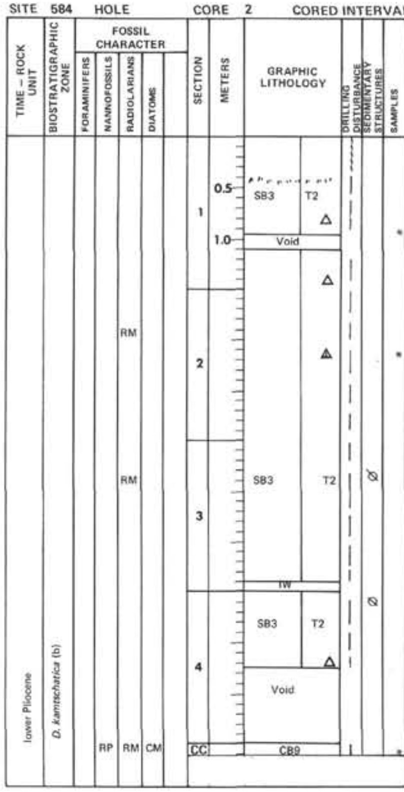
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	1.1

Disturbed ashy (V1) layer black silty spots

Void

SITE 584 HOLE CORE 2 CORED INTERVAL 10.3–20.0 m



LITHOLOGIC DESCRIPTION

V1

T5

CB3

5Y 4/2

V1: 2.5Y N5/1

Micritic limestone (5Y 7/2) with dewatering veins

BIOSILICEOUS MUD

Olive gray (5Y 4/2)

SMEAR SLIDE SUMMARY (%):

	1, 95 M	2, 65 M	CC, 10 M
Texture:			
Sand	25	7	10
Silt	45	75	75
Clay	30	18	15
Composition:			
Quartz	15	3	4
Feldspar	4	–	–
Heavy minerals	1	Tr	1
Clay	–	10	–
Volcanic glass	3	–	–
Pyrite	14	7	3
Carbonate unspec.	–	2	–
Calc. nannofossils	–	3	70
Diatoms	45	45	15
Sponge spicules	15	30	7
Plant debris	3	–	–

SITE 584 HOLE CORE 3 CORED INTERVAL 20.0–29.4 m

TIME – ROCK UNIT: lower Pliocene
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* (b)
FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS — Section 1: RM; Section 3: RM; Section 4: RP; CC: B, RP, RM, AG
SECTION: 1, 2, 3, 4, CC
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: SB3 T2; IW; SB3 T2; Void; SB3 T2
DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Fragments of limestone

BIOSILICEOUS MUD
5Y 4/2 with light colored 5Y 6/3 nanno-rich bioturbation traces

Diffuse areas, blacker than surrounding – pyrite concentrations

70 cm to 90 cm: sponge spicules and black mottling, pyrite reduction spots

25 cm to 47 cm, dark gray (N1 to N3 mottles)

Plant debris

SMEAR SLIDE SUMMARY (%):

	1, 96 D	1, 42 M	4, 95 M	4, 93 D	1, 20 D
Texture:					
Sand	40	–	41	32	25
Silt	30	5	39	48	40
Clay	30	95	20	20	35
Composition:					
Quartz	7	8	10	15	8
Feldspar	2	–	2	1	2
Mica	–	–	3	–	–
Heavy minerals	1	–	1	1	–
Clay	10	10	5	10	15
Volcanic glass	2	Tr	–	1	1
Pyrite	10	3	5	5	7
Carbonate unspec.	3	–	5	3	3
Foraminifers	2	–	–	1	1
Calc. nannofossils	–	–	4	3	3
Diatoms	50	66	50	45	50
Radiolarians	5	5	5	–	–
Sponge spicules	8	3	15	14	10
Silicoflagellates	–	1	–	–	Tr
Plant debris	–	–	–	1	–
Lithic fragments	–	4	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 1	2, 50
Carbonate	52.0	0.0

SITE 584 HOLE CORE 4 CORED INTERVAL 29.4–38.8

TIME – ROCK UNIT: lower Pliocene
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* (b)
FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS — CC: B, RP, RM, AG
SECTION: 1, 2, 3, 4, 5, 6, 7, CC
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: SB1 T2; SB3 T2; SB1 T2; SB1 T2; Void; SB1 T2; IW; SB1 T2; BRY; OG; SB1 T2
DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

V1, 2.5 N4/1
V1, gray (2.5N 4/1) coarse sandy layer

DIATOMACEOUS MUD
Olive gray (5Y 4/3)

Slightly lighter color interval

Thin, slightly mottled layer, sandier (T4)

Ashy patch – V1 – 2.5 N4/1

Ash spot
2.5Y 5/1 (V1)

2.5Y N5/1
(113 cm to 118 cm)

(V1) 2.5Y 5/1

V1: 2.5Y 5/1

V1: 2.5Y 5/1

SMEAR SLIDE SUMMARY (%):

	1, 2 M	1, 2 M	1, 50 D	4, 115 M
Texture:				
Sand	50	35	3	45
Silt	40	30	12	25
Clay	10	35	85	30
Composition:				
Quartz	25	–	5	32
Feldspar	7	18	1	10
Heavy minerals	8	21	1	7
Clay	15	39	–	40
Pyrite	20	15	4	–
Opaque	–	–	–	8
Foraminifers	–	–	1	Tr
Diatoms	5	5	59	Tr
Radiolarians	–	2	3	–
Sponge spicules	5	–	3	3
Silicoflagellates	–	–	1	–
Fish remains	–	–	1	–
Lithic fragments	–	–	6	–

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	14.5

SITE 584 HOLE CORE 5 CORED INTERVAL 38.8–48.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b)	B	B	RM	AG	1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	SB3 T2; SB3 T2; IW; SB3 T2; PP; SB3 T2			*

LITHOLOGIC DESCRIPTION

MUDDY BIOSILICEOUS OOZE
Olive gray (5Y 4/3)

White (5Y 7/3) silty ash (V1)
5Y 5/3 mottles

(V1) dark gray ash, smeared by drilling

(V1)

(V1) 140 cm to 150 cm, dark gray sandy patches

(V1)

5Y 5/3
47 cm–54 cm
63 cm–84 cm
5Y 5/3 mottled,
assumed to be
bioturbation

SMEAR SLIDE SUMMARY (%):

	1, 50	1, 128	2, 15
	D	M	M
Texture:			
Sand	5	45	55
Silt	15	30	30
Clay	80	25	15
Composition:			
Quartz	8	7	15
Feldspar	–	3	7
Heavy minerals	2	5	8
Clay	10	20	–
Volcanic glass	Tr	4	45
Palagonite	–	1	–
Glauconite	Tr	–	–
Pyrite	–	6	–
Opaque	–	–	25
Foraminifers	–	1	Tr
Calc. nannofossils	–	2	–
Diatoms	61	40	Tr
Radiolarians	5	5	–
Sponge spicules	8	5	–
Silicoflagellates	1	–	–
Lithic fragments	5	1	–

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

Olive gray (5Y 4/3)

SITE 584 HOLE CORE 6 CORED INTERVAL 48.2–57.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b)	B	B	RM	AG	1, 2, 3, CC	0.5, 1.0	SB3 T2; IW; SB3 T2			*

LITHOLOGIC DESCRIPTION

BIOSILICEOUS MUD

Deformed uppermost 70 cm contains rounded gravel, stream pebbles, hard carbonate clasts, granite, all reworked from above – ice rafter debris

Section 1, 80 cm: small dark spots

Mottling interpreted as bioturbation throughout

SMEAR SLIDE SUMMARY (%):

	1, 50	3, 30
	D	D
Texture:		
Sand	–	45
Silt	25	30
Clay	75	25
Composition:		
Quartz	15	10
Feldspar	1	2
Heavy minerals	4	2
Clay	20	20
Volcanic glass	<1	–
Glauconite	–	1
Pyrite	8	8
Calc. nannofossils	<1	2
Diatoms	47	43
Radiolarians	2	3
Sponge spicules	2	9
Silicoflagellates	Tr	–

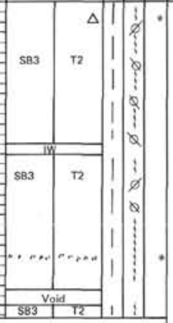
ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 7 CORED INTERVAL 57.8–67.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
lower Pliocene	*D. kamtschatica* (b)	RG	B	FM		1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

V1, gray fine volcanic ash

Sponge spicules

FIRM BIOSILICEOUS MUD
Dark olive gray (5Y 4/2)

V1, N6, silty ash layer, 101 cm to 105 cm

SMEAR SLIDE SUMMARY (%):

	1, 16 M	2, 103 M
Texture:		
Sand	2	15
Silt	49	40
Clay	49	45
Composition:		
Quartz	10	15
Feldspar	–	8
Heavy minerals	–	3
Clay	38	17
Volcanic glass	7	40
Palagonite	Tr	–
Glauconite	Tr	–
Pyrite	5	11
Diatoms	30	4
Sponge spicules	10	2

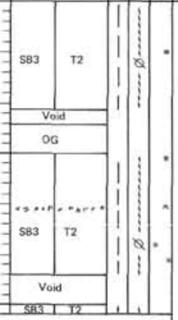
ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 8 CORED INTERVAL 67.4–77.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
lower Pliocene	*D. kamtschatica* (b)	VR/M	B, B	RM	AM	1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

FIRM BIOSILICEOUS MUD
5Y 4/2

V1, N3, sandy volcanic ash

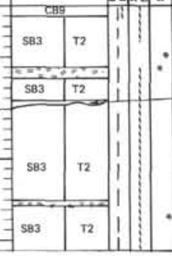
SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 5 M	2, 56 M	2, 102 M	2, 90 M
Texture:					
Sand	2	22	40	10	8
Silt	38	45	40	80	50
Clay	60	33	20	10	42
Composition:					
Quartz	4	4	28	2	19
Feldspar	3	5	12	2	18
Heavy minerals	–	Tr	7	–	Tr
Clay	45	24	20	9	22
Volcanic glass	1	44	20	1	1
Palagonite	Tr	1	–	Tr	1
Glauconite	Tr	–	–	–	Tr
Pyrite	2	4	9	5	3
Carbonate unspec.	–	–	–	10	–
Foraminifers	Tr	–	–	1	–
Diatoms	35	12	1	60	28
Radiolarians	Tr	–	–	–	–
Sponge spicules	10	6	3	10	8
Plant debris	–	–	–	Tr	–

SITE 584 HOLE CORE 9 CORED INTERVAL 77.0–86.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
lower Pliocene	*D. kamtschatica* (b)	B	RM	RM		1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Siderite-dolomite clasts (XRD) 2.5Y 7/2

FIRM BIOSILICEOUS MUD
Dark grayish brown (5Y 4/2)

V1, gray (N5) silty volcanic ash

Void

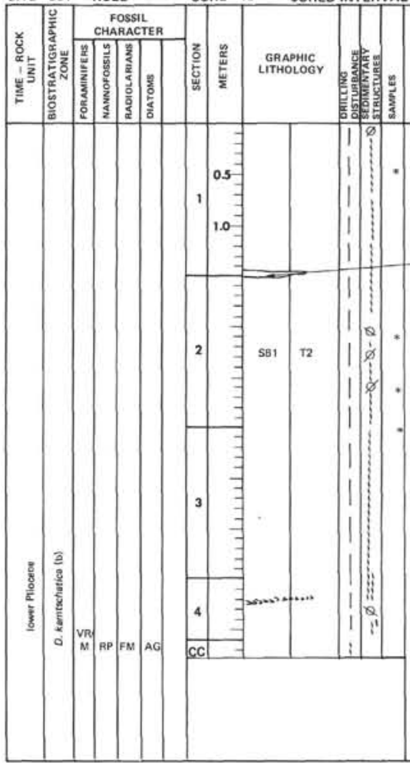
Olive (5Y 4/4)

Light gray (5Y 7/3)

SMEAR SLIDE SUMMARY (%):

	1, 50 D	1, 65 M	2, 60 M
Texture:			
Sand	15	10	30
Silt	50	50	40
Clay	35	40	30
Composition:			
Quartz	4	4	15
Feldspar	3	5	6
Heavy minerals	Tr	–	–
Clay	28	28	30
Volcanic glass	1	51	21
Palagonite	2	1	–
Glauconite	Tr	–	–
Pyrite	4	7	3
Carbonate unspec.	1	–	–
Diatoms	44	3	18
Radiolarians	–	–	Tr
Sponge spicules	11	1	4
Silicoflagellates	1	–	–
Plant debris	1	–	–
Lithic fragments	–	–	3

SITE 584 HOLE CORE 10 CORED INTERVAL 86.5–96.0 m



LITHOLOGIC DESCRIPTION

0 cm to 3 cm: concentration of pebbles, pumice and dark shale, up to 5 mm maximum subrounded, but low sphericity

FIRM DIATOMACEOUS MUD
Olive gray to olive (5Y 4/2–4/4)

Void — End wire cutting
Begin saw-cutting

Section 2: 60 cm to 90 cm, color changes to a yellower shade in laminations and burrows.

Section 3: beginning of thin drilling laminae
Irregular, wispy darker sediment concentrations at 10 cm and again at 60 cm to 70 cm

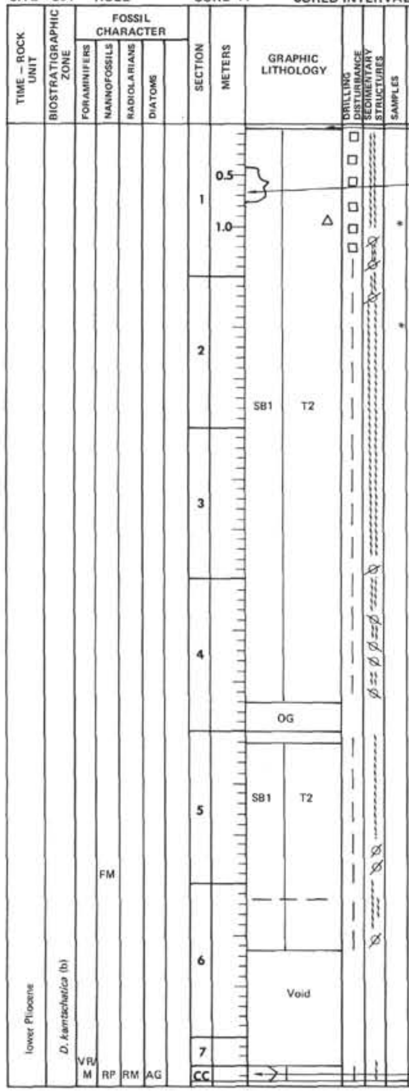
Zoophycus

5Y 4/2

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 118 M	2, 62 D	3, 7 M
Texture:				
Sand	38	25	3	18
Silt	37	55	39	50
Clay	25	20	58	32
Composition:				
Quartz	8	8	1	7
Feldspar	8	7	1	6
Heavy minerals	1	Tr	–	Tr
Clay	16	12	48	26
Volcanic glass	2	58	–	–
Palagonite	1	–	–	1
Glauconite	Tr	–	Tr	2
Pyrite	4	9	2	35
Carbonate unspec.	1	–	–	–
Foraminifers	2	–	–	–
Diatoms	50	4	43	22
Radiolarians	–	–	Tr	–
Sponge spicules	7	2	5	1

SITE 584 HOLE CORE 11 CORED INTERVAL 96.0–105.5 m



LITHOLOGIC DESCRIPTION

Void

FIRM DIATOMACEOUS MUD
Olive gray to olive (5Y 4/2 to 4/4)
Vertical cracks opening with drying, dessication

Void

V1, ashy blebs, reworked into burrows

60 cm–70 cm, pyrite

0 cm to 30 cm, closely spaced irregular fracturing

SMEAR SLIDE SUMMARY (%):

	1, 96 M	2, 50 D
Texture:		
Sand	9	8
Silt	51	52
Clay	40	40
Composition:		
Quartz	15	6
Feldspar	13	5
Clay	23	36
Volcanic glass	30	3
Palagonite	Tr	2
Glauconite	–	1
Pyrite	5	4
Carbonate unspec.	–	1
Diatoms	10	35
Sponge spicules	3	6
Silicoflagellates	1	–
Lithic fragments	–	1

3 mm thick lignite layer

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

5Y 3/1
5Y 4/1
15 cm to 30 cm unique burrowing filled with ash

Section 6, 60 cm, 1 large Robulus

Void

SITE 584 HOLE CORE 12 CORED INTERVAL 105.5–115.1 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b) *Sphaeropyle langii* zone	RM	B, RP	FM	AG	1–7, CC	0.5, 1.0	SB3 T2; SB3 T2; IW; SB3 T2; Void; SB3 T2			

LITHOLOGIC DESCRIPTION

FIRM BIOSILICEOUS MUD
Olive to olive gray (5Y 4/4 to 4/2)
Large ovoid burrows, as large as 2 cm x 1 cm throughout core – smaller, more densely packed traces near ash layers and below color changes

5Y 4/2 to 3/2

V1, ash layer 3 mm thick
39 cm to 42 cm, highly irregular, bioturbated interval

5Y 3/2
Diffuse color change back to 5Y 4/4
100 cm – diffuse concentration of fine sand grains

Offset, perhaps drilling induced?

V1 ashy concentration

Slight color change to 5Y 5/3

Lighter color
5Y 6/2

5Y 4/2
bioturbation obvious as lighter color sediments worked downward into darker matrix
(15 cm to 20 cm)

V1, irregular ash bed

SMEAR SLIDE SUMMARY (%):

	5, 14 D	1, 50 M	1, 16 M	3, 28 M	3, 41 M	3, 128 M
Texture:						
Sand	14	32	45	23	5	27
Silt	36	42	35	47	60	43
Clay	50	26	20	30	35	30
Composition:						
Quartz	7	11	18	12	10	7
Feldspar	6	8	12	16	8	5
Heavy minerals	–	–	1	–	–	Tr
Clay	43	18	15	18	20	28
Volcanic glass	22	2	–	36	40	28
Palagonite	1	1	–	–	–	–
Glauconite	–	1	–	1	–	1
Pyrite	3	3	5	4	3	4
Carbonate unspec.	1	2	–	–	–	–
Foraminifers	–	1	–	–	–	–
Calc. nannofossils	–	1	–	–	–	–
Diatoms	13	43	37	8	12	22
Radiolarians	–	Tr	2	1	–	Tr
Sponge spicules	4	8	7	4	7	5
Silicoflagellates	–	1	Tr	–	–	–
Lithic fragments	–	–	3	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	2.2

SITE 584 HOLE CORE 13 CORED INTERVAL 115.1–124.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b)	B	B, FP, CM, RP	RM	AG	1–7, CC	0.5, 1.0	SB1 T2; SB1 T2			

LITHOLOGIC DESCRIPTION

FIRM DIATOMACEOUS MUD
5Y 4/4 to 4/2

Disrupted dark band

Section 1: drill laminations throughout

Deformed contact
5Y 4/1

Olive gray (5Y 6/2)

Irregular ash layer, burrows beneath

120 cm,
pale specks
nannofossils

5Y 4/1

Glauconite speck

SMEAR SLIDE SUMMARY (%):

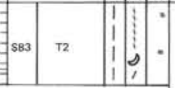
	1, 50 D	2, 104 M	3, 100 M	2, 21 M
Texture:				
Sand	38	8	25	12
Silt	40	60	45	36
Clay	22	32	30	52
Composition:				
Quartz	5	8	4	4
Feldspar	3	5	3	3
Heavy minerals	–	–	–	1
Clay	20	28	15	52
Volcanic glass	3	36	51	–
Palagonite	–	–	Tr	Tr
Glauconite	1	–	–	–
Pyrite	3	4	3	–
Carbonate unspec.	1	1	Tr	2
Foraminifers	–	–	–	2
Calc. nannofossils	–	Tr	–	10
Diatoms	56	12	18	18
Radiolarians	1	–	–	–
Sponge spicules	7	4	4	8
Silicoflagellates	–	–	1	–
Lithic fragments	–	2	1	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 14 CORED INTERVAL 124.7–134.3 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b)	B	CM FP	RM	AM	1, CC	0.5	SB3 T2			* *



LITHOLOGIC DESCRIPTION

0 cm to 10 cm, zone of wispy black pyrite concentration
5Y 4/2 to 4/4

FIRM BIOSILICEOUS MUD

SMEAR SLIDE SUMMARY (%):

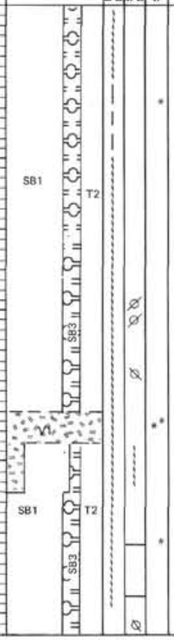
	1, 10 M	1, 50 D
Texture:		
Sand	20	18
Silt	35	30
Clay	45	52
Composition:		
Quartz	6	5
Feldspar	4	3
Clay	38	51
Volcanic glass	–	2
Palagonite	–	1
Glauconite	Tr	1
Pyrite	15	7
Carbonate unspec.	1	1
Foraminifers	–	Tr
Calc. nannofossils	2	1
Diatoms	14	22
Radiolarians	–	Tr
Sponge spicules	5	6
Lithic fragments	15	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.5

SITE 584 HOLE CORE 15 CORED INTERVAL 134.3–144.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*D. kamtschatica* (b)	B	RP	RM	AM	1, 2, 3, 4, CC	0.5, 1.0	SB1 T2, SB3, SB1 T2, SB3			* ** *



LITHOLOGIC DESCRIPTION

Hole cavings: rock fragments, clayey matrix white angular fragments and black smooth (well rounded) pebbles

0 cm to 70 cm, hole cavings

Feldspers very fresh and angular not much volcanic glass
Drill laminations every 5 mm
5Y 4/3

FIRM DIATOMITE

SMEAR SLIDE SUMMARY (%):

	1, 99 M	3, 110 M	3, 115 M	4, 80 D
Texture:				
Sand	5	5	4	3
Silt	10	85	21	10
Clay	85	10	75	87
Composition:				
Quartz	20	12	13	5
Feldspar	4	9	6	–
Heavy minerals	3	–	2	–
Clay	Tr	–	–	10
Volcanic glass	3	43	3	–
Pyrite	8	6	5	5
Carbonate unspec.	–	Tr	–	–
Diatoms	44	13	44	61
Radiolarians	6	8	10	4
Sponge spicules	12	9	13	10
Silicoflagellates	–	–	4	5
Fish remains	–	–	Tr	–

30 cm to 40 cm, few tiny black chunks, pyrite

2.5Y 6/1

Yellower green (5Y 5/4) than above

Ash reworked downward both by drilling and by bioturbation

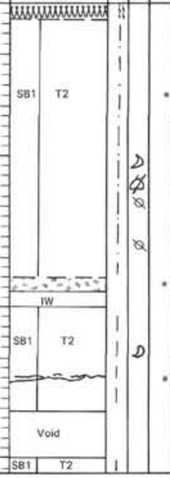
ORGANIC CARBON AND CARBONATE (%):

	3, 50
Carbonate	0.0

5Y 4/3

SITE 584 HOLE CORE 16 CORED INTERVAL 144.0–153.7 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower Pliocene	*Sphaeropyle langii* zone / *D. kamtschatica* (b)	VR/M	RP	FM	AM	1, 2, 3, CC	0.5, 1.0	SB1 T2, IW, SB1 T2, Void, SB1 T2			* * *



LITHOLOGIC DESCRIPTION

5Y 4/4

FIRM DIATOMACEOUS MUD

SMEAR SLIDE SUMMARY (%):

	1, 90 D	2, 130 M	3, 73 M
Texture:			
Sand	30	25	–
Silt	30	50	10
Clay	50	25	90
Composition:			
Quartz	7	9	8
Feldspar	3	4	3
Mica	1	–	–
Heavy minerals	2	2	20
Clay	48	24	–
Volcanic glass	3	51	3
Palagonite	–	Tr	–
Glauconite	1	–	–
Pyrite	2	1	4
Carbonate unspec.	1	–	–
Foraminifers	2	–	1
Calc. nannofossils	–	–	Tr
Diatoms	23	8	40
Radiolarians	1	–	8
Sponge spicules	6	1	10
Silicoflagellates	–	–	3
Fish remains	–	–	Tr

5Y 5/1 V1

5Y 4/4

5Y 6/4, slightly yellower layer, neither ash nor calcareous

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 17 CORED INTERVAL 153.7–163.4 m

TIME – ROCK UNIT: lower Pliocene
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* (b)
FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS CP; RADIOLARIANS RM; DIATOMS AG

SECTION 1–3, CC; METERS 0.5, 1.0
GRAPHIC LITHOLOGY: SB3 T2; OG; SB3 T2; SB3 T2; Void; SB3 T2 △

LITHOLOGIC DESCRIPTION

Void
0 cm to 40 cm, drill hash = hole cavings including poorly sorted gravel, pebbles ⩾5 cm diameter, black pebbles subrounded

5Y 4/3

120 cm, black pebbles

Void

V1, 5Y 3/1, includes green hornblende, rare apatite, and glass characteristically has vesicles
5Y 5/4

V1, ash layer, 5 mm thick

FIRM BIOSILICEOUS MUD

SMEAR SLIDE SUMMARY (%):

	2, 25	3, 40	CC, 7
	D	M	M
Texture:			
Sand	20	55	10
Silt	35	30	50
Clay	45	15	30
Composition:			
Quartz	10	15	9
Feldspar	5	15	14
Heavy minerals	1	5	1
Clay	21	–	29
Volcanic glass	–	54	38
Palagonite	–	1	–
Pyrite	4	3	2
Zeolite	–	–	Tr
Carbonate unspec.	2	2	–
Calc. nannofossils	1	–	–
Diatoms	45	5	6
Sponge spicules	10	Tr	1
Silicoflagellates	Tr	–	–
Lithic fragments	1	–	–

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	1.1

SITE 584 HOLE CORE 18 CORED INTERVAL 163.4–173.1 m

TIME – ROCK UNIT: lower Pliocene
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)
FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS CP; RADIOLARIANS FM; DIATOMS AM

SECTION 1, CC; METERS 0.5, 1.0
GRAPHIC LITHOLOGY: SB3 T2; SB3 T2; Void; SB3 T2

LITHOLOGIC DESCRIPTION

5Y 5/3
2 mm white ash

5Y 5/4

FIRM BIOSILICEOUS MUD

SMEAR SLIDE SUMMARY (%):

	1, 32
	D
Texture:	
Sand	15
Silt	45
Clay	40
Composition:	
Quartz	4
Feldspar	3
Clay	38
Pyrite	2
Carbonate unspec.	1
Calc. nannofossils	5
Diatoms	38
Radiolarians	4
Sponge spicules	5

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	2.2

SITE 584 HOLE CORE 19 CORED INTERVAL 173.1–182.8 m

TIME – ROCK UNIT: lower Pliocene
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* (b)
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS CP; RADIOLARIANS RM; DIATOMS AM

SECTION 1–7, CC; METERS 0.5, 1.0
GRAPHIC LITHOLOGY: SB1 T2; SB1 T2; SB1 T2; △; SB1 T2; IW; SB1 T2

LITHOLOGIC DESCRIPTION

FIRM DIATOMITE
Prominent drill laminations at 3 cm to 5 cm
Gray to light olive gray (5Y 6/1 to 6/2)

Olive (5Y 4/3)

Laminations faint (5Y 7/3) and lighter than groundmass, may not show up in photograph

V1, white (N7/1) ash
Olive (5Y 4/4)

This lamination may be ash

10 cm to 70 cm – faint laminations

5Y 4/3

SMEAR SLIDE SUMMARY (%):

	1, 37	1, 65	2, 62	3, 136
	M	M	D	M
Texture:				
Sand	20	35	20	25
Silt	30	35	50	25
Clay	50	30	30	50
Composition:				
Quartz	8	9	5	10
Feldspar	5	6	3	7
Heavy minerals	–	–	–	2
Clay	46	28	16	13
Volcanic glass = pumice	15	20	2	3
Glauconite	–	1	1	–
Pyrite	1	1	2	7
Diatoms	18	30	62	42
Radiolarians	–	1	1	5
Sponge spicules	6	4	8	11
Lithic fragments	1	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	3, 50
Carbonate	0.0

SITE 584 HOLE CORE 20 CORED INTERVAL 182.8–192.5 m

TIME-ROCK UNIT: lower Pliocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* (b)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS FP; RADIOLARIANS RM; DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: SB3 T2 (Section 1); SB3 T2 (Section 3); OG (Section 5); SB3 T2 (Section 6); SB3 T2 (CC)

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Olive green gray (5Y 4/2)

FIRM BIOSILICEOUS MUD

Black grains (pyrite?)

Light-colored laminations

5Y 4/3

Very large burrows, filling is lighter green (5Y 5/2)

Gray sandy layer

Smear slide taken from lighter color, burrow fill

90 cm, small, blue green streak

100 cm, black specks = ?organic C

Section 5: laminated throughout

5Y 4/3
34 cm – V1
thin ash layer

Black spots

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 95 M	2, 141 M	6, 34 M
Texture:				
Sand	15	25	32	25
Silt	65	65	17	65
Clay	20	10	51	10
Composition:				
Quartz	10	11	10	8
Feldspar	4	6	2	4
Heavy minerals	3	–	1	–
Clay	20	8	15	7
Volcanic glass	–	66	1	74
Palagonite	–	–	–	1
Glauconite	–	1	–	–
Pyrite	5	1	7	1
Carbonate unspec.	–	–	3	–
Foraminifers	Tr	–	2	–
Calc. nannofossils	2	–	5	1
Diatoms	40	6	42	2
Radiolarians	2	–	5	–
Sponge spicules	10	1	7	1
Silicoflagellates	2	–	Tr	–
Lithic fragments	2	–	–	1

ORGRANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	1.7

SITE 584 HOLE CORE 21 CORED INTERVAL 192.5–202.1 m

TIME-ROCK UNIT: lower Pliocene

BIOSTRATIGRAPHIC ZONE: N19/20 *D. kamtschatica* (b)

FOSSIL CHARACTER: FORAMINIFERS FM; NANNOFOSSILS FM; RADIOLARIANS FM; DIATOMS AM

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: SB3 T2 (Section 2); SB3 T2 (Section 5); SB3 T2 (Section 7)

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

BIOSILICEOUS OOZES
Olive (5Y 4/3)

Section 1: laminations are lighter color than groundmass

Section 2: laminated throughout – probably represent differential concentrations of diatoms versus silt and clay – diatom-rich layers producing lighter color

16 cm–17.5 cm, lighter color layer

80 cm, black mottling

100 cm, coarse black grains, = ?pyrite

Laminated throughout (Sections 2, 3, and 4)

130 cm, black spots, as above

SMEAR SLIDE SUMMARY (%):

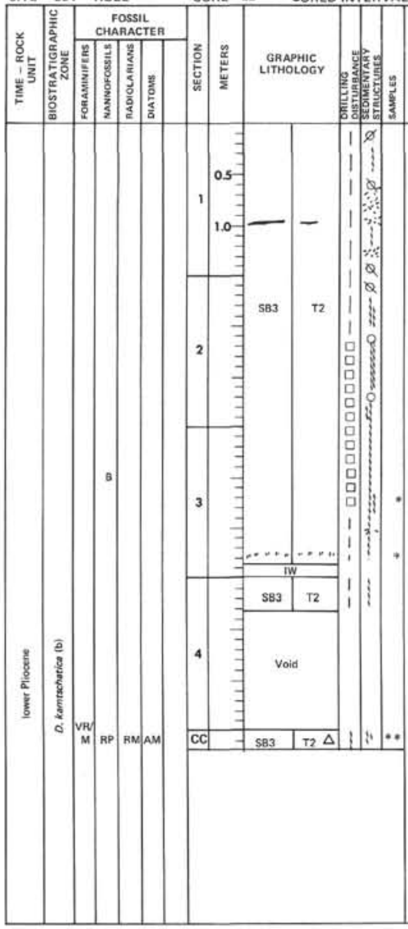
	1, 92 D	3, 16 D	4, 100 D	6, 120 D	7, 27 D
Texture:					
Sand	25	25	31	25	20
Silt	35	40	25	40	30
Clay	40	35	44	35	50
Composition:					
Quartz	8	5	10	7	5
Feldspar	4	4	3	3	3
Heavy minerals	1	1	1	2	–
Clay	28	16	25	28	34
Volcanic glass	1	35	–	–	1
Palagonite	–	–	–	Tr	–
Glauconite	–	–	1	1	–
Pyrite	2	1	4	3	2
Carbonate unspec.	1	1	–	1	–
Foraminifers	–	–	1	–	–
Calc. nannofossils	1	–	3	2	5
Diatoms	44	27	41	40	42
Radiolarians	22	2	3	2	3
Sponge spicules	7	7	5	10	5
Silicoflagellates	1	1	1	1	–
Lithic fragments	–	–	2	–	–

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

5Y 4/3
Massive olive gray with a few slightly lighter color, large burrows

SITE 584 HOLE CORE 22 CORED INTERVAL 202.1–211.7 m



LITHOLOGIC DESCRIPTION

Olive gray (5Y 4/2)

BIOSILICEOUS MUD

Lignite, ~1 mm thick
115 cm, dark spot = ?pyrite

Olive (5Y 4/4)

74 cm to 87 cm, burrows filled with volcanic ash

Pale yellow (5Y 7/3), ash layer

N3, N4 sand (T6)

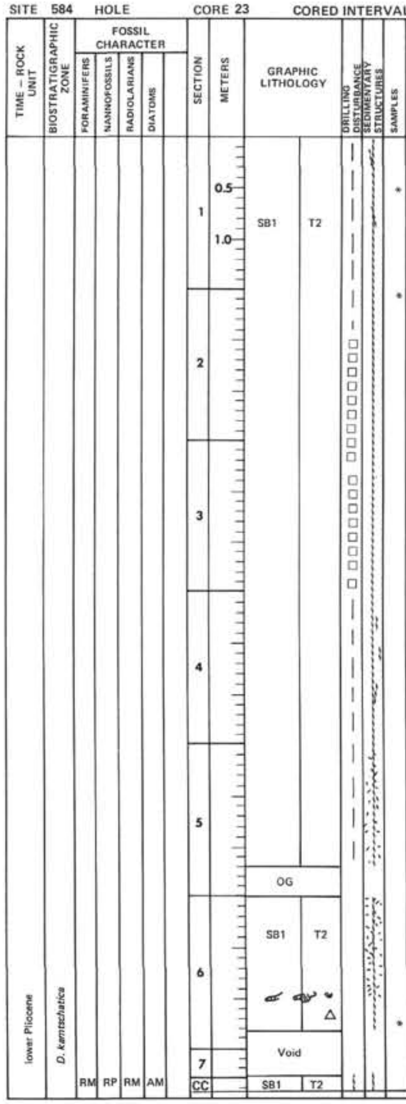
SMEAR SLIDE SUMMARY (%):

	3, 75 D	3, 128 M	CC M	CC M
Texture:				
Sand	20	20	80	80
Silt	30	60	10	10
Clay	50	20	10	10
Composition:				
Quartz	6	4	20	20
Feldspar	3	3	39	31
Mica	–	–	–	1
Heavy minerals	–	1	12	12
Clay	35	4	–	10
Volcanic glass	–	83	7	7
Pyrite and opaque	2	1	15	15
Calc. nannofossils	1	–	–	–
Diatoms	41	3	7	5
Radiolarians	2	–	–	–
Sponge spicules	6	1	–	–
Silicoflagellates	4	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 23 CORED INTERVAL 211.7–221.3 m



LITHOLOGIC DESCRIPTION

FIRM DIATOMACEOUS MUD

5Y 4/4

Dark olive gray (5Y 3/2), with lighter 5Y 4/4 mottles

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 9 M	6, 125 M
Texture:			
Sand	28	30	–
Silt	47	35	90
Clay	25	35	10
Composition:			
Quartz	5	9	4
Feldspar	4	8	7
Heavy minerals	1	1	–
Clay	22	30	–
Volcanic glass	–	2	81
Palagonite	1	1	1
Glauconite	1	–	–
Pyrite	4	11	–
Carbonate unspec.	1	Tr	–
Foraminifers	Tr	–	–
Calc. nannofossils	Tr	–	–
Diatoms	49	33	5
Radiolarians	1	1	–
Sponge spicules	8	4	2
Silicoflagellates	–	Tr	–
Plant debris	1	–	–
Lithic fragments	2	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

Burrows,
ash filled
V1, ash patch, N7

SITE 584 HOLE CORE 24 CORED INTERVAL 221.3–230.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
lower Pliocene	*Denticulopsis kamtschatica* zone (b subzone) *Sphaeropyle langii*	RM	RP	FM	AM	1–6 (0.5, 1.0)		SB1 T2; SB1 T2				

5Y 4/4

Burrowing may be Chondrites, but if so, not to be confused with the small black dots from above and Sites 582 and 583

5Y 4/4

Pumice clasts, ovoid, 8 mm x 5 mm

5Y 6/1, irregular, bioturbated top, sharp base

100 cm, V1 1 mm thick ash layer

"Obstruse" layer of fine sand

SMEAR SLIDE SUMMARY (%):

	1, 50 D	4, 19 M	4, 49 M	4, 99 M	5, 63 M
Texture:					
Sand	32	10	32	10	45
Silt	38	75	48	65	40
Clay	30	15	20	25	15
Composition:					
Quartz	4	5	3	8	18
Feldspar	2	4	3	4	20
Heavy minerals	–	Tr	–	–	2
Clay	26	12	20	23	15
Volcanic glass	3	56	35	23	–
Palagonite	1	1	–	1	–
Glauconite	1	–	–	1	1
Pyrite	3	2	5	6	10
Carbonate unspec.	–	1	1	1	–
Foraminifers	1	–	2	1	–
Calc. nannofossils	Tr	–	–	1	–
Diatoms	54	10	22	23	13
Radiolarians	1	1	–	–	–
Sponge spicules	5	8	8	7	3
Silicoflagellates	–	–	1	–	–
Plant debris	–	–	–	1	8
Lithic fragments	–	–	–	–	10

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 25 CORED INTERVAL 230.8–240.3 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
lower Pliocene	*D. kamtschatica* zone (b subzone) *R. pseudoumbilica* zone	RM	CP	FM	AM	1, 2, CC (0.5, 1.0)		SB1 T2; Void; CC: SB1 T2				

Hole cavings: pebbles and cobbles of Quaternary origin: limestone clasts, red chert, siltstone, sandstone, dacite

Thin section

T4, sandier lenses

T4, sandier lenses

SMEAR SLIDE SUMMARY (%):

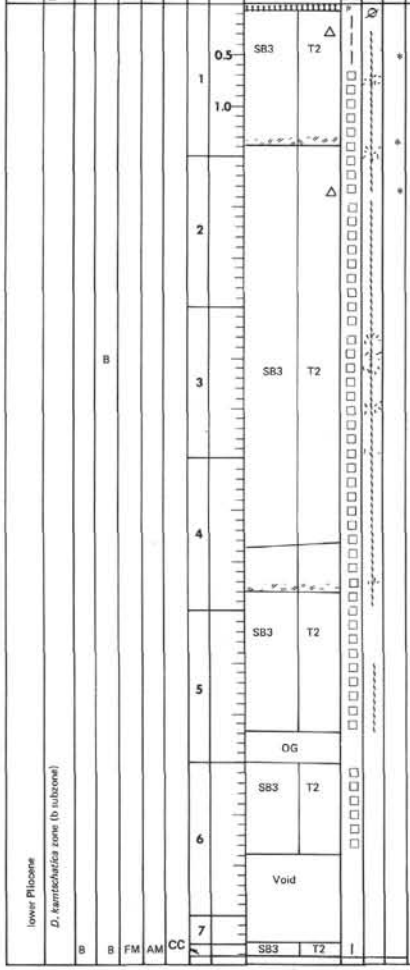
	1, 50 D	2, 3 M
Texture:		
Sand	22	45
Silt	53	30
Clay	25	25
Composition:		
Quartz	4	12
Feldspar	5	14
Heavy minerals	Tr	–
Clay	25	22
Volcanic glass	3	14
Palagonite	Tr	1
Glauconite	1	1
Pyrite	4	4
Carbonate unspec.	Tr	–
Calc. nannofossils	Tr	1
Diatoms	49	17
Radiolarians	Tr	Tr
Sponge spicules	4	4
Silicoflagellates	–	Tr
Lithic fragments	5	10

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 26 CORED INTERVAL 240.3–249.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
lower Pliocene	*D. kamtschatica* zone (b subzone)	B	B	FM	AM	1–7, CC						



0 cm to 5 cm, hole cavings

5Y 5/2 fine sand
Green blebs – probably glauconite

Subtle color change from 5Y 4/2 to 5Y 4/4

V1 silty ash, gray (5Y 6/2 to 9/2) diffuse upper boundary, sharp lower

5Y 4/2 – Section 2: large burrows
26 cm, thin yellow streak

FIRM BIOSILICEOUS MUD AND BIOSILICEOUS MUDSTONE

5Y 4/3

Section 4: ~ beginning of mudstone

Glauconite

Healed fracture

V1, ash, sharp basal contact, gradual above

SMEAR SLIDE SUMMARY (%):

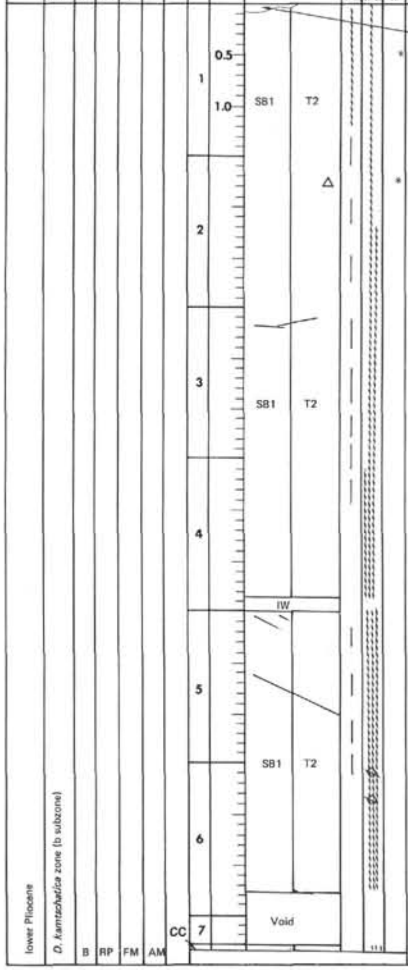
	1, 50 D	1, 139 M	2, 37 M
Texture:			
Sand	28	8	5
Silt	42	77	70
Clay	30	15	25
Composition:			
Quartz	5	3	7
Feldspar	3	4	4
Heavy minerals	Tr	Tr	1
Clay	25	12	20
Volcanic glass	3	65	51
Palagonite	1	1	–
Glauconite	Tr	–	–
Pyrite	3	1	4
Carbonate unspec.	1	1	1
Calc. nannofossils	Tr	Tr	–
Diatoms	46	8	8
Radiolarians	1	–	–
Sponge spicules	9	4	4
Silicoflagellates	–	1	Tr
Plant debris	1	–	–
Lithic fragments	2	Tr	Tr

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 27 CORED INTERVAL 249.8–259.3 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
lower Pliocene	*D. kamtschatica* zone (b subzone)	B	RP	FM	AM	1–7, CC						



5Y 4/2 to 4/4

Void

DIATOMACEOUS MUDSTONE

V1, sandy ash

Very large burrows

Healed fracture truncated by a drilling lamination

85 cm to 110 cm, burrows inclined to horizontal

112 cm to 118 cm, healed fracture

Healed fractures

78° dip, healed fracture

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 29 M
Texture:		
Sand	25	65
Silt	45	30
Clay	30	5
Composition:		
Quartz	8	8
Feldspar	6	7
Heavy minerals	Tr	Tr
Clay	26	3
Volcanic glass	1	75
Palagonite	1	–
Glauconite	1	Tr
Pyrite	4	3
Carbonate unspec.	1	–
Diatoms	38	2
Radiolarians	1	–
Sponge spicules	8	1
Silicoflagellates	Tr	–
Lithic fragments	5	1

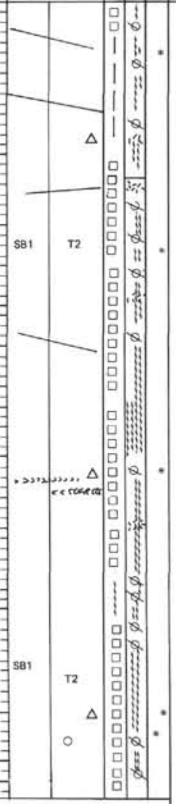
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 28 CORED INTERVAL 259.3–268.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
lower Pliocene	D. kamtschatica zone (b subzone)	RM	CP	RM	AM	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2

63° dip

DIATOMACEOUS MUDSTONE

Healed fractures 67° dip
Poorly defined ash layer, 1 cm thick

20 cm vertical offset

69° dip, healed fracture

5Y 4/2

Large burrows

5Y 4/3 to 4/2

Fracture

77 cm, black clast = ?organic C

V1, dissrupted ash bed, gray silty

5Y 4/2

20 cm to 40 cm, loaded with sponge

100 cm, V1, deformed ash

125 cm, large burrow tube, filled with ash

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 97 M	4, 15 M	5, 102 M	5, 127 M
Texture:					
Sand	40	10	30	5	75
Silt	20	60	20	5	10
Clay	40	30	50	90	15
Composition:					
Quartz	16	8	15	12	12
Feldspar	3	2	12	8	8
Heavy minerals	2	Tr	3	–	1
Clay	31	20	20	27	15
Volcanic glass and pumice	Tr	Tr	32	25	5
Pyrite and opaques	5	4	18	6	7
Carbonate unspec.	Tr	Tr	–	–	–
Foraminifers	Tr	Tr	–	–	–
Calc. nannofossils	2	5	–	5	Tr
Diatoms	34	56	Tr	10	42
Radiolarians	2	Tr	–	3	Tr
Sponge spicules	5	5	–	4	10
Fish remains	Tr	–	–	Tr	–

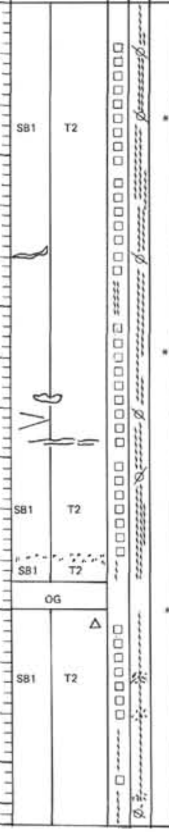
ORGANIC CARBON AND CARBONATE (%):

	3, 50
Carbonate	5.0

SITE 584 HOLE CORE 29 CORED INTERVAL 268.8–278.3 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
lower Pliocene	D. kamtschatica zone (b subzone)	RM	FP	FM	AG	1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2

DIATOMACEOUS MUDSTONE

Section 2: 0 cm to 65 cm strongly bioturbated: black (5Y 3/1) veins, 5Y 4/2 mottles, 5Y 5/2 rounded yellowish mottles

Burrow-filled with sponge

Ash filled burrow
Healed fractures within drill biscuits (offset burrows)
Dark wispy black veins = ?pyrite

Ash layer highly bioturbated

Dark spot (T4)

5Y 4/2 drilling biscuits at 3 cm to 5 cm

SMEAR SLIDE SUMMARY (%):

	1, 112 M	3, 49 D	5, 4 M
Texture:			
Sand	25	25	45
Silt	55	30	35
Clay	20	45	20
Composition:			
Quartz	5	12	7
Feldspar	–	3	10
Heavy minerals	–	1	–
Clay	13	33	18
Volcanic glass	–	–	2
Palagonite	–	–	1
Glauconite	–	–	1
Pyrite	5	5	18
Carbonate unspec.	1	2	–
Calc. nannofossils	1	–	–
Diatoms	30	35	30
Radiolarians	–	1	1
Sponge spicules	45	8	10
Silicoflagellates	–	Tr	–
Lithic fragments	–	–	2

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	1.7

SITE 584 HOLE CORE 30 CORED INTERVAL 278.3–287.8 m

TIME – ROCK UNIT: lower Pliocene

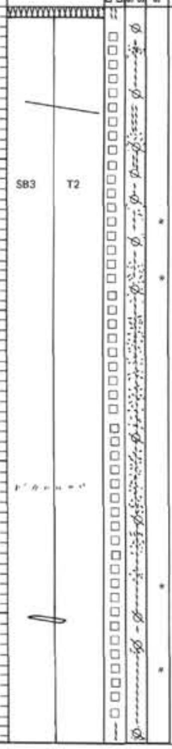
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS FM; DIATOMS AM

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Hole cavings

5Y 4/2

BIOSILICEOUS MUDSTONE

5Y 4/2

Large burrows and Chondrites

Section 3: drill biscuits at 3 cm to 5 cm

5Y 4/2
V1, faint ash layer or inclined bedding, dipping ~20°

Possible healed fractures or small scale drilling deformation

Section 5: lots of black mottling

5Y 4/2
Chondrites

SMEAR SLIDE SUMMARY (%):

	2, 64 D	2, 117 D	4, 121 M	5, 56 M
Texture:				
Sand	30	30	20	32
Silt	35	20	40	25
Clay	35	50	40	43
Composition:				
Quartz	5	7	3	7
Feldspar	3	3	2	2
Mica	–	1	–	–
Heavy minerals	–	–	–	1
Clay	30	30	36	45
Volcanic glass	1	–	1	–
Glauconite	1	1	–	–
Pyrite	3	4	1	7
Carbonate unspec.	–	1	–	2
Foraminifers	–	1	–	1
Calc. nannofossils	1	5	1	2
Diatoms	47	30	25	25
Radiolarians	1	2	1	1
Sponge spicules	7	15	30	7
Silicoflagellates	1	–	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 31 CORED INTERVAL 287.8–297.3 m

TIME – ROCK UNIT: lower Pliocene

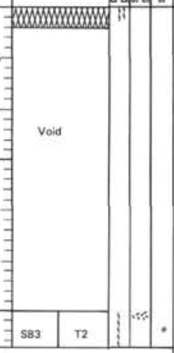
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS AG

SECTION: 1, 2, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

10GY 5/2 hole cavings
including: red chert, sandstone, and dacite pebbles

BIOSILICEOUS MUDSTONE

20 cm, dark green spot
10GY 3/2 matrix color

SMEAR SLIDE SUMMARY (%):

	CC D
Texture:	
Sand	15
Silt	20
Clay	65
Composition:	
Quartz	10
Feldspar	5
Heavy minerals	1
Clay	24
Glauconite	3
Pyrite	5
Carbonate unspec.	1
Calc. nannofossils	1
Diatoms	30
Radiolarians	5
Sponge spicules	15

ORGANIC CARBON AND CARBONATE (%):

	1, 32
Carbonate	0.0

SITE 584 HOLE CORE 32 CORED INTERVAL 297.3–306.8 m

TIME – ROCK UNIT: lower Pliocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone) / *R. pseudoumbilica* zone

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS CP; RADIOLARIANS RM; DIATOMS AG

SECTION: 1, 2, 3, 4, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: SB3 T2; IW; SB1 T2; OG; Void; SB1 T2

LITHOLOGIC DESCRIPTION

20 cm to 34 cm, bedding inclined 25°

5Y 4/2

BIOSILICEOUS MUDSTONE

5Y 4/2
Burrow-fill 5Y 4/3

5Y 4/3

SMEAR SLIDE SUMMARY (%):

	1, 70 D	3, 76 D	CC, 3 M
Texture:			
Sand	15	15	15
Silt	40	40	40
Clay	45	45	45
Composition:			
Quartz	10	8	4
Feldspar	4	2	2
Heavy minerals	1	1	–
Clay	26	39	29
Volcanic glass	–	2	–
Pyrite	6	3	5
Carbonate unspec.	–	–	1
Calc. nannofossils	2	1	12
Diatoms	35	37	38
Radiolarians	1	1	1
Sponge spicules	15	5	7
Silicoflagellates	Tr	1	1

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 33 CORED INTERVAL 306.8–316.4 m

TIME – ROCK UNIT: lower Pliocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS FM; DIATOMS AG

SECTION: 1, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: SB1 T2; Void; SB1 T2

LITHOLOGIC DESCRIPTION

Hole cavings, drill breccia and large pebbles

DIATOMACEOUS MUDSTONE
Variety previously described in first sections of preceding cores.

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

5Y 4/2

SITE 584 HOLE CORE 34 CORED INTERVAL 316.4–326.0 m

TIME – ROCK UNIT: lower Pliocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS FP; RADIOLARIANS FM; DIATOMS AM

SECTION: 1, 2, 3, 4, 5, 6, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: SB3 T2; SB3 T4 T2; SB3 T2; SB3 T2; SB3 T2; SB3 T2; SB3 T2

LITHOLOGIC DESCRIPTION

BIOSILICEOUS MUDSTONE

50 cm to 85 cm: plane of burrows ~20° to horizontal

5Y 4/2
15 cm to 25 cm, burrows inclined
Zoophycus

Healed fracture and dewatering veinlet

Black, mottled, sandier at base of Section 2
5Y 4/2

Healed fracture

110 cm, black round pebble in mud

Black specks

Healed fracture

5Y 4/2

Black specks

SMEAR SLIDE SUMMARY (%):

	1, 12 D	4, 72 M	6, 22 M
Texture:			
Sand	15	5	10
Silt	40	85	30
Clay	45	10	60
Composition:			
Quartz	10	6	15
Feldspar	5	5	10
Heavy minerals	1	2	2
Clay	26	5	15
Volcanic glass	–	77	30
Palagonite	–	–	3
Pyrite	4	–	2
Foraminifers	2	–	–
Calc. nannofossils	2	–	–
Diatoms	30	4	15
Radiolarians	5	–	Tr
Sponge spicules	15	1	8

ORGANIC CARBON AND CARBONATE (%):

	3, 50
Carbonate	0.0

145 cm, ash

Ash layer
2.5Y N4/1 top
2.5Y N7/1 middle
2.5Y N6/1 bottom

SITE 584 HOLE CORE 35 CORED INTERVAL 326.0–335.6 m

TIME – ROCK UNIT: lower Pliocene

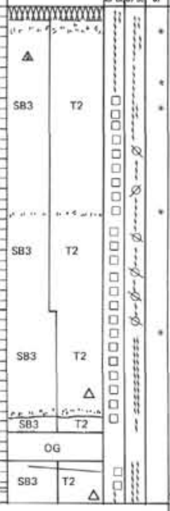
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone)

FOSSIL CHARACTER: FORAMINIFERS VR/M; NANNOFOSSILS FP; RADIOLARIANS CM; DIATOMS CP

SECTION: 1, 2, 3, 4, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Hole cavings

5Y 4/2

BIOSILICEOUS MUDSTONE

From yellowish, burrow-fill

5Y 4/2

V1, silty ash

100 cm, pyrite

SMEAR SLIDE SUMMARY (%):

	1, 25 M	1, 73 M	1, 100 D	2, 56 M	3, 22 D
Texture:					
Sand	5	25	15	35	25
Silt	80	45	35	10	35
Clay	15	30	50	55	40
Composition:					
Quartz	15	5	7	11	11
Feldspar	10	3	12	10	3
Heavy minerals	1	1	1	2	2
Clay	15	25	22	10	25
Volcanic glass	50	–	4	55	3
Palagonite	1	–	–	–	–
Pyrite	2	2	6	–	2
Carbonate unspec.	1	–	5	10	2
Calc. nannofossils	–	–	1	2	Tr
Diatoms	5	30	25	–	32
Radiolarians	–	3	2	–	5
Sponge spicules	Tr	5	15	–	15
Opal-cement	–	26	–	–	–

T6, sandy pocket
Ashy mudstone, N6/2

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.4

2.5Y 4/2
5 cm to 10 cm, healed fracture
Burrow fill much yellower than surrounding gray matrix

Burrow fill
2.5Y 5/2
CB9

SITE 584 HOLE CORE 36 CORED INTERVAL 335.6–345.1 m

TIME – ROCK UNIT: lower Pliocene

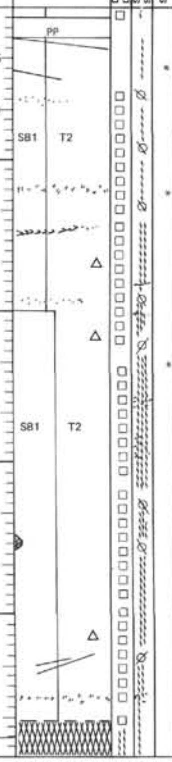
BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (b subzone) *Sphaeropyle langii*

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS FM; DIATOMS CP

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

2.5Y 4/2

30° dip, healed fracture

Healed fracture ending in a drill biscuit

Pyrite grains

DIATOMACEOUS MUDSTONE

N6/2, ash, 4 cm thick

100 cm, ash, V1

Pyrite, black and grainy, in blue-green sediment

5Y 4/2
25 cm, thin, disrupted ash, V1

SMEAR SLIDE SUMMARY (%):

	1, 62 D	2, 30 M	3, 56 D
Texture:			
Sand	25	15	15
Silt	55	52	52
Clay	20	33	33
Composition:			
Quartz	15	8	12
Feldspar	10	8	8
Heavy minerals	2	–	2
Clay	11	18	25
Volcanic glass	15	32	4
Glauconite	1	–	–
Pyrite	5	5	5
Carbonate unspec.	3	5	3
Calc. nannofossils	1	–	1
Diatoms	30	19	25
Sponge spicules	7	5	15

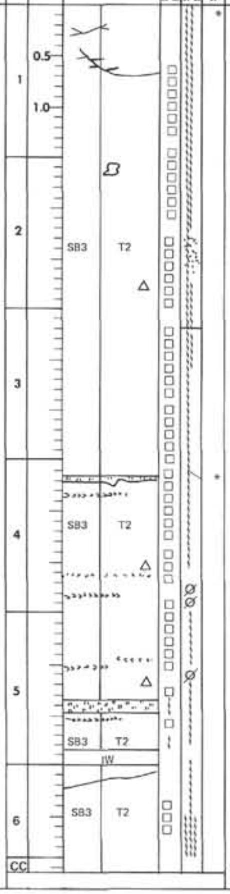
Burrow with spicule filling
65 cm to 85 cm,
yellower shades of burrow fill,
V1,
fractures

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.4

SITE 584 HOLE CORE 37 CORED INTERVAL 345.1–354.6 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
lower Pliocene	*D. kamtschatica* zone (b subzone)	R/MP	CP	RM	AP



LITHOLOGIC DESCRIPTION

2.5Y 4/2 with black to olive green mottling
Section 1: mosaic of healed fractures, wealth of detail

Healed fractures

BIOSILICEOUS MUDSTONE

Black spot in blue-green matrix

5Y 4/2

110 cm, steeply dipping healed fracture

Irregular ash layer, V1, 125 cm

Glauconitic interval ending
with lamination

2.5Y 4/2

90 cm — light color burrow traces
95–100 cm, black spots

5Y 5/2

V1

V1

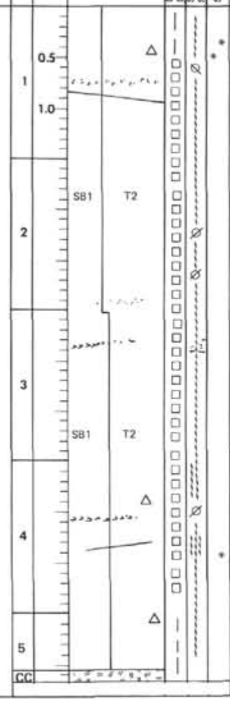
SMEAR SLIDE SUMMARY (%):

	1, 10 D	4, 18 M
Texture:		
Sand	32	3
Silt	25	38
Clay	43	59
Composition:		
Quartz	15	12
Feldspar	5	15
Heavy minerals	1	–
Clay	24	10
Volcanic glass	3	46
Glauconite	2	–
Pyrite	5	6
Carbonate unspec.	2	4
Foraminifers	1	–
Calc. nannofossils	1	–
Diatoms	30	5
Radiolarians	1	–
Sponge spicules	9	2
Silicoflagellates	Tr	–
Plant debris	1	–

Healed fracture
dip = 62°
5Y 4/2
Below 68 cm abundant
zoophycus aligned at
12°, carbonate-rich
burrow fill
5Y 4/2

SITE 584 HOLE CORE 38 CORED INTERVAL 354.6–364.1 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
lower Pliocene	*D. kamtschatica* zone (b subzone) / *Sphaeropyle langii* / *R. pseudoumbilica* zone	RM	B (CM, CP)	FM	AM



LITHOLOGIC DESCRIPTION

0 cm to 40 cm, small glauconitic blebs

V1

5Y 4/2, locally 5Y 4/4 in burrows

Healed fracture, 58° dip

DIATOMACEOUS MUDSTONE

Dark specks

SMEAR SLIDE SUMMARY (%):

	1, 38 M	1, 50 D	4, 90 D
Texture:			
Sand	25	8	30
Silt	70	62	45
Clay	5	30	25
Composition:			
Quartz	4	10	8
Feldspar	4	8	7
Heavy minerals	5	Tr	–
Clay	–	28	18
Volcanic glass	76	8	11
Palagonite	–	1	1
Glauconite	1	Tr	Tr
Pyrite	3	3	7
Carbonate unspec.	4	1	1
Calc. nannofossils	–	Tr	Tr
Diatoms	3	29	39
Radiolarians	–	1	–
Sponge spicules	–	6	6
Plant debris	–	1	–
Lithic fragments	–	4	2

0 cm to 28 cm, pale olive, carbonate-rich mottles

T6

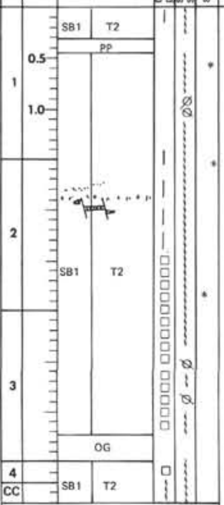
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

V1
15 cm to 25 cm
offset Zoophycus
and healed fracture
Section 5: dropped
after photo

SITE 584 HOLE CORE 39 CORED INTERVAL 364.1–373.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. kamtschatica* (a subzone) *Sphaeropyle langii*	VR/M	B	CM	AM	1, 2, 3, 4, CC	0.5, 1.0	SB1 T2; PP; SB1 T2; OG; SB1 T2			



LITHOLOGIC DESCRIPTION

18 cm to 23 cm in section inset below

5Y 4/2, predominant color, with 5Y 5/3 burrow fill

100 cm to 110 cm – see inset below

120 cm, subhorizontal veinlets

Slightly darker silty layer

Healed fractures and normal offset

25 cm, burrow-fill with green (10G 4/2) mud

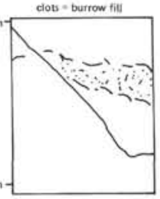
Section 3: closely spaced fractures throughout

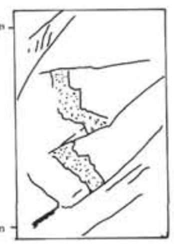
SMEAR SLIDE SUMMARY (%):

	1, 60 D	2, 9 M	2, 134 M
Texture:			
Sand	13	10	12
Silt	37	75	58
Clay	50	15	30
Composition:			
Quartz	3	5	5
Feldspar	5	4	3
Heavy minerals	1	–	–
Clay	45	15	20
Volcanic glass	2	57	2
Palagonite	1	–	–
Glauconite	1	–	–
Pyrite	4	2	7
Carbonate unspec.	1	1	5
Diatoms	30	10	50
Radiolarians	–	–	Tr
Sponge spicules	5	6	8
Lithic fragments	2	–	–

ORGANIC CARBON AND CARBONATE (%):

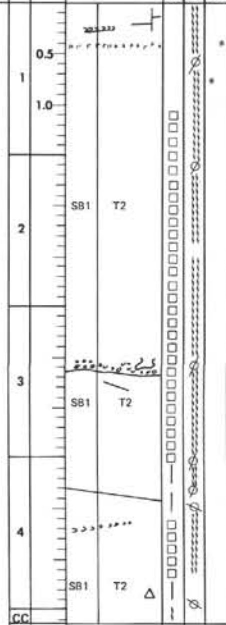
	1, 50
Carbonate	0.0





SITE 584 HOLE CORE 40 CORED INTERVAL 373.7–383.3 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. kamtschatica* zone (a subzone) *Sphaeropyle langii*	B	VR/P B	FM	AM	1, 2, 3, 4, CC	0.5, 1.0	SB1 T2; SB1 T2; SB1 T2			



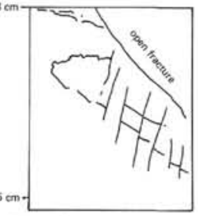
LITHOLOGIC DESCRIPTION

Inclined burrow?
Olive gray (5Y 4/2); pale olive (5Y 6/3) fill

DIATOMACEOUS MUDSTONE

130 cm to 150 cm: dark flecks of organic matter

Section 4



Particularly pale olive burrow fill – not carbonate-rich
Large concentration of pumice flecks, grains, etc.
3 mm offset on fracture
70 cm to 90 cm, burrows slightly inclined (following bedding?)

Glauconite bleb

120 cm to 130 cm
(see inset below)
V1, disrupted ash

SMEAR SLIDE SUMMARY (%):

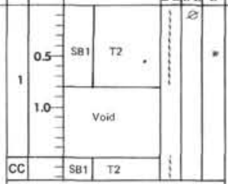
	1, 45 M	1, 80 D
Texture:		
Sand	45	22
Silt	45	28
Clay	10	50
Composition:		
Quartz	6	8
Feldspar	5	4
Heavy minerals	1	–
Clay	–	35
Volcanic glass	74	8
Palagonite	1	1
Glauconite	–	1
Pyrite	1	4
Carbonate unspec.	4	1
Diatoms	–	30
Sponge spicules	–	5
Silicoflagellates	–	Tr
Lithic fragments	8	3

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	5.2

SITE 584 HOLE CORE 41 CORED INTERVAL 383.3–392.9 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. kamtschatica* zone (a subzone) / *Sphaeropyle langii*	VR/M	B	FM	AM	1, CC	0.5, 1.0	SB1 T2; Void; SB1 T2			*



LITHOLOGIC DESCRIPTION

20 cm, veinlets

60 cm, hollow glauconite concentration

5Y 4/2

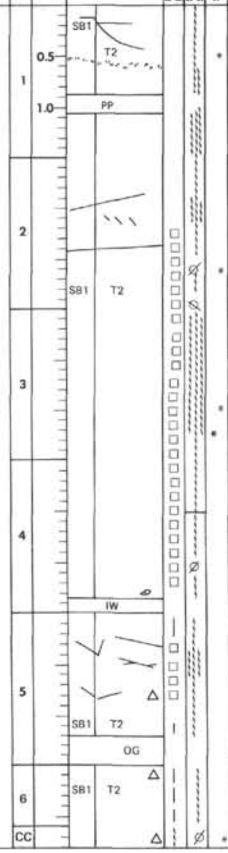
DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 50 D
Texture:	
Sand	22
Silt	38
Clay	40
Composition:	
Quartz	8
Feldspar	5
Heavy minerals	2
Clay	32
Volcanic glass	3
Palagonite	1
Glauconite	1
Pyrite and opaque	6
Carbonate unspec.	1
Diatoms	27
Sponge spicules	5
Plant debris	2
Lithic fragments	7

SITE 584 HOLE CORE 42 CORED INTERVAL 392.9–402.6 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. kamtschatica* zone (a subzone) / *Sphaeropyle langii*	RM	B; RP	FM	CP	1, 2, 3, 4, 5, 6, CC	0.5, 1.0	SB1 T2; PP; SB1 T2; IW; SB1 T2; OG; SB1 T2			*



LITHOLOGIC DESCRIPTION

5Y 4/2

DIATOMACEOUS MUDSTONE

58 cm to 61 cm sandy ash layer filling burrow, 17° dip

Bioturbation inclined

en echelon offsets

90 cm to 120 cm minor scattered very dark (smear slides show pyrite) and light (pumice) gray clasts

Olive gray mottles

Inclined black lamination

2 mm x 4 mm dark pyrite granule

3 mm of offset on burrow trace

Sand concentration T6

T6

T6

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 118 M	3, 100 M	3, 122 M	CC, 10 M
Texture:					
Sand	25	–	5	28	35
Silt	35	–	45	27	35
Clay	40	–	50	45	30
Composition:					
Quartz	7	3	3	3	11
Feldspar	8	2	2	2	8
Heavy minerals	1	–	–	–	–
Clay	35	–	40	40	28
Volcanic glass	5	22	–	–	11
Palagonite	1	–	–	–	1
Glauconite	2	–	–	–	–
Pyrite	8	60	8	4	4
Carbonate unspec.	1	–	1	8	–
Diatoms	24	8	29	29	30
Radiolarians	Tr	–	–	Tr	1
Sponge spicules	4	5	16	14	6
Silicoflagellates	–	–	1	–	–
Lithic fragments	4	–	–	–	–

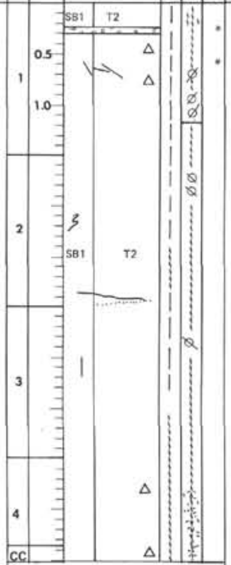
ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 43 CORED INTERVAL 402.6–412.3 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Miocene	*D. kamtschatica* zone (a subzone) *Sphaeropyle langii*	B	B	CM	AM

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

T4 – scattered sand grains

V1 DIATOMACEOUS MUDSTONE AND FIRM DIATOMACEOUS MUD

15 cm to 20 cm, slightly olive = ?vitric layer

5Y 4/2

Fine sandy lamina

Conjugate fractures, may be drilling induced
Vertical healed fracture

Hard

5G 4/1

T4, black color change (80 cm) 5GY 6/1

Soft

T4, black

SMEAR SLIDE SUMMARY (%):

	1, 60 D	1, 28 M
Texture:		
Sand	14	2
Silt	40	60
Clay	46	38
Composition:		
Quartz	11	6
Feldspar	9	6
Heavy minerals	1	–
Clay	40	28
Volcanic glass	2	41
Palagonite	1	1
Glauconite	1	–
Pyrite	3	5
Carbonate unspec.	1	2
Diatoms	20	7
Sponge spicules	5	4
Lithic fragments	6	–

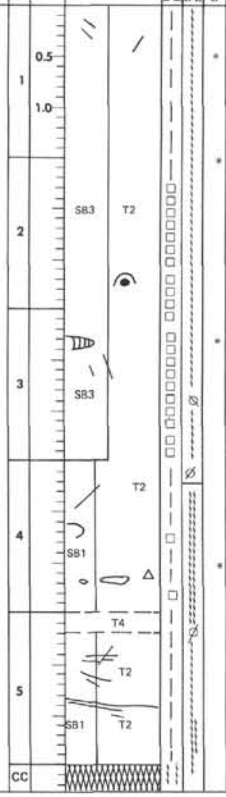
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 44 CORED INTERVAL 412.3–422.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Miocene	*D. kamtschatica* zone (a subzone)	B	B	FM	CP

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2

Small, healed fractures

5Y 4/2

50 cm to 80 cm, larger burrows, yellow-olive green fill

Bluish green spot, with concentric band

Lighter-colored burrow-fill

T6
White patches

5Y 4/2

110 cm to 150 cm heavily mottled, 5Y 5/3

SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 8 M	3, 33 M	4, 104 D
Texture:				
Sand	20	35	21	18
Silt	35	40	30	37
Clay	45	25	49	45
Composition:				
Quartz	5	25	10	7
Feldspar	2	8	1	4
Mica	–	–	2	–
Heavy minerals	–	4	2	–
Clay	40	–	32	43
Volcanic glass	1	10	–	3
Glauconite	1	2	–	–
Pyrite	3	9	3	3
Carbonate	1	–	–	4
Calc. nannofossils	1	–	–	3
Diatoms	35	23	25	27
Radiolarians	–	3	5	5
Sponge spicules	10	10	20	1
Silicoflagellates	1	–	–	–
Plant debris	–	4	–	–

SITE 584 HOLE CORE 45 CORED INTERVAL 422.0–431.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
upper Miocene	*D. kamtschatica* (a subzone) *Sphaeropyle langii*	B	B	FM	AM	CC						5Y 4/2 DRILL BRECCIA Includes: shell fragments dacite red chert black shale

SITE 584 HOLE CORE 46 CORED INTERVAL 431.5–441.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
upper Miocene	*D. kamtschatica* zone (a subzone)	VR/M	B	FM	CP	1 CC	0.5 1.0	Void SB1 T2 Void			**	5Y 4/2 DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 50 D	1, 50 D
Texture:		
Sand	10	30
Silt	5	52
Clay	85	18
Composition:		
Quartz	10	25
Feldspar	2	5
Heavy minerals	2	1
Clay	30	16
Volcanic glass	Tr	–
Glauconite	–	1
Pyrite	4	4
Carbonate unspec.	–	1
Diatoms	36	30
Radiolarians	–	2
Sponge spicules	8	15

SITE 584 HOLE CORE 47 CORED INTERVAL 441.0–450.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
upper Miocene	*D. quinqueramus* zone *D. kamtschatica* zone (a subzone) *Sphaeropyle langii*	FM B	B	FM	CP	1 2 3 4 CC	0.5 1.0	SB1 T2 IW SB1 T2			*	5Y 4/2 DIATOMACEOUS MUDSTONE Black pyrite lamination 110 cm to 130 cm, inclined burrows Fill 5Y 6/2 5Y 4/2 Burrows are black, local reducing conditions

SMEAR SLIDE SUMMARY (%):

	3, 10 M
Texture:	
Sand	15
Silt	30
Clay	55
Composition:	
Quartz	20
Feldspar	3
Mica	1
Heavy minerals	2
Clay	23
Glauconite	2
Pyrite	7
Carbonate unspec.	1
Calc. nannofossils	5
Diatoms	25
Radiolarians	1
Sponge spicules	10

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	1.9

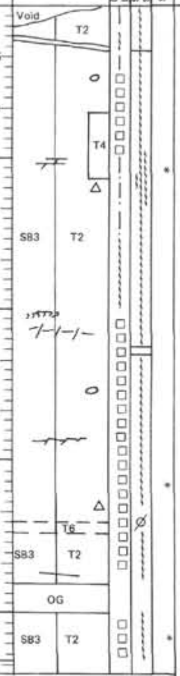
SITE 584 HOLE CORE 48 CORED INTERVAL 450.5–460.1 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (*a* subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS VR/P; RADIOLARIANS FM; DIATOMS CP

SECTION 1, 2, 3, 4, 5, CC; METERS 0.5, 1.0



LITHOLOGIC DESCRIPTION

5Y 3/2

Dipping bedding planes, laminations

Basalt pebble, in brecciated interval

BIOSILICEOUS MUDSTONE

T4

80 cm to 150 cm, almost drill breccia

Soft sediment deformation
Small offsets

Black halo, and black splotches 80 cm to 150 cm and 0 cm to 120 cm, Section 4

Good color contrast, offsets
yellow above, dark olive gray beneath

V1

Healed fracture

5Y 4/1
black
staining
throughout
Section 5

SMEAR SLIDE SUMMARY (%):

	2, 14 M	4, 22 M	5, 28 D
Texture:			
Sand	52	55	35
Silt	38	25	42
Clay	10	20	23
Composition:			
Quartz	15	8	18
Feldspar	5	2	2
Mica	15	10	12
Heavy minerals	–	2	–
Clay	13	5	24
Pyrite	4	45	2
Carbonate unspec.	4	3	4
Calc. nannofossils*	2	2	2
Diatoms	30	15	25
Radiolarians	2	1	1
Sponge spicules	10	5	10

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

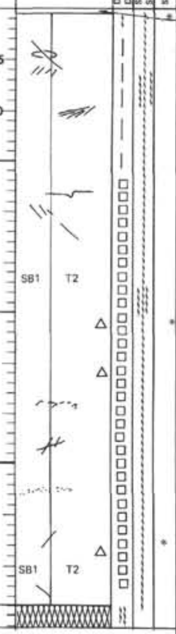
SITE 584 HOLE CORE 49 CORED INTERVAL 466.1–469.7 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. quinqueramous* zone; *Thalassionema schraderi* zone; *Sphaeropyle langii*

FOSSIL CHARACTER: FORAMINIFERS VR/M; NANNOFOSSILS B; RADIOLARIANS FM, FM; DIATOMS AM

SECTION 1, 2, 3, 4, CC; METERS 0.5, 1.0



LITHOLOGIC DESCRIPTION

Void

5Y 6/2

50 cm to 53 cm (see close-up below)

110 cm, thin anastamosing, dewatering veins

DIATOMACEOUS MUDSTONE

5GY 3/2

V1

V1
Irregular color contrast, as in flame structures
110 cm to 120 cm, dewatering veinlets and/or multiple healed fractures

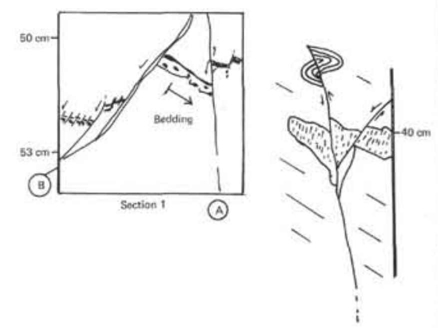
Offset burrows

5Y 4/2
Black grains

T4, volcanic sand

SMEAR SLIDE SUMMARY (%):

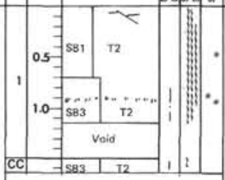
	1, 8 D	3, 12 M	4, 80 M
Texture:			
Sand	15	42	45
Silt	38	35	30
Clay	47	23	25
Composition:			
Quartz	15	22	12
Feldspar	4	5	27
Mica	7	–	–
Heavy minerals	1	2	–
Clay	29	10	20
Volcanic glass and pumice	–	41	20
Palagonite	–	12	–
Pyrite	4	4	5
Carbonate unspec.	1	4	–
Foraminifers	1	–	–
Calc. nannofossils	2	–	–
Diatoms	30	–	6
Radiolarians	2	–	–
Sponge spicules	4	–	2
Lithic fragments	–	–	8



SITE 584 HOLE CORE 50 CORED INTERVAL 469.7–479.3 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: *T. schraderi* zone
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS FM; DIATOMS AM
SECTION: 1, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/3
25 cm, inclined burrows

Large, partially deformed burrows (yellow)

~90 cm, black streaks
V1

DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 50	1, 93	1, 90
	D	M	D
Texture:			
Sand	15	42	18
Silt	25	32	35
Clay	60	26	47
Composition:			
Quartz	4	12	20
Feldspar	2	15	11
Mica	–	2	–
Heavy minerals	–	3	1
Clay	54	50	19
Glauconite	–	–	2
Pyrite	3	3	4
Carbonate unspec.	1	–	2
Calc. nannofossils	3	–	1
Diatoms	27	–	25
Radiolarians	1	–	3
Sponge spicules	5	–	10
Silicoflagellates	–	–	2
Biotite	–	15	–

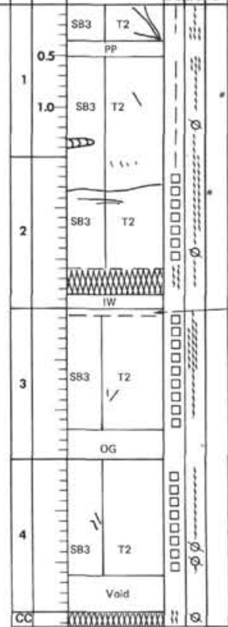
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.4

SITE 584 HOLE CORE 51 CORED INTERVAL 479.3–488.9 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: *T. schraderi* zone
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS FM; DIATOMS AM
SECTION: 1, 2, 3, 4, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Healed fractures

BIOSILICEOUS MUDSTONE

100 cm to 110 cm, slickensides in plane of core cut

Yellow green (5Y 5/3) burrow
Veinlets

5Y 4/1

T4

Section 3: mottles generally 5Y 4/3

80 cm to 90 cm, complicated set of fractures

SMEAR SLIDE SUMMARY (%):

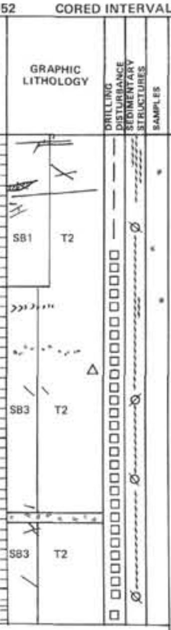
	1, 90	2, 38
	D	M
Texture:		
Sand	18	82
Silt	35	8
Clay	47	10
Composition:		
Quartz	20	15
Feldspar	11	20
Heavy minerals	1	2
Clay	19	10
Volcanic glass	–	30
Glauconite	2	–
Pyrite	4	5
Carbonate unspec.	2	–
Calc. nannofossils	1	–
Diatoms	25	10
Radiolarians	3	–
Sponge spicules	10	3
Silicoflagellates	2	–
Lithic fragments	–	5

ORGANIC CARBON AND CARBONATE (%):

	2, 50
Carbonate	0.0

SITE 584 HOLE CORE 52 CORED INTERVAL 488.9–498.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*T. schraderi* zone	B	B	FM	AM	1, 2, 3, 4, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

Disrupted burrow traces

DIATOMACEOUS MUDSTONE

15 cm to 30 cm, thin, yellow-brown, contorted burrows

V1, disrupted ash
V1

5Y 4/2

V1
Offset, clearly shown by black

5Y 4/2

SMEAR SLIDE SUMMARY (%):

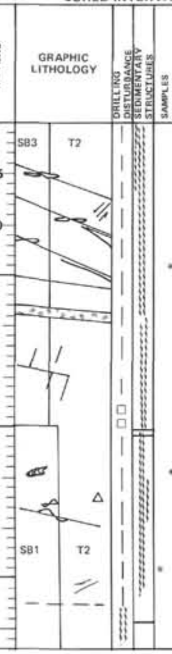
	1, 39	1, 112	2, 15
	M	D	D
Texture:			
Sand	40	15	25
Silt	35	35	30
Clay	25	50	45
Composition:			
Quartz	11	10	15
Feldspar	3	7	5
Mica	–	–	3
Heavy minerals	2	Tr	–
Clay	18	34	34
Volcanic glass	3	–	–
Glauconite	3	–	–
Pyrite	35	3	7
Carbonate unspec.	–	–	3
Diatoms	15	35	25
Radiolarians	–	1	1
Sponge spicules	10	10	7

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 53 CORED INTERVAL 498.5–508.1 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*T. schraderi* zone	B	B	FM	AM	1, 2, 3, 4, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

5Y 4/2

BIOSILICEOUS MUDSTONE

Healed fractures and veinlets offset ~3 mm to 5 mm

V1

140 cm to 150 cm, small burrows, 1–2 mm diameter filled with white, sandy ash

Inclined burrows

V1

5GY 4/1

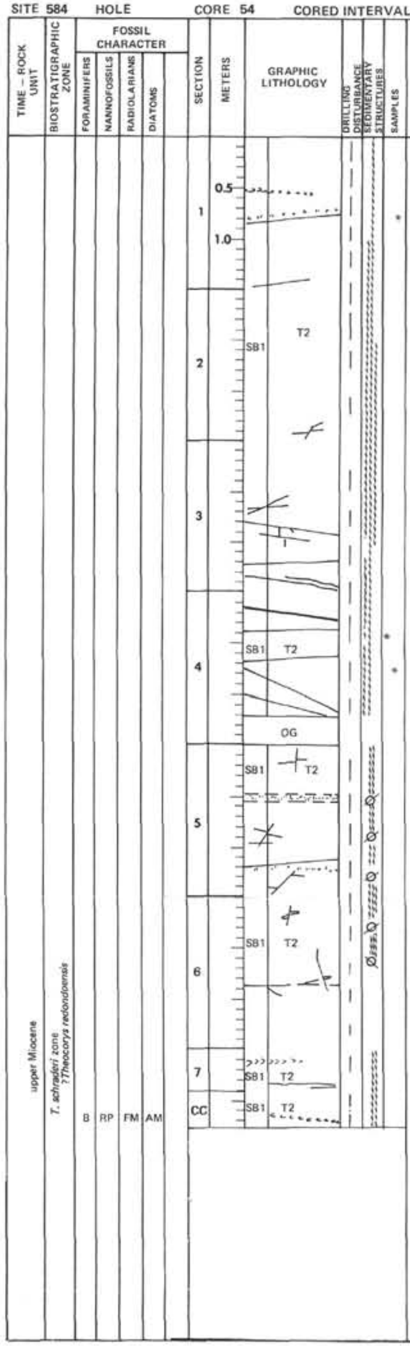
SMEAR SLIDE SUMMARY (%):

	1, 149	3, 48	3, 141
	D	D	M
Texture:			
Sand	35	25	12
Silt	25	30	15
Clay	40	45	73
Composition:			
Quartz	12	15	5
Feldspar	5	2	3
Mica	2	3	2
Heavy minerals	1	–	–
Clay	38	25	50
Volcanic glass	–	3	–
Pyrite	5	5	5
Carbonate unspec.	1	1	–
Calc. nannofossils	–	3	–
Diatoms	25	35	24
Radiolarians	1	1	1
Sponge spicules	10	7	10
Silicoflagellates	–	Tr	–

ORGANIC CARBON AND CARBONATE (%):

	1, 29
Carbonate	1.4

SITE 584 HOLE CORE 54 CORED INTERVAL 508.1–517.6 m



LITHOLOGIC DESCRIPTION

Section 1: grayish olive (10Y 4/2)

DIATOMACEOUS MUDSTONE

70 cm to 80 cm, see blow-up, below

Section 2: large olive burrows, serrated edges inclined about 35°

80 cm, greenish bleb = glauconite

5Y 5/1
Color change
5Y 4/2 to 5/2

Veinlet network

Section 4: major offsets shown, but these are surrounded by a network of or a boxwork of finer healed offsets

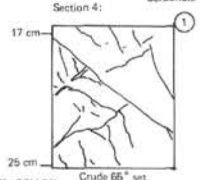
SMEAR SLIDE SUMMARY (%):

	1, 81 M	4, 49 D	4, 80 D
Texture:			
Sand	35	25	12
Silt	40	25	33
Clay	25	50	55
Composition:			
Quartz	12	4	6
Feldspar	8	4	5
Heavy minerals	1	–	–
Clay	18	50	53
Volcanic glass	45	4	4
Palagonite	1	–	1
Glauconite	1	1	1
Pyrite	4	5	6
Carbonate unspec.	2	1	1
Foraminifers	–	Tr	Tr
Calc. nannofossils	–	–	1
Diatoms	–	24	15
Sponge spicules	2	4	4
Lithic fragments	6	3	3

ORGANIC CARBON AND CARBONATE (%):

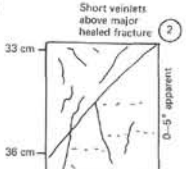
	6, 100
Carbonate	0.9

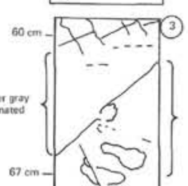
Section 4:



V1

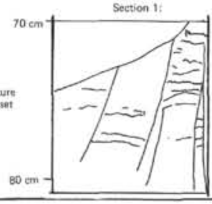
5Y 6/1–5GY 5/1



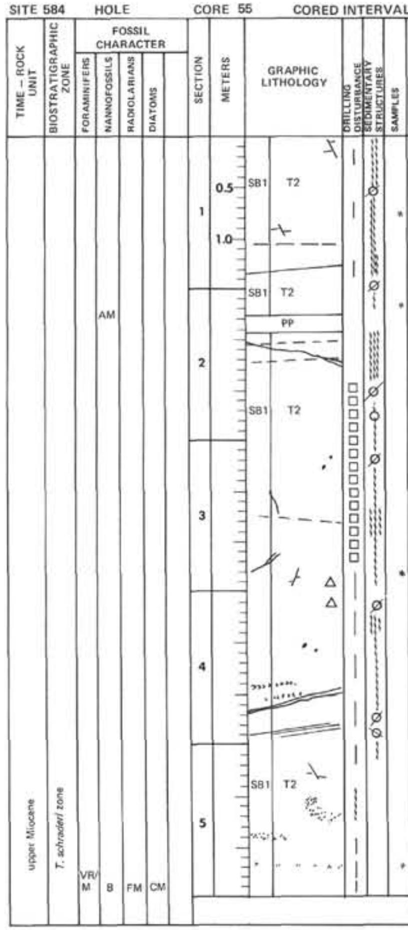


5Y 6/1 to 5GY 5/1

Section 1:



SITE 584 HOLE CORE 55 CORED INTERVAL 517.6–527.1 m



LITHOLOGIC DESCRIPTION

Gray olive (10Y 4/2)

DIATOMACEOUS MUDSTONE

Glauconitic spot

Large serrate olive burrows recovered beneath this black, inclined, healed fracture

= bedding planes, inclined ~ 20°

Branching healed fracture
End burrows from 1–130 cm

Glauconite blebs

22° dip, 65 cm to 95 cm, olive burrows

V1, vitric burrow fill
T4
10 cm to 45 cm olive color dominates burrows and matrix

Network 55°

10Y 4/2

Burrow trace filled with black sand

V1

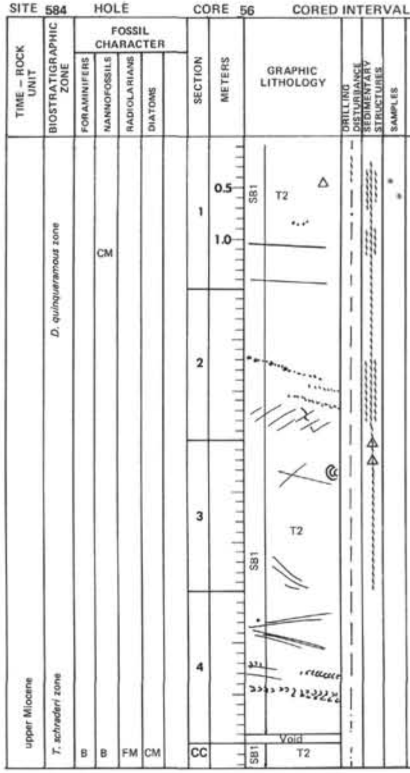
SMEAR SLIDE SUMMARY (%):

	1, 80 D	2, 16 M	3, 138 M	5, 120 M
Texture:				
Sand	25	15	30	45
Silt	25	35	45	45
Clay	50	50	25	10
Composition:				
Quartz	8	2	10	10
Feldspar	5	2	8	12
Heavy minerals	1	–	Tr	2
Clay	46	50	18	10
Volcanic glass	2	–	32	42
Palagonite	1	1	1	2
Glauconite	–	–	1	–
Pyrite	3	3	3	10
Carbonate unspec.	1	3	1	–
Foraminifers	–	Tr	–	–
Calc. nannofossils	2	12	–	–
Diatoms	24	22	15	1
Radiolarians	–	–	Tr	–
Sponge spicules	4	5	3	3
Plant debris	–	–	2	–
Lithic fragments	3	–	6	8

ORGANIC CARBON AND CARBONATE (%):

	2, 16
Carbonate	0.0

SITE 584 HOLE CORE 56 CORED INTERVAL 527.1–536.6 m



LITHOLOGIC DESCRIPTION

Predominant color 10Y 4/2

Ovoid burrow filled with ash, V1

DIATOMACEOUS MUDSTONE

Green, glauconitic specks

100 cm to 150 cm, network of healed fractures predominant dip∼35° offset, not determined

85 cm to 95 cm, ash filled burrows 48° dip
Veinlet pattern dips 80° to 85° and offsets burrows

Glauconitic spot

A
Zoophycus inclined 50°

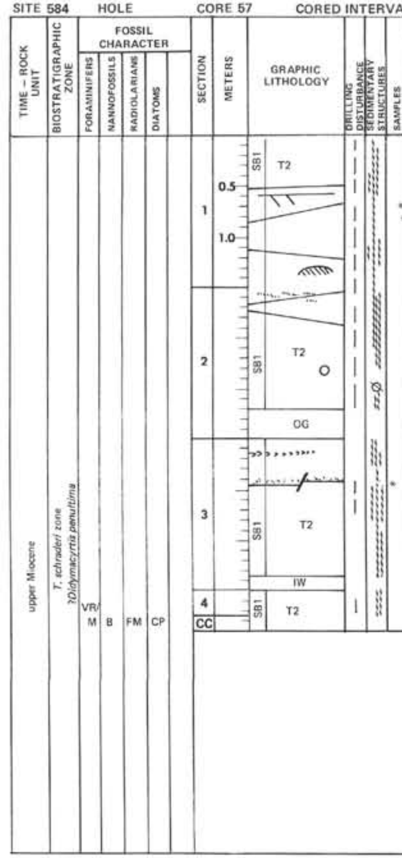
SMEAR SLIDE SUMMARY (%):

	1, 60 D	1, 40 M
Texture:		
Sand	15	10
Silt	25	80
Clay	60	10
Composition:		
Quartz	7	6
Feldspar	5	4
Clay	55	10
Volcanic glass	4	71
Palagonite	1	–
Glauconite	1	–
Pyrite	4	3
Carbonate unspec.	1	1
Foraminifers	–	Tr
Calc. nannofossils	Tr	2
Diatoms	18	2
Sponge spicules	4	1
Plant debris	Tr	–

ORGANIC CARBON AND CARBONATE (%).

	3, 31
Carbonate	0.0

SITE 584 HOLE CORE 57 CORED INTERVAL 536.6–546.1 m



LITHOLOGIC DESCRIPTION

Grayish olive (10Y 4/2)

DIATOMACEOUS MUDSTONE

Orientation of burrow traces, here bedding dips 35°

Rounded, silt-size grains common

Orientation of veinlets
Beard-like dewatering veinlets

Section 2: burrows inclined at∼45° average burrow traces stop at healed fracture

Burrow filled with light-colored sediments

10Y 4/2
Gradual color change
5Y 3/2
Color change
10Y 4/2

SMEAR SLIDE SUMMARY (%):

	1, 83 D	3, 46 M	1, 72 M
Texture:			
Sand	7	35	18
Silt	40	45	42
Clay	53	20	40
Composition:			
Quartz	10	20	12
Feldspar	8	16	8
Heavy minerals	Tr	5	1
Clay	45	19	35
Volcanic glass	–	3	1
Palagonite	1	4	1
Glauconite	1	2	–
Pyrite	3	–	4
Carbonate unspec.	1	–	–
Calc. nannofossils	Tr	–	–
Diatoms	15	3	26
Sponge spicules	8	3	8
Plant debris	–	–	1
Lithic fragments	8	25	3

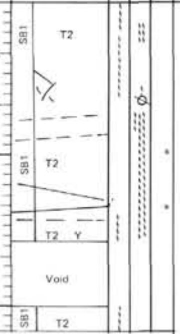
ORGANIC CARBON AND CARBONATE (%):

	3, 91
Carbonate	0.4

SITE 584 HOLE CORE 58 CORED INTERVAL 546.1–555.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*T. schraderi* zone	VR/M	B	RM	CM	1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Grayish olive (10Y 4/2) mottled with 5Y 3/2 serrated burrows

DIATOMACEOUS MUDSTONE

Olive (5Y 5/3)

SMEAR SLIDE SUMMARY (%):

	1, 146	2, 50
	M	D
Texture:		
Sand	15	10
Silt	60	45
Clay	25	45
Composition:		
Quartz	20	13
Feldspar	15	9
Heavy minerals	2	1
Clay	20	35
Volcanic glass	–	2
Palagonite	1	–
Glauconite	2	1
Pyrite	5	5
Carbonate unspec.	Tr	Tr
Diatoms	7	22
Sponge spicules	3	4
Plant debris	–	1
Lithic fragments	25	7

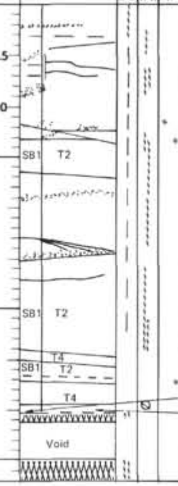
ORGANIC CARBON AND CARBONATE (%)

	1, 126
Carbonate	36.6

SITE 584 HOLE CORE 59 CORED INTERVAL 555.6–565.1 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*T. schraderi* zone	B	B	RP	FP	1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

10Y 4/2, 5Y 4/1, and 5Y 3/2, irregular mozaic
125–126 cm thin section

T6, swirled sandy lenses, soft sediment deformation

5Y 3/1, dark, coarser layers

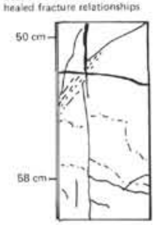
SMEAR SLIDE SUMMARY (%):

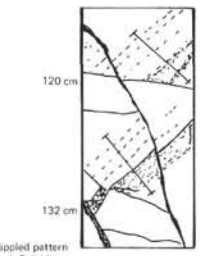
	1, 139	1, 115	3, 71
	D	M	M
Texture:			
Sand	19	8	20
Silt	36	67	–
Clay	45	25	80
Composition:			
Quartz	8	28	13
Feldspar	4	12	2
Heavy minerals	1	1	3
Clay	40	23	30
Volcanic glass	3	2	–
Palagonite	–	1	–
Glauconite	1	–	–
Pyrite	5	–	6
Carbonate unspec.	1	1	–
Diatoms	23	8	44
Sponge spicules	4	1	–
Lithic fragments	10	23	2

ORGANIC CARBON AND CARBONATE (%):

	2, 32
Carbonate	0.0

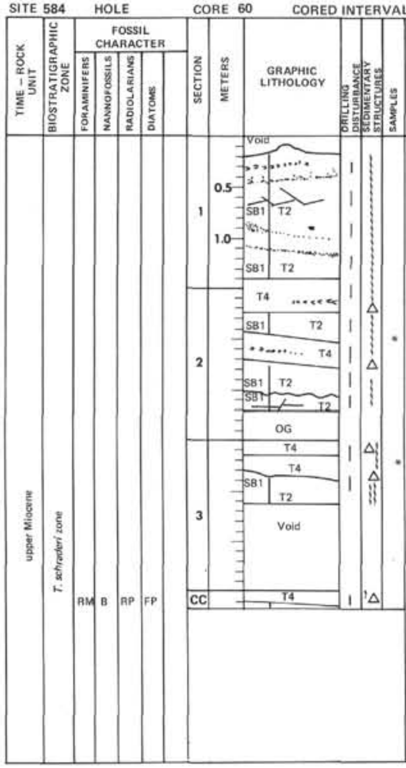
Section 1: 50 cm to 60 cm healed fracture relationships





Section 1: stippled pattern represents sand. Solid lines represent healed fractures. Dashed lines represent bedding orientation. I = repeated intervals

SITE 584 HOLE CORE 60 CORED INTERVAL 565.1–574.6 m



LITHOLOGIC DESCRIPTION

5Y 3/1

Soft sediment deformation – sand swept up into clay layers

DIATOMACEOUS MUDSTONE

Dewatering veinlets

115 cm to 140 cm, 10Y 4/2, light color interval

5Y 4/1

Wavy contact

Dips ~ 25°

5Y 4/1

SMEAR SLIDE SUMMARY (%):

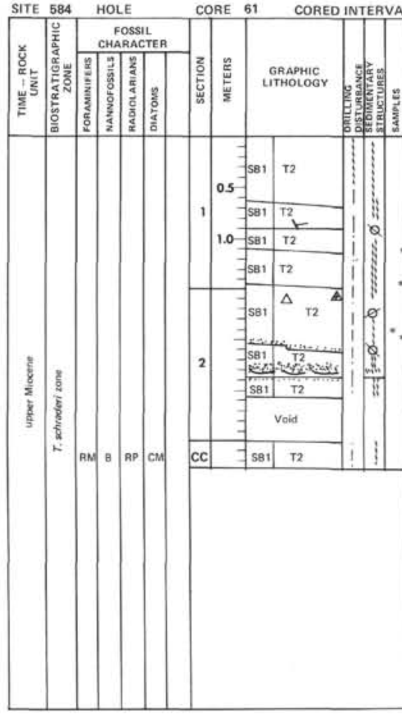
	2, 50 D	3, 25 M
Texture:		
Sand	45	75
Silt	25	15
Clay	30	10
Composition:		
Quartz	25	30
Feldspar	12	7
Mica	4	–
Heavy minerals	–	3
Clay	10	12
Glauconite	2	–
Pyrite	3	5
Diatoms	25	15
Radiolarians	2	–
Sponge spicules	5	3
Lithics	12	25

ORGANIC CARBON AND CARBONATE (%):

	1, 30
Carbonate	0.0

Section 1: 62–68 cm

SITE 584 HOLE CORE 61 CORED INTERVAL 574.6–584.1 m



LITHOLOGIC DESCRIPTION

5Y 4/1–3/2

DIATOMACEOUS MUDSTONE

55 cm to 150 cm, multiple fractures, healed and not – so disrupted sense of offset difficult to decipher

T4, silty pockets

Scour, rip-ups, cross bedding

SMEAR SLIDE SUMMARY (%):

	1, 112 D	1, 146 D	2, 40 D	2, 50 D
Texture:				
Sand	10	60	12	25
Silt	10	20	35	45
Clay	80	20	53	30
Composition:				
Quartz	20	35	15	18
Feldspar	5	8	5	10
Heavy minerals	5	7	1	1
Clay	40	23	43	21
Volcanic glass	6	5	1	–
Palagonite	–	–	1	–
Pyrite and opaques	6	6	4	7
Carbonate unspec.	–	–	–	15
Diatoms	10	8	25	20
Sponge spicules	4	–	5	3
Fish remains	Tr	–	–	–
Lithics	4	8	–	5

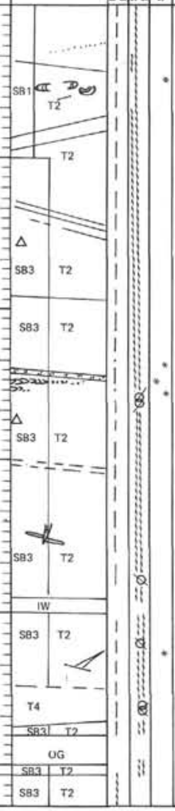
ORGANIC CARBON AND CARBONATE (%):

	1, 115
Carbonate	0.0

SITE 584 HOLE CORE 62 CORED INTERVAL 584.1–593.6 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: *T. schraderi* zone
FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): B (Section 1); B (Section 3); CC: B, B, RP
SECTION: 1, 2, 3, 4, 5, 6, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/1
Clots = ?orientation of burrows

Fracture
V1, ash filled burrows
80 cm to 100 cm, horizontal slickensides

DIATOMACEOUS MUDSTONE

Veinlets
T4

V1, N6, burrow fill 5Y 5/2
50 cm to 150 cm, black grains throughout

T4

T4, silty bed dips 35°
5Y 4/1

SMEAR SLIDE SUMMARY (%):

	1, 79 M	3, 60 M	3, 75 M	3, 85 D	5 40 D
Texture:					
Sand	62	90	30	35	25
Silt	15	5	–	41	45
Clay	23	5	70	24	30
Composition:					
Quartz	8	5	15	15	18
Feldspar	10	–	–	8	5
Heavy minerals	2	3	5	1	–
Clay	7	7	37	26	19
Volcanic glass	52	80	15	2	–
Palagonite	–	–	–	1	–
Glauconite	–	–	–	–	2
Pyrite and opaques	6	4	3	–	7
Diatoms	12	1	15	35	27
Radiolarians	–	–	–	–	2
Sponge spicules	3	–	10	12	12
Silicoflagellates	–	–	–	–	1
Lithics	–	–	–	–	7

ORGANIC CARBON AND CARBONATE (%):

	1, 58
Carbonate	0.0

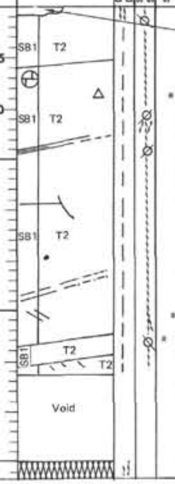
Black streak, apparent dip 25°

5Y 3/2

SITE 584 HOLE CORE 63 CORED INTERVAL 593.6–603.2 m

TIME – ROCK UNIT: upper Miocene
BIOSTRATIGRAPHIC ZONE: *Denticulopsis hustedtii* zone (a subzone)
FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): CC: RM, B, RP, FP
SECTION: 1, 2, 3, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2–3/2
Void

DIATOMACEOUS MUDSTONE

5B 5/1
Calcareous concretion – CB9 – 2 cm diameter
T4

100 cm to 105 cm, pumic filled burrows

Olive gray (5Y 4/4)

60 cm to 100 cm, pyrite concentration

Glauconite

Section 3: true dip of structures = 20°
5Y 3/2
5B 4/1
Strong color contrast
5Y 3/2

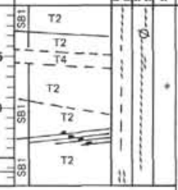
SMEAR SLIDE SUMMARY (%):

	1, 90 D	3, 4 M	3, 32 D
Texture:			
Sand	–	5	10
Silt	20	–	55
Clay	80	95	35
Composition:			
Quartz	21	10	20
Feldspar	4	3	Tr
Heavy minerals	9	8	8
Clay	36	43	45
Volcanic glass	–	Tr	1
Glauconite	–	–	5
Pyrite	7	6	5
Carbonate unspec.	–	1	–
Calc. nannofossils	–	9	–
Diatoms	18	8	15
Sponge spicules	5	12	1
Fish remains	Tr	–	–

SITE 584 HOLE CORE 64 CORED INTERVAL 603.2–612.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*D. hustedtii* zone (a subzone)	B	B	RM	CP	1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 3/2

Section 1: apparent bedding 47°, real 54°

DIATOMACEOUS MUDSTONE

Small, en echelon fractures
Marker beds, 5Y 4/3 mudstone

5Y 3/2

SMEAR SLIDE SUMMARY (%):

	1, 80
	D
Texture:	
Sand	15
Silt	52
Clay	33
Composition:	
Quartz	24
Feldspar	7
Mica	1
Heavy minerals	1
Clay	40
Volcanic glass	2
Glauconite	1
Pyrite	4
Carbonate unspec.	1
Diatoms	14
Sponge spicules	5

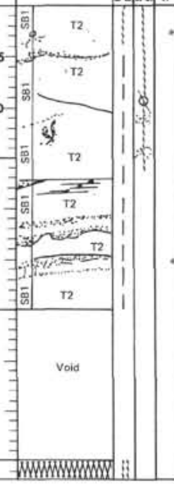
ORGANIC CARBON AND CARBONATE (%):

	1, 35
Carbonate	0.0

SITE 584 HOLE CORE 65 CORED INTERVAL 612.8–622.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*D. hustedtii* zone (*Denticulopsis dimorpha* subzone)	B	B	RM	FP	1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5GY 2/1

DIATOMACEOUS MUDSTONE

5Y 3/1, bedding dips 35°–40° throughout Section 2
En echelon offsets, exaggerated here

Dark sandy layers, 2 phases of slumping

5GY 4/1

SMEAR SLIDE SUMMARY (%):

	1, 30	2, 102
	D	M
Texture:		
Sand	18	45
Silt	42	25
Clay	40	30
Composition:		
Quartz	15	35
Feldspar	9	17
Heavy minerals	2	4
Clay	46	29
Volcanic glass	2	–
Glauconite	2	3
Pyrite	4	7
Diatoms	15	3
Radiolarians	Tr	–
Sponge spicules	5	1
Garnet	–	1

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

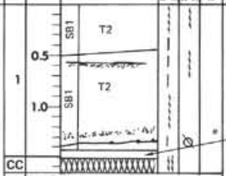
SITE 584 HOLE CORE 66 CORED INTERVAL 622.4–632.1 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS FP

SECTION: 1, CC



LITHOLOGIC DESCRIPTION

5Y 3/1

Bedding dips 28°

T6

Void

Blue-green streak parallel to bedding

SMEAR SLIDE SUMMARY (%):

	1, 127
	M
Texture:	
Sand	60
Silt	25
Clay	15
Composition:	
Quartz	37
Feldspar	22
Heavy minerals	10
Clay	7
Glauconite	3
Pyrite	5
Lithics	8
Hornblende	3

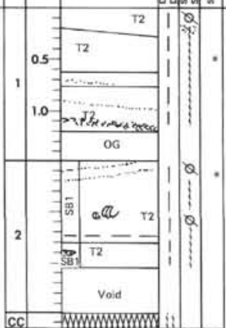
SITE 584 HOLE CORE 67 CORED INTERVAL 632.1–641.8 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS FP

SECTION: 1, 2, CC



LITHOLOGIC DESCRIPTION

5Y 3/1

DIATOMACEOUS MUDSTONE

Healed fracture

Sand layer truncated by healed fracture

2 large burrows, fill is structureless, 5Y 5/2

Thin silty layers, apparent dip 60°

5Y 3/2

SMEAR SLIDE SUMMARY (%):

	1, 50	2, 19
	D	D
Texture:		
Sand	95	15
Silt	3	42
Clay	2	43
Composition:		
Quartz	35	35
Feldspar	30	10
Heavy minerals	10	8
Clay	5	22
Glauconite	2	–
Pyrite and opaque	10	5
Carbonate unspec.	–	1
Diatoms	Tr	15
Radiolarians	–	Tr
Sponge spicules	Tr	4
Silicoflagellates	–	Tr
Lithic fragments	8	–

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

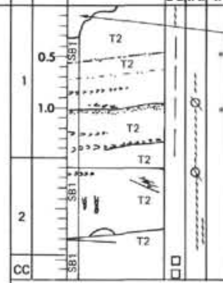
SITE 584 HOLE CORE 68 CORED INTERVAL 641.8–651.5 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS FP

SECTION: 1, 2, CC



LITHOLOGIC DESCRIPTION

5GY 2/1

Void

Thin silty layers, mud between

Thin silty layers, mud between

DIATOMACEOUS MUDSTONE

Apparent dip: 55°

5Y 4/1

Vertical zoophycus

Healed fracture

Lighter colored truncated burrow

5Y 4/1

SMEAR SLIDE SUMMARY (%):

	1, 50	1, 101
	D	M
Texture:		
Sand	20	60
Silt	40	25
Clay	40	15
Composition:		
Quartz	25	35
Feldspar	8	21
Heavy minerals	7	7
Clay	36	12
Glauconite	–	3
Pyrite	5	5
Carbonate unspec.	2	–
Diatoms	12	4
Radiolarians	1	–
Sponge spicules	4	1
Green hornblende	–	6
Lithic fragments	–	6

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 69 CORED INTERVAL 651.5–661.2 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS CP

SECTION: CC

LITHOLOGIC DESCRIPTION

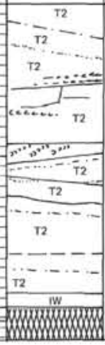
DRILL BRECCIA

5Y 4/1

Containing some reworked pebbles

SITE 584 HOLE CORE 70 CORED INTERVAL 661.2–670.9 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. hustedtii* zone (*D. dimorpha* subzone)	B	B	RP	FP	1, 2, 3, CC	0.5, 1.0	T2, IW			*



LITHOLOGIC DESCRIPTION

5Y 5/1 to 4/1 dominant, with 4/2 in burrows

45 cm to 55 cm, wispy bioturbation traces

MUDSTONE

140 cm to 150 cm, calcareous sandstone
Olive (5Y 6/3) fine carbonate sand

5Y 4/1

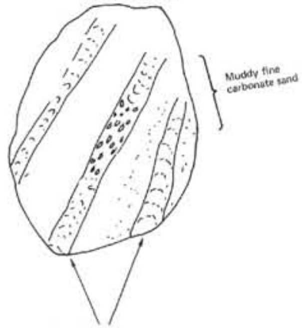
T4

5Y 4/1

SMEAR SLIDE SUMMARY (%):

	1, 32 D	2, 119 M
Texture:		
Sand	5	10
Silt	35	70
Clay	60	20
Composition:		
Quartz	15	22
Feldspar	5	15
Heavy minerals	Tr	5
Clay	58	20
Volcanic glass	2	4
Palagonite	1	2
Glauconite	Tr	1
Pyrite	2	3
Carbonate unspec.	Tr	–
Calc. nannofossils	Tr	–
Diatoms	5	2
Sponge spicules	3	1
Lithic fragments	9	25

Section 1:
140 cm to 150 cm



SITE 584 HOLE CORE 71 CORED INTERVAL 670.9–680.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene	*D. hustedtii* zone (*D. dimorpha* subzone)	B	B, FP	RM	CP	1, 2, CC	0.5, 1.0	T2, Void			*

LITHOLOGIC DESCRIPTION

Predominantly gray (5Y 4/1 to 5/1 and 4/2)

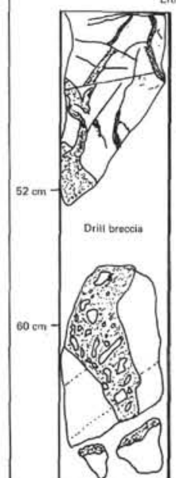
MUDSTONE

V1, ash filled burrows

Details missing from description space available here

SMEAR SLIDE SUMMARY (%):

	1, 25 D	1, 125 M
Texture:		
Sand	2	10
Silt	23	70
Clay	75	20
Composition:		
Quartz	18	3
Feldspar	13	4
Heavy minerals	–	1
Clay	49	8
Volcanic glass	1	74
Palagonite	1	1
Pyrite	4	3
Carobnate unspec.	Tr	–
Calc. nannofossils	Tr	–
Diatoms	4	1
Sponge spicules	4	Tr
Lithic fragments	6	5



Section 2: stippled pattern represents and. Solid lines represent healed fractures. Blank areas are mudstone, unless otherwise labelled. Clotted lines represent bedding traces.

SITE 584 HOLE CORE 72 CORED INTERVAL 680.6–690.2 m

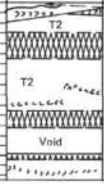
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: D. hustedtii zone (D. dimorpha subzone)

	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
Section 1		B		
CC	B	B	RP	FP

SECTION: 1, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Void

10 cm gray (5Y 4/1)

Mottled throughout, mostly 5Y 5/1, 4/3, 4/4

MUDSTONE

35° dip on this zoophycus

SMEAR SLIDE SUMMARY (%):

	1, 60 D	1, 72 M
Texture:		
Sand	10	7
Silt	35	21
Clay	55	72
Composition:		
Quartz	12	4
Feldspar	9	6
Heavy minerals	1	1
Clay	54	68
Volcanic glass	1	1
Palagonite	1	1
Glauconite	1	4
Pyrite	2	3
Diatoms	7	4
Radiolarians	Tr	–
Sponge spicules	2	2
Lithic fragments	10	6

SITE 584 HOLE CORE 73 CORED INTERVAL 690.2–699.8 m

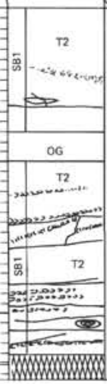
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: D. hustedtii zone (D. dimorpha subzone)

FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
B	VR/P	RP	CP

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Grey olive green (5GY 3/2)

DIATOMACEOUS MUDSTONE

Sandy with ovoid pellets, very green (5G 4/2)

SMEAR SLIDE SUMMARY (%):

	1, 35 D
Texture:	
Sand	5
Silt	30
Clay	65
Composition:	
Quartz	12
Feldspar	6
Heavy minerals	1
Clay	59
Volcanic glass	1
Palagonite	Tr
Pyrite	2
Calc. nannofossils	Tr
Diatoms	8
Sponge spicules	5
Lithic fragments	7

ORGANIC CARBON AND CARBONATE (%):

	1, 28
Carbonate	0.4

SITE 584 HOLE CORE 74 CORED INTERVAL 699.8–709.4 m

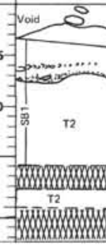
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: D. hustedtii zone (D. dimorpha subzone)

FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
B	RP	RP	CP

SECTION: 1, 2, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5Y 4/2–5/2, to 5GY 3/2, mottled

DIATOMACEOUS MUDSTONE

T4, silter layer with suspended clasts of clay, grading upward into clays

Blue, olive gray, mottled, burrows and bedding dip 45°

5Y 3/1: drill breccia

5Y 3/1

SMEAR SLIDE SUMMARY (%):

	1, 60 D
Texture:	
Sand	–
Silt	15
Clay	85
Composition:	
Quartz	18
Heavy minerals	5
Clay	57
Volcanic glass	1
Pyrite	5
Carbonate unspec.	1
Diatoms	5
Sponge spicules	5
Lithics	3

ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.0

SITE 584 HOLE CORE 75 CORED INTERVAL 709.4–719.1 m

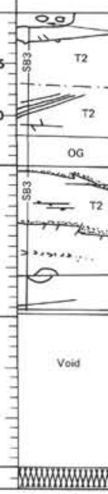
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: D. hustedtii zone (Coscinodiscus yabei subzone)

FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
RM	RP	RP	CP

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5GY 3/2

Void

BIOSILICEOUS MUDSTONE

Thin silt layer, T4

Dewatering veins

5Y 4/2

T4

5GY 3/2, mudstone

T4, darker

SMEAR SLIDE SUMMARY (%):

	1, 30 D	2, 60 M
Texture:		
Sand	15	60
Silt	30	20
Clay	55	20
Composition:		
Quartz	25	44
Feldspar	5	2
Mica	–	Tr
Heavy minerals	2	10
Clay	49	22
Volcanic glass	–	2
Glauconite	1	1
Pyrite	3	5
Calc. nannofossils	–	4
Diatoms	8	2
Sponge spicules	7	Tr
Plant debris	Tr	–
Lithics	–	8

Note: smear slide 2, 60 – no nannofossils here, T4.

5GY 3/2

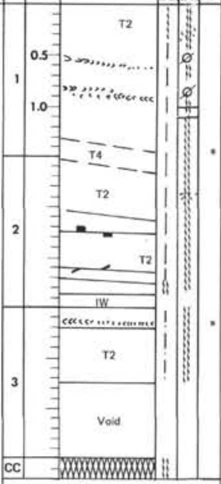
SITE 584 HOLE CORE 76 CORED INTERVAL 719.1–728.8 m

TIME-ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*C. yabei* subzone)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS CP

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5GY 3/2–5Y 4/2
Section 1: deformed burrow traces and mud clasts

MUDSTONE

Burrows dip at ~40° to 47°

Color change
5Y 6/2 to 6/4 siltstone
with mudclasts

Section 2: deformed burrow traces, mottles

Subtle color change

5Y 4/1
Section 3: strongly deformed burrows and mottles

5Y 4/1

SMEAR SLIDE SUMMARY (%):

	1, 145 D	3, 20 D
Texture:		
Sand	10	12
Silt	30	34
Clay	60	54
Composition:		
Quartz	46	25
Feldspar	6	5
Mica	–	2
Heavy minerals	4	–
Clay	22	54
Volcanic glass	8	1
Palagonite	–	1
Pyrite	4	3
Carbonate unspec.	2	1
Calc. nannofossils	–	Tr
Diatoms	2	3
Sponge spicules	2	5
Lithics	4	–

ORGANIC CARBON AND CARBONATE (%):

	1, 98	1, 144
Carbonate	0.0	4.2

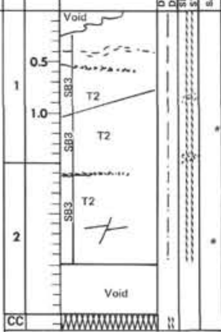
SITE 584 HOLE CORE 77 CORED INTERVAL 728.8–738.5 m

TIME-ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*C. yabei* subzone)

FOSSIL CHARACTER: FORAMINIFERS RM; NANNOFOSSILS RP; RADIOLARIANS RP; DIATOMS FP

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/1

BIOSILICEOUS MUDSTONE

5Y 4/2 to 5/1 with 5Y 6/2 mottles

SMEAR SLIDE SUMMARY (%):

	1, 120 D	2, 80 D
Texture:		
Sand	15	5
Silt	10	–
Clay	75	95
Composition:		
Quartz	31	8
Feldspar	3	–
Heavy minerals	–	5
Clay	36	22
Volcanic glass	2	2
Pyrite	6	4
Carbonate unspec.	–	31
Calc. nannofossils	–	25
Diatoms	5	2
Sponge spicules	11	1
Lithics	6	–

ORGANIC CARBON AND CARBONATE (%):

	1, 82	2, 82
Carbonate	0.0	19.0

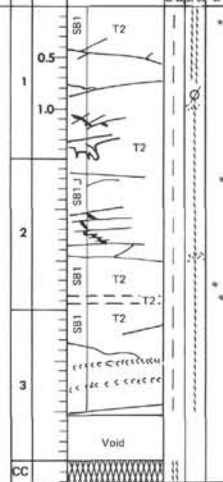
SITE 584 HOLE CORE 78 CORED INTERVAL 738.5–748.0 m

TIME-ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*C. yabei* subzone)

FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B (RP); RADIOLARIANS RP; DIATOMS FP

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2, mottled

DIATOMACEOUS MUDSTONE

5Y 3/2 to 5Y 4/3

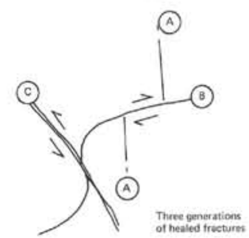
Section 2: mottled, burrowed, multiple, small healed fractures

5Y 4/3

SMEAR SLIDE SUMMARY (%):

	1, 20 D	2, 22 M	2, 126 D	2, 140 D
Texture:				
Sand	25	55	10	5
Silt	35	15	55	20
Clay	40	30	35	75
Composition:				
Quartz	25	15	35	15
Feldspar	5	20	5	Tr
Mica	–	–	12	–
Heavy minerals	2	–	Tr	4
Clay	36	10	12	54
Volcanic glass	2	42	–	4
Palagonite	–	5	–	–
Glauconite	1	–	–	–
Pyrite	4	5	7	5
Carbonate unspec.	–	–	2	–
Calc. nannofossils	–	1	–	–
Diatoms	18	2	20	6
Radiolarians	–	–	2	–
Sponge spicules	7	–	5	7
Lithics	–	–	–	5

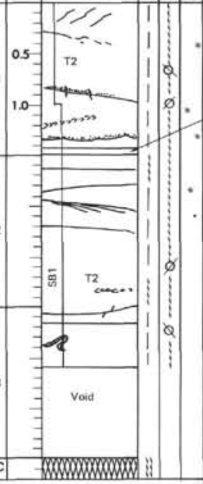
Section 1: 130 cm to 150 cm



Three generations of healed fractures

SITE 584 HOLE CORE 79 CORED INTERVAL 748.0–757.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
upper Miocene	*D. hustedtii* zone (*C. yabei* subzone) ?*Didymocyrtis antepenultima*	B	RP	RP	CP	1, 2, 3, CC	0.5, 1.0	T2, SB1, Void				



DIATOMACEOUS MUDSTONE

5Y 4/2 burrowed silt
Void

Sharp contact 5Y 3/1 / 5BG 5/1, silt

5Y 4/1
Burrows and fractures (2 mm offset), dip~60°
Small anastamosing fractures, apparent dip 34°

5Y 4/2

T4, deformed silty pocket

5Y 4/2

SMEAR SLIDE SUMMARY (%):

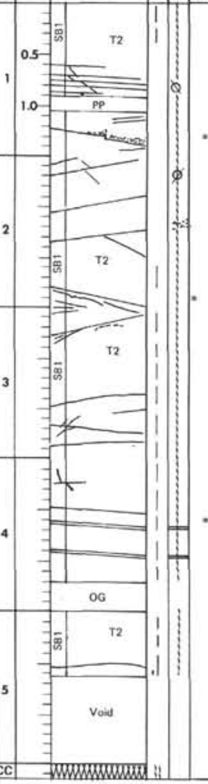
	1, 43 D	1, 104 D	1, 130 M	2, 38 D
Texture:				
Sand	–	25	60	15
Silt	25	45	25	40
Clay	75	30	15	45
Composition:				
Quartz	26	35		
Feldspar	8	6	8	7
Mica	–	–	–	2
Heavy minerals	6	1	9	1
Clay	32	22	35	43
Volcanic glass	1	3	3	–
Glauconite	–	2	1	–
Pyrite	3	4	5	9
Carbonate unspec.	1	–	–	–
Diatoms	10	17	5	20
Radiolarians	–	2	–	1
Sponge spicules	5	7	4	5
Plant debris	–	1	–	–
Lithics	8	–	10	–

ORGANIC CARBON AND CARBONATE (%):

	1, 62
Carbonate	0.0

SITE 584 HOLE CORE 80 CORED INTERVAL 757.5–767.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
middle Miocene	*D. hustedtii* zone (*C. yabei* subzone) *Diartus hughesi*	B	B, B, B	CP	CP	1, 2, 3, 4, 5, CC	0.5, 1.0	SB1, T2, PP, OG, Void				



5Y 4/2
Numerous, small healed fractures

SMEAR SLIDE SUMMARY (%):

	1, 131 M	2, 136 M	4, 60 D
Texture:			
Sand	70	25	15
Silt	15	–	45
Clay	15	75	40
Composition:			
Quartz	12	29	25
Feldspar	–	3	5
Mica	–	–	1
Heavy minerals	–	6	2
Clay	23	42	38
Volcanic glass	49	–	3
Pyrite	7	11	5
Diatoms	6	–	12
Radiolarians	–	–	1
Sponge spicules	3	1	8
Lithics	–	8	–

5Y 5/4

See inset below

Structures exaggerated

Section 4: dewatering veinlets parallel to core axis
5Y 4/1–4/2

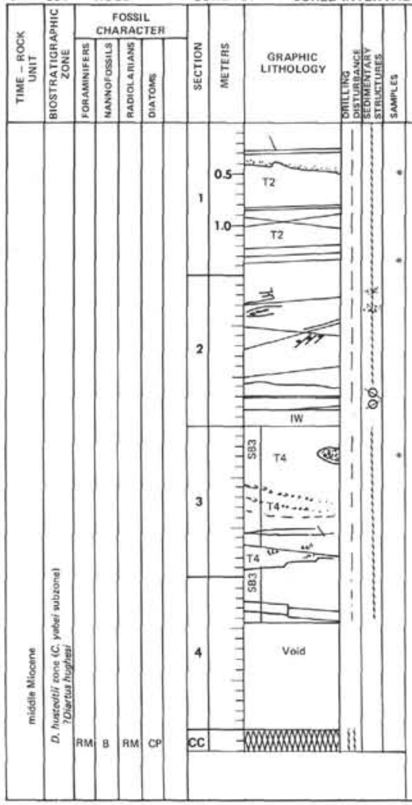
Section 2: 65 cm to 80 cm

Clastic dike with flow structures

5Y 4/2

5Y 3/1

SITE 584 HOLE CORE 81 CORED INTERVAL 767.0–776.7 m



LITHOLOGIC DESCRIPTION

5Y 3/1
Clastic dike
Dark 5Y 3/1
5Y 4/2

MUDSTONE, SILTSTONE, AND BIOSILICEOUS MUDSTONE

Clastic dike

5Y 3/1
Clastic dike
Mottled blue, green (5BG 3/2, 5GY 3/2)
Blue green burrow

Clastic dike = CD

5Y 3/1, Section 3: sandy mudstone with glauconitic spots
25 cm to 26 cm: thin section
T6, pebble, or clast of darker, very sandy mudstone

Boundary not recovered, coarse above, fine beneath

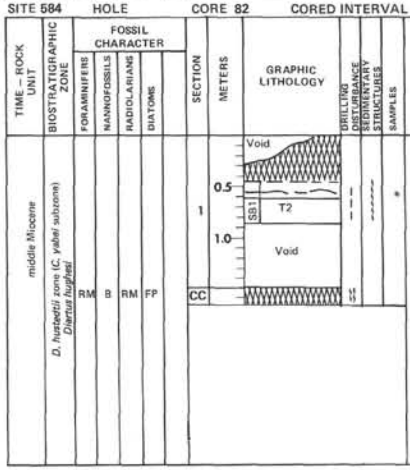
5Y 4/2
5Y 3/1
5Y 4/2

Green spot, glauconitic
Darker, offset beds
5Y 3/3

SMEAR SLIDE SUMMARY (%):

	1, 50	1, 85	3, 30
	D	M	D
Texture:			
Sand	25	–	40
Silt	50	28	35
Clay	25	80	25
Composition:			
Quartz	25	25	35
Feldspar	4	–	5
Heavy minerals	7	5	3
Clay	51	60	24
Volcanic glass	–	Tr	3
Glauconite	–	–	9
Pyrite	4	–	4
Diatoms	2	5	9
Radiolarians	–	–	4
Sponge spicules	2	5	4
Lithic fragments	5	–	–

SITE 584 HOLE CORE 82 CORED INTERVAL 776.7–786.4 m



LITHOLOGIC DESCRIPTION

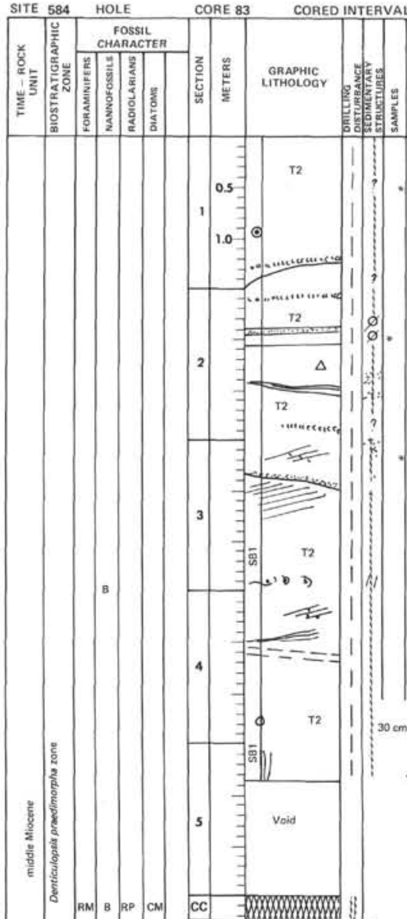
5GY 3/2–10GY 3/2
Dark interval
Nature and extent of burrowing unsure
Dark greenish gray clasts throughout

DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 60
	D
Texture:	
Sand	21
Silt	33
Clay	46
Composition:	
Quartz	19
Feldspar	3
Heavy minerals	2
Clay	50
Glauconite	1
Pyrite	3
Carbonate unspec.	1
Diatoms	12
Radiolarians	2
Sponge spicules	7

SITE 584 HOLE CORE 83 CORED INTERVAL 786.4–796.1 m



LITHOLOGIC DESCRIPTION

Dark greenish gray (5G 4/1)
Microvein network throughout, spacing so dense extent of bioturbation *difficult to estimate*

Halo

MUDSTONE AND DIATOMACEOUS MUDSTONE

T6, sandy ash

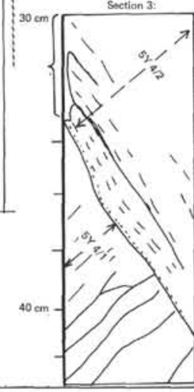
V1

5Y 4/2
30 cm to 50 cm, see inset
Veinlet orientation
5G 4/1

Circular and swirled olive (5Y 5/3) burrow fill
Carbonate rich

Inclined bed, faint color contrast

Section 3:



SMEAR SLIDE SUMMARY (%):

	1, 50	2, 50	3, 20
	D	M	D
Texture:			
Sand	–	45	8
Silt	24	55	27
Clay	76	–	65
Composition:			
Quartz	7	10	6
Feldspar	3	14	2
Heavy minerals	Tr	1	–
Clay	76	–	65
Volcanic glass	2	62	4
Palagonite	1	–	1
Glauconite	1	–	1
Pyrite	2	11	1
Carbonate unspec.	–	–	1
Diatoms	5	–	12
Radiolarians	Tr	–	–
Sponge spicules	1	–	5

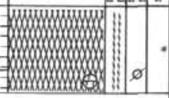
ORGANIC CARBON AND CARBONATE (%):

	3, 134
Carbonate	35.2

SITE 584 HOLE CORE 84 CORED INTERVAL 796.1–805.8 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: *D. praedimorpha* zone
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS CP
SECTION: 1, CC
METERS: 0.5

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

DRILL BRECCIA

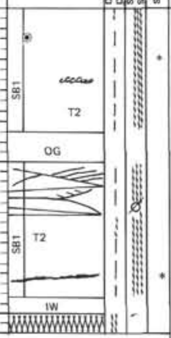
SMEAR SLIDE SUMMARY (%):

	1, 41 D
Texture:	
Sand	4
Silt	26
Clay	70
Composition:	
Quartz	8
Feldspar	5
Heavy minerals	Tr
Clay	65
Volcanic glass	2
Palagonite	1
Pyrite	3
Carbonate unspec.	1
Diatoms	9
Sponge spicules	4
Lithic fragments	2

SITE 584 HOLE CORE 85 CORED INTERVAL 805.8–815.5 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: *D. praedimorpha* zone
FOSSIL CHARACTER: FORAMINIFERS B; RADIOLARIANS RP; DIATOMS CP
SECTION: 1, 2, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Veinlets less common than in Core 83
5GY 4/1

DIATOMACEOUS MUDSTONE

Large burrow network

5Y 2/1

Bedding trace, 64° apparent

Dusky green (5G 3/2) 5 mm to 8 mm bed
Glauconite-rich
Dip 38° apparent

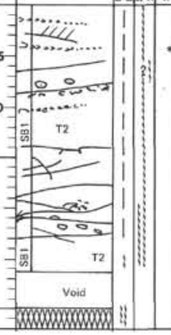
SMEAR SLIDE SUMMARY (%):

	2, 113 M	1, 50 D
Texture:		
Sand	6	8
Silt	34	32
Clay	60	60
Composition:		
Quartz	9	8
Feldspar	3	5
Heavy minerals	Tr	–
Clay	44	60
Volcanic glass	8	3
Glauconite	8	Tr
Pyrite	8	4
Carbonate unspec.	–	1
Diatoms	15	11
Sponge spicules	5	5
Plant debris	–	1
Lithic fragments	–	2

SITE 584 HOLE CORE 86 CORED INTERVAL 815.5–825.2 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: *Dlartus hughesi* / *D. praedimorpha* zone
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B, B; RADIOLARIANS FM; DIATOMS CP
SECTION: 1, 2, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5GY 4/1

DIATOMACEOUS MUDSTONE

Zoophycus, apparent dip 55°
Halos
Soft sediment deformation

Burrows apparent dip 27°

8 mm olive bed, apparent dip 40°

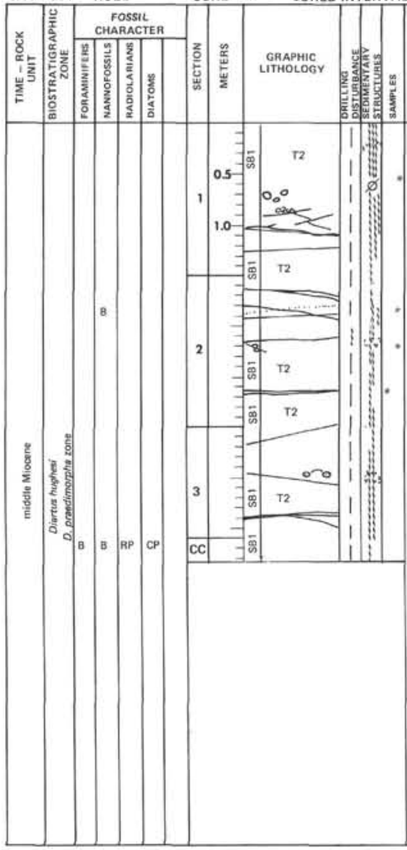
SMEAR SLIDE SUMMARY (%):

	1, 40 D
Texture:	
Sand	5
Silt	25
Clay	70
Composition:	
Quartz	6
Feldspar	2
Heavy minerals	Tr
Clay	70
Volcanic glass	2
Glauconite	1
Pyrite	3
Carbonate unspec.	Tr
Diatoms	8
Sponge spicules	4
Plant debris	2
Lithic fragments	2

ORGANIC CARBON AND CARBONATE (%):

	2, 82
Carbonate	0.0

SITE 584 HOLE CORE 87 CORED INTERVAL 825.2–834.8 m



LITHOLOGIC DESCRIPTION

Predominant color
5G 4/1 to 5GY 3/2 to 5G 6/1
Local olive gray (5Y 4/3) in burrows

4 cm thick olive (5Y 6/4) calcareous bed
(carbonate mud turbidite?)

Smear slides: no nannofossils, but unspecified carbonate
Dakrer bed 65 cm to 78 cm

Clastic dike

Linked, hollow cylindrichnus

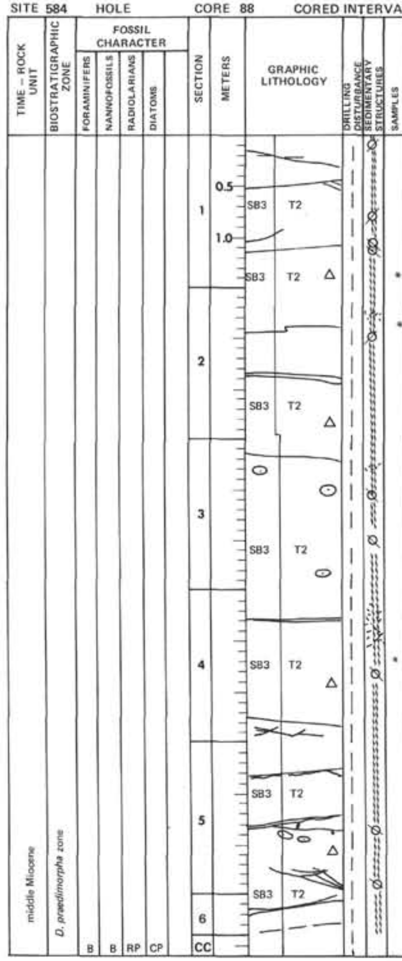
SMEAR SLIDE SUMMARY (%):½

	1, 60 D	2, 38 M	2, 73 M	2, 118 M
Texture:				
Sand	13	8	2	5
Silt	27	32	33	20
Clay	60	60	65	75
Composition:				
Quartz	4	1	12	6
Feldspar	2	1	7	2
Heavy minerals	–	–	1	–
Clay	61	20	52	73
Volcanic glass	3	–	2	5
Palagonite	–	–	–	Tr
Glauconite	–	–	1	Tr
Pyrite	2	3	5	2
Carbonate unspec.	1	64	–	1
Diatoms	18	8	8	7
Sponge spicules	4	3	3	3
Plant debris	–	–	2	–
Lithic fragments	–	–	7	1

ORGANIC CARBON AND CARBONATE (%):

	3, 51
Carbonate	0.0

SITE 584 HOLE CORE 88 CORED INTERVAL 834.8–844.4 m



LITHOLOGIC DESCRIPTION

5Y 4/1
Multiple fractures and dewatering veinlets throghout,
only largest shown here

BIOSILICEOUS MUDSTONE

110 cm: chondrites

V1 ash

Yellow-green (10YR 5/4) small streaks and patches

Blue green (5BG 3/2) above

SMEAR SLIDE SUMMARY (%):

	1, 140 M	2, 36 D	4, 70 D
Texture:			
Sand	35	10	15
Silt	45	57	60
Clay	20	33	25
Composition:			
Quartz	5	15	25
Feldspar	15	4	5
Heavy minerals	–	1	1
Clay	–	38	25
Volcanic glass	61	–	–
Palagonite	Tr	–	–
Glauconite	3	Tr	–
Pyrite	12	4	4
Carbonate unspec.	–	1	–
Calc. nannofossils	–	2	–
Diatoms	3	25	30
Radiolarians	–	2	Tr
Sponge spicules	1	8	10

T6

5Y 4/1

T6

ORGANIC CARBON AND CARBONATE (%):

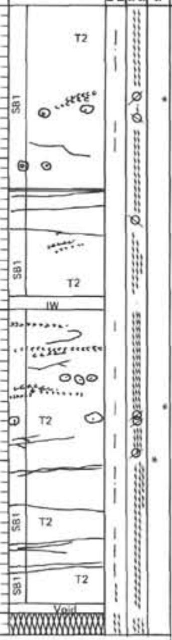
	3, 51
Carbonate	0.0

T4

SITE 584 HOLE CORE 89 CORED INTERVAL 844.4–854.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*D. praedimorpha* zone	RM	B	RP	CP	1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

5Y 4/2

Section 1: complex, numerous very small healed fractures

Blue green (5BG 3/2) — may be glauconitic

5BG 3/2
5GY 3/2
Blue green
48 cm, burrow filled with gray-white sand = ?ash

110 cm to 135 cm, green chunks throughout

5Y 3/1

Siltier patches in burrowed sediments

Normal fault, offset 3 cm

Large cylindrichnus

5Y 4/1 to 5GY 4/1

SMEAR SLIDE SUMMARY (%):

	1, 91 D	3, 96 D	3, 147 M
Texture:			
Sand	15	10	15
Silt	35	35	35
Clay	50	55	50
Composition:			
Quartz	32	12	12
Feldspar	7	7	7
Heavy minerals	1	1	–
Clay	37	49	47
Volcanic glass	–	7	16
Glauconite	–	2	–
Pyrite	3	1	3
Carbonate unspec.	–	–	2
Diatoms	12	16	10
Sponge spicules	8	5	1
Other	–	–	2

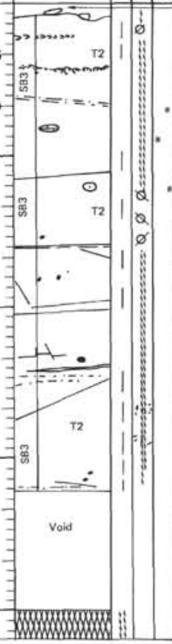
ORGANIC CARBON AND CARBONATE (%):

	1, 44
Carbonate	0.0

SITE 584 HOLE CORE 90 CORED INTERVAL 854.0–863.7 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*Denticulopsis nicobarica* zone	B	B	RP	RP	1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Void

BIOSILICEOUS MUDSTONE

T4, silty layer
102 cm, 5GY 3/2 ash, cut by fault
10YR 4/2

5Y 4/1

Cylindrichnus

Yellowish green wedge, calcareous

5Y 5/4

Burrows dip 15°, healed fracture 80°

Homogeneous olive gray (5Y 4/1) mud

Reducing spots
$CaCO_3$ patches?, light brown color
Silty layer cut by healed fracture

SMEAR SLIDE SUMMARY (%):

	1, 102 M	1, 131 M	2, 32 D
Texture:			
Sand	20	10	10
Silt	50	35	35
Clay	30	55	55
Composition:			
Quartz	10	4	25
Feldspar	8	3	5
Mica	–	–	1
Heavy minerals	–	–	1
Clay	27	42	39
Volcanic glass	36	–	2
Palagonite	2	–	–
Glauconite	3	–	–
Pyrite	4	5	–
Carbonate unspec.	–	31	–
Diatoms	6	13	15
Radiolarians	–	–	2
Sponge spicules	3	–	10
Silicoflagellates	–	3	–
Hornblende	1	–	–

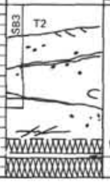
ORGANIC CARBON AND CARBONATE (%):

	1, 123
Carbonate	0.9

SITE 584 HOLE CORE 91 CORED INTERVAL 863.7–873.4 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*D. nicobarica* zone	B	B	RP	FP	1, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5G 4/1 to 4/2
Fine-grained authigenic carbonates disseminated throughout core

Black spots, represent burrows, and micro-reducing environments

Black spots

Void

BIOSILICEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 19 M	1, 52 M	1, 83 D	1, 120 D
Texture:				
Sand	20	45	15	–
Silt	50	30	20	–
Clay	30	25	65	–
Composition:				
Quartz	7	12	8	15
Feldspar	5	–	4	–
Heavy minerals	1	–	–	5
Clay	28	37	52	28
Volcanic glass	17	–	3	–
Glauconite	3	–	1	1
Pyrite	10	47	3	5
Carbonate unspec.	18	1	12	42
Diatoms	8	–	9	–
Sponge spicules	3	3	8	4

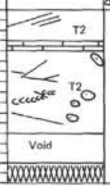
ORGANIC CARBON AND CARBONATE (%):

	1, 68
Carbonate	4.7

SITE 584 HOLE CORE 92 CORED INTERVAL 873.4–883.1 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*Denticulopsis lauta* zone (b subzone)	B	B, B	RP		1, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5Y 4/2
Faulted, mottled, heavy bioturbation

MUDSTONE

Cylindrichnus

SMEAR SLIDE SUMMARY (%):

	1, 32 M
Texture:	
Sand	3
Silt	45
Clay	52
Composition:	
Quartz	3
Feldspar	1
Heavy minerals	1
Glauconite	2
Pyrite	3
Carbonate unspec.	85
Diatoms	2
Sponge spicules	3

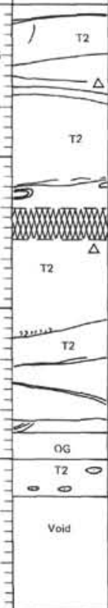
ORGANIC CARBON AND CARBONATE (%):

	1, 50
Carbonate	0.4

SITE 584 HOLE CORE 93 CORED INTERVAL 883.1–892.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*D. lauta* zone (a subzone)	RM	B	RP	FP	1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5Y 3/1 to 5GY 3/2

MUDSTONE

CB9 (triangle)
Black bed, true dip 55°
5Y 2.5/1, overlain by mixed black and light brown layer, broken so that relationships are unclear

5Y 3/2, noncarbonate nodules

CB9

5Y 4/1
Black reducing spots and yellow spots

60 cm to 70 cm, grainy white and brown

5Y 4/2

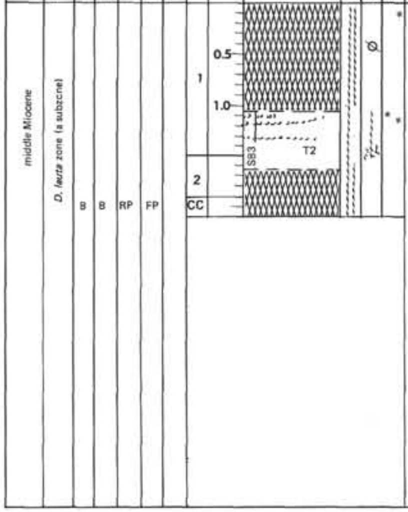
5Y 4/2 to 3/2, mottled blue-green, black

SMEAR SLIDE SUMMARY (%):

	1, 85 D	3, 60 M
Texture:		
Sand	5	35
Silt	35	–
Clay	60	65
Composition:		
Quartz	30	17
Feldspar	5	2
Mica	Tr	–
Clay	59	28
Carbonate unspec.	–	40
Diatoms	4	8
Radiolarians	–	2
Sponge spicules	2	3

SITE 584 HOLE CORE 94 CORED INTERVAL 892.8–902.5 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: *D. lauta* zone (a subzone)
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS FP



LITHOLOGIC DESCRIPTION

DRILL BRECCIA

Brown spots, not calcareous (a subzone)

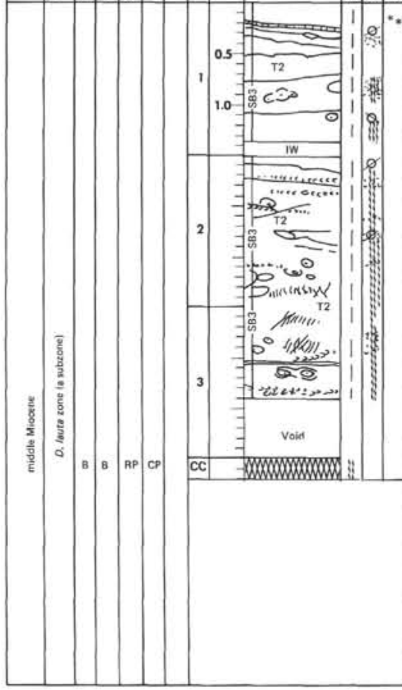
Blue green, mottled, multiple fractures
5GY 3/2 to
5G 4/2
Brown spots, not $CaCO_3$ rich

SMEAR SLIDE SUMMARY (%):

	1, 10 M	1, 111 M	1, 118 D
Texture:			
Sand	25	5	5
Silt	50	–	35
Clay	25	95	60
Composition:			
Quartz	35	22	19
Feldspar	10	2	5
Mica	2	–	8
Heavy minerals	2	–	–
Clay	15	70	45
Volcanic glass	–	Tr	1
Glauconite	7	–	–
Pyrite	3	1	3
Carbonate unspec.	–	1	–
Diatoms	19	4	15
Radiolarians	1	Tr	–
Sponge spicules	6	–	4

SITE 584 HOLE CORE 95 CORED INTERVAL 902.5–912.2 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE: *D. lauta* zone (a subzone)
FOSSIL CHARACTER: FORAMINIFERS B; NANNOFOSSILS B; RADIOLARIANS RP; DIATOMS CP



LITHOLOGIC DESCRIPTION

CB9
Yellow brown (10YR 7/4) grain
Matrix is generally blue-green (5BG 3/2)

110 cm, contact – 110 cm to 111 cm thin section

Section 1: mud turbidites?

Section 2: abundant zoophycus and cylindrichnus halos, burrowing cyclicity apparent in Section 1 not so obvious here. Color: 5BG 3/2 to 5G 3/2 with blue-green gray (5G 4/2) intervals.

Section 3: 5G 5/1 predominant color with blue-green gray (5G 4/2) intervals

5Y 4/1
Mosaic of veinlets

BIOSILICEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

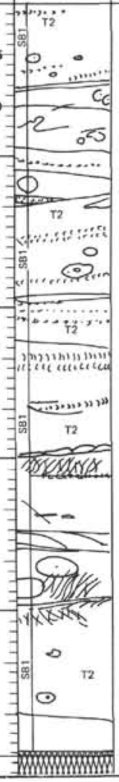
	1, 20 M	1, 16 D
Texture:		
Sand	12	6
Silt	38	24
Clay	50	70
Composition:		
Quartz	7	5
Feldspar	4	3
Clay	48	70
Volcanic glass	15	1
Palagonite	1	–
Glauconite	Tr	1
Pyrite	10	2
Carbonate unspec.	1	7
Diatoms	9	7
Sponge spicules	3	4
Plant debris	2	–

SITE 584 HOLE CORE 96 CORED INTERVAL 912.2–921.8 m

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

Section 1: Nannofossils B; Section 2: Nannofossils B; CC: Foraminifers B, Nannofossils B

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



INTENSELY MOTTLED AND BURROWED MUDSTONE
5G 4/2 and 5G 5/1 primarily with other shades of gray and blue-green mixed, i. e.: 5BG 5/2 and 5Y 4/3

5G 4/2
Beds, almost laminae, grade into groundmass
Dark flecks of organic matter

113 cm to 140 cm, highly contorted
5G 4/2
Gray brown (5Y 5/1), highly bioturbated

41 cm to 45 cm interval
Fine silty volcanic ash layer with dark green thin laminations

Section 2: abundant zoophycus, parallel to bedding, numerous halos with chondrites-rich centers, = ? bioturbation or more likely mud pellets (shark droppings?)

Zoophycus maximus

Section 4: 76 cm to 100 cm, steep bedding, complex pattern of folded laminations, zooclinal hinges, and healed fractures

10 mm offset

Flow, soft sediment deformation?

Wide seams 20 cm to 40 cm, highly irregular fractures

Glauconite halo

55 cm to 85 cm complex network of veinlets
58° = true dip

SMEAR SLIDE SUMMARY (%):

	1, 50	2, 43
	D	M
Texture:		
Sand	8	20
Silt	22	50
Clay	70	30
Composition:		
Quartz	8	7
Feldspar	2	2
Clay	68	10
Volcanic glass	5	73
Palagonite	Tr	2
Glauconite	1	–
Pyrite	2	1
Carbonate unspec.	Tr	Tr
Diatoms	9	1
Sponge spicules	2	3
Lithic fragments	3	1

ORGANIC CARBON AND CARBONATE (%):

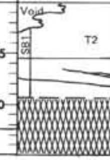
	4, 130
Carbonate	0.0

SITE 584 HOLE CORE 97 CORED INTERVAL 921.8–931.4 m

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

CC: Foraminifers B, Nannofossils B, Radiolarians RP

Sections: 1, CC — Meters: 0.5, 1.0



5G 5/1 hard mudstone
Highly brecciated (healed fractures above contact phyllitic sheen)

Contact, lost in drilling
5GY 4/1 below contact
Contortions and burrow traces along contact
5GY 5/1

DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

	1, 40
	D
Texture:	
Sand	6
Silt	19
Clay	35
Composition:	
Quartz	5
Feldspar	2
Clay	74
Volcanic glass	2
Pyrite	5
Carbonate unspec.	1
Diatoms	9
Sponge spicules	2

SITE 584 HOLE CORE 96 CORED INTERVAL 931.4–941.0 m

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

Foraminifers B, Nannofossils B, Radiolarians RP

Sections: 1, CC

T2

Resembles uppermost 55 cm in Core 97.
Hard phyllitic cobbles, feels like talc, i. e. soapstone, metamorphic rock formed by drilling.

MUDSTONE AND HOLE CAVINGS

SITE 584 HOLE A CORE H1 CORED INTERVAL 0.0–602.2 m

TIME – ROCK UNIT: upper Miocene lower Pliocene Pleistocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica* zone (a subzone) (b subzone) *R. curvirostris* zone

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): CM; AG; RP AG

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

METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

WASH CORE

SITE 584 HOLE A CORE H2 CORED INTERVAL 611.8–698.8 m

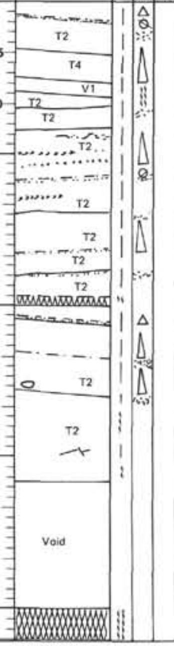
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): CP; B FP

SECTION: 1, 2, 3, 4, CC

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

5GY 4/1
5G 4/1

MUD TURBIDITES

5Y 3/1

Yellowish gray (5Y 8/1)

Black flecks

5GY 4/1

5GY 4/1

V1? = ashy or silty sand

5Y 3/1, with 5GY 5/1 basalt basal layers

Some color banding

Microveins

SITE 584 HOLE A CORE 1 CORED INTERVAL 602.2–611.8 m

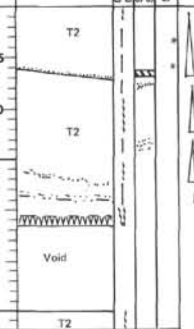
TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. hustedtii* zone (*D. dimorpha* subzone)

FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS): B B RP FP

SECTION: 1, 2, CC

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

MUD TURBIDITES IN MUDSTONE
Olive gray (5Y 4/1) with dark green-gray laminae

Swirled silt and mud

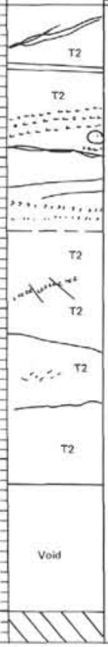
SMEAR SLIDE SUMMARY (%):

	1, 34 D	1, 61 M
Texture:		
Sand	8	35
Silt	20	45
Clay	72	20
Composition:		
Quartz	8	28
Feldspar	4	12
Heavy minerals	1	8
Clay	69	–
Volcanic glass	2	–
Palagonite	1	3
Glauconite	1	1
Pyrite	5	7
Diatoms	5	1
Sponge spicules	3	–
Plant debris	1	–
Lithic	–	22

SITE 584 HOLE A CORE 2 CORED INTERVAL 698.8–708.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*D. hustedtii* zone (*C. yabei* subzone)	B	B	RP	CM	1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

Veinlets

MUDSTONE
Grayish olive (10Y 4/2)
and numerous greenish and olive
(burrow fill only) hues

Bedding contacts

45
45° apparent dip

Section 2: shot-through with microfractures
Intense fracturing with conjugate set of healed fractures

N6–N7 fine silty ash (thin – 64–68 cm, cut)
Contact broken 5Y 5/2
5Y 4/1

Sub-vertical, up to 8 mm offset with
zoophycus trace, exaggeration
here makes these appear as reverse
faults, which they probably are not

Microfractures throughout

Black spots

Light gray (5Y 5/1)
Dark gray (5Y 3/1)

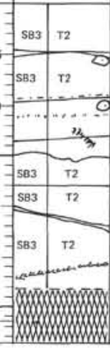
SMEAR SLIDE SUMMARY (%):

	1, 50 D	2, 62 M
Texture:		
Sand	4	7
Silt	26	43
Clay	70	50
Composition:		
Quartz	11	6
Feldspar	6	3
Heavy minerals	1	Tr
Clay	61	30
Volcanic glass	–	46
Palagonite	1	–
Glauconite	1	Tr
Pyrite	5	4
Carbonate unspec.	–	2
Calc. nannofossils	–	1
Diatoms	6	5
Radiolarians	Tr	Tr
Sponge spicules	3	2
Lithic fragments	5	1

SITE 584 HOLE A CORE H3 CORED INTERVAL 708.4–795.1 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
upper Miocene	*D. hustedtii* zone (*C. yabei* subzone)		B		CM	1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

5Y 4/1

BIOSILICEOUS MUDSTONE

Fracture network (healed)
5Y 4/2

Grainy, dark green

5Y 3/1
5Y 4/2
5Y 3/1

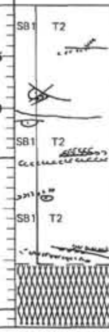
SMEAR SLIDE SUMMARY (%):

	1, 97 M	2, 76 D
Texture:		
Sand	10	15
Silt	50	55
Clay	40	30
Composition:		
Quartz	16	25
Feldspar	5	5
Heavy minerals	1	1
Clay	38	30
Glauconite	8	1
Pyrite	5	2
Carbonate unspec.	1	–
Calc. nannofossils	–	1
Diatoms	17	25
Radiolarians	1	3
Sponge spicules	4	7
Hornblende	4	–

SITE 584 HOLE A CORE 3 CORED INTERVAL 795.1–804.8 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene	*D. lauta* zone (a subzone)	B	B	RP	FP	1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

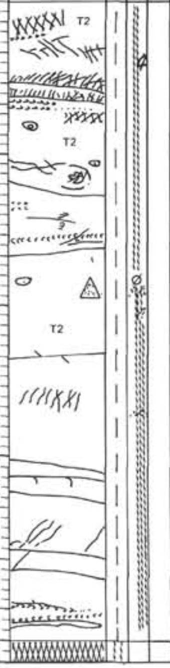
5Y 4/1

SMEAR SLIDE SUMMARY (%):

	1, 113 D
Texture:	
Sand	20
Silt	30
Clay	50
Composition:	
Quartz	10
Feldspar	3
Heavy minerals	2
Clay	47
Volcanic glass	2
Pyrite	8
Carbonate unspec.	2
Diatoms	22
Radiolarians	Tr
Sponge spicules	4

5Y 4/1

SITE 584 HOLE A CORE H4 CORED INTERVAL 804.8–901.5 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
middle Miocene	*D. lauta* zone (a subzone)		VR/P		FP	1, 2, 3, 4, 5, CC	0.5, 1.0					

T2

T2

T2

Section 1: dewatering veins!
5Y 3/1 to 4/1

Lignite MUDSTONE

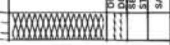
5GY 4/1

Blue green streak

V1
5GY 4/1

60 cm to 75 cm yellow patches, calcareous

SITE 584 HOLE A CORE X1 CORED INTERVAL 882.0–890.0 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOME	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
middle Miocene	*D. lauta* zone (a subzone)				FP	1						

Horizon DRILL BRECCIA
From somewhere above bottom, basement, got stuck
Horizon

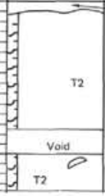
SITE 584 HOLE B CORE 1 CORED INTERVAL 0.0–1.4 m

TIME – ROCK UNIT: upper Quaternary

BIOSTRATIGRAPHIC ZONE: *Denticulopsis marina zone* / *Botryostrobus aquilonaris*

FOSSIL CHARACTER — FORAMINIFERS: B; NANNOFOSSILS: B; RADIOLARIANS: CM; DIATOMS: CM

SECTION: 1, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

Void

GLAUCONTIC, SOUPY DIATOMACEOUS MUD

Olive (5Y 4/3)

Siltstone, glauconitic crust 5G 5/2–5G 4/2

SMEAR SLIDE SUMMARY (%):

	1, 49 D	1, 60 D
Texture:		
Sand	45	24
Silt	25	50
Clay	30	26
Composition:		
Quartz	15	28
Feldspar	7	12
Heavy minerals	4	5
Clay	35	24
Volcanic glass	–	2
Glauconite	7	7
Pyrite	10	6
Diatoms	9	8
Sponge spicules	8	2
Lithic fragments	5	5

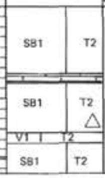
SITE 584 HOLE B CORE H1 CORED INTERVAL 1.4–509.7 m

TIME – ROCK UNIT: lower Pliocene; upper Miocene

BIOSTRATIGRAPHIC ZONE: *D. kamtschatica zone (b)*; *D. kamtschatica zone (a)*

FOSSIL CHARACTER — FORAMINIFERS: RM; NANNOFOSSILS: B, RP, B; RADIOLARIANS: CM; DIATOMS: AG, AG, AG, CM, CM

SECTION: 1, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

DIATOMITE

5GY 4/1 coarse vitric sand with various granules and pebbles

5Y 7/2 CB9

Fragments of calcareous nodules

H_2S odor

CB9 Light yellow (5Y 7/4) calcareous layer

N7 White, fine silty ash

Gray (5Y 5/1–5GY 5/1) hard mudstone

SMEAR SLIDE SUMMARY (%):

	1, 100 D
Texture:	
Sand	55
Silt	30
Clay	15
Composition:	
Quartz	10
Feldspar	2
Clay	15
Pyrite	4
Carbonate unspec.	3
Diatoms	60
Radiolarians	1
Sponge spicules	5

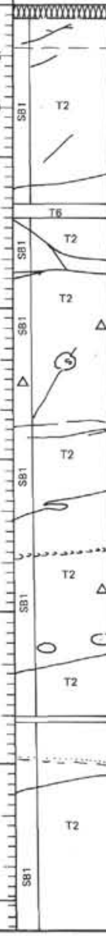
SITE 584 HOLE B CORE H2 CORED INTERVAL 509.7–644.1 m

TIME – ROCK UNIT: upper Miocene

BIOSTRATIGRAPHIC ZONE: *T. schraderi zone*

FOSSIL CHARACTER — FORAMINIFERS: RM; NANNOFOSSILS: RM; RADIOLARIANS: FM; DIATOMS: AM

SECTION: 1, 2, 3, 4, 5, 6, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Dusky yellow (5Y 6/4) mottles = serrated

Burrow fill

Matrix is 5GY 3/2 to 10Y 3/2

100 cm to Section 2, 30 cm, completely bioturbated, yellow burrow fill with serrated, often black rims

Burrow and pyrite concentration

Healed fracture network

115 cm, color change

T4, ~1 cm thick silty sand layer

Offset cylindrichnus

T6 – very coarse sand pod

Offset burrow

V1

V1

Thin sand

Section 6: scattered pyrite and glauconite

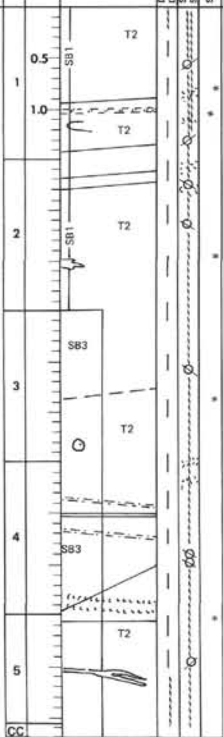
5Y 4/2

SMEAR SLIDE SUMMARY (%):

	1, 71 D	2, 15 M	2, 55 M	4, 135 M
Texture:				
Sand	15	5	15	8
Silt	5	5	–	–
Clay	80	90	85	92
Composition:				
Quartz	11	8	10	8
Feldspar	–	2	15	10
Heavy minerals	2	–	–	–
Clay	50	15	38	37
Volcanic glass	3	–	20	27
Pyrite	5	75	7	13
Foraminifers	3	–	–	–
Calc. nannofossils	4	–	–	–
Diatoms	18	–	6	3
Sponge spicules	4	–	4	2
Fish remains	Tr	–	–	–

SITE 584 HOLE B CORE 2 CORED INTERVAL 644.1–653.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Miocene	*T. schraderi* zone	RM	B	RM	CP



LITHOLOGIC DESCRIPTION

BIOSILICEOUS MUDSTONE

5BG 5/1 with 5Y 4/1

Apparent dip
V1

All that is left of the serrated burrows of the previous core are the irregular, black outlines

Blue-black mottle

5Y 4/1

Direction of apparent dip of mottles

Veinlets =?healed fractures

5Y 4/2, giant burrows, matrix is 5Y 4/1

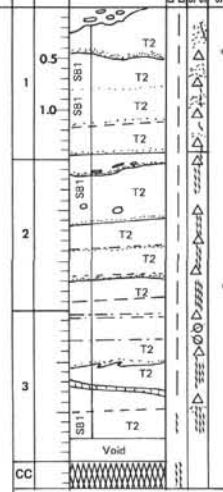
Burrow orientation

SMEAR SLIDE SUMMARY (%):

	1, 80 D	1, 102 M	2, 96 M	3, 90 D	5, 3 M
Texture:					
Sand	10	30	10	25	15
Silt	30	30	35	40	35
Clay	60	40	55	35	50
Composition:					
Quartz	8	10	17	12	15
Feldspar	4	6	8	3	6
Heavy minerals	2	2	3	1	–
Clay	55	35	51	30	46
Volcanic glass	10	33	3	–	15
Glauconite	3	–	6	–	2
Pyrite	4	5	3	4	7
Carbonate unspec.	2	–	–	2	–
Diatoms	10	7	7	35	8
Radiolarians	–	1	1	3	–
Sponge spicules	2	1	–	10	1
Plant debris	–	–	–	Tr	–
Lithic fragments	–	–	1	–	–

SITE 584 HOLE B CORE H3 CORED INTERVAL 653.8–846.8 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
upper Miocene	*D. hustedtii* zone (a subzone?)		FP		
		RM	B	RP	CM



LITHOLOGIC DESCRIPTION

5Y 4/1–5GY 4/1 DIATOMACEOUS MUDSTONE

Dark gray (5Y 2.5/1) coarse silt

small-scale features indicate flow, up-dip (w. r. t. present dip)

Clastic dike
Silt beds are slumped
Dendriti-form burrows
Halos

5Y 4/2
Gradational color contrast, smoothed by burrowing 5Y 3/2

△ Section 3: color changes within each cycle, light above, grading downward to darker colors.

Bioturbation between 2 healed fractures

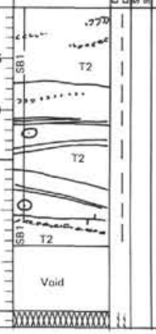
Mottled blue green and olive

SMEAR SLIDE SUMMARY (%):

	1, 47 M	2, 125 D
Texture:		
Sand	90	10
Silt	–	30
Clay	10	60
Composition:		
Quartz	21	5
Feldspar	9	3
Heavy minerals	16	1
Clay	11	46
Volcanic glass	26	–
Glauconite	–	1
Pyrite	11	3
Carbonate unspec.	–	13
Calc. nannofossils	–	2
Diatoms	3	22
Radiolarians	–	1
Sponge spicules	3	3

SITE 584 HOLE B CORE H4 CORED INTERVAL 846.8–943.1 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
upper Miocene?	*D. hustedtii* zone (*C. yabei* subzone?)	B	FP	RP	FP	1, 2, CC	0.5, 1.0				*



LITHOLOGIC DESCRIPTION

Greenish gray (5G 5/1, 5BG 5/1), locally bluish gray (5B 5/1) highly bioturbated, intense anastamosing veinlets, classic
PAISLEY MUDSTONE

Offset

Veinlets

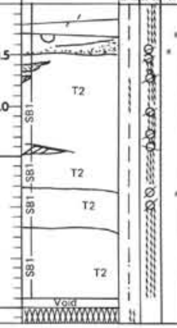
Section 2: 0 cm to 20 cm, highly dipping features, burrows, veins, etc.

SMEAR SLIDE SUMMARY (%):

	1, 140
	D
Texture:	
Sand	5
Silt	20
Clay	75
Composition:	
Quartz	8
Feldspar	2
Heavy minerals	Tr
Clay	73
Volcanic glass	2
Palagonite	Tr
Pyrite	2
Carbonate unspec.	2
Diatoms	7
Radiolarians	Tr
Sponge spicules	4
Lithic fragments	Tr

SITE 584 HOLE B CORE 3 CORED INTERVAL 943.1–954.0 m T. D. (3.06)

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
lower middle Miocene	*Denticulopsis lauta* zone (a subzone)	B	B	RP	FP	1, 2, CC	0.5, 1.0				* * *



LITHOLOGIC DESCRIPTION

Veinlet
Crack grading

PAISLEY MUDSTONE
Grayish green (5G 4/2)
Greenish gray (5G 5/1)
Dark gray (5Y 4/1)
Olive (5Y 5/3), heavily bioturbated, colors stirred as splotches

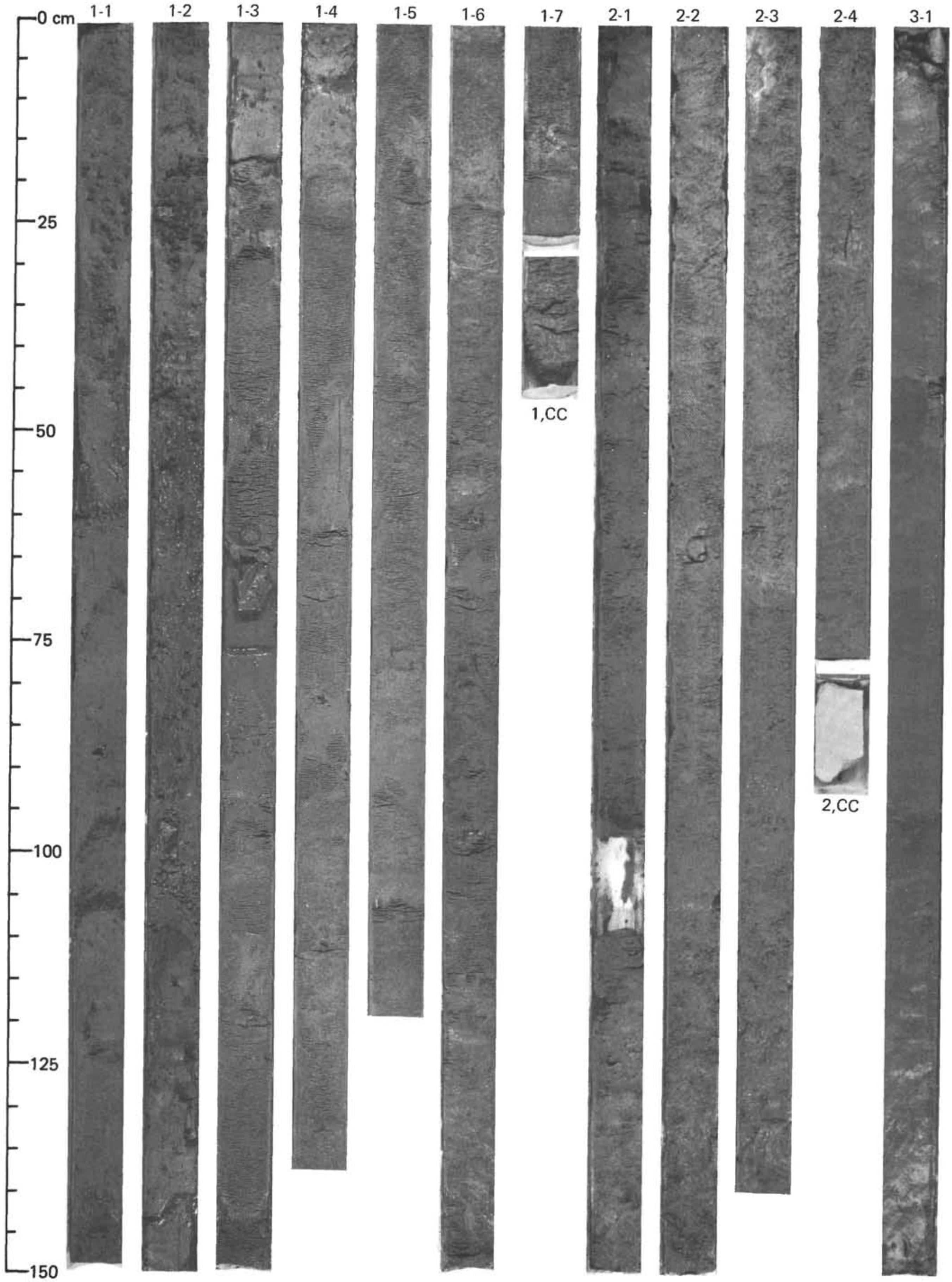
Dark black stain, offset at intersection with veinlet network

Healed fracture

Black pyrite spot, 30 cm and 55 cm

SMEAR SLIDE SUMMARY (%):

	1, 31	1, 49	2, 38
	D	M	M
Texture:			
Sand	7	40	40
Silt	18	30	40
Clay	75	30	20
Composition:			
Quartz	6	25	8
Feldspar	3	12	4
Heavy minerals	Tr	Tr	18
Clay	72	29	–
Volcanic glass	5	4	57
Palagonite	Tr	1	–
Pyrite	1	12	–
Diatoms	8	2	1
Sponge spicules	3	1	2
Plant debris	–	2	–
Lithic fragments	2	12	10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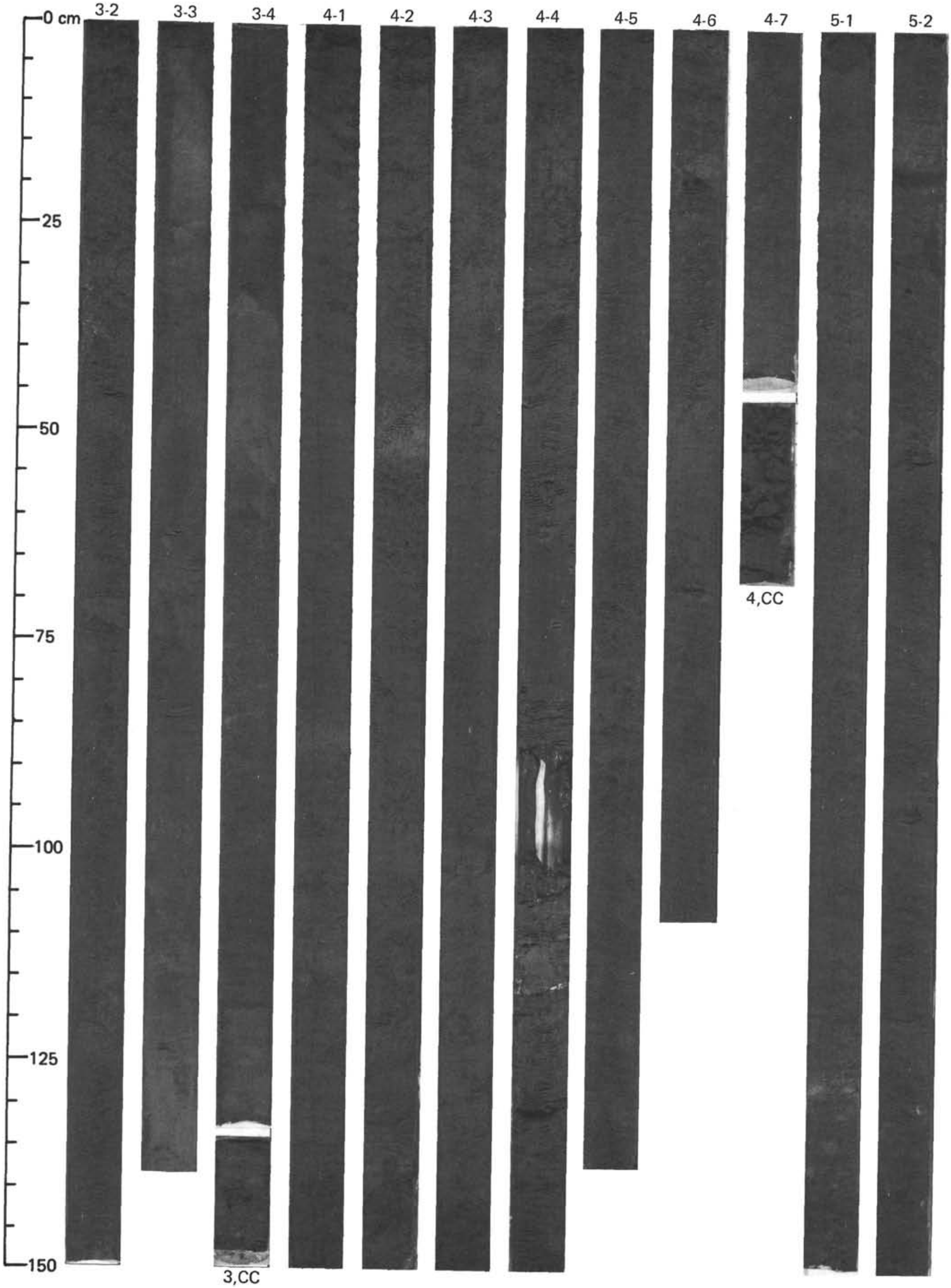
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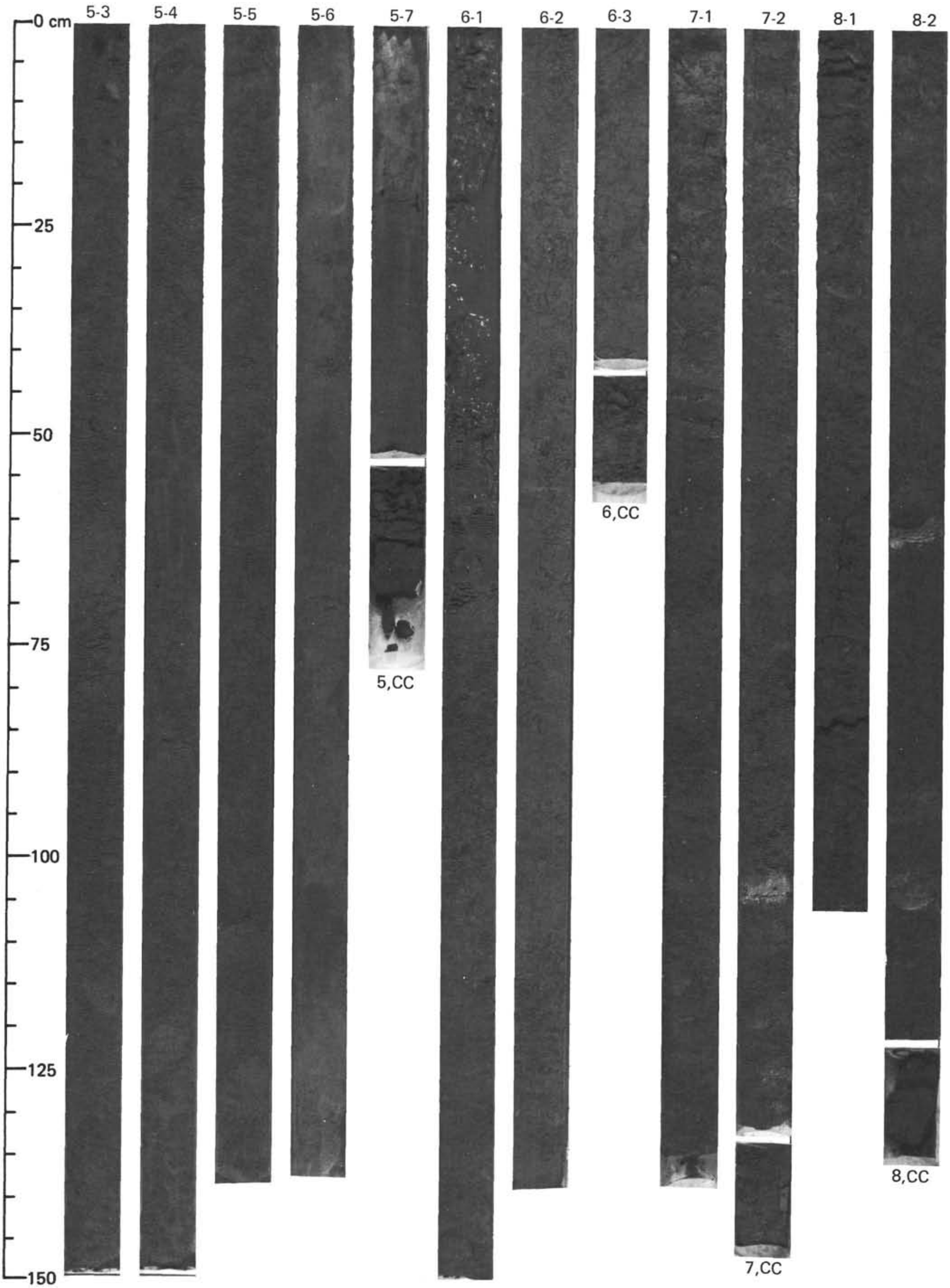
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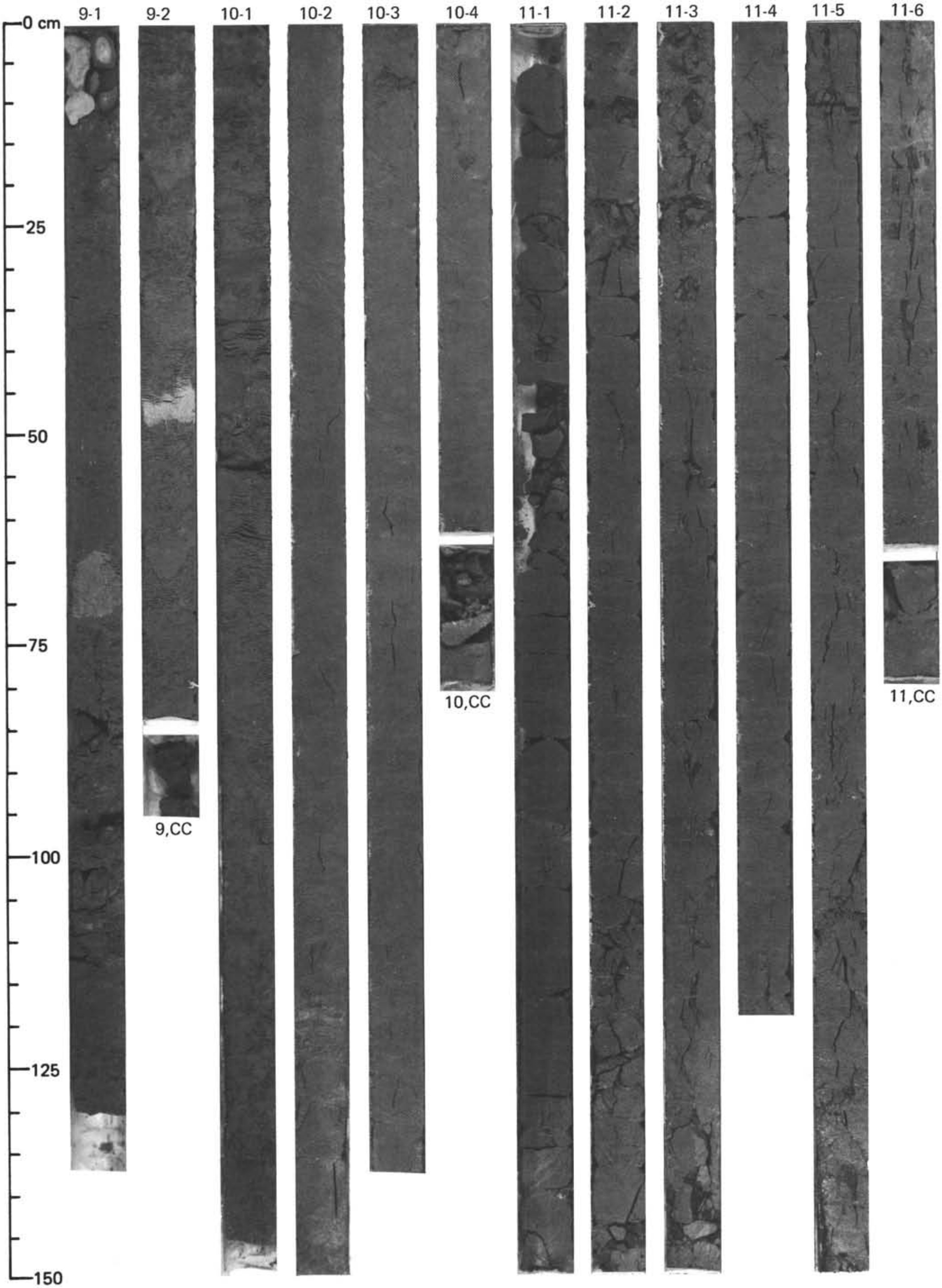
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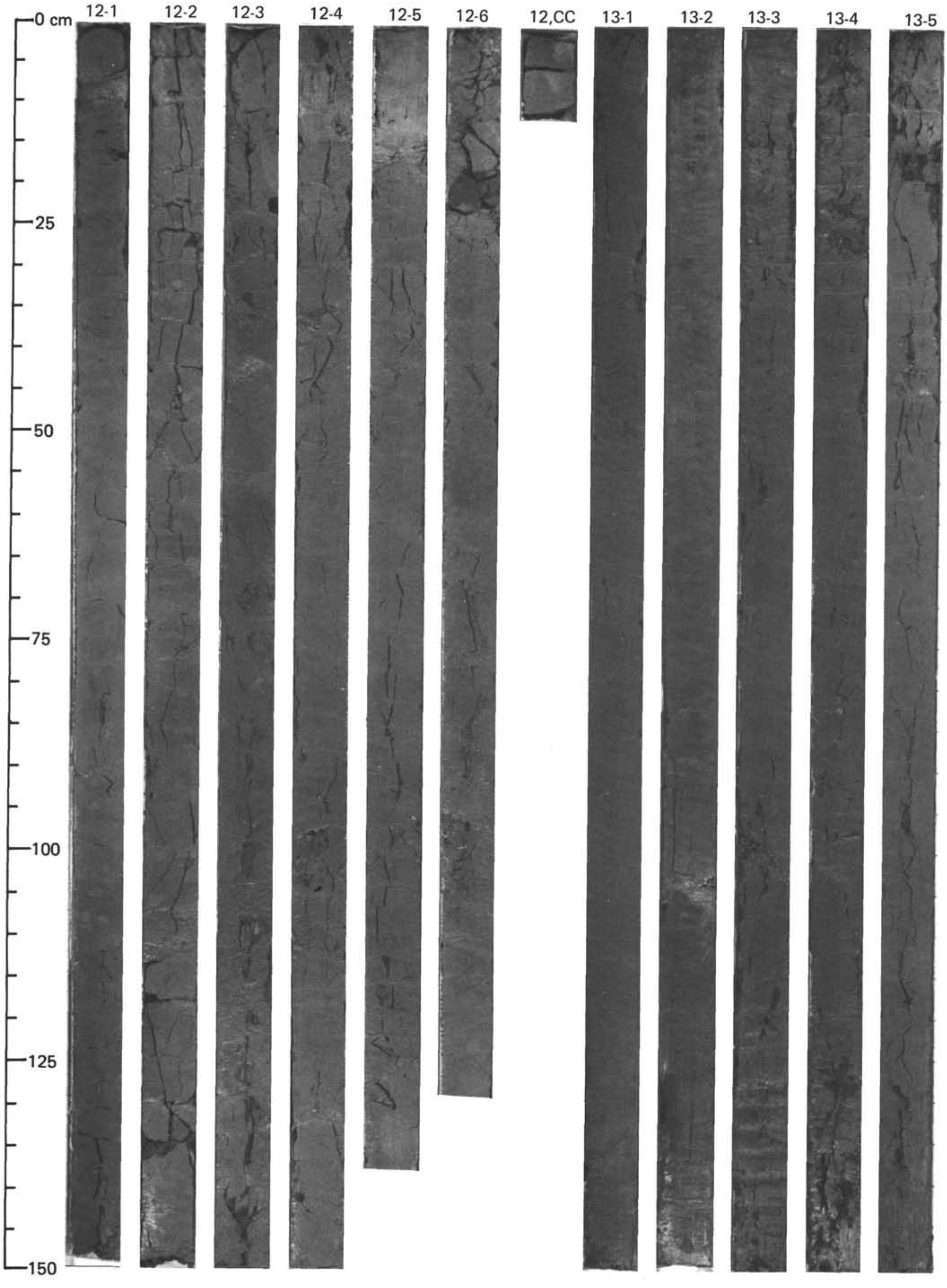
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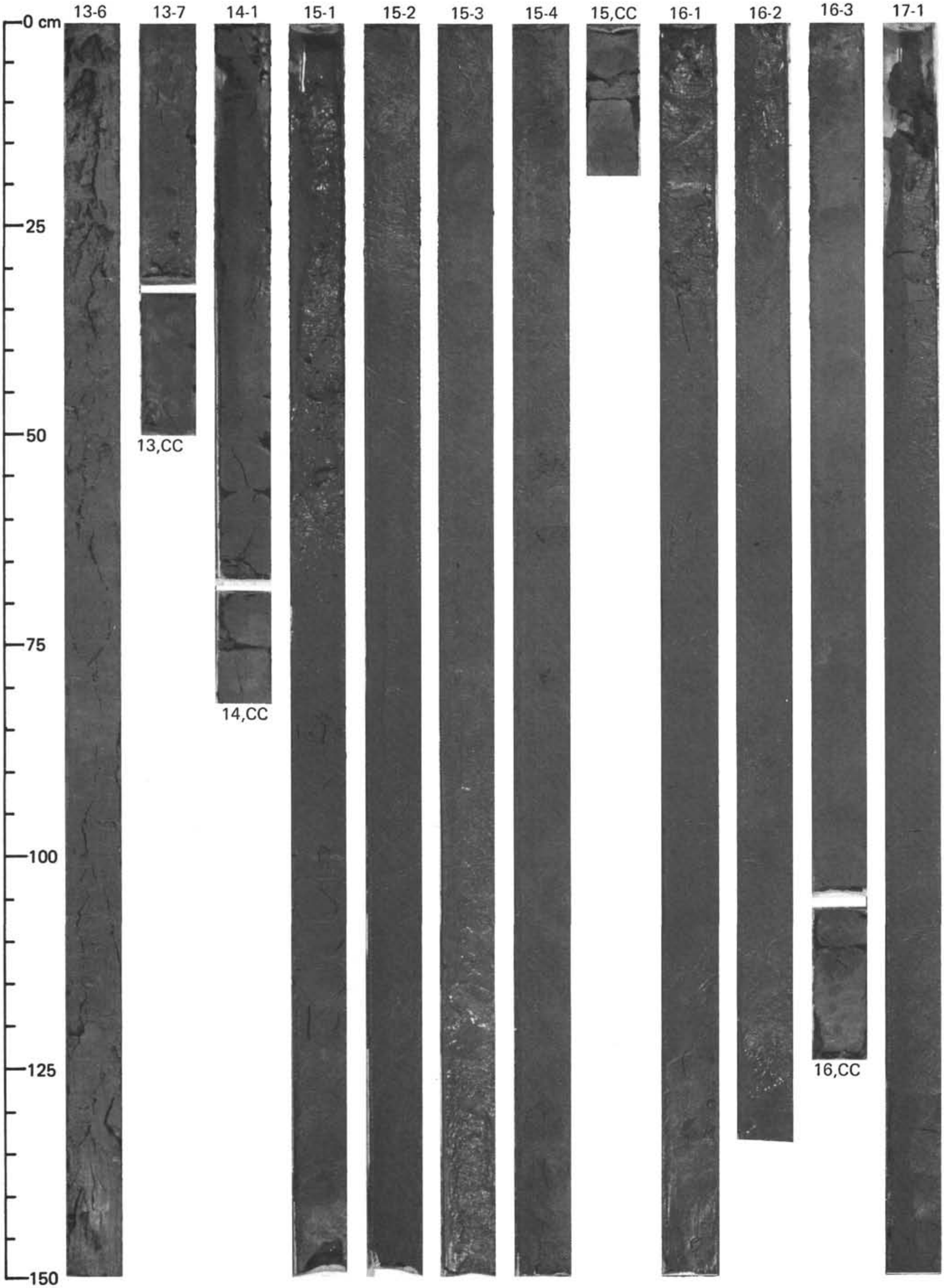
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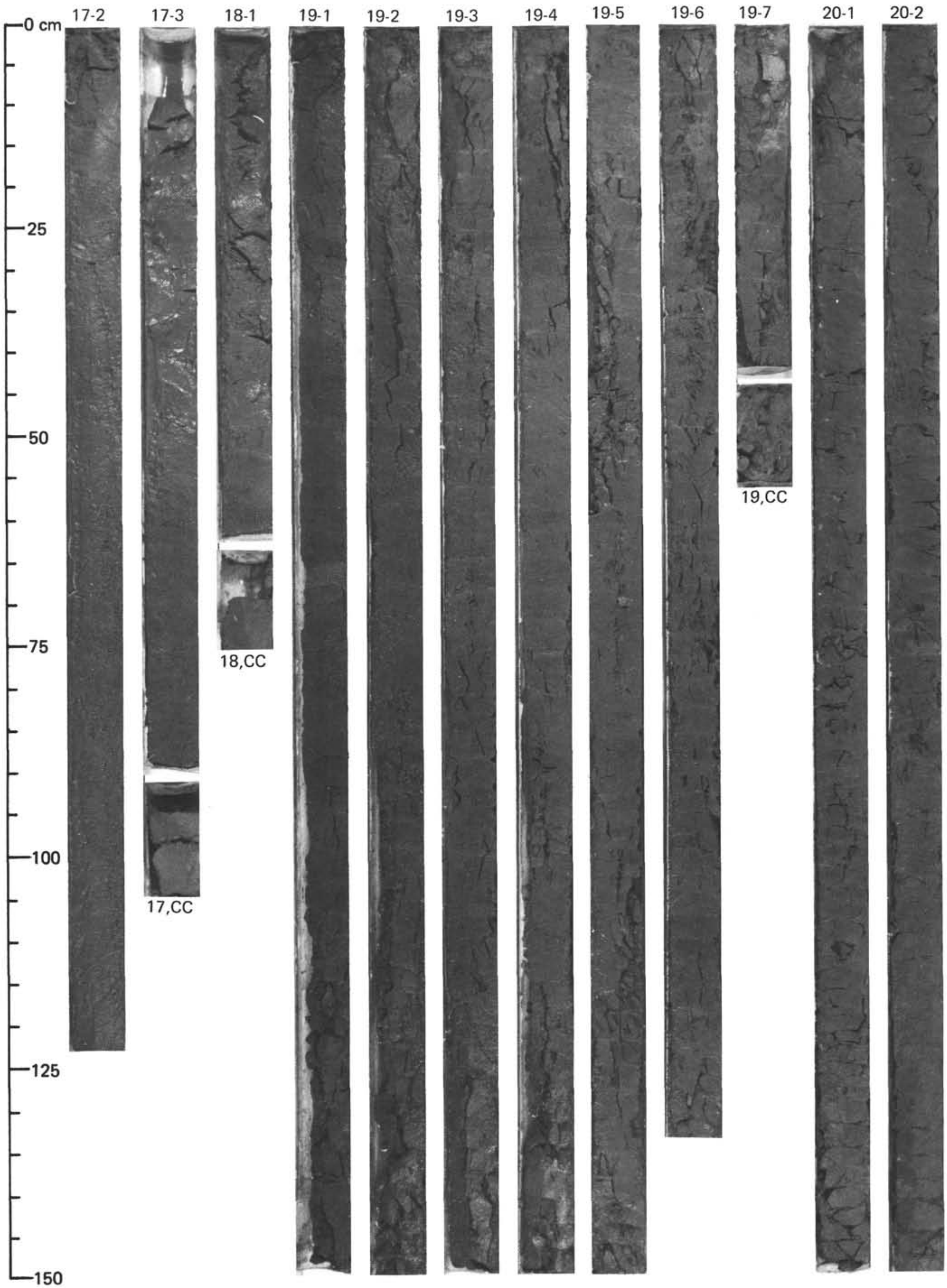
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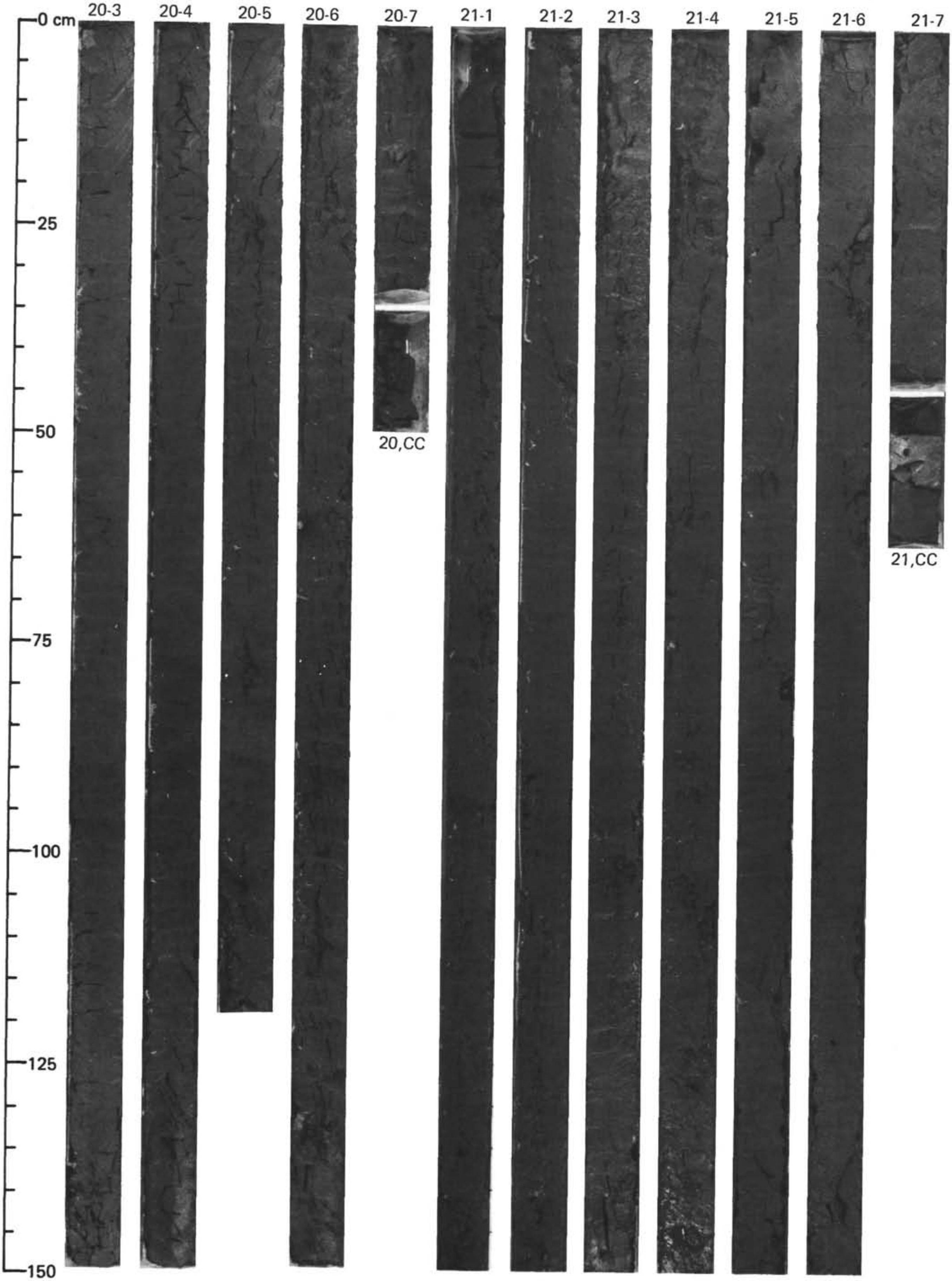
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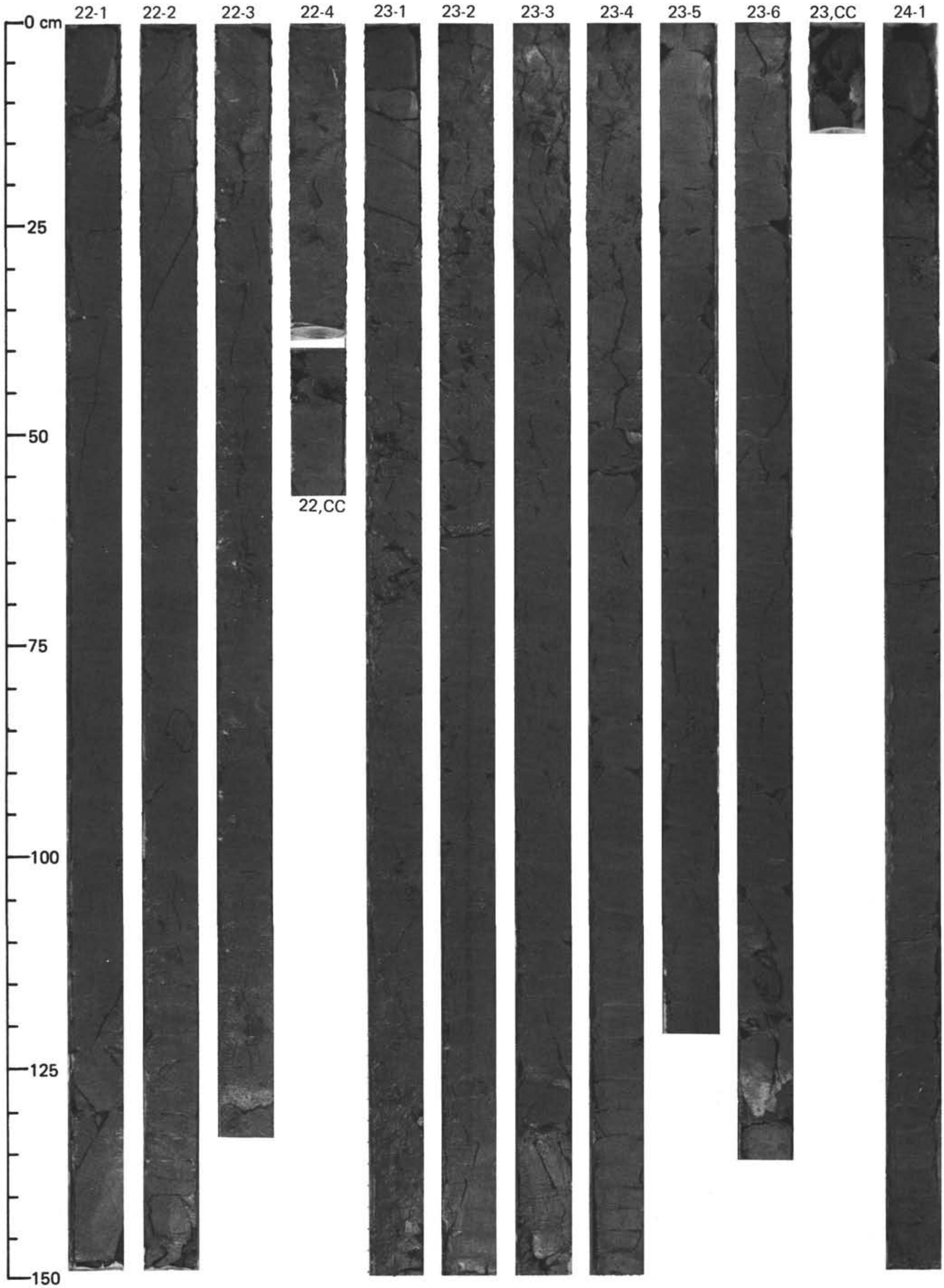
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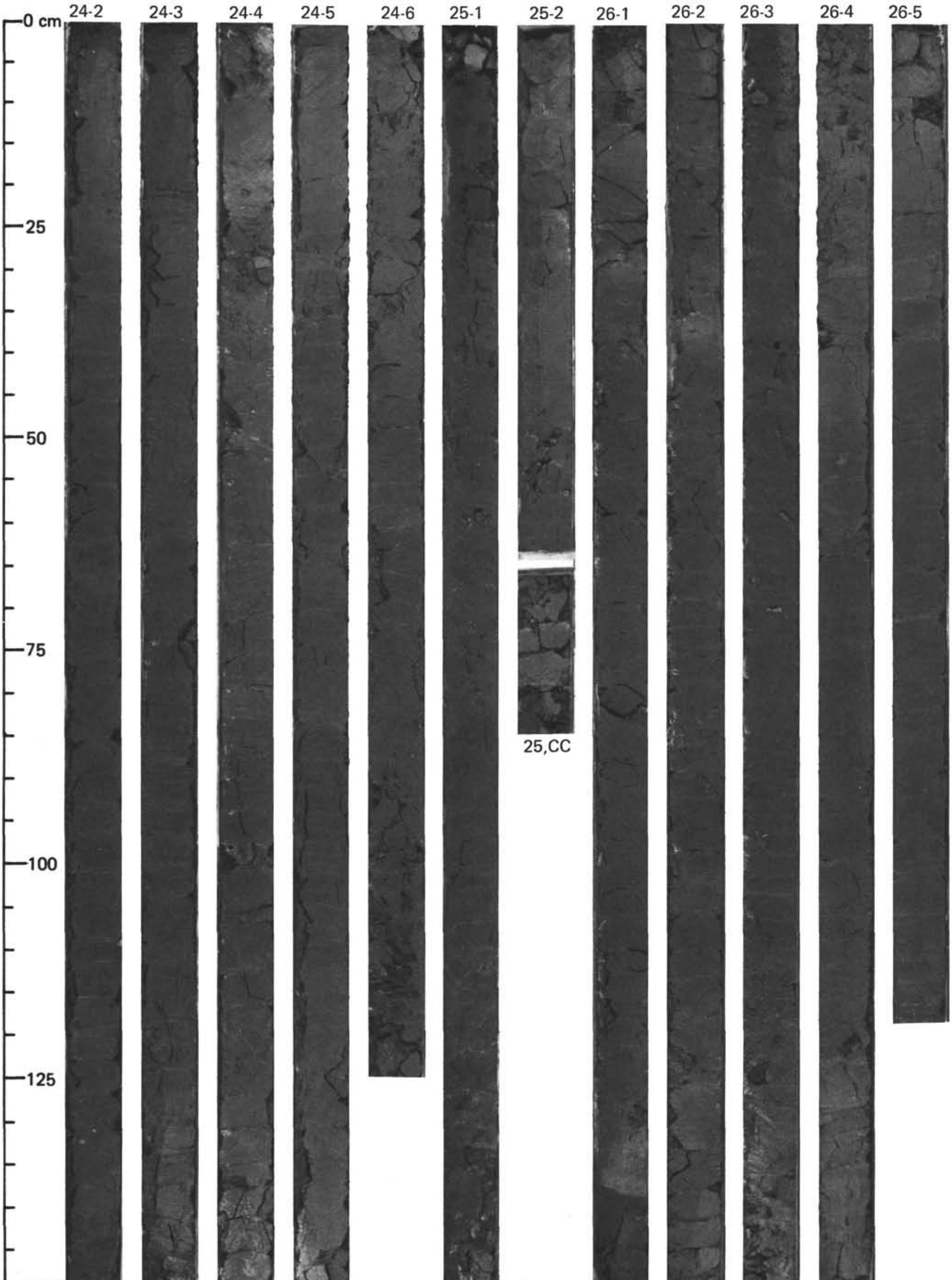
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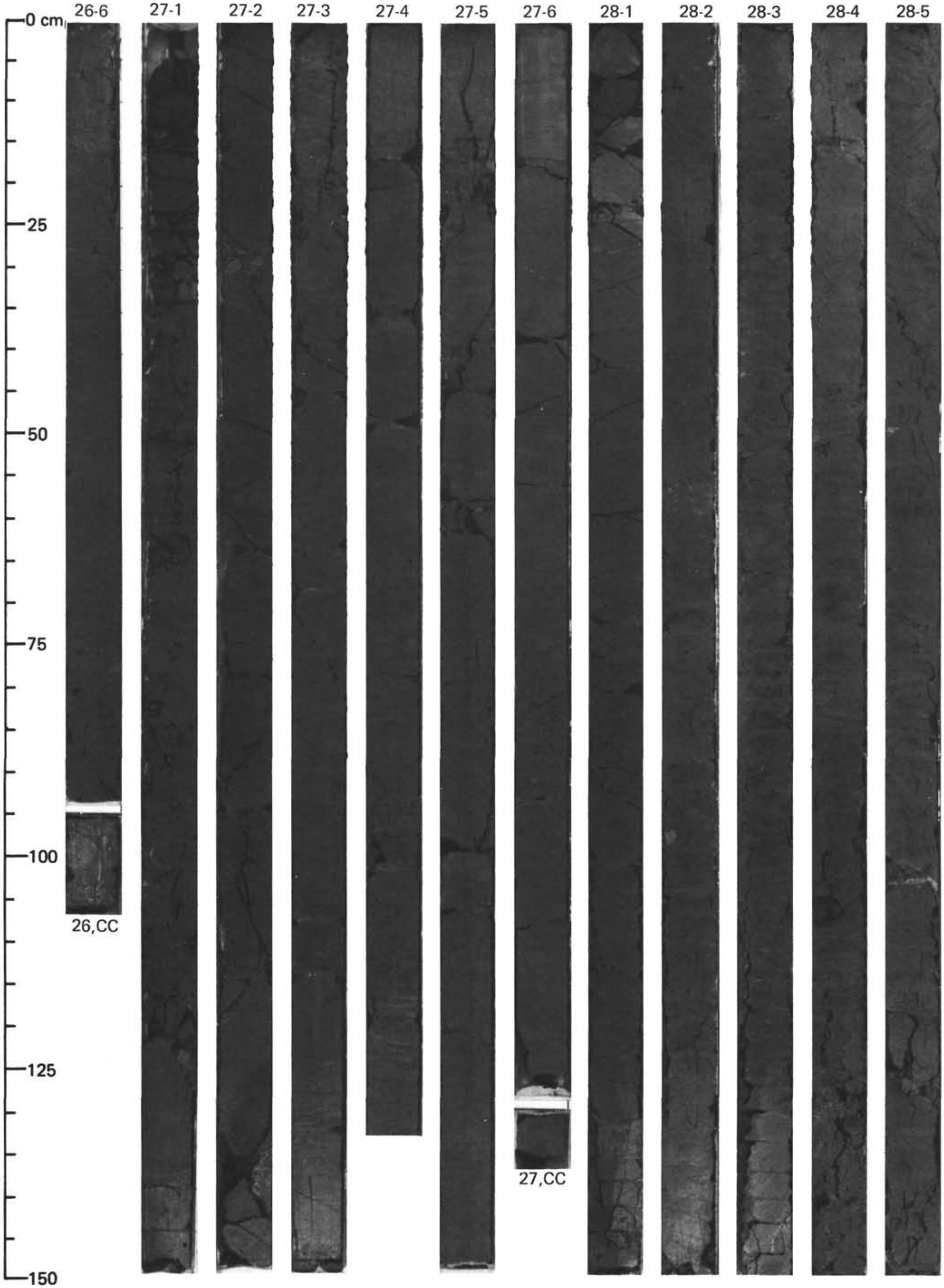

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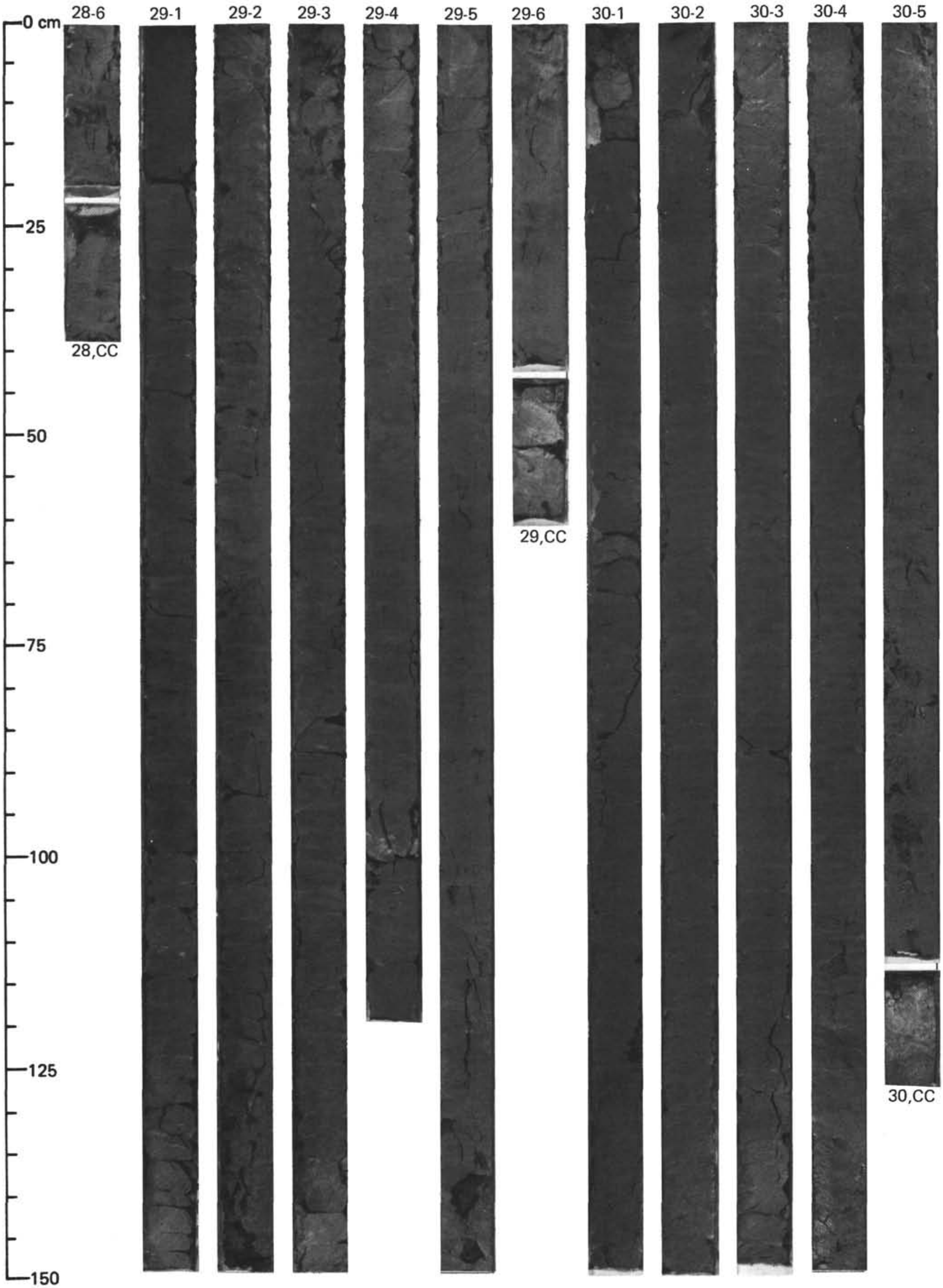
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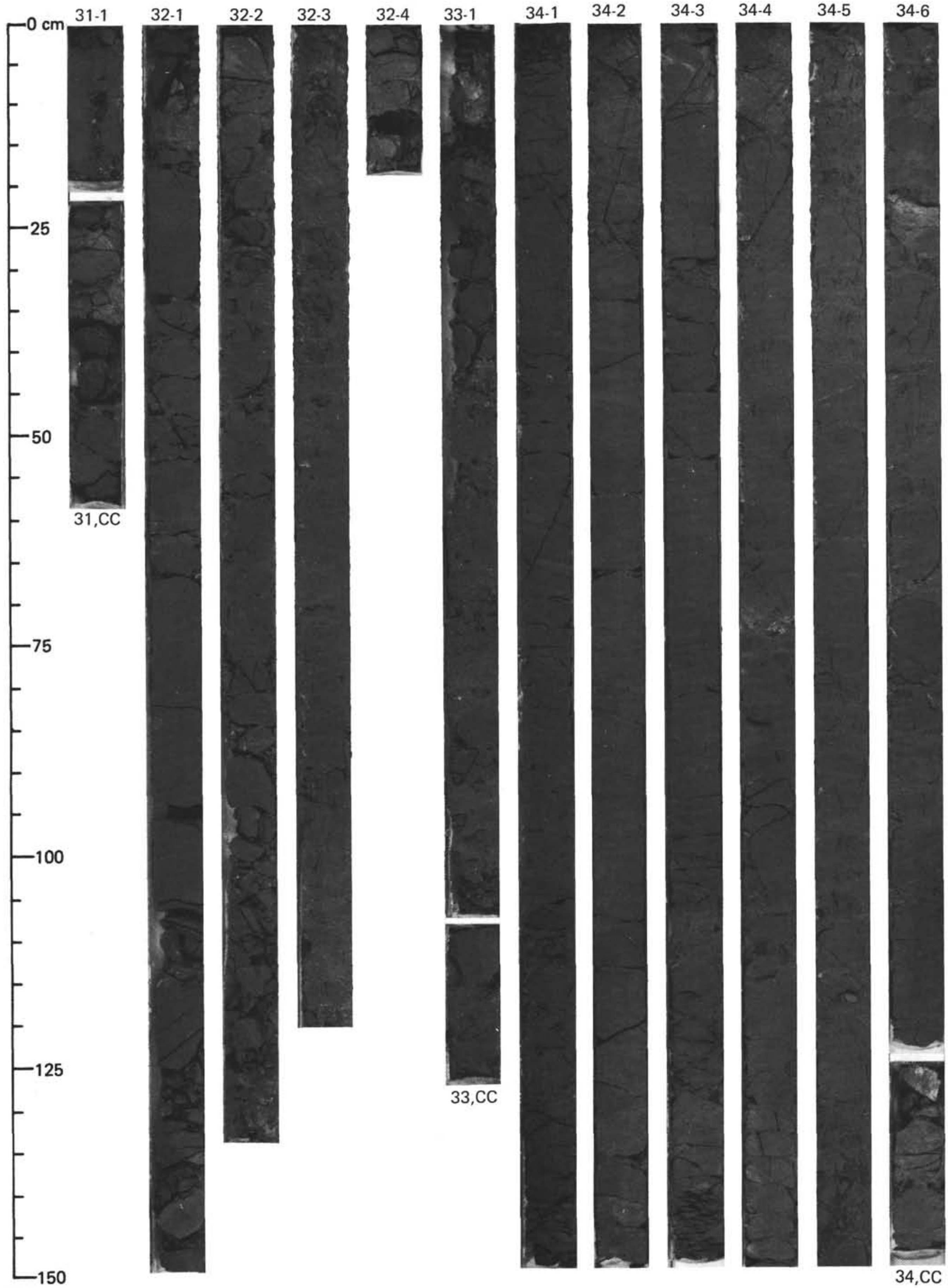
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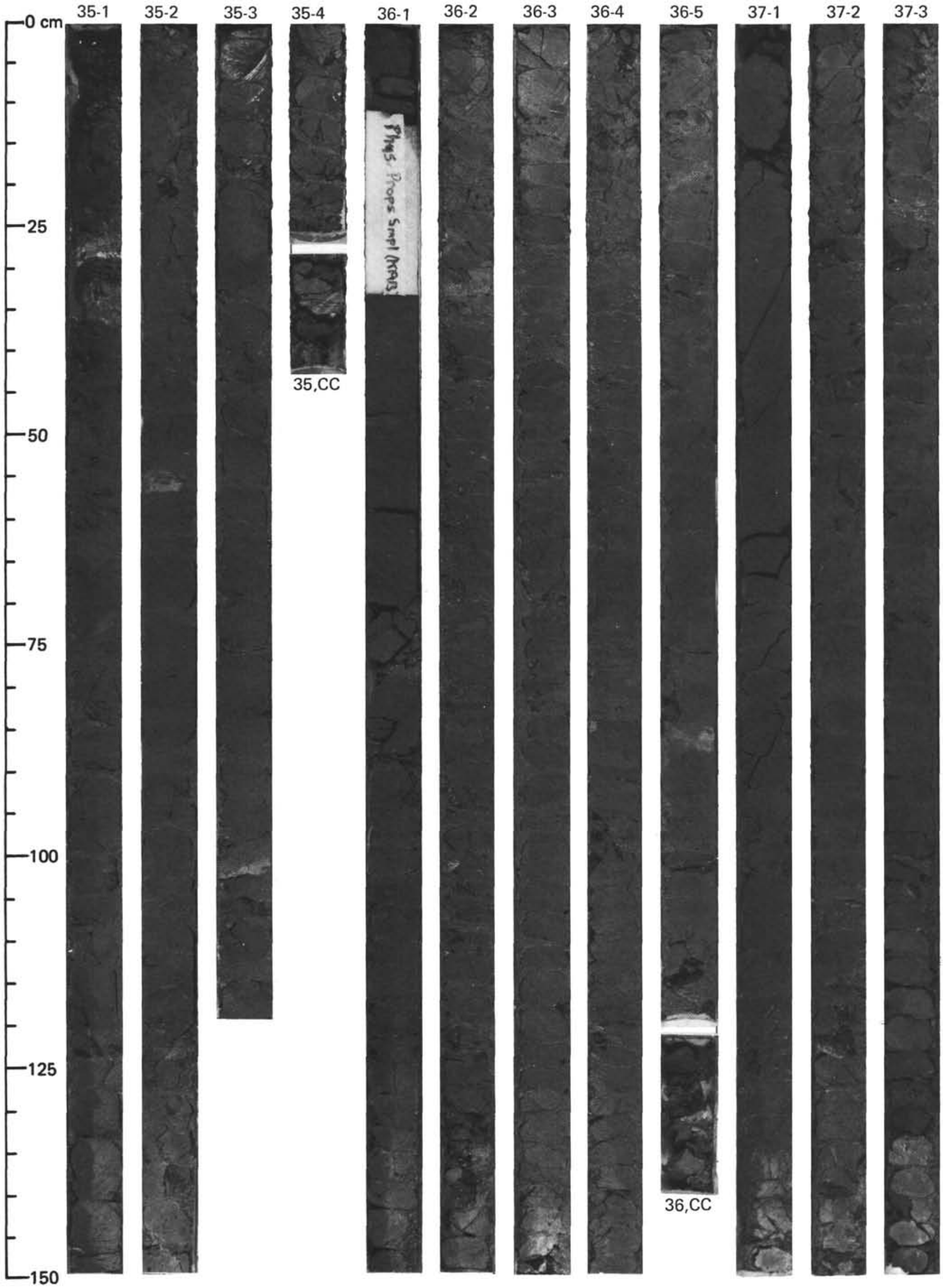

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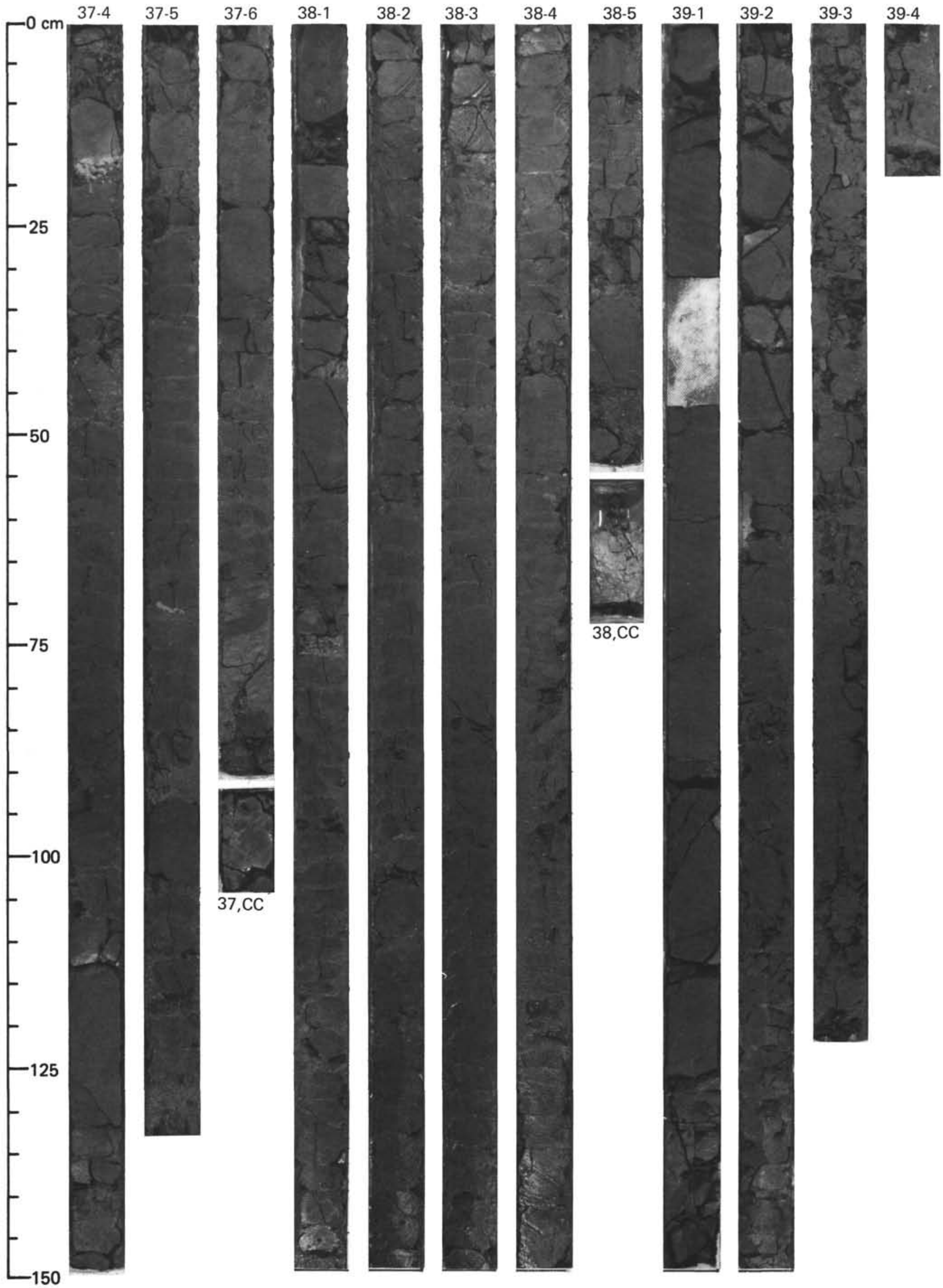
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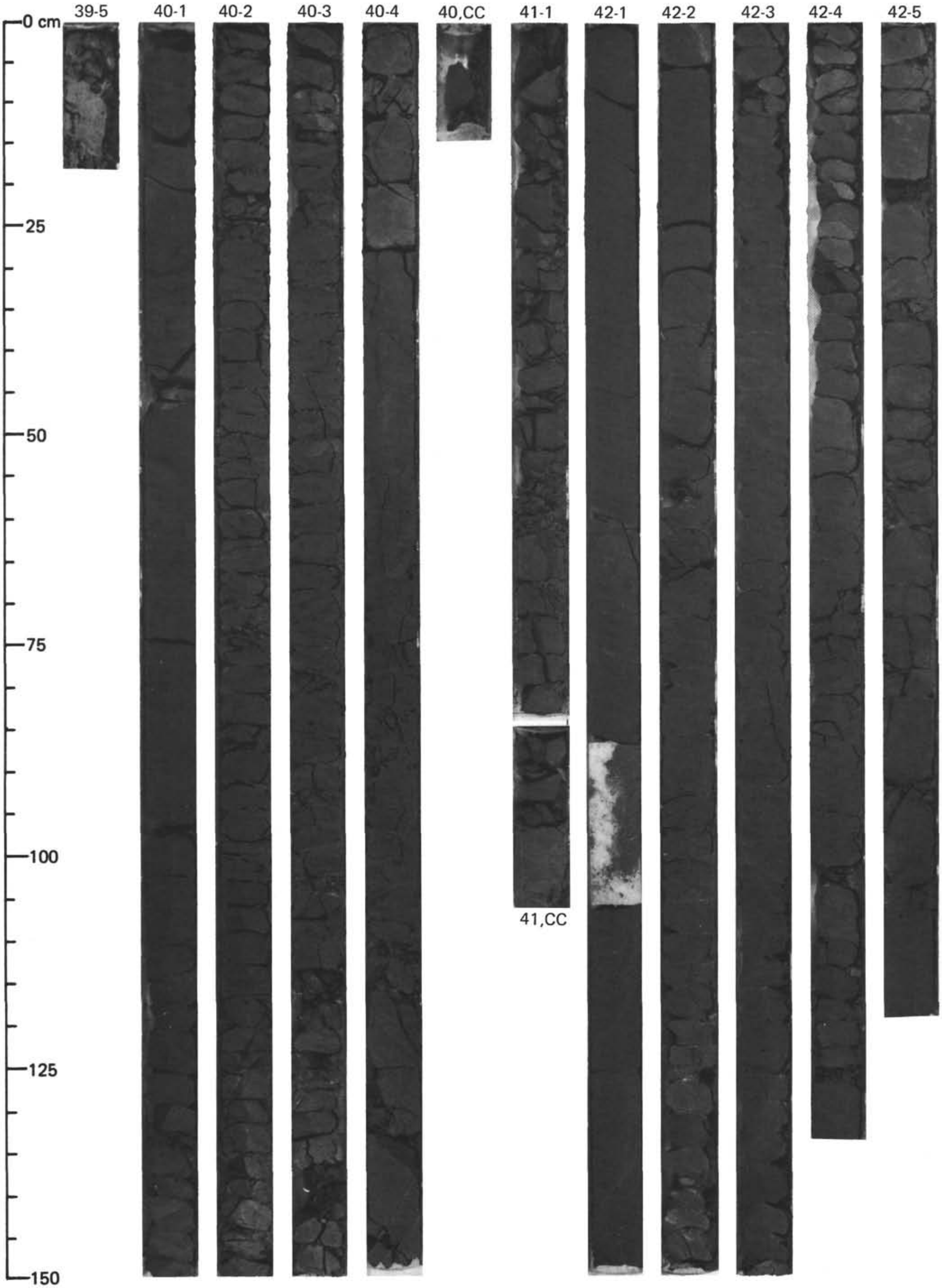
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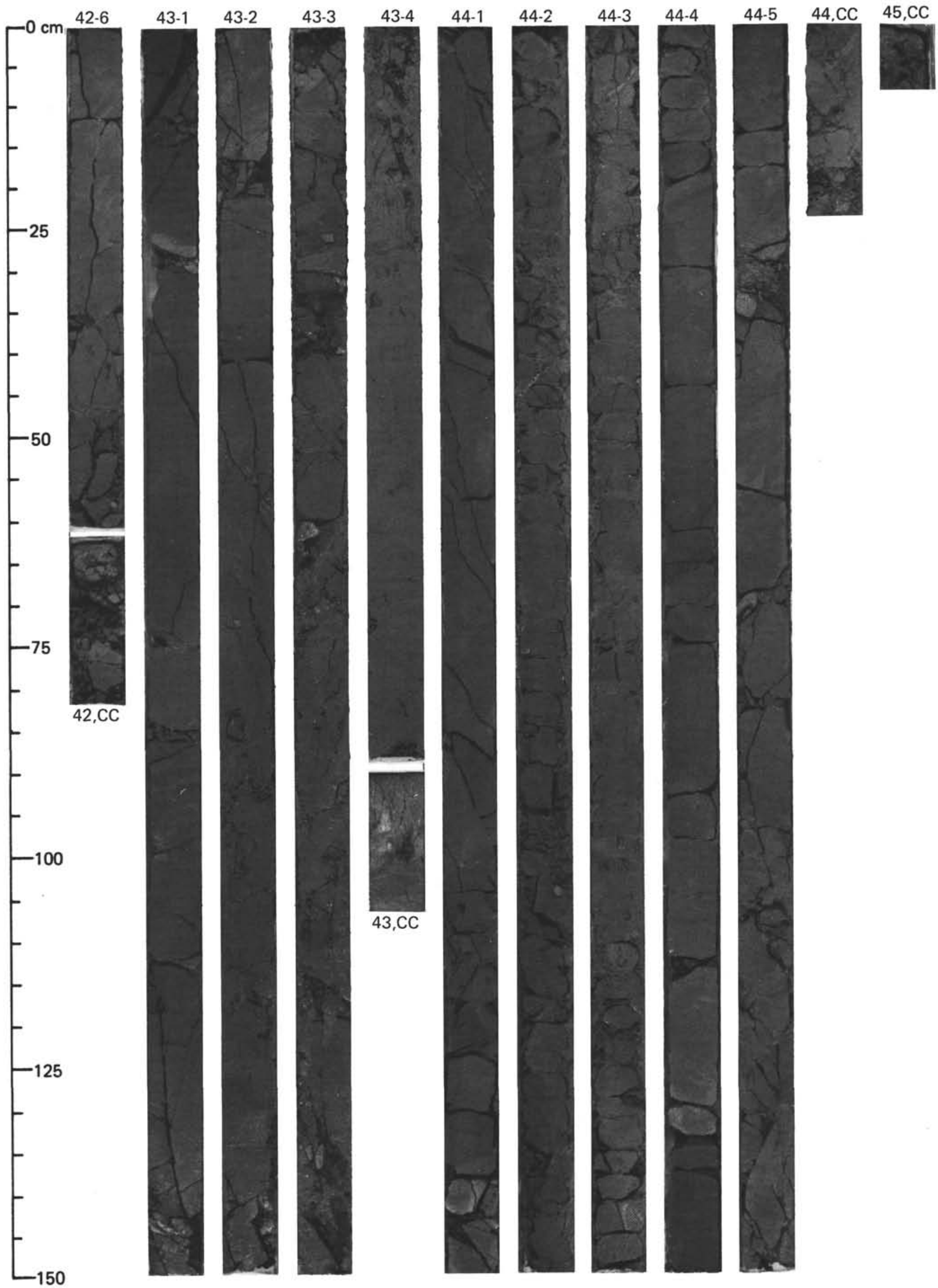
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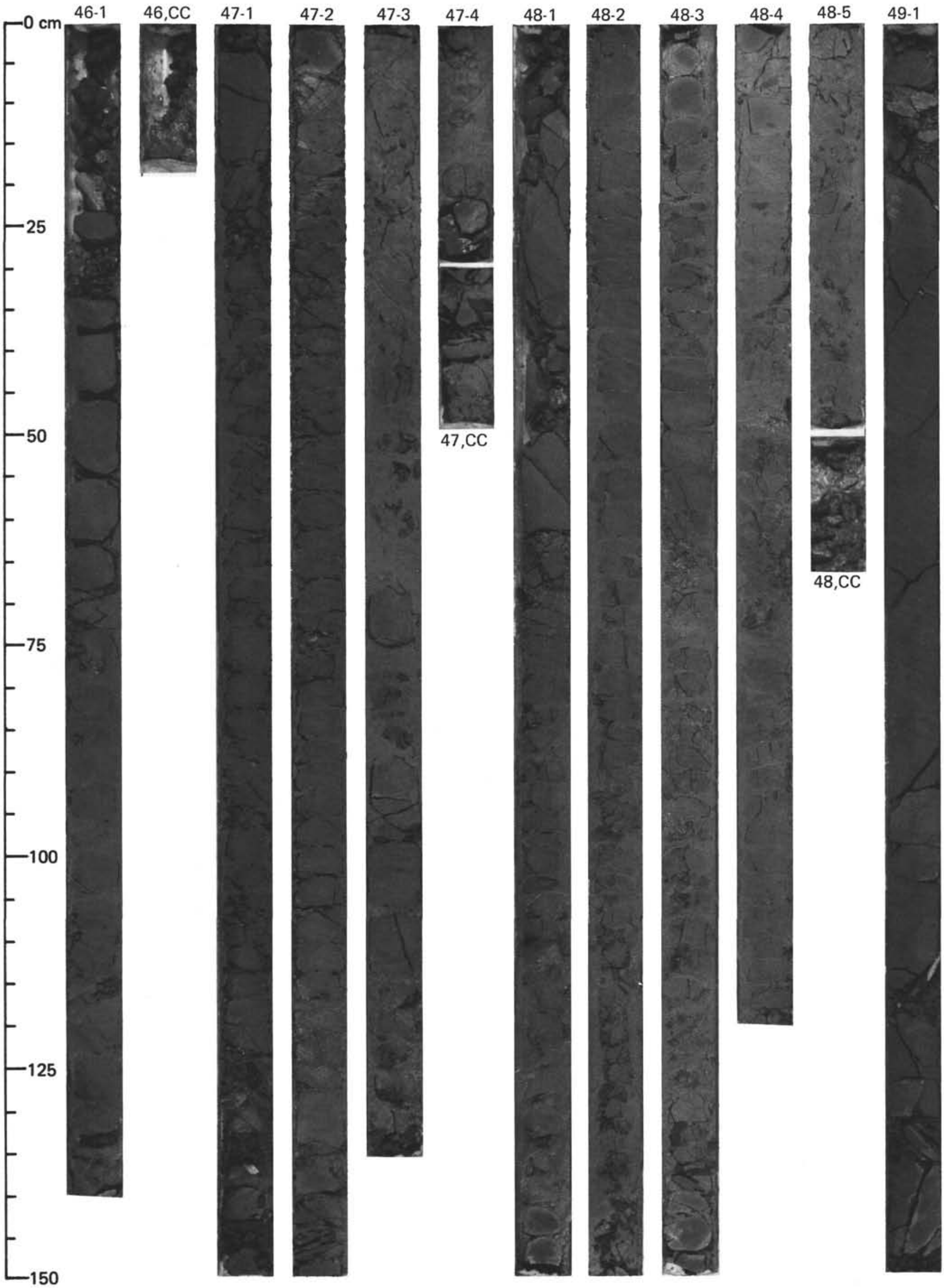
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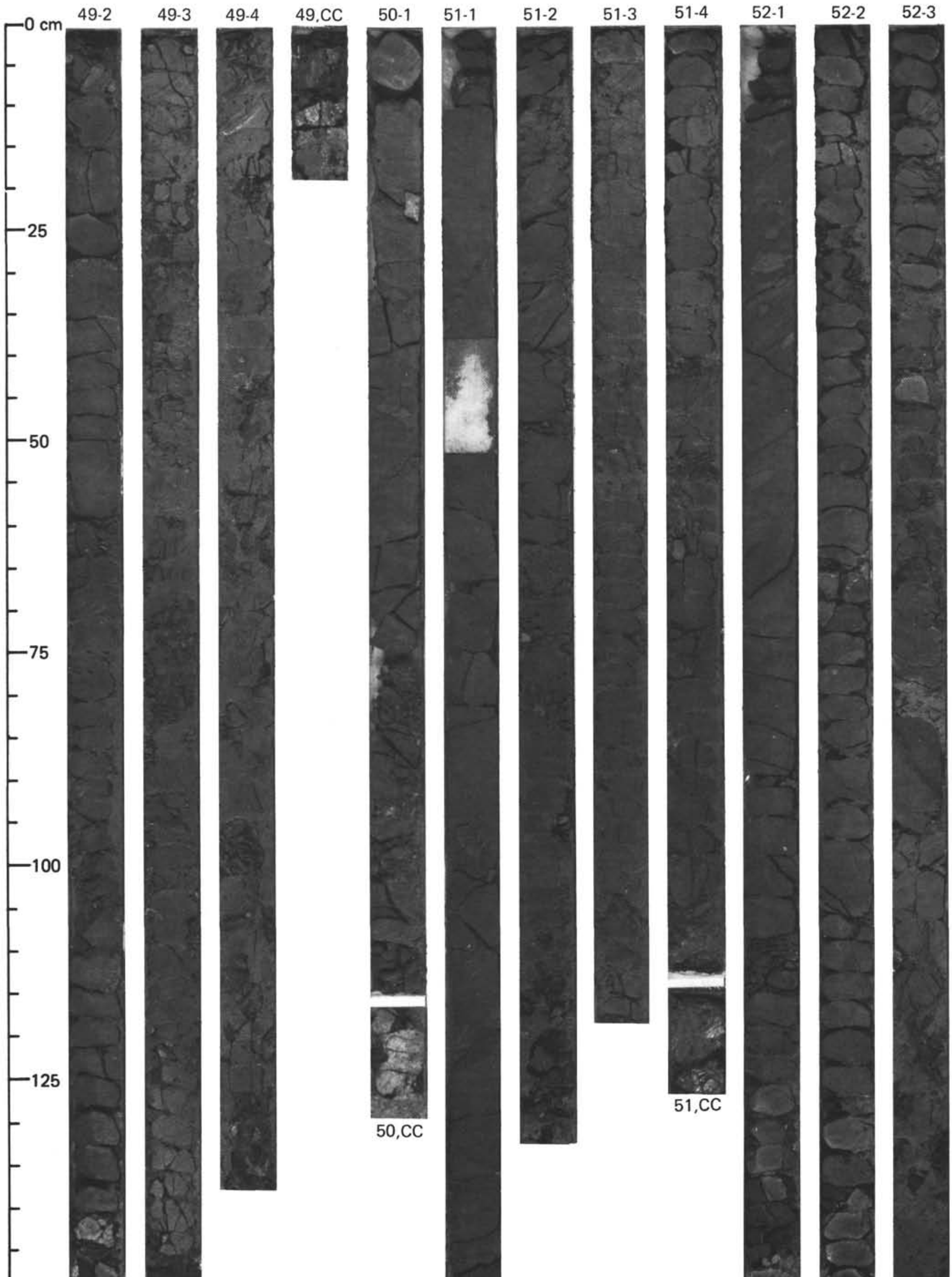
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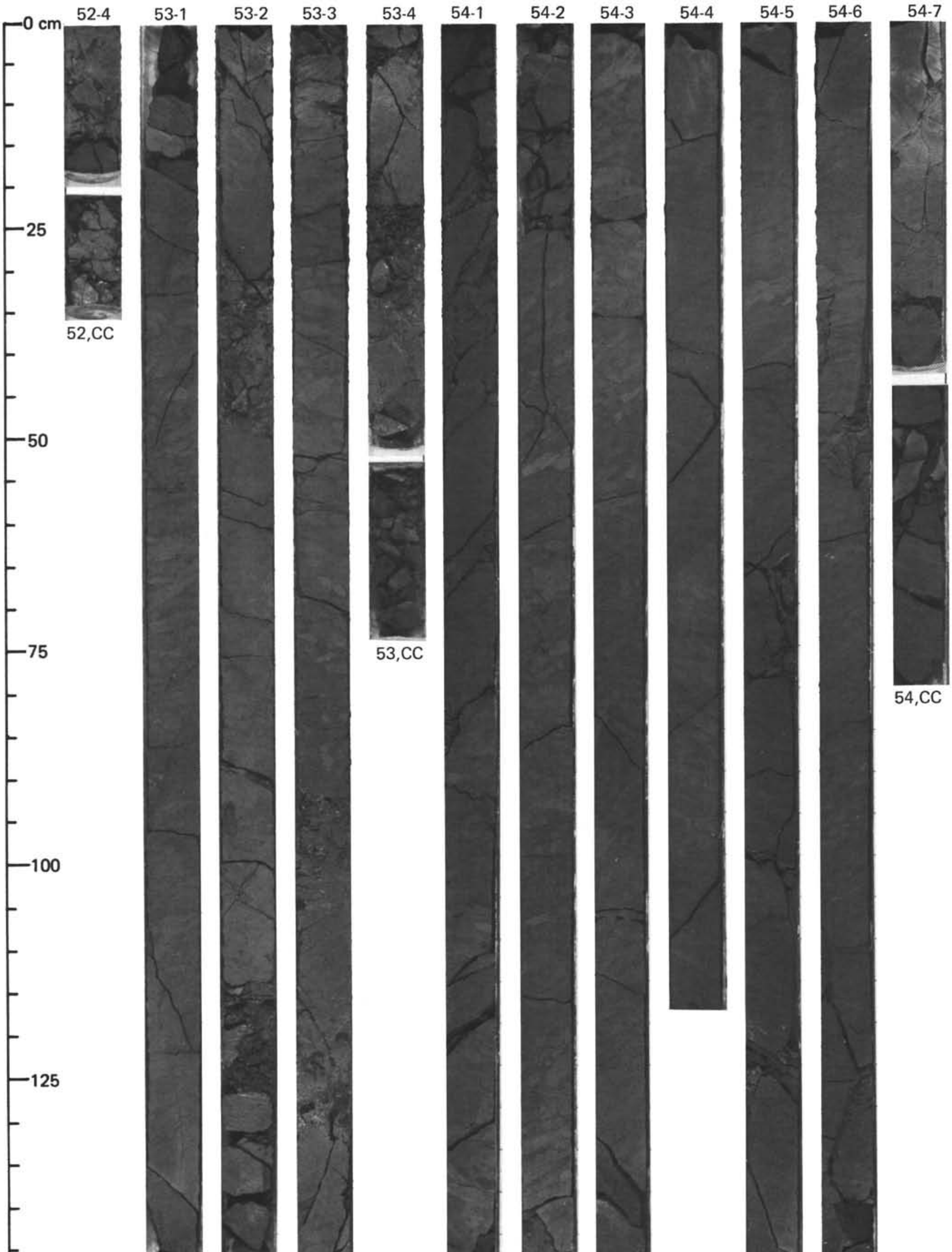
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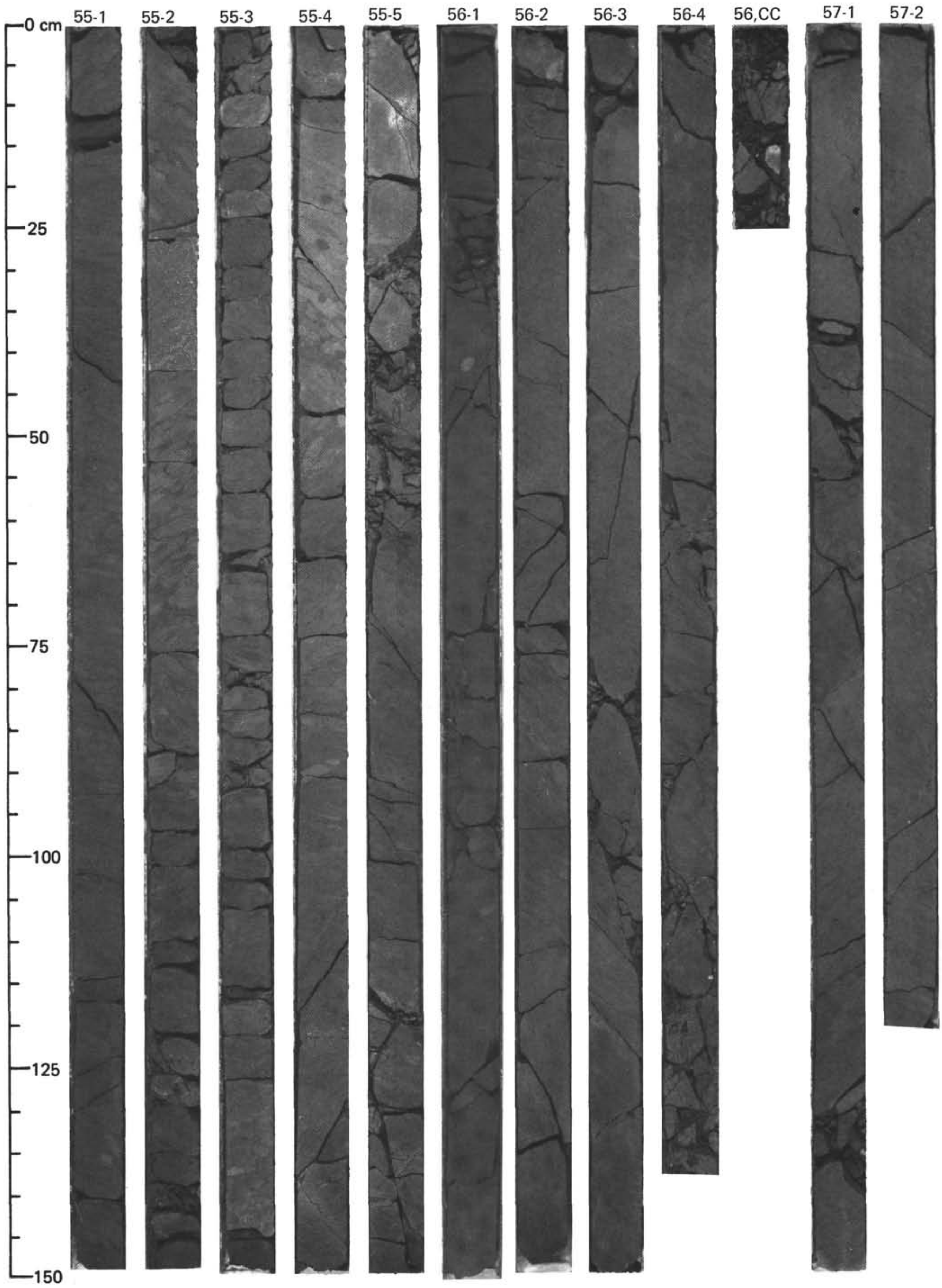
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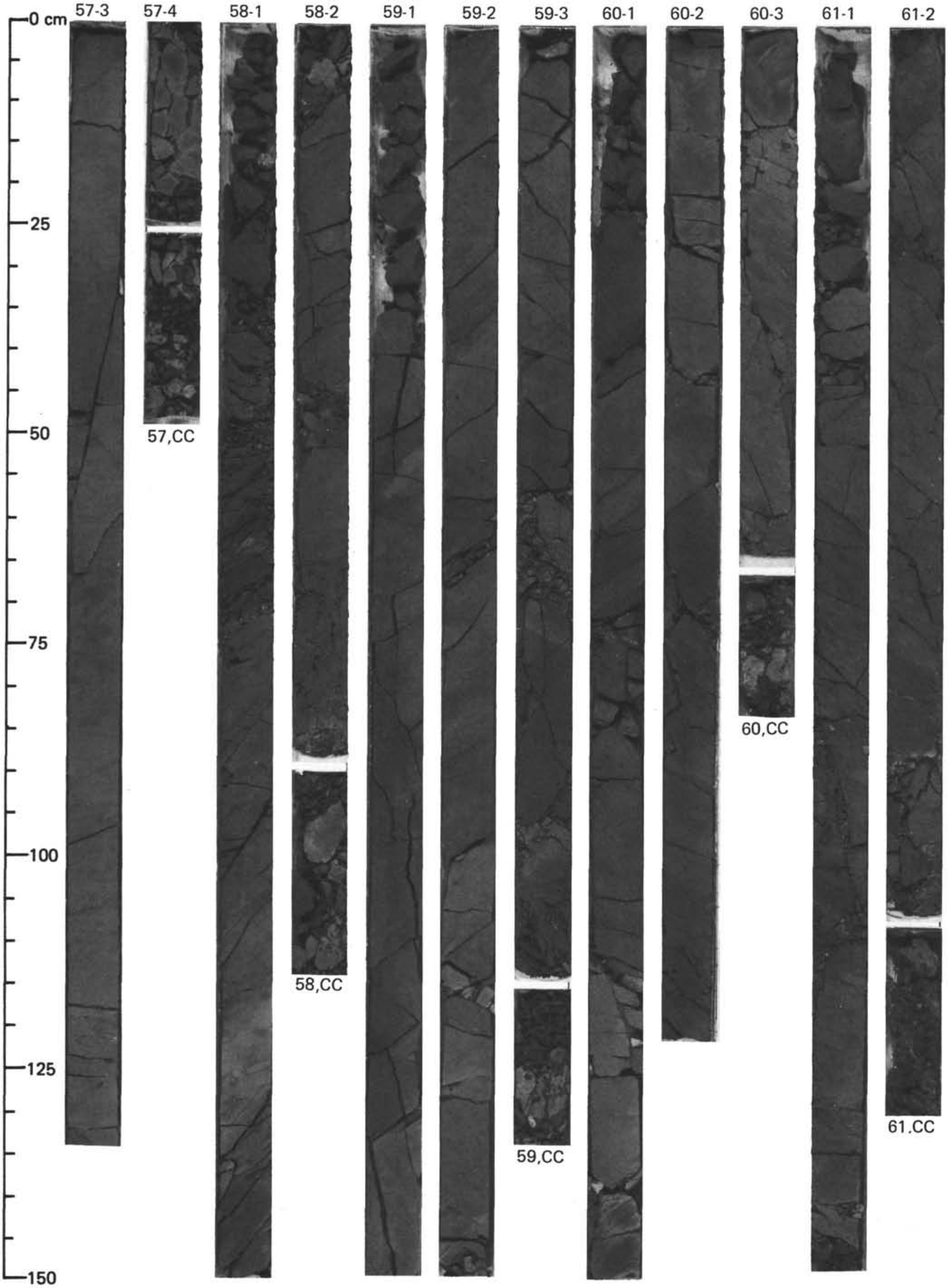
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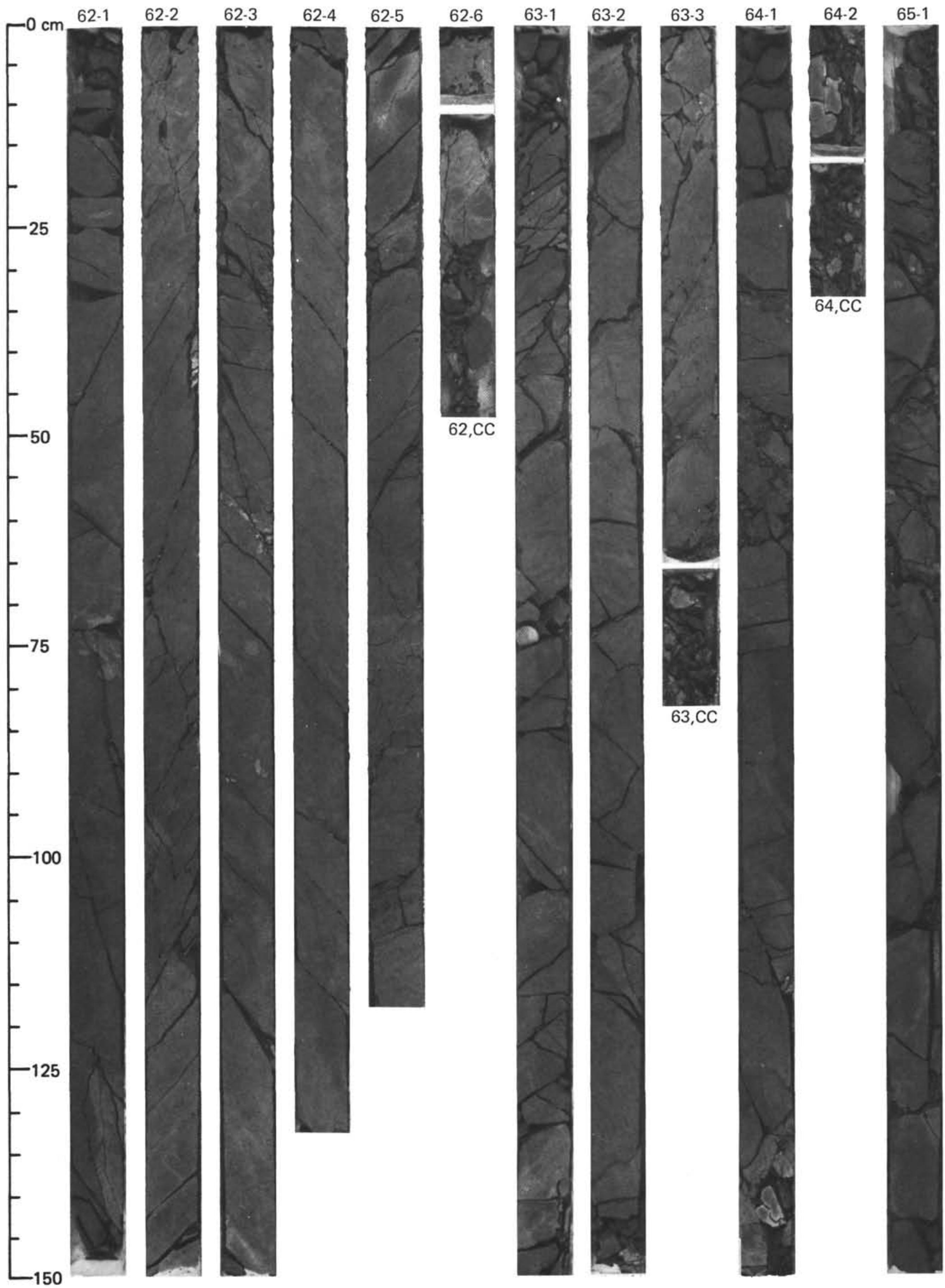
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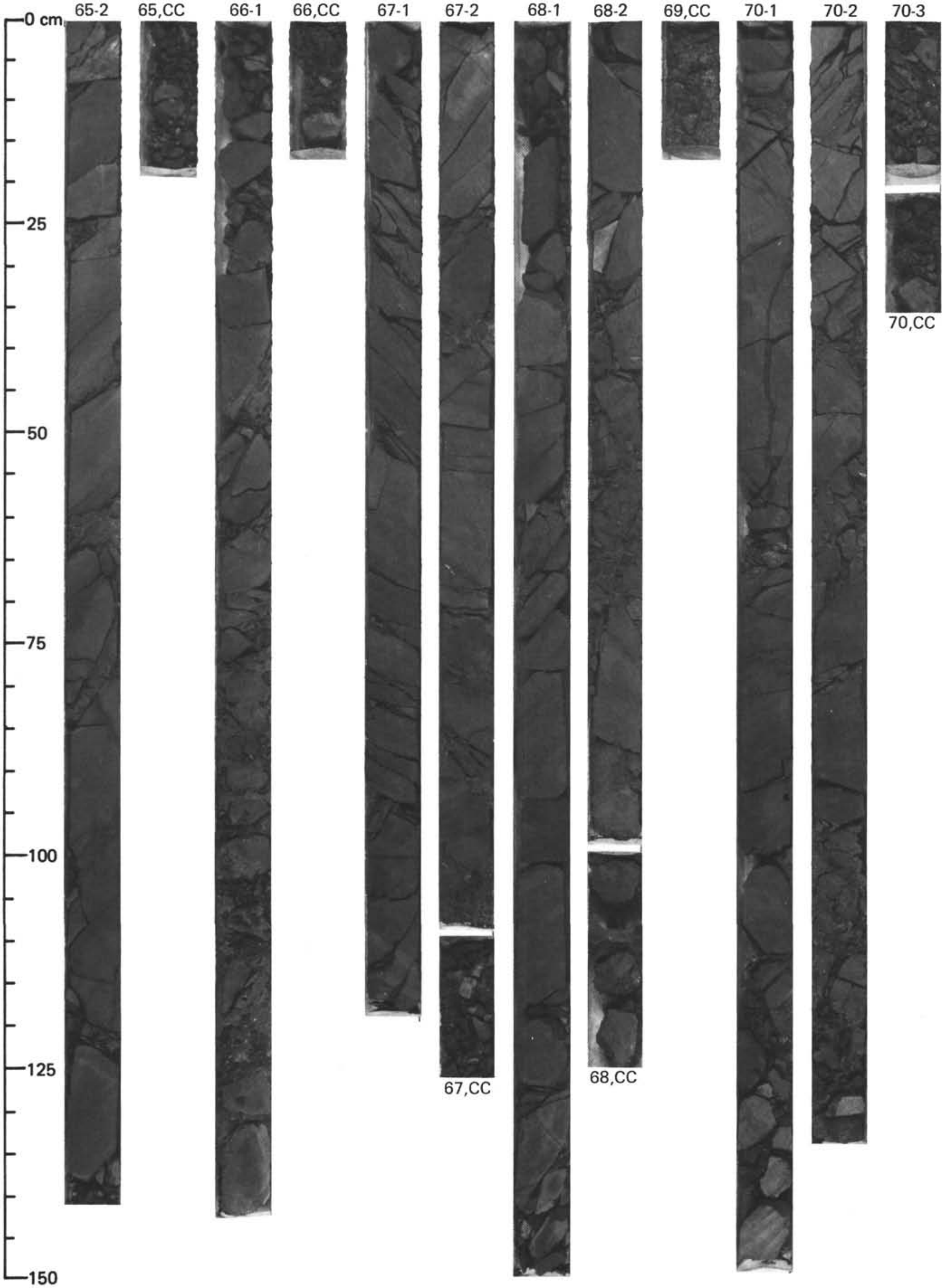
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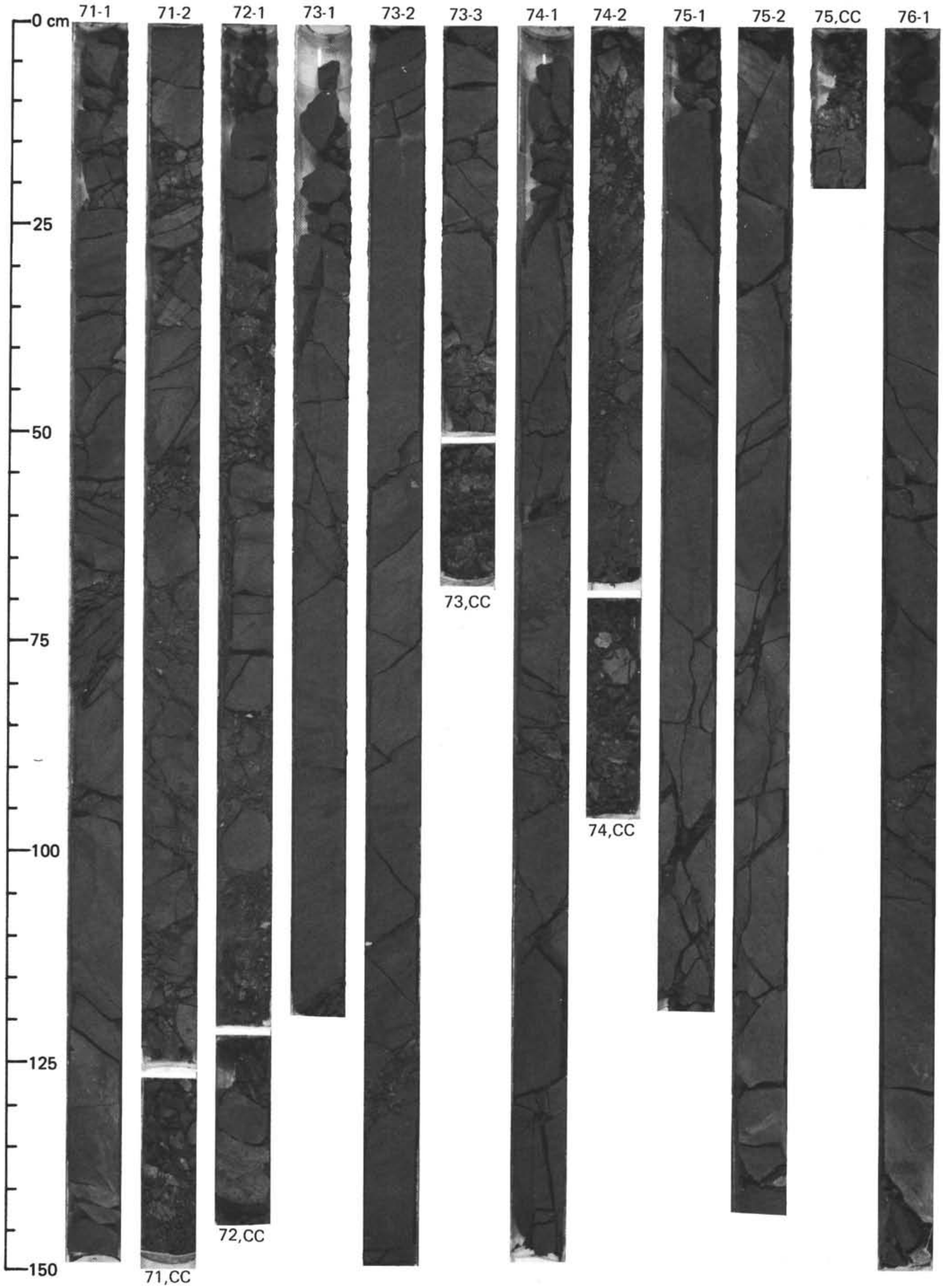
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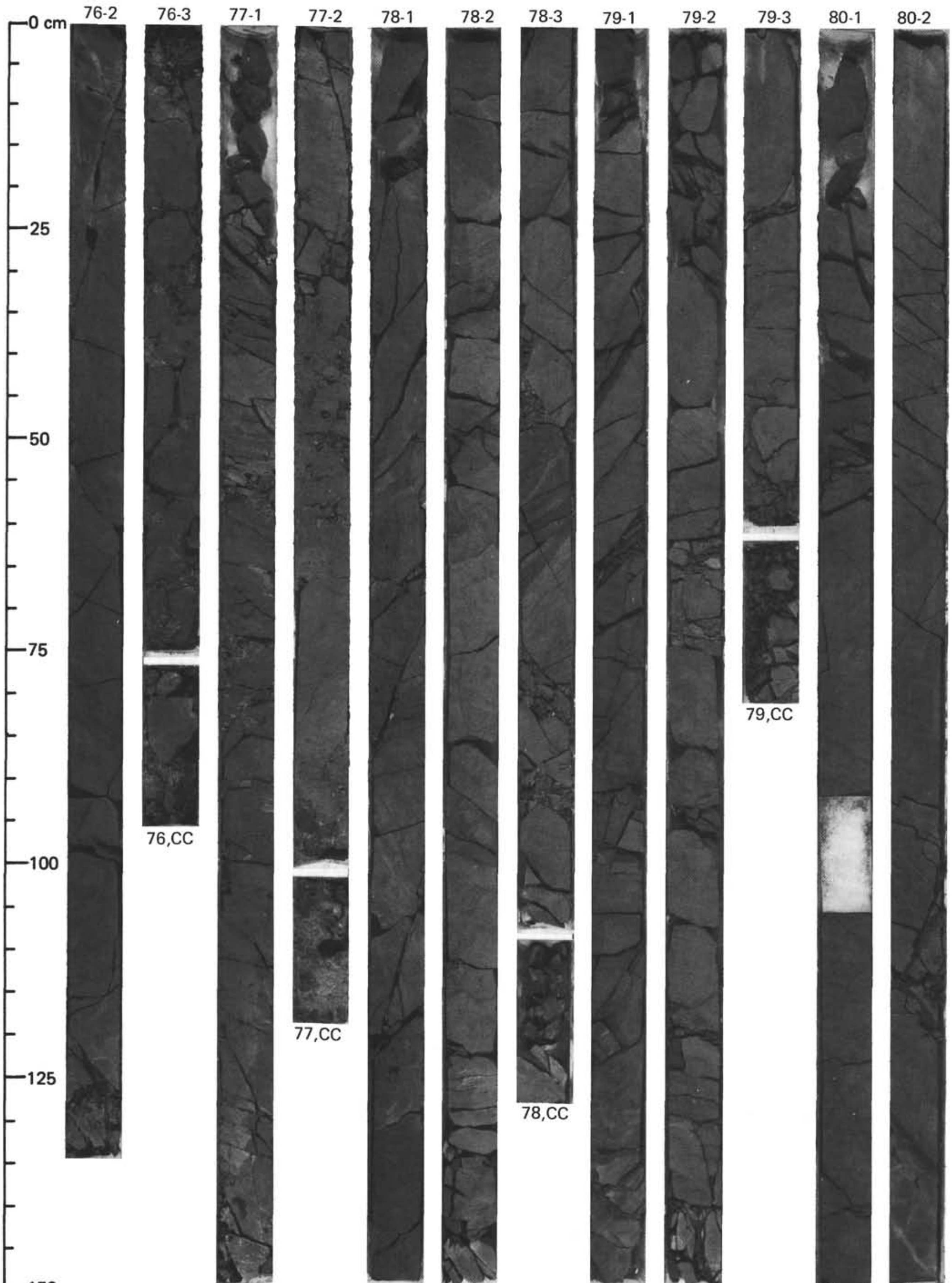
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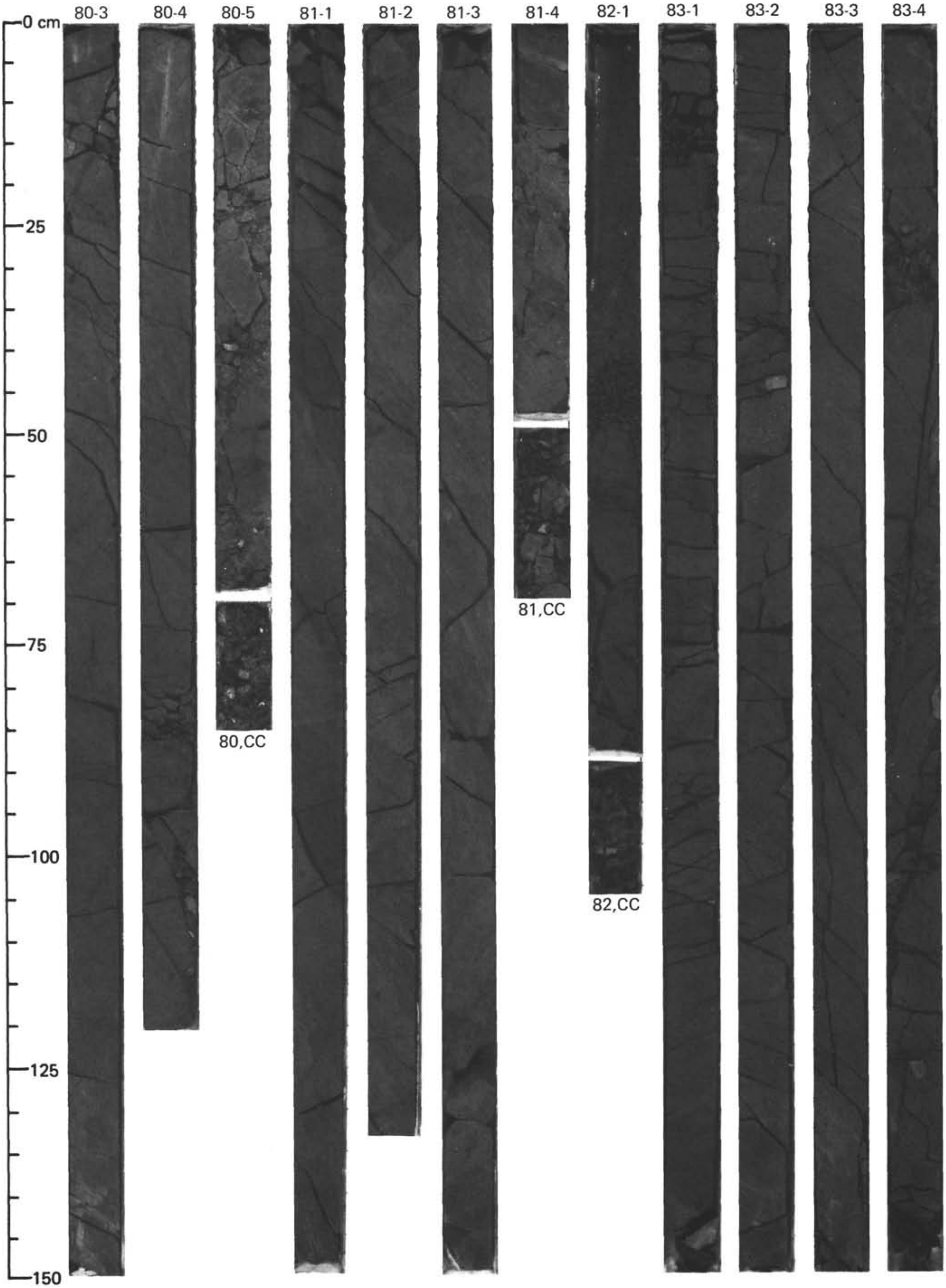
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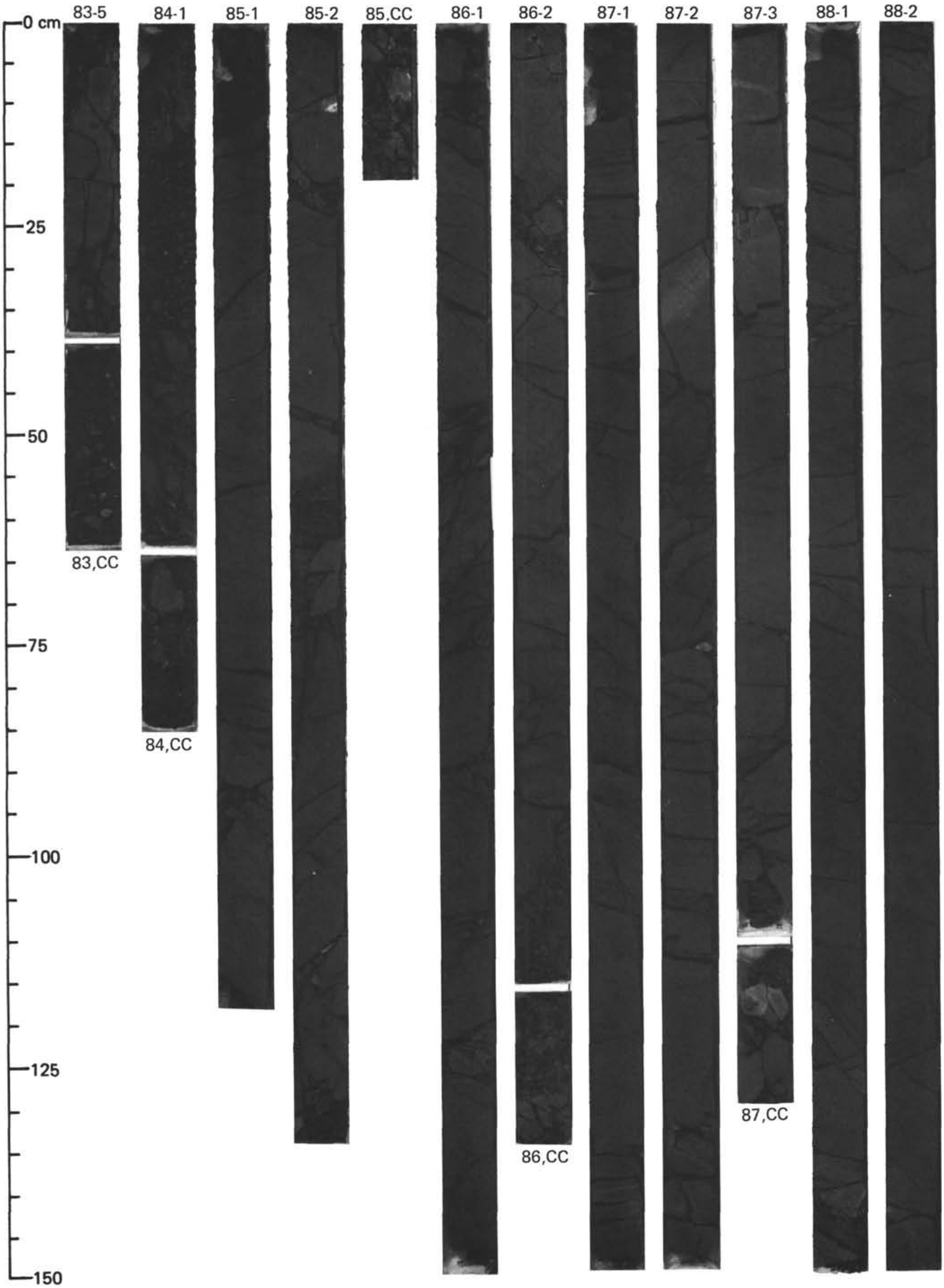
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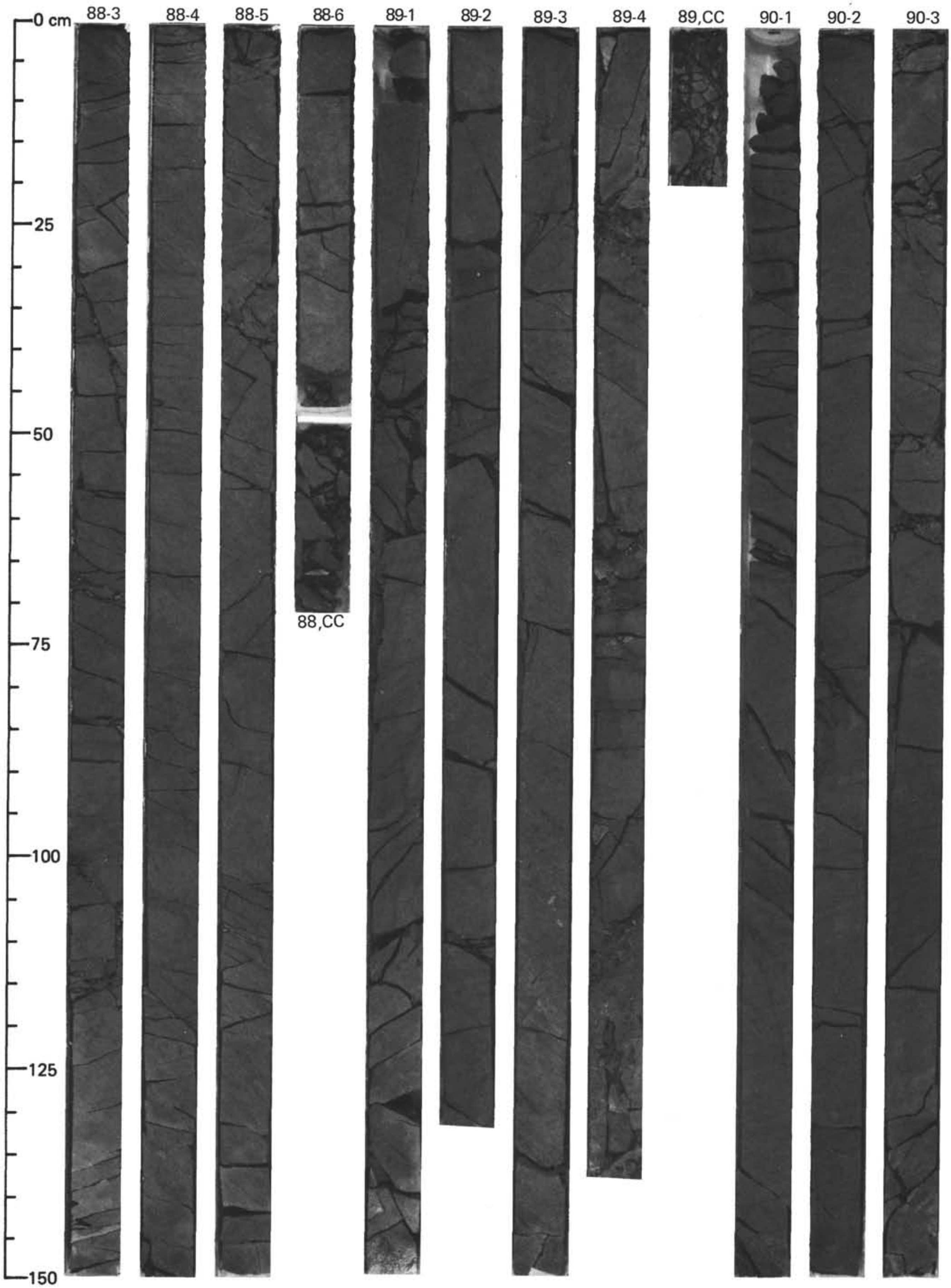
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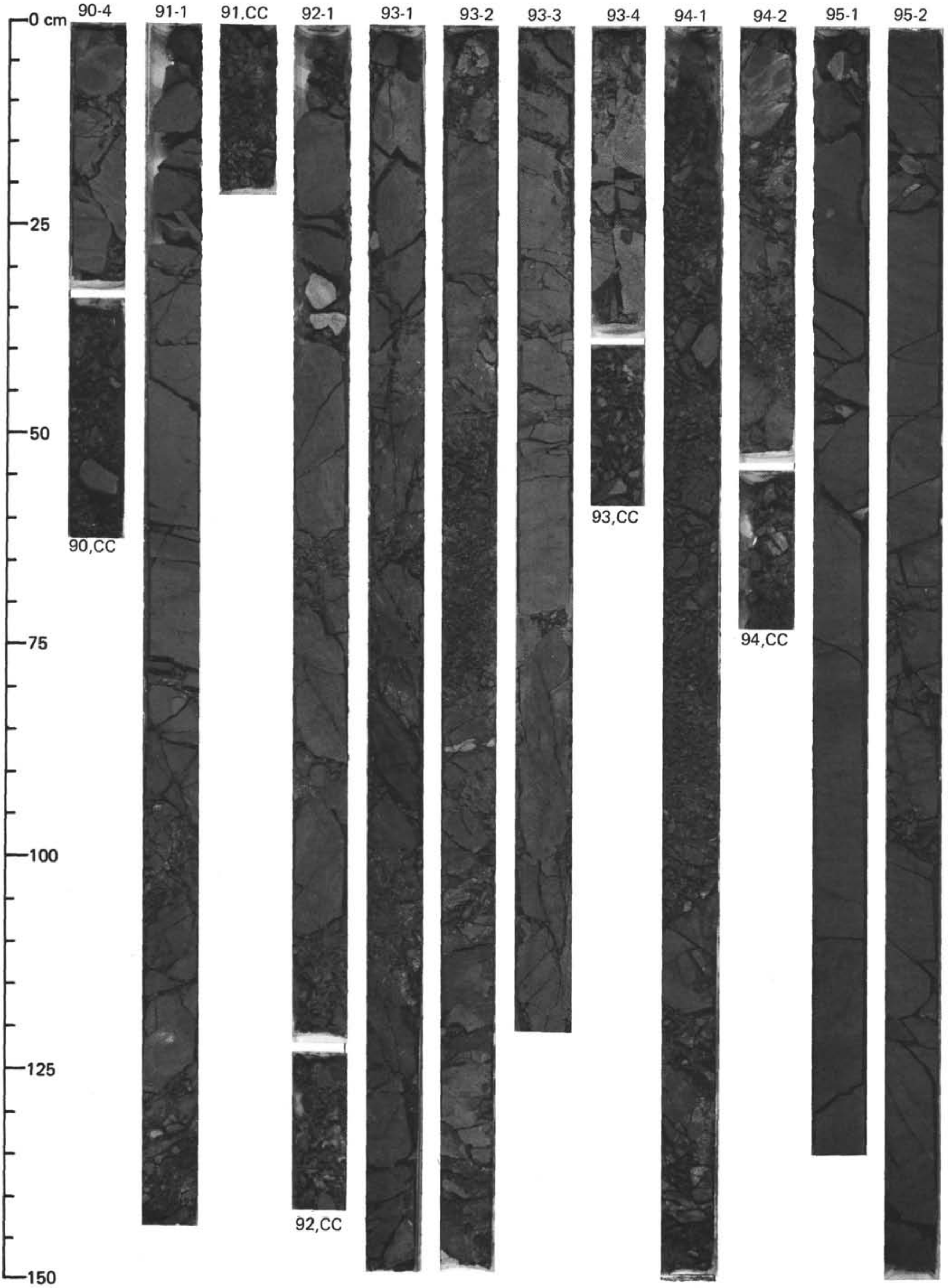
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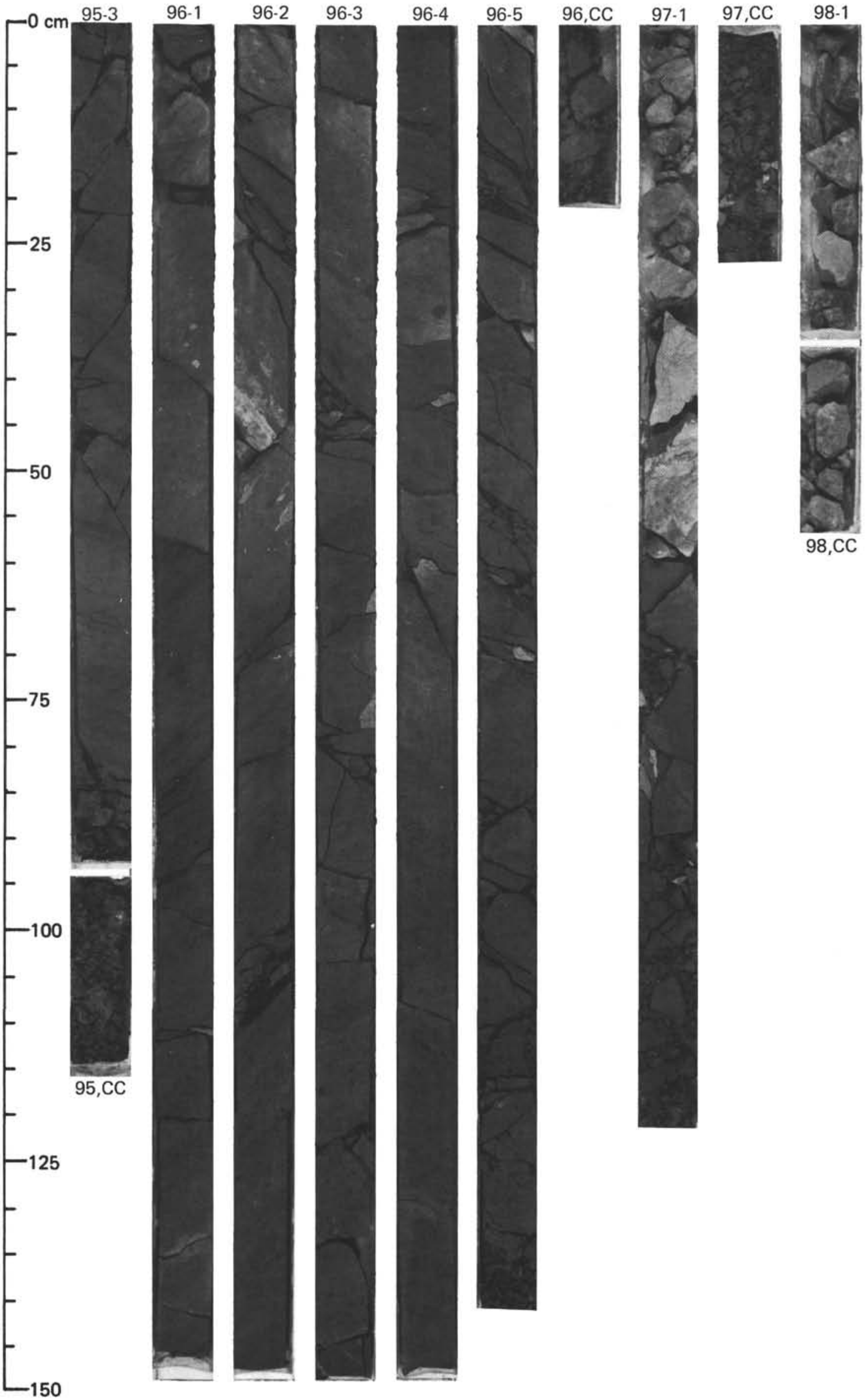
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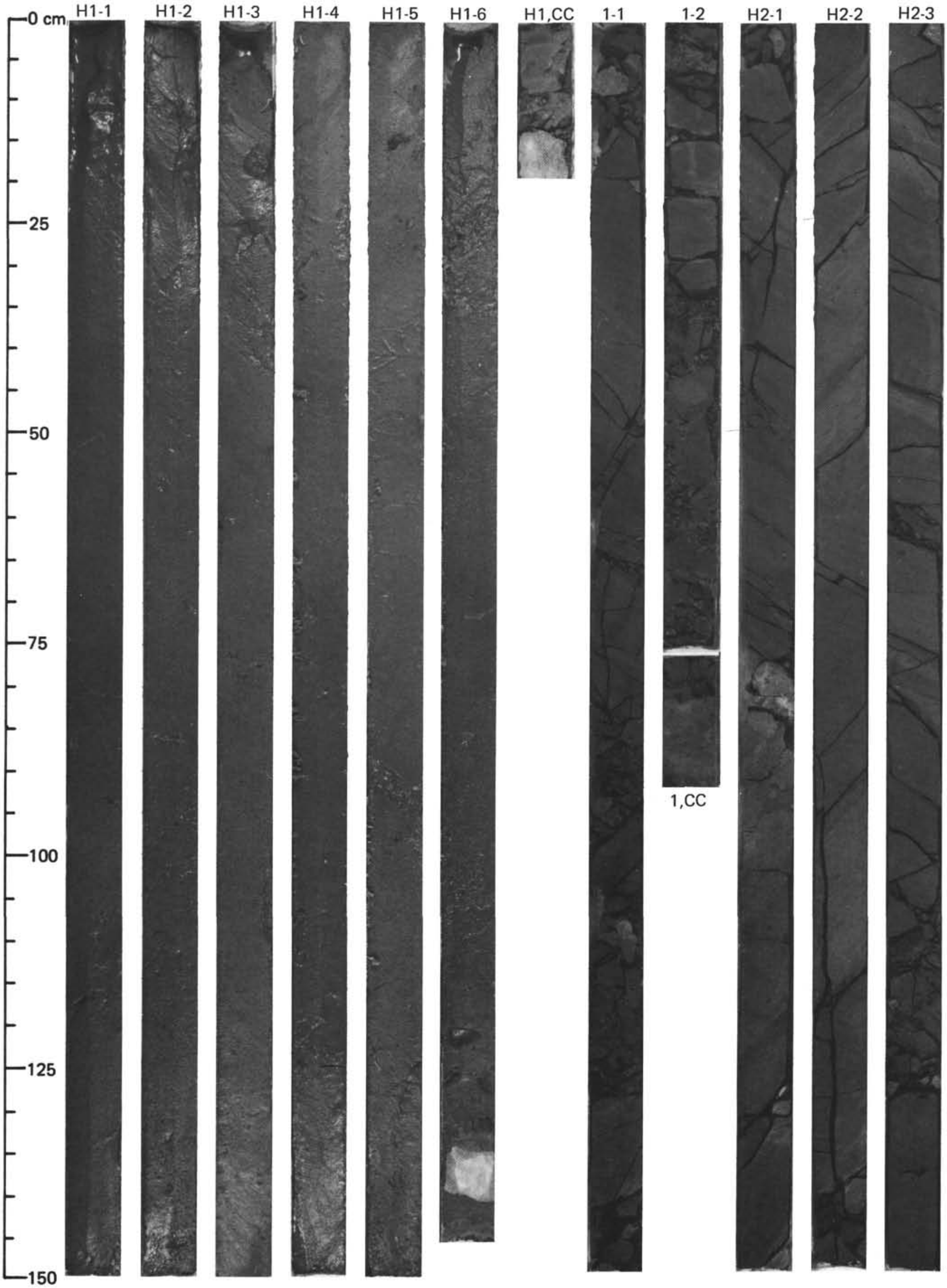
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H1-6
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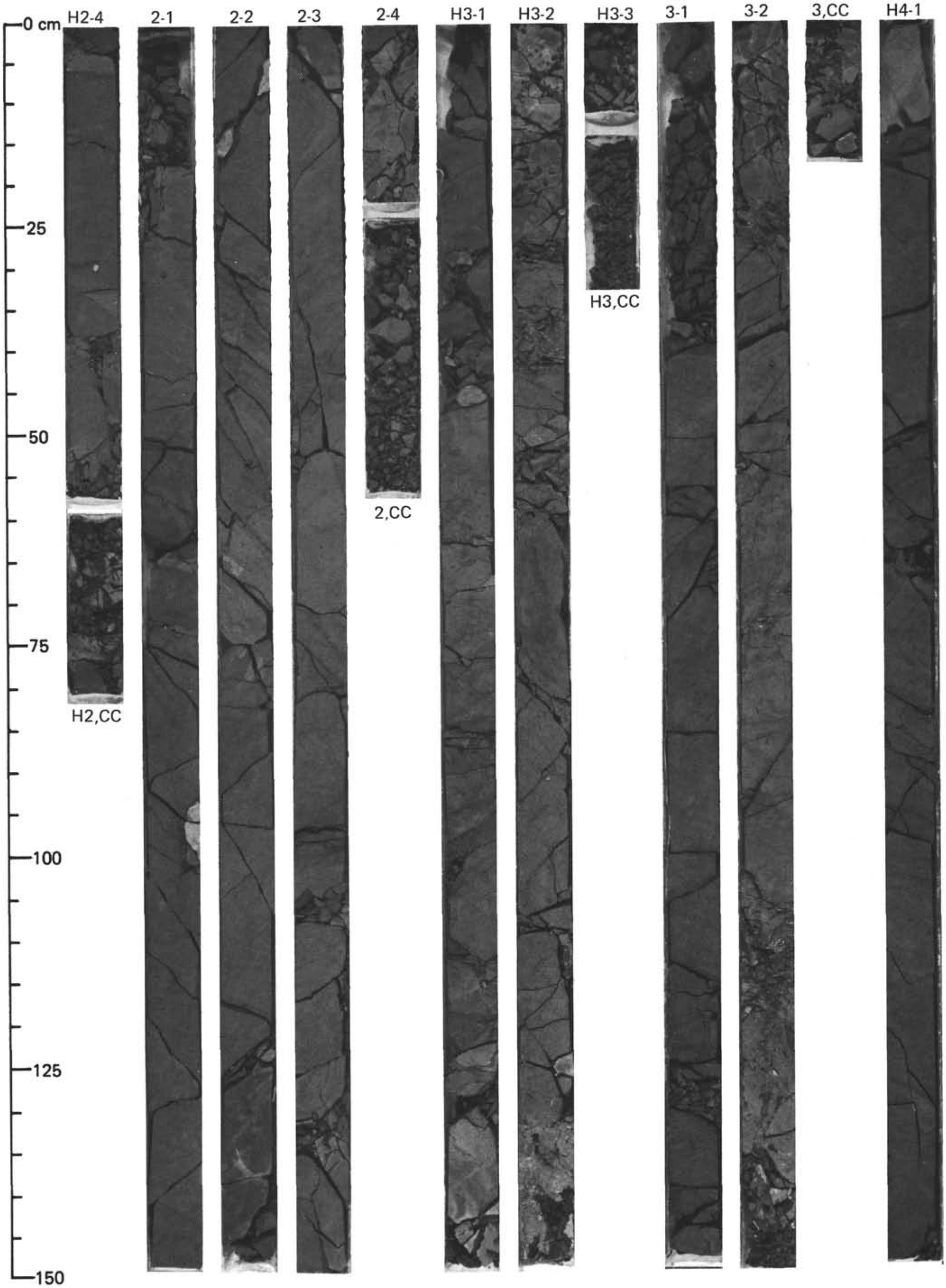
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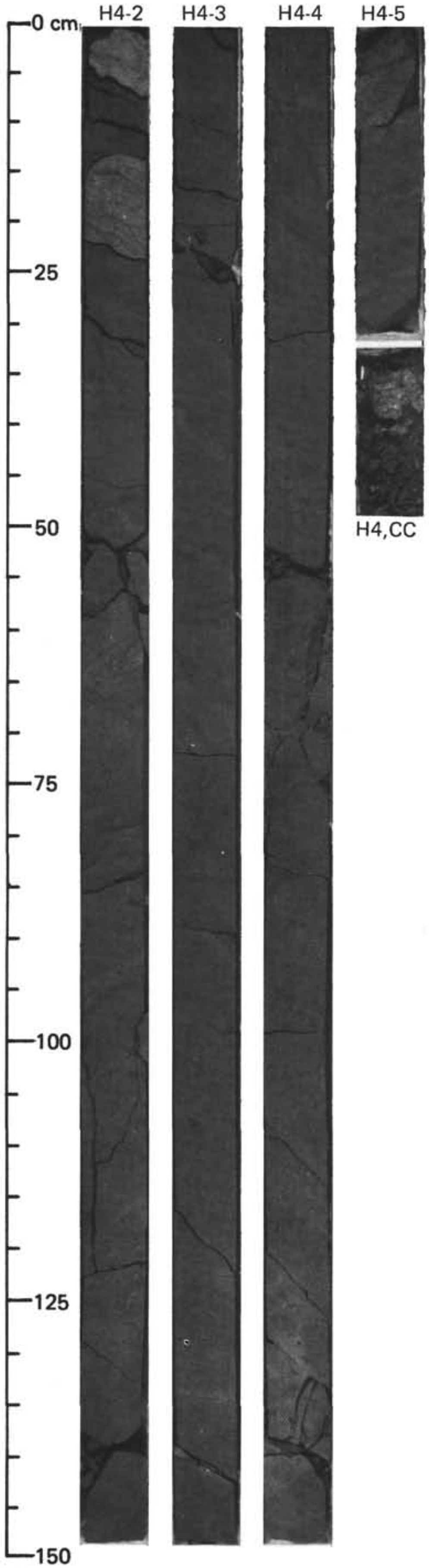
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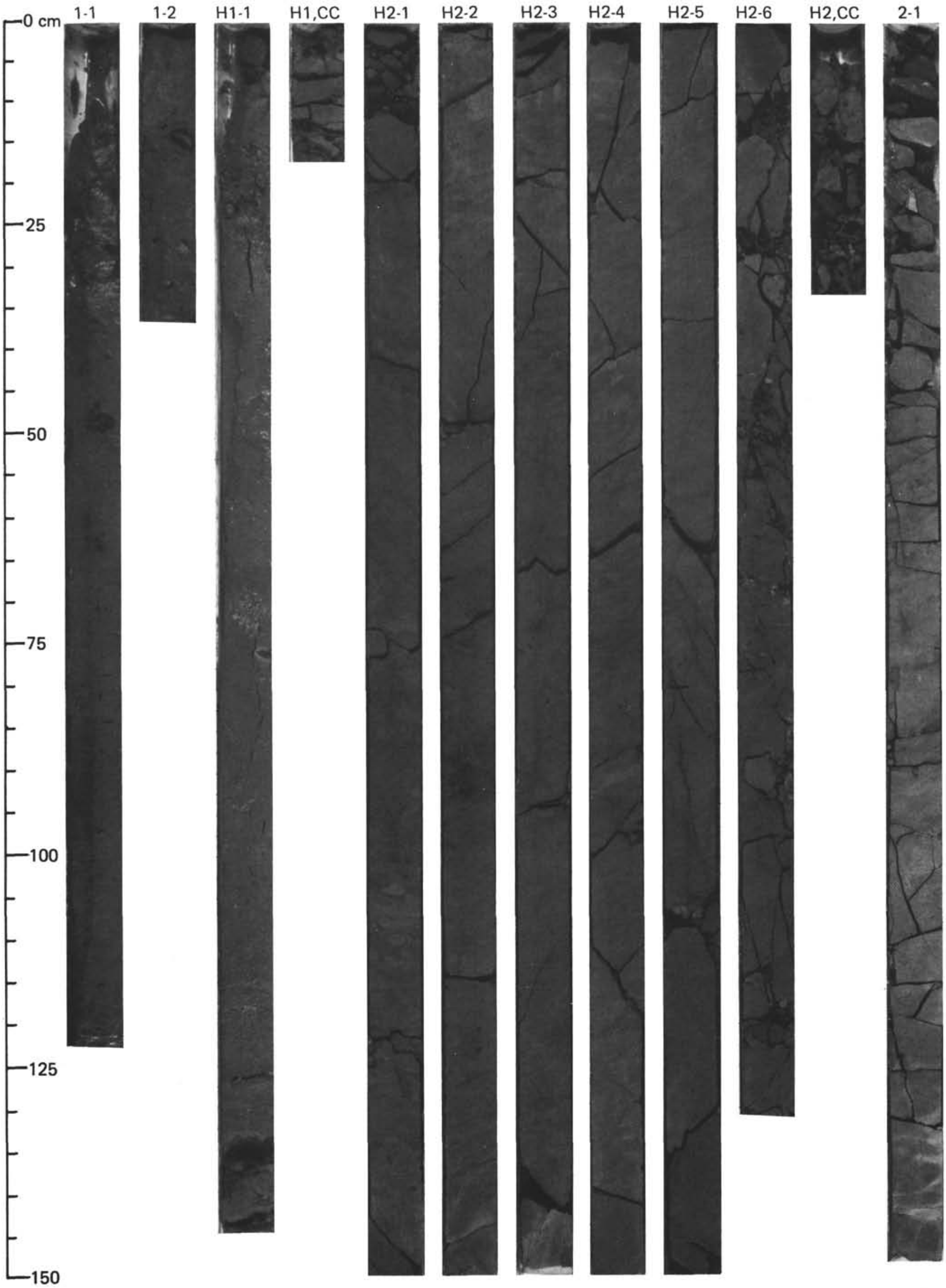
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H1-1
H1,CC
H2-1
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0 cm
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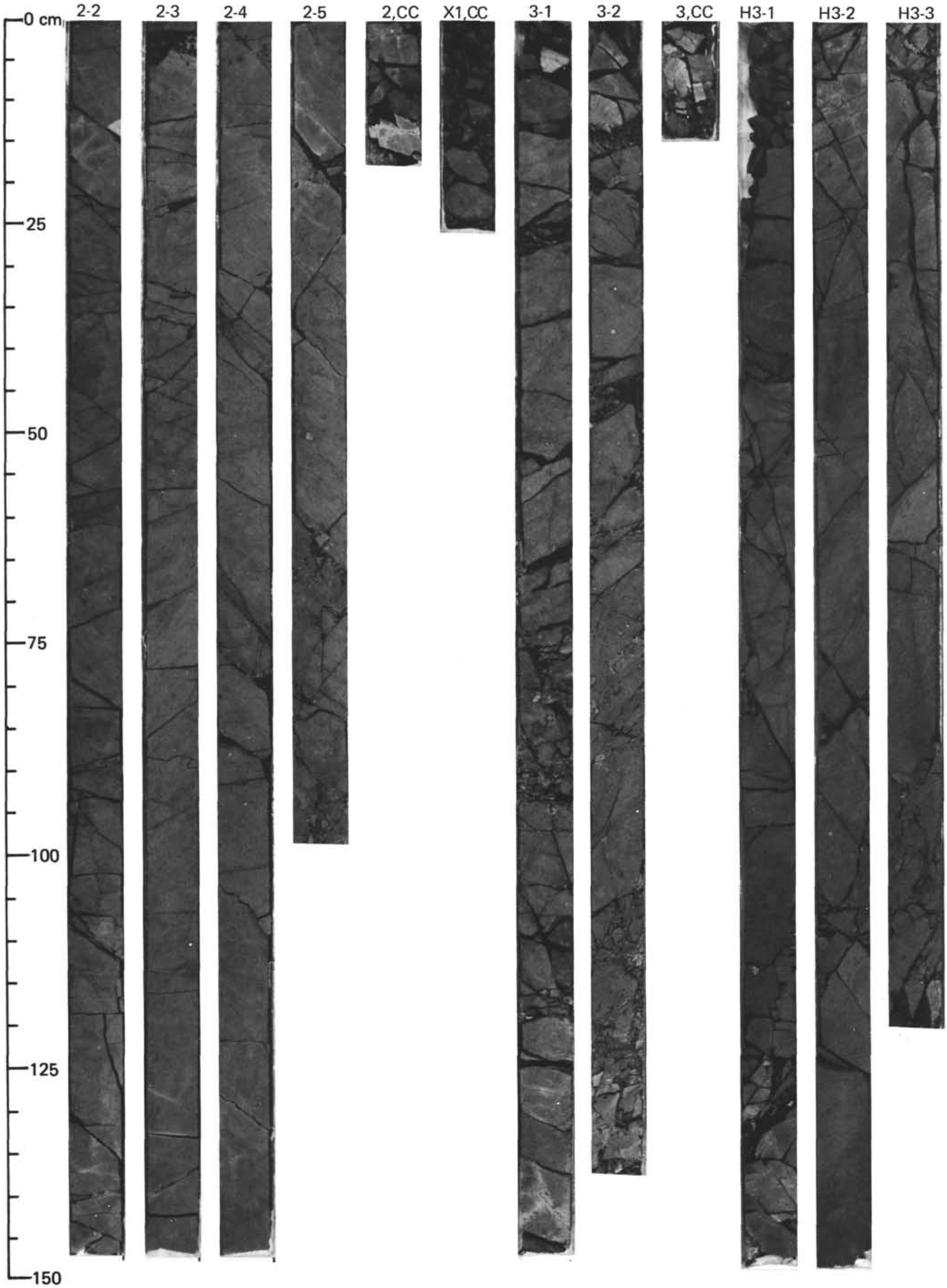
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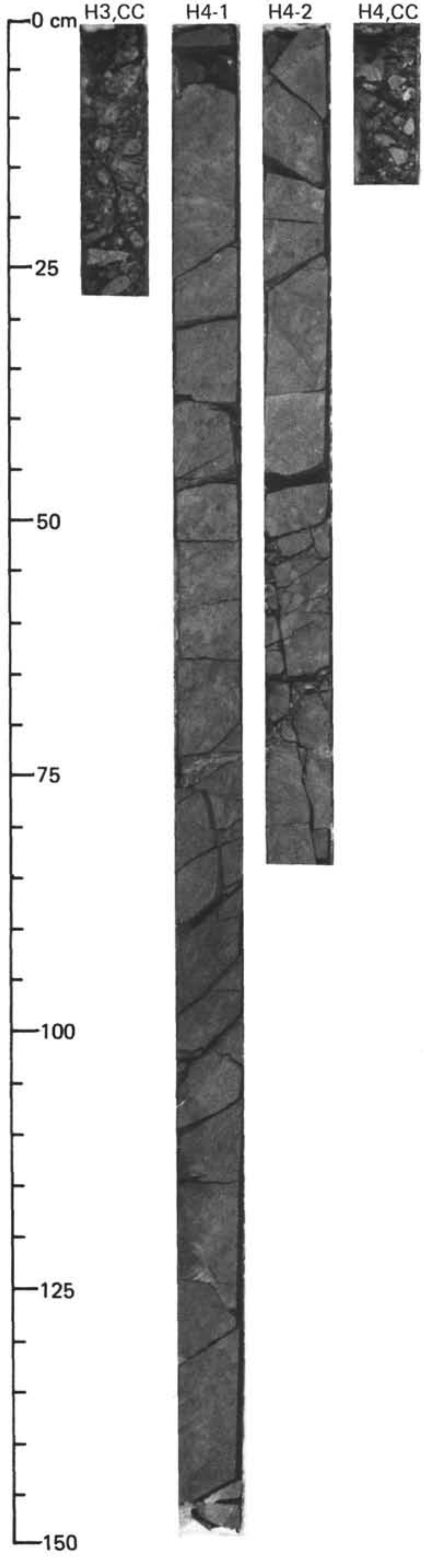
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